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Editorial Preface

From the Desk of Managing Editor...

It may be difficult to imagine that almost half a century ago we used computers far less sophisticated than current home desktop computers to put a man on the moon. In that 50 year span, the field of computer science has exploded.

Computer science has opened new avenues for thought and experimentation. What began as a way to simplify the calculation process has given birth to technology once only imagined by the human mind. The ability to communicate and share ideas even though collaborators are half a world away and exploration of not just the stars above but the internal workings of the human genome are some of the ways that this field has moved at an exponential pace.

At the International Journal of Advanced Computer Science and Applications it is our mission to provide an outlet for quality research. We want to promote universal access and opportunities for the international scientific community to share and disseminate scientific and technical information.

We believe in spreading knowledge of computer science and its applications to all classes of audiences. That is why we deliver up-to-date, authoritative coverage and offer open access of all our articles. Our archives have served as a place to provoke philosophical, theoretical, and empirical ideas from some of the finest minds in the field.

We utilize the talents and experience of editor and reviewers working at Universities and Institutions from around the world. We would like to express our gratitude to all authors, whose research results have been published in our journal, as well as our referees for their in-depth evaluations. Our high standards are maintained through a double blind review process.

We hope that this edition of IJACSA inspires and entices you to submit your own contributions in upcoming issues. Thank you for sharing wisdom.

Thank you for Sharing Wisdom!

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A Multiple-Criteria Decision Making Model for Ranking Refactoring Patterns

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Abstract—The analytic network process (ANP) is capable of structuring decision problems and finding mathematically determined judgments built on knowledge and experience. Researches suggest that ANP can be useful in software development, where complicated decisions happen routinely. In extreme programming (XP), the refactoring is applied where the code smells bad. This might cost more effort and time. As a result, in order to increase the advantages of refactoring in less effort and time, the analytic network process has been used to accomplish this purpose. This paper presents an example of applying the ANP in order to rank the refactoring patterns regarding the internal code quality attributes. A case study that was conducted in an academic environment is presented in this paper. The results of the case study show the benefits of using the ANP in XP development cycle.

Keywords—Analytic network process; extreme programming; refactoring practice; refactoring patterns

I. INTRODUCTION

The process of enhancing the structure of an existing code by altering the internal design without changing the external design is called code refactoring [1]. It is a significant issue in the XP development cycle to enhance software design, and to minimize the cost and effort that are needed for testing and coding. Some researchers have concentrated on guidelines for the refactoring process; for example, a 3-stage model has been introduced by Kataoka *et al.* [2], and the model contains “identification of refactoring candidates, validation of refactoring effects, and application of refactoring” [2]. Meanwhile, Mens and Tourwe [3] have described the refactoring phases in more detail. These phases start with specifying the portion of the software that should be refactored, then determining which refactoring technique is suitable to be applied, performing the refactoring, and finally measuring the influence of the applied refactoring technique on the code quality [3]. Other researchers investigated various aspects of refactoring techniques. Simmonds and Mens [4] studied four software-refactoring methods: Eclipse, Together ControlCenter 6.0, SmalltalkWorks 7.0, and Gurn. In addition, Murphy-Hill *et al.* [5] conducted an empirical investigation to compare four techniques. These four techniques were applied to collect refactoring data in order to assist in establishing a powerful refactoring technique.

Maticorna and Perez [6] introduced refactoring interpretation and the possibility of using it as a method in order to

compare various refactoring explanations, involving refactoring catalogs. Moreover, Maticorna and Perez [6] have worked on various refactoring concerns, like actions, application on scheduling, design, and scope, which might lead to the building of refactoring tools.

Several open-source Java systems have been investigated by Brunel *et al.* [7] in order to measure the accuracy of refactoring methods. This measuring is done by examining the following Java systems: MegaMek, Velocity, Antlr, HSQldb, PDFBox, Tyrant, and JasperReports. Murphy-Hill [8] built a model to investigate how refactoring techniques work in terms of the style of the refactoring browser. The model is made up of the following phases: identify, initiate, and execute [8].

Roberts *et al.* [9] examined the practical factors and technical requirements for the refactoring techniques. The authors emphasized that the ability to search the whole program and the accuracy are the most technical requirements. In addition, integration and speed are the most practical factors.

Marija and Kresimir [10] evaluated seven refactoring tools in order to choose the most suitable one. The seven tools were: Refactoring Browser (Smalltalk), Eclipse (C++, Java), Refactor (C# VB.NET, C++, ASP.NET), IntelliJ Idea (Java), Refactor (C# VB.NET, ASP.NET), NDepend (.NET code base), and Refactor (C++, Java). These refactoring tools were compared to each other concerning various issues, such as reliability, scalability, automation, discover-ability, coverage, and configurability.

Mahmood and Reddy [11] examined three refactoring techniques in order to avoid human errors while performing the manual refactoring. The authors evaluated the following refactoring tools: JBuilder 2008, RefactorIT 2.7 beta, and IntelliJ Idea 7.0.4. The authors compared these techniques with respect to various issues, such as user control, consistency, information processing, user experience, goal assessment, errors, design for the user, and ease of use. The authors proposed some enhancements in order to maximize the consistency of software usability.

Other studies focused on the identification of code smells in order to locate possible refactoring. For example, Hayashi *et al.* [12] introduced a tool for Eclipse using plug-ins. This tool directs the developer in terms of how to perform refactoring and which part of the code uses the histories of program

modification. The proposed tool focused on answering the following questions: Where to refactor? Which suitable refactoring technique should be used? When should refactoring be applied?

II. THE ANP

The Analytic Network Process (ANP) is a multi-criteria approach of estimation used to infer relative need sizes of supreme numbers from singular judgments (or from genuine estimations standardized to a relative frame) that likewise have a place with a central size of outright numbers [13]. The ANP gives a structure to show an solution for a specific problem, which prompts a choice for that issue. In the ANP technique, dependencies among different criteria are considered making it not the same as the Analytic Hierarchy Process (AHP) [13]. Saaty stated that in truth the ANP utilizes a system without the need to indicate levels. As in, the AHP, strength or the relative significance of impact is a focal idea [13]. In the ANP, one structures a judgment from the principal size of the AHP by noting two sorts of inquiries with respect to quality of strength: 1) Given a rule, which of two components is more overwhelming concerning that basis? 2) Which of two components impacts a third component more, as for a measure [13]?

In pairwise comparisons, entered values reflect the relative impact among components regarding a control paradigm. These entered values depend on the significance of every criterion. As such, the ANP is a helpful approach for forecast and for representing to an assortment of contenders with their expressly known and verifiably accepted cooperations and the relative qualities with which they use their impact in making a decision. It is likewise helpful in struggle determination where there can be many contradicting impacts [13]. The system structure comprises of various clusters, and these clusters contain different nodes or components. These clusters are associated with each other in view of the relative impacts among the nodes. The connections can either have outer relative impact, which implies components in cluster X influence component in cluster Y, or interior relative impact, which implies components in a similar cluster (e.g.X) influence each other. For this situation, the outside relative impact is named external reliance, and the interior relative impact is named internal reliance [13]. The network structure permits criticism models through cycle association, and the ANP gives distinctive sorts of nodes, for example, source, middle, and sink. Again, as indicated by Saaty that a source node is a starting point of ways of impact (significance) and never a goal of such ways. A sink node is a goal of ways of impact and never a root of such ways. A full network can incorporate source nodes; middle of the road nodes that fall on ways from source nodes; lie on cycles, or fall on ways to sink nodes; lastly sink nodes [14]. Fig. 1 gives a general idea of the ANP structure [14].

Another part of the ANP structure is the organizing of various alternatives keeping in mind the end goal to make a suitable decision. This begins by making pairwise comparisons, in light of a principal scale, as appeared in Table I. Following this, the vector of priorities is the foremost eigenvector of the matrix. This vector gives the relative priority of the criteria measured on a ratio scale. That is, these priorities

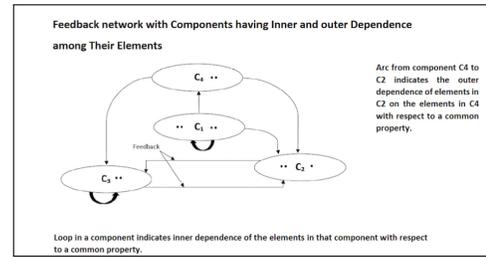


Fig. 1. The analytic network process structure [14].

TABLE I. ANP FUNDAMENTAL SCALE DEVELOPED BY SAATY [15]

Scale	Numerical rating	Reciprocal
Equal importance	1	1
Moderate importance of one over other	3	$\frac{1}{3}$
Very strong or demonstrated importance	7	$\frac{1}{7}$
Extreme importance	9	$\frac{1}{9}$
Intermediate values	2,4,6,8	$\frac{1}{2}, \frac{1}{4}, \frac{1}{6}, \frac{1}{8}$

TABLE II. RANDOM INDEX [14]

Order	1	2	3	4	5	6	7	8	9	10
R.I	0	0	0.52	0.89	1.11	1.25	1.35	1.4	1.45	1.49

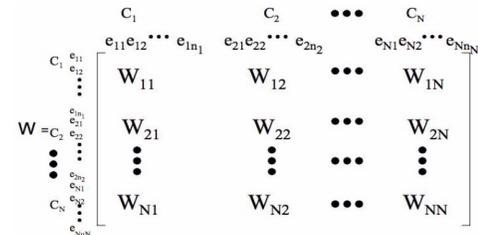


Fig. 2. The Super-matrix of a network [14].

are remarkable inside augmentation by a positive consistent. In the event that one guarantees that they whole to one they are then extraordinary and have a place with a size of supreme numbers [14]. "The consistency index of a matrix is given by C.I. (max n)/(n-1), where n is the number of alternatives. The consistency ratio (C.R.) is obtained by forming the ratio of C.I. The suitable group of numbers is exhibited in Table II, each of which is an average random consistency index computed for n 10 for very large samples. They create randomly generated reciprocal matrices using the scale $\frac{1}{9}, \frac{1}{8}, \frac{1}{2}, 1, 2, 8, 9$ and calculate the average of their eigenvalues. This average is used to form the Random Consistency Index R .I" [14]. The consistency proportion (C.R) ought to be lower than 0.10 (or 0.20), something else, the entered judgements should be improved.

In the wake of getting all priorities from the pairwise comparisons, these priorities are set in a supermatrix. As per Saaty [14] the supermatrix represents the impact priority of a component on the left of the matrix on a component at the top of the matrix as for a specific control rule. A supermatrix alongside a case of one of its general passage matrices is appeared in Fig. 2. The segment C1 in the supermatrix incorporates all priority vectors inferred for nodes that are parent nodes in the C1 cluster [14].

III. REFACTORING TECHNIQUES

Refactoring assists the development team to enhance the software design, understand the software more easily, find errors, and program faster, as Fowler *et al.* [1] confirmed. Fowler *et al.* [1] specified several refactoring techniques and arranged them into the following categories: moving features between objects, making method calls simpler, simplifying conditional expressions, composing methods, dealing with generalization, and organizing data. Each of these categories influences the quality attributes. Each project might have different quality attribute priorities, and using the refactoring techniques enhances the software design and the code. Therefore, in order to maximize the benefit from the system, it is important to assign the developers' efforts to the most significant quality attributes. Selecting the refactoring techniques consumes time and might lead to conflicting opinions.

In this paper, the main objective is to rank refactoring techniques according to their influence on the internal code quality attributes. Five refactoring techniques have been selected in this study, in order to examine their importance using the ANP. These techniques were selected from the four different groups introduced by Fowler *et al.* [1]. The selected refactoring techniques are: Extract Method, Extract Class, Inline Class, Pull UP Method, and Rename Method.

IV. METHODOLOGY

The main objective in this research is to investigate how the analytic network process might be used to rank the refactoring patterns in order to determine the most suitable one for the software project. The case study methodology, which is explained in [16], is the research methodology.

The following research questions provide more focus for the research case study:

- 1) What is the significance of engaging the ANP when applying refactoring?
- 2) How can refactoring patterns be ranked using the ANP?
- 3) How does the ANP influence the development team's communication and productivity in the refactoring practice?
- 4) How can the development team reduce time when refactoring using the ANP?

Moreover, the study propositions are as follows:

Proposition 1: *The ANP catches significant criteria and alternatives that affect refactoring patterns.*

Proposition 2: *The ANP supports ranking and selection activities in the refactoring practice.*

Proposition 3: *The ANP includes creative debate and enhances team communication.*

Proposition 4: *The ANP focuses on the most valuable refactoring methods in order to increase the quality of the code.*

Proposition 5: *The ANP clarifies conflicting perspectives between the development teams when performing refactoring.*

From the above inquiries, we determined the units of analysis for our investigation. The primary target is ranking different XP refactoring patterns in regards to the inside quality attributes. Properly, assessing and ranking are two units of analysis. Another is the members' point of view of the ANP benefits in refactoring practice. Hence, the plan of this case study incorporates numerous cases, installed with different units of analysis. The rationale connecting of the gathered information to the study propositions is appeared at the end of this paper.

V. DATA COLLECTION AND SOURCES

At the beginning of each use for the ANP in extreme programming, we investigate the ANP benefits and ability by introducing the related criteria and extreme programming areas. Data is gathered from looking past studies and literature review. Too, data triangulation is gained with a specific end goal to expand the validity of the study.

The main data origin of this paper is an extreme programming project, developed during the winter semester of 2016 at the University of Regina. The data sources in this research are:

- Questionnaires given to the students during the development of the XP project.
- Archival records, such as study plans, from the students.
- Comments from the customer.
- Open-ended interviews with the students.

VI. CASE STUDY

At the beginning, the authors would like to address that a part of this case study has been published in [17]. The case study was organized during a 12-week Winter 2016 semester at the University of Regina. Several researches, as [18], [19] and [20], tended to that the reasonable XP team size is in the vicinity of three and seven individuals. In addition, Ambler [21] accentuated that the accomplishment of agile project is 83 % with group estimate under eleven individuals, and the rate runs bring down with expanding the group measure for more than eleven individuals [21]. The significant reason for this diminishing in the achievement rate is in regards to correspondence need or misconstruing with the the large team size. In this way, we had 12 graduate students from the University of Regina, and one extra member, a customer, who was incorporated into this case study. These students had transitional information of XP process and practices, and various programming levels. The dominant part of these students was a part of an expert program, implying that their graduate degree was a part of their expert development and that they had past work involvement in the software industry. Some of these students were proceeding to work part-time. The members' experiences included different programming languages, for example, C++, Java, and PHP. The members were sorted out into two groups, the principal group utilized the ANP strategy with a specific end goal to make their decisions in ranking the refactoring techniques, and the second group took after the traditional XP way, which is based on voting, for their decisions. The two groups were made a request to develop an

XP project called “Professors’ Availability Managing System” finish with an arrangement of requirements. The undertaking was produced in 5 iterations, permitting two weeks for each. Toward the finish of the project, the two groups actualized all framework requirements. The members were asked to working on refactoring techniques amid the improvement cycle to rank them. Help materials that concentrated on refactoring practice were given to the members so as to guarantee their comprehension. The ANP group was given white papers, a few introductions, and other imperative materials about the ANP keeping in mind the end goal to enable them to apply it in their development. Team 1 honed on a few pairwise comparisons and expanded their understandings of the ANP structure. At the end, the researcher handed out a questionnaire to the participants in order to gather more data about the members’ points of view.

VII. APPLYING ANP IN REFACTORING

The main objective of applying the ANP in refactoring is to assist the XP team members in ranking the refactoring techniques with respect to the code quality attributes. In this paper, the ANP is used to rank the refactoring techniques based on internal quality attributes. The following sections present the ANP structure, evaluation and process.

A. Background

This section will introduce some previous studies that have examined the effect of refactoring techniques on the internal code quality attributes. This is following by introducing the ANP applying to rank the refactoring techniques.

Zhao and Hayes [22] conducted two case studies in order to investigate an approach that specifies which packages and classes need to be refactored according to various measures, like complexity, coupling, and code size. Using a measure-driven refactoring decision, the authors presented a rank-based software in order to support the team members’ decisions about where resources can be applied during refactoring.

Dallal and Briand [23] presented an automated refactoring method to enhance the cohesion of the software in order to enhance program testability. Sahraoui et al. [24] organized an empirical study in order to examine the effect of coupling and inheritance metrics on maintainability. The authors discovered a portion of the system that needed to be enhanced and refactored.

Stroulia and Kapoor [25] studied the possibility of enhancing the design and code quality using refactoring. Several refactoring techniques, such as Extract Abstract Class and Extract Superclass, were applied, and the results showed decreases in the number of methods, the number of statements, lines of code, and the number of collaborators in the individual system classes.

Moser et al. [26] organized a case study to investigate the influence of refactoring on the internal quality attributes of source code. The case study was done in an Agile environment, and the selected quality attributes were coupling, response of class, number of children, number of methods per class, depth of inheritance tree, cohesion, and complexity. Based on their proposed method, the authors found that refactoring might

enhance the internal metrics of object-oriented classes that are written in Java for reusability.

Bois and Mens [27] introduced a framework for the internal code qualities, like cohesion, number of children, number of methods, coupling, and response for a class. In order to achieve this, the authors investigated various refactoring techniques, such as Encapsulate Filled, Pull Up Method, and Extract Method.

Elish and Alshayeb [28] categorized refactoring patterns according to their influence on external and internal code quality attributes. The authors selected the following refactoring techniques: Form Template Method, Replace Construction with Creation Methods, Replace Conditional Dispatcher with Command, Chain Constructors, Introduce Null Object, Unify Interface, and Compose Method. The authors investigated different internal code quality metrics such as Number of Test Cases (NOTC) for the size of test case, Lines of Code for Class (LOCC), FOUT, LOC, DIT, LCOM, Number of Methods (NOM), Number of Fields (NOF), Number of Children (NOC), RFC, and WMC.

Over the course of 15 months, Ratzinger et al. [29] evaluated an industrial system. The authors exhibited the way that refactoring could improve the software evolvability and minimize the change couplings. In addition, Kataoka et al. [30] emphasized that refactoring patterns like extract class and extract method enhance system maintainability and minimize coupling in the code.

B. Proposed Criteria for Ranking the Refactoring Techniques

It is important to specify code quality attributes in order to rank refactoring techniques. The code quality attributes should be identified based on their value to the organization or the team member. Different projects will have different factors and alternative refactoring techniques to be examined. In this thesis, there are four internal code quality attributes that are selected as criteria used to rank the refactoring patterns:

- **Complexity:** The degree of connectivity among components of a design unit [31].
- **Cohesion:** Each component implements one function and implements it well [31].
- **Code Size:** Size in terms of number of files, number of lines of code (#LOC), functions, tables, classes, etc. [31].
- **Coupling:** The strength of the interconnections between the system components [31].

C. ANP Structure for Ranking Refactoring Methods Based on the Internal Attributes

Structuring the problem as a network that consists of three clusters is the first step in the ANP. The first cluster is the objective, which ranks the refactoring patterns. The second cluster contains the criteria: coupling, code size, complexity, and cohesion. The third cluster includes the alternatives: Pull Up Method, Extract Class, Rename Method, Extract Method, and Inline Class. Fig. 3 shows the ANP structure for the problem.

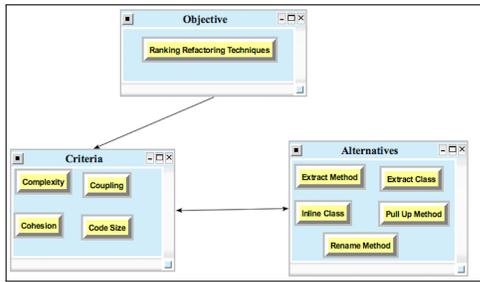


Fig. 3. ANP network for ranking refactoring techniques based on the internal attributes.

TABLE III. RANKING THE REFACTORING PATTERNS BASED ON INTERNAL ATTRIBUTES BY TEAM 1

Refactoring Patterns	Scores (%)
Extract Method	29.17 %
Extract Class	25.01 %
Pull Up Method	18.74 %
Inline Class	17.58 %
Rename Method	9.48 %

D. Pairwise Comparisons for the Refactoring Techniques

The participants have applied the refactoring techniques in their XP project in order to note the effect on the code. After that, based on the proposed criteria, the students evaluated each refactoring technique. The ANP team received the suitable ANP papers and tables in order to facilitate the comparisons process. Examples of the participants' questions are:

- With respect to Extract Method: which criterion is more important, cohesion or coupling and by how much?
- With respect to Extract Class: which criterion is more important, complexity or cohesion and by how much?
- With respect to cohesion: which method do you prefer, Extract Method or Extract Class?
- With respect to coupling: which method do you prefer, Extract Method or Extract Class?

The same comparisons and questions were done again for all refactoring techniques and code quality attributes.

VIII. FINDING AND RESULTS

Team 1's results of ranking the refactoring patterns with respect to all four criteria is as follows: first, Extract Method; second, Extract Class; third, Pull Up Method; fourth, Inline Class; and fifth, Rename Method. Table III shows the scores of each pattern. Team 1 ranked cohesion as the most important criterion, followed by complexity in the second position, while code size and coupling were ranked in the third and fourth positions, respectively. Fig. 4 exhibits the importance of each criterion as a percentage according to Team 1.

Team 2 ranked the refactoring patterns as follows: first, Extract Class; second, Extract Method; third, Inline Class; fourth, Pull Up Method; and fifth, Rename Method. Table IV displays the ranking of refactoring patterns by Team 2. Moreover, in terms of the most important criterion, Team 2

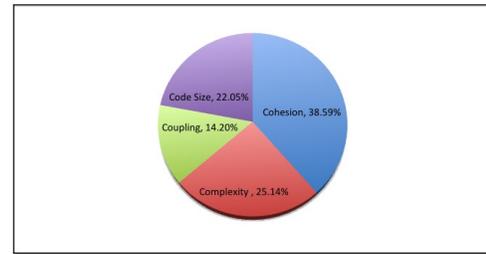


Fig. 4. The importance of the internal attributes for the refactoring patterns by Team 1.

TABLE IV. REFACTORING TECHNIQUES RANKING BY TEAM 2

Ranking	Refactoring Techniques
1	Extract Class
2	Extract Method
3	Inline Class
4	Pull Up Method
5	Rename Method

ranked coupling in the first position. Table V shows the ranking of the criteria by Team 2.

TABLE V. THE IMPORTANCE OF THE CRITERIA BY TEAM 2

Ranking	Criteria
1	Coupling
2	Cohesion
3	Complexity
4	Code Size

A. Observations

- 1) With respect to all of the criteria, Team 1 ranked the Extract Method as the highest refactoring technique.
- 2) Team 2 ranked Extract Class as the highest refactoring technique.
- 3) Both teams ranked Rename Method in the last position.
- 4) Team 1 ranked cohesion as the most important criterion, while Team 2 ranked coupling as the most important criterion.
- 5) With respect to each criterion individually, Team 1 ranked the Pull Up Method highest in terms of code size. Table VI shows the ranking of all refactoring techniques with respect to each criterion.
- 6) Inline Class was ranked highest with respect to the coupling criterion by Team 1.
- 7) With respect to each refactoring technique individually, we can see that reducing complexity was ranked highest according to Rename Method. Table VII shows the weight of each criterion with respect to each refactoring pattern.

IX. REFACTORING VALIDATION

Based on the previous ANP evaluation, we discovered that three refactoring patterns received high rankings: Extract Method, Extract Class, and Rename Method. This section shows several collected technical information in order to validate the ANP evaluation findings.

TABLE VI. REFACTORING TECHNIQUES WITH RESPECT TO EACH CRITERION FOR TEAM 1

Techniques	Cohesion	Techniques	Coupling	Techniques	Code-Size	Techniques	Complexity
Extract Method	53.09 %	Inline Class	46.23 %	Pull Up Method	41.22 %	Extract Class	47.30 %
Extract Class	28.42 %	Pull Up Method	28.51 %	Inline Class	31.20 %	Extract Method	23.16 %
Pull Up Method	9.26 %	Rename Method	11.96 %	Rename Method	13.44 %	Inline Class	11.38 %
Rename Method	5.91 %	Extract Method	7.75 %	Extract Method	7.96 %	Rename Method	10.10 %
Inline Class	3.29 %	Extract Class	5.52 %	Extract Class	6.16 %	Pull Up Method	8.04 %

TABLE VII. CRITERIA WEIGHTS WITH RESPECT TO EACH REFACTORING TECHNIQUE FOR TEAM 1

	Extract Method	Extract Class	Inline Class	Pull Up Method	Rename Method
Cohesion	64.32 %	66.36 %	7.01 %	5.48 %	15.54 %
Coupling	11.32 %	10.36 %	14.13 %	26.61 %	6.29 %
Code-Size	20.28 %	18.24 %	22.33 %	34.88 %	6.29 %
Complexity	4.06 %	5.02 %	56.51 %	33.01 %	71.86 %

TABLE VIII. REFACTORING PATTERNS EFFECT ON THE INTERNAL ATTRIBUTES BY TEAM 1

	Cohesion	Coupling	Code-Size	Complexity
Extract Method	+	+	+	+
Inline Class	-	-	-	+
Extract Class	+	+	+	-
Pull Up Method	-	-	-	-
Rename Method	+	0	-	-

TABLE IX. REFACTORING PATTERNS EFFECT ON THE INTERNAL ATTRIBUTES BY TEAM 2

	Cohesion	Coupling	Code-Size	Complexity
Extract Method	+	0	+	-
Inline Class	+	-	-	+
Extract Class	-	+	+	-
Pull Up Method	+	+	-	-
Rename Method	0	0	0	-

A. Observations of the Internal Effect of Refactoring

This section shows the effect of the refactoring patterns on the internal quality metrics. The students were asked to use (-) to indicate a decrease, (+) to indicate an increase, and (0) to indicate no use or no change. Tables VIII and IX display the effect of refactoring on the internal quality attributes as reported by both teams.

B. Number of Times Applying the Refactoring Patterns

Tables X and XI show the number of refactoring patterns that have been applied by both teams in each iteration.

X. INTERVIEW RESULTS

Subsequent to finishing the project, the consequences of the ANP assessment for ranking the refactoring patterns were appeared to the members so as to lead the interviews. Not all outcomes were as expected and a few results were surprising. The interviews included open-ended inquiries so as to gather the members' viewpoints about the ANP, their points of view on its advantages and disadvantages in XP, too to gather their perspectives about the best application for ANP in XP among all specified practices. The gathered information was contained written by hand notes from the interviews.

The interview findings show positive remarks from the members with respect to the ANP. The ANP was a useful approach in explaining struggle points of view, and urged each colleague to take an interest in deciding. The fundamental concern was the time it took amid the ANP assessment, and the quantity of pairwise comparisons. Another suggestion was applying the ANP in more XP practices and concentrate the impacts. All ANP colleagues recommended applying ANP in their future XP projects.

On the other hand, Team 2 was not totally happy with the procedure of their decisions. A portion of the colleagues complained about that the most experienced member had more voting weight than others, which lead them to take after decisions that they dislike. Another issue is that the ANP enabled us to know the distinction between each ranking position in a rate; in any case, Team 2 couldn't determined the measure of contrast between each ranked pattern and criterion.

XI. QUESTIONNAIRES

Surveys were dispersed among the members keeping in order to gather their experiences and perspectives. The given surveys comprised of two areas. The principal area included inquiries concerning ANP as a ranking and decision tool, for example, catching the required data, decency of the decision structure, clearness of criteria included, and clearness of alternatives included. The second area included inquiries regarding the advantages of every XP practice, and the students' fulfillment, for example, improving the group correspondence, elucidating the ranking issue, making positive discourse and learning chances, group performance, and fulfillment of the last consequences of the ANP. In this study, a seven-point Likert scale was used to decide the worthiness level of the ANP approach as follows:

- 1) Totally unacceptable.
- 2) Unacceptable.
- 3) Slightly unacceptable.
- 4) Neutral.
- 5) Slightly acceptable.
- 6) Acceptable.
- 7) Perfectly Acceptable.

In the wake of finishing the questionnaire, the same steps were followed as in [32] with a specific end goal to total the gathered information and show the aggregate agreeableness rate.

TABLE X. NUMBER OF REFACTORING PATTERNS WAS APPLIED BY TEAM 1 IN EACH ITERATION

	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5	Total
Extract Class	0	7	6	4	5	22
Inline Class	0	4	2	3	5	14
Rename Method	0	42	38	24	7	101
Pull Up Method	0	0	0	0	0	0
Extract Method	0	19	13	11	16	59

TABLE XI. NUMBER OF REFACTORING PATTERNS WAS APPLIED BY TEAM 2 IN EACH ITERATION

	Iteration 1	Iteration 2	Iteration 3	Iteration 4	Iteration 5	Total
Extract Class	0	3	5	2	6	16
Inline Class	0	2	0	0	0	2
Rename Method	0	3	4	4	6	17
Pull Up Method	0	1	0	4	1	6
Extract Method	0	4	3	2	3	12

The total acceptability percentage can be obtained as follows:

The total acceptability percentage (TAP)= $\frac{\text{the average score} \times 100}{7}$.

Where the average score = the sum of all scores given by team members / number of the team members.

The following rates show the worthiness level of the ANP as a ranking and decision tool:

- Enhancing team communication: 82%.
- Maximizing team performance: 87%.
- Supporting positive discussion and learning chances: 72%.
- Clearing up conflict perspectives among the team members: 87%.
- Defining the ranking problem: 91%.
- Satisfaction of the ANP final results 71%.

From various information sources, the information was gathered. By contrasting the gathered information and the study propositions in view of the understanding of the criteria that were specified above, we will investigate this gathered information. The followings are the study propositions and their answers:

- For the first proposition, we can see that both the alternatives and criteria are organized adequately, and considered in Fig. 3. Likewise, the final results and targets of the ANP use in ranking the refactoring techniques can be found in Table III, which showed the ranking of the ANP team for the XP refactoring patterns, and extract method was ranked as the highest.
- The survey statement ‘satisfaction of the ANP final outcomes’ supported the second proposition, and the comment of this was positive, which is 71 %. In addition, the statement ‘clearing up conflict points of view among the developers’ supported the third proposition, and the score was 87 %.

XII. VALIDITY

In this part, related threats to the validity are clarified. These threats are construct validity, external validity, internal

validity, and reliability. Several studies underscored that case studies are hard to analyze because of biases and validity threats as described in [33] empirical studies in general and case studies specifically are inclined to predispositions and validity threats that make it hard to control the nature of the study in order to generalize its outcomes [33].

A. Construct Validity

Construct validity guarantees that the treatment mirrors the develop of the reason well, and the result mirrors the construct of the impact well [34]. It manages coordinating the idea being inquired about and considered, to the particular measurements. The modest number of members is the fundamental risk to this case study.

Using different strategies to guarantee the validity of the outcomes decreased this threat. Some of these strategies are:

- Data triangulation: a noteworthy favorable position of case study is the chance to utilize different sources of proof [35]. A proof chain is built through using interviews and questionnaire with different sorts of members with various abilities and experience levels, and the utilization of members’ remarks and numerous perceptions. Hence, a valid conclusion can be come to.
- Methodological triangulation: employing a combination of research techniques such as organizing an XP project to serve the study purpose, questionnaire, findings of ANP pairwise comparisons, researchers’ notes, and interviews.
- Member checking: showing the final results to the members is recommended. This issue was addressed by showing the final findings to all participants in order to ensure the study accuracy and to avoid researcher bias.

B. Internal Validity

Internal validity is tied in with ensuring the result is caused by the treatment (the impact). This kind of validity is just identified with explanatory case study. This issue might be tended to by connecting all information sources with respect to the research questions, and connecting the research questions to the study propositions.

C. External Validity

External validity guarantees the connection between the construct and the impact to ensure that the study will be generalized to a different environment [34]. In this investigation, extra case study will be need to be conducted in various situations, for example, industry to include more specialists from the field. Leading such a case study will help in looking at the different outcomes and discoveries from various conditions. Future work will add to expanded External validity.

D. Reliability

Reliability deals with the procedure of the gathered data and results. Similar conclusions and findings can be arrived by different researchers when following the same procedure, and using the same data. This might be done through the availability of same research questions, data collection, and case studies designed by other researchers.

XIII. CONCLUSION

After using the analytic network process to rank the refactoring patterns used in extreme programming, ANP was an appropriate and beneficial tool that gave the development team a good understanding for determining the most valuable refactoring patterns. The participants evaluated various refactoring patterns based on four internal code quality attributes, which were complexity, cohesion, code-size, and coupling. The most refactoring patterns that have enhanced the code quality in our study were Extract Method and Extract Class. in addition, the other mentioned refactoring patterns have added advantages to the code quality as well. Moreover, the ANP allowed us to specify the difference between each element in our model by a percentage, while the traditional XP team were not be able to do that. The ANP helped the team members resolve conflicts based on a structured approach grounded in scientific principles. The ANP ended up simplifying decision making, which maximized the effect of the software being developed. Team 1 members reconciled their conflicts of perspectives based on a mathematical approach. This maximized their satisfaction with the team's decisions.

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Classification of Alzheimer Disease based on Normalized Hu Moment Invariants and Multiclassifier

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Abstract—There is a great benefit of Alzheimer disease (AD) classification for health care application. AD is the most common form of dementia. This paper presents a new methodology of invariant interest point descriptor for Alzheimer disease classification. The descriptor depends on the normalized Hu Moment Invariants (NHMI). The proposed approach deals with raw Magnetic Resonance Imaging (MRI) of Alzheimer disease. Seven Hu moments are computed for extracting images' features. These moments are then normalized giving new more powerful features that highly improve the classification system performance. The moments are invariant which is the robustness point of Hu moments algorithm to extract features. The classification process is implemented using two different classifiers, K-Nearest Neighbors algorithm (KNN) and Linear Support Vector Machines (SVM). A comparison among their performances is investigated. The results are evaluated on Alzheimer's Disease Neuroimaging Initiative (ADNI) database. The best classification accuracy is 91.4% for KNN classifier and 100% for SVM classifier.

Keywords—Alzheimer disease; machine learning; Hu moment invariants; SVM; K-Nearest Neighbors (KNN) classifier

I. INTRODUCTION

Alzheimer's disease (AD) is a permanent, progressive neurological brain disorder and complex disease which gradually destroys brain cells, reducing memory and thinking ability causing the dead, and eventually loss of the capability to perform even the simplest tasks. The mental weakening produced by this illness leads to dementia in the end [1]. AD was named after the German psychoanalyst and pathologist Alois Alzheimer when he tested a female patient (post mortem) in 1906 [2]. The first area affected is the hippocampus, which is responsible for episodic and spatial memory and works as a communicate structure between the brain and the body. The hippocampus shrinks unusually in an AD patient; where the normal decrease is between 0.24 and 1.73 percent yearly, a hippocampus imposed with AD might shrink between 2.2 and 5.9 percent [3].

Magnetic resonance imaging (MRI) is a medical imaging technique used in radiology to examine the body's anatomy and physiology in both healthy and diseased patients [4]. MRI

scans can offer a utilitarian tool for estimating the properties of anti-dementia drugs in clinical tests which can highly serve the researchers in these fields. Scans can provide information about the levels and location of cell damage over time, and that would help to get valuable information about the optimistic effects of potential treatments.

Basically, the most distinctive structure which different a normal brain from a pathological brain is the symmetry. If it is clear from any view in either coronal or axial directions, that indicates a normal brain, and if broken it is a pathological brain [5]. Though, sometimes there is a strong similarity between the normal cognitive brain image and the brain with AD, especially when the brain is compromised by the start of AD. These situations also result in distinguishing the disease correctly. To beat this problem and to enhance the recognition accuracy, Hu moments approach presented by Hu [6] is used in this work, where the values are invariant with respect to the scale, translation, and rotation. Moment invariants were chosen because they are one of the most important and most used methods in the object recognition field.

In this work, seven-moment invariants have been computed for each image of normal cognitive and AD cases, and they are kept as a 1D vector. These calculations are repeated for the testing dataset, too. To highly improve the classification performance, these moments are then normalized to get more efficient features, which can be easily distinguished by the classifiers later. Two different classifiers are used for the classification process, KNN and SVM, to measure the minimum matching between the training and testing datasets for each class. Minimum matching indicates the closer case of testing dataset to the specific class of the training dataset.

The organization of this paper is as follows: Section II illustrates the related work with this study. Section III explains the Hu moments theory. Section IV describes the proposed material and methods. The NHMI is trained based on that database by applying Hu moment invariants algorithm designed for feature extraction. Section V explains a comparison between KNN and SVM classifiers. Section VI shows the experiments' results. Finally, Section VII and VIII summarizes the conclusions and discussion of this work.

II. LITERATURE REVIEW

Numerous systems have been used to solve classification problems. One of the influential methods is machine learning algorithms. Hu moments theory has been considered as a powerful way to extract the dominant features of an image as we did in our earlier work in [7]. It highly proved the strength of the extracted features for different human actions. On other hand, Support Vector Machine (SVM), an influential binary classifier, is one of the most broadly used classifiers. It is suitable for high dimensional classification problems, where not too many examples exist. SVM has been utilized, for instance, in [8] for classifying MR images and in [9], [10] to classify Position Emission Tomography (PET) images. All these works used voxel intensity (VI) as features. In a different approach, a single multi-kernel SVM has been employed for the multimodal classification of MRI, PET, and CSF using VI within regions of interest [11]. Although SVM has been the preferred single classifier, other options such as Gaussian Naives Bayes [4], [12] or Gaussian Processes [13] have also been used successfully.

Another way to classify accurately is to use ensembles which combine the outputs of several classifiers. Several well-known ensemble methods have already been explored for AD classification. For instance, [14] propose the favorite class ensemble of classifiers where each base classifier in the ensemble uses a different feature subset which is optimized for a given class. In [15], an ensemble classifier was learned from different random subsets of local patches. Ensemble methods have also been used in order to combine information from different modalities such as EEG, MRI and PET [16]. Many of these methods use a prior feature selection step in order to reduce dimensionality. Different techniques have been used for this purpose, such as PCA [9] or selecting the best ranking features according to some criteria such as the t-test [11].

An Atrophy Differential Diagnosis Approach for early detection of Alzheimer disease (AD), where the atrophy is located on the brain and it offers hippocampus, a regional atrophy analysis for differential diagnosis of different neurodegenerative diseases, which is a computer aided system [17]. Wavelet Fuzzy C- Means (WFCM) algorithm is used for image segmentation in noisy medical images. The feature extraction is done by wavelet decomposition, and the feature vector is fed as input to FCM [18].

Another method to classify AD is to use voxel-wise, cortical thickness, and hippocampus shape volume features of the sMRI [19]. In this method, the first step is co-aligning (registering) all the brain image. So, each brain voxel will be associated with a vector of many scalar measurements. Then, voxel-wise features were extracted. While the work of [20] extracted the features by using the gray matter (GM) voxels, and use them to train an SVM to distinguish between the AD and NC subjects. A different view to extract features is from brain volume. The work of [21] was segmented the brain volume to GM, white matter (WM), and CSF parts, and then estimate all voxel-wise densities and relating each voxel with a vector of GM, WM, and CSF densities for classification.

III. HU MOMENTS THEORY

The moment invariants were initially presented by Hu [6]. Hu moments algorithm is selected to extract image features since the created features are rotation scale translation. Basically, Geometric Moment (GM) was effectively used in aircraft documentation, texture classification, and radar images for optical images matching [22].

Basic terms in the construction of the invariant moments have two steps. First, consider an image that has a gray function $f(x, y)$ having a bounded support and a finite nonzero integral. Second, geometric moment m_{pq} of the digital sampled $M \times M$ image $[f(x, y)]$ which can be computed using (1) [23].

$$m_{pq} = \sum_{x=0}^{M-1} \sum_{y=0}^{M-1} (x)^p \cdot (y)^q f(x, y), \quad (1)$$

$p, q = 0, 1, 2, 3, \dots$, where p, q are non-negative integers and $(p+q)$ is called the order of the moment.

The moments of $f(x, y)$ are translated by an amount (a, b) , which is calculated by (2).

$$\mu_{pq} = \sum_x \sum_y (x+a)^p \cdot (y+b)^q f(x, y) \quad (2)$$

Consequently, the central moment μ_{pq} can be calculated from (2) by replacing $a = -\bar{x}$, and $b = -\bar{y}$ as

$$\bar{x} = \frac{m_{1,0}}{m_{0,0}}, \bar{y} = \frac{m_{0,1}}{m_{0,0}}, \quad (3)$$

$$\mu_{pq} = \sum_x \sum_y (x-\bar{x})^p \cdot (y-\bar{y})^q f(x, y),$$

The central moment of the image is invariant to translation, while the scaling invariance can be achieved by normalizing the moments of the scaled image by the scaled energy of the original image that can be computed as stated below:

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^\gamma}, \gamma = \frac{p+q}{2} + 1,$$

where γ is the normalization factor.

$$\left. \begin{aligned} M_1 &= \eta_{20} + \eta_{02}, \\ M_2 &= (\eta_{20} - \eta_{02})^2 + 4\eta_{11}^2, \\ M_3 &= (\eta_{30} - 3\eta_{12})^2 + (3\eta_{21} - \eta_{03})^2, \\ M_4 &= (\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2, \\ M_5 &= (\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] + \\ &\quad (3\eta_{21} - \eta_{03})(\eta_{21} + \eta_{03})[(\eta_{30} + \eta_{12})^2 + (\eta_{21} + \eta_{03})^2], \\ M_6 &= (\eta_{20} - \eta_{02})[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] + \\ &\quad 4\eta_{11}(\eta_{30} + \eta_{12})(\eta_{21} + \eta_{03}), \\ M_7 &= (3\eta_{21} - \eta_{03})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] + \\ &\quad (\eta_{30} - 3\eta_{12})(\eta_{21} + \eta_{03})[3(\eta_{30} + \eta_{12})^2 - (\eta_{21} - \eta_{03})^2] \end{aligned} \right\} \quad (4)$$

In fact, Hu defined seven values, calculated by normalizing central moments completed order three that are

invariant to object scale, position, and orientation. In terms of the central moments, the seven moments are given as shown in (4) [24].

IV. MATERIAL AND METHODOLOGY

The proposed NHMI approach goals to obtain the more powerful features of the brain images for both healthy and AD cases. It extracts the features of the training and testing datasets using HMI algorithm. The extracted features of each image for both training and testing datasets are then normalized, representing the distinctive features of that image which results in a better classification performance. Subsequently, the classification process is taken over using two different supervised classifiers; KNN, and Linear SVM. Eventually, the closed features of the maximum matching would be selected as a matching output class. Fig. 1 shows the block diagram of NHMI approach.

A. Data

The investigated data in this work was obtained from the ADNI (Alzheimer’s Disease Neuroimaging Initiative) database <http://www.adni-info.org/>. The ADNI initiative includes a longitudinal multi-modal track of all applicants through 36 months in which bio specimen, imageology, and clinical data were composed.

ADNI began its work in 2004. It is an enormous, 7-year effort to support and assist the discovery and development research that limits or restricts the growth of AD. Its target is to govern the features of AD as the pathology which grows from normal cognitive to mild symptoms, to Mild Cognitive Impairment MCI, and finally to dementia. ADNI is dedicated to creating standardized methods for imaging/biomarker groups and analysis to be used in clinical trials. In this paper, MRI core is only the interested core [25].

Generally, ADNI’s subjects are between 55-90 years old, of both genders male and female. They have a study partner that can offer an independent estimation of functioning. Basically, there are two important criteria for diagnosing AD; Mini-Mental State Examination (MMSE), and Clinical Dementia Rating (CDR). MMSE ranges between 0-30, while CDR has five values; 0, 0.5, 1, 2, 3. For healthy applicants; MMSE scores are between 24-30, CDR of 0, this case refers to non-depressed, non-MCI, and non-demented subjects. With MCI subjects, MMSE scores between 24-30, but they have objective memory loss and a CDR of 0.5, basically conserved activities of daily life with absence of dementia. They do not classify as AD. Nevertheless, if MMSE scores are less than 20, and CDR scores are more than 0.5 (1, 2, and 3), that case would be considered as AD. They illustrate measures of disease severity.

In this paper, 100 subjects have been selected for training purposes, 50 with healthy controls (normal cognitive or MCI), and 50 subjects with AD. While another 28 subjects are used for testing purposes, 16 of them with AD and 12 of healthy subjects (normal control). An example of the used data in this work are shown in Fig. 2.

B. Feature Extraction and Selection

Features extraction process is a technique of image conversions, which transfers high-dimension features to the low-dimension features vector. In other words, the feature extraction achieves dimensional reduction at the same time it preserves the valuable information, which is most representative and essential to the image [26]. Features selection is an outstanding process among the most significant steps in image recognition, which could highly influence upcoming recognition process phases [27].

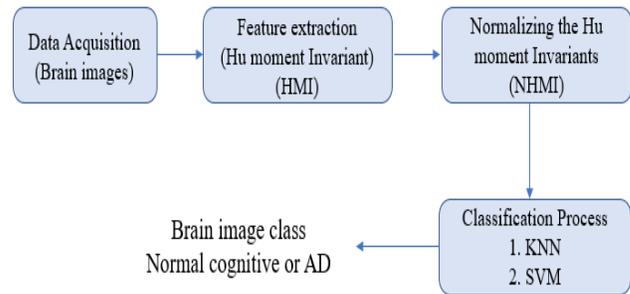


Fig. 1. Block diagram of the proposed technique.

TABLE I. HU MOMENTS FOR FOUR DIFFERENT BRAIN IMAGES

Hu moments	Image1 (CDR=0)	Image2 (CDR=1)	Image3 (CDR=2)	Image4 (CDR=3)
M1	1.5176	1.7704	1.6916	1.9289
M2	0.1508	0.6493	0.4815	0.9766
M3	0.7273	0.4747	0.2239	0.9659
M4	0.5079	0.2675	0.0367	0.7407
M5	0.1245	0.6307	0.1517	0.6169
M6	0.0833	0.0922	0.7775	0.7290
M7	-8.8941	10.4012	9.9237-	-11.4032

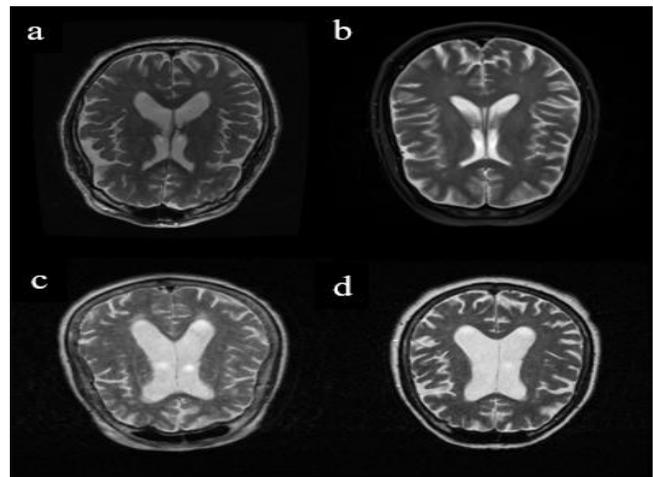


Fig. 2. MRI brain images: (a) Healthy brain with CDR=0. (b) AD brain with CDR=1. (c) AD brain with CDR=2. (d) Severe AD brain with CDR=3.

It is obvious that HMI is a set of seven invariants moments which can be used in applications that require scale, translation and rotation invariants. Truly, in this work, feature extraction process contains calculating seven Hu moments for each brain image as in (4), and all moment's values are concatenated into a 1D vector. Under those circumstances, a vector of seven Hu moments has been calculated for each brain image for both cases the normal control and AD. Therefore, each 2D brain image is transformed to a 1D vector containing the most significant feature of that image. Table 1 shows an example of seven Hu moments for four different brain images as in Fig. 2.

C. Normalizing the Hu moments

As it is clear from Table 1, there is some convergence among moments' values, which make it confuse for the classifiers to make the classification decision. To handle this issue, normalizing these moments has been found as the perfect way to diverge among them and make them specific features for each category to which they belong. The input features are normalized to real values between 0 and 1. The normalized moments have dissimilar values.

Normalization is the method used to reduce the needless repetition of data i.e., redundant data. It makes the data in a normalized arrangement. The main advantage of normalizing is to separate data into distinct, unique sets. Mostly, data normalizing is performed to improve the performance. Database normalization is a sequence of steps followed to get a database structure that permits reliable storage and effective access of data in a relational database. These steps decrease data redundancy and the hazard of data being unpredictable. Normalizing a database helps design the database construction to store data in a rational and related way. It is common for all databases to be normalized. First, normalizing data could reduce data duplication. Since databases can hold a significant amount of information, maybe millions or billions of pieces of data, normalizing the database reduces its size and prevents data duplication from happening. It makes sure that every piece of data is stored just once. Second, normalizing can group data logically.

Practically, application providers who make applications dealing directly with the database discover it is easier to treat with a normalized database. The data is arranged more logically when it is normalized. Normalizing gives fewer null values and less redundant data, making the database more compact. Conceptually, normalization is cleaner and easier to preserve and change whenever change is needed. As a result, normalizing highly improves the performance of the two classifiers used for identifying each image's class exactly. Table 2 displays the normalized Hu moments that shown in Table 1. Fig. 3 illustrates the feature extraction process.

D. Classification Process

The similarity measurement among images is still a hot topic and an essential issue in the machine learning and computer vision. Several applications in machine learning have usually used the Euclidean distance, for example, K-Nearest Neighbor (KNN), K-Means Clustering (KMC), and the Gaussian kernel. Some of them have used a binary classifier like SVM. Each classifier has specific

characteristics, in terms of time consumption, performance accuracy, and cost, which make it the proper classifier for some applications.

The basic classifiers that are used in this study are KNN and linear SVM. The main idea of using different classifiers is to demonstrate that the proposed technique is appropriate for more than one classifier. The option of these classifiers rested in KNN and SVM, both are suitable to high dimensional application, particularly when the available training examples are quite few. Both KNN and SVM are distinctive classifiers; they attempt to estimate classification limits in the feature space as a substitute of modelling the conditional density of the class. Fig. 4 shows the structure of the classification process in this work.

In general, The classification methods can be classified into parametric and non-parametric problems. In fact, parametric methods are based upon the assumptions of normally distributed population, and they estimate the parameters of the distributions to solve the problem. However, nonparametric methods make no assumptions about the specific distributions involved, and are therefore distribution-free [28].

TABLE II. NORMALIZED HU MOMENTS OF TABLE I

Hu moments	Image1 (CDR=0)	Image2 (CDR=1)	Image3 (CDR=2)	Image4 (CDR=3)
M1	0.4377	0.5107	0.4879	0.5564
M2	0.1181	0.5086	0.3772	0.7650
M3	0.5518	0.3602	0.1699	0.7328
M4	0.5416	0.2852	0.0391	0.7898
M5	0.1377	0.6978	0.1679	0.6826
M6	0.0776	0.0859	0.7246	0.6794
M7	-0.4362	0.5101	0.4867	0.5592

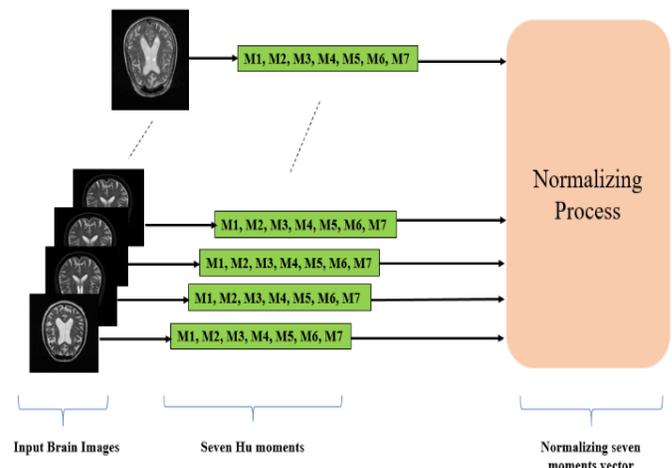


Fig. 3. Structure of feature extraction process.

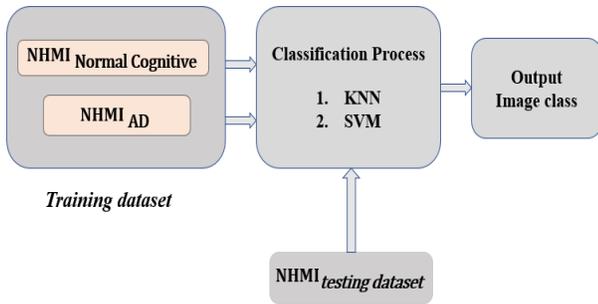


Fig. 4. Block diagram of classification process.

1) K- Nearest Neighbor KNN

The KNN classifier assists as a design of a non-parametric statistical method. When a testing data is examined, a K-NN classifier tries to find the pattern space for the k training cases which are alike in unknown cases. These k training cases consider the “K-nearest neighbors” of the unknown cases. K-NN classifier can also be suitable for the dependent variable that deals with more than two principles like high risk, medium risk, and low risk. Besides, K-NN classifier needs an identical number of good and bad sample cases for improved performance. The selection of k also influences the performance of the k-NN process [28].

The K-nearest neighbor algorithm depends on the knowledge of clustering components of similar nature. In other words, items of the same class should be nearer in distance [29]. The execution process of the K-nearest neighbor algorithm is as follows:

Let T be a training dataset, and S a test dataset. Individually, every sample x_a is a tuple $(x_{a1}, x_{a2}, \dots, x_{ad}, z)$, where, x_{af} is the value of the f-th feature of the a-th sample. This sample belongs to a class z, represented as xza , and a specific dimensional space. For the T set, the class z is identified, while it is unidentified for S set. Basically, for each sample x_{test} held in the S set, the k-NN model searches for the k nearest samples in the T set. Mathematically, it calculates the distances between x_{test} and all the samples of T set. Normally, the Euclidean distance is used for this task. According to this calculated distance, the k closest samples ($neigh_1, neigh_2, \dots, neigh_k$) are found by placing the training samples in ascending direction. Based on the k closest neighbors, a majority vote is managed to compute which class is prime among the neighbors. The value of k could possibly affect the performance and the noise of this method [30]. So, the KNN algorithm can be summarized as two main procedures [29]:

a) First, the number of closest points of test sample x against training data T is determined using a Euclidean distance equation. If there are two points in j dimensional space, $x = [x_1, x_2, \dots, x_j]$ and $y = [y_1, y_2, \dots, y_j]$, the Euclidean distance between them can be denoted by (15) [28]:

$$d(x, y) = \sqrt{\sum_{i=1}^k (y_i - x_i)^2} \quad (5)$$

b) When a test sample x has more representatives than a specific class of data, which means the number of K-nearest

points accounting for the majority, it is judged that x is of that specific class [29].

2) Linear SVM

Support Vector Machines (SMVs) were used as a classification method, using LIBSVM toolbox under MATLAB as simulation software [31]. Firstly, SVMs are expressed for binary classification. The SVM technique is a familiar model which has shown to perform perfectly in various applications by similar or improved performance than many other models. SVM has an additional benefit over other approaches. It is computationally less sensitive to the dimensionality of the application, which permits dealing with complex applications of a large number of variables [32].

SVM is a supervised learning technique. It is a binary classifier which returns a class label. SVM splits binary labels of the training data by the following hyperplane:

$$g(x) = w^T x + w_0 \quad (6)$$

Where, w is known as the weight vector and w_0 as the threshold. Fig. 5 illustrates the hyperplane of a linear SVM. This hyperplane is extremely distant from the two classes [33]. The thematic of a binary classifier is to build a function f :

$\mathbb{R}^n \rightarrow \{\pm 1\}$ using training data that is, n -dimensional patterns x_i and class labels y_i :

$$(X_1, Y_1), (X_2, Y_2), \dots, (X_n, Y_n) \in (\mathbb{R} \rightarrow \{\pm 1\}) \quad (7)$$

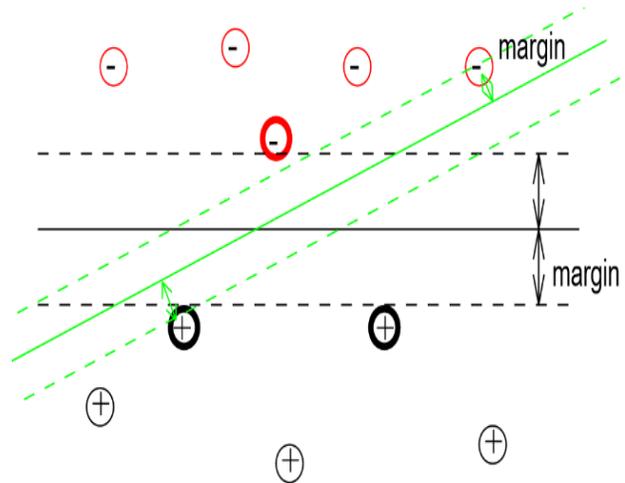


Fig. 5. The hyperplane of a linear SVM.

So as to f will properly categorize the new samples (x, y) [29]. This linear separating is found with a maximum-margin in a richer feature space made by kernel function $k(x, z)$. There are many general kernel functions consisting of polynomial, RBF, sigmoid, etc. The typical formula of SVM classifier is defined as follows [34]:

$$f(x) = \sum_{i=1}^n \alpha_i y_i k(x, v_i) + b \quad (8)$$

Where, $\{v_i\}_{i=1}^n$ are denoted the support vectors which are a minor set of training data close to the splitting hyperplane.

V. KNN vs SVM

Several classifiers have been established by many researchers, which are used in systems that include object recognition. Practically, both K-Nearest-Neighbor (KNN) and Support-Vector-Machine (SVM) classifiers are well known and commonly used.

In KNN, the object is classified based on the labels of its k nearest neighbors by popular vote. When $k=1$, the object is easily classified as the class of the object closest to it. If there are just two classes, k should be an odd number. A core benefit of the KNN algorithm is its strong performance with multi-modal classes, since the base decision is built on a minor neighborhood of the same objects. So, the system can still result with good accuracy if the goal class is multi-modal. However, a main weakness of the KNN algorithm is that it uses all the features equally in calculating for similarities. This could result in classification errors, particularly when there are just few subsets of features that are valuable for classification.

KNN has some suitable properties. It is mechanically non-linear; it can recognize linear or non-linear distributed data; and it works very well with a lot of data points. On the other hand, KNN has some negatives. It needs to be carefully tuned; the selection of K and the metric (distance) to be used are crucial. Besides, KNN may be slower to use when the value of K is to be reserved high, or the total number of points is high.

A main positive of SVM classification is that SVM performs well when datasets have numerous characteristics, even if there are just a few cases that exist for the training process. SVM performs in a different way and it is a good and fast solution for many applications. But, some disadvantages of SVM classification include limits in speed and size throughout both training and testing processes of the system and the collection of the kernel function parameters. Eventually, if the application has a lot of points in a low dimensional space, then KNN is perhaps an excellent choice. If the application has a few points in a high dimensional space, then a linear SVM is possibly better.

VI. EXPERIMENTAL RESULTS

The experiments have been evaluated using two different classifiers: KNN and SVM. Alzheimer database images in this work have been classified into two classes: normal cognitive (MCI) and brain suffered from AD. The proposed approach is trained with different numbers of training databases for each classifier, and their performance in discriminating the healthy and AD brain images are investigated.

A. Training

In this stage, the system is trained using the NHMI algorithm. The feature extraction process is performed for two distinct categories. Using NHMI, the moments' values will be separated into distinct, unique sets to guarantee the performance of the classifiers during the classification process. At the end of this stage, the most important features were constricted as 1D vector, which contains normalized moments for each training set (healthy and AD).

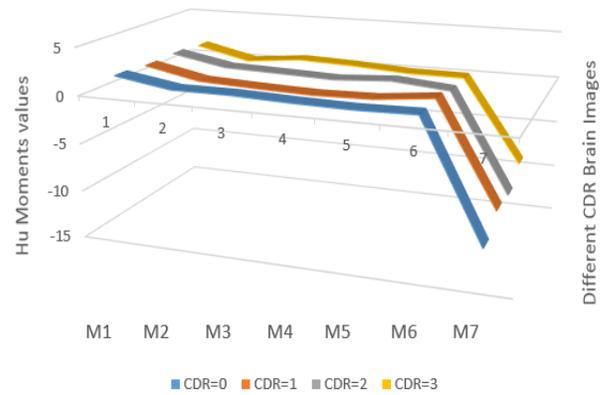


Fig. 6. Hu moment invariants for four different brain images.

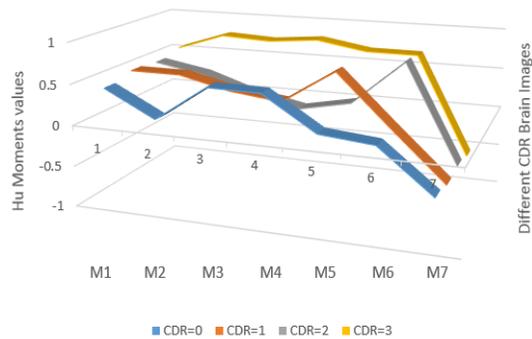


Fig. 7. Normalized Hu moment invariants of Fig. 5.

By way of example, Table 2 illustrates the normalized moments of four different brain images. It shows the effective power of NHMI weights. These weights represent the dominant distinct features of each image. Fig. 6 displays an example of the salient HMI features, there is a clear convergence of their moment's values which make it kind of confusing for the classifiers to do the classification tasks and put each test dataset in its right class. Therefore, the idea of normalizing these moments has been proposed to ensure the moments of every class are separated differently from each other. This step highly improves the classification system performance and the accuracy reaches 100% for the SVM classifier. Fig. 7 shows the same moments after normalization and how they look spaced out between each other, which was the key point in this work.

B. Testing and Results

With a view to accomplish best-expected accuracy, we tested the system using two sets of brain images; MCI and AD with two different classifiers, KNN and SVM. The classification accuracy is also estimated for each classifier, too. Indeed, NHMI model demonstrates an improved classification performance, as well as training, once the moments are normalized. Fig. 8 shows the training datasets distribution for SVM classifier and how the hyperplane separates the two classes non-linearly. However, the normalizing process has solved this problem and enables the classifier to recognize each class perfectly. For evaluation purposes, the testing results are approved using ADNI datasets. It is proven that the designed NHMI shows

promising results. As shown in Tables 3 and 4, confusion matrices include the classification accuracy for each used classifier. The usefulness of the normalized moments is demonstrated in Table 5, where the confusion matrices and the classification accuracy are recorded before normalizing the Hu moments, even though we use 100 subjects as a training dataset. To be fair, we run the same number of training and testing datasets for the two different classifiers. Also, the running time that is required for both classifiers to do the classification process has been computed. Table 6 displays the running time values. As it is clear in this work, KNN is faster than the SVM classifier, since we have just two classes. However, SVM performs better than KNN in the classification performance. Table 3 illustrates how the NHMI performance improved as the number of training datasets increased for KNN classifier. While for SVM, it got its perfect performance from the beginning when the training dataset is 50, so, SVM does not need any increase with the training datasets. However, each classifier has its strength in classifying the testing datasets in our model.

C. Sensitivity and Specificity

In addition to the accuracy rate of the classification approach, there are other statistical measures for a binary classification test named as sensitivity and specificity. They are widely used to describe a diagnostic test. In any medical study, each subject may have or may not have the disease. The test result can be either positive (having the disease), or negative (does not have the disease). Nevertheless, there is still a possibility that the test outcome does not match the actual case of the patient. Sensitivity calculates the ratio of actual positives which are correctly diagnosed (the percentage of the patients who are recognized to have the disease). While Specificity computes the ratio of negatives which are correctly diagnosed (the percentage of healthy people who are recognized as not having the disease). They can be expressed as follows:

$$\begin{aligned} \text{Sensitivity} &= TP / (TP + FN), \\ \text{Specitivity} &= TN / (TN + FP) \end{aligned} \tag{9}$$

where *TP* is the number of true positives, which means number of AD patients who were correctly classified, *TN* is the number of true negatives which is the number of normal cognitive correctly classified; *FN* is the number of false negatives, the number of AD patients classified as normal cognitive, and *FP* is the number of false positives which is the number of normal cognitive people classified as AD patient. These probabilities expose the skill to distinguish MCI/AD patterns as illustrates in Table 7.

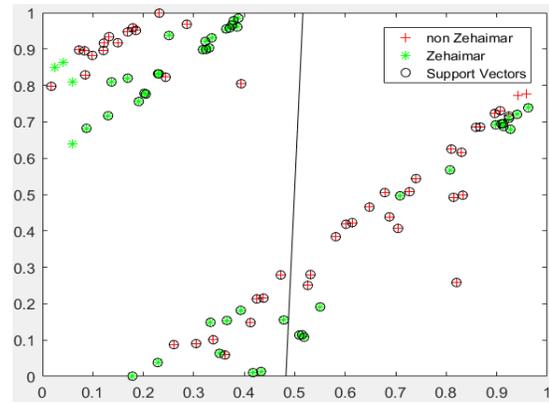


Fig. 8. Separating Hyperplane for the input training data space using SVM classifier.

TABLE III. CONFUSION MATRICES OF CLASSIFICATION ACCURACY FOR KNN CLASSIFIER

Brain images	Training dataset =50			Training dataset=75		
	MCI	AD	Accuracy	MCI	AD	Accuracy
MCI	16	0	100%	16	0	100%
AD	4	8	66%	2	10	83%
Average Accuracy	83%			91.5%		
MCI	Training dataset =100					
	MCI	AD	Accuracy			
	16	0	100%			
AD	2	10	83%			
Average Accuracy	91.5%					

TABLE IV. CONFUSION MATRICES OF CLASSIFICATION ACCURACY FOR SVM CLASSIFIER

Brain images	Training dataset =50			Training dataset=75		
	MCI	AD	Accuracy	MCI	AD	Accuracy
MCI	16	0	100%	16	0	100%
AD	0	12	100%	0	12	100%
Average Accuracy	100%			100%		
MCI	Training dataset =100					
	MCI	AD	Accuracy			
	16	0	100%			
AD	0	12	100%			
Average Accuracy	100%					

TABLE V. CONFUSION MATRICES OF CLASSIFICATION ACCURACY BEFORE NORMALIZING THE MOMENTS WITH TRAINING DATASETS=100

Brain images	KNN			SVM		
	MCI	AD	Accuracy	MCI	AD	Accuracy
MCI	11	5	68.7%	12	4	75%
AD	3	9	75%	9	3	75%
Average Accuracy	71.85%			75%		

TABLE VI. RUNNING TIME FOR CLASSIFICATION PROCESS WITH DIFFERENT TRAINING DATASETS FOR BOTH KNN AND SVM CLASSIFIERS (MSEC.)

Training datasets	KNN	SVM
50	2.1	4.9
75	2.1	13.7
100	2.5	28.9

TABLE VII. AVERAGE ACCURACY, SENSITIVITY, SPECIFICITY, FOR KNN AND SVM WHEN TRAINING DATASETS=100

Classifier	Sensitivity	Specificity	Average Acc.
KNN	0.833	1	91.5%
SVM	1	1	100%

D. Results Comparison

The work of the NHMI model in this paper is compared with other state-of-the-art techniques which used the same ADNI database. Table 8 clarifies the classification accuracy results of the ADNI database literature works used different algorithms, in comparison with ours. Overall, the proposed NHMI proves a considerable enhancement in performance compared with other state-of-the-art methods.

VII. DISCUSSION

As has been noted, normalizing the Hu moments significantly affects our proposed system performance and gives an outstanding result, especially for SVM classifier. SVM classifier has reached its best performance (accuracy of 100%) once we normalize the Hu moments no matter how much we increase the training datasets. From the other point of view, the KNN classifier affected with increasing the training datasets which enhances its performance, but no longer than 75 training datasets. It is quite obvious that KNN classifier has a simpler model structure, which makes it the faster classifier for low-level classification applications of the two classes, having low dimensional features like our application. On the other hand, SVM classifier has the better performance, but it is a little bit more complex and slower than KNN. As a future work, we are looking headlong to classify Alzheimer disease into four different classes, depending on measures of disease severity (normal cognitive CDR=0, simple AD (CDR=1), moderate AD (CDR=2), severe AD (CDR=3)). Besides, investigating new classification schemes to recognize and classify other diseases, ECG signals classification, or classification of various medical images for healthy and non-healthy people.

TABLE VIII. COMPARISON CLASSIFICATION ACCURACY OF OUR NHMI WITH THE STATE-OF-THE-ART EXISTING ALGORITHMS FOR THE SAME ADNI DATASETS

ADNI literature	Classification Methods	Acc (%)
Carlos Cabral et al. [14]	Favourite Class Ensembles	66.78%
L. Herrera et al. [25]	DWT and SVM classifier	83.63%
J. Iglesias et al. [35]	Self-Smoothing Operator	97.5%
D. Zhang et al. [36]	Multimodal classification based on MRI, PET, and CSF	93.2%
M. López et al [37]	Principle Component Analysis with neural network	96.7%
This work	NHMI with KNN classifier	91.5%
	NHMI with SVM classifier	100%

VIII. CONCLUSION

In this paper, we investigate and prove the usefulness of a NHMI technique for Alzheimer disease classification. The NHMI system serves medical requests in a specific area for diagnosing medical images using good classification techniques with fast processes. It offers greater advantages, perfect classification accuracy (100% for SVM classifier), and fast computational processes.

Hu moments Invariant algorithm has been used in this approach. The key point in this work is to normalize these moments and make them diverge from each other, which results in perfect classification performance. This step has made the proposed system very efficient, even though it is built from common classifiers. Two different classifiers have been used in this study, KNN and SVM. The experiments' results are obtained during short running time and ideal classification accuracy. To guarantee the preferred results, different numbers of the training datasets are used (50, 75, and 100), and 28 datasets are used for testing purposes later. Best results, in terms of best accuracy and low running time, are obtained with moderate numbers of training datasets.

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Multi-Valued Autoencoders and Classification of Large-Scale Multi-Class Problem

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Abstract—Two-layered neural networks are well known as autoencoders (AEs) in order to reduce the dimensionality of data. AEs are successfully employed as pre-trained layers of neural networks for classification tasks. Most of the existing studies conceived real-valued AEs in real-valued neural networks. This study investigated complex- and quaternion-valued AEs for complex- and quaternion-valued neural networks. Inputs, weights, biases, and outputs in complex-valued AE (CAE) are complex variables, whereas those in quaternion-valued AE (QAE) are quaternions. In both methods, a split-type activation function is used in the hidden and output units. To deal with the images using the proposed methods, pairs of pixels are allotted to complex-valued inputs in the CAE and quartets of pixels are allotted to quaternion-valued inputs in the QAE. Proposed autoencoders are tested and performance compared with conventional AE for several tasks which are encoding/decoding, handwritten numeral recognition and large-scale multi-class classification. Proposed CAE and QAE revealed as good recognition methods for the tasks and outperformed conventional AE with significance performance in case of large-scale multi-class images recognition.

Keywords—Autoencoder; classification; complex-valued autoencoder; quaternion-valued autoencoder; recognition

I. INTRODUCTION

Autoencoding refers the automatic learning of encoding and decoding functions from examples without engineered by an expert or a human. A two-layered neural network is well known as an autoencoder (AE) in order to reduce the dimensionality of data. Recent studies proposed many types of AEs [1]-[6] which are composed of input, hidden, and output units, and are based on the gradient descent method. AEs generally deal with image data. If a network is trained with image data, some features of the input image appear in the learned weights. These parameters can be used as the initial parameters to train neural networks for classification tasks. Most of the existing studies conceived real-valued AEs in real-valued neural networks [1]-[6].

Artificial neural networks involve in a large number of applications with significant varieties and recent multi-valued version is found efficient for higher-dimension data. Nowadays, real-world data contain higher-dimensional

information; examples include image, medical, and web data. In conventional real-valued neural networks (RNNs), a multi-dimension values are often treated by using multiple real-valued neurons. The use of these multi-valued quantities is now spreading to artificial neural networks in the form of complex-valued neural networks (CVNNs) and quaternion neural networks (QNNs).

Complex and quaternion numbers are widely used in various areas of engineering. Complex numbers are used to deal with two-dimensional vectors and wave information, whereas quaternions are used for three-dimensional graphics and computer vision. The gradient descent method to tune complex-valued weights in CVNNs [7] and quaternion-valued weights in QNNs [8] made efficient to tackle such high dimensional problems efficiently. With the advent of CVNNs and QNNs, multi-valued data can now be used as complex and quaternion signals. The convergence of CVNNs and QNNs is found better than that of RVNNs to solve such higher dimension problems. The study of CVNNs has been developing widely in various areas [9]-[20]. Applications of CVNNs include those in radar image processing [17], real-time image recognition [19], and traffic and power systems [20]. There have also been active studies of QNNs [21]-[24] in, for example, color image compression [21] and color night vision [22].

This study proposed two multi-valued autoencoders extending conventional AE which are complex-valued AE (CAE) and quaternion-valued AE (QAE). The CAE is a complex-valued neural network with input, hidden, and output units; its learning is based on the complex gradient descent method. The QAE is a quaternion neural network with input, hidden, and output units; its learning is based on the quaternion gradient descent method. The signal flows in the networks are almost the same as those of the AE. In order to simplify the network calculations, easy-to-use split-type activation functions are considered in the hidden and output units of the CAE and QAE. Proficiency of the proposed AEs are identified comparing with the conventional AE for encoding/decoding and classification of image objects.

Although CAE and QAE have been outlined in our previous study [25], the present study is extended and complete presentation in both theoretical analysis and experimental results. In this study, proposed methods are tested for two different activation functions (sigmoid and

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rectified linear unit). Recognition of handwritten numerals and large-scale multi-class objects is the main significance of the present study. In another study, complex-valued are investigated for linear autoencoders [26]; the algorithm is different from those of our methods. The autoencoders have considered in this study are nonlinear in category based on neural network with nonlinear activation function and have focused on the classification task.

The remainder of this paper is structured as follows. Conventional AE and proposed multi-valued autoencoders (i.e., CAE and QAE) are explained in Section II. This section also demonstrates autoencoder based classification. In Section III, performance of proposed autoencoders are investigated for several tasks which are encoding/decoding, handwritten numeral recognition and a large-scale multi-class classification. Finally, the study is concluded in Section IV with future research directions.

II. MULTI-VALUED AUTOENCODERS AND CLASSIFICATION WITH THOSE

This section first explains conventional autoencoder (AE) with a sample architecture for better understanding of proposed multi-valued autoencoders. It then presents proposed complex-valued autoencoder (CAE) and quaternion-valued autoencoder (QAE) extending conventional AE. Finally, classification based on autoencoders is demonstrated.

A. Conventional Autoencoder(Ae)

An AE is a two-layered neural network that is based on the gradient descent method. In an AE, the number of outputs is the same as the number of inputs, and common weights are used in the first and second layers (weight sharing). To describe the network architecture clearly, consider a network with four-input, three-hidden, four-output units as shown in Fig. 1.

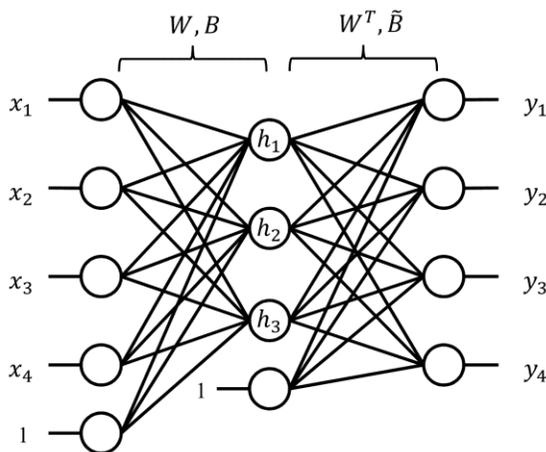


Fig. 1. Network structure of an autoencoder with four-input, three-hidden and four-output units. In conventional case the inputs and outputs are real number.

Here, the input vector is $X = [x_1 \cdots x_4]$, and the bias vectors in the first and second layers are $B = [b_1 \cdots b_3]$ and $\tilde{B} = [\tilde{b}_1 \cdots \tilde{b}_4]$, respectively. The weight matrix W is represented as:

$$W = \begin{pmatrix} w_{11} & \cdots & w_{14} \\ \vdots & \ddots & \vdots \\ w_{31} & \cdots & w_{34} \end{pmatrix}. \quad (1)$$

The hidden-unit output vector $H = [h_1 \cdots h_3]$ is obtained as

$$H = f(WX + B), \quad (2)$$

where $f(x)$ is an activation function such as the sigmoid or rectified linear unit (ReLU) function. The output vector $Y = [y_1 \cdots y_4]$ is computed as

$$Y = f(W^T H + \tilde{B}). \quad (3)$$

Here, W^T is the transpose of W . When training data are given to this network, the weights and biases are tuned by back propagation to minimize the error between inputs and outputs. The squared error given by (4) is applied as the error function:

$$E = \|X - Y\|^2. \quad (4)$$

The tuning equations of the network parameters b_q , \tilde{b}_p , and w_{qp} are as follows:

$$\Delta \tilde{b}_p = -\alpha \frac{\partial E}{\partial \tilde{b}_p} = 2\alpha(x_p - y_p)f'(z_p) \quad (5)$$

$$\Delta b_q = -\alpha \frac{\partial E}{\partial b_q} = \sum_{p=1}^4 \{\Delta \tilde{b}_q w_{qp}\} f'(c_q) \quad (6)$$

$$\Delta w_{qp} = -\alpha \frac{\partial E}{\partial w_{qp}} = \Delta \tilde{b}_p h_q, \quad (7)$$

Where, α is the learning rate and $z_p = \sum_{q=1}^3 w_{qp} h_q + \tilde{b}_p$ and $c_q = \sum_{p=1}^4 w_{qp} x_p + b_q$ are the net inputs to the p^{th} output and q^{th} hidden unit, respectively. The learning process is performed by giving initial values to the parameters and iterating (5)–(7).

Autoencoders can generate some features in learned parameters by training with data. For example, if an AE is trained on a dataset of cat images, features such as silhouettes, eyes, and ears appear in the learned weights. Furthermore, AEs can be employed for pre-training weights of different layers of deep neural networks and hence perform classification tasks (e.g., image classification). By stacking AEs, deep neural networks are shown better convergence than in the case without pre-training of AEs [2].

B. Complex-Valued Autoencoder(CAE)

Proposed CAE is an extension of conventional AE to the complex domain with complex-valued neurons. To consider network structure of Fig. 1 for CAE, inputs, weights, biases, and outputs are all complex valued. CAE operation steps are similar to AE but perform in complex domain. Input signals are given to the network through the input units; then, the weighted sum of the inputs is given to some activation function in each of the hidden units. Finally, in the output units, the weighted sums of the hidden outputs are passed through some activation function.

A complex value contains a real and an imaginary parts and CAE learning algorithm is based on the complex-valued gradient descent method. For network structure with Fig. 1,

the input vector is $X = [x_1 \cdots x_4]$, the bias vector in the first layer $B = [b_1 \cdots b_3]$, the bias vector in the second layers $\tilde{B} = [\tilde{b}_1 \cdots \tilde{b}_4]$ and the weight matrix W (represented by the same form as (1)) are all complex-valued numbers in CAE. To describe the real and imaginary parts of the parameters, $x_p = x_p^R + ix_p^I$, $w_{qp} = w_{qp}^R + iw_{qp}^I$, $b_q = b_q^R + ib_q^I$, and $\tilde{b}_p = \tilde{b}_p^R + i\tilde{b}_p^I$ ($i^2 = -1$). The net input $c_q = c_q^R + ic_q^I$ and output $h_q = h_q^R + ih_q^I$ of the q^{th} hidden unit are calculated as

$$c_q = \sum_{p=1}^4 w_{qp} x_p + b_q$$

$$= \left\{ \sum_{p=1}^4 (w_{qp}^R x_p^R - w_{qp}^I x_p^I) + b_q^R \right\}$$

$$+ i \left\{ \sum_{p=1}^4 (w_{qp}^R x_p^I + w_{qp}^I x_p^R) + b_q^I \right\} \quad (8)$$

$$h_q = f(c_q^R) + if(c_q^I) \quad (9)$$

Here, the hidden output is generated by a split-type activation function [27]. The net input $z_p = z_p^R + iz_p^I$ and output $y_p = y_p^R + iy_p^I$ of the p^{th} output unit are calculated similarly as

$$z_p = \sum_{q=1}^3 w_{qp} h_q + \tilde{b}_p \quad (10)$$

$$y_p = f(z_p^R) + if(z_p^I) \quad (11)$$

The error function to be minimized is the same formula as (4). For the training, we update the weights and biases by using (12)–(14):

$$\Delta \tilde{b}_p = -\beta \frac{\partial E}{\partial \tilde{b}_p^R} - i\beta \frac{\partial E}{\partial \tilde{b}_p^I} = \Delta \tilde{b}_p^R + i\Delta \tilde{b}_p^I \quad (12)$$

$$\Delta b_q = -\beta \frac{\partial E}{\partial b_q^R} - i\beta \frac{\partial E}{\partial b_q^I} = \Delta b_q^R + i\Delta b_q^I \quad (13)$$

$$\Delta w_{qp} = -\beta \frac{\partial E}{\partial w_{qp}^R} - i\beta \frac{\partial E}{\partial w_{qp}^I} = \Delta w_{qp}^R + i\Delta w_{qp}^I$$

$$= \Delta b_q \bar{h}_q, \quad (14)$$

Where, β is the learning rate and \bar{h}_q is the complex conjugate of h_q . The following equations are for the partial derivatives within (12)–(14):

$$\frac{\partial E}{\partial \tilde{b}_p^R} = -2(x_p^R - y_p^R) f'(z_p^R) \quad (15)$$

$$\frac{\partial E}{\partial \tilde{b}_p^I} = -2(x_p^I - y_p^I) f'(z_p^I) \quad (16)$$

$$\frac{\partial E}{\partial b_q^R} = (\sum_{p=1}^4 \Delta \tilde{b}_p^R w_{qp}^R + \sum_{p=1}^4 \Delta \tilde{b}_p^I w_{qp}^I) f'(c_q^R) \quad (17)$$

$$\frac{\partial E}{\partial b_q^I} = (\sum_{p=1}^4 \Delta \tilde{b}_p^I w_{qp}^R - \sum_{p=1}^4 \Delta \tilde{b}_p^R w_{qp}^I) f'(c_q^I) \quad (18)$$

The learning process is performed by giving initial values to the parameters and iterating (12)–(14).

C. Quaternion-Valued Autoencoder(QAE)

Proposed QAE is an extension of conventional AE to the quaternion domain with quaternion-valued neurons. To consider network structure of Fig. 1 for QAE, inputs, weights, biases, and outputs are all quaternion valued. The signal flow

in a QAE network is the same as that in an AE or CAE but perform in quaternion domain.

A quaternion value contains one real and three imaginary parts and QAE learning algorithm is based quaternion-valued gradient descent method [21]. For network structure with Fig. 1, the input vector is $X = [x_1 \cdots x_4]$, the bias vector in the first layer $B = [b_1 \cdots b_3]$, the bias vector in the second layers $\tilde{B} = [\tilde{b}_1 \cdots \tilde{b}_4]$ and the weight matrix W (represented by the same form as (1)) are all quaternion-valued numbers in QAE. To describe the real and imaginary parts of the parameters $x_p = x_p^R + ix_p^I + jx_p^J + kx_p^K$, $w_{qp} = w_{qp}^R + iw_{qp}^I + jw_{qp}^J + kw_{qp}^K$, $b_q = b_q^R + ib_q^I + jb_q^J + kb_q^K$, and $\tilde{b}_p = \tilde{b}_p^R + i\tilde{b}_p^I + j\tilde{b}_p^J + k\tilde{b}_p^K$ ($i^2 = j^2 = k^2 = ijk = -1$). The net input $c_q = c_q^R + ic_q^I + jc_q^J + kc_q^K$ and output $h_q = h_q^R + ih_q^I + jh_q^J + kh_q^K$ of the q^{th} hidden unit are calculated as:

$$c_q = \sum_{p=1}^4 w_{qp} x_p + b_q$$

$$= \left\{ \sum_{p=1}^4 (w_{qp}^R x_p^R - w_{qp}^I x_p^I - w_{qp}^J x_p^J - w_{qp}^K x_p^K) + b_q^R \right\}$$

$$+ i \left\{ \sum_{p=1}^4 (w_{qp}^R x_p^I + w_{qp}^I x_p^R + w_{qp}^J x_p^K - w_{qp}^K x_p^J) + b_q^I \right\}$$

$$+ j \left\{ \sum_{p=1}^4 (w_{qp}^R x_p^J + w_{qp}^I x_p^K + w_{qp}^J x_p^R - w_{qp}^K x_p^I) + b_q^J \right\}$$

$$+ k \left\{ \sum_{p=1}^4 (w_{qp}^R x_p^K + w_{qp}^I x_p^J + w_{qp}^J x_p^I - w_{qp}^K x_p^R) + b_q^K \right\} \quad (19)$$

$$h_q = f(c_q^R) + if(c_q^I) + jf(c_q^J) + kf(c_q^K). \quad (20)$$

Here, a split-type activation function is adopted to generate the hidden output. The net input $z_p = z_p^R + iz_p^I + jz_p^J + kz_p^K$ and output $y_p = y_p^R + iy_p^I + jy_p^J + ky_p^K$ of the p^{th} output unit are also calculated as

$$z_p = \sum_{q=1}^3 h_q w_{qp} + \tilde{b}_p \quad (21)$$

$$y_p = f(z_p^R) + if(z_p^I) + jf(z_p^J) + kf(z_p^K). \quad (22)$$

The same formula as (4) is used as the error function. For the training, the weights and biases are updated using the following equations:

$$\Delta \tilde{b}_p = -\gamma \frac{\partial E}{\partial \tilde{b}_p^R} - i\gamma \frac{\partial E}{\partial \tilde{b}_p^I} - j\gamma \frac{\partial E}{\partial \tilde{b}_p^J} - k\gamma \frac{\partial E}{\partial \tilde{b}_p^K}$$

$$= \Delta \tilde{b}_p^R + i\Delta \tilde{b}_p^I + j\Delta \tilde{b}_p^J + k\Delta \tilde{b}_p^K \quad (23)$$

$$\Delta b_q = -\gamma \frac{\partial E}{\partial b_q^R} - i\gamma \frac{\partial E}{\partial b_q^I} - j\gamma \frac{\partial E}{\partial b_q^J} - k\gamma \frac{\partial E}{\partial b_q^K}$$

$$= \Delta b_q^R + i\Delta b_q^I + j\Delta b_q^J + k\Delta b_q^K \quad (24)$$

$$\Delta w_{qp} = -\gamma \frac{\partial E}{\partial w_{qp}^R} - i\gamma \frac{\partial E}{\partial w_{qp}^I} - j\gamma \frac{\partial E}{\partial w_{qp}^J} - k\gamma \frac{\partial E}{\partial w_{qp}^K}$$

$$= \Delta w_{qp}^R + i\Delta w_{qp}^I + j\Delta w_{qp}^J + k\Delta w_{qp}^K$$

$$= \bar{h}_q \Delta b_q, \quad (25)$$

Where, γ is the learning rate and \bar{h}_q is the quaternion conjugate of h_q . The following equations are for the partial derivatives within (23)–(25):

$$\frac{\partial E}{\partial \bar{b}_p^R} = -2(x_p^R - y_p^R)f'(z_p^R) \quad (26)$$

$$\frac{\partial E}{\partial \bar{b}_p^I} = -2(x_p^I - y_p^I)f'(z_p^I) \quad (27)$$

$$\frac{\partial E}{\partial \bar{b}_p^J} = -2(x_p^J - y_p^J)f'(z_p^J) \quad (28)$$

$$\frac{\partial E}{\partial \bar{b}_p^K} = -2(x_p^K - y_p^K)f'(z_p^K) \quad (29)$$

$$\frac{\partial E}{\partial \bar{b}_q^R} = \left(\sum_{p=1}^4 \Delta \tilde{b}_p^R w_{qp}^R + \sum_{p=1}^4 \Delta \tilde{b}_p^I w_{qp}^I \right) f'(c_q^R) \quad (30)$$

$$\frac{\partial E}{\partial \bar{b}_q^I} = \left(\sum_{p=1}^4 \Delta \tilde{b}_p^I w_{qp}^R - \sum_{p=1}^4 \Delta \tilde{b}_p^R w_{qp}^I \right) f'(c_q^I) \quad (31)$$

$$\frac{\partial E}{\partial \bar{b}_q^J} = \left(\sum_{p=1}^4 \Delta \tilde{b}_p^J w_{qp}^R - \sum_{p=1}^4 \Delta \tilde{b}_p^K w_{qp}^I \right) f'(c_q^J) \quad (32)$$

$$\frac{\partial E}{\partial \bar{b}_q^K} = \left(\sum_{p=1}^4 \Delta \tilde{b}_p^K w_{qp}^R + \sum_{p=1}^4 \Delta \tilde{b}_p^J w_{qp}^I \right) f'(c_q^K) \quad (33)$$

The learning process is performed by giving initial values to the parameters and iterating (23)–(25).

D. Classification using Autoencoder

Conventional AEs are found effective to build networks for classification task. Proposed CAE and QAE based networks also might perform well in classification; which is the main intuition of this study. Size of output layer (i.e., nodes in the layer) of the network depends on number of classes to be identified; and size of input layer depends on data and how it process. Hidden layer numbers and sizes are user defined parameters. Autoencoder(s) is used to pre-train hidden layer(s). Output layer is trained only in fine tuning with backpropagation in supervised mode.

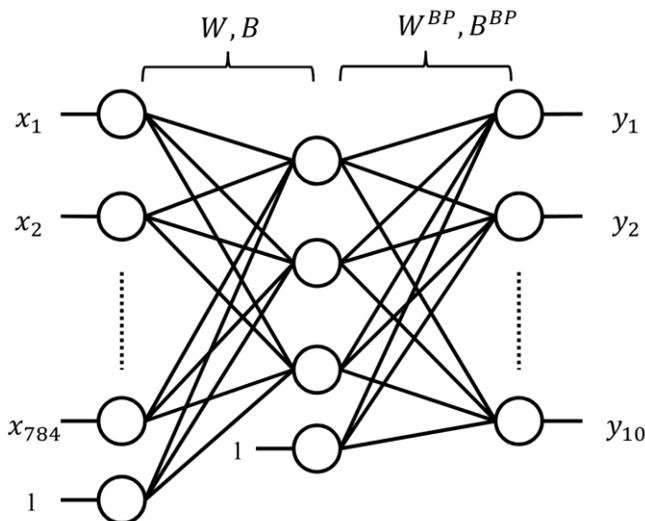


Fig. 2. Network structure using conventional autoencoder for handwritten numeral recognition from 28×28 ($=784$) size images.

For better understanding of classification using autoencoder, Fig. 2 is the network structure based on conventional AE for MNIST handwritten numeral recognition [28]. MNIST contains handwritten numeral images of 28×28 pixels. Therefore, total input nodes I_{AE} is 784 ($=28 \times 28$) considering an individual node for a pixel value. To classify the digit images, 10 outputs (corresponding to the class labels from 0 to 9) are considered in the output layer. If number of nodes in the hidden layer is defined as H_{AE} , hidden layer weights (W) and biases (B) are size of $H_{AE} \times I_{AE}$ and H_{AE} , respectively. W and B are pre-trained through conventional AE. W^{BP} and B^{BP} are the weight and bias vectors of output layer, respectively, that have to be tuned by back propagation. In the output units, signals from the hidden units are processed by the sigmoid function.

The networks for classification using CAE and QAE are complex and quaternion-valued, respectively. In CAE based network, the complex-valued input neuron manipulate two conjugative pixel values in real and imaginary parts of it. Therefore, number of input in CAE based network (I_{CAE}) will be half of conventional AE based network of Fig. 2. Similarly, number of input in QAE based network (I_{QAE}) will be one fourth of conventional AE based network. At a glance, $I_{AE} = 2I_{CAE} = 4I_{QAE}$. Due to higher dimension operation, relatively less number of hidden neurons in CAE and QAE might be sufficient. However, real valued output neuron is necessary to classify in both the cases. In order to generate real-valued outputs from the CAE output units, activation functions for CAE and QAE are shown in (34) and (35), respectively.

$$f_{C \rightarrow R}(x) = (f(x^R) - f(x^I))^2 \quad (34)$$

$$f_{Q \rightarrow R}(x) = (f(x^R) - f(x^I))^2 - (f(x^J) - f(x^K))^2 \quad (35)$$

In both the equations, $f(x) = 1/(1 + e^{-x})$, i.e., sigmoid function. Equation (34) has been investigated for complex-valued neural networks to solve real-valued classification problems [27]. Equation (35) is the proposed activation function for QAE to convert quaternions to real numbers. The methods used back propagation to tune the weights and biases between the hidden and output units.

III. EXPERIMENTAL STUDIES

This section investigates effectiveness of proposed multivalued AEs (i.e., CAE and QAE) in encoding/decoding and classification of image objects. The outcome of the proposed methods compared with conventional AE. Encoding/decoding ability is observed on handwritten numeral images. Recognition of handwritten numeral is also considered to observe classification ability. Finally, recognition on large-scale objects with many classes is performed. Following individual sections explain experimental setup and compare outcomes of the encoding/decoding and both classification tasks. The algorithms are implemented in PGI® Accelerator C Workstation. Experiments of this study have been conducted on HP Z440 Workstation having CPU Intel(R) Xeon (R) CPU

E5-1603 @ 2.80GHz and RAM 32.0GB in Windows 10 Pro (64 bit) environment.

A. Encoding/Decoding

Performance of encoding/decoding is observed on MNIST database [28]. MNIST database comprises 28×28-pixel gray-scale images of handwritten digits from 0 to 9. From the available samples, 2500 samples are considered as training set and different 2500 samples are used as test set. In each set (training/test) 250 of each digit from 0 to 9 are considered. Same training and test set are used for all three networks (conventional AE, proposed CAE and QAE).

In training/testing, a pattern is represented in different forms in AE, CAE and QAE. Each individual pixel value is an input in AE; therefore, AE required total 784 input neurons. On the other hand, number of input is less in CAE and QAE due to multi-valued neurons. Fig. 3 shows pattern construction for CAE and QAE from a sample numeral image. CAE treated each pair of pixels as one complex number, and QAE considered each quartet of pixels as one quaternion number. Therefore, CAE and QAE required input neurons 392 (=784/2) and 196 (=784/4), respectively.

Two popular activation functions sigmoid and ReLU were considered to the hidden units of each method. On the other hand, only the sigmoid function was applied to the output units of each method. The number of hidden nodes were considered less than input of a method as of many previous studies. Experiments conducted for two different number of hidden units. Table 1 shows the parameters for all the three methods. Here, the notation AE₇₈₄₋₂₇₂ signifies the method name “AE” as conventional method; and the number of input and hidden units are 784 and 272, respectively. Due to less number of inputs as well as much less number of hidden units considered in proposed multi-valued autoencoders, total parameters were much less than conventional AE.

To assess the learning abilities of the proposed methods, mean squared error (MSE) for the test set and the execution time required for the training were compared. The test error was calculated by

$$MSE = \frac{1}{2N} \sum_{n=1}^N \|X_n - Y_n\|^2 \tag{36}$$

Where, n is the pattern number and N is the total number of test samples. Furthermore, we discuss the features appeared in the learned weights of each method.

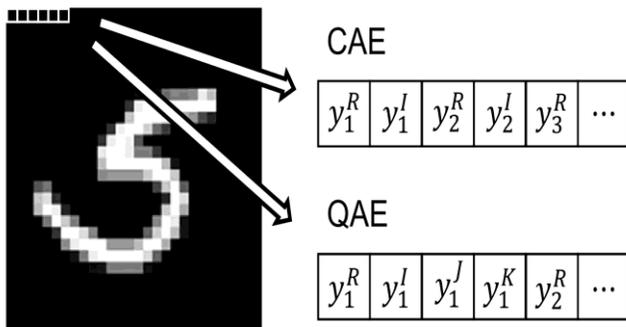


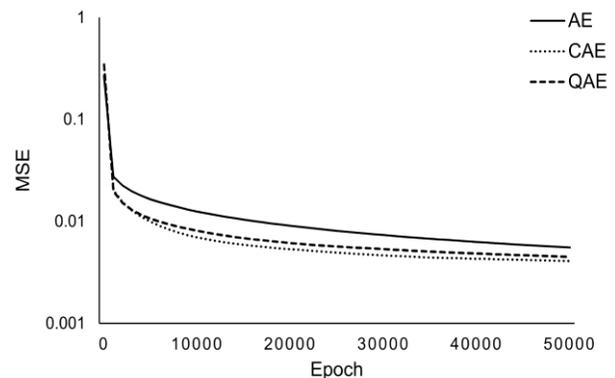
Fig. 3. Pattern construction from a sample MNIST image for CAE and QAE.

TABLE I. NUMBER OF PARAMETERS FOR ENCODER/DECODER TEST ON MNIST IMAGES

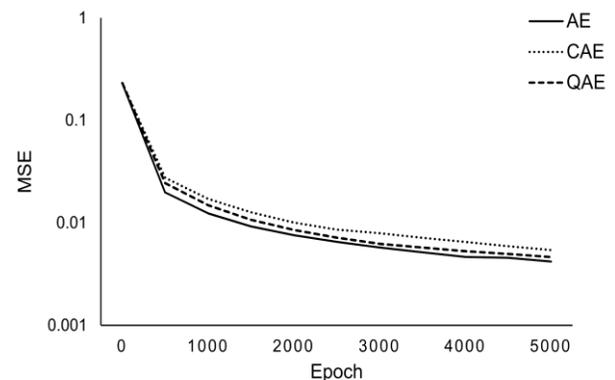
Method	Number of parameters			
	Input unit	Hidden unit	Output unit	Total ^a
AE ₇₈₄₋₂₇₂	784	272	784	214,304
AE ₇₈₄₋₃₉₂	784	392	784	308,504
CAE ₃₉₂₋₁₃₆	392	136	392	107,680
CAE ₃₉₂₋₁₉₆	392	196	392	154,840
QAE ₁₉₆₋₆₈	196	68	196	54,368
QAE ₁₉₆₋₉₈	196	98	196	78,008

^a Total number of parameters includes real and imaginary parts of weights and biases in the CAE and QAE.

Fig. 4 depicts MSE for three methods (AE₇₈₄₋₃₉₂, CAE₃₉₂₋₁₉₆, and QAE₁₉₆₋₉₈) for both sigmoid and ReLU functions in hidden units on a sample run. It is observed from the figure that the nature of the MSE curve almost same for all the three methods for a particular activation function. The significance observation from the figure is that all the methods with the ReLU function (Fig. 4(b)) converged much faster than the methods with the sigmoid function (Fig. 4(a)). For ReLU function, MSE reached steady state position for 5000 epochs; whereas, steady state position with similar MSE value for sigmoid was shown to reach for 50000 epochs. Therefore, in further experiments, 5000 and 50000 epochs are considered for ReLU and sigmoid functions, respectively.



(a) Sigmoid function



(b) ReLU function

Fig. 4. Training process of AE₇₈₄₋₃₉₂, CAE₃₉₂₋₁₉₆, and QAE₁₉₆₋₉₈ methods with sigmoid and ReLU activation functions in the hidden units.

TABLE II. AVERAGE TEST ERROR ON AE, CAE AND QAE WITH DIFFERENT ARCHITECTURE AND ACTIVATION FUNCTIONS

Method	Hidden unit act. function	Epoch	MSE ($\times 10^{-3}$)	Time (s)
AE ₇₈₄₋₂₇₂	Sigmoid	50000	10.62 \pm 0.14	1356
	ReLU	5000	6.41 \pm 0.16	154
AE ₇₈₄₋₃₉₂	Sigmoid	50000	7.39 \pm 0.08	2048
	ReLU	5000	6.08 \pm 0.12	228
CAE ₃₉₂₋₁₃₆	Sigmoid	50000	9.17 \pm 0.07	376
	ReLU	5000	10.53 \pm 0.35	43
CAE ₃₉₂₋₁₉₆	Sigmoid	50000	6.23 \pm 0.08	579
	ReLU	5000	8.60 \pm 0.35	63
QAE ₁₉₆₋₆₈	Sigmoid	50000	8.88 \pm 0.19	206
	ReLU	5000	7.39 \pm 0.18	24
QAE ₁₉₆₋₉₈	Sigmoid	50000	6.33 \pm 0.09	306
	ReLU	5000	6.10 \pm 0.15	35

Averages are taken over 5 independent runs.

Table 2 shows test error and required time for each method after fixed number epoch. In relation to the test error, the AE and the QAE with the ReLU function showed better results than those of the methods with the sigmoid function even training epoch is much less in case of ReLU. However, the error of the CAE with the sigmoid function was better than that with the ReLU function. Furthermore, each of the methods showed better convergence as the number of parameters increased. As an example, MSE value of QAE₁₉₆₋₉₈ (having 98 hidden units) was less than QAE₁₉₆₋₆₈ (having 68 hidden units) for both sigmoid and ReLU. In terms of the execution time, the period for QAE was much shorter than period for the other two methods as seen from Table 2. This is because the execution time is related to the number of parameters and the computational complexity of the methods. For better understanding, Fig. 5 shows sample output images of AE₇₈₄₋₃₉₂, CAE₃₉₂₋₁₉₆, and QAE₁₉₆₋₉₈ with the ReLU function in the hidden units. Comparing with the output images, the proposed methods showed almost the same qualities as that of the conventional AE.

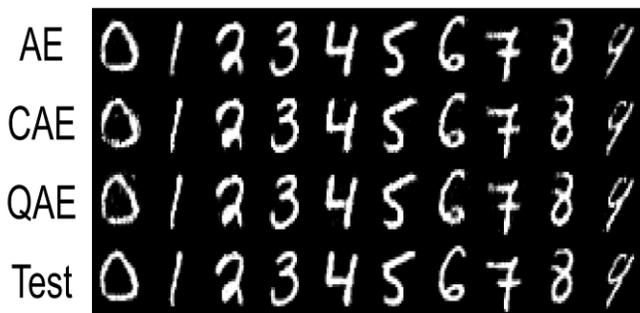


Fig. 5. Sample output images of the conventional and proposed methods. The images were obtained using AE₇₈₄₋₃₉₂, CAE₃₉₂₋₁₉₆, and QAE₁₉₆₋₉₈ with ReLU function in the hidden units. The bottom images are the desired outputs of the test set.

B. Handwritten Numeral Recognition (HNR)

HNR is a complex classification task and MNIST database is well studied for this purpose. Classification performance using proposed CAE and QAE is observed and compared with conventional AE on MNIST database [28]. Autoencoder based network construction for classification task is already

explained in Section II-D. The learned parameters that were obtained from the encoding/decoding problem in previous section are used as pre-trained hidden layer. To classify the digit images, output layer having 10 output nodes (corresponding to the class labels from 0 to 9) is added. In the output units, signals from the hidden units are processed by the sigmoid function. Finally, back propagation is used to tune the weights and biases between the hidden and output units. Fine tuning performed on fixed iteration to compare execution time among the methods. The methods with the ReLU function converged faster than the methods with the sigmoid function; therefore the epochs for fine tuning were 5000 and 10000 for ReLU and sigmoid, respectively.

Table 3 compares the methods in relation to the test set accuracy and the execution time for both sigmoid and ReLU as activation function in hidden units. The method AE₇₈₄₋₃₉₂₋₁₀ indicates AE₇₈₄₋₃₉₂ autoencoder from previous section is used and output layer weight (W^{BP}) size is 10×392 which are trained in fine tuning. In relation to the accuracy rate, ReLU achieved better results for AE and QAE; but sigmoid showed better for CAE. However, both proposed methods is found better than conventional AE regardless the activation function. As an example, accuracy for AE₇₈₄₋₃₉₂₋₁₀ with ReLU was 81.0%; one the other hand, CAE₃₉₂₋₁₉₆₋₁₀ and QAE₁₉₆₋₉₈₋₁₀ achieved 85.5% and 85.4 %, respectively, for same activation function. Although both CAE and QAE showed competitive accuracy; in relation to the execution time, the QAE was faster than CAE and much faster than AE. For 5000 epochs with ReLU, QAE₁₉₆₋₉₈₋₁₀ took 18 seconds; whereas, CAE₃₉₂₋₁₉₆₋₁₀ and AE₇₈₄₋₃₉₂₋₁₀ took 31 and 139 seconds, respectively.

TABLE III. AVERAGE TEST SET ACCURACY ON MNIST HANDWRITTEN NUMERAL RECOGNITION

Method	Hidden unit act. function	Epoch	Accuracy rate (%)	Time (s)
AE ₇₈₄₋₃₉₂₋₁₀	Sigmoid	10000	76.1	280
	ReLU	5000	81.0	139
CAE ₃₉₂₋₁₉₆₋₁₀	Sigmoid	10000	85.6	64
	ReLU	5000	85.5	31
QAE ₁₉₆₋₉₈₋₁₀	Sigmoid	10000	85.2	38
	ReLU	5000	85.4	18

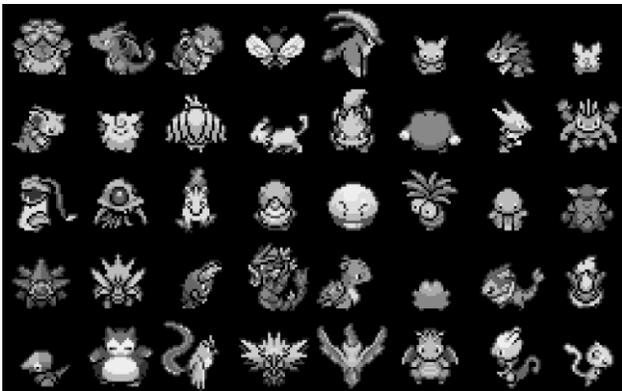
Averages are taken over 5 independent runs.

C. Pokémon Character Recognition (PCR)

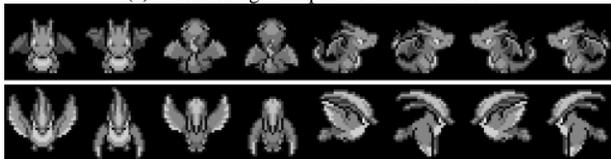
In this section, proposed CAE and QAE are evaluated and compared with AE on Pokémon dataset¹ which is relatively much complex problem. Pokémon is the registered trademark of Nintendo /Creatures Inc. /GAME FREAK Inc. The dataset is a collection of RGB images of 151 Pokémon where each character image is 32×32 pixels. A gray-scaled dataset is considered in this study to perform experiments. Fig. 6 shows few samples from of the dataset. A single character has eight patterns: two for each of the front, back, right, and left sides as shown in Fig. 6(b). Therefore, the dataset is a collection of $1208 (=151 \times 8)$ images; and the task is to recognize the images into 151 character classes. Depending on the characters, the images have quite different patterns. Due to large number of classes, PCR is much complex than MNIST recognition task.

¹ <http://hikochans.com/pixelart/>

Network structure and total parameters for AE, CAE and QAE are shown in Table 4. An image with 32×32 pixels is feed to AE network as 1024 (=32×32) inputs. Pattern construction for CAE and QAE is similar to pattern construction from MNIST image data: one CAE neuron processes a pair of pixels as a complex number and one QAE processes four conjugative pixels values as one quaternion number. Therefore, in the experiments, inputs of CAE and QAE networks were 512 (=1024/2) and 256 (1024/4), respectively. Hidden nodes of the networks were also selected in similar fashion. Total parameter of a method depends on nodes in the input and hidden layers. Due to quaternion presentation and less number of hidden neurons, total parameters in QAE is less than CAE and AE. The activation function in hidden units was the ReLU function for each method. 75% of available objects were considered as training set and rest 25% were used for test purpose. In two different selections, two different data sets (training and test sets) were prepared.



(a) Some image samples of the characters.



(b) Each of eight pattern images of two characters (classes).

Fig. 6. Image samples of the Pokémon characters.

TABLE IV. PARAMETERS FOR POKÉMON CHARACTER RECOGNITION

Method	Number of parameters			
	Input unit	Hidden unit	Output unit	Total ^a
AE ₁₀₂₄₋₄₀₀₋₁₅₁	1024	400	151	470,551
CAE ₅₁₂₋₃₅₀₋₁₅₁	512	350	151	465,102
QAE ₂₅₆₋₂₀₀₋₁₅₁	256	200	151	327,004

^aTotal number of parameters includes real and imaginary parts of weights and biases in the CAE and QAE.

Similar to other autoencoder based classification, training performs in two different phases: autoencoder based pre-training of hidden layer and fine tuning of output layer. More specifically, in AE₁₀₂₄₋₄₀₀₋₁₅₁, the hidden layer is conventional AE with size 400×1024 and output layer weight (W^{BP}) with size 151×400 are trained in fine tuning through back propagation. Training epochs in first phase (autoencoder) were 10000 for all three methods. On the other hand, training

epochs of a method in second phase (fine tuning) were 5000 with mini batch of 151.

Fig. 7 shows sample output images of the methods for training set of data set 1 in the first phase. It is noticeable from the figure that all the methods were able to learn the training images. Table 5 compares test set recognition accuracy as well as required times in both phases for the three methods. It is noticeable that conventional AE method showed the worst recognition accuracy for both the data sets which were only 11.4% and 11.9% for data set 1 and 2, respectively. Besides better encoding in first phase (as seen in Fig. 7), the worst recognition performance of AE revealed the limitation of real valued network for a problem to classify objects in such a large number of classes. Number of hidden node enlargement might improve performance but not significant level. In such a case number of parameters and hence computation complexity will increase much. With similar number of parameters, CAE showed very good recognition accuracy which were 94.1% and 96.2% for data set 1 and 2, respectively. On the other hand, with less number of parameters, QAE showed competitive performance to CAE and which were 92.1% for both the data sets. In relation to training time, QAE took less time in both the phases with respect CAE and AE. Finally, proposed CAE and QAE revealed as good recognition methods for such large-scale multi-class images.

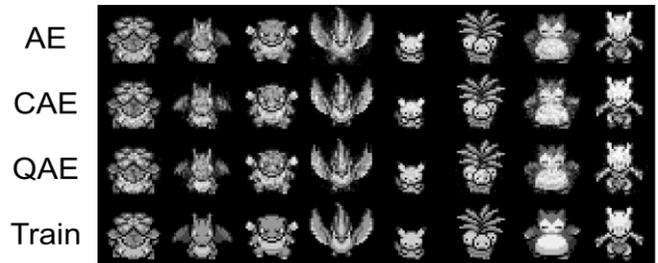


Fig. 7. Sample output images of the conventional and proposed methods for training set 1 in the first phase. The bottom images are the desired outputs.

TABLE V. TEST SET ACCURACY ON POKÉMON CHARACTER RECOGNITION

Method	Data Set	Accuracy Rate (%)	Time (s)	
			First Phase	Second Phase
AE ₁₀₂₄₋₄₀₀₋₁₅₁	1	11.4	349	1211
	2	11.9	350	1183
CAE ₅₁₂₋₃₅₀₋₁₅₁	1	94.1	196	685
	2	96.2	196	637
QAE ₂₅₆₋₂₀₀₋₁₅₁	1	92.1	115	595
	2	92.1	115	560

Averages are taken over 5 independent runs.

IV. CONCLUSIONS

This paper investigated two multi-valued autoencoders by extending the conventional AE to complex and quaternion domains which are complex-valued autoencoder (CAE) and quaternion-valued autoencoder (QAE). Proposed CAE is a two-layered neural network with inputs, outputs, weights, and biases in complex domain. The tuning equations of the weights and biases are based on the complex gradient descent method. We adopted an easy-to-use split-type activation function in the hidden and output units. On the other hand,

proposed QAE is also a two-layered neural network but with inputs, outputs, weights, and biases in quaternion domain. The tuning equations of the parameters are based on the quaternion gradient descent method. The split-type activation function is also applied to the QAE. Although computational complexities become higher in the proposed multi-valued encoders relatively small sized architecture is found worthy to handle a given task.

Proposed multi-valued autoencoders outperformed conventional AE while tested for encoding/decoding and classification tasks. In encoding/decoding task, proposed CAE and QAE showed better convergence than AE for fixed number of epochs. In terms of the execution time, QAE took the shortest time and CAE also took less time than AE. In case of MNIST handwritten numeral recognition based on the individual autoencoders, proposed CAE and QAE was better than conventional AE. The most significant outcomes of the proposed methods are observed on Pokémon Character Recognition (PCR) which is a large-scaled multi-class problem having 151 classes. In PCR, CAE and QAE achieved more than 90% accuracy; whereas accuracy for AE was below 20%. Moreover, proposed methods took less time than convention AE. Experimental studies with different settings identified the proficiency of the proposed multi-valued autoencoders.

A number of future researches are opened from this study. In the present study, split-type activation functions were considered for the proposed autoencoders. Complex-valued and quaternion neural networks with fully complex- and quaternion-valued activation functions have been studied recently [29], [30]. Thus, such activation functions into CAE and QAE might improve their performance and remained as future work. Furthermore, only gray-scale image data is used in the experiments. In a previous study, a QNN was used to treat color image data [22]. It dealt with RGB color values as quaternion numbers and showed good performance. Applications of the QAE to such color image data would be desired. Moreover, deep neural networks based on the proposed autoencoders might perform well and remain as future study.

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An Adaptive Intrusion Detection Method for Wireless Sensor Networks

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Abstract—Current intrusion detection systems for Wireless Sensor Networks (WSNs) which are usually designed to detect a specific form of intrusion or only applied for one specific type of network structure has apparently restrictions in facing various attacks and different network structures. To bridge this gap, based on the mechanism that attacks are much likely to be deviated from normal features and from different shapes of aggregations in feature space, we proposed a knowledge based intrusion detection strategy (KBIDS) to detect multiple forms of attacks over different network structure. We firstly, in the training stage, used a modified unsupervised mean shift clustering algorithm to discover clusters in network features. Then the discovered clusters were classified as an anomaly if they had a certain amount of deviation from the normal cluster captured at the initial stage where no attacks could occur at all. The training data combined with a weighted support vector machine were then used to build the decision function that was used to flag network behaviors. The decision function was updated periodically after training by merging newly added network features to adapt network variability as well as to achieve time efficiency. During network running, each node uniformly captured their status as feature vector at certain interval and forwarded them to the base station on which the model was deployed and run. Using this way, our model can work independently of network structure in both detection and deployment. The efficiency and adaptability of the proposed method have been tested and evaluated by simulation experiments deployed on QualNet. The simulations were conducted as a full-factorial experiment in which all combinations of three forms of attacks and two types of WSN structures were tested. Results demonstrated that the detection accuracy and network structure adaptability of the proposed method outperforms the state-of-the-art intrusion detection methods for WSN.

Keywords—Wireless sensor network; intrusion detection system; knowledge based detection; clustering algorithm; weighted support vector machine

I. INTRODUCTION

Wireless Sensor Network (WSN) is usually composed of many randomly distributed tiny wireless sensor nodes that collect and send sensory data in a coordinated way. In contrast to traditional wireless networks, inherent advantages such as lower cost and more convenient deployment have largely extended WSN application fields, e.g., health care monitoring

[1], smart home [2] and military surveillance and reconnaissance [3]. The security of WSN for those crucial fields has been an important demand [4]. Since wireless sensor nodes usually are limited by power supply, computation capability and communication range [5], traditional encryption/decryption techniques that require an uninterrupted power supply to retain frequently key management and access control are unrealistic to be applied to WSN [6]. Thus, establishing an intrusion detection system (IDS) to meet the security requirements in WSN is essential.

In contrast with wired and ad hoc wireless networks, WSNs are susceptible to various forms of security threats due to their open and unreliable communication channel, dynamic topology structure as well as lacking central coordination [7]. In general, intrusion can be made by singular or multiple attacks. The singular attack, such as flooding attack, black hole attack, rushing attack and so on, occurs independently in WSNs during a certain interval. In flooding attack, a malicious node usually attempts to overwhelm processing capacity and energy of the sensor node as well as network bandwidth by constantly sending a stream of insignificant packets at a very short interval [8]. In black hole attack, an intruder tampers with packets by advertising itself as the possible shortest path to the destination node, which results in the fact that most of the packets are forwarded to the intruder [9]. In rushing attack, the attacker forwards RREQ (route request packets) packets immediately without processing after received them from other nodes, which results in high jitter of the entire network [10]. For the multiple attack situations in which various types of attacks occur simultaneously, the intrusion features might be blurred by the intertwined attacks. For example, if flooding attack and black hole attack occurring simultaneously, when the relay nodes received the flooding packets, they may forward these packets to the black hole attacker instead of keeping flooding them, which makes the attacks appearing reasonable and thus covers the intrusion. Since multiple-attacks is much likely to happen than single ones, it would be benefit to have an intrusion detection solution that is capable of handling multiple attacks [11].

In recent years, many intelligent intrusion detection systems that can only deal with singular form of malicious attacks have been developed for WSN. Athmani et al. [12] protected hierarchical WSN from black hole attack by

controlling packets transfer between sensor nodes and the base station. Although this lightweight scheme demonstrated significant improvement in energy saving, it was unable to defend flooding attack that aims to increase packets transfer between sensor nodes [13]. In order to minimize energy consumption in intrusion detection activities, Di Sarno and Garofalo [14] proposed a method in which status of node energy was only necessary to detect multi-layer flooding attacks. However, this cross-layer intrusion detection approach has not shown the ability to detect attacks in which energy is irrelevant. For example, in a selective forwarding attack, a malicious node either forwards packets of a certain node or not does not significantly affect its energy consumption. Lim and Huie [15] introduced a Hop-by-Hop Cooperative Detection (HCD) method to decrease the probability of misbehavior forwarding while achieve more than 95% package delivery. However, the paper did not mention how to detect attacks that are not misbehavior forwarding revelant, such as flooding attack. Sarigiannidis et al. [16] presented an expert system, i.e., the RADS (rule-based anomaly detection system), based on an ultra-wideband (UWB) ranging-based detection algorithm. It seemed promising in detecting sybil attack in large-scale WSN with high detection rate and low false alarm rate, while no cooperation and data sharing between nodes are needed. However, no evidence has been shown that the RADS is able to detect unknown attacks. Obado et al. [17] calculated the number of hops on the shortest paths between a source node and a destination node as input to a Hidden Markov Model (HMM) Viterbi algorithm to identify wormhole attack. Although the HMM Viterbi algorithm reduced power consumption of the sensor nodes, it was unable to recognize other attacks that are path independent, such as flooding attack and rushing attack. Although these intrusion detection systems demonstrated merits in terms of detection capability or minimization in resource consumption, the bottleneck is that they just can detect singular threat. Researchers have been seeking available information that can be helpful to detect multiple attacks. According to Butun et al. [7], if a profile representing stochastic network behavior is generated in feature space based on the captured network traffic, malicious behaviors against a WSN could lead profile in the feature space to be deviated from the normal range and form different aggregations. Thus, different forms of attacks are much likely to have different shapes of aggregations in feature space.

In general, WSN has two types of network structures (topologies), i.e., hierarchical (cluster) network and flat network [18]. In the hierarchical network, nodes are organized into clusters according to their range of transmission. Each cluster has a cluster head that is responsible to transmit information to the base station. In the flat network, all nodes are identical in routing functions, i.e., transmitting packets in a multi-hop way [7]. Current intrusion detection systems usually take advantage of information of network structures to detect attacks [18]. Shamshirband et al. [19] proposed a cooperative multi-agent based fuzzy artificial immune system to detect DDoS (distributed denial-of-service attack), where the sink node and base station work together to choose the best strategy for discovering an impending attack. However, the authors did not detail the cooperative manner between the common nodes and the base station in the flat network as well as the

implementation. Based on the mechanism that the residual energy of nodes around the sinkhole is much less than other nodes when a flat network is suffering sinkhole attack, Shafiei et al. [20] built a geostatistical hazard model and a distributed monitoring method to detect and defend sinkhole attacks. However, this strategy does not apply to hierarchical case, because it is very difficult to identify sinkhole attack launched in a cluster head when there is no significant difference in residual energy of nodes around the cluster head between normal and attacked situations. Therefore, the information of network structure may be helpful to form patterns in intrusion detection on one hand, it may also restrict the application scope of IDS [21] on the other hand. That means that how to efficiently use network structures while not be constrained by them, i.e., to make the IDS to be network structure independent, is tricky.

The aim of this research was to develop a network structure independent intrusion detection model for WSN. The proposed model employed a knowledge-based detection strategy in which the mechanism is based on the fact that different forms of attacks are much likely to have different shapes of aggregations in feature space. Specifically, we captured network traffics and projected them into feature space as profiles representing stochastic network behaviors, and then the shapes of aggregations of the profiles could be regarded as an indicator to flag network behavior as normal or abnormal. To achieve this goal, we firstly, in the training stage, used a modified unsupervised mean shift clustering algorithm to discover clusters from the profile in the feature space. Then the discovered clusters can be classified as an anomaly if they have a certain amount of deviation from the normal cluster (behavior) captured at the initial stage where no attacks could occur at all. The training data combined with a weighted support vector machine were then used to build the decision function that was used to flag network behaviors. The decision function was updated periodically after training by merging newly added network traffic to mitigate the impact of outliers and noise as well as improve detection accuracy. During network running, each node uniformly captured network traffics as profiles at certain interval and forwarded them to the based station on which the model was deployed and run. Using this way, our model can work independently of network structure in both detection and deployment.

The rest of this paper is organized as follows. Section 2 briefly describes related work. The proposed model is presented in Section 3. Simulation intended to evaluate the performance of the model is presented in Section 4. Section 5 summarizes this paper with indications of future work.

II. RELATED WORKS

A typical anomaly detection technique usually identifies behavior that has a certain amount of deviation from normal behavior as an anomaly. Garofalo et al. [22] utilized decision tree classification and lightweight detection techniques to achieve trade-off between high detection rate and energy saving. However, the paper did not give detail how to deal with unknown attacks not described in the reference dataset. A lightweight IDS was developed by using a wrapper based feature selection algorithm to remove redundant features and

employing a neural network based decision tree to optimize feature selection [23]. Although this detection paradigm increased the generalization ability by incorporating neural networks, its ability to identify unseen pattern was incomplete due to lacking updated decision function. A bio-inspired approach, i.e., the Watchdog based Clonal Selection Algorithm (WCSA), was implemented by Nishanthi and Virudhunagar [24]. It was successful in detecting known attacks but failed to detect unknown ones [4]. While these intrusion detection methods were featured as energy saving and high detection accuracy, they failed to detect “unknown” attacks. To address this problem, we used an unsupervised data mining method to classify an anomaly from normal behavior without any prior knowledge. In addition, the decision function was updated periodically to adapt to changes in network features over time to increase the generalization ability.

Improving detection accuracy can be achieved from two directions, i.e., increasing detection rate and decreasing false alarm rate. Salmon et al. [25] utilized a tailored Dendritic Cell Algorithm (DCA) derived from Danger Theory immune-inspired techniques in which different input signals can be categorized by DCA, i.e., the signals that caused damage were regarded as anomalous while others were classified as normal signals. Experimental data showed that DCA has high detection rate but no low false alarm rate. An agent-based artificial immune system was developed by [26]. In their method, two types of agents, e.g., the dendritic cells agents and the T-cell agents, collaborated with each other to count danger value being regarded as indicators to detect malicious attacks. This scheme achieved low false alarm rate but still cannot obtain enough detection rate [19]. Accordingly, we used a weighted support vector machine to maximize the margin between clusters of normal and anomaly to minimize the classification error, which in turn effectively enhanced detection accuracy.

III. THE MODEL

In this model, network traffics are discretized by time slice defined as Δt (Fig. 1). Each node captures and sends its status as a d -dimensional feature vector $x_t = (x_t^1, x_t^2, \dots, x_t^d)$ to the base station at interval of Δt , where d is the number of feature types (see Table 3 for detail).

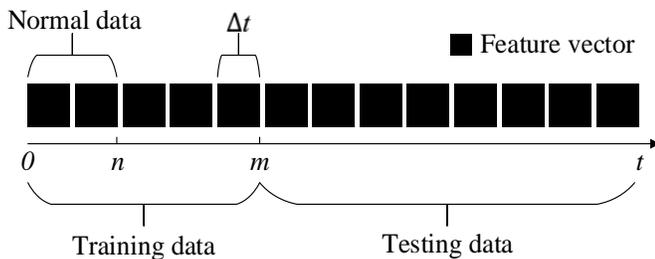


Fig. 1. Network traffic. Each node captures its status at regular time interval Δt as a feature vector. Network traffic is divided into training data and testing data based on time boundary m . The feature vectors extracted in a short period of time $[0, n]$ after WSN initialization are regarded as normal data.

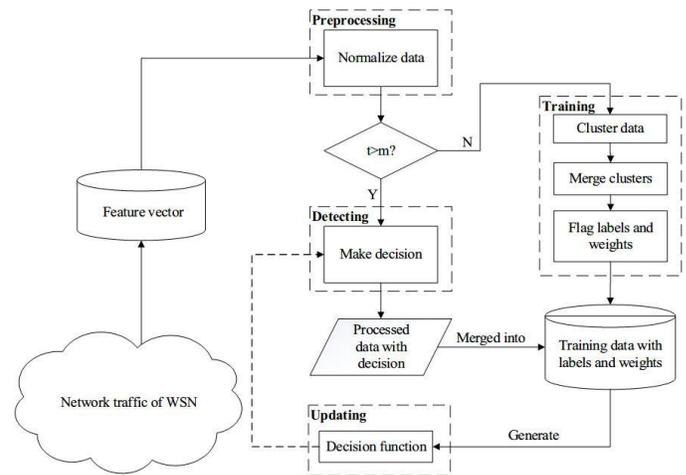


Fig. 2. The schematic diagram of processing steps in KBIDS.

Definition 1: Network traffic is defined as a matrix $X_{All} = \{x_1, x_2, \dots, x_{all}\}$ that contains all feature vectors recorded in interval $[0, t]$, where $all = N * t / \Delta t$, and N is the total number of nodes.

Definition 2: Normal data is defined as a matrix $X_{Nor} = \{x_1, x_2, \dots, x_{nr}\}$, $nr = N * n / \Delta t$, which contains all feature vectors captured at the initial stage $[0, n]$ where no attacks could occur at all.

Definition 3: Training data is defined as a matrix $X_{Train} = \{x_1, x_2, \dots, x_{tr}\}$, $tr = N * m / \Delta t$, which contains all feature vectors captured at the training stage $[0, m]$.

Definition 4: Testing data is defined as a matrix $X_{Test} = \{x_{tr+1}, x_{tr+2}, \dots, x_{te}\}$, $te = N * (t - m) / \Delta t$, which contains all feature vectors captured at the testing stage (m, t) .

The proposed method is performed at the base station and includes the following four steps (Fig. 2):

1) *Preprocessing*: Training data are normalized by the min-max normalization method.

2) *Training*: The normalized training data are grouped into a certain number of clusters by a modified mean shift clustering algorithm. These clusters are eventually merged into two clusters according to the distance between them and the center of other clusters. Each feature vector in the training data is tagged as normal or anomaly by comparing with the normal data and the result of clustering. Further, each feature vector is assigned a weight representing the distance between it and its cluster center. The training data with labels of weights are served as inputs to a weighted support vector machine to establish a decision function.

3) *Detecting*: The testing data are flagged as normal or anomaly by the decision function.

4) *Updating*: In the testing stage, the feature vectors that has been processed are merged into the training data to rebuild the decision function at specific an interval of $\Delta T = k \Delta t, k \in N_+$.

The intrusion detection algorithm is deployed on the base station of a WSN and other nodes are only responsible for capturing and transmitting their own network status.

A. Preprocessing

In order to mitigate the effects of extreme value at one or several dimensions on final results as well as speed convergence of the algorithm [23], training data are normalized by the min-max normalization method. Giving the training data X_{Train} :

$$X_{Train} = \begin{bmatrix} x_1^1 & x_1^2 & \dots & x_1^d \\ x_2^1 & x_2^2 & \dots & x_2^d \\ \vdots & \vdots & \ddots & \vdots \\ x_{tr}^1 & x_{tr}^2 & \dots & x_{tr}^d \end{bmatrix}_{tr \times d}$$

A set of the minimum and the maximum values for each column of X_{Train} are respectively obtained as $x_{tmin} = \{x_{min}^1, x_{min}^2, \dots, x_{min}^d\}$ and $x_{tmax} = \{x_{max}^1, x_{max}^2, \dots, x_{max}^d\}$. Each feature vector $x_t \in X_{All}$ is then normalized by (1):

$$x_{tp} = \frac{x_t - x_{tmin}}{x_{tmax} - x_{tmin}} \quad (1)$$

Where, x_{tp} is a normalized feature vector.

B. Training

The feature vectors (points) should be aggregated into a certain region in the feature space in the normal situation. But they would be deviated from the normal region while being attacked. From the perspective of feature space, different forms of attacks may result in significant difference in degree of deviation from the normal region, and thus generate several aggregations. The unsupervised mean shift clustering algorithm (MSCA) [27] can effectively discover different concentrated regions in the feature space to form arbitrary clusters, which represents the aggregation of the features resulted from attacks. In this step, the MSCA is employed to cluster training data, flag them as normal or anomaly and feeds them into the classifier for training.

Given nr data points $x_t \in X_{Nor}, t = 1, 2, \dots, nr$ on a d -dimensional space R^d , the initial feature vector x_1 is continuously shifted by adding a shifting vector m_h , where m_h can be calculated by (2) (please note that the shifting of x_1 results in changes in m_h). x_1 stops shifting when m_h falls below a certain threshold.

$$m_h = F(x_1) = \frac{\sum_{t=1}^{nr} x_t g(\|\frac{x_1 - x_t}{h}\|^2)}{\sum_{t=1}^{nr} g(\|\frac{x_1 - x_t}{h}\|^2)} - x_1 \quad (2)$$

Where, $g(x) = -k'(x)$. $k'(x)$ and h are respectively the derivative and the bandwidth of the kernel profile $k(x)$ which is defined by a multivariate normal kernel function $K(x)$:

$$K(x) = (2\pi)^{-\frac{d}{2}} \exp\left(-\frac{1}{2} \|x\|^2\right) = c_{k,d} k(\|x\|^2) \quad (3)$$

Where, $c_{k,d}$ is a normalization constant assuring $K(x)$ integrates to 1. During the process of the x_1 shifting, the points that it has traveled are regarded belong to the same cluster and the last one is regarded as the cluster

center c_1 . In the standard MSCA, all data points do the same work as x_1 did. However, in order to speed the convergence and promote precision of the standard MSCA, a modified version that recording the track of shifting of feature vectors is given as follows:

Each point p_k on the track of x_1 and its shifting distances d_k are recorded to form a similar set s_1 :

$$s_1 = \{(p_1, d_1), (p_2, d_2), \dots, (p_k, d_k)\}, k = 1, 2, \quad (4)$$

For all feature vectors we have the similar sets:

$$S = \{s_1, s_2, \dots, s_i\}, i = 1, 2, \quad (5)$$

The cluster centers are defined as:

$$C = \{c_1, c_2, \dots, c_j\}, j = 1, 2, \quad (6)$$

Based on the track of x_1 , the subsequent each feature vector $x_t \in X_{tr}, t = 2, 3, \dots, tr$ is clustered by the following two steps:

Step 1: The Euclidean distances $d_{x_t p_k}$ between x_t and each point p_k in each similar set $s_i \subseteq S$ is calculated by (7). If $d_{x_t p_k}$ is less than the shifting distance d_k , the tuple $(x_t, d_{x_t p_k})$ is added to s_i ; Otherwise, proceed to step 2.

$$d_{x_t p_k} = \sqrt{\sum_{l=1}^d (x_t^l - p_k^l)^2} \quad (7)$$

Step 2: x_t does the same work as x_1 did to generate a new similar set s_t and a cluster center c_t . If C has a cluster center c_j which is equal to c_t , then merge s_t into s_j : $s_j = s_t \cup s_j$; Otherwise, c_t and s_t are inserted to C and S , respectively.

After the two steps are completed, the training data are grouped into several clusters. The cluster including the normal data is regarded as the normal cluster. The cluster whose cluster center is farthest from the normal cluster is classified as the abnormal cluster. The rest of clusters are then merged into either the normal or abnormal cluster based on the relative distance to them.

When a feature vector is received after time n , it is immediately classified into the nearest cluster thus can be flagged as normal or anomaly without extra training. In addition, to mitigate the effect of outliers or noise in clustering process on final decision and improve the detection accuracy, a weighted support vector machine (WSVM) was introduced to build a decision function (i.e. the optimal margin hyperplane classification) from the clustering results.

Given tr data points:

$$\{x_t, y_t\}_{t=1}^{tr}, x_t \in X_{Train}, y_t = \{-1, 1\}$$

Where y_t denotes class labels (i.e. normal or anomaly), the classification is defined as:

$$f(x) = \text{sign}(\langle w, x \rangle + b) \quad (8)$$

Where w is a **weight vector** and b is the bias. In order to optimize w and b , the WSVM requires the solution of the following optimization problem:

$$\begin{cases} \min \frac{1}{2} \|w\|^2 + \frac{1}{v*tr} \sum_{t=1}^{tr} \xi_t W_t, 0 < v < 1 \\ s.t. t(y_t < w, \varphi(x_t) > +b) \geq 1 - \xi_t, \xi_t \geq 0, t = 1, 2, \dots, tr \end{cases} \quad (9)$$

Where, v is the penalty factor of misclassification. ξ_t is the slack parameter to control noise. Vectors x_t is mapped into a higher dimensional space by the function φ . W_t is a weight, which represents the relative contribution of x_t to the decision function. W_t assigned to data point x_t is calculated by (10):

$$W_t = \exp(-\sqrt{\sum_{l=1}^d (x_t^l - c^l)^2}) \quad (10)$$

Where c is the cluster center of x_t . Unlike the standard SVM, where all training data points in one class are equally important, WSVM reduces the effect of outliers and noises by setting different weights [28]. According to Lagrangian duality theory, the WSVM optimization problem in (9) is converted to a quadratic programming problem:

$$\begin{cases} \min \sum_{t=1}^{tr} a_t - \frac{1}{2} \sum_{t=1}^{tr} \sum_{k=1}^{tr} a_t a_k y_t y_k < \varphi(x_t), \varphi(x_k) > \\ s.t. \sum_{t=1}^{tr} a_t y_t = 0, 0 \leq a_t \leq \frac{1}{v*tr} W_t, i = 1, 2, \dots, tr \end{cases} \quad (11)$$

where a_t is the Lagrangian parameter. The Karush–Kuhn–Tucker conditions of the SVM are defined as:

$$\begin{cases} a_t [y_t (< w, \varphi(x_t) > +b) - 1 + \xi_t] = 0, t = 1, 2, \dots, tr \\ \left(\frac{1}{v*tr} W_t - a_t\right) \xi_t = 0, t = 1, 2, \dots, tr \end{cases} \quad (12)$$

Finally, the optimal value of w and b are gained by:

$$\begin{cases} w = \sum_{t=1}^{tr} a_t y_t \varphi(x_t) \\ b = y_k - \sum_{t=1}^{tr} y_t a_t < \varphi(x_t), \varphi(x_k) >, \forall k \in [1, tr] \end{cases} \quad (13)$$

Hence, the decision function is obtained by:

$$\begin{aligned} f(x) &= \text{sgn}(\sum_{t=1}^{tr} a_t y_t < \varphi(x_t), \varphi(x) > - \sum_{t=1}^{tr} y_t a_t < \varphi(x_t), \varphi(x_k) > + y_k) \\ &= \begin{cases} 1 : Normal \\ -1 : Anomalous \end{cases} \end{aligned} \quad (14)$$

C. Detecting

In this step, each feature vector in testing data is flagged as normal or anomaly by the decision function (14). The feature vector is then merged into either normal or anomaly cluster according to the decision that has been made by the decision function. After that, it is used to update the decision function afterwards.

D. Updating

In order to cope with the possible changes in network features over time, the decision function needs to be updated at an interval of time ΔT . In this step, the cluster centers are reevaluated by MSCA with updated training data, and the weight of each feature vector is adjusted as well. After that, the decision function is updated accordingly by WSVM.

The pseudo code of KBIDS is shown in Algorithm 1.

Algorithm 1: KBIDS

Input:

$X_{All} = \{x_1, x_2, \dots, x_t\}$ feature vectors
 ΔT interval of updating

Output:

1 flag of normal
-1 flag of anomaly

1. Normalize each feature vector $x_t \in X_{All}, t = 1, 2, \dots$ by (1).
2. Shift x_1 in feature space constructed by normal data $X_{nor} = \{x_1, x_2, \dots, x_{nr}\}$ by (2) until the shift distance m_n falls below a certain threshold ϵ .
3. Record the tracks that x_1 has traveled as a similar set $s_1 = \{(p_1, d_1), (p_2, d_2), \dots, (p_k, d_k)\} k = 1, 2, \dots$ and a cluster center c_1 .
4. Cluster the training data $X_{Train} = \{x_1, x_2, \dots, x_{tr}\}$:
For each feature vector $x_t \in X_{Train}$
If the distance $d_{x_t p_k}$ between x_t and point p_k in similar set $s_i \subseteq S$ less than d_k
Add $(x_t, d_{x_t p_k})$ into s_i .
Else
Generate a new cluster center c_t and a similar set s_t by MSCA.
If c_t is equal to $c_j \in C$
 $s_j = s_t \cup s_j$.
Else
Add c_t into C and s_t into S .
End If
End If
End For
5. Merge clusters into two clusters and allocate label for $x_t \in X_{Train}$.
6. Allocate weights for $x_t \in X_{Train}$ by its relative distance to cluster center (10).
7. Generate the decision function by WSVM.
8. Flag each subsequent feature vector x_t in $X_{Test} = \{x_{tr+1}, x_{tr+2}, \dots, x_{te}\}$ as 1 or -1 by decision function. Merge the feature vector x_t and its label into training data.
If time $t = m + k\Delta T, k = 1, 2, \dots$
Update the cluster center by MSCA.
Allocate weights for each feature vector x_t of the training data again.
Update decision function by WSVM.
End If

IV. SIMULATION EXPERIMENTS

In order to evaluate the performance of KBIDS, eight experiment scenario (Table 1) were simulated by QualNet on a PC with Inter(R) Core (TM) i7-4470k, 3.50GHz, 8GB memory (RAM). In a flat network, we randomly deployed 30 sensor nodes in a region with dimension of 1000(m) x 1000(m) and deployed the base station in the center of the region, as shown in Fig. 3(a). Ten percent of nodes were designated as malicious nodes that performed attack. Compared with the flat network, the hierarchical protocol is more suitable for large-scale

networks in reducing node energy consumption and communication bandwidth [29]. Hence, the number of nodes in the hierarchical network was 100, and the number of attackers was 10. The relationship between nodes in the hierarchical network is given in Fig. 3(b).

TABLE I. SIMULATION SCENARIOS

Experiment	Attack type	Network structure
Case 1	Black hole attack	Flat network
Case 2	Flooding attack	Flat network
Case 3	Rushing attack	Flat network
Case 4	Multiple attacks	Flat network
Case 5	Black hole attack	Hierarchical network
Case 6	Flooding attack	Hierarchical network
Case 7	Rushing attack	Hierarchical network
Case 8	Multiple attacks	Hierarchical network

For all types of network structure, the MAC layer and routing protocol of all devices were IEEE802.11 and Ad hoc On-demand Distance Vector Routing (AODV), respectively. Simulation time for each experiment scenario was set as 10000 seconds. The value of time n was 100 seconds and m was 5000 seconds. Network traffic flow was simulated by constant bit rate (CBR) with packets of 512 bytes. The mobility model of nodes was simulated random waypoint (RWP) model with pause time of 5 seconds and the maximum speed of 10m/s. The statistical data of the energy consumption was counted by MicaZ radio energy model [30]. The key parameters of the simulation experiments were presented in Table 2.

In each singular attack scenario, only one type of the three attacks, e.g., the black hole attack, flooding attack or rushing attack, was lunched during 4000 and 7000 seconds. Unlike singular attack scenarios, the three attacks were simultaneously lunched during 4000 and 7000 seconds in the multiple attacks scenarios. Each of these scenarios was replicated five times by setting different initial position of sensor nodes.

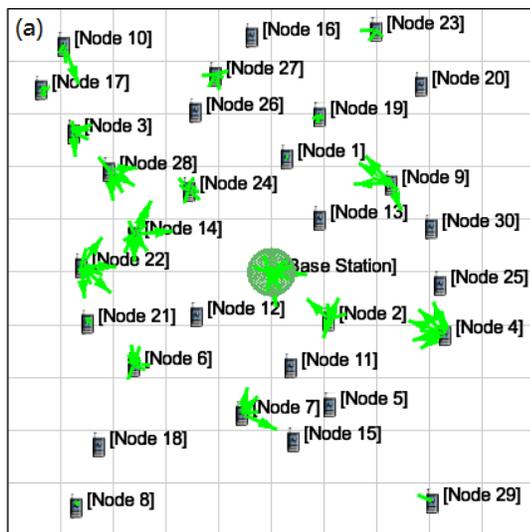


TABLE II. WSN CONFIGURATION

Parameter	Flat network	Hierarchical network
	Value	Value
Simulation time	10000(s)	10000(s)
Field size	1000(m) x 1000(m)	1000(m) x 1000(m)
Total number of nodes	30	100
Number of attackers	3	10
Traffic type	CBR	CBR
Traffic size	512(B)	512(B)
Routing protocol	AODV	AODV
MAC protocol	IEEE802.11	IEEE802.11
Mobility model	RWP	RWP
Pause time	5(s)	5(s)
Max moving speed	10(m/s)	10(m/s)

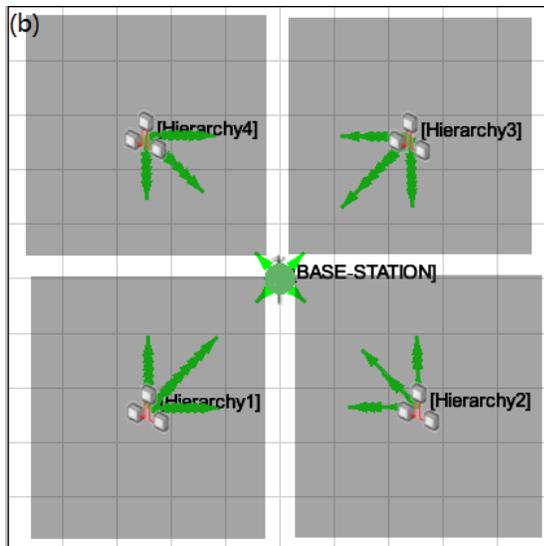


TABLE III. FEATURES VECTOR CONSTRUCTED BY 13 VALUES REPRESENTING NODE STATUS

Feature	Description
numRequestRecved	Number of route requests received
numRequestResent	Number of route requests resent because node did not receive a route reply.
numRequestRecvedAsDest	Number of route requests received by the destination.
numRequestInitiated	Number of route request messages initiated
numRequestRelayed	Number of route request messages forwarded by intermediate nodes.
numReplyInitiatedAsDest	Number of route replies initiated from the destination.
numReplyInitiatedAsIntermediate	Number of route replies initiated as an intermediate hop.
numReplyRecved	Number of route replies received by the node.
numReplyRecvedAsSource	Number of route replies received as data source
numReplyForwarded	Number of route replies forwarded by intermediate hops
numDataInitiated	Number of data packets sent as the source of the data.
numDataRecved	Number of data packets received as the destination of the data
numHops	Aggregate sum of the hop counts of all routes added to the route cache.

Fig. 3. QualNet simulation of two types of network structure in WSN. (a) Flat network, in which nodes transmit data in a multi-hop way. (b) Hierarchical network, in which nodes transmit data to base station in a hierarchy way.

A feature vector (Table 3) which is the basic unit of information processing in KBIDS was constructed by capturing 13 types of features representing node status [31].

In order to test the efficiency of KBIDS, detection rate and false alarm rate were used as index of assessment [32] Detection rate was calculated as the percentage of the numbers of successfully detected anomalies over the total numbers of anomalies. False alarm rate was calculated as the numbers of false alarm over the total numbers of normal data [18].

V. RESULTS

Simulation results of KBIDS were compared with mainstream intrusion detection methods, such as PCA-based centralized approach (PCACID) [33] K-Means, Mean Shift, Decision Trees (DT) and Logistic Regression (LR), to evaluate efficiency of detection and adaptively of network structure (Fig. 4). Results showed that in the eight experiment scenarios, the average detection rate and the false alarm rate of KBIDS were 97.854% and 1.875% with small standard deviation 0.922% and 1.069%, respectively, which demonstrated an obvious advantage than other mainstream methods. Although K-Means, Decision Trees and Logistic Regression obtained more than 92% average detection rate and less than 3% average false alarm rate at the same situation, their results had a large fluctuation, i.e., 4.831% and 4.291%, 1.327% and 1.348% as well as 3.922% and 2.547%. This exhibited their weak capability in dealing with various forms of attacks. In some cases, PCACID and Mean Shift achieved lower false alarm rate than KBIDS. However, they failed to detect anomaly constantly in all scenarios. Overall, KBIDS showed advantages over other mainstream detection algorithms in term of detection rate and false alarm rate. In addition, KBIDS achieved stable performance in all scenarios, particularly in scenarios with different network structure. This was a strong evidence showing that KBIDS is network independent.

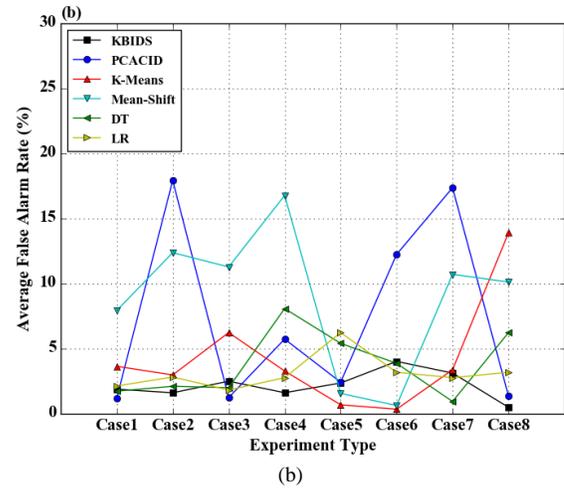
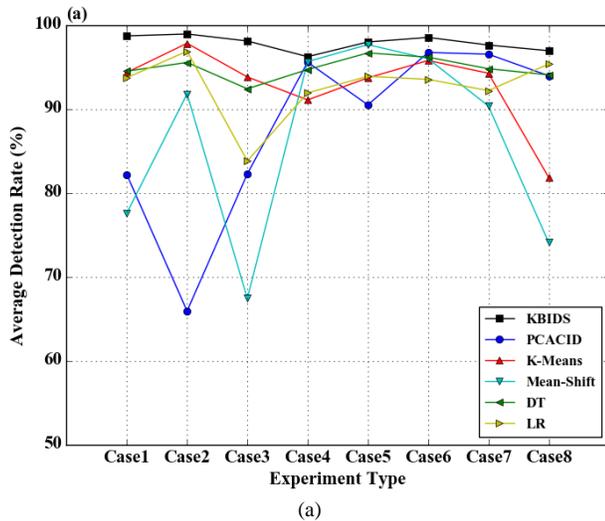
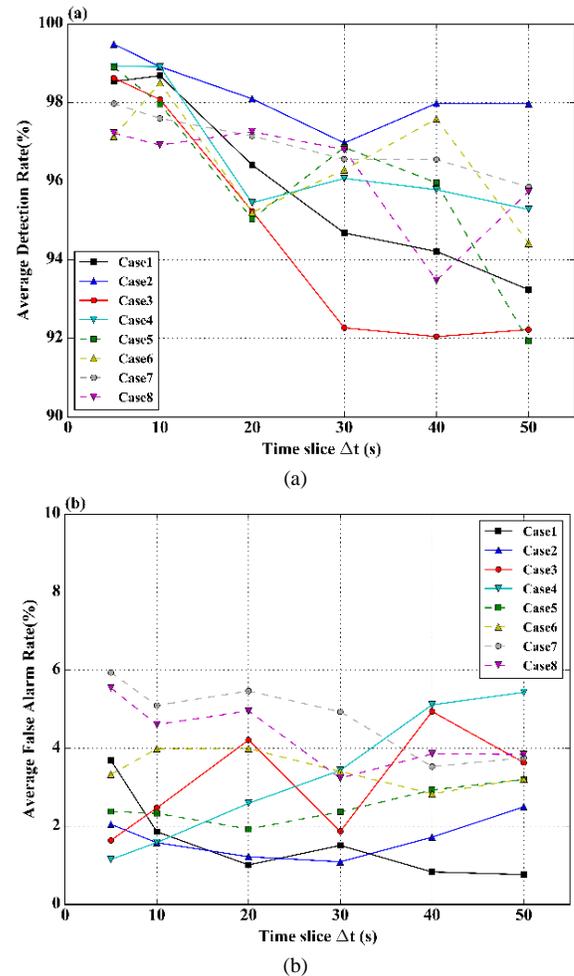


Fig. 4. Comparison of detection rate (a) and false alarm rate (b) between KBIDS and other mainstream detection algorithms in eight experiment scenarios.



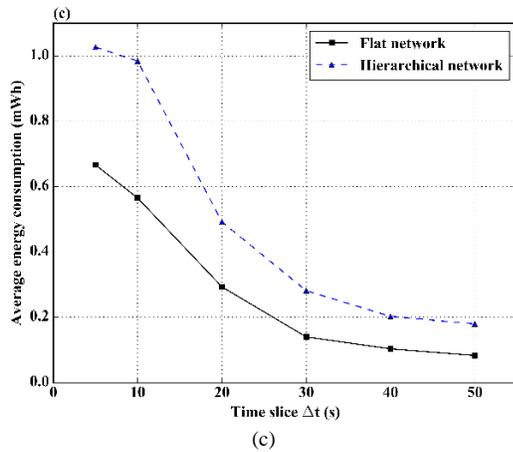


Fig. 5. Performance of KBIDS for different values of Δt .

As one of the key parameters, the length of time slice Δt might be one important factor affecting results and network performance. Fig. 5 revealed the relationship between the variations in time slice Δt and detection accuracy as well as energy consumption when the interval of updating ΔT was 300s. With the increasing of Δt , the average detection rate and the energy consumption of data transmission decreased gradually while the average false alarm rate rose steadily for these cases. Overall, the time slice $\Delta t=10s$ achieved a well trade-off between detection accuracy and energy consumption.

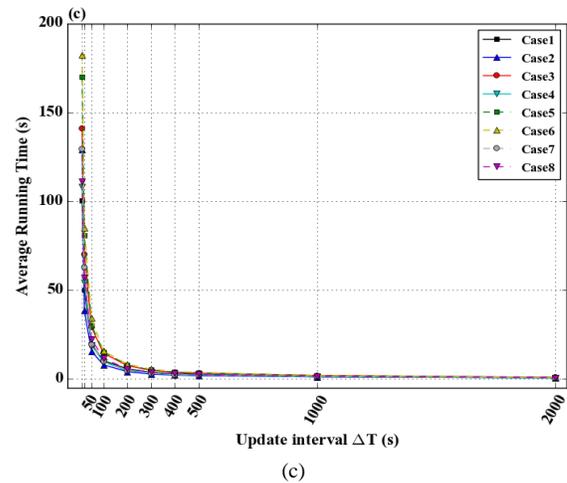
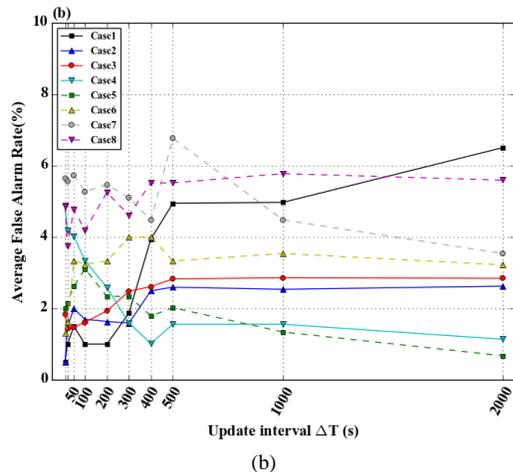
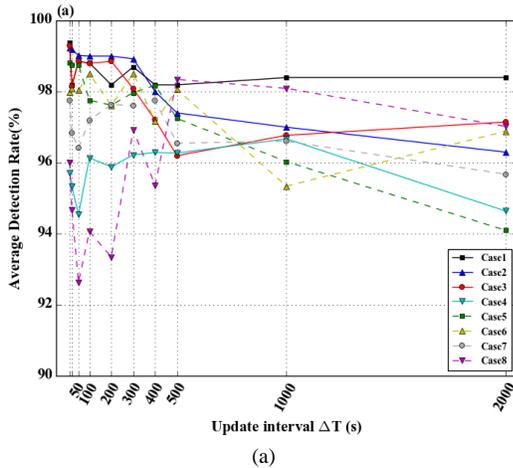


Fig. 6. Performance of KBIDS for different values of ΔT .

Since KBIDS employed a constant updating strategy to adapt network variability over time, the impact of update interval ΔT on the average running time (ART, i.e., the energy cost) of the updating step and the average detection accuracy cannot be ignored. When $\Delta t=10s$, although lower ΔT (20s) achieved high detection rate and low false alarm rate (Fig. 6), its cost, i.e., $ART=62.16s$ was much larger than $\Delta T=100s$ where $ART=1.34s$. No surprise, the average detection rate and the average false alarm rate respectively decreased and increased with the increasing of ΔT . However, the trend became stable after $\Delta T=500s$. Overall, $\Delta T=300s$ achieved a great balance between detection accuracy and energy cost, where ART was about 3.83s which was much less than time slice $\Delta t=10s$.



In this algorithm, the computational complexity of the clustering step is $O(Tn^2)$, where T is the average number of shifting, and n is the number of feature vectors. The computational complexity of building WSVM is $O(dn^2)$ where d is the dimension of feature vector. The computational complexity of the updating step is $O(M(T+d)n^2)$ where M is the number of updates. Overall, the computational complexity of the algorithm can be approximated as $O(n^2)$, which is not significantly affected by the number of dimensions of feature vector. We acknowledge that with the increasing number of feature vectors, it is inevitable to increase the time cost for the updating step, which is the main source of energy consumption that delays the decision process. We used two strategies to solve this problem. First, decision can be made immediately after learning stage when WSVM has been established, no full training process is necessary at each decision making; Second, old feature vectors are removed from training data when new feature vectors come in, so that the size of the training data can be kept at a constant level.

VI. CONCLUSION

In this research, we developed KBIDS, a network structure independent intrusion detection model for WSN. KBIDS employed knowledge based detection strategy based on the

mechanism that attacks are much likely to be deviated from normal features and from different shapes of aggregations in feature space. In KBIDS, an unsupervised data mining method was used to classify an anomaly from normal behavior without any prior knowledge. In addition, the decision function was updated periodically to adapt to changes in network features over time to increase the generalization ability. Further, a weighted support vector machine was used to maximize the margin between clusters of normal and anomaly to minimize the classification error, which in turn effectively enhanced detection accuracy. During network running, each node uniformly captured their status as feature vector at certain interval and forwarded them to its neighbor. The based station runs the model to detect attack. Using this way, our model can work independently of network structure in both detection and deployment. Simulation experiments conducted on QualNet platform demonstrated that our model outperformed other mainstream algorithms in terms of detection efficiency, stability across different network structures and computational complexity. Sensitivity analysis gave insights into how model performance can be affected by some key parameters, thus future improvement can be directed.

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User based Recommender Systems using Implicative Rating Measure

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Abstract—This paper proposes the implicative rating measure developed on the typicality measure. The paper also proposes a new recommendation model presenting the top N items to the active users. The proposed model is based on the user-based collaborative filtering approach using the implicative intensity measure to find the nearest neighbors of the active users, and the proposed measure to predict users' ratings for items. The model is evaluated on two datasets MovieLens and CourseRegistration, and compared to some existing models such as: the item based collaborative filtering model using the Jaccard measure, the user based collaborative filtering model using Jaccard measure, the popular items based model, the latent factor based model, and the association rule based model using the confidence measure. The experimental results show that the performance of the proposed model is better when compared to other five models.

Keywords—Implicative rating measure; recommender system; user-based collaborative filtering

I. INTRODUCTION

Recommender systems/recommendation systems (RSs) [1] are techniques or software tools embedded in an application or website to predict the preferences of an individual or a group of users for a specific product or service; and/or to recommend the appropriate products or services to an individual or a group of users, thereby reducing the information overload. Currently, the recommendation systems are applied in many areas of life [2] such as e-commerce, e-learning, e-services, etc. The techniques (methods) of recommendation are based on the ones used in data mining and machine learning [3], [4] such as classification, clustering, association rule mining, regression models, or some of the supervised or unsupervised learning methods. Recommendation techniques are divided into two main classes: the class of basic techniques such as collaborative filtering, content filtering or hybrid; and the class of techniques developed on the basic techniques and the additional data such as the contextual information or the social information. Recommendation systems can be classified into different groups [2], [3], [5]: content based, collaborative, demographic based, knowledge based, hybrid, context based, social based, and group based. In the fields of research on recommendation systems, proposing the new recommendation models or improving the existing recommendation methods has still been the mainstream of research and received the most attention.

In recommendation techniques, collaborative filtering [1], [6]-[8] is the most important and widely used technique. A collaborative filtering system provides recommendations to an active user based on the assumption that similar users like similar items or a user prefers similar items. Therefore, the core component of collaborative filtering is the use of measures to find items or users with strong relationships, to predict ratings, and then to recommend the most relevant items to the active users.

Statistical implicative analysis is a method of data analysis initiated by Gras [9] to study the trends among data attributes [10]. Statistical implicative analysis is applied in many areas such as psychology, education, bioinformatics, knowledge management, art history, etc. [10], [11]. In this method, statistical implicative measures are used to detect the strong relationships, or to measure the typicality of an object for the formation of a relationship, or to measure the responsibility of an object for the existence of a relationship. Therefore, statistical implicative measures can be used to develop the collaborative filtering systems.

This paper proposes a new recommendation model based on user-based collaborative filtering and the implicative rating measure to present to the active users the top N items. In the proposed model, the matrix of binary ratings is used as the main input; the implicative intensity is used to find the nearest neighbors of the active users; and the implicative rating measure developed on the typicality measure is used to predict users' ratings for items.

The remaining of the paper is organized into four sections. Section 2 describes the statistical implicative measures briefly. Section 3 not only proposes the implicative rating measure developed on the above mentioned measures, but also proposes the recommendation model using the user based collaborative filtering approach and the implicative rating measure. Section 4 presents the experimental results and the discussion of those results. Section 5 is the conclusions.

II. STATISTICAL IMPLICATIVE MEASURES

A. Implicative Intensity

Let E be a set of n objects described by a finite set of binary attributes I . Let $A \subseteq E$ be a subset of objects with the attribute a . Let $B \subseteq E$ be a subset of objects with the attribute b ; B_c be the complement of B ; $n_a = \text{card}(A)$ be the number of elements of A ;

$n_b = \text{card}(B)$ be the number of elements of B , $n_{b-} = n - n_b$ be the number of elements of B_- ; and $n_{ab-} = \text{card}(A \cap B_-)$ be the number of objects that has the attribute a but does not have the attribute b . Let X and Y be two random sets with the element numbers to be n_a and n_b respectively.

The random variable $\text{card}(X \cap Y_-)$ follows the Poisson distribution with the parameter $\lambda = n_a n_b / n$. The probability of the $\text{card}(X \cap Y_-) \leq \text{card}(A \cap B_-)$ is defined by (1).

$$Pr(\text{card}(X \cap Y_-) \leq \text{card}(A \cap B_-)) = \sum_{s=0}^{\text{card}(A \cap B_-)} (\lambda^s / s!) e^{-\lambda} \quad (1)$$

For $n_b \neq 0$, the random variable $\text{card}(X \cap Y_-)$ is normalized to the random variable $Q(a, b_-)$ as (2). In experiment, the observed value of $Q(a, b_-)$ is represented by $q(a, b_-)$ and is defined according to (3). $q(a, b_-)$ is called the implicative index.

$$Q(a, b_-) = (\text{card}(X \cap Y_-) - n_a n_b / n) / \text{sqr}t(n_a n_b / n) \quad (2)$$

$$q(a, b_-) = (n_{ab-} - n_a n_b / n) / \text{sqr}t(n_a n_b / n) \quad (3)$$

The implicative intensity [9] of the relationship $a \rightarrow b$ is defined by (4).

$$\varphi(a, b) = 1 - Pr(Q(a, b_-) \leq q(a, b_-)) \text{ if } n_b \neq n \quad (4)$$

$$\varphi(a, b) = 0 \text{ otherwise}$$

The relationship $a \rightarrow b$ is admissible for a given threshold α if $\varphi(a, b) \geq \alpha$.

B. Typicality

To measure the typicality of an object i for the formation of the relationship $a \rightarrow b$, the typicality is proposed as (5) [9].

$$\gamma(i, a \rightarrow b) = 1 - d_I(i, a \rightarrow b) / \max_{j \in E} d_I(j, a \rightarrow b) \quad (5)$$

$d_I(j, a \rightarrow b)$ is the distance between the object i and the relationship $a \rightarrow b$. The value of $d_I(j, a \rightarrow b)$ is calculated by formula (6) where $\varphi(a, b)$ is the implicative intensity of $a \rightarrow b$ and $\varphi_{i, a \rightarrow b}$ is the contribution (the responsibility) of the object i for the existence of the relationship $a \rightarrow b$.

$$d_I(i, a \rightarrow b) = ((\varphi(a, b) - \varphi_{i, a \rightarrow b})^2 / (1 - \varphi(a, b)))^{1/2} \quad (6)$$

The contribution $\varphi_{i, a \rightarrow b}$ is defined by (7) where $a(i)$ (resp. $b(i)$) is the binary value which characterizes the presence/absence of the attribute a (resp. b) for object i .

$$\varphi_{i, a \rightarrow b} = 1 \text{ if } [a(i)=1 \text{ or } a(i)=0] \text{ and } b(i)=1 \quad (7)$$

$$\varphi_{i, a \rightarrow b} = 0 \text{ if } [a(i)=1 \text{ and } b(i)=0]$$

$$\varphi_{i, a \rightarrow b} = p \in]0, 1[\text{ if } a(i)=b(i)=0$$

In practice, p is set to the neutral value 0.5.

III. USER-BASED RECOMMENDATION MODEL USING IMPLICATIVE RATING MEASURE

Like the two-dimensional recommendation problem [7], the proposed recommendation model can be formalized by the follows:

- Let $U = \{u_1, u_2, \dots, u_n\}$ be a set of users.

- Let $I = \{i_1, i_2, \dots, i_m\}$ be a set of items (e.g. products, movies, etc.).
- Let $R = (r_{jk})$ where $j=1..n$ and $k=1..m$ be a rating matrix storing the feedbacks of users on items. $r_{jk}=1$ if the user u_j likes the item k ; $r_{jk}=0$ if the user u_j does not like (or know) the item k .
- Let $f: U \times I \rightarrow R$ be a function that maps the user-item combinations to the ratings r .

The objective of the proposed model is to find a function f' : $U \times I \rightarrow R'$ such that the performance (e.g. the precision and the recall) of the model is better when compared to some other models.

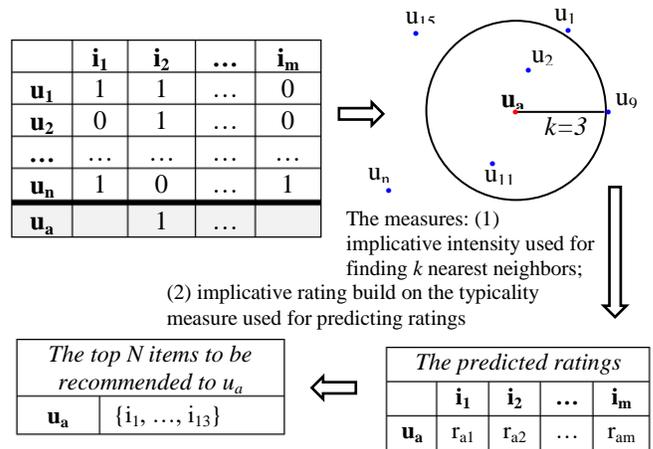


Fig. 1. The sketch of the proposed recommendation model.

The proposed recommendation model is sketched as Fig. 1. This model uses the user-based collaborative filtering approach and the implicative rating measure to recommend the top N items to the active user as described in Algorithm 1. During the recommendation process, the model will also use Algorithms 2 and Algorithm 3.

A. Implicative Rating Measure

We propose the implicative rating measure $KnnIR$ (K nearest neighbors based implicative rating) to predict the ratings that can be given by the active user u_a for each item $i \in I$. $KnnIR$ is built on the typicality measure γ and defined in formula (8).

$$KnnIR(u_a, i) = KIR(u_a, i) / \max_{l \in I} KIR(u_a, l) \quad (8)$$

Where

$$KIR(u_a, i) = \sum_{j=1}^k \gamma(i, u_a \rightarrow u_j) \text{ if } R(u_j, i) = 1 \quad (9)$$

k is the number of nearest neighbors; and $\gamma(i, u_a \rightarrow u_j)$ is the typicality of item i for the relationship formation $u_a \rightarrow u_j$.

B. Recommending the Top N Items to the Active User

The inputs of Algorithm 1 (recommending the top N items to the active user – UBCFImplicativeRS) are: the vector A of size m representing the active user u_a with given known ratings; the rating matrix R of U users and I items; and k nearest neighbors. Its output is the list of top N items to be

recommended to the active user u_a . The processing steps of Algorithm 1 are as follows:

- Calculating the implicative intensity of the relationship between the user u_a and a user $u_i \in U$ according to Algorithm 2.
- Identifying k nearest neighbors of u_a that have the highest implicative intensity values.
- Calculating the typicality value of each item $i_j \in I$ for the formation of relationship (u_a, u_i) where u_i is one of k nearest neighbors of u_a according to Algorithm 3.
- Predicting the rating value for each item $i_j \in I$ based on the implicative rating measure.
- Removing the given known items of u_a from the predicted list.
- Sorting the filtered list in descending order and recommending the top N items to the active user u_a .

UBCFImplicativeRS (vector A , ratingmatrix R , int k) {

$IIntensity = calculateImplicativeIntensity(A, R);$

$Neighbors = findKNearestNeighbors(IIntensity, k);$

$Typic = calculateTypicality(A, Neighbors, R, IIntensity);$

for each $i_j \in I$ do

$KIR[u_a, i_j] = \frac{sumColumn(Typic[Neighbors, i_j]}{*R[Neighbors, i_j];}$

$KnnIR[u_a] = KIR[u_a] / maxRow(KIR[u_a]);$

$Filteredlist = removeKnownRatings(A, KnnIR);$

$Reclist = getTopNItems(Filteredlist);$

return $Reclist;$

}

C. Calculating the Implicative Intensity of Relationship (U_a, U_i)

The inputs of Algorithm 2 (calculating the implicative intensity of relationship (u_a, u_i) – calculateImplicativeIntensity) are: the vector A of size m representing the active user u_a with given known ratings; and the rating matrix R of U users and I items. The output of this algorithm is the implicative intensity of relationship (u_a, u_i) with $u_i \in U$. Algorithm 2 conducts the following steps:

- Finding the values n , n_a , n_b and n_{ab} which represent the implicative relationship between two users u_a and u_i .
- Calculating the implicative intensity of (u_a, u_i) using formula (4).

calculateImplicativeIntensity(vector A , ratingmatrix R) {

$R = bindRow(R, A); \quad IIntensity = Null;$

for each $u_i \in U$ do {

$sum = 0;$

$n = countColumn(R); \quad n_a = 0;$

$n_b = 0; \quad n_{ab} = 0;$
for each $i_j \in I$ do {
 $n_a += R[u_a, i_j];$
 $n_b += R[u_i, i_j];$
 $n_{ab} += R[u_a, i_j] * R[u_i, i_j];$
}
 $n_{ab_} = n_a - n_{ab};$
 $lambda = n_a * (n - n_b) / n;$
for $s=0$ to $n_{ab_}$ do
 $sum += (lambda^s / fact(s)) * exp(-lambda);$
 $p = 1 - sum;$
 $IIntensity = bindRow(IIntensity, p);$
}
return $IIntensity;$
}

D. Calculating the Typicality of an Item for the Formation of a Relationship

Algorithm 3 (calculateTypicality) gets the following inputs: the vector A of size m representing the active user u_a with given known ratings; the vector $Neighbors$ consisting of k nearest neighbors of u_a ; the rating matrix R of U users and I items; and the vector $IIntensity$ containing the implicative intensity values of the relationship (u_a, u_i) with $u_i \in U$. This algorithm outputs the matrix $Typicality$ consisting of the typical values of item $i_j \in I$ for the relationship formation (u_a, u_i) with $u_i \in Neighbors$. The processing steps of Algorithm 3 are as follows:

- Filtering the rating matrix R that only contains the ratings of k nearest neighbors of u_a .
- Filtering the vector $IIntensity$ that only consists of the implicative intensity of k nearest neighbors of u_a .
- Calculating the contribution of item i_j for the existence of relationship (u_a, u_i) with $u_i \in Neighbors$ according to formula (7).
- Calculating the distance from i_j to the relationship (u_a, u_i) with $u_i \in Neighbors$ according to formula (6).
- Finding the typical value of item i_j for relationship formation (u_a, u_i) with $u_i \in Neighbors$ according to formula (5).

calculateTypicality($A, Neighbors, R, IIntensity$) {

$R = R[Neighbors,];$

$IIntensity = IIntensity[Neighbors];$

for each $u_i \in Neighbors$ do

for each item $i_j \in I$ do {

if $(R[u_i, i_j] = 1)$ Contribution $[u_i, i_j] = 1;$

else if $(A[i_j] = 1$ and $R[u_i, i_j] = 0)$

Contribution $[u_i, i_j] = 0;$

else if $(A[i_j] = 0$ and $R[u_i, i_j] = 0)$

Contribution $[u_i, i_j] = 0.5;$

Dist $[u_i, i_j] = sqrt((IIntensity[u_i]$
 $- Contribution[u_i, i_j])^2 / (1 - IIntensity[u_i]));$

}

Typicality = Null;

for each $u_i \in Neighbors$ do {

Rowmax = maxRow(Dist $[u_i,]$);

```
Typic = 1 - Dist[ui,] / Rowmax;  
Typicality = bindRow(Typicality,Typic);  
}  
return Typicality;  
}
```

IV. EXPERIMENTS

A. Experimental Setup

1) Experimental Data

Two datasets used in the experiment are MovieLens and CourseRegistration. The MovieLens dataset is collected through website movielens.umn.edu during the seven-month timeframe. The dataset consists of 943 users, 1664 movies, and 99392 ratings (with values of 1-5) storing the feedbacks of users to movies. To be used in the proposed model, the MovieLens dataset is binarized with the threshold of 3. The ratings are set to 1 if they are greater than or equal to this threshold and 0 otherwise. The CourseRegistration dataset is collected through the Cantho University's admissions website <https://htql.ctu.edu.vn>. The dataset saves the course registration of students who will take part in the third semester (of a program of study) at Faculty of Information and Communication Technology. The dataset consists of 1172 students, 81 courses and 5705 ratings (registrations) with values of 1.

To increase the accuracy of recommendations, the experimental datasets need to be preprocessed. If we keep items that are only rated a few times and users who only rate a few items, the evaluations may be biased. Besides, we should also pay attention to the constraints in the registration regulations when conducting the recommendation on the CourseRegistration dataset. For example, the maximum number of credits a student can register for a semester (except in the last semester of study) is limited to 20 credits; in most cases, each course is worth 3 credits; one of eligibility criteria for receiving the scholarship is that a student has to register at least 15 credits per semester; and in order to open a course, there must be at least 25 students registered.

Therefore, with the MovieLens dataset, the number of users viewing at least 50 movies and the number of movies viewed by at least 100 users are selected to extract data. With the CourseRegistration dataset, the number of students registering at least 5 courses and the number of courses registered by at least 25 students are chosen to extract the data. The general information of these datasets after filtering is shown in Table 1.

TABLE I. GENERAL INFORMATION OF MOVIELENS AND COURSEREGISTRAION AFTER FILTERING

Dataset	The number of users	The number of items	The number of ratings	The maximum number of given items*
MovieLens	565	336	48,698	14
CourseRegistration	779	36	4,095	3

*The maximum number of given items for each user of the query set (the maximum number of known items of an active user) is used for building recommendations and evaluating the recommendation models. This number is based on the percentiles of ratings.

2) Experimental Tool

The proposed recommendation model is developed in the R language and uses the functions that we built in the Interestingnesslab tool [12]. Besides, we also use some recommendation models of the recommenderlab package¹, to compare with the proposed model. Those models are: the item based collaborative filtering model using the Jaccard measure (IBCF), the user based collaborative filtering model using the Jaccard measure (UBCF), the popular model recommending the most common items to the active users (POPULAR), the latent factor model (ALS_implicit), and the association rule based model using the confidence measure (AR).

3) Evaluation

To evaluate the recommendation models, the rating matrix (dataset) is splitted into the training set and the test set. The test set is then divided into the query set and the target set which have the same size. However, for each user, the query set only has the randomly selected *given* known ratings; the target set consists of the remaining ratings. The query set together with the training set are used to predict recommendations whereas the target set is used to evaluate the recommended results. The k-fold cross validation method is used to split the dataset into *k* folds (subsets) of equal size, evaluates *k* times, and then calculates the average. For each time of evaluation, (*k*-1) folds are used as the training set and the remaining fold is used as the test set. In this experiment, *k* is chosen as 4.

When the number of items (the length of recommendation list) that need to be presented to the user is not predetermined, evaluating the algorithm over a range of lengths of recommendation list is preferable rather than using a fixed length. Therefore, the Precision- Recall and ROC (Receiver Operating Characteristic) curves are often used [13]. In addition, the ROC curve is often used to compare the performance of multiple algorithms. An algorithm is more efficient if its ROC curve completely dominates the ROC curves of other algorithms [13]. The Precision - Recall curve is built on the precision and the recall. The ROC curve is based on the sensitivity and the complement of specificity. The sensitivity (also called True Positive Rate - TPR) is equivalent to the recall. The complement of specificity is also called False Positive Rate (FPR). In addition, we also use the accuracy measure (the fraction of correct recommendations to total possible recommendations) and the F1 measure (the harmonic mean of the precision and the recall) to evaluate the performance of recommendation models. These six measures are built on the values of the confusion matrix shown in Table 2, and defined in formula (10), (11), (12), (13), and (14). In Table 2, TN is the number of items not recommended by the system and also not preferred by users; FP is the number of items recommended by the system but not preferred by users; FN is the number of items not recommended by the system but preferred by users; and TP is the number of items recommended by the system and also preferred by users.

¹<https://cran.r-project.org/web/packages/recommenderlab>

TABLE II. CONFUSION MATRIX

Actual/ Predicted	Not recommended	Recommended
Not preferred	True-Negative (TN)	False-positive (FP)
Preferred	False-Negative (FN)	True-Positive (TP)

$$Precision = TP/(TP+FP) \tag{10}$$

$$Recall \text{ or } TPR=TP/(TP+FN) \tag{11}$$

$$FPR=1-specificity=1-TN/(TN+FP)=FP/(TN+FP) \tag{12}$$

$$Accuracy = (TN+TP)/(TN+FP+FN+TP) \tag{13}$$

$$F1=2*precision*recall/(precision+recall) \tag{14}$$

B. Results

To compare the proposed model and some existing recommendation models of the recommenderlab package, six RSs are developed. They are named as: IBCFJaccard RS, UBCFJaccard RS, Popular RS, LatentFactor RS, ARConfidence RS, and UBCFImplicative RS. IBCFJaccard RS is created by using item based collaborating filtering model whereas UBCFJaccard RS is created by using user based collaborating filtering model. Both systems use the Jaccard measure to find the nearest neighbors. LatentFactor RS is based on the latent factor model. Popular RS uses the popular model to recommend the most common items to the active users. ARConfidence RS is developed by using the association rule based model and the confidence measure for finding the relevant items. UBCFImplicative RS is developed by using the proposed model and the implicative rating measure.

1) Evaluating the recommendation models on the MovieLens dataset

We conduct 30 times of evaluation (times = 30) where the number of known ratings (i.e. items) of each user in the query set is 14 (given = 14); the number of nearest neighbors is 50 (knn = 50); and the numbers of recommendations to be presented to the active user are: 1, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100. Each time of evaluation uses 4-fold cross validation method described above. Fig. 2 and 3 show the average F1 values and the average accuracy values of six recommendation models. The results indicate that the F1 values and the accuracy values of the proposed model are higher when compared to other models. However, the difference between the proposed model and the user based collaborating filtering model using the Jaccard measure is small.

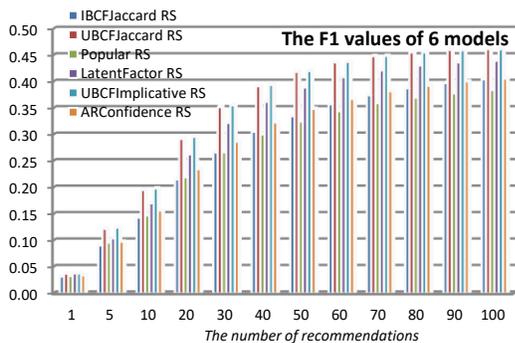


Fig. 2. The F1 values of six recommendation models on the MovieLens dataset.

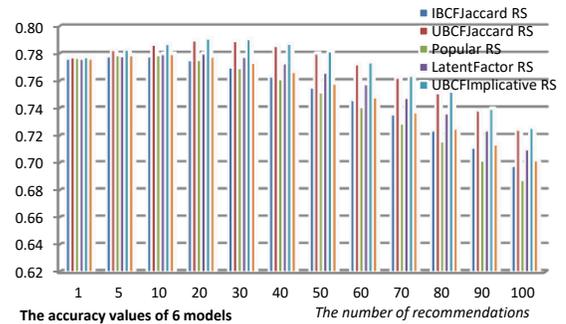


Fig. 3. The accuracy values of six recommendation models on the MovieLens dataset.

Fig. 4 and 5 display the ROC curves and the Precision – Recall curves of the six recommendation models with times = 30, given = 8, and knn = 50. The results show that the ROC curve of the proposed model dominates the other ROC curves; the probability of false alarm (FPR) of the proposed model is lower than that of the other models; as well as the precision and the recall of the proposed model are higher than those of the other models.

When changing the parameters: the number of times of evaluation (times), number of ratings of each user in the query set (given) from 3 to 14, and the number of nearest neighbors (knn), we get the results similar to the above figures. Therefore, the performance of the proposed recommendation model is better than that of other five models.

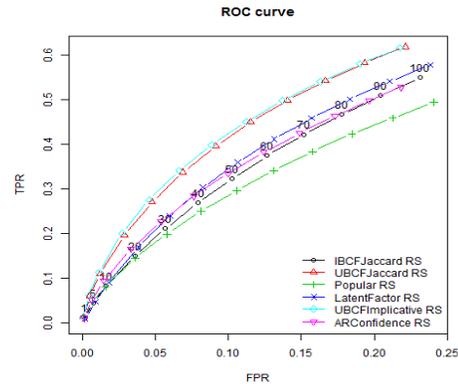


Fig. 4. The ROC curves of six recommender systems on the MovieLens dataset.

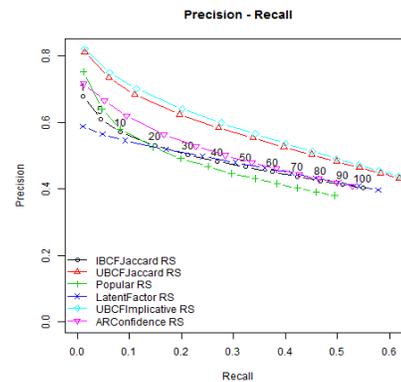


Fig. 5. The Precision – Recall curves of six recommender systems on the MovieLens dataset.

2) Evaluating The Recommendation Models On The CourseRegistration Dataset

Fig. 6 and 7 show the ROC curves and the Precision – Recall curves of the six recommendation models where the number of times of evaluation is 50 (times = 50); the number of known ratings of each user in the query set is 3 (given = 3); the number of nearest neighbors is 30 (knn = 30); and the numbers of courses to be presented to the active student is: 1, 2, 3, 4, and 5. The results indicate that the ROC curve of the proposed model dominates the other ROC curves; the probability of false alarm of the proposed model is lower than that of the other models; and the precision and the recall of the proposed model are higher than those of the other models.

Fig. 8 and 9 display the average F1 values and the average accuracy values of six recommendation models with times = 50, given = 2, and knn = 30. The results show that the F1 values and the accuracy values of the proposed model are higher when compared to other models.

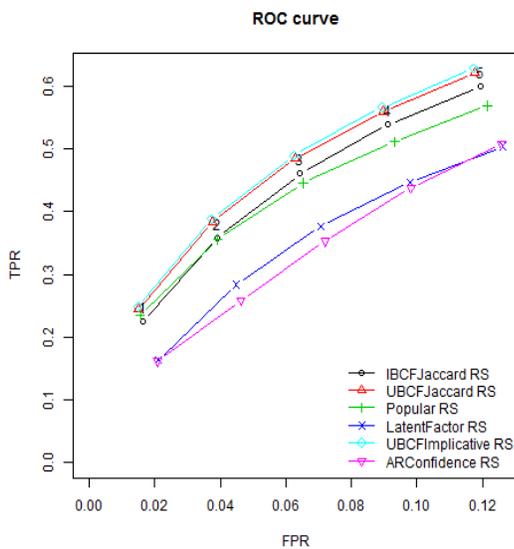


Fig. 6. The ROC curves of six recommender systems on the CourseRegistration dataset.

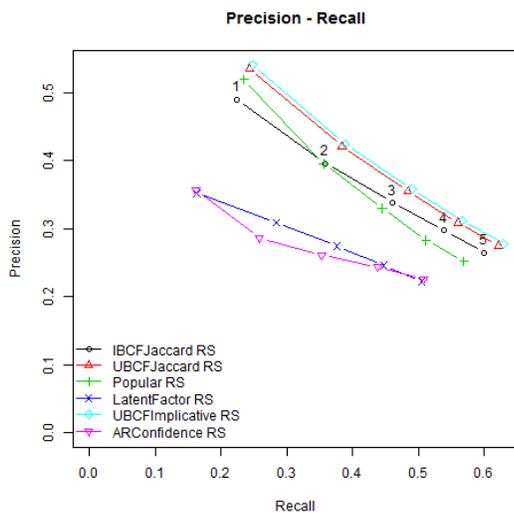


Fig. 7. The Precision – Recall curves of six recommender systems on the CourseRegistration dataset.

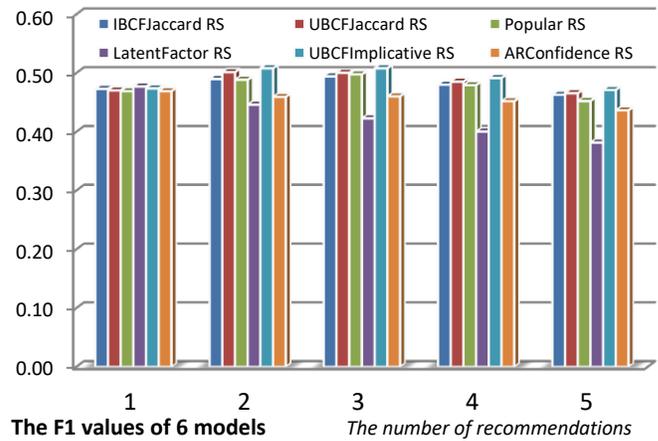


Fig. 8. The F1 values of six recommendation models on the CourseRegistration dataset.

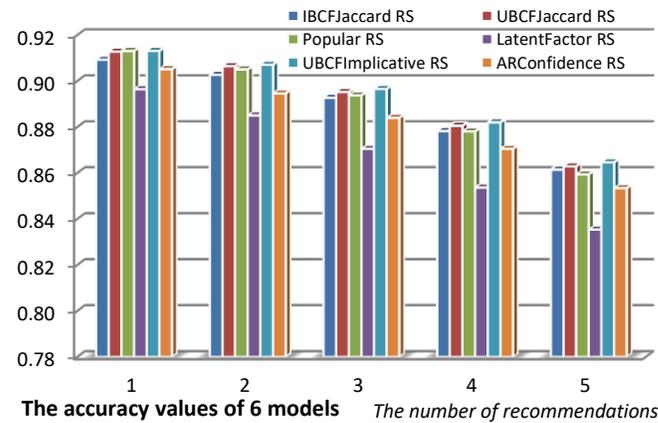


Fig. 9. The accuracy values of six recommendation models on the CourseRegistration dataset.

When the parameters (times, given and knn) are changed, we also get the results similar to the above figures. Therefore, the performance of the proposed recommendation model is better than that of other five models.

V. CONCLUSION

This paper proposes: the implicative rating measure developed on the statistical implicative measures, and a new recommendation model based on the user based collaborative filtering and the proposed measure. The input of the proposed model is the binary rating matrix. In order to filter out, rank, and recommend the top N items to the active users, the proposed model uses the implicative intensity measure to find the nearest neighbors of the active users; the proposed implicative measure to predict users’ ratings for items. The performance of the proposed model is compared to the performance of five existing models of the recommenderlab package: the item based collaborative filtering model using the Jaccard measure, the user based collaborative filtering model using the Jaccard measure, the popular model recommending the most common items to the active users, the latent factor model, and the association rule based model using the confidence measure. The experimental results on the MovieLens dataset and the CourseRegistration dataset show

that the performance of proposed model (through the ROC curves, the Precision – Recall curves, the F1 measure, and the accuracy measure) is better than that of the compared five models.

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A New Architecture for Real Time Data Stream Processing

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Abstract—Processing a data stream in real time is a crucial issue for several applications, however processing a large amount of data from different sources, such as sensor networks, web traffic, social media, video streams and other sources, represents a huge challenge. The main problem is that the big data system is based on Hadoop technology, especially MapReduce for processing. This latter is a high scalability and fault tolerant framework. It also processes a large amount of data in batches and provides perception blast insight of older data, but it can only process a limited set of data. MapReduce is not appropriate for real time stream processing, and is very important to process data the moment they arrive at a fast response and a good decision making. Ergo the need for a new architecture that allows real-time data processing with high speed along with low latency. The major aim of the paper at hand is to give a clear survey of the different open sources technologies that exist for real-time data stream processing including their system architectures. We shall also provide a brand new architecture which is mainly based on previous comparisons of real-time processing powered with machine learning and storm technology.

Keywords—Data stream processing; real-time processing; Apache Hadoop; Apache spark; Apache storm; Lambda architecture; Kappa architecture

I. INTRODUCTION

With the exponential growth of the interconnected world to the internet, a very large amount of data is produced coming in a form of continuous streams from several sources such as sensor networks, search engines, e-mail clients, social networks, e-commerce, computer logs, etc. McKinsey [1] relates that 5 billion individuals use diverse mobile devices. The increase of generating data doesn't have a limit. This phenomenon is known as "big data". According to the study of IBM on Big data, by 2020 there will be approximately 35 zetta bytes of data generated annually [2] and the data growth will be as high as 50 times than it is nowadays [3]. 2.5 quintillion bytes of data are produced every day [4]. Besides, in every second data are produced continuously; 34,722 Likes in Facebook, about 571 new websites, and almost 175 million tweets. All these multiple internet technology actors generate a very large data and information in the form of streams. These data are incremented in real-time according to the 5Vs of Gartner.

With recent technologies, such as applications of the Internet of Things, the stream of data is multiplied in volume, velocity and complexity. In addition to that these streams of data are processed with high velocity in real time which brings some unique challenges. The system of big data depends on the

Hadoop framework which is considered as the most effective processing technique.

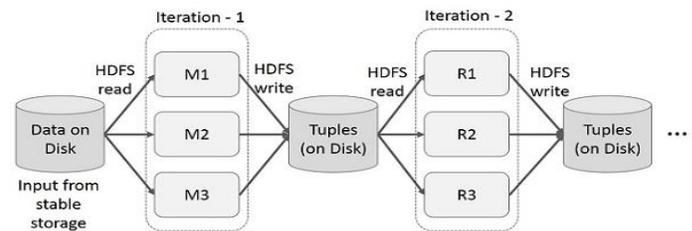


Fig. 1. Map reduce jobs.

Hadoop has a proportional performance to the complexity of large data. It is an effective tool for solving massive data problems. Despite the success it has had, this model has some limitations. Among the major limitations, Hadoop, precisely Map Reduce framework, is not the best tool for processing the latest version of data; it is limited to process data in batch mode. In other words, it cannot handle what is happening in real time. In several cases, it is very important to process data as created and have knowledge of what is happening in real time.

MapReduce is a simple programming model that permits processing a fixed amount of data but is not appropriate for real time stream processing. It is a batch processing system [5] which means that when the first batch is terminated, the data, that are offered for the final user, are aged at least until the second batch is terminated. Furthermore, MapReduce is appropriate for parallelizing processing on a big amount of data. However, it relies on a disk based approach. That is to say, each iteration output is written to disk making it slow. The following illustration in Fig. 1 shows that MapReduce reads the data from the disk and writes them back to the disk four times. There is one more disk read/write operation. In every MapReduce job, the disk reads and writes twice which makes the complete stream very slow and downgrades the performance. Hence, the need to create a tool that processes data immediately and gets a response of a query in real time with low latency.

In this paper we present an overview of some fundamental notions of big data, stream processing and the increasing volume of data. Then, we describe different tools and systems that permit processing data in real time. A thorough comparison is also taken into account in the following section. In addition, we propose a new architecture based on

the previous comparison. And last but not least, we compare our proposed architecture with the two existing architectures.

II. BIG DATA

Nowadays the term “big data” is frequently used in industry, science and so many other fields. Big data is a broad concept which refers to the explosion of large data sets that traditional database cannot process and manage due to the high volume and complexity of data generated in any time.

O’Reilly describes Big Data as [6] “data that exceeds the processing capacity of conventional database systems. The data is too big, moves too fast, or does not fit the structures of existing database architectures. To gain value from these data, there must be an alternative way to process it”. According to McKinsey Global Institute [1], “Big Data” refers to datasets whose size is beyond the ability of typical database software tools to capture, store, manage and analyze. IDC’s definition of Big Data technologies describes a new generation of technologies and architectures designed to economically extract value from very large volumes of a wide variety of data by enabling high-velocity capture, discovery, and/or analysis [7]. According to these definitions, big data refers to technologies that allow companies to quickly analyze a very large volume of data and get a synoptic view by mixing storage, integration, predictive analysis and applications. The Big data allows gaining time, efficiency and quality in data interpretation.

Gartner sees that this concept uses a set of tools and technologies to solve the problematic of the five Vs of Big data which include: Volume, Variety, Velocity, Veracity and Value. Volume stands for the very large quantity of data gathered by an organization, from datasets with sizes of terabytes to zetta bytes and beyond. Data comes from everywhere and the size continues to increase; by 2020 data will have become 44 times bigger (about 40 ZB) than that of 2009 [8]. Data come from a variety of sources and in many types. This is the second aspect of big data ‘variety’ [9] which refers to the various data types including structured, unstructured, or semi-structured data such as textual database, streaming data, sensor data, images, audios, videos, log files and more. These various types of data are going to be combined and analyzed together for producing a new insight. Velocity represents the speed of processing, analyzing and visualizing data for immediate response. Veracity stands for the reliability of data; the user must have confidence in the data to use for the right decision making. This characteristic is very hard to achieve with big data and represents an important challenge. Last but not least, Value which indicates the insights we can reveal within the data. It is not necessary to analyze and process a large data without value; rather we must focus on data with real value.

To summarize, big data do not refer to a huge volume of data and complex analysis, but on how to process, analyze and store rapidly at the moment this great size of information coming from different sources and in the shape of streams. This is done in order to obtain the right answer and make the best decision.

Unlike the traditional data processing systems, stream processing systems can process an unbounded source of events.

It can also transform the streams of data in real time with low latency so as to get real time response and make processed data directly accessible for the final user. SQL Stream defines “stream processing [as] the real-time processing of data continuously, concurrently, and in a record-by-record fashion. It treats data not as static tables or files, but as a continuous infinite stream of data integrated from both live and historical sources”.

Stream processing systems are invented to deal with big data in real time with a high scalability, high availability, and high fault tolerance architecture [10]. It permits to process data in motion as it is produced. We can say that a stream processing is a real time processing of continuous series of data stream by implementing a series of operations on every data point. The objectives of Stream processing are to collect, integrate, process, analyze and visualize the data as they arrive in real time to extract a greater insight. Processing streams of data in real time brings some challenges.

In the following section, we will give an overview of some tools of data stream processing and compare them so as to choose the best tool that satisfies the constraint of real time.

III. DATA PROCESSING TOOLS

In this section, we are going to present an overview of data stream processing tools including; Apache Hadoop, Apache spark and Apache storm to better understand very the difference between systems. Based on this description, we will show that older methods, precisely MapReduce, do not allow the processing in real time as it has the possibility to process a very large volume of data regardless of the speed with which the data arrives.

A. Apache Hadoop

The Apache Hadoop is a project of apache foundation, created by Doug Cutting in 2009, which is an open source software framework designed for scalable, reliable, and distributed computing. This framework allows the distributed processing of big data sets on clusters of computers. The Hadoop Framework includes several modules: Hadoop common, Hadoop Distributed files system (HDFS), Hadoop yarn, and Hadoop MapReduce. Fig. 2 represents the Hadoop ecosystem and shows the core components of this framework, namely, HDFS for storing a large volume of data sets and MapReduce for processing big data in batch mode.

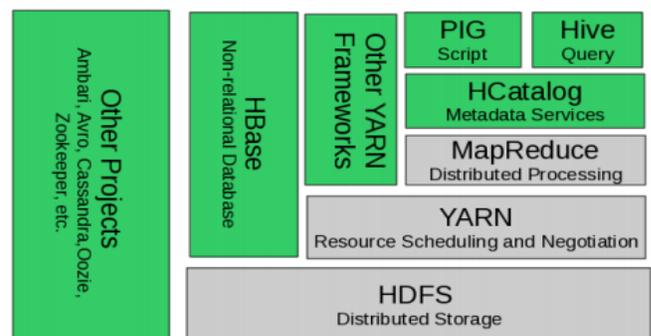


Fig. 2. Hadoop Ecosystem [11].

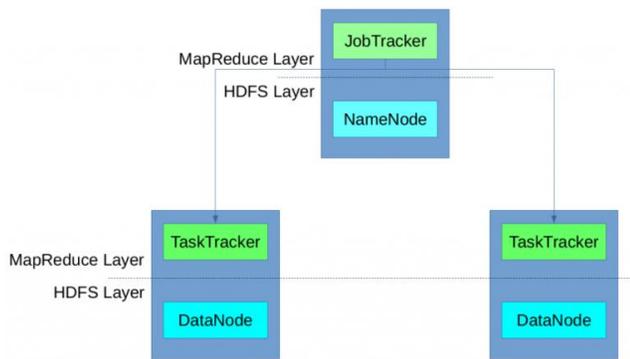


Fig. 3. Architecture of Hadoop [12].

Hadoop has a master/slave architecture that consists of two servers which are the basics of MapReduce framework, a single master node and several worker nodes [13]. A master node namely Job Tracker is responsible of accepting jobs from customers, dividing jobs into tasks, assigning tasks to worker nodes and re-executing failed tasks. Every worker executes a task tracker process which is responsible to execute and manage the tasks assigned by Job Tracker on a single computation node in the cluster as shown in Fig. 3. HDFS [14] is designed to be a distributed, scalable and resilient storage system that is designed to interact easily with MapReduce. It provides an important aggregation bandwidth throughout the network. HDFS is composed of a master node called Namenode and data servers called Datanodes. The structure of the HDFS file is divided into blocks of 128 MB.

MapReduce, which was first developed in 2004 by Google, is a framework whose role is to facilitate processing vast amount of data in parallel on large clusters of commodity hardware in a fault tolerant manner [12]. It is divided into two separate steps, namely, map phase and reduce phase [15], [16]. First, the user defines a map function to process the input data and produce a group of intermediate key/value pairs. Second, the intermediate values with the same intermediate key are grouped together by MapReduce library and transferred to the reduce function. And finally, the reduce function processes the intermediate results and finishes the job. Fig. 4 indicates the execution workflow of MapReduce job. The MapReduce library splits the input data into M disjunctive partitions for the parallel execution of map operation about 16-64 MB per piece [16]. The copies of program are launched on computer of the cluster. The Master assigns map and reduce tasks to running worker instance, the worker with map task reads assigned partition, processes all input pairs with map function, buffers output pairs in local main memory and flushes buffer periodically to disk. Storage location is reported to the master, which coordinates hand-over to reducers. Worker with reduce task gets the location of intermediate results and reads them. Shuffle means sorting pairs by key to group them and write results of reduce function into the output file that is associated with reducer's input partition. After all map and reduce task have been processed completely the master returns to wake up the user program [16].

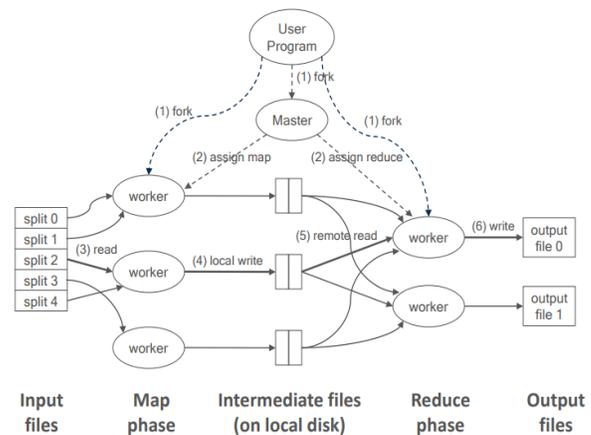


Fig. 4. Map reduce model.

MapReduce is a fault tolerant framework that processes a big amount of data due to its elasticity and scalability, but it is not a perfect way for real time data processing. The MapReduce programming model has some limitations. These limitations are presented as follows:

- 1) Only suitable for processing data on batch
- 2) No real time
- 3) Stock data on disk which makes Disk intensive
- 4) No repetitive queries
- 5) Not efficient for caching; MapReduce can't maintain the intermediate results in memory
- 6) Not efficient for iterative algorithms and interactive data querying
- 7) One-input and two-stage data flow is extremely rigid
- 8) Common operations must be coded at hand
- 9) Semantics hidden inside map reduce functions, difficult to maintain, extend and optimize

B. Apache Spark

Spark is an open source framework for distributed computing [17]. It is a set of tools and software components structured according to a defined architecture. It is developed and designed at the University of California at Berkeley by AMPLab. Spark is now a project of the Apache Foundation. This product, which is an application framework of big data processing to Spark, performs a data read at the cluster level (cluster of servers on a network), and performs all necessary analysis operations by writing the results at this same level. Despite the fact that it is written with Scala, Java and Python languages, it makes the best use of its capabilities with its native language 'Scala'.

The main difference between MapReduce and spark is that MapReduce from Hadoop works on stages while Spark works on all the data at the same time. It is up to ten times faster for batch processing and up to a hundred times faster for performing in-memory analysis. Spark performs all the data analysis operations in memory and in real time [18]. It relies on disks only when its memory is no longer sufficient. Conversely, with Hadoop the data are written to disk after each operation. This work in memory reduces latency between treatments which explains such rapidity.

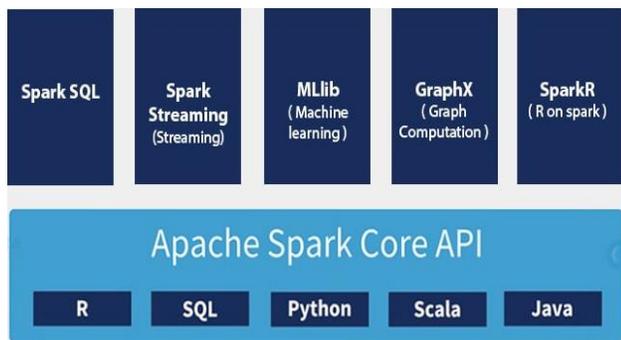


Fig. 5. Spark framework ecosystem.

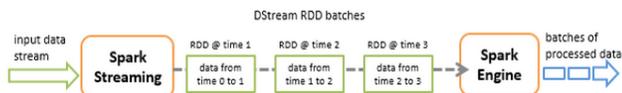


Fig. 6. Spark streaming.

However, Spark does not have a file management system of its own. It is necessary to provide one, e.g. Hadoop Distributed File System, Informix, Cassandra, OpenStack Swift or Amazon. It is recommended to use it with Hadoop which is currently the best overall storage solution thanks to its more advanced administration, security and monitoring tools. In case of failure or system failure: Data objects are stored in so-called resilient distributed datasets (RDDs) distributed over the data cluster for a complete data recovery.

Spark wants to be a response to the limitations of MapReduce and allows in the same environment to easily access a wide variety of use cases, such as SQL, Streaming, Machine Learning and Graph Analysis, in a more efficient and interactive way as shown in Fig. 5.

Spark Streaming is a programming interface for processing data flows on a Spark platform. Data can be received in a variety of ways: file system transfers, TCP sockets reception (generic network connections), or Twitter, Kafka, Flume, etc. Fig. 6 [19] shows several operations that can be directly applied to the streams. Each stream is being represented by a DStream, It is a transformation of a stream to obtain another stream, merging of several streams into one, joining of stream, joining between a stream and a single RDD, filtering a stream from another stream, updating a state from a stream, and so on. These operations can be applied both through spark-shell and from a program.

C. Apache Storm

Storm [20] is a real-time computing system that is distributed, fault-tolerant and guarantees data processing. Storm was created at BackType which is a company acquired by Twitter in 2011. It is an open source and open source project under the Eclipse Public License. The EPL is a very permissive license, allowing you to use Storm either in open source or for proprietary purposes. Storm makes the processing of unlimited data flows clear and reliable, making for real-time processing what Hadoop has done for batch processing. Storm is very simple and has been designed from the ground up to be usable with any programming language.

Storm can be used for some different use cases:

- Streams/flows processing: Storm can be used to process a stream of new data and update databases in real time.
- Continuous calculation: Storm can make a continuous query and disseminate the results to customers in real time.
- Distributed RPC: Storm can be applied to parallelize an intense request on the fly. If Storm is configured correctly, it can also be very fast: a frame rate reference of more than one million tuples treated per second per node.

A storm cluster consists of three nodes: “Nimbus” which is equivalent to the Hadoop Job Tracker, “Supervisor” that is responsible for initiating and terminating the process, and “Zookeeper” node which is a shared coordination service that directs the storm cluster as explained in Fig. 7.

Instead of using “MapReduce jobs” like in Hadoop, we use “topologies” in Apache Storm. It consists of spouts and bolts with bonds among them to show how streams are passing encompassing. We describe it as a data processing Directed Acyclic Graph (DAG) which draws the entire stream processing method. A topology design is presented below in Fig. 8.

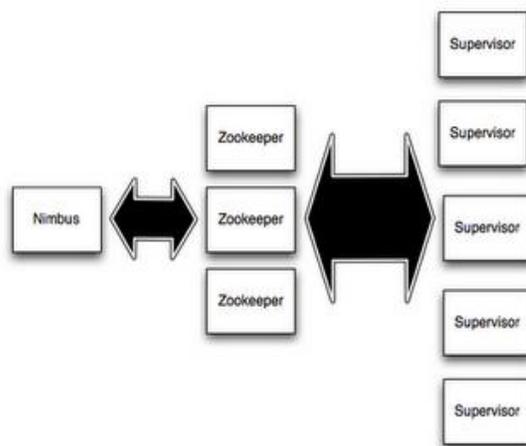


Fig. 7. Storm architecture.

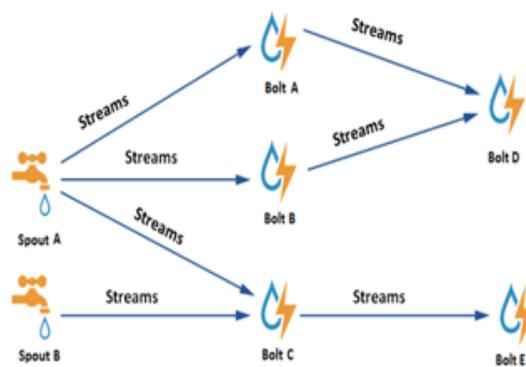


Fig. 8. Topology of storm.

IV. A COMPARISON OF DATA PROCESSING TECHNOLOGIES

In this section, we differentiate between the different tools used for the real-time stream processing and based on this comparison; we will determine the most suitable tool.

TABLE I. DATA PROCESSING TECHNOLOGIES

Tools	Hadoop	Spark	Storm
Criteria			
Source Model	Open source	Open source	Open source
Architecture	Master/slaves	Master/slaves	Peer
Coordination tool	Zookeeper	Zookeeper	Zookeeper
API Programmation	Java-Python and Scala	Java-Python, R, and Scala	Any PL
Execution Model	Batch	Micro-batch	Real-time(one-at-a-time)
Big data processing	Batch	Batch and Streaming	Streaming
achievable latency	High	A few seconds (< 1s)	Less than a second (< 100ms)
Ordering guarantees	Yes	Yes	No
Guaranteed Data Processing	exactly-once	exactly-once	At least once processing
In memory processing	No	Yes	Yes
Storage data	yes	yes	No
Fault tolerance	Yes	Yes	Yes

The illustration above in Table 1 shows that storm is the best tool for real-time stream processing, Hadoop performs batch processing, and spark is able of doing micro-batching. Storm employs the spouts and bolts to do one-at-a-time processing to avoid the inherent latency overhead inflicted by batching and micro-batching.

V. REAL TIME PROCESSING ARCHITECTURES

In this part, we will present two architectures based on real-time processing called Lambda and Kappa. According to this description, we will compare them then deduce a more robust architecture that satisfies the real-time constraint.

A. Lambda Architecture

The lambda architecture unifies real-time and batch processing in a single framework which provides low latency and better results. It was founded thanks to Nathan Marz’s motivation to build the hybrid system.

The lambda architecture [21], shown in Fig. 9, consists of three layers and each of these layers can be made using various large technologies, described as follows:

Batch layer: Stores the master copy of dataset and computes arbitrary batch views.

Serving layer: Integrates results from the batch and speed layer.

Speed layer: Only processes the recent data to compensate the high latency of the services layer updates.

Firstly, all the original data streams are dispatched to the batch and speed layer for processing. **The Batch layer** allows batch processing for pre-computation of large amounts of datasets. It provides the managing of the Master Dataset; a set of immutable, append-only and exclusive raw data, but also provides a pre-computation of arbitrary query functions, called batch views. This layer doesn’t update regularly batch views which lead to latency. MapReduce is a good example of batch processing that can be used at the level of this layer. Secondly, **the Serving layer** means computing in Real-time (Speed time) to minimize latency by performing real-time calculations as data arrive. This layer indexes batch views produced by the batch layer so that they can be queried in Ad-Hoc with low latency. Typically, technologies such as HBase, Impala, and Cassandra can be used to implement this layer. And finally, **Speed layer** which responses to queries, interfacing, querying and providing calculation results. This layer accepts all requests that are subject to low latency requirements, using fast and incremental algorithms but only deals with recent data. In this layer, we can use stream processing technologies like Apache spark, SQLstream, Apache storm. In a high-level point of view, the figure below shows the basic architecture and how the Lambda architecture works.

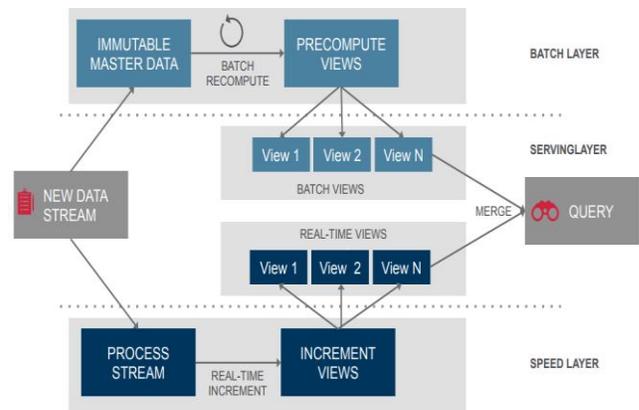


Fig. 9. Lambda generic architecture [22].

The lambda architecture has some flaws [23]:

- The business logic is implemented twice in the real-time and batch layers. The developers need to maintain code in two separate distributed systems.
- Lambda is an architecture for asynchronous processing. Hence, the computed results are not immediately consistent with the incoming data.
- Resulting operational complexity of systems implementing the Lambda architecture is huge.

- The operational burden of managing and tuning two operating systems for batch and speed layers is very high.
- Need for more frameworks to master.
- More straightforward solutions when the need is less complicated.

B. Kappa Architecture

Kappa architecture [24] is a simplification of lambda architecture. It was created by Jay Kreps in 2014 by the experience in LinkedIn and is a software architecture pattern. A Kappa architecture system is like the lambda architecture with the batch processing system eliminated. To replace batch processing, data is transmitted merely through the streaming system rapidly [24]. Rather than utilizing a relational DB like SQL or a key-value store similar to Cassandra, the canonical data store in a Kappa Architecture system is an append-only permanent log. From the log, data is streamed to a computational system and forwarded into auxiliary stores for serving.

Unlike the Lambda architecture, the Kappa architecture is more dedicated to processing data. It does not allow their permanent storage. Even though it is limited, the Kappa employs only a single code path for the two layers which reduces system complexity [25] as opposed to lambda architecture, which uses two separate code routes for the batch and the speed layer. The Kappa architecture illustrated in figure 10 is composed of two layers: The stream processing layer which executes the stream processing jobs and the serving layer which is used to query the results.

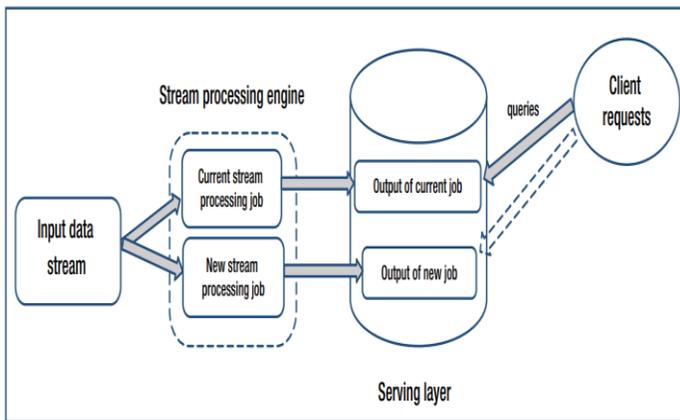


Fig. 10. Kappa architecture [23].

The advantages of Kappa architecture is allowing users to develop, test, debug and operate their systems on top of a particular processing framework. The Kappa architecture can be implemented using various technologies like Apache Storm, Spark, Kafka, HBase, HDFS or Samza. This architecture has been chosen to meet the need for data consistency and streaming processing because it allows a real-time and reliable execution of its log system.

Table 2 presents a short comparison of the two architectures as has been explained before, specifically Lambda and Kappa, following particular criteria.

TABLE II. A COMPARISON OF LAMBDA AND KAPPA ARCHITECTURES

Architectures	Lambda architecture	Kappa architecture
Criteria		
Architecture	Immutable	Immutable
Layers	Batch, serving and real-time layer	Stream processing and serving layer
Processing data	Batch and real-time	real-time
Processing guarantees	Yes in batch but approximate in streaming	Exactly once with consistency
Re-processing paradigm	In every batch cycle	Just when code change
Scalability	Yes	Yes
Fault tolerance	Yes	Yes
permanent storage	Yes	No
Real-time	Isn't accurate	Accurate

VI. PROPOSED ARCHITECTURE

Many advantages and drawbacks of the two architectures were presented. Based on what has been noted in previous paragraphs, we have designed a novel architecture that is open source and follows a different set of characteristics mainly its ability to process large data in real time at high speed. In addition to that, it allows a limitless number of users to set up several new and creative features as well as applying many reforms.

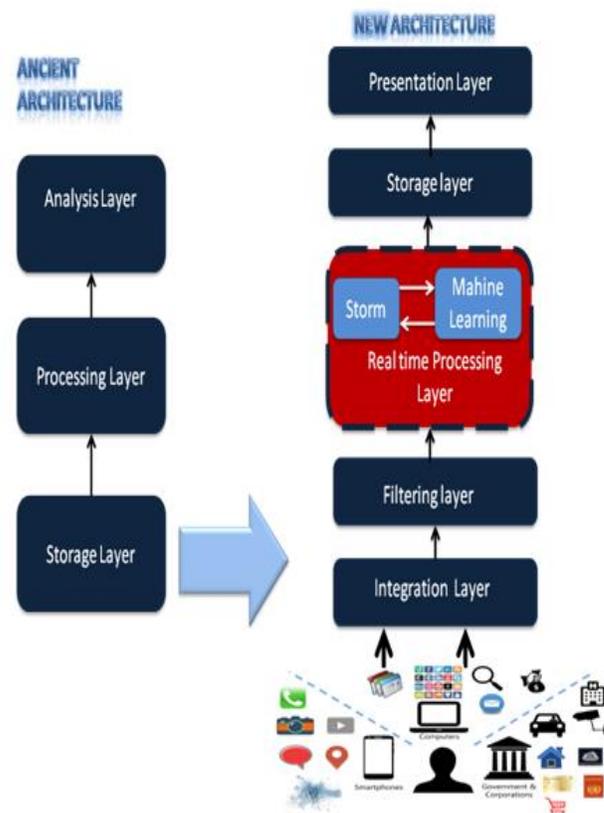


Fig. 11. Proposed architecture.

The architecture at hand has to gather- organize- integrate- process-analyze-store and visualizes influent data streams with low latency. Thus the responding of the system ought to be fast depending on the used architecture be it spark or storm, or the amount of the data and the complicatedness of the performed calculations. Nevertheless, the choice of the most suitable and efficient medium or tool should be taken into consideration as it has to be relatively easy to use allowing the analysts or the developers to deal with infrastructure problems.

Ideally, we aim to create an architecture that permits to make a transition to scale uncomplicated and visually changing resource allocation. Moreover, the configured resources must be chained to the cluster and should deal with changes in load or traffic without interruption. Finally, this architecture has to offer a live visualization of streaming data. It should also allow the creation of dashboards, custom graphics as well as UI extensions.

Both traditional architectures of big data and the proposed one are represented in Fig. 11. The traditional architecture consists of three layers viz. storage, processing, and analysis. On the other hand, our newly proposed architecture works differently. That is to say, the data incoming as a stream from various sources, like social media, cyber-infrastructure, web, sensors, email, and networks, come with a high speed. These data are delivered on time as they occur in the integration layer. This latter acquires the use of a set of tools and functionalities as is the case of Apache Kafka.

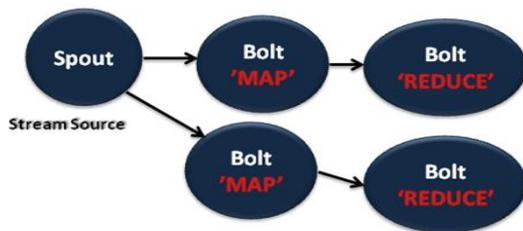


Fig. 12. Real-time processing Layer.

This layer makes it possible for the data to be ingested whatever are the formats and velocity. The data are going to be filtered into ELT, extract-transform-load operations (e.g., PIG), directly after being ingested. This layer is an important phase to filter streams of data in real time data processing. That is to say, the data will be cleaned and their qualities analyzed. This preprocessing stage, the filtering layer, gets rid of unwanted fields and special characters to make the processing and analysis reliable. To filter data streams we are going to use some algorithms such as sliding window, load shedding and synopsis data model. All this leads to the preparation of data for the real-time processing layer which mainly targets the processing of data in real time and with reduced latency. In this layer, we need robust and dynamic algorithms to confront the diversity of data. Fig. 11 represents two technologies that are used in this layer specifically storm and machine learning. The use of this latter in the present layer permits to archive the data and its objective is to visualize recent trends through a request/respond tool on similar inputs. It learns continuously from the newly arriving data the thing that makes the processing easy. On the other hand, in this layer storm is used

to process the data in real time as it uses the so-called topology which is a network of Spout and Bolt. As mentioned previously, the streams arrive from Spout which broadcasts data arriving from external sources in Storm topology.

In Bolts, many functionalities can be used including filters, functions, joins, aggregations, etc. Consequently, we can apply map function in Bolt to mark the words of the stream. This resulting stream which comes from Bolt 'Map' proceeds into the following Bolt which implements the 'Reduce' function to aggregate the words into numbers as shows Fig. 12.

After the processing phase meets an end, the storage layer takes over. The storage is performed at the level of HBase. After the database is prepared and configured, region servers are created, and finally, backup and tables are mastered. The main role of the visualization layer is to present to the user the final data and results in streaming mode. This layer can give a quick response if all phases are achieved successfully.

VII. COMPARISON WITH RELATED ARCHITECTURES

The proposed architecture has been put in place to deal with some problems at the level of both lambda and Kappa architectures. Lambda allows providing customers with the freshest vision possible. However the business logic is implemented at the level of both layers, two different sources of the same data are needed namely files and Web Services, and several frameworks are necessary to set up this architecture. Consequently, Kappa architecture was born in response to the complexity of lambda architecture. Unlike lambda, Kappa brings an evolution in a way that it is more dedicated to data processing even though it does not permit the permanent storage of data. This architecture is more straightforward than lambda and gives the user the freedom to single out the composers of implementation. Nevertheless, Kappa does not have a separation between the needs and is not a magical spell to solve all the problems in big data. In addition to that, these two architectures focus on addressing performance issues by balancing throughput and latency rather than data quality issues and data analysis results.

Our architecture, on the other hand, is based on the principle of Kappa architecture. It is a data processing streaming approach that processes all incoming data as streaming data and allows permanent data storage. It can also provide real-time processing by using storm and machine learning. Storm, which is a distributed real-time computing system, is fault tolerant as it manages the errors happening in working procedure and nodes. This method does for real-time processing what Hadoop does for batch processing. Storm can quickly compile and expand complicated real-time computation in a computer cluster and permit to process endless streams of data reliably.

Topologies of storm should be created inside it to realize real-time computation. In this layer, we integrate a distributed machine learning algorithms. Traditional supervised machine learning algorithms form data models based on historical and static data, whereas Traditional unsupervised machine learning re-examines all datasets if new data analysis is needed to detect the pattern.

Conversely, our architecture is going to use both supervised and unsupervised approaches to implement the distributed streaming version of adopted machine learning algorithms. The supervised learning in streaming approach learns continuously as new data arrives and is labeled. Unlike the traditional one, unsupervised learning in streaming approach can detect unusual patterns in streaming data in real time without any reexamination of the data that were analyzed before.

VIII. CONCLUSION

With the recent evolution of big data, processing a large amount of data becomes a big challenge. Map-reduce technology provides a distributed computing platform for processing a large dataset on larger clusters. Nevertheless, it does not satisfy the real-time processing capacity, hence the need for a strong system that meets these expectations to overcome the limitations of the traditional system.

The main goal of this paper is to propose a real-time processing architecture that builds on the storm technology as well as machine learning. Storm allows processing a very large volume of data with low latency and high velocity. Machine learning, on the other hand, learns continuously from new coming data which facilitates processing. Furthermore, this proposed architecture is based on a survey of open-source real-time processing systems, including Hadoop, spark, and storm. Two major architectures, namely lambda and kappa, were compared to create a brand new strong one.

In this proposed architecture, we suggested giving priority to real-time processing layer, and we tried our best to enhance it by integrating storm and machine learning. This new architecture was mainly inspired by the advantages of lambda and kappa. Our next step is to validate and evaluate its performance. We also decided to analyze the same dataset with several machine learning techniques. In addition to that, we intend to build a real-time stream processing framework for IoT and sensing environment. Most studies are constrained by a few limitations, and this research is no exception. However, we cannot talk about its limitations until the validation stage is finished.

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A Brief Survey on 5G Wireless Mobile Network

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Abstract—The new upcoming technology of the fifth generation wireless mobile network is advertised as lightning speed internet, everywhere, for everything, for everyone in the nearest future. There are a lot of efforts and research carrying on many aspects, e.g. millimetre wave (mmW) radio transmission, massive multiple input and multiple output (Massive-MIMO) new antenna technology, the promising technique of SDN architecture, Internet of Thing (IoT) and many more. In this brief survey, we highlight some of the most recent developments towards the 5G mobile network.

Keywords—5G; millimetre wave (mmW); Internet of Thing (IoT); SDN; massive multiple input and multiple output (Massive-MIMO)

I. INTRODUCTION

The fifth generation network (5G) is coming sooner than we expect, some say by 2020 [1], which is expected to have a speed exceeding the 1Gbit/s [2]. There has been a great interest in the research of the 5G future technology, so 700 million euro from the public fund has been committed only for this research over seven years [3]. Many aspects could play an important role in forming the 5G network, in [4] they concentrated on five elements: millimetre wave (mmW), massive multiple input and multiple output (massive -MIMO), device-centric architectures, smarter devices, and native support for machine-to-machine (M2M). The authors in [2] emphasized five things as a challenge for 5G: Heterogeneous Networks (HetNets), Software Defined Cellular Networks (SDN), M-MIMO and 3D MIMO, M2M Communications and other technologies. In [5] the authors talked about four generic elements which could form the 5G era: Big Data Analytics (Big Data), Cloud Computing (Cloud), Internet of Things (IoT), and SDN. In [1] the authors discussed in detail about many aspects related to the upcoming 5G network: Engineering Requirements for 5G and the design issues, mmW, M- MIMO, Cloud-Based Networking, SDN, Energy Efficiency, spectrum regulation and standardization for 5G and many more. Fig. 1 depicts some of the related aspects to the new 5G mobile networks.

The remainder of the paper is organized as follows. Section 2 presents the evolution of the mobile networks. Section 3 gives an overview of the 5G network architecture. Section 4 explains the Software-Defined network (SDN) architecture. Section 5 describes the cloud Radio Access Network (RAN). Section 6 explains the radio network evaluation. Section 7 explains the advanced air interface. Section 8 presents the

Heterogeneous Network (HetNets). Section9 explains the big data. Section10 describes the Internet of Things (IoT). Section11 presents Internet of Vehicles (IoV). Section12 explains the Device to Device communication (D2D). Section13 presents the Machine to Machine communication (M2M). Section14 explains the millimetre Wave Mobile Communication (mmW). Section15 describes the Massive-Multiple Input Multiple Output (M-MIMO) antenna system. Section16 presents briefly some proposed ideas of the 5G Energy Efficiency. Section 17 explains the Healthcare related issues to the 5G network. Section 18 presents some of the available simulations software for the 5G mobile network. Section 19 draws some possible directions for future research directions. Finally, Section 20 presents the conclusion.

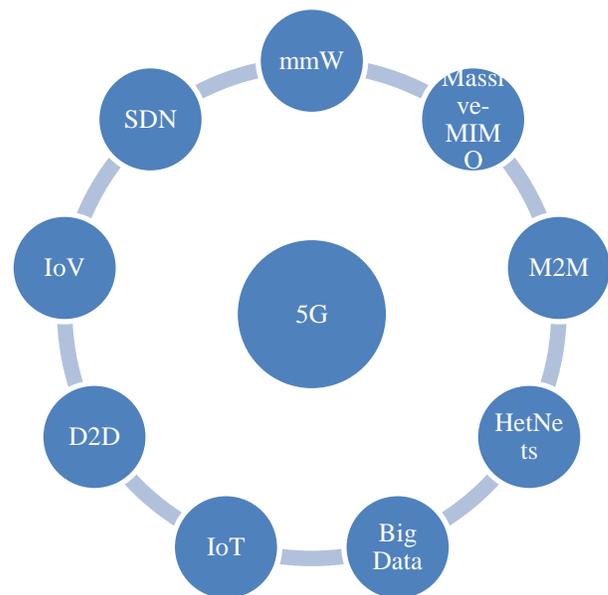


Fig. 1. Some aspects related to the new 5G mobile networks.

II. MOBILE NETWORKS EVOLUTION

It seems that telecommunication technology advances every decade or so, as 1G started around 1980, 2G by 1992, 3G by 2001, 4G or Long-Term Evolution (LTE) by 2011 and the new 5G network expectantly by 2020 [6]. 4G nowadays supports 1 Gbits/s for low mobility and 100 Mbit/s for high mobility. For the new upcoming 5G they estimate 10 Gbits/s for low mobility and 1Gbit/s for high mobility [7]. The latency in 4G is 15 ms while in 5G it is expected to be 1 ms or so [1].

So how could all of that happen? The answer lies in the new architecture of the 5G network.

III. 5G NETWORK ARCHITECTURE

The architecture of the new network will be changed, many aspects will try to utilize and get the most out of the existing technology and add new ones to form much faster network capable to deliver the rich content of the multimedia (HD-4K [High Definition] streaming/none streaming video and Hi-Res [High Resolution] images) and the data flood produced from mobile phones and social media apps. One proposed idea is software-defined network architecture. The 5G mobile network needs to deal with some of the challenges facing the 4G network nowadays such as high energy consumption, spectrum crisis, bad interconnectivity, poor coverage, flexibility, and poor Quality of Service (QoS) [8].

IV. SOFTWARE-DEFINED NETWORK (SDN)

In [9] the author describes SDN as a promising technique for 5G. SDN and Network Function Virtualization (NFV) have been applied to the cloud in data centres to enable load balance [5]. Furthermore, SDN will play a big role in the design of 5G network as it will be flexible, open and will not be based on switching and routing as the traditional network [9]. Many proposed SDN architectures systems summarized as follows:

- SDN controller that adjusts the bandwidth dynamically as proposed by [10] for each radio access point (RAP) in the network the bandwidth will be dynamically adjusted to the baseband unit (BBU), the SDN controller core consists of two parts: unified control entity (UCE) and unified data gateway (UDW) each part plays a different role in the proposed system, as a whole the SDN controller of the proposed system is providing the flexibility management for the system.
- A new SDN architecture is called SoftAir was proposed by [11]. In this system, the main themes are flexibility and scalability via cloud and virtualization, the data flow is optimized and managed via software-defined switches (SD-switches) and software-defined base station (SD-BSS) in the RAN.
- A new multi-tiered cloud controller SDN architecture, Software Defined Wireless Network (SDWN) proposed by [12] is based on service-oriented and user-centric architecture. The 5G heterogeneous radio access would efficiently improve by decreasing traffic, another advantage of the proposed system is controlling of the quality of user experience (QoE) by varying latency, jitter and throughput to reduce the end-to-end delay to few millisecond to satisfy some future applications.
- Open-source OpenAirInterface (OAI) SDN architecture proposed by [13] is based on two existing technology components used in the LTE architecture: the Evolved Universal Terrestrial Radio Access Network (E-UTRAN) and Evolved Packet Core (EPC), the proposed system model is highly realistic as it is based upon a stack of protocols from the network layer all the way to physical layer, the main features of the proposed system are that it is a real-time open-source software

implementation of the existing 4G network model (i.e. 3GPP LTE standard) and it could be used in-door as well as out-door.

- Cross-layer scheme combining Software-Defined Radio (SDR) and SDN architecture was proposed by [14] to combine the two layers together. We need to create this cross-layer to exchange information between them to achieve the best performance of the 5G mobile network, the proposed system suggests the idea of spectrum reuse to decrease the flow of the traffic in certain frequencies, all of these administration rules need to be governed by the cross-layer controller.
- An intelligent way to deliver data flow SDN architecture was proposed by [15]. This system is based on the SDN controller and how it could analyse the network conditions such as packet loss rate and throughput of the traffic data flow. Based on that it could find the bottleneck and try to solve congestion after calculating the QoS budget. In addition, it can use the network policies to find other alternative routing for the data flow and dynamically update the WAN path routes consequently.
- SoftRAN (Soft Radio Access Network) SDN architecture was proposed by [16], the idea is based on a centralized architecture similar to the SDN architecture by controlling the base stations in one geographical area and uniting them in a big virtual base station, expressed by [11] as attempting to restructure the control plane of RAN in a software-defined way.

V. CLOUD RADIO ACCESS NETWORK (RAN)

Cloud Radio Access Network (C-RAN) might solve some problems related to high data rates demands, this technology is based on centralisation and virtualisation [17]. Centralized RAN (C-RAN) is attracting a huge attention as a possible way to centralise computational resources efficiently [18]. In [19], the authors proposed a Dynamic Energy Savings in the 5G Cloud-RAN mobile communication network by combining multiple Base Band Units (BBUs) for signal processing in the centralized BBU pools and using the Wake-on-LAN (WoL) packets to wake up BBUs depending on traffic.

VI. RADIO NETWORK EVALUATION

The 5G network works towards using mm-W signals as a way of transferring high frequency communication. However, there are some limitations for that signal outdoors [6]. When there is no obstacles between the sender and receiver, we have a line of sight (LOS) communication which has a better performance over the non-line of sight (NLOS) communication. If there are obstacles in between the sender and receiver, the signal will reflect and bounce over objects and communication still happens with some loss [20]. To cope with the new communication challenges, this proposed technology will provide low cost and less latency by extending the coverage using large beamforming while improving link quality and reducing interference at the end user. The base stations which are used in all previous generations are still a key figure in the coming 5G network and a new technology

like mm-W-BS grid proposed by Samsung [21] might be added to them to enhance the performance. An acceptable overlap spectrum occurs from using narrow beams which improves link quality between the base stations and the vast number of end users [22]. The main candidate for the 5G physical layer is orthogonal frequency-division multiplexing frequency (OFDM). Although, many variants of OFDM are available and have some weakness, tunable OFDM for 5G is proposed to meet the requirement of the coming 5G network [23].

VII. ADVANCED AIR INTERFACE

The antenna topology will change from omni-directional to a directional one [24]. Frequency reuse could be improved by using Spatial Division Multiple Access (SDMA) for beamforming antennas at sender and receiver sides [25]. BS model is governed by many parameters which maximize its performance such as receiver sensitivity, transmit power, antenna height and type, load capacity, operational costs, and capital [26]. In [27], the authors proposed a multiband OFDMA via different mmWave bands, (i.e. the V-band -60 GHz and the E-band- 70–80 GHz) and the Long Term Evolution (LTE) band for maximizing the overall data rate of the 5G network by efficient resource allocation. A hybrid analogue and digital beamforming for the large-scale mmWave broadband have been proposed [28] for the single-user MIMO (SU-MIMO) antenna array as it needs to be employed to the transmitter as well as the receiver.

VIII. HETEROGENEOUS NETWORK (HETNETS)

The idea of a big and vast network, which has different classes of base stations: macro, pico and femto [2] by using smaller cells. Here we densify the network by using less power (Green Communication) and improve the coverage of the network [9], by deploying low power small BS to connect with small cells (low transmission power), so the network capacity is improved and coverage is extended [29] to cover indoor and outdoor. If indoor areas have low coverage, the coverage could be enhanced by placing small cells indoor and offloading traffic from macro cells when needed [2]. Unnecessary signalling overhead is generated from Radio Access Technology (RAT) proposed solution to use an efficient multi-RAT handover [30]. The architecture of the new 5G network will move from the BS centric to device centric or user centric networks, from small to femto cells deployment which will form the HetNeT. Many technologies are emerging also like cloud-RAN and SDN [31].

IX. BIG DATA

The new 5G mobile network is referred to a huge integrated framework of big data [32] passed from multiple sources which needs to be stored and processed. Big data is among the possible technologies which will lead to the 5G revolution in the nearest future and will aid the traffic for the 5G users, i.e. Smart cities, VR (virtual reality), IoT, HD videos, Games, and many more [33]. The architecture of the Big data in 5G is complicated as detailed in the 3GPP standardization process and OIS architecture and could be divided into four layers: application, network, link and physical layer [34].

X. INTERNET OF THINGS (IoT)

The next big thing in 5G is IoT [5] or Internet of Everything (IoE) and sometimes named as Web of Things (WoT)[2]. IoT technology has become embedded in many applications and part of many practical fields like transportation, healthcare, manufacturing, and logistics [35]. Network tasks have become more complex as more and more User Equipment (UE), cars, robots, sensors, and wearables getting smarter and more intelligent, for that different levels, it is required to support reliability, mobility, and spectrum management [36]. As everything will have an IP address (IPv6) and will be connected to the Web. Huge number of devices and millions of sensors are connected concurrently to the next 5th generation mobile networks like smart houses and transportation means [37]. There are major threats related to the IoT which need to be considered like security, context sharing, and privacy. Many levels of obstruction and granularity are involved in the HetNet which will be difficult to control [38]. In the future the human centric of the IoT will transform gradually to be Machine to Machine (M2M) platform [39]. Device to Device (D2D) communication and M2M communication also will be part of the 5G [2]. IoT can be processed online through cloud-base services, for example, Xively provides [40]:

- Open free, source and easy to use graphical user interface (GUI) for the application programming interface.
- Compatibility with many protocols and environments to manage real time sensors and export data in many formats.
- Web-base, real-time visualizing sensor's data graphically, and controlling the sensors remotely.
- Supporting the Original Equipment Manufacturers (OEM) for many manufacturers.

XI. INTERNET OF VEHICLES (IOV)

IoV is one of the evaluation application of IoT [41] in which vehicles will be able to communicate between each other and this leads to a smarter transportation with close to null collisions [42]. There are limitations to vehicle-to-vehicle (V2V) communication, while the adjacent car could access the data flow of some sensors and outside viewing cams, the manufacturer of the car could access the full CAN (controller area network) bus sensors and all the viewing cams of the vehicle [43]. Another issue related to the V2V is security, the authors in [44] proposed a new security protection named Multi-factor protection strategy that distinguishes multiple level of privileges of data flow reading from the system controlling. Google with some auto industry are establishing a new protocol related to the vehicles named Open Auto Alliance (OAA) in which they are planning to add new features to Android (the open source platform) to speed up the implementation process of IoV paradigm [45]. A newer standard protocol called IEEE1609 for the Wireless Access in Vehicular Environment (WAVE) has been presented in [46].

The development of self-drive vehicles leads to the Intelligent Transportation System (ITS), many countries have

started to standardise it such as Europe, USA, and Japan, in order to find a common base of protocols to govern the following challenging issues:

- Privacy, anonymity, and liability
- Congestion control and prioritization of data packets
- Reliability and cross-layering between network and transport layers
- Secure localization
- Addressing and geographical location addressing
- Verification and data-centric trust
- Delay constraints
- Forwarding algorithms
- Risk analysis and management.

Intelligent Transportation System (ITS) may develop further to form Heterogeneous Vehicular NETWORKS (HetVNETs) which connect with the 5G HetNets[47]. A new standard of Vehicular Ad-hoc networks (VANETs) is forming a new protocol by 2020, which integrates with mobile networks cloud that leads to a safer and smarter transportation system [48].

XII. D2D COMMUNICATION

Device to Device communication (D2D) is a device centric which originally represents one feature of the new upcoming mobile networks [4] in which indoor small devices close to each other are capable to communicate and share information directly between them and not via the BS [49]. The data traffic of the D2D is growing every year and it is anticipated to increase to 30.6 exabytes monthly by 2020 [50]. By 2021, it is expected the number of machines connected to the net to exceed 28 billion [51]. In [52] the authors proposed for the new 5G network an ad-hoc D2D network using a group key agreed between the devices which allow them to control routing processes. Many existing technologies will be used in the D2D communication like Near Field Communications (NFC), Ultra-wideband (UWB), ZigBee, Bluetooth 4.0, WiFi Direct and LTE Direct, the transmission distance for these wireless standards ranging from less than a meter up to 500 meters [53]. In [54] the authors addressed low latency and how D2D increases the scalability and energy efficiency by controlling the signalling and end to end network communication. Two of the main open issues related to the D2D communication are security and privacy [55]. Therefore, sending and receiving controlling signals and user data in the network of D2D are subject to many kinds of threats including fabrication, manipulation, and eavesdropping [56], in addition, the attacker could hack the system via the broadcast of the wireless communication [57].

XIII. M2M COMMUNICATION

In 5G network it is expected that M2M communication to have a native support just like D2D communication [4]. The M2M communication technology becomes smarter and more mobile via the 3GPP protocols even in the existing LTE

network [58]. The M2M data flow is increasing rapidly, i.e. in the mobile network in USA only the M2M traffic volume increased by 250% in 2011, and by 2020 it is expected to occupy 45% of the total traffic of the Internet [59]. The main features about the M2M in 5G are self-processing, sharing, and transforming automated data between them with little human effort [60]. The difference between M2M and D2D communication is that M2M communication connects a vast number of devices, smart meters, sensors and smart grid equipments covering a wide geographical area [49]. The main features of M2M communication in 5G mobile network are real time operation, low latency, and high reliability [61]. Radio-Frequency Identification (RFID) which comes in many flavours of tag and reader (active, passive or semi-passive/active), passive tags do not need battery, whereas active tags are powered by a battery. Also, the second generation (2G-RFID) is a smarter way for the M2M to communicate between them. The process of the communication loops is via five steps: delivering for the mobile code, sensing the object and gathering the information, delivering the information, handling the information, and finally the service response [62]. For the security of the M2M technology using the conventional symmetric and asymmetric cryptographic techniques is enough to secure the communication, but in the case of internal attacks, more advance security methods are need [63].

XIV. MILLIMETRE WAVE MOBILE COMMUNICATION (mmW)

As the available bandwidth below 6 GHz is limited, engineers start to experiment in the millimetre Wave (mmW) range [2], starting from 3 up to 300 GHz [4]. In [6] the authors did many tests on the 28 GHz and 38 GHz frequencies where they measured loss and gain using different distances. Testing was carried out on many building materials with typical rough and smooth surfaces, i.e. brick and drywalls, clear and tinted glass for their signal reflection and penetration properties. They found 200 m is the ideal distance with the minimal loss in most conditions. A Google project related to the 5G millimetre-wave under the name of SkyBender [64] is under testing to deliver very fast internet access (40 times faster than 4G LTE) using multiple-drones powered by solar cells, the testing is taking place at Spaceport America in New Mexico. Before that, Defense Advanced Research Projects Agency (DARPA) had experimented on a similar field, the name of the project is Mobile Hotspots, aiming to help the communication for the military troops in remote areas via deploying multi-drones or Unmanned Aerial Vehicles (UAVs) which provide a communication up to the speed 1 Gb/s [65]. The authors in [66] have experimented in merging wire communication with the wireless communication by using low coherence based mmW carrier generation with a dual-colour encoded laser diode to form the hybrid wireless mmW over Fiber (mmWoF), 12 Gb/s is achieved in the newly proposed mmWoF link compared to 36 Gb/s in the optical wired band. In [67] the authors proposed a new hybrid architecture for 5G cellular systems called; RF/millimetre wave, which integrates the RF bands (e.g. 2.4 GHz and 5 GHz), and mmWave (e.g. spanning the spectrum between 30 GHz to 300 GHz) interfaces for beamforming and data transfer.

XV. MASSIVE- MULTIPLE INPUT MULTIPLE OUTPUT (M-MIMO)

The next big thing which could change the game in 5G is the Massive- Multiple Input Multiple Output (M-MIMO). Big communication companies start testing the usability of this technology like SAMSUNG [68], ZTE, and HUAWEI [69] and still are in a race to find the perfect frequency and number of the antenna array with the best beamforming algorithm. In the prototype results, they managed to achieve a data rate of 1.056 Gb/s [68] with negligible packet error. Bristol and Lund University with National Instruments (NI) achieved a spectral efficiency of 79.4 bits/s/Hz for the first time, and are trying to increase it to 145.6 bits/s/Hz. All of these results were accomplished via the real-time 128-antenna massive-MIMO testbed, which has been developed by the programmable city initiative- Bristol Is Open (BIO) with National Instruments (NI) and Lund University [70]. Along that they are working in many fields including client localisation, wave front analysis and optimised power control algorithms. To improve the terminal Signal to Interference plus Noise Ratios (SINRs), we need to control the power going to the MIMO system to gain performance in the user side. Using great number of antennas at the massive MIMO-BS side has an effect called channel hardening, which generates new potential for the implementation of efficiency algorithms [71]. The channel hardening effect is a phenomenon which happens when the number of the antennas rises in the MIMO array causing a small percentage of fading. However, in large dimensional signal processing, channel hardening may bring some advantages to the system [72]. If we need to improve the overall massive MIMO system performance, we have to reduce the pilot contamination in Location-based channel-dense deployments estimation by disallowing all mobiles with similar Angle of Arrivals (AoAs) from sharing the same pilot [73]. The conventional massive MIMO is less energy efficient than the hybrid massive MIMO (HMM) system as it is benefited from the newer 5G architecture technologies including energy harvesting networks, heterogeneous networks, and millimetre wave [74]. Large scaled antenna system (LSAS) or large scale MIMO is a large number of base station configured to serve as one entity and it could serve multiple users in the same time [75]. In [76] the authors discussed the full-dimensional MIMO (FD-MIMO) and how it is explored in the international standardization in 3GPP and how elevation and azimuth get effected from the surrounding environment. Moreover, they addressed the 3-dimensional Multiple-Input Multiple-Output (3D MIMO) which could provide a smart way of implementation, for example, a large number of antennas in a cylindrical array format can serve many users scattered in elevation and azimuth domains.

XVI. ENERGY EFFICIENCY

Controlling power is a major issue in any communication system. Mobile networks worldwide consume 0.5 % of the world's total energy, so one of the main issues should be taken into consideration in the coming 5G mobile network is reducing the consumption of energy [77]. In [78] a project called 5GrEEen introduces energy-efficient and low latency heterogeneous network (HetNet) architecture. A new idea to save energy proposed in [79] called economical energy

efficiency (E3) was based on three things: energy efficiency (EE), spectral efficiency (SE), and cost. It allows analysing the total gain for the 5G heterogeneous network. Minimising power consumption due to health concerns which requires the power consumption to be reduced in variable transmissions as well as fixed circuits has been discussed in [80].

XVII. HEALTHCARE

The rapid development of sensors leads to a new field in health monitoring [81]. Developing devices with multiple sensors could measure multiple physiological signals at home (just like you are in an Intensive care unit (ICU)) and this technology is available nowadays [82]. Real-time remote patients health monitoring leads to Body Area Networks (BAN) in which big data are collected and processed with a higher data rate and bandwidth, which could be realized in the new 5G network [83]. New range of clinical devices will join the 5G network to form the eHealth and mHealth, In [84], a wide range of wireless, Bluetooth, and NFC devices using the new 6LoWPAN/IEEE 802.15.4 protocol have been addressed.

In [85], an algorithm called Channel State Estimation is designed based on Transmission Power Control (CSE-TPC) for the optimization of the quality of Experience that targets the received signal strength indicator (RSSI) threshold and adjusts the transmission power level. All these factors for the energy efficiency are required for the medical applications in the 5G. Wireless Body Area Networks (WBANs) and Wireless Body Sensor Networks (WBSNs) need this improvement to reduce the consumption of energy to the minimum as mostly the energy for such applications comes from small batteries or embedded rechargeable batteries.

XVIII. 5G SIMULATIONS SOFTWARE

Many simulation softwares are available online and some are free but others you have to purchase, as mentioned below:

- New York University (NYU) releases 5G mmW simulator; NYUSIM: The open source 5G channel model simulator software is free as a simulation code (in Matlab) specially for modelling channels from 2 to 73 GHz which is suitable in 3GPP and other standard bodies and academic/industrial simulations [86].
- Fig. 2 shows the graphical user interface (GUI) of the 5G mmW simulator -NYUSIM.
- A research group under the name of mmMagic supported by SAMSUNG from CSN Group part of Universities of Bristol are working on a simulation of visualising mmWave and beamforming[87]. Fig. 3 depicts the animation of the mmMagic simulation.
- Some Youtube videos are available:
- <https://www.youtube.com/watch?v=AaefATDPZMg>
- 5G and MIMO using Wireless InSite
- Remcom has a simulator for MIMO in 5G which handles 3D structures mm-wave and in the near future MIMO with Wireless InSite will be added [88]. Fig. 4

depicts some of the output results of the InSite Simulator.

- SIRADEL offers simulations since 1994, and ready to simulate the new 5G, e.g. 3D beamforming or mmW massive MIMO. They also have a key role in 3GPP and IEEE standardizations [89]. Fig. 5 depicts the animation of the SIRADEL simulation.
- MATLAB and Simulink to design, test, and prototype 5G wireless systems
- This simulator which uses MatLab and Simulink are designed for the coming 5G wireless system (design, test and prototype). It includes massive MIMO systems with the beamforming and precoding algorithms for antenna arrays RF system architecture, 5G algorithms, real-time Rapid prototyping, and channel models data for frequencies > 6Ghz [90]. Fig. 6 shows the MATLAB and Simulink prototype 5G wireless systems.

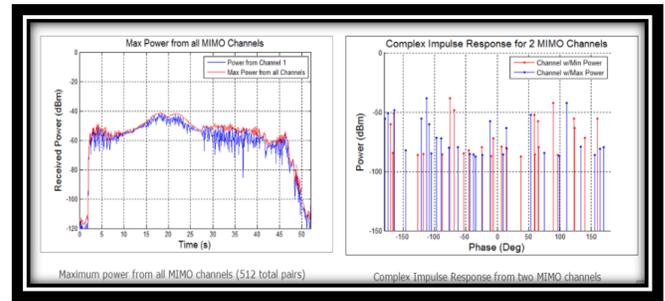


Fig. 4. Some of the output results of the InSite Simulator.

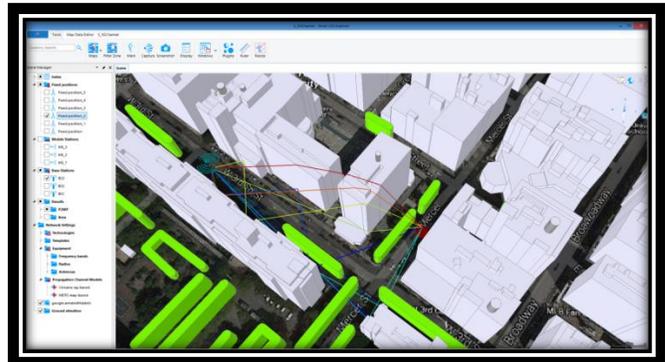


Fig. 5. The animation of the SIRADEL simulation.

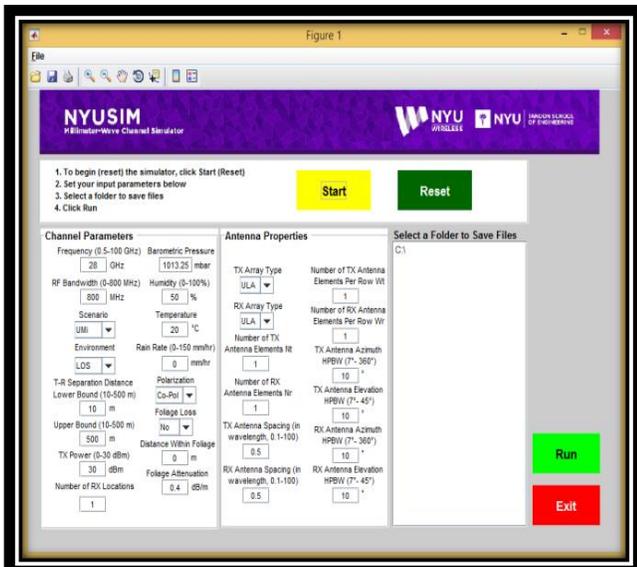


Fig. 2. The GUI of the 5G mmW simulator - NYUSIM.



Fig. 6. The MATLAB and Simulink prototype 5G wireless systems.

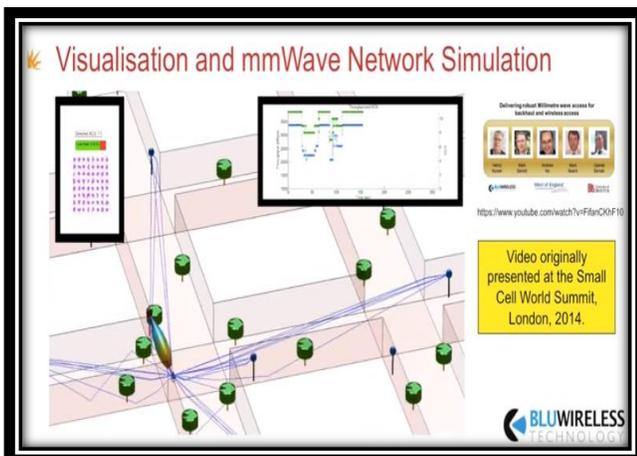


Fig. 3. The animation of the mmMagic simulation.

XIX. FUTURE RESEARCH DIRECTIONS

This survey-as the title depicts- just scratch the surface of the upcoming 5G mobile networks, many aspects needs to be researched further such as latency and beamforming, backward compatibility with the older generations, multiplexing, power efficiency and green network, 5G applications, standardization, health issues related to the negative impact of the high frequency waves on humans, connectivity problems and QoS.

XX. CONCLUSION

In this survey paper, we briefly addressed some evolving technologies related to the 5G futuristic network. We focused on the main approaches and did not go deeply into the algorithms which govern the power consumption in the 5G network or any machine learning techniques which could help optimizing the network. This survey could be an adequate entrance knowledge to the new 5G mobile network technology.

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Improved-Node-Probability Method for Decision Making in Priority Determination of Village Development Proposed Program

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Abstract—This research proposes a new method, the probability of nodes (NP) and the cumulative frequency of indicators within the framework of Bayesian networks to calculate the weight of participation. This method uses the PLS-PM approach to examine the relationship structure of participatory factors and estimate latent variables. Data were collected using questionnaires involving participants offering proposals, the village residents themselves. The participation factors identified in this research were divided into two categories, namely, internal factors (abilities) and external factors (motivation). The internal factors included gender, age, education, occupation, and income, while the external factors included motivation relating to economic, political, socio-cultural, norm-related, and knowledge-related issues. Moreover, there are three factors directly affecting the level of participation, they are: the level of attendance in meetings, participation in giving suggestions, and involvement in decision making. The test results showed that the application of participation weight in decision making priority of proposal of village development program give change of final rank of decision with test result as: recall 50%, precision 80% and accuracy 50%.

Keywords—Bayesian networks; PLS-PM; participation weight; decision making; village

I. INTRODUCTION

In the last decades, there has been an increasing interest among the community in decision making [1]. Community participation has become part of the various environments for the implementation of decisions made, such as in the sectors of government [2], integrated watershed management [3], [4] development in agriculture [5], environmental management [6] forest management [7], and planning [8].

The significance of participation is asserted by Conyers [9], who states that first, community participation is a tool to collect information about the conditions, needs, and attitudes of the local community, without which development programs

and projects will end in failure; second, people tend to have a higher level of confidence in particular development projects or programs if they feel involved in the process of preparation and planning of such projects or programs as this makes them know more about the project and develop a sense of belonging towards the project; third, engaging the community in the development of their own community constitutes a right acknowledged in democracy.

Decision making relating to determination of proposed village development programs taking priority falls into the category of group decision-making. In the group decision-making, community participation can be seen in the process of proposing programs and making decisions. In fact, decision-making through participation does not work properly. This is because the role the government plays in the implementation remains centralistic with top-down planning, thus both the aspirations and the resulting proposals lack quality, decision making is dominated by the village elite, are regular annual routine, and cannot accommodate the needs of the community.

This research aims to identify factors affecting participation in village development program planning and quantify them in the form of participation scores. Then, those participation scores were used in decision making to determine the rank of the proposed development programs in order of priority.

II. LITERATURE REVIEWS

A. Factors Affecting Participation

There are many factors affecting community participation in the village development process. Factors classified as internal factors or abilities included gender, age, education level, income rate, and occupation. Participation of a man and that of a woman in development are different because of the established social system that differentiates the position between men and women. Such differences in position and degree will lead to differences in rights and duties between

men and women, where men have a number of privileges compared to women. Thus, men will tend to contribute more [10]-[15].

Age is a factor that influences one's attitude towards the existing social activities. The middle-to-upper age group with moral attachment to the values and norms of the community which is more stable tends to have a higher level of participation than the other age groups [10], [15]-[18].

Good jobs and good income which support daily needs can encourage a person to participate in community activities [11], [14], [15], [18], [19].

Education is considered to affect the way one behaves towards his/her environment, an attitude necessary for improving the welfare of the whole community [10], [14], [16]-[19].

In addition to those internal factors, external factors also influence motivation to participate, for example economic motivation [10], [16], [20]-[23], political and leadership-related motivation [11], [21], [24], socio-cultural motivation [10], [20]-[23], [25], [26], knowledge-related motivation [10], [22] and motivation to participate which is influenced by norms or obedience to the existing rules ([23], [25], [26]).

B. Bayesian Networks

Bayesian networks [27] are a state-of-the-art model for reasoning under uncertainty in the machine learning field. They are especially useful in real-world problems composed by many different variables with a complex dependency structure. Examples of areas where these models have been successfully applied include genomics, text classification, automatic robot control, fault diagnostic, etc.

Every Bayesian network has a qualitative part and a quantitative part. The qualitative part (i.e., the structure of the Bayesian network) consists of a directed acyclic graph (DAG) where the nodes correspond to the variables in the domain problem and the edges between two variables correspond to direct probabilistic dependencies. On the other hand, the quantitative part consists of the specification of the conditional probability distributions that are stored in the nodes of the network [28].

DAG describes the relationship between attributes and consists of nodes and arcs, where each arc describes a probabilistic dependence. If an arc is drawn from A to B, then A serves as the parent or immediate predecessor of B and B serves as a descendant of A. The DAG illustration can be seen in Fig. 1.

In the illustration below, the arc displays the causal relationship-related information. For example, the node (attribute) C results either from the existence of the attribute A or not, and likewise, it may result either from the existence of the attribute B or not. It can be seen that the attribute D is independent of the attributes A and B. This implies that when the result of the attribute C is generated, attributes A and B do not provide additional information about whether the attribute D occurs or not.

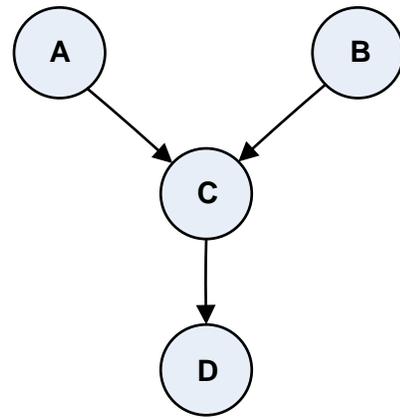


Fig. 1. Directed Acyclic Graph (DAG).

Suppose data $X = (x_1, \dots, x_n)$ are data with attributes Y_1, \dots, Y_n . To calculate the possibility of a variable, (1) below is used:

$$P(x_1 \dots x_n) = \prod_{i=1}^n P(x_i | \text{Parents}(Y_i)) \quad (1)$$

With:

$P(x_1, \dots, x_n)$ = Probability base on attribute x_1, \dots, x_n

n = Number of attributes

x_i = the i th data value

$\text{Parents}(Y_i)$ = Immediate predecessor or parent of the Y_i attribute

For example, to calculate $P(A, B, C, D)$, then the probability is:

$$P(A, B, C, D) = P(A) * P(B | A) * P(C | A, B) * P(D | C)$$

To calculate $P(B | A)$, Bayes' theorem is used, which calculates the probability of an attribute based on a particular attribute. The formula of Bayes' theorem can be seen in (2):

$$P(A | B) = \frac{P(B | A)P(A)}{P(B)} \quad (2)$$

where:

$P(A|B)$ = Probability A based on evidence B

$P(B|A)$ = Probability B based on evidence A

$P(A)$ = Probability A

$P(B)$ = Probability B

III. RESEARCH METHOD

The method used in the weighting calculation (level of importance) of participation is using the Partial Least Square Path Modeling (PLS-PM) method and the Bayesian networks. The PLS-PM method is used to estimate the value of latent variables. The latent variable is a variable that cannot be measured directly and is measured through the indicator variable. In addition, PLS-PM is also used to examine the relationship structure of factors that influence participation built on expert opinion. Bayesian networks method is used to

construct DAG structure and calculate the probability node (node probability) of each indicator variable.

- 1) Collect data using questionnaires on the participants of a particular community, which in this case the village community.
- 2) Then, identify parameters consisting of indicators in each of the factors affecting participation.
- 3) Afterwards, build a model illustrating the relationship between those factors affecting participation in the form of a Directed Acrylic Graph (DAG) structure of Bayesian networks. The initial DAG structure was developed based on experts' views derived from previous research and interviews with participants.
- 4) Estimate the score of latent variables and test the structure of the DAG model already built using PLS-PM. The test results will determine whether the constituent parameters of the model structure built will change or not.
- 5) The DAG model structure that already had a complete data set was then used as a model structure to calculate the Bayesian network inference using the complete data sets.
- 6) Calculate the probability of all node probability (NP) and the frequency (f) of showing up of each indicator of all factors.

Furthermore, results of the NP and f calculation were saved as 'a reference value' used as a guideline in the calculation of score for the participation interest of each participant. The calculation of participation scores was undertaken using two variables, namely NP and f of the indicators for each factor of participation. The score calculation for the participation interest of each participant was undertaken using (3), namely:

$$W_p = \sum_{i=1}^n (NP_i * f_i) \quad (3)$$

Where,

W_p : weighted value of participant participation interest

NP_i : the probability node value of the participant indicator

f_i : participant indicator frequency value

Where, W_p refers to participation score, NP refers to an indicator's node probability score of the indicator, and f_i refers to an indicator's frequency score.

After the participation score had been obtained, score normalization was undertaken. Normalization is a technique to standardize or make the data range equal, thus no attribute is too dominant over the other attributes. The normalization process was undertaken using (4), namely:

$$W_{p_{normalization}} = \frac{W_p - W_{p_{min}}}{W_{p_{max}} - W_{p_{min}}} \quad (4)$$

The participation score that had undergone normalization was then used in the calculation to determine the proposed village development programs taking priority.

IV. EXPERIMENT

A. Establishing the Structure for the Relationship between Factors Affecting Participation

This study used questionnaire data from 130 participants, consisting of 3 latent variables and 13 manifest variables (indicators). Parameters identified in the study are divided into two types of parameters, namely internal parameters (ability) and external parameters (motivation). Internal parameters are: gender, age, education, occupation, income, while external parameters are: economic, political, socio-cultural, norms and knowledge motivation. In addition, there are also three parameters that directly affect the level of participation, they are: attendance meetings (meeting), give suggestions (proposal), and involvement in providing decisions (decision).

The first step was to the structure for the relationship between factors affecting participation based on experts' views as illustrated in Fig. 2.

Afterwards, the model illustrating the structure of the relationship between the factors influencing participation was tested using PLS-PM.

The Outer evaluation of this model specifies the relationship between latent variables and their indicators. or it can be said that the outer model defines how each manifest variable (indicator) corresponds to its latent variable. Test on outer model for formative indicator that is:

- Significance of weights. The weight value of the formative indicator with its construct should be significant.
- Multicollinearity. Multicollinearity test is done to know the relationship between indicators. To find out if the formative indicator is having multicollinearity by knowing the VIF value. VIF values between 5 to 10 can be said that the indicator occurs multicollinearity.

The test result shows that weight value almost all indicator variables produce significant weight value, that is not less than 0,1, that is allowed limit value [29]. Only one indicator variable whose value is less than 0.1 is a gender variable with a value of 0.048, so the gender variable can be excluded from the model. The result of coefficient path test can be seen in Fig. 3.

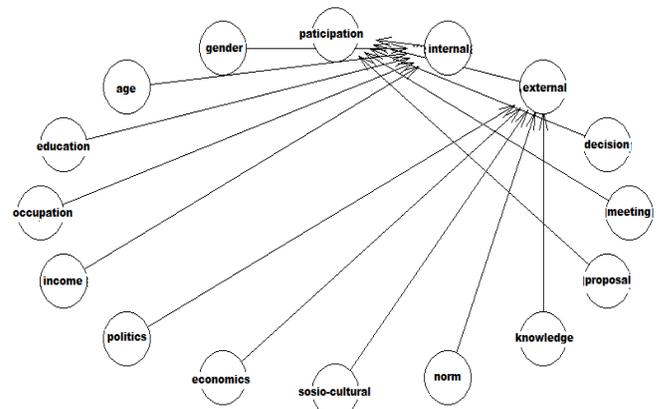


Fig. 2. The model of the relationship structure of factors of participation.

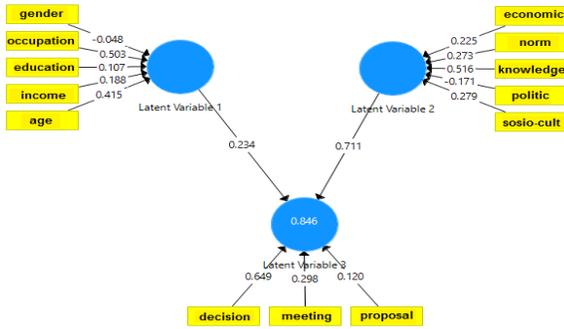


Fig. 3. Outer weight factors of participation.

The manifest variable in a formative block must be tested for its multicollinearity. Multicollinearity testing among indicators in a formative block uses the value of variance inflation factor (VIF). If a VIF value of > 10 occurs in the form of collinierity between the indicators in one such formative block [30]. Test results show all VIF indicator values less than 10 (Fig. 3), so it can be concluded that there is no collinierity between indicators.

After assessing quality of the measurement model, the next step was to assess the structure. To examine results of each regression in a structural equation, it is necessary to display the results contained in the inner model. In addition to the results of the regression equation, quality of the structural model was evaluated by examining three quality indexes or matrices, namely the coefficient of determination R^2 .

The coefficient of determination R^2 is the coefficient of determination of endogenous latent variables. For each regression in the structural model, the matrix R^2 was used which was interpreted in the same way as in the multiple regression analysis. R^2 indicates the number of variances an endogenous latent variable has which is described by its independent latent variable. The R^2 value generated in this research is equal to 0.849.

B. Calculating the NP and Frequency of Each Indicator

Results of the testing using data obtained from questionnaires show that the factors of gender has no significant correlation so that the DAG structure used in inference calculation involved 12 indicators only. Afterwards, a DAG structure was developed based on the data set obtained from the testing results and PLS estimation (latent variables) undertaken. The DAG structure was built using expert approach as shown in Fig. 4.

The DAG structure (Fig. 4), illustrates a graphical representation and a combination of probability P (age, education, occupation, income, politics, economy, socio-culture, norms, knowledge, proposals, meetings, decisions, motivation, abilities, and participation) that can be factored as a set of conditional independence relations expressed as follows (1):

$$P(Ag, Ed, Oc, Inc, Po, Ec, So, N, Kn, Pr, Me, De, Mo, Ab, Pa) = P(Ag, Ed, Oc, Inc, Po, Ec, So, N, Kn, Pr, Me, De, Mo, Ab, Pa) = P(Ag) (Ed) (Oc), (Inc), (Po) (Ec) (So) (N) (Kn) (Pr) (Me) (De) (Int| Ag, Ed, Oc, Inc) (Ext| Po, Ec, So, N, Kn) (Pa|Int,Ext)$$

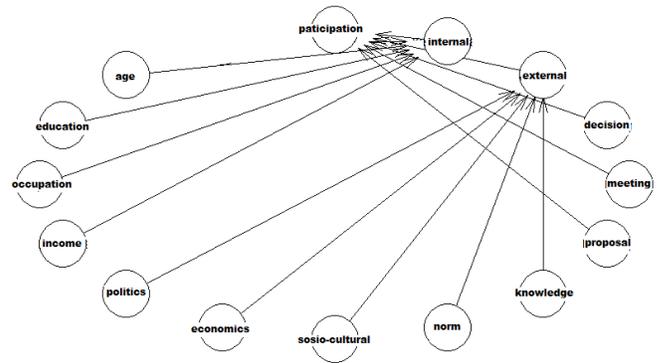


Fig. 4. DAG structure of factors of participation.

Where,

Ag = Age, Ed = Education, Oc = Occupation, Inc = Income, Po = Politics, Ec = Economics, So = Socio-culture, N = Norm, Kn = Knowledges, Pr = Proposals, Me = Meetings, De = Decision, Int = Internal, Ext = External, Pa = Participation

Based on Fig. 4, it can be seen that 12 (twelve) nodes are nodes with a conditional independence relation. Those twelve nodes are age, education, occupation, income, politics, economy, socio-culture, norms, knowledge, proposals, meetings, and decisions. The score of each node can be calculated based on its indicator, which in this research is called node probability (NP). The following is an example of the calculation of the node age with age between 18 to 40 years as the indicator, where the NP is calculated as follows:

$$P(Ag=18-40) = P(Ag=18-40, Ed, Oc, Inc, Po, Ec, So, N, Kn, Pr, Me, De, Int, Ext, Pa)$$

$$P(Ag = 18 - 40) = \frac{P(Ag = 18 - 40, Ed, Oc, Inc, Po, Ec, So, N, Kn, Pr, Me, De, Int, Ext, Pa)}{P(Ag, Ed, Oc, Inc, Po, Ec, So, N, Kn, Pr, Me, De, Int, Ext, Pa)}$$

The prior probability score or the confidence value of the participation variable is the resulting score to explain the level of confidence of each participation variable. Furthermore, inference Bayesian networks with DAG structure built based on data that has been tested and estimated using PLS. Probability inference in Bayesian network was calculated so as to determine the Node Probability (NP) and the probability of showing up/ frequency (f) of each indicator as shown in Table 1, which were then used as a guideline in the calculation of the score of participation interests of the participants.

TABLE I. CALCULATION RESULTS OF NP AND FREQUENCY SCORES OF EACH INDICATOR

Variable	Indicator	NP	f	NP*f
age	1	0.0422	0.31	0.0131
age	3	0.3879	0.39	0.1513
age	2	0.5655	0.3	0.1697
education	2	0.0803	0.06	0.0048
education	4	0.5330	0.22	0.1173
education	5	0.3339	0.16	0.0534
education	1	0.0001	0.34	0.0000
education	3	0.0457	0.22	0.0101
occupation	2	0.0221	0.04	0.0009
occupation	4	0.1676	0.24	0.0402

Variable	Indicator	NP	f	NP*f
occupation	5	0.7675	0.14	0.1075
occupation	1	0.0000	0.17	0.0000
occupation	3	0.0337	0.41	0.0138
icome	1	0.1219	0.22	0.0268
icome	3	0.1071	0.27	0.0289
icome	2	0.3103	0.12	0.0372
icome	4	0.4285	0.34	0.1457
icome	5	0.0296	0.05	0.0015
politic	3	0.0495	0.03	0.0015
politic	5	0.6938	0.16	0.1110
politic	2	0.0709	0.24	0.0170
politic	4	0.1798	0.16	0.0288
politic	1	0.0000	0.41	0.0000
economics	3	0.0414	0.04	0.0017
economics	2	0.0836	0.16	0.0134
economics	4	0.7379	0.18	0.1328
economics	5	0.1430	0.44	0.0629
economics	1	0.0000	0.18	0.0000
socio-culture	2	0.0660	0.04	0.0026
socio-culture	4	0.6012	0.24	0.1443
socio-culture	5	0.2693	0.17	0.0458
socio-culture	1	0.0000	0.34	0.0000
socio-culture	3	0.0620	0.21	0.0130
norm	2	0.0138	0.03	0.0004
norm	4	0.1875	0.26	0.0487
norm	5	0.7439	0.16	0.1190
norm	3	0.0507	0.15	0.0076
norm	1	0.0000	0.4	0.0000
knowledges	1	0.0015	0.16	0.0002
knowledges	3	0.0869	0.15	0.0130
knowledges	2	0.0012	0.12	0.0001
knowledges	5	0.1220	0.44	0.0537
knowledges	4	0.7876	0.13	0.1024
proposal	2	0.0000	0.05	0.0000
proposal	1	0.0000	0.16	0.0000
proposal	4	0.8077	0.15	0.1212
proposal	3	0.0688	0.51	0.0351
proposal	5	0.1148	0.13	0.0149
meeting	1	0.0000	0.12	0.0000
meeting	3	0.1491	0.13	0.0194
meeting	5	0.3833	0.16	0.0613
meeting	2	0.0000	0.32	0.0000
meeting	4	0.4740	0.27	0.1280
decision	1	0.0000	0.2	0.0000
decision	3	0.1119	0.12	0.0134
decision	5	0.0723	0.16	0.0116
decision	2	0.0000	0.4	0.0000
decision	4	0.8098	0.12	0.0972

C. Calculating the Participation Score of the Participants

The example of the data on the indicators of the factors of proposal makers' participation with the input data for *Proposal Maker 1* (P_1) is presented in Table 2. The participation score was calculated by referring to the "data reference" of the NP and frequency scores generated from the calculation in Table 1.

The example calculation of the participation interest score used (3), using the indicators of participation factors P_1 in Table 2 adjusted to the NP and f scores in Table 1, the participation score (W_p) can be calculated.

$$W_{p1} = \{(NP * f)_{age} + (NP * f)_{occupation} + (NP * f)_{education} + (NP * f)_{income} + (NP * f)_{politic} + (NP * f)_{economics} + (NP * f)_{socio-cultural} + (NP * f)_{norm} + (NP * f)_{knowledges} + (k * f)_{proposal} + (NP * f)_{meeting} + (NP * f)_{decision}\} = 0.4209$$

TABLE II. INDICATORS FOR THE FACTORS OF PARTICIPATION P1

Factors of Participation	Indicators	NP * f
age	18-40 years old (1)	0.0131
occupation	Labour (2)	0.0009
education	Junior high school (2)	0.0048
income	1	0.0268
politic	2	0.0170
economics	5	0.0629
sosio-cultural	4	0.1443
norm	4	0.0487
knowledges	4	0.1024
proposal	1	0
meeting	2	0
decision	1	0

TABLE III. MULTIPLICATION VALUE OF NP AND HIGHEST AND LOWEST FREQUENCY

variable	(NP*f) _{min}	(NP*f) _{max}
age	0.0201	0.1591
occupation	0.0043	0.0987
education	0.0014	0.0725
income	0.0038	0.1517
politic	0.0026	0.0857
economics	0.0015	0.1074
sosio-cultural	0.0028	0.1051
norm	0.0025	0.0808
knowledges	0.0013	0.0881
proposal	0.0000	0.1040
meeting	0.0000	0.1220
decision	0.0000	0.0774

1) Score normalization

The normalization process was done by calculating the highest participation score $W_{p\ max}$ using (5) and the lowest participation score $W_{p\ min}$ using (6). The data on the lowest and highest NP and frequency scores can be seen in Table 3. $W_{p\ max}$ can be calculated by multiplying the NP by the frequency of each indicator with the highest score. Conversely, $W_{p\ min}$ can be calculated by multiplying the Np by the frequency of each indicator with the lowest score.

$$W_{p\ min} = \sum_{indicator\ min=1}^n (NP \times f)_{indicator\ min} \quad (5)$$

$$W_{p\ max} = \sum_{indicator\ max=1}^n (NP \times f)_{indicator\ max} \quad (6)$$

The calculation of the lowest participation score using (5) is described as follows:

$$W_{p\ min} = \{(NP * f)_{age\ min} + (NP * f)_{occupation\ min} + (NP * f)_{education\ min} + (NP * f)_{income\ min} + (NP * f)_{politic\ min} + (NP * f)_{economics\ min} + (NP * f)_{sosio-cultural\ min} + (NP * f)_{norm\ min} + (NP * f)_{knowledge\ min} + (NP * f)_{proposal\ min} + (NP * f)_{meeting\ min} + (NP * f)_{decision\ min}\} = 0.2615$$

The calculation of the highest participation score using (6) is described as follows:

$$W_{p\ max} = \{(NP * f)_{age\ max} + (NP * f)_{occupation\ max} + (NP * f)_{education\ max} + (NP * f)_{income\ max} + (NP * f)_{politic\ max} + (NP * f)_{economics\ max} + (NP * f)_{sosio-cultural\ max} + (NP * f)_{norm\ max} + (NP * f)_{knowledges\ max} + (NP * f)_{proposal\ max} + (NP * f)_{meeting\ max} + (NP * f)_{decision\ max}\}$$

$$\left. \begin{aligned} &f)_{knowledge\ max} + (NP * f)_{proposal\ max} + (NP * f)_{meeting\ max} + (NP * \\ &f)_{decision\ max} \end{aligned} \right\} = 1.5322$$

Furthermore, normalization was calculated using (4). Thus, the normalized W_{p1} is equal to

$$W_{pnormalization} = 0.12$$

The calculation results for the score of proposal makers' participation interest (W_{p1}) that had undergone normalization to equal to 0.12, which is the score of participation interest for the first proposal maker (W_{p1}). In the same way, the score of participation interest for the subsequent proposal maker can also be calculated.

The score of participation interest for the subsequent proposal maker (W_{p1}) was used to calculate the score of DM's preference in relation to the alternatives according to the alternatives proposed by each proposal maker.

The score of participation interest for the subsequent proposal maker (W_{p1}) can be used to determine the ranking of decisions relating to village development planning programs. The W_p calculation results were then tested by applying them to the current decision-making model.

2) Implementation of participation scores in multiple-criteria decision making

The current decision-making model relating to determination of proposed village development programs taking priority involves many criteria and decision makers. Those decision makers consist of several people, ranging from 7 to 11 persons, and commonly are referred to as the team of 7 or 11 persons. These teams are considered as representatives of all stakeholders in the village. All decision makers use the same criteria in making a decision, namely felt by many people (C1), extremely serious (C2), better income (C3), the number of occurrences (C4), potential support resources (C5). Such criteria are used to assess programs proposed by the community. To help illustrate a problem, the attributes of the problem can be represented by the following notations:

a) DM = {dm₁, ..., dm_n} refers to decision makers, i.e. the persons who will make decisions

b) A = {a₁, ..., a_n} with n ≥ 2, refers to a program proposed by the community, which is a group of alternatives to be ranked.

c) C = {c₁, ..., c_n} with n ≥ 2, refers to a group of criteria, i.e. the criteria taken into account in the decision-making process.

d) T = {t₁, ..., t_n} refers to the final goal, which is the resulting ranking in the form of a sequence of alternatives decided by decision makers.

The hierarchy of the decision making relating to determination of proposed village development programs taking priority is illustrated in Fig. 5.

In the decision-making process with a hierarchy as shown in Fig. 5, decision makers use the same criteria without considering the score of each criterion.

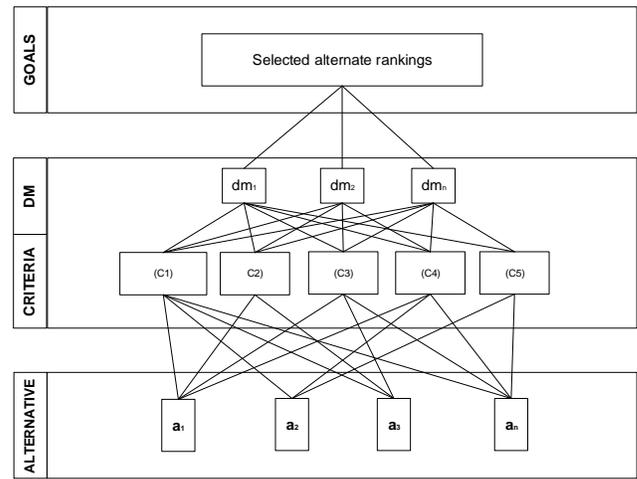


Fig. 5. Hierarchy of decision-making.

The data used to test the proposed model consisted of data of nine decision makers, namely dm₁..dm₉ and were associated with factors influencing participation. The data on proposed programs (a) data consisted of 10 proposals, namely, a₁,..a₁₀, where each alternative had its own score for participation of proposal makers (W_p). The data on the scores for participation of proposal makers used are presented below:

$$W_{p1}(a_1)=0.12; W_{p2}(a_2)=0.18; W_{p3}(a_3)=0.29; W_{p4}(a_4)=0.23; W_{p5}(a_5)=0.45; W_{p6}(a_6)=0.45; W_{p7}(a_7)=0.49; W_{p8}(a_8)=0.48; W_{p9}(a_9)=0.34; W_{p10}(a_{10})=0.45$$

Each criterion has the same score and thus the total participation score (T_{model}) was calculated by multiplying each participation score W_p by the total initial score ($T_{initial}$), (7) as follows:

$$T_{model} = T_{initial} * W_p \tag{7}$$

Results of the score calculation using the participation score (T_{model}) was compared with program realization as shown in Table 4.

Afterwards, testing was done using a confusion matrix to calculate accuracy, precision, and recall. Results of the calculation are presented in Table 4 and summarized in Table 5.

Calculation of the confusion matrix is described as follows:

$$\begin{aligned} Accuracy &= \frac{TP+TN}{TP+TN+FP+FN} \times 100\% \\ &= 50\% \end{aligned}$$

$$\begin{aligned} Precision &= \frac{TP}{TP+FP} \times 100\% \\ &= 80\% \end{aligned}$$

$$\begin{aligned} Recall &= \frac{TP}{TP+FN} \times 100\% \\ &= 50\% \end{aligned}$$

TABLE IV. THE RESULTS OF THE CALCULATION OF THE SCORE WITH THE WEIGHTED VALUE OF PARTICIPATION

ID. Alternative	Criteria and score					Score Total (T)	The weight of participation (Wp)	Score Total of model (T _{model})	Initial rank	model rank	Actual (2015)
	C1	C2	C3	C4	C5						
a ₁	77	72	75	76	79	379	0.12	45.48	1	7(N)	Y
a ₂	78	77	76	73	74	378	0.18	68.04	2	5(Y)	Y
a ₃	78	70	76	76	77	377	0.29	109.33	3	8(N)	N
a ₄	78	78	67	76	77	376	0.23	86.48	4	4(Y)	Y
a ₅	78	75	76	67	77	373	0.45	167.85	5	2(Y)	Y
a ₆	79	76	76	70	70	371	0.45	166.95	6	1(Y)	N
a ₇	77	75	75	71	72	370	0.49	181.3	7	10(N)	N
a ₈	66	67	76	79	81	369	0.48	177.12	8	6(N)	N
a ₉	77	75	76	69	70	367	0.34	124.78	9	9(N)	N
a ₁₀	79	77	69	81	59	365	0.45	164.25	10	3(Y)	Y

TABLE V. CONFUSION MATRIX TABLE

Prediction	Actual	
	Positif	Negatif
True	4	1
False	1	4

A model is deemed good if it has high precision and recall values. Results of the test calculation using a confusion matrix generated scores for recall, precision, and accuracy by 50%, 80%, and 50%, respectively. These results are not too ideal for a model because the decision to realize a program within the government does not only depend on whether the program will facilitate development or not but also on the various interests other than objectives of the development.

V. CONCLUSION

Research conclusions are presented as follows:

1) Community participation in development planning programs is influenced by the factors of interests of the respective participants. The model structure of the relationship between those participation factors can be constructed using the PLS-PM approach with latent variables

2) The interest factors affecting participation can be quantified in the form of a participation score. This participation score can be calculated using the DAG structure and inferred from Bayesian networks, namely the calculation of probability nodes and the cumulative frequency of each indicator.

3) The participation interest score can be used to represent participants' interests with regard to decision making. In the case of for decision making priority determination of proposed program for village development program, the confusion matrix testing generates accuracy by 0.5, precision by 0.8, and recall by 0.5.

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Low Cost Countermeasure at Authentication Protocol Level against Electromagnetic Side Channel Attacks on RFID Tags

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Abstract—Radio Frequency Identification (RFID) technology is widely spread in many security applications. Producing secured low-cost and low-power RFID tags is a challenge. The used of lightweight encryption algorithms can be an economic solution for these RFID security applications. This article proposes low cost countermeasure to secure RFID tags against Electromagnetic Side Channel Attacks (EMA). Firstly, we proposed a parallel architecture of PRESENT block cipher that represents a one way of hiding countermeasures against EMA. 200 000 Electromagnetic traces are used to attack the proposed architecture, whereas 10 000 EM traces are used to attack an existing serial architecture of PRESENT. Then we proposed a countermeasure at mutual authentication protocol by limiting progressively the number of EM traces. This limitation prevents the attacker to perform the EMA. The proposed countermeasure is based on time delay function. It requires 960 GEs and represents a low cost solution compared to existing countermeasures at primitive block cipher (2471 GEs).

Keywords—Radio Frequency Identification (RFID); electromagnetic side channel attack; PRESENT; mutual authentication protocol; countermeasures

I. INTRODUCTION

Passive RFID tag consists of an integrated circuit (IC) attached to an antenna. This integrated circuit is entirely remotely powered from the RF reader. Contactless RFID tags are used in different security applications such as access control and contactless payment systems. For example, among the commercial HF tags that implement cryptographic functions for the authentication protocol, there are MIFARE Ultralight C [2] and MIFARE DESFire EV1 [3] integrating 3DES [4] and AES [5] block cipher circuits, respectively. The mutual authentication protocol implemented in these tags is based on the symmetric challenge-response technique. In addition, in an academic context, Feldhofer et al. [21], [22] presented a strong authentication scheme, also using a symmetric challenge-response technique, based on an AES algorithm for RFID systems. The protocols for these symmetric challenge-response techniques based on encryption are defined in the ISO/IEC 9798-2 standard [27].

Strong cryptographic algorithms, such as AES and 3DES are often too expensive in terms of area and power [6] and are used for applications requiring high level of security. In other hand, many works suggest the implementation of lightweight

block ciphers, such as SIMON/ SPECK [7], HIGHT [8], XTEA [9], PRESENT [10], KATAN/KTANTAN [11], PRINCE [12], TWINE [13] and CRYPTON [14]. These lightweight block ciphers satisfy the security needs of some low level of security RFID applications such as access control, ticketing, etc. Indeed, for resource limited embedded systems, it is important to use an adapted level of security (often related to the number of bits of the secret key) in order to reduce both hardware overhead and power consumption. For example, Sai Seshabhattar et al. [15] proposed an implementation of PRESENT in EPC Class1 Gen2 protocol for UHF RFID tags. They implemented a low cost mutual authentication protocol based on encryption operations in the tag and decryption operations in the reader. On the other hand, Naija Yassine et al. [16] proposed a HF tag architecture respecting the IEC/ISO 14443 Type A [1]. This architecture is based on the implementation of the PRESENT block cipher in Mifare Ultralight C mutual authentication protocol.

Side Channel Attacks (SCA) represents a serious threat for RFID tags. SCA are non-invasive attacks and are based on the observation during the execution of the cryptographic devices of physical phenomena such as response time [17], power consumption [18] or electromagnetic radiation [19]. In this article, we focus our study to the Electromagnetic Side Channel Attack (EMA). For example, Timo Kasper et al. attacked some Mifare products (Mifare Desfire, Mifare MF3ICD40 and Mifare Classic) using EMA [28], [29]. These products implement mutual authentication protocols vulnerable to EMA.

This article proposes a low cost countermeasure at the authentication protocol level by limiting the number of successive wrong authentication requests. This limitation prevents the attacker to save enough electromagnetic traces to perform the EMA. First, we choose to study the vulnerability of an existing mutual authentication protocol proposed by Sai Seshabhattar et al. [15] against EMA. This protocol integrating PRESENT block cipher is used for low cost full-fledged RFID tags. Then, we proposed a parallel implementation of PRESENT in order to hide the information leakage (electromagnetic radiation) generated by its S-box function. The EMA is performed in our proposed PRESENT architecture and compared to existing work [20] (serial architecture). Finally, a countermeasure based on time delay function is proposed to delay the response of the tag (especially the

encryption operation) for each wrong authentication. This time delay function allows the tag to enter in killed state progressively and prevents the EMA.

This article is organized as follows. Section II describes the Seshabhata et al. protocol and explains its vulnerability against EMA. Section III describes the PRESENT algorithm and our parallel implementation. Section IV is devoted to the description of the EMA methodology on PRESENT, EM attack setup and EM attack results and comparison. The countermeasure at protocol level based on time delay function is proposed in Section V. Finally, we conclude the paper in Section VI.

II. AUTHENTICATION PROTOCOL DESCRIPTION AND EMA VULNERABILITY

Mutual authentication protocols (ISO/IEC 9798-2 [27]) in RFID communication ensure the authentication of both readers and tags. This authentication phase prevents the attacker to impersonate the identity of the tag. However, several passive attacks such as EMA can be a threat to recover the secret parameters of the tag. In this section, we describe the Seshabhata et al. protocol used for the UHF tags and its vulnerability against EMA in the aim to propose security solutions to overcome this attack.

A. Mutual Authentication Protocol Description

Seshabhata et al. proposed [15] the integration of two security levels to secure the EPC GEN2 communication between a tag and a reader. The level1 is represented in the secure identification phase that allows the security of the tag identity, whereas the level2 is represented in the mutual authentication protocol that allows to ensure the authenticity of the reader and the tag. In the following, we name the Seshabhata et al. protocol the ProtocolS. ProtocolS as shown in Fig. 1 consist of five steps roughly described as follows:

- Step (1): Reader sends the request command to start the authentication phase.
- Step (2): Tag generates a 8-byte random number PT1. It replies with PT1.
- Step (3): Reader generates a 8-byte random number PT2. It decrypts PT1 and decrypts PT2 with the key related to the tag ID and then concatenates and sends the results. It replies with Challenge = Dk (PT1) || Dk (PT2).
- Step (4): Tag encrypts the Challenge to get CT1= Ek (Challenge (127 down to 64)) || Ek (Challenge (63 down to 0)). It generates a 8-byte random number PT3. It compares CT1 (127 down to 64) to PT1. If they match, the reader is authenticated. Then, the tag replies with Response = Ek (PT3) || Ek (CT1 (63 down to 0)).
- Step (5): Reader decrypts the Response to get PT4 = Dk (Response (127 down to 64)) || Dk (Response (63 down to 0)). If PT4 (63 down to 0) = PT2 then the tag is authenticated.

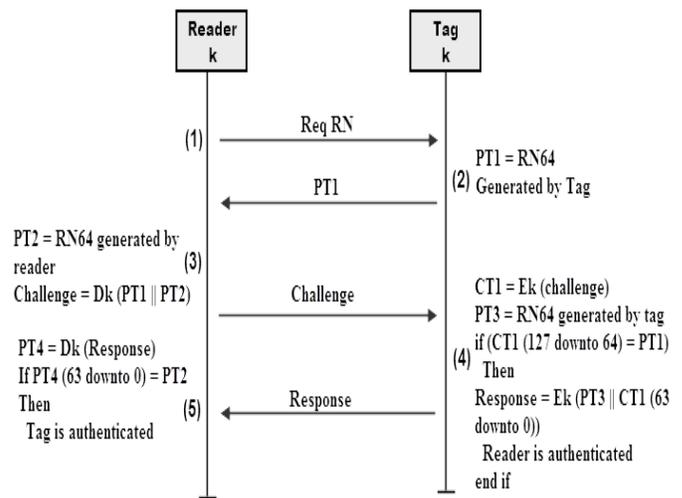


Fig. 1. Seshabhata et al. protocol (ProtocolS) [15].

B. Protocols Vulnerability against EMA

The ProtocolS is vulnerable against EMA in Step (4). A malicious reader can send wrong challenges to tag. Even though the tag does not respond to these wrong challenges, the attacker obtains the information leakage of the block cipher during the encryption operation. For example, Timo Kasper et al. proposed a technique [28] to save the electromagnetic radiations generated by the Mifare Desfire block cipher. The technique is based on analog demodulator and filters that allows bypassing the influence of the reader field by removing the unwanted carrier frequency. We suppose that we are in Timo Kasper et al. conditions. The ProtocolS integrating unprotected PRESENT block cipher can be attacked by EMA. In Step (3), the attacker can send a 128-bit random challenge. As indicated in (4), the tag encrypts the MSB 64-bit of each received challenge and compares the result with the generated PT1. During the encryption operation of the challenge the attacker can exploit the electromagnetic radiation of the PRESENT block cipher.

In the following, we will propose a parallel architecture of PRESENT in order to test its vulnerability against EMA and compared it (number of EM traces to obtain the key) with an existing unprotected serial PRESENT architecture. A description of PRESENT and its hardware implementation is shown in the next section.

III. PRESENT-80 BLOCK CIPHER

A. PRESENT Description

PRESENT is an ultra-lightweight block cipher proposed by A. Bogdanov et al. [10]. It has been designed for secured low power and low area devices such as passive RFID tags. It has a block size of 64-bit and two key lengths of 80 (PRESENT-80) and 128-bit (PRESENT-128) are supported. We chose the implementation of PRESENT-80 bit rather than PRESENT-128 bit because the first one showed a lower area [29]. The algorithm of PRESENT-80 is shown in Fig. 2.

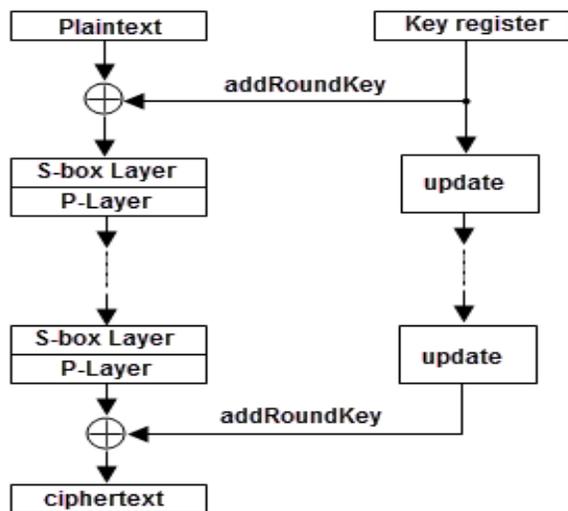


Fig. 2. PRESENT algorithm.

It consists of 31-rounds Substitution-Permutation (SP) network and a final key-whitening, during which:

- Round key is added to plaintext.
- Plaintext goes through S-boxes (substitution boxes).
- Plaintext after S-boxes goes through P-Layer (permutation layer).
- Round key is updated.

The result of the key updaters operation for every round is taken as a round key and it is added to the current state $b_{63} b_0$. This operation is performed as shown below:

$$b_j \leftarrow b_j \oplus k^i_j \text{ where } 1 \leq i \leq 32 \text{ and } 0 \leq j \leq 63 \quad (1)$$

Where, i is the round in processing and j is the bit position.

The second stage is a non-linear S-box Layer that consists of 4-bit to 4-bit S-boxes, which are given in hexadecimal notation in Table 1.

TABLE I. PRESENT S-BOX FUNCTION

x	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
S[x]	C	5	6	B	9	0	A	D	3	E	F	8	4	7	1	2

The permutation layer of PRESENT is the third stage of the round operation. It is a linear bit permutation and it is described in (2), (3), (4) and (5).

$$\text{For } 0 \leq i \leq 15$$

$$b_i \leftarrow b_{4 \times i} \quad (2)$$

$$b_{i+16} \leftarrow b_{4 \times i+1} \quad (3)$$

$$b_{i+32} \leftarrow b_{4 \times i+2} \quad (4)$$

$$b_{i+48} \leftarrow b_{4 \times i+3} \quad (5)$$

The key updaters process operates on the user supplied 80-bit key and outputs a 64-bit key for every round. The user-supplied key is stored in a key register K and represented as

$k_{79}k_{78} \dots k_{16}k_0$. For the round i , the left most 64 bits of the current state of register K are the round key. Thus we have:

$$K_i = k_{63}k_{62} \dots k_{16}k_0 = k_{79}k_{78} \dots k_{17}k_{16} \quad (6)$$

After the round key K_i is extracted, the key register $K = k_{79}k_{78} \dots k_{16}k_0$ is updated as follows:

$$1. [k_{79}k_{78} \dots k_{16}k_0] = [k_{18}k_{17} \dots k_{20}k_{19}] \text{ (bitwise rotation)} \quad (7)$$

$$2. [k_{79}k_{78}k_{77}k_{76}] = S [k_{79}k_{78}k_{77}k_{76}] \quad (8)$$

$$3. [k_{19}k_{18}k_{17}k_{16}k_{15}] = [k_{19}k_{18}k_{17}k_{16}k_{15}] \oplus \text{round counter} \quad (9)$$

C. PRESENT-80 Implementation

There are many implementations of PRESENT-80 algorithm. For example, Axel Poschmann et al. proposed a serial implementation of the PRESENT algorithm [20]. This unprotected implementation (4-bit data path) requires 1100 gate equivalents (GEs) and 547 clock cycles to process one block of data. Generally, the more parallel level of the data path, the harder it is to attack (Side Channel Attack) the design because parallelism is one way of hiding countermeasures. For this reason, we proposed a parallel architecture of PRESENT in the aim to evaluate its vulnerability against EMA and compared its attack results with serial PRESENT architecture.

Our proposed PRESENT-80 implementation given in Fig. 3 is based on a parallel hardware processing rather than a sequential processing. This parallel architecture is based on 64-bit data path. It means the 16 S-box blocks operates at the same time which makes saving electromagnetic traces corresponding to one S-box operation is very difficult. The attack setup will be presented in details in the next section. Our PRESENT version has two inputs (data-in, key) and one output (data-out). The data-in and data-out are both on 64-bit and the key is on 80-bit. The architecture consists of two MUXs, one XOR, two 64-bit registers Reg1 and Reg2, 16 4-bit S-boxes, 64-bit shift-register (permutation layer operator), 80-bit key update and 5-bit counter.

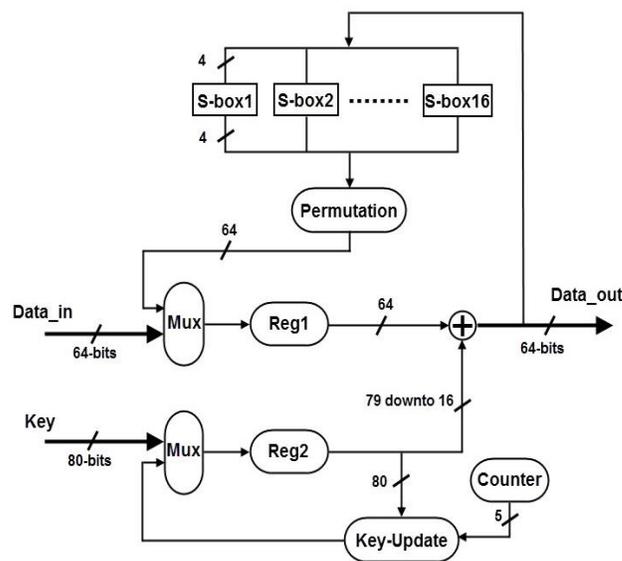


Fig. 3. Hardware architecture of PRESENT-80.

Due to the parallelism of our implementation, one round requires only one clock cycle to substitute the data (S-box), to perform the data permutation and the key updater. Including the initialization phase, 33 clock cycles are required to process one block of data. The synthesis of PRESENT-80 on an ASIC has been done with Leonardo Spectrum from Mentor Graphics using the scl05u library (without optimization). Our architecture requires about 2050 GEs and 33 clock cycles to process one block of data. This implementation is not the best in term of area compared to [20]. However, it is more secure against EMA (see next section).

IV. EM ATTACK ON PRESENT

Until this section, we only present EMA on commercial tags (with a chip based on an ASIC). However, our architecture and its countermeasure will be validated on a FPGA platform. The EMA can also be performed on FPGA that implements the digital tag architecture. The evaluation of EMA performed on FPGA platform is generally considered as realistic. In fact, the exploitation of the extracted information leakage on FPGA is generally also possible once the architecture is implemented on ASIC technology. We chose to implement our parallel architecture of PRESENT in a SAKURA-G starter board to perform EMA. The EM attack methodology on the PRESENT block cipher is presented in order to recover the key. Then, we calculate the attack setup time that depends to the saved electromagnetic traces. Finally, we compare our attack results with Axel Poschmann et al. results [20].

A. EM Attack Methodology on PRESENT

The first DPA (Differential Power Analysis) attack based on the analysis of power consumption has been proposed by P. Kocher in 1999 [18]. The Electromagnetic attack uses the same hypothetical model but using the EM radiations rather than the power consumption. The EM radiations measured with a near field probe are often less noisy than the global circuit power consumption signal. In this work, EMA uses the CPA (Correlation Power Analysis) [23] between the radiations emitted by the encryption circuit and a hypothetical model.

First, we start by locating the best attack point. For PRESENT, this point is the output of the nonlinear S-box

function (see Section III-A). This point is chosen because the secret key (ks) information is contained in the power consumption of the circuit when performing the S-box operations. We model the dynamic power of the output of the S-box operation P_{dyn_Sbox} as follows with the Hamming Weight (HW) function:

$$P_{dyn_Sbox} = HW(S\text{-box}(PT \oplus ks)) \quad (10)$$

The presence of the secret key in the power consumption will be exploited by the EM attack. Once the attack point is identified, the EM attack on PRESENT can be realized. Fig. 4 shows the different steps of the EM attack:

- Plain texts of 64-bit are randomly generated and encrypted by the PRESENT block cipher. During each of those encryptions, the electromagnetic emissions of the chip, as well as plain texts sent to the circuit are recorded.
- The PRESENT secret key on 80-bit is divided into 20 4-bit wide sub-keys. The MSB 16 sub-keys (k79 k78 k16) are recovered in the first round of the encryption operation and the LSB 4 sub-keys (k15 k14 ... k0) are recovered in the second round of the encryption operation (see, (6), (7), (8) and (9)).
- The PRESENT architecture previously described shows that the random input data and the key are XORed 4-bit to 4-bit and fed out to the non-linear S-box function. The output of each S-box is on 4-bit. These S-box outputs are the locations of ours attacks. Each attack location allows us to recover one sub-key (4 bits).
- To recover each sub-key, we calculate the Pearson Correlation [23] between the output of the attack model (HW) and the real traces. For each sub-key hypothesis, we obtain for each EM trace oscilloscope sample, a correlation value.
- A comparison is performed between the correlations for all hypothetical sub-keys, and the correlation with the highest amplitude corresponds to the value of the right sub-key. The attack setup will be described in detail in Section IV-C.

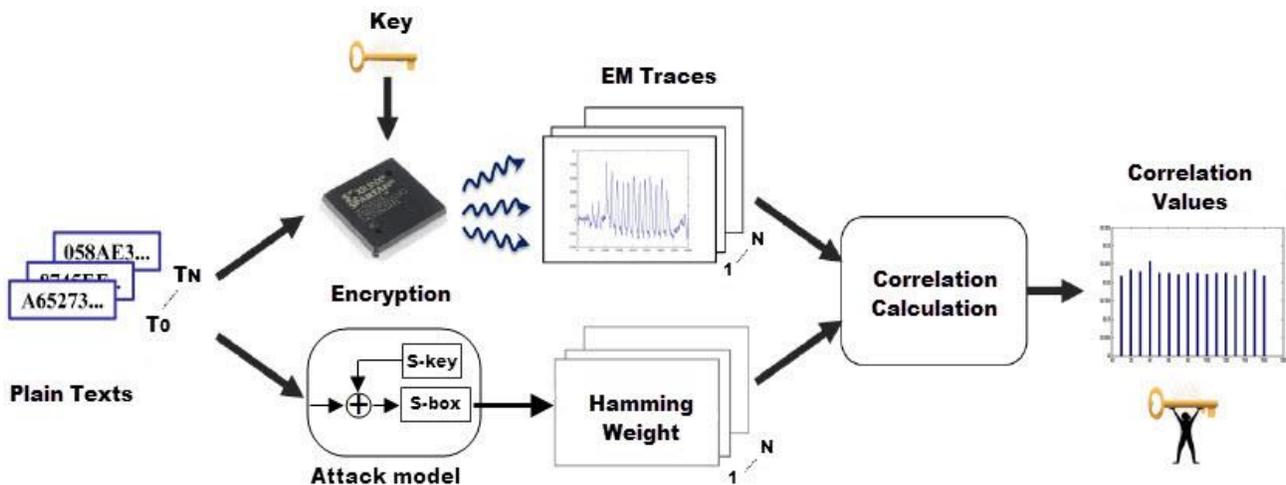


Fig. 4. EM attack methodology.

B. Measurement Set-Up

In order to perform the EM attack, the PRESENT encryption unit has been implemented on a SAKURA-G [24] starter board containing a Spartan 6 FPGA (XC6SLX75). Electromagnetic radiations during the encryption operation are measured using a near field probe RF-U5-2 [25] and a Wave Runner 6 Zi oscilloscope features 400 MHz - 4 GHz of bandwidth and 40 GS/s sampling rate [26]. We used also a XY table to control the placement of the EM probe on the FPGA surface to find the best point to make the attack. Fig. 5 shows the electromagnetic measurement bench to perform the EM attack.

The interconnection of the oscilloscope to the FPGA platform is performed by two cables. The first cable is connected to one pin of the User Header Pin (in/out logic pins) to detect the trigger signal coming from the FPGA to trig the oscilloscope sampling. The trigger signal is coming from the encryption design and appears in every first round to save the EM traces. The second cable is connected to the near field probe to visualize the Electromagnetic radiation of the encryption block.

C. Attack Setup

The controlling design shown in Fig. 6 has been built for carrying out the functioning of the PRESENT unit cipher. This design also contains a Linear Feedback Shift Register (LFSR) that allows us to generate random plain texts to feed the encryption unit. In addition, we use a frequency divider block to transform the FPGA frequency from 48 MHz to 100 kHz. Indeed, this 100 kHz frequency is a widely used as operating frequency in RFID tags. A controller block is implemented to control LFSR and PRESENT blocks.

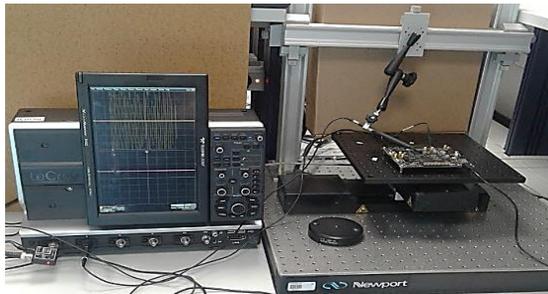


Fig. 5. Electromagnetic measurement bench.

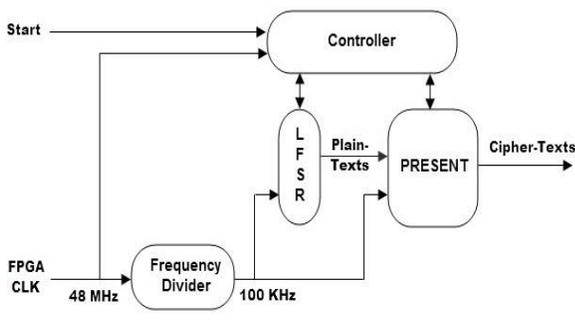


Fig. 6. Design architecture controlling the PRESENT block cipher during EMA.

To synchronize the generation of the plain text with the sampling of its corresponding electromagnetic radiation, we add a delay state in the finite state machine of the controller. This delay is necessary to give more time for the oscilloscope to perform the storage of the EM trace (0.5 ms). When the attack is performed at the first or the second round of PRESENT, for each trigger signal event the oscilloscope saves one EM radiation trace. A matrix T of 100 000 plaintexts is used as PRESENT encryption inputs and thus a matrix M comprising 100 000 Electromagnetic traces is obtained. The same 100 000 plaintexts and their relative 100 000 EM traces are used to recover the 16 MSB 4-bits sub-keys. Each of these traces consists of 4002 oscilloscope samples.

In this work, we use the previous EM attack model: the Hamming Weight (HW) at the S-box (10). This attack model was developed with Matlab. The first step performs the attack at the first round of the encryption unit where we are able to recover 16 MSB 4-bits sub-keys. After recovering these 16 sub-keys, the second step performs the attack at the second round of PRESENT to get the last 4 sub-keys. To predict one sub-key in the step one of the attack, the attack model input (plaintext) is a matrix T of 4-bits vectors of dimension (100000×1) . This matrix is XORed with the 16 possible 4-bits sub-keys to get a matrix with dimension of (100000×16) . As we mentioned before, the output of the logic gate XOR is fed out to the attack S-box function and the output of this S-box is a matrix of dimension (100000×16) . Using the same 100 000 traces, permits doing all the attacks on all the S-box functions. For each attack, the attack model input changes but the EM traces remain the same 100 000 traces. At this stage, if we apply the Hamming Weight model, we must calculate the HW of each S-box 4-bits vector to get the H_W matrix of dimension (100000×16) . The last step of the attack is to calculate the correlations between the real traces, which is a matrix of dimension (100000×4002) , and the H_W matrix to get a CORL matrix of dimension (4002×16) . The correlation with the highest value corresponds to the recovered sub-key.

After recovering the MSB 64-bits of the secret key, in the second step of the attack we recover the last 4 sub-keys. We keep the same attack model but the inputs are the cipher outputs data of the first round of the algorithm instead of the random data generated by our LFSR. Also we save 100 000 electromagnetic traces corresponding to the second round of PRESENT. As it was mentioned in the PRESENT algorithm description, in each encryption round the key must be updated (see Section III-A). So when we recover the 64-bits of the key updated used in the second round, we can recover the initial LSB portion key $(k_{15} k_{14} \dots k_{1k0})$ by the use of the key updater reverse operation (see, (7), (8) and (9)).

D. EM Attack Results and Comparison

This section shows the EM attack results on PRESENT. Fig. 7 is a sample of an electromagnetic radiation trace of the block cipher saved during the encryption operation. In Fig. 7 every round of PRESENT is associated with a voltage peak. Therefore, there are 32 voltage peaks.

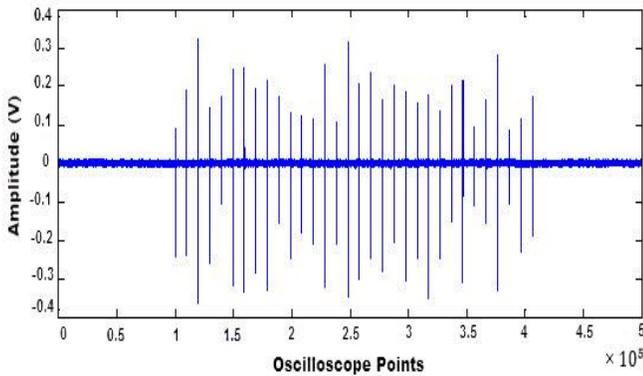


Fig. 7. Electromagnetic trace observe during the encryption operation.

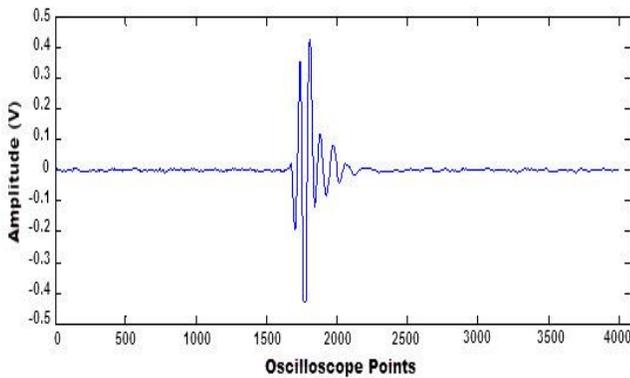


Fig. 8. Electromagnetic trace of the first round.

Fig. 8 shows the electromagnetic trace saved at the first round.

In order to extract information from the leakage resources, an EM attack was performed using the power model based on the HW of the S-box outputs. As we have mentioned in Section IV-C, during the first step of the attack we are able to recover the MSB 64-bit of the key. This first step of the attack is performed in the first round of the PRESENT algorithm. The experimental results show that after the encryption of 100 000 plaintexts (corresponding to the sampling of 100 000 EM traces), we achieve to recover all the 16 sub-keys. Fig. 9 shows the correlations according to the oscilloscope points. These correlation values are extracted from the CORL correlation matrix (4002 x 16) previously described in Section IV-C.

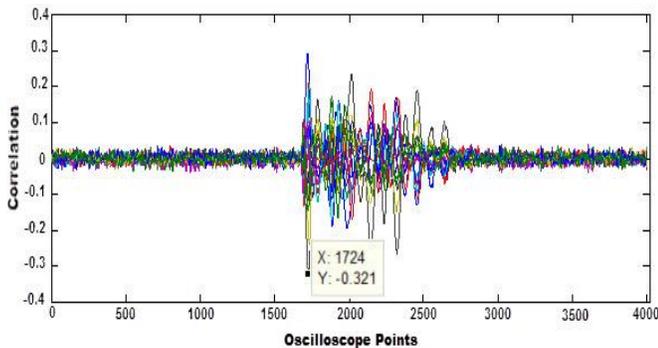


Fig. 9. EM attack correlations using the HW model.

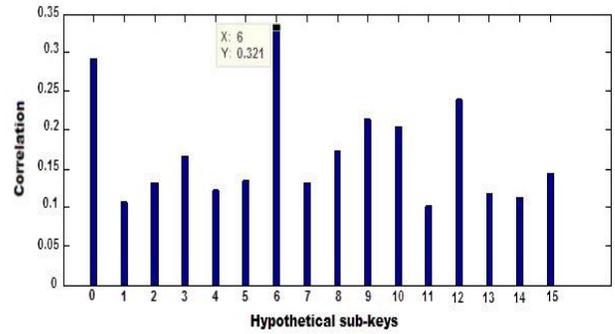


Fig. 10. Example of calculated correlations for one 4-bit PRESENT hypothetical sub-key.

In this example, the EM attack was done with the HW model performed at the 10th sub- key nibble (4 bits). The correlations between the traces and the HW model show a maximum correlation value ($y=0.321$) that corresponds to the correct hypothetical sub-key which is ($x=6$) h as shown in Fig. 10.

After recovering the MSB 64-bit (16 4-bit sub-keys) of the total key, the second step of the attack allows predicting the rest of the key (4 LSB 4-bit sub-keys) by the use of the same HW model. As we mentioned before (see, Section IV-C), this second step of the attack is performed in the second round of the algorithm in order to recover the round key after the first update. We use the outputs of the permutation layer of the first round as the inputs of the HW model. We obtain the correlation between the outputs of the HW model and the 100 000 EM traces extracted at the second round of the PRESENT algorithm. Finally, we reverse the update operations of the round key to compute the missed part of the initial key.

After processing 100 000 EM traces at the first round and 100 000 EM traces at the second round of PRESENT, we succeed to recover the key. Table 2 summarizes the attack results on our PRESENT architecture compared to Axel Poschmann et al. architecture [20]. Our parallel architecture is attacked using 200 000 EM traces, whereas the serial PRESENT architecture proposed by Axel Poschmann et al. is attacked using only 10 000 traces. As we mentioned before that the attack is located at the output of the S-box function. Each attack location allows us to recover one sub-key (4 bits). So, the parallelism of the S-boxes hides the amplitude of the signal of interest. The parallel implementation of PRESENT represents one way of countermeasure against EMA.

TABLE II. ATTACK RESULTS

Block cipher	Our PRESENT	[20]
Number of traces to perform SCA	200 000	10 000
Attack setup time (s)	100 000	5 000
Area (GEs)	2050	1100

We note that the save of one EM trace on the oscilloscope memory needs about 0.5 s. Thus, the attack setup time equals to number of traces multiplies to 0.5 s.

A parallel implementation of PRESENT block cipher can be a solution to protect the architecture against EMA. However, this solution can be attacked with the use of 200 000 traces. For this reason, in the next session we propose a countermeasure at the authentication protocol level based on time delay function. This function limits the number of successive wrong authentication requests. Then, this limitation of false request prevents the attacker to perform the EM attack previously presented.

V. PROTOCOL BASED COUNTERMEASURE

Different countermeasures can be used to protect RFID chips against SCA. Countermeasures are generally implemented either at the primitive security level (i.e. in the block cipher) or at the communication protocol level. For example, Axel Poschmann et al. proposed a hardware countermeasure on the PRESENT block cipher [20]. In other hand, Chiraag S Juvekar et al. proposed a design of a secure authentication tag [30] that updates the secret key every challenge-response protocol. The tag is based on specific technologies (FRAM and Energy backup unit) which represents high cost security solution.

As we mentioned in Section II-A that ProtocolS is vulnerable to EMA in Step (4). We note that the EMA is always possible in ProtocolS by using a valid reader. However, this attack needs the use of eavesdropping attack to know the RFID communication between reader and tag. To perform the EMA, the attacker needs to eavesdrop the challenge (plaintext) or the response of the tag (cipher text) (see Fig. 1). This attack is considered difficult because the hardness of setting up of the eavesdropping attack. In addition, the EMA is longer because the attacker is oblige to wait for the availability of the reader. In other hand, the ProtocolS allows the attacker to emulate the tag with invalid reader. Therefore, the attacker can send wrong challenges (plaintext) to tag and saves the EM traces easily. In this section, we proposed a countermeasure at ProtocolS to prevent an attacker to emulate the tag with wrong challenges and getting the electromagnetic traces rapidly to perform the EMA. The proposed countermeasure is based on the incrementation of a counter Iwrong every successive wrong authentication request. A delay function allows delaying the response of the tag (especially the encryption operation) with a time delay for each wrong authentication. The time delay function will be described in the following (see Fig. 13). More the number of the wrong authentication request increases (Iwrong), more the time delay increases, more the time to save EM traces increases (see Fig. 12). A state diagram describing this countermeasure is shown in Fig. 11.

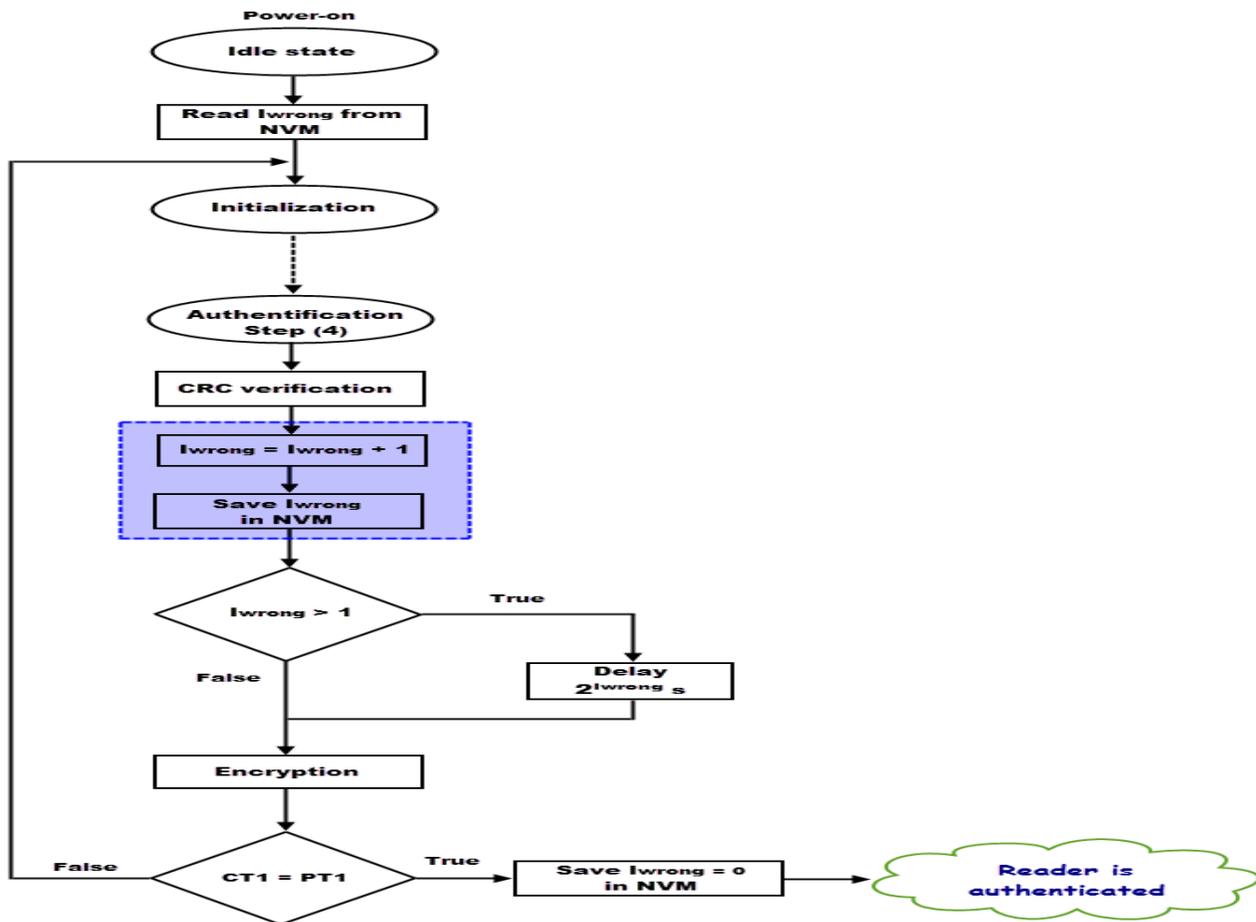


Fig. 11. State diagram describing the countermeasure at ProtocolS.

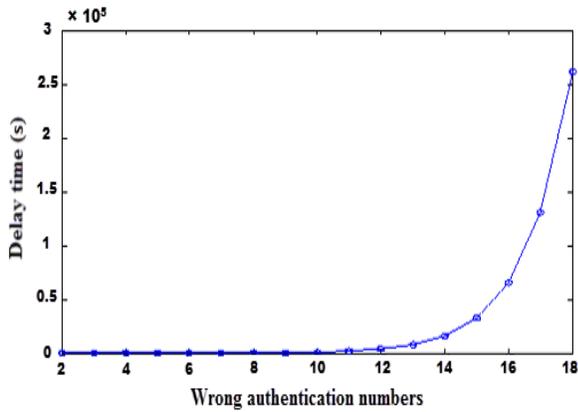


Fig. 12. Delay function description.

At the Step (4) of the ProtocolS, the tag controller verifies the challenge CRC to ensure the integrity of data. If this CRC is correct the Iwrong counter value is first incremented and then saved in a NVM. This backup operation avoids an under-powering attack, which could prevent the incrementation of the counter when the authentication request is false. After this backup operation, in the case of a first authentication, the challenge encryption operation is performed by the PRESENT block cipher without time delay. After each successful authentication (generated CT1= PT1), the tag controller resets the Iwrong value and resets its backup value. The time delay is introduced when the tag detects more than one wrong authentication. It allows delaying the encryption operation when it receives a wrong challenge. The time delay is an exponential function described as:

$$\text{Time Delay (s)} = 2^{Iwrong}$$

Fig. 12 shows the time delay progression based on the wrong authentication numbers.

Table 3 shows examples of time delay, which is depending to the wrong authentications (Iwrong).

TABLE III. TIME DELAY

Iwrong	2	6	10	14	18
Delay (s)	4	64	1024	16384	262 144

Let's assume that an attacker sends 18 wrong challenges, the total time delay is:

$$\text{Total time delay (s)} = \sum_{Iwrong=1}^{18} 2^{Iwrong}$$

The attacker must wait about 524 288 s (~ 145 hours) to obtain 18 EM traces. The results of the table shows that more the number of the wrong authentication increase, more the time to obtain EM traces increases. However, the time delay function allows the tag to enter in killed state progressively. Only the tag manufacturer can reinitialize the tag state to the idle state. The delay function is implemented in our RFID tag prototype described in Fig. 13.

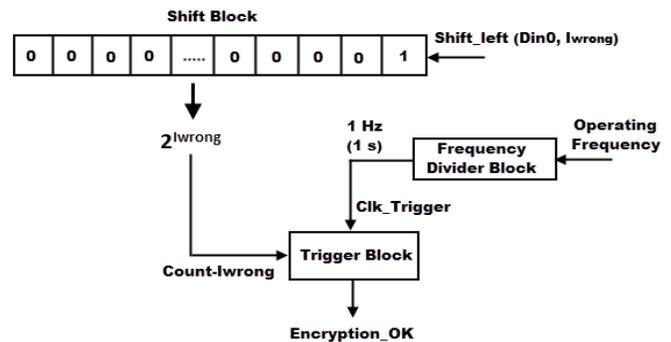


Fig. 13. Delay function description.

The delay function consists of three main blocks: Shift Block, Frequency Divider Block and Trigger Block. The Shift Block uses the shift left operation to calculate 2^{Iwrong} : shift_left (Din0, Iwrong). For example, we designed a Shift Block allows the calculation of a time delay 2^{Iwrong} , with $2 \leq Iwrong \leq 20$ (2^{20} second (~ 291 hours) is needed to obtain the 20th EM trace). Din0 is initially defined to (00001) hexadecimal. The Frequency Divider Block generates a frequency of 1 Hz from the operating frequency of the tag. Finally, depending to the Iwrong value, the Trigger Block allows generating a time delay between: $22 \text{ s} \leq \text{time delay} \leq 2^{20} \text{ s}$. The Trigger Block receives the count-Iwrong (from 2 to 20) from the Shift Block. Then it loads its intern counter value by the received count-Iwrong value. The Trigger Block operates at frequency of 1Hz. When the decrementation of the intern counter achieves zero, the Trigger Block generates the signal Encryption_OK that gives the order to perform the encryption operation of the challenge.

The countermeasure at ProtocolS implements the time delay function requires about 960 GEs. It prevents the attacker to save enough EM traces to perform the EMA. It looks economic compared to countermeasures proposed by Axel Poschmann et al. [20] that require 2471 GEs. They proposed countermeasures to PRESENT block cipher based on data masking, key masking and random permutations.

VI. CONCLUSION

This article addresses the issue of EM attacks against mutual authentication protocol in RFID. An improved authentication protocol limiting the number of successive wrong authentication requests is proposed as a countermeasure against EM attacks. This countermeasure prevents an attacker to save enough electromagnetic traces to perform the EMA.

In the first part of this paper, we analyzed the mutual authentication protocol (ProtocolS) and showed how attackers can perform the EM attack on this protocol. Then, we proposed a parallel implementation of PRESENT block cipher in order to hide its information leakage against EMA. Our architecture is attacked after 200 000 traces, whereas the serial architecture of PRESENT proposed by Axel Poschmann et al. [20] is attacked after 10 000 traces. Our PRESENT architecture (2050 GEs) occupies more gates than Axel Poschmann et al. architecture (1100 GEs), but it's more secure against EMA.

In the second part of the paper, we proposed a countermeasure at the protocol level based on time delay function. This countermeasure prevents an attacker to emulate the tag using malicious reader and getting the electromagnetic traces to perform the EMA. Our countermeasure requires only 960 GEs, whereas the countermeasures proposed by Axel Poschmann et al. [20] at PRESENT block cipher requires 2471 GEs. In addition, our countermeasure at protocol level is compatible with unprotected symmetric block ciphers.

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Task Scheduling in Cloud Computing using Lion Optimization Algorithm

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Abstract—Cloud computing has spread fast because of its high performance distributed computing. It offers services and access to shared resources to internet users through service providers. Efficient performance of task scheduling in clouds is one of the most important research issues which needs to be focused on. Various task scheduling algorithms for cloud based on metaheuristic techniques have been examined and showed high performance in reasonable time such as scheduling algorithms based on Ant Colony Optimization (ACO), Genetic Algorithm (GA), and Particle Swarm Optimization (PSO). In this paper, we propose a new task-scheduling algorithm based on Lion Optimization Algorithm (LOA), for cloud computing. LOA is a nature-inspired population-based algorithm for obtaining global optimization over a search space. It was proposed by Maziar Yazdani and Fariborz Jolai in 2015. It is a metaheuristic algorithm inspired by the special lifestyle of lions and their cooperative characteristics. The proposed task scheduling algorithm is compared with scheduling algorithms based on Genetic Algorithm and Particle Swarm Optimization. The results demonstrate the high performance of the proposed algorithm, when compared with the other algorithms.

Keywords—Cloud computing; task scheduling algorithm; cloud scheduling; lion optimization algorithm; optimization algorithm

I. INTRODUCTION

Cloud computing is considered to be a distributed system that offers services to internet users through service providers such as Amazon, Google, Apple, and Microsoft. Cloud computing uses internet technologies to offer elastic services that support variable workloads and dynamic access to computing resources.

Many of the scientific researches on cloud computing had focused on the performance efficiency of task scheduling. Task scheduling focuses on mapping tasks to appropriate resources, efficiently. Finding an optimal solution in cloud computing is considered an NP-complete problem. Each scheduling algorithm is based on one or more strategy. The most important strategies or objectives commonly used are time, cost, energy, quality of service (QoS), and fault tolerance [1], [2]. Several scheduling algorithms based on heuristic algorithms, such as Min-Min, Max-Min, and Heterogeneous Earliest Finish Time (HEFT) algorithms have been developed for cloud systems [3], [4]. In addition, different metaheuristic task scheduling algorithms that generate optimal schedules, such as the scheduling algorithm based on Genetic Algorithm (GA), Particle Swarm Optimization (PSO), and Ant Colony Optimization (ACO) [3], [5] have also been developed.

In this study, a new task scheduling algorithm is proposed for cloud environment using the concept of lion optimization algorithm (LOA), which was proposed in [6]. LOA is a nature-inspired algorithm based on the special lifestyle of lions and their cooperative behaviors. To evaluate the performance of the proposed algorithm, a comparative study is done among the proposed algorithm, task scheduling based on PSO algorithm, and task scheduling using the GA.

The main objective of this research paper is to propose a task-scheduling technique for cloud computing using the LOA to minimize the total execution time of the task on the cloud resources (makespan). Section 2 reviews some literature on LOA and some metaheuristic algorithms. Section 3 describes the proposed algorithm. Section 4 presents the experimental methodology and simulation parameters, followed by metrics used in experiment in Section 5. Section 6 presents the results of simulations and comparisons. Finally, conclusion and the future work are discussed in Section 7.

II. RELATED WORK

Many metaheuristic algorithms have been proposed and applied for task scheduling in the area of cloud computing. Metaheuristic algorithms depend on two techniques to be effective. The first technique is “exploitation”, which exploits the best solution from among the previous results. The second technique is “exploration”, which explores new areas of the solution space. Most of these algorithms are distinguished and remarkable, such as the Genetic Algorithms (GA), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), and League Championship Algorithm (LCA), and many more algorithms [5], [7].

The GA is a metaheuristic technique that was introduced by Holland in 1975 [8]. It provides useful solutions to optimization problems by applying the principles of evolution. The GA begins by initializing a population with random candidate solutions called individuals. Each individual is evaluated by a fitness function, which can be different according to the given optimization objective. Then, a proportion of the population is selected to reproduce a new generation. After that two main genetic operators are used to generate the new-generation population. These two operators are: crossover and mutation [9].

Using the GA in cloud task scheduling is a powerful approach as it provides better solutions with increase in the population size and number of generations. However, the

random generation of the initial population leads to schedules that are not very fit. Therefore, when these schedules are mutated with each other, there is a very low probability of producing a child better than the parents. Therefore, many researches have been conducted on improving the GA, especially, the initial steps, in order to improve the performance. For example, the authors in [10] improved the GA by using the Min-Min and Max-Min algorithms for generating the initial population. This provided a better initial population and better solutions than the standard GA, which initialized the population randomly.

The PSO metaheuristic algorithm was proposed by Kennedy and Eberhart in 1995 [11]. It was derived from the social behavior of particles. Each particle has position and velocity, which are initialized randomly. Moreover, each particle has a fitness value, and knows its personal best value (pbest) and the global best value (gbest). In each iteration, the particle improves its position based on its velocity using the gbest and pbest values [5], [12].

Task scheduling in clouds using PSO algorithm was found to be faster than that using the GA. It spent shorter time to complete the different scheduling tasks. In addition, the PSO provided better results for large-scale optimization problems, than the GA. However, many techniques and strategies were developed to improve the PSO for task scheduling. For example, [13] proposed an algorithm that combined the ACO and PSO algorithms in order to improve the performance. This combination improved the convergence speed and the resource utilization ratio.

In this paper, a new task-scheduling algorithm has been proposed using the concept of a new optimization algorithm called Lion Optimization Algorithm. It is based on the lifestyle and social organization of lions. In 2012, Wang [14] proposed an algorithm inspired by a few characteristics of lions, named the “Lion Pride Optimizer”. It was based on the fighting and mating between lions. Rajakumar [15] proposed an algorithm named “The Lion’s Algorithm”, which was based on the mating, territorial defense, and territorial takeover. In 2015, Yazdani and Jolai [6] proposed the Lion Optimization Algorithm (LOA), which was different from the previous algorithms. It was inspired by simulating the isolated life style and cooperative behaviors of lions, such as hunting, territory marking, migration, and the different life styles of the nomad and resident lions, in addition to mating and fighting.

III. TASK SCHEDULING BASED ON LION OPTIMIZATION ALGORITHM

The LOA was developed based on the simulations of the behaviors of lions, such as hunting, mating, and defense. Lions have two organizational behaviors: resident behavior and nomadic behavior. Residents live in groups called prides. A resident lion may become a nomad, and vice versa. In the LOA, the initial population is generated randomly over the solution space where every single solution is called a “Lion”. (%N) of lions in the population are selected randomly as nomad lions and the rest of the population are residents. Residents are divided randomly into (P) prides. (%S) of the lions in each pride are considered female and the rest are male.

However, this proportion is reversed for nomad lions. The parameters and their meanings are shown in Table 1.

The proposed task-scheduling algorithm based on the LOA is detailed in the following steps:

Step 1: Initialize population

In this study, our target is to resolve the task scheduling for cloud computing and minimize the makespan of the solution, which is the maximum completion time for all tasks. Therefore, we should map each underlying solution to a lion. A lion represents a task scheduling solution, which is initialized randomly by mapping cloud tasks (cloudlets) to cloud resources (virtual machines (VMs)). For example, Fig. 1 shows a lion represents a schedule of five tasks that have been assigned randomly to three VMs. Such that, each lion will represent a random schedule solution, so the initial lion population is constructed randomly over the solution space for the LOA algorithm.

The goal of the proposed algorithm is to find the best lion (solution) that has the best fitness value. The fitness value is the makespan of that solution, which is the maximum completion time for the tasks. Moreover, each lion knows its own best solution (schedule of tasks), as well as the global best solution, which are updated progressively during optimization.

TABLE I. PARAMETERS OF LOA

Parameter	Definition of the parameters
%N	Percent of nomad lions
P	Number of prides
%S	Percent of female lions in each pride
%R	Roaming percent
%Ma	Mating percent of female lions
%I	Immigrate rate of female lions in each pride

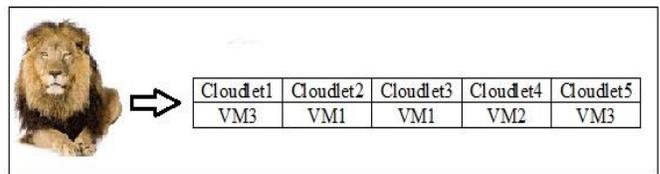


Fig. 1. A lion representation.

TABLE II. VALUES OF LOA PARAMETERS

Parameter	Value
%N	20
P	4
%S	80
%R	20
%Ma	30
%I	40

In our proposed algorithm, each lion has the following parameters:

- **vmPositions List:** initially contains random schedule of VMs
- **vmBestPositions List:** in order to save the best schedule for that lion.
- **Fitness:** represents the makespan of current *vmPositions*
- **Best Fitness:** represents the makespan of *vmBestPositions*

As mentioned previously, the initial population will be classified into residents and nomads. Table 2 shows the value of parameters used in the experiment. %20 of lions are nomads. Residents will be divided into 4 prides randomly, and in each pride, %80 of lions are females, whereas the rest are males. However, it is the reverse for nomad lions: %(100-80) of the nomads are females and the rest are males.

Moreover, each pride has its own territory. **Territory** is a collection of the best visited positions of the pride members. In our study, the territory of the pride is formed by the best solution (task scheduling) of each lion in the pride. This will help to save the best positions or solutions obtained over each iteration. In our proposed algorithm, the territory of the pride will consist of *vmBestPositions* of each lion in the pride.

Step 2: Each pride will do the following:

Step 2.1: Hunting

Based on LOA, some females of the pride are selected randomly for hunting. These hunters move toward the prey and encircle it, to catch it. In our proposed algorithm, this strategy will help achieve a better solution, as each hunter will update its best visited position (task schedule solution) and the global best position (solution) by moving toward the prey.

First, the selected female hunters are partitioned into three groups randomly: left wing, center, and right wing. The group with highest cumulative fitness is considered as the center while the other two groups as the two wings.

Next, a prey is generated at the center of the hunters, as follows [6]:

$$PREY = \frac{\sum \text{hunters positions}}{\text{number of hunters}}$$

During hunting, each hunter moves toward the prey according to its group, as follows [6]:

If a hunter belongs to the center group:

$$Hunter' = \begin{cases} rand((Hunter) PREY) & (Hunter) < PREY \\ rand(PREY.(Hunter)) & (Hunter) > PREY \end{cases}$$

If it belongs to the left or right wings:

$$Hunter' = \begin{cases} rand((2 \times PREY - Hunter) PREY) & (2 \times PREY - Hunter) < PREY \\ rand(PREY.(2 \times PREY - Hunter)) & (2 \times PREY - Hunter) > PREY \end{cases}$$

Where, *PREY* and *Hunter* are their current positions, and *Hunter'* is the new position of the hunter.

Throughout hunting, if the new position of the hunter is better than its previous position, which means that it has improved its own fitness, the prey will escape from the hunter, and the new position of the prey will be [6]:

$$PREY' = PREY + rand(0.1) \times PI \times (PREY - Hunter)$$

Where, *PI* is the percentage of improvement in the hunter's fitness.

Step 2.2: Remaining Females

As some females in each pride go hunting, remained females in the pride will move toward one of the positions of territory. The first step based on LOA is calculating the tournament size of the pride. This is done by first calculating the number of lions in the pride, who improved their fitness in the last iteration (Success value). Then, the tournament size for this pride is calculated as follows [6]:

$$T_j^{Size} = \max \left(2, \text{ceil} \left(\frac{K_j(S)}{2} \right) \right)$$

Where, *K_j(S)* is the number of lions in pride *j*, who improved their fitness in the last iteration.

Tournament size of a pride is varied in every iteration based on success value. If success value decreased, the tournament size increases and this will enhance diversity.

After that, for each remaining female in the pride, a place is selected from the pride's territory by tournament selection to move the female toward the selected place. As mentioned before, the lion's personal best visited position is updated as well as the global best position.

Step 2.3: Roaming

Roaming strategy is a strong local search and it helps our proposed algorithm to find a good solution and improve it. Based on LOA, each resident male in the pride roams within the pride's territory.

First, %*R* of the territory positions is selected randomly so that the lion will visit these selected positions. During roaming, if the new place of that male lion is better than its personal best visited position, its best visited position is updated, and that place is marked as territory. Finally, the best visited position for that lion is set as its current position and the global best position is updated if necessary.

Step 2.4: Mating

Based on LOA, %*Ma* of the female lions in the pride mate with one or more resident males, where all of them are selected randomly, to produce offspring. This will share information between genders and new offspring will inherit characteristics from both genders.

Each mating operation will produce two new offspring, according to the following equations:

$$Offspring1 = \beta \times Female\ Lion + \sum_{\sum_{i=1}^{NR} S_i} \frac{(1-\beta)}{S_i} \times Male\ Lion \times S_i$$

$$Offspring2 = (1-\beta) \times Female\ Lion + \sum_{i=1}^{NR} \frac{\beta}{S_i} \times Male\ Lion \times S_i$$

Where, β is a randomly generated number with normal distribution with mean 0.5 and standard deviation 0.1. $S_i = 1$ if male i is selected for mating, otherwise it is 0. NR is the number of resident males in the pride.

One of the two offspring is considered as male and the other as female, randomly. Our proposed algorithm by mating strategy will share solutions between each other and produce new solutions that may have better fitness value.

Step 2.5: Defense

New mature resident males will fight other males in the pride. The weakest males will leave their pride and become nomads. This behavior can be simulated by merging new mature males and old males. Then, all males are sorted according to their fitness values. The weakest males are driven out of the pride and become nomads, whereas the remaining males become resident males. This strategy assists our proposed algorithm to retain powerful male lions as solutions that play an important role in LOA.

Step 3: Each lion of Nomads will do the following:

Step 3.1: Roaming

All nomad male and female lions roam and move randomly in the search space. The new positions of the nomad lions are determined as follows:

$$Lion' = \begin{cases} Lion & \text{if } rand > pr \\ RAND & \text{otherwise} \end{cases},$$

$$pr = 0.1 + \min\left(0.5, \frac{Nomad-BestNomad}{BestNomad}\right),$$

where, $rand$ is a random number between 0 and 1, pr is a probability, $Nomad$ is the fitness value of the current nomad, and $BestNomad$ is the best fitness value of the nomad lions.

If the new place of a nomad lion is better than its personal best visited position, the best visited position of that lion is updated. The global best position is also updated, if necessary.

Step 3.2: Mating

$\%Ma$ of female nomads are selected randomly. Every female mates with only one male nomad, who is also selected randomly, and produces two offspring according to the equations mentioned in the previous part; one of them is male and the other is female.

Step 3.3: Defense

Nomad males attack prides randomly to try to take over a pride by fighting the male lions in the pride. If the nomad lion is strong enough, the weak male lion will be driven out of the pride and will become a nomad.

Step 4: Migration

For each pride, the maximum number of females is determined by $\%S$ of the population. For migration, $\%I$ of the maximum number of female lions plus the surplus females (number of female offspring) are selected randomly to migrate

from their pride and become nomads. This mechanism will preserve the diversity of the population and share information among prides.

Step 5: Equilibrium

At the end of each iteration, the number of live lions must be controlled. Therefore, the female nomad lions are sorted based on their fitness values. The best females are selected and distributed to prides to fill the empty places of the migrated females.

The weakest females are removed with respect to the maximum number of female nomads $\%(I-S)$. Male nomads are also sorted based on their fitness values, and the lions with the least fitness will be removed with respect to the maximum number of male nomads $\%S$.

Step 6: Steps 2, 3, 4, and 5 are repeated till the last iteration.

The previous steps of the LOA are summarized in the pseudo code presented below:

<i>Pseudo code : LOA-based Task Scheduling</i>
<i>Input: List of Cloudlets (Tasks), List of VMs</i>
<i>Output: the best solution for tasks allocation on VMs</i>
<i>Steps:</i>
<ol style="list-style-type: none"> 1. Initialize Set value of parameters Number of Lions, VMs, Iterations Generate random solution for each Lion Initiate Prides and Nomad lions 2. For each Pride Some females are selected randomly for hunting. Remained females move toward best selected positions of territory. Each male roams in $\%R$ of territory. $\%M$ of females mate with one or more resident males. Weakest male drive out from pride and become nomad. 3. For each Nomad lion Both male and female move randomly in the search space $\%M$ of females mate with only one male Nomad males attack prides . 4. For each pride $\%I$ of females Immigrate from pride and become nomad. 5. Do Each gender of nomad lion are sorted based on their fitness value Best females are selected and distributed to prides filling empty places Nomad lions with least fitness value will be removed based on the max permitted number of each gender. 6. If ($t < Iterations$) Go to step 2
Return best solution.

IV. EXPERIMENTAL METHODOLOGY

The proposed algorithm was implemented using CloudSim. CloudSim is a simulation framework that enables us to simulate, model, and experience the cloud system [16]. The main nodes of ClouSim are Datacenters, hosts, VMs, cloudlets and brokers [17].

The Datacenter is responsible for creating the core infrastructure services that are required for the cloud. It acts as the cloud service provider and it consists of same or different configuration hosts (servers).

A host in a datacenter represents the characteristics of the physical resources such as storage server or compute server. It is characterized by host id, RAM, storage, bandwidth, processing power (MIPS) and number of processing elements (PE). Hosts are responsible for creating VMs and managing the VM migration, VM destruction, and VM provisioning. The VMs created on a host are characterized by VM id, image size, RAM, bandwidth, processing power (MIPS) and number of processing elements (PE).

Cloudlets in CloudSim represent the tasks that should be uploaded to the cloud for processing. Each cloudlet has a pre-defined length, file input size, and file output size. The broker is a mediator between the users and cloud service providers. It maps the requests of users to the appropriate provider such that it insures the achievement of the Quality of Service (QoS) requirements [18].

Scheduling of CPU resources (Processor elements PE) in CloudSim is modeled at two levels: Hos and VM. At Host level, fractions of each PE are shared among VMs running on the host. This scheduler is called *VmScheduler* and it is a parameter of the Host constructor. At VM level, each VM divides the resources received from the host and shares them to each cloudlet running on that VM. This scheduler is called *CloudletScheduler* and it is a parameter of VM constructor.

There are two default policies in both levels: *SpaceShared* and *TimeShared*. This means that *VmScheduler* and *CloudletScheduler* can be in any combinations of these two policies. For example, it is possible to use *VmSchedulerTimeShared* and *CloudletSchedulerSpaceShared* or vice versa. Also, it is possible to use the same policy for both schedulers. In the *SpaceShared* scheduling policy, only one VM/cloudlet is allowed to be executed at a given instance of a time. In *TimeShared* scheduling policy, it allows multiple VMs/cloudlets to multitask and run simultaneously within a host/VM [19].

The proposed algorithm was written in the Java programing language. It has been simulated on Intel Core i5 Processor, 2.3 GHz machine having 3 MB of L3 Cache and 4 GB of RAM running Mac OS, Eclipse IDE 4.4 and CloudSim Toolkit 3.0.3.

The cloud is simulated in CloudSim with 1 datacenter. Two hosts are created in the datacenter where each host has the following configuration: RAM = 2048 MB, storage = 1 GB, and bandwidth = 10 Gbps. Each VM has the following characteristics: RAM = 512 MB, processing power is varied between 100-1000 MIPS, bandwidth = 1 Gbps, and image size = 10 GB. The cloudlets have the characteristics: file size = 300 MB, output file = 300 MB, and the length is varied between 1000 – 2000 MI. In our experiment, both *VmScheduler* and *CloudletScheduler* utilized the *TimeShared* policy.

The testing dataset is produced randomly. Tasks (cloudlets) are generated randomly with different lengths between 1000 and 2000 million instructions (MI). VMs are also generated randomly with different capacities between 100 and 900

million instructions per second (MIPS). The cost of resources for calculating cost based on VM's specification is as follow: \$0.12, \$0.13, \$0.17, \$0.48, \$0.52, and \$0.96 per hour. The parameter set for CloudSim is shown in Table 3 [20].

TABLE III. CLOUDSIM PARAMETERS

Entity	Parameter	Values
Cloudlet	No of cloudlets	50 – 500
	length	1000-2000
Virtual Machine	No of VMs	15
	RAM	512 MB
	MIPS	100-1000
	Size	10000
	bandwidth	1000
	Policy type	Time Shared
	VMM	Xen
	Operating System	Linux
	No of CPUs	1
Host	No of Hosts	2
	RAM	2048MB
	Storage	1000000
	Bandwidth	10000
	Policy type	Time Shared
Data Center	No of Data Center	2

V. EXPERIMENTAL METRICS

The performance metrics for the proposed task scheduling is based on makespan, cost, average utilization, and degree of imbalance. The following describes these performance metrics [20], [21]:

A. Makespan

Makespan determines the maximum completion time by indicating the finishing time of last task. Minimizing the makespan is the most popular optimization criteria for task scheduling. It can be calculated using the following equation:

$$Makespan = \max_{task\ i} (Fn_{Time})$$

Where, Fn_{Time} shows the finishing time of task i.

B. Cost

Cost means the total amount of payment to cloud provider against the resource utilization. The main purpose for cloud providers is to increase revenue and profit while cloud users aim to reduce the cost with efficient utilization. Cost is measured as follows:

$$Cost = \sum_{resource\ i} (C_i * T_i)$$

Where, C_i represents the cost of VM i per time unit and T_i represents the time for which VM i is utilized.

C. Average Utilization

Maximizing resource utilization is another important criteria for cloud providers by keeping resources as busy as possible to earn maximum profit. The following equation is used to measure the average utilization:

$$Average\ Utilization = \frac{\sum_{i=1}^n Execution\ time\ of\ resource\ i}{Makespan * n}$$

Where, n is the number of resources.

D. Degree of Imbalance

Degree of imbalance (DI) means the amount load distribution among the VMs regarding to their execution capacity. The small value of DI shows that the load of the system is more balanced. It is computed by:

$$DI = \frac{T_{max} - T_{min}}{T_{avg}}$$

Where, T_{max} , T_{min} , and T_{avg} are the maximum, minimum, and average execution time of all VMs.

VI. RESULTS AND EVALUATION

The results of the proposed algorithm are compared with scheduling algorithms that based on two popular metaheuristic algorithms: PSO and GA [22], [23]. In all cases, the population size is set to 100 and the number of iterations is 100. These algorithms are compared with each other based on makespan, cost, average resource utilization, and degree of imbalance.

Fig. 2 shows the comparison of makespan between LOA, PSO, and GA. The x-axis denotes the number of cloudlets and the y-axis denotes the makespan. When the numbers of cloudlets are less, the makespan of the three algorithms are convergent. However, LOA produces much better makespan time when the number of cloudlets increases.

In Fig. 3, the comparison of cost is shown between LOA, PSO, and GA. The x-axis indicates the number of tasks and the y-axis indicates the cost per hour of the execution of tasks. The outcomes show the cost of LOA is between PSO and GA although the difference is not great.

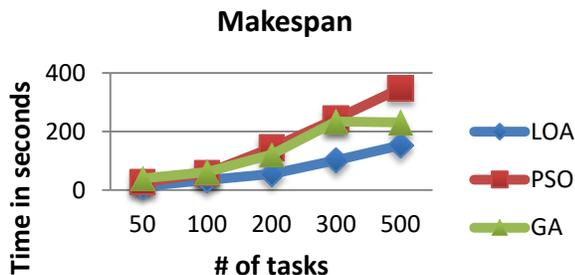


Fig. 2. Makespan results.

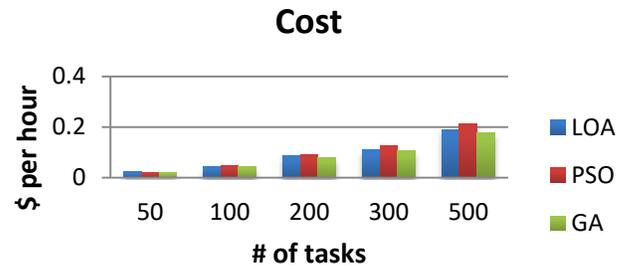


Fig. 3. Cost results.

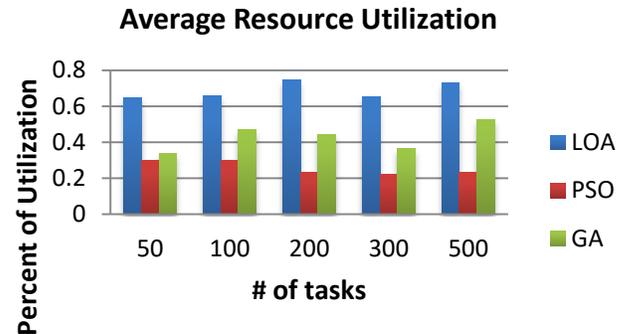


Fig. 4. Average resource utilization.

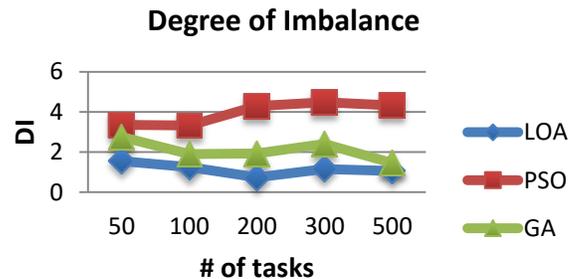


Fig. 5. Degree of imbalance.

Fig. 4 shows the comparison of average resource utilization between LOA, PSO, and GA. It is obvious that LOA provides a very high utilization of resources when compared with PSO and GA.

Fig. 5 explains the comparison of degree of imbalance between LOA, PSO, and GA. The x-axis signifies the number of cloudlets and the y-axis signifies the degree of imbalance. The comparison result tells that LOA produces much better degree of imbalance than PSO and GA.

It is obvious that the proposed task scheduling algorithm based on LOA provides a high performance and much better results than the other two algorithms. It can solve the optimization problems in task scheduling with high performance because it searches for the optimal solution using different strategies. Each solution "lion" has a specific gender and is classified as a resident or nomad, and all of them have their own strategies to search for the optimal solution, as explained previously.

VII. CONCLUSION

Various metaheuristic optimization algorithms have been used to develop task scheduling techniques for cloud computing. In this paper, a new cloud task-scheduling algorithm was proposed, based on the concept of LOA, which is a newly constructed algorithm based on the lifestyle of lions. The performance of the proposed algorithm was compared with that of the PSO and GA metaheuristic algorithms. It provided an outstanding result in minimizing the makespan and degree of imbalance. Also, it produced high utilization of resources.

In future work, we aim to enhance the proposed algorithm to decrease the cost of executing the tasks on cloud resources, using cloud pricing models.

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Restructuring of System Analysis and Design Course with Agile Approach for Computer Engineering/Programming Departments

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Abstract—Today software plays an increasingly important and central role in every aspect of everyday life. The number, size, complexity and application areas of the programs developed continue to grow. Many software products have serious problems in cost, timing and quality. It has become almost normal for software projects to exceed their planned cost and schedule. A significant number of development projects have never been completed and many of them have not met user requirements. Employers are not satisfied with new graduates for a variety of reasons (They do not know how to communicate. They do not have enough experience and preparation to work as a team member. They do not have the ability to manage their individual works efficiently and productively. This work was reconfigured and conducted with Scrum from the Agile methodologies of the System Analysis and Design course, which is especially taught in Vocational Schools and Engineering faculties. The recommended approach is available for software development departments. The suggested approach is applied in System Analysis and Design course.

Keywords—Agile software development; scrum; course re-design; computer science education

I. INTRODUCTION

In this study, it was explained to reconstruct the System Analysis and Design course with Scrum which is one of the Agile technologies for the daily adaptation of the course in order to take the project course in the Higher Schools/Engineering Faculties. It is available for parts of computer. Students want relevant assignments/projects that are engaging, creative and prepare them for their careers. Finishing and research projects are realistic and beneficial for students. It also emphasizes the balance between product and process [1], [2]. Trainees recommend real industry projects to prepare students for industry and improve their implementation skills. It is evident that teaching develops learning by supporting with familiar, concrete and related examples. According to Shaw and Dermoudy, competition tends to create higher academic achievement. Competition in engineering team-based is a way of bringing students' achievements to the top while giving "weak" students confidence and motivation [3].

There are thousands of academic programs in the field of computers in the world. These programs give tens of thousands of computer specialist graduates per year. Less than 15% of them are undergraduate education. What remains is the

software industry. These programs represent a variety of disciplines (including computer science, computer engineering, information systems and software engineering), and are in various academic units (engineering, research institutes and vocational colleges). Employers complain about new graduates for a variety of reasons (I do not know how to communicate, I do not have enough experience and preparation to work as a team member, I lack the ability to manage my own individual works efficiently and productively, organizational structures are insufficient and business practices are inadequate [4].

Because of the increasing use of agile methods in recent years, teaching agile methods for software development has become an important issue [5]. Although some universities have begun to teach lectures on agile methods, they are still quite new [6]. The course "System Analysis and Design" is a suitable course for starting the development of the Agile software because the basic engineering courses mainly teach the traditional plan-oriented approach.

Agile surveys conducted by VersionOne since 2006 show that Scrum is the most common Agile method and that its share is constantly increasing. One of Scrum's key features is that each sprint consists of repeats called sprints, which finish with a subset of the final product properties. The application of agile methodologies has resulted in impressive results in terms of team performance, product quality and customer satisfaction.

Agile development methods have roots in design and development that are based on repeating, increasingly decades before [2]. The 1970s and 1980s included various forms of agile development with modern methods emerging in the 1990s. For example, XP (eXtreme Programming) began in 1996 at Chrysler Corp. During this time, lightweight methods such as Scrum have gained popularity.

The Scrum Guide describes Scrum as "a framework in which people can solve complex adaptive problems while producing and delivering products with the highest possible value" [3]. Scrum consists of a series of short repetitions called sprints. Each sprint simultaneously performs analysis + design + code + test and ends with an output of a subset of a final product specification. This is the final result, unlike the traditional waterfall method, that results in a long linear progression of requirements, design, code and test. Scrum methods are relatively simple and provide greater visibility,

predictability and flexibility. It also encourages high-performance teams. The user supports prioritization of stories/scenarios and job forecasting with story scores. Each sprint has a target that focuses on the punch [4], [5].

CS 4911 is a finishing course organized at Georgia Tech as a sprint throughout the semester [7]. The Rochester Institute of Technology has a computer engineering technology graduation course that uses an agile-like methodology for embedded systems design. Project management emphasizes learning outcomes related to product idea, entrepreneurship and professional skills [8]. [9]. Slovenia Ljubljana University taught and implemented Scrum in a software engineering graduation course [10]. The Royal Swedish Institute (KTH) studied Scrum's integration in mechatronic finishing projects. Their assessment has focused on individual student responsibility and initiative taking [11], [12]. Vicentin applied a two-part survey to assess the impact of Scrum's possible use in a Software Office. Based on the answers, Vincentin Scrum was the result of what could be a good vehicle for managing the squadrons. In Wagh's work [13], Scrum was implemented to provide students with a practical view of the software development industry. In the class project proposed by Wagh, the Scrum application evaluation was carried out through a questionnaire answered anonymously by the students. The aim was to understand how much the students learned and influenced this approach. As a result, many students saw how the project was managed and developed teamwork using Scrum. Questions about the evaluation of the works and the Scrum meetings showed that the day-to-day meetings were the most popular technique in this group and that they needed to evaluate the team calendar, sprint planning, user stories.

In our curriculum, system analysis and design is a tool that allows students groups to develop software in a project course using an Agile (Scrum based) method. One of the skills required to demonstrate this is system design. System design also includes documenting the project. We are designing and introducing an approach to improve the course. In this article we present the relevant approach. This article contributes to the literature by explaining how to reconstruct the courses whose content should be updated according to the conditions of the day.

II. "SYSTEM ANALYSIS AND DESIGN" COURSE

System Analysis and Design course is a profession which is seen within the scope of completion project in Engineering/Institute/Vocational Schools. This course is mostly designed and handled as a process management. The shortest possible definition of system analysis and design lesson is the act of converting a system into an information system. This conversion action is not limited to software. System analysis and design are provided to meet everything needed for a system such as software, hardware, suitable human resources, appropriate physical space and environment. The system is in the center of all activities. Among the expected achievements of the course:

- Identify the types of computer-based systems that the system analyst needs to determine and fulfill its core roles.

- To plan and schedule a project by its activities.
- To design and manage effective questionnaires.
- Create data dictionary entries for the logical and physical elements of the data processing, storage, streams and running systems, based on the data flow diagrams.
- Build databases for information systems.
- Designing output tables and graphics with input screens for information systems users.

These gains are not enough for the software development departments. Today, software development processes are diversified. The course consists of 4-hour sessions per week. At the end of the semester, there will be project presentations of the students, with or without a midterm or final exam. The content of this lesson, which usually lasts 12-14 weeks:

- Introducing systems, roles and development methods
- Understanding and modeling organizational systems
- Project management
- Knowledge acquisition and prototyping
- Use of data flow diagrams
- Analyze systems using data dictionaries, explain job descriptions and structured decisions
- Designing effective output and input
- Designing databases
- Object-oriented system analysis and design using UML (Unified Modeling Language)
- Successful implementation of information systems
- Group Project Presentations

Looking at the course content, especially the group interactions are lacking. It is not possible to measure features, such as working together, sharing information, taking responsibility. It is also not possible to develop these features. In this course, the teacher is a consultant. The teacher examines the work of each group during the weekly lecture hours and has recommendations. However, the work part of the group and its work do not interfere. This makes it hard to guess who finished the project and how much it contributed. In addition, there is no customer as a product owner in the current course content. The absence of the client removes the developed project from the real world and affects the motivation of students negatively.

In this study, System Analysis and Design course is reorganized as content and operation to be used especially in computer sections (software integrated projects). The reason for this configuration is as follows:

- Existing System Analysis and Design course is not enough for today's computer departments. In particular, the course should be conducted in an observational manner.

- Students who develop computer (software) based projects need to develop projects on more realistic conditions.
- Software development alone is no longer possible with the development of software technologies. It is necessary to develop software as a team. It is necessary to manage alignment, information sharing, and task distribution within the team.
- From the software development methodologies, Scrum is the most appropriate method for managing the course.
- Documenting the developed software in succession with success stories and reports and transferring it to the next students so that a software literature can be obtained.

III. COURSE DESIGN

System Analysis and Design is an experience for students in the fields of computer science and information technology, where students combine the skills they learn and apply in an important team project. In order to provide a realistic and motivating experience, the course is structured with Agile contacts, exact dates, genuine customers and competitions. We believe that these elements contribute to the success of the course. Scrum's block diagram of the System Analysis and Design course is given in Fig. 1. Sprints are given with start and end times in the time tables. A new sprint begins immediately with the end of the previous sprint.

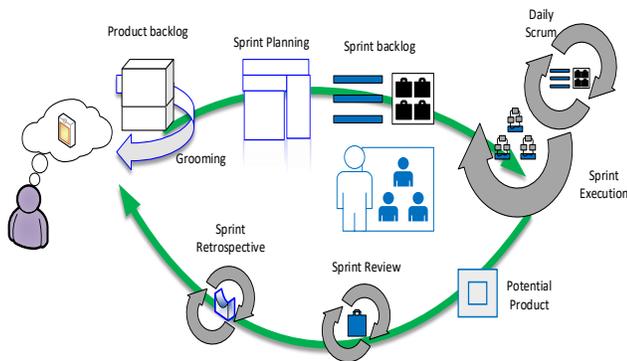


Fig. 1. Scrum process for system analysis and design course.

Table 1 gives the Scrum Sprints used in the course planning. Typically, a SCRUM project requires several iterations or sprints to improve the full set of stories in product accumulation. During the development process, a series of meetings or workshops are organized to configure the entire sprint kit together with the product increment and the product to be developed. These are mainly planning sessions. The Planning sessions development team meets at the beginning of each sprint to plan the work to be developed in future sprint. To do this, the scrum master picks stories from the product's accumulation, and the entire development team analyzes the story and possibly gets a consensus about when it might have been assigned to that story.

TABLE I. CURRICULUM

Sprint 0	Week 1-3	Lessons on Scrum and user stories Presentation of initial product accumulation, prediction of user stories, development of release plan.
Sprint 1	Week 4	Sprint planning meetings Beginning sprint buildup development
	Week 5-6	Project work. Daily Scrum meetings. Do not take care of Sprint accumulation.
	Week 7	Sprint review meetings. Sprint retrospective meetings.
Sprint 2	Week 8	Making Sprint planning meetings. Beginning sprint buildup development.
	Week 9	Project work. Daily Scrum meetings. Do not take care of Sprint accumulation. Sprint review meetings. Sprint retrospective meetings.
Sprint 3	Week 10	Making Sprint planning meetings. Beginning sprint buildup development
	Week 11-12	Project work. Daily Scrum meetings. Do not take care of Sprint accumulation.
	Week 13-14	Sprint review meetings. Sprint retrospective meetings.
Release		Presentation of observational study results. Present your desired functionality in the project.

The planning process continues until product size reaches the sprue size of the selected set of traces. These stories are the main result of the sprint spool planning session and configure the job during the next sprint. The second session is development. A set of stories to be applied to each developer is assigned and studied. This sprint is generally defined as “30 days” a month. Repetition in this study varies depending on the structure of the product produced. Another session is the daily Scrum sessions. The development team analyzes how many hours of work each day should be working if there are any deviations from the planned one as soon as possible. The time or technical difficulties attributed to each story are determined. This iteration is a sprint cycle that can be labeled “24 hours - 12 hours”. The Scrum master notes the amount of time spent and compares it to the amount of time ahead and the expected duration of the sprint. It keeps a graph showing the duration if the last session type is a meeting ending session. After the Sprint is completed, the development team tries to analyze what it does well (to maintain it), analyze what has not been done, and how to improve it so as to follow a retrospective session. After these last negotiations and when the project is not completed, a new sprint will start with a new planning session.

To facilitate project management, each team has a spreadsheet loaded into the special Google Drive/OneDrive folder, which allows students to aggregate basic information and automate all reports and dashboards. The product, which will be developed in the project by looking at the roles and product components in Scrum, consists of laboratory tasks for each team whose main functional characteristics are defined by the content introduced by the teacher in the content.

There are several interpretations of roles in Scrum [14] [15]. However, in this study, product-oriented teachers and

development teams were identified as students. Development teams are encouraged throughout the course to encourage better implementation of mutual knowledge and methodology. Scrum master is one of the students. The role of the Scrum master is decided internally by the team, as it turns between the team members. Thus, the leadership qualities of each member in the team are improved.

Students can develop their homework (in the lab) or weekly (homework) in order to fulfill the estimated development time. Then, at the beginning of each laboratory session, the teacher talks up to five or ten minutes with each group in the daily scrum session and is guided by the scrum master (leading student) and reviews all the work done up to that date. The Scrum master, the leader of the team, records the “clear development time” and “the actual development time” values of “who” and “which story” he did.

Lesson planning consists of four sprints. There is a preparation Sprint (Sprint 0), three development Sprints (Sprint 1, 2, 3) and a release step that includes a finisher. Sprint lasts for 0, 5 to 20 days (1 or 3 weeks). Sprint 0 is a preparation sprint for students to meet with their customers (teachers) to build their product portfolios. Sprint 0 provides students with enough time to talk to their customers about their offers and decide what can be done in the course schedule on a timely basis. Teams should try to develop high-level, concise, and clear user stories to show all the expected features in the software. The relative amount of time per user story is estimated. It is better to start Sprints (1, 2 and 3) on Monday. On the first day of Sprint, the groups realized the Sprint planning meetings. It took 45 minutes to complete the event. Like many similar events, meetings were held on time, so that the class was used efficiently. Planning is primarily used in the development of Sprint Backlog, where the highest priority user stories are received and decided as a team to be added to Sprint Backlog. The Product Owner (teacher) brings top-level user stories to the Sprint Planning Meeting. The team decides together which stories to handle. At the end of this sprint, all resources related to the project are graded. The operation of the Sprint evaluation process in Scrum is given in Fig. 2. According to Fig. 2, the initial-desired product in this work is defined as Initial Input. The final output represents the final product. With the Sprints constantly recurrent, the process evolves towards the final product through product control and feedback.

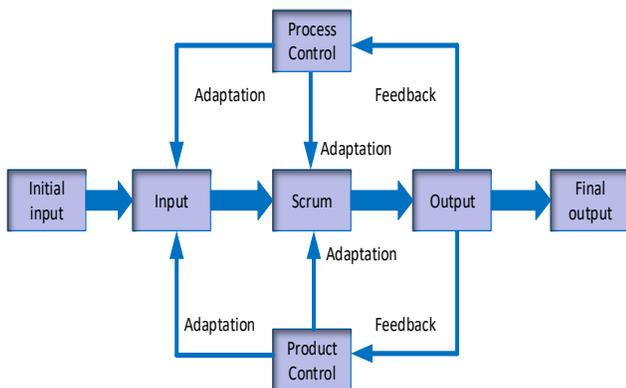


Fig. 2. Sprint processes.

The end of each sprint is designated as Friday. First, each group has to present the status of its projects to the whole class. The groups are obliged to meet with the client (teacher) to talk about progress and present their progress within a few days. Then groups are given 10 minutes to complete the Sprint Retrospective. The release includes the presentation of the results of the observational study of the project. It is also at this stage that the desired functionality is presented in the project.

Following the open questionnaire filled by 28 students before the project presentations, the main results are as follows:

- 92% of the students liked the lab sessions.
- Overall, 84% of the students liked the course to be handled by Scrum.
- 79% of the students liked the evaluation method.
- 86% of students liked SCRUM.
- 72% of the students liked to work in teams.

Also, 3 of the students did not succeed in the class and left in the middle of the class. The remaining 28 students (89.2%) completed the course successfully. 18 (72%) of the students who completed the course got a score of 8 out of 10. Four of the students (16%) were between 7 and 5. The remaining 3 students (12%) were between 5 and 4 (including four).

The results in Table 2 clearly show that the course fully fulfills its overall objectives. The proposed approach is influenced by new learning (Question 2) during software development.

TABLE II. SOME QUESTIONNAIRE SURVEYS

Survey results 2014-2015/2015-2016 (N=28)			
Questions		Median	p-value
1	Benefits of agile software development methodology	4	0.081
2	Contribution of method to new learning	5	0.024
3	Contribution of method to software project development and management	4	0.92
4	Contribution of method to group work in software development process	5	0.85
5	Contribution of method to group communication in software development process	4	0.067

IV. RESULTS AND DISCUSSION

The new course content implemented as a semester in 2014-2015 has increased the success. The questionnaire in Table 2 showed that the opinions of the students were overwhelmingly positive (see Table 2). All students found the course useful (92%). Scrum itself is simple, but its implementation is difficult. For this reason, there is no need for extensive formal courses to promote the concepts. Rather, projects should be preferred as means for bringing together all the different issues that affect implementation and for spreading them against each other. Nevertheless, when compared to traditional plan-based software development, students must have sufficient background in the philosophy and techniques of software engineering and information systems development to accurately assess the benefits and deficiencies of the agile approach.

In addition to teaching everyone involved in the project, the ScrumMaster Scrum should ensure that everyone follows Scrum’s rules and practices. It is especially important to prevent the Product Owner from interfering with team management, redefining the scope or objectives of a Sprint, or adding new requirements when a Sprint starts.

In this study, both the product owner (customer) and the teacher in the position of consultant reduced the performance of the students. Students do not want to see the same teacher in two different roles, and the real customer wants to focus. For this purpose, this consultant has come to the conclusion that a consultant teacher is an assistant but also a teacher in the customer role.

The study is proposed to identify, discuss and quantify how Scrum can become flexible and collaborative in software development teaching. To assess the impact of this approach, a survey was conducted among students who completed the course at the end of 2014/15. Given the perspective of the pupils, the approach allows students to gain experience. The adaptations that students make when they consider the flexibility, communication and release of the functional parts of the system are important.

The System Analysis and Design course is often project-based and can be easily designed to meet the needs of others. Such needs are also available at the university level, as new technologies are constantly being sought to support faculty, research, teaching and services throughout the university. This course also enhances intra-departmental collaboration opportunities where the skills and efforts of computer science students focus on needs. This model provides students with authentic learning opportunities that they have been working on in college and real-world projects that the community has benefited from.

The grading of the note was obtained at the end of each Sprint as a result of observations of the Scrum master and the product owner (teacher). Table 3 shows the notes the groups received. Here it appears that the grades are generally increased with each Sprint. The group with the highest rating is Group 7. The overall increase in grades indicates that students are used to Scrum.

TABLE III. GROUP’S NOTES DURING THE PROJECT DEVELOPMENT PROCESS

Sprint name	Group name	Grade	Total Grade
Sprint 0	Group 1	60	485
	Group 2	70	
	Group 3	75	
	Group 4	65	
	Group 5	65	
	Group 6	70	
	Group 7	80	
Sprint 1	Group 1	70	500
	Group 2	75	
	Group 3	60	
	Group 4	70	
	Group 5	70	
	Group 6	75	
	Group 7	80	
Sprint 2	Group 1	75	548
	Group 2	75	
	Group 3	80	
	Group 4	75	
	Group 5	80	
	Group 6	80	
	Group 7	83	
Sprint 3	Group 1	70	538
	Group 2	75	
	Group 3	76	
	Group 4	80	
	Group 5	77	
	Group 6	80	
	Group 7	80	
Release	Group 1	75	570
	Group 2	78	
	Group 3	80	
	Group 4	82	
	Group 5	80	
	Group 6	85	
	Group 7	90	

The last line in Table 3 shows the final grades received by the release groups. Comparison of these notes with the past three-year average is given in Fig. 3. Group 6 and Group 7 do not have notes in 2011 and 2012. Since the number of students was not sufficient, these groups were not formed in the relevant years.

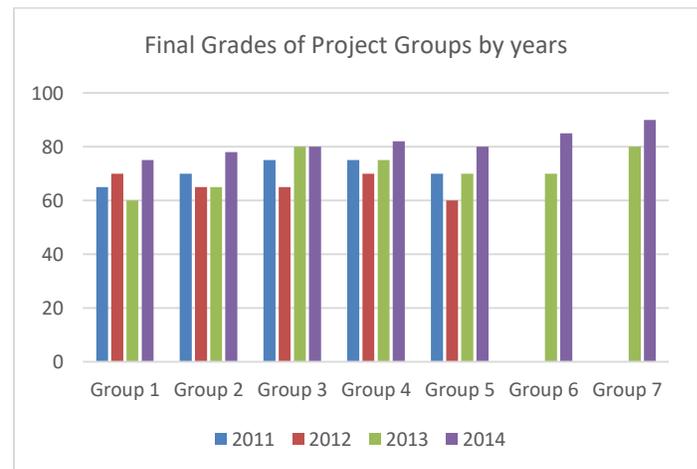


Fig. 3. Comparison of grades by years.

According to Fig. 3, the average of the final grades of the last three years is (2011, 2012, and 2013) lower than the year 2014 when the course was processed with Scrum. These results show that if the course is processed with Scrum, it will be more efficient. Not only the notes, but also the self-confidence that students gain is influencing the performance of the proposed approach positively.

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Linear Prediction Model for Effort in Programming based on User Acceptance and Revised use Case Point Method

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Abstract—As long as most of the processes of verification and validation of software to grant acceptance by the customer/user, are subjective type, it is aimed to design a standard mathematical model with empirical to perform an appointment with areas or stages where development teams most fail involving large-scale software projects. This model will be based on a survey that the user must fill as going testing and validating the software, and which response curve must be linear with respect to the software development process. This paper aims to discuss the aspects surrounding the estimation of mathematical model in the validation and acceptance by a user through the revised Use Case Point Method. First, an assessment of the most recent techniques of application of the method are done, and then a simulation of the process of acceptance and validation by a standard user (Beta Test) will be taken as a practical example. For purposes of this paper, revised use case point method (Re-UCP) must have a specific weight, based on the prerequisites for the development of large-scale software. Once obtained this weighting, the user shall assess the finished product and then an approximation function will be to determine the coefficients of the final model approach, and indicating that is the efficient trend of the development team.

Keywords—Function; point; software; engineering; mathematical; model; large-scale; programming; acceptance; validation

I. INTRODUCTION

The evaluation of design and usability, centered on user, has become a common practice in many organizations, however, in most software development companies is still in its infancy and is not used as often. Development cycles of typical software engineering do not use these practices because they may represent additional costs, especially those related to governmental or educational institutions [1]. Currently, usability, understood as an effective means for obtaining acceptability and validation by the user, is an area that takes strength worldwide in software engineering. Countries that are traditionally powers in software development are concerned more by the satisfaction and comfort that produce their products on their customers, taking it as their top priority, while one hand on the performance of the product. Starting with software for personal computers, cellular and even system for cars, they have adapted better to the type of people who require, avoiding with this, that people take too long to use and optimally understand the software of the equipment [2]. Lately, there have been significant changes in the computing

revolution; changes covering all aspects of its main function: ‘To serve mankind’ changes both quantitative in nature, as some more fundamental emerging diversity located in the global context. It is known, moreover, that computers are included in a wide range of aspects of our daily life, to the point that directly influence our lifestyle. The human-computer relationship is intensifying on a global scale that result in even governmental, cultural and / or social tensions, issues that fall outside the scope of this study; however, the importance of thoroughly analyze these characteristics lies in the fact that this relationship (human-computer) is the spearhead to generate a vast multidisciplinary field, if willing, that is just beginning and whose growth is exponential [3]. In conceptual terms of human-computer relationship, the validation and acceptance of usability refers to the process with which the interaction is designed with a computer program. The term is also often used in the context of products like consumer electronics or in areas of communication. It can also refer to the efficient design of mechanical objects such as, for example, a handle or a hammer. As rules adopted worldwide and given the growing importance of ensuring the proper functioning of computer systems, emerged the need to establish parameters and standards governing the acceptance and usability of computer systems. This paper is based on the recommendations of the ISO/IEC 25010 standard which establishes regulations about quality requirements and evaluation of large-scale software development. It is well known that the acceptance and validation of a software depends purely on human behaviour and preferences, based, of course, in their ability to interact with the technology that is being presented, this is why in this paper is established a mathematical model with linear trend and empirical basis, as a reference between the work of a development team, estimated effort of development by the Rev-UCP method and preferences of a user. Here, will be used the experiences of software development of operational management of a private hospital, which is considered large-scale and small modules will break down in this way to be able to use this proposed model. As a case study, this article will discuss the acceptance and validation of an operational management software in a private hospital, as it can give a tangible perspective of the advantages or disadvantages of the software to analyze the acceptance by the user.

II. THEORETICAL BASIS

A. Requirements Engineering, Assuring the Product Quality

Properly Application of Requirements Engineering increases the chances of producing software that meets the needs of users, many errors in the requirements stage are rooted in the ambiguity presented between end users and developers.

On his book, Pohl [4] suggest that the 'vision' defines the change the reality of any system. In other words, a vision states the goal of making any change on any system. When a client have a vision we have to mind on the goal to change the reality of that client. However, Pohl also talks that the vision must be supplemented with the context of the system, in fact, they are taken as the two main inputs of the engineering requirement.

Much of the problems that arise during the process of software development, due to the lack of a proper process of definition and understanding of the requirements and the problem to solve, and the unclear interpretation of customer needs. That is why requirements management, in software engineering, is one of the main strategies to ensure the quality of applications from the earliest stages of software development [5].

B. Understanding the Software Complexity and Its Relation with Acceptance

The complexity of the software is, by tradition, a linearly direct indicator of software quality and, especially, the cost. While the complexity is greater, so the cost will be. In recent years they have invested large amounts of money and effort in the development of techniques and metrics to "measure" the complexity of software modules all dimensions. Obviously, many of these measures are correlated with each other. Understanding these relationships is important metrics to assess themselves and ultimately reducing software development efforts and maintenance [6].

Jay et al. [6] found a statistical method to establish the linearity between the lines of program code and McCabe cyclomatic complexity of using empirical inferences and refuting earlier studies had conflicting results. It also suggests that there is some instability in the predictions based on empirical collinear factors, in any case, dependent on language and the complexity inherent in it. In principle, to establish a relationship between the complexity of software and acceptance by the customer is quite difficult as acceptance depends solely on human behavior which can not be modeled linearly as suggested by this study, is why it is done necessary to have statistical tools with the same type and customer/user feedback to find satisfactory results of our interest.

Following the scheme proposed by Bentley [7] in which the software should follow three basic stages:

Verification: where it is confirmed that the software meets all technical specifications.

Validation: that software should meet all business requirements.

Find Defects: Any variation between the output of software and expected.

The true value of software testing go beyond pure test the code. It also examines the behavior of the software from the premise that the code is not necessarily bad if the behavior is too [7].

Meanwhile, Cristia [8] raises two questions regarding verification and validation.

Verification: Are we building the right product?

Validation: Are we building the product correctly?

In this sense, verification is an activity carried out by engineers having at hand a model of the program, while validation is carried by the user and must make taking into account what is expected by the program. Cristia, at his work proposes the existence of various techniques for validation and verification, ranging from the most informal and empirical to the formal involving calculation refinement, etc. [8].

Jones in his work of 2012 [9], gives an economic to the third stage of the previously proposed scheme approach. He mentions that the industry spends about 50% of the cost of development, finding and fixing software defects. It indicates, moreover, that a synergistic combination of defect prevention, removal of defects in prototyping and formal test can dramatically reduce costs by more than 50% compared with the results of 2012 [9].

C. Objects Oriented Programming and use Case Points

As Glasser [10] suggests, object-oriented programming makes programs organized as a collection of interactive objects with their own data and functions. One of the advantages of this paradigm is that objects can be reusable and configurable. Separating concerns and focusing on each object separately makes oriented objects very attractive, especially for large-scale software programming.

This facilitates, in the best, identification and classification of the use cases.

Wirfs [11] on her presentation describes the action to determine the use cases as a full script, and makes it an art, calling it 'The art of writing use cases'. There she mentions, step by step, philosophy of establishing a use case ranging from understanding the case models, including actors, diagrams and glossaries, to a detailed and accurate description of the prototype to develop. There is highlighted the fact that each use case consists of a reference and a different perspective that involves, of course, the actors considered in the step. The mention of the requirements is a 'point of honor' in her presentation because it is repeatedly diagram as an essential basis for all work of lifting use cases.

On his book, *Software Engineering*, Marsic [12] indicates that projects with many complicated requirements take more effort to design and implement than projects with few simple requirements. In addition, the effort depends specially on what tools the developers employ and how skilled the developers are. The factors that determine the time to complete a project include:

- Functional requirements: The complexity of use cases, in turn, depends on the number and complexity of the

actors and the number of steps (transactions) to execute each use case.

- Nonfunctional requirements: These describe the system nonfunctional properties, known as FURPS+, such as security, usability, and performance. These are also known as the technical complexity factors.
- Environmental factors: Various factors such as the experience and knowledge of the development team, and how sophisticated tools they will be using for the development.

An estimation method that took into account the above factors early in a project life cycle, and produced a reasonable accurate estimate, say within 20% of the actual completion time, would be very helpful for project scheduling, cost, and resource allocation [12].

However, Jones said that more than 80% of software applications are not new because they were developed in past. Because of this, most applications today are replacements for older and obsolete applications. Because these applications are obsolete and also in spite of the lack of information documents, the older applications contain hundreds or thousands of business rules and algorithms that need to be transferred to the new application. This is a different paradigm in the development of the list of requirements for large-scale software [13].

Jones also refers to the vital importance of the intervention of software engineer in raising the requirements for the application, because it is a serious mistake to think that the user, who is not a software engineer, is able to express, optimally, 100% of these requirements, and this lies in the fact that precisely these requirements represent the state of the art of engineering applicable to software. He mentioned, in any case, that one of the ways in which we can base this symbiotic relationship is data mining for business rules and appropriate algorithms. And while this happens, data mining is also used for sizing through function points and lines of code [13].

D. Revised use Case Point Method as Extension of Function Point Method

In addition to his work of 2012, Jones emphasizes, among other things, that there are two very useful metrics to show both the economic value and the quality of software. These metrics are:

- Function points for normalization of results.
- Defect removal efficiency [14].

In the work of Manzoor et.al [15], is indicated that the UCP method is originated, in principle, from the method of Function Point except that the UCP makes an analysis of requirements in the object-oriented process. It begins with the system functionality measurement based on the Use Case Model on a count called Unadjusted Use Case Point (UUCP). The technical factors in which UCP is based are equal to those of function points. The UCP estimates the total size of the system that leads to the goals of acceptability and user validation [15]. In other work, Mazoor et.al, suggests that the validation process involving Re-UCP should be carried out for different large scale software projects in order to increase and perform a

better acceptability. Future research should be conducted to enhance the benefits of Re-UCP for large-scale software projects through vertical and horizontal [16].

- Transactions of Re-UCP:

The calculation process involved in UCP need case diagrams and descriptions. To understand the logic of UCP utilization, it must be known that there are several steps for implementing a use case. These steps are so called ‘transactions’ [17].

- Steps for an effective Re-UCP:

Step 1: Classification of Actors through calculation of its weights UAW (Unadjusted Actor Weight) [18]. Table 1 refers to classification of actors:

TABLE I. CLASSIFICATION OF ACTOR

Actor Category	Description	Actor Weight
Simple	Actor use API's	1
Medium	Actor use Protocol	2
Complex	Actor use GUI's	3

UAW has an equation:

$$UAW = \sum_{i=1}^n AW_i \tag{1}$$

Where:

n= Number of Actor.

AW= Weight of each Actor Category (Table 1).

Step 2: Classification of Unadjusted Use Case Weight (UUCW) through its calculation. Table 2 represents the number of transactions in a use case.

TABLE II. CLASSIFICATION OF USE CASE

Use Case Category	Description	Use Case Weight
Simple	A use case has 3 or less transactions	5
Medium	A use case has 3 to 7 transactions	10
Complex	A use case has more than 7 transactions	15

From this classification, the study can synthesize the equation that allows the study to calculate the UUCW:

$$UUCW = \sum_{i=1}^n UUCW_i \tag{2}$$

Where:

n= Number of Use Case.

UCW= Weight of each Use Case Category (Table 2).

Step 3: Calculating Unadjusted Use Case Point (UUCP).

$$UUCP = UUCW + UAW \tag{3}$$

Step 4: Calculating Technical Complexity Factor (TCF). TCF is involved with the software size, considering the technical aspects of the system. This is ranged from 0 (non-

relevant) to 5 (important factor) [18]. Table 3 summarizes the technical factor weight.

TABLE III. TECHNICAL FACTOR WEIGHT

Ti	Technical Factor	Weight
T1	Required Distributed Systems	2
T2	Response Time Is Important	1
T3	End User Efficiency	1
T4	Required Complex Internal Processing	1
T5	Reusable code to Focus	1
T6	Installation Easy	0.5
T7	Usability	0.5
T8	Cross-Platform Support	2
T9	Easy To Change	1
T10	Highly Concurrent	1
T11	Custom Security	1
T12	Dependence On Third-Part Code	1
T13	User Training	1

TF is obtained as the sum of multiplying score and weight and the following is the equation [18]

$$TF = \sum_{i=1}^{13} Score_i * Weight_i \quad (4)$$

And TCF is obtained using TF

$$TCF = 0.6 + (0.01) * TF \quad (5)$$

Step 5: Environmental Complexity Factor. It is determined through a score of between 0 (no experience) to 5 (expert) for each of the 8 environmental factors [17], as referred in Table 4.

TABLE IV. ENVIRONMENTAL FACTOR WEIGHT

Ei	Environmental Factor	Weight
E1	Knowledge of the Project	1.5
E2	Application Experience	0.5
E3	OO Programming Experience	1
E4	Lead Analyst Capability	0.5
E5	Motivation	1
E6	Stable Requirements	2
E7	Part Time Staff	-1
E8	Difficulty Programming Language	-1

First, the study should calculate the previous EF (Environmental Factor) and then calculate the ECF.

$$EF = \sum_{i=1}^8 Score_i * Weight_i \quad (6)$$

and ECF:

$$ECF = 1.4 + (-0.03 * EF) \quad (7)$$

Step 6: UCP (Use Case Point) [17].

$$UCP = UUCP * TCF * ECF \quad (8)$$

Step 7: Calculating the effort. For the purpose of this investigation, the latter factor Effort is used to determine how much time/hours/staff was invested in the development of the application and thereby effectively determine quantitatively if

the expectations and requirements of users are met and if the development team is working efficiently. The value of effort is obtained by multiplying the value of UCP and the constant ER in staff hours/UCP. Sholiq suggest that a value of ER equal to 20 staff hours/UCP can be used. Following this proposal, for small and medium-scale business applications the ER can be 8.2 or 4.4 in the case of development of websites using a template or component [17].

$$Effort = UCP * ER \quad (9)$$

E. Linear Model for Mathematical Characterization, using Least Square Model

When a linear pattern is formed from a graph of scattered data, the relationship between the two variables is often modeled by a straight line [20].

The Statistical Models traditionally are used to predict the response of a dependent variable on the observed values of the independent variables. The independent variables are known better as predictor variables. Using linear models as predictor for phenomena can be very straightforward [19].

Because of the relation between the score and production effort of software, obtained via the method of Re-UCP, and the score given by the user, upon completion of the software, is linear where the desired value is a slope equal 1, was chosen for purposes of this research a model scheme with quadratic approximation or least squares.

Van der Geer in 2005 associated with the statistical approach, behavioral science through the use of least squares. The method of least squares is about estimating parameters by Minimizing the squared discrepancies Between Observed data, on the one hand, and Their expected values on the other [21].

Schmidt, in his 2005 project [22] proposes a parameter estimation based on linear regression of least squares with an L1 penalty in the regression coefficients. Indicating the special interest in this issue given the appeal that may be able to create fairly accurate prediction models with the simplicity of a well-known mathematical methodology.

The main work of Schmidt, beyond focusing directly on the properties of the model was the assessment of a variety of previous approaches to the estimation of these parameters.

• The Regression Problem

The most frequent use of LS was linear regression, which corresponds to the problem of finding a line (or curve) that best fits a set of data points. In the standard formulation, a set of N pairs of observations (Y_i,X_i) is used to find a function relating the value of the dependent variable (Y) to the values of an independent variable (X)[23].

The prediction is given by:

$$\hat{Y} = a + bX \quad (10)$$

Where:

a: Intercept with Y axis.

b: the slope of the function.

The least square method involve the estimate of these last parameters as the values which minimize the sum of the squares between the real measurements and the theoretical model [23].

The minimizing expression is:

$$\varepsilon = \sum_i (Y_i - \hat{Y}_i)^2 = \sum_i [Y_i - (a + bX_i)]^2 \quad (11)$$

Where:

ε : Error to be minimized

Using the property that derivating a quadratic expression the study can achieve its minimum value. Calculating the derivative of ε with respect to **a** and **b** and making them to zero, gives the following set of equations:

Derivative respect to **a**

$$\frac{\partial \varepsilon}{\partial a} = 2Na + 2b \sum X_i - 2 \sum Y_i = 0 \quad (12)$$

Derivative respect to **b**

$$\frac{\partial \varepsilon}{\partial b} = 2b \sum X_i^2 + 2a \sum X_i - 2 \sum Y_i X_i = 0 \quad (13)$$

Solving these equations results the following least square estimates of a and b as:

$$a = M_Y - bM_X \quad (14)$$

Where:

M_Y : Mean of Y

M_X : Mean of X

And:

$$b = \frac{\sum (Y_i - M_Y)(X_i - M_X)}{\sum (X_i - M_X)^2} \quad (15)$$

[24].

F. Method for Linear Adjustment using Average Line

Based on the well known Line Equation [25]

$$y = mx + b \quad (16)$$

The study would have two lines with m_1, m_2, b_1 and b_2 , these are the parameters which define the straight average, if the study does the semi-sum of the coefficients m_1, m_2, b_1 and b_2 , the study obtains m and b of the average line. While semi-difference give us the range of uncertainty, Δm and Δb .

So, the semi-sum:

$$m = (m_1 + m_2)/2; b = (b_1 + b_2)/2 \quad (17)$$

and the semi-difference:

$$\Delta m = (m_1 - m_2)/2; \Delta b = (b_1 - b_2)/2 \quad (18)$$

Considering that $m_1 > m_2$ Therefore the best set of lines that inform us within what range the study expects to drop a new measure is given by the expression:

$$y = (m \pm \Delta m)x + (b \pm \Delta b) \quad (19)$$

To graph the lines of maximum and minimum slope should mark the centroid, in other words, the $P(\bar{x}, \bar{y})$ point that emerges from the average of the coordinates from the data:

$$\bar{x} = \frac{\sum_{i=1}^N x_i}{N}; \bar{y} = \frac{\sum_{i=1}^N y_i}{N} \quad (20)$$

Where:

N is the number of data.

(x_i, y_i) are the experimental data.

Once located the centroid, draw the line with maximum and minimum slope passing through this point $P(\bar{x}, \bar{y})$ [26].

G. Human Behaviour in Software Technology

Today the changes generated by technological advances, affect the behavior and actions of the individual, leading to approach new rules or disciplines to address and provide answers to the problems generated by the Information and Communication Technologies.

Kusumari et al. [28] said that capability of using software development and collaboration tools would increase the quality of resulting software and, this way, may incide in acceptance and validation. Some calculated tools and/or models would make the development phase easier to do.

Humans are an integral part of a more complex systems. If the study wants to describe a system of this type with good accuracy, it is necessary to model the human components with the same precision as the technical components. Human behavior is structurally very complex. As human behavior is influenced by physical, emotional, cognitive and social factors, it is very intricate [29].

Ghezzi et al. [30] in their work of 2014 emphasizes the importance of knowing and predicting the different behaviors of users for successful software application, which, the fact, dismiss these factors can lead almost always failures of type techniques and even non-technical that in the end entail significant loss of economic order. However, it takes into account when the number of users grows as it is clear that the behavior will vary greatly; in any case, a population of users of the same application can be handled uniformly, in both, the respective corrective training and knowledge in the application itself is true.

Part of these corrections should be made in the software development stage involving users in the same [30].

III. CALCULATIONS DEVELOPMENT

To start the calculations, the paper proposes the following block diagram which will guide the reader step by step analysis of the study as shown in Fig. 1:

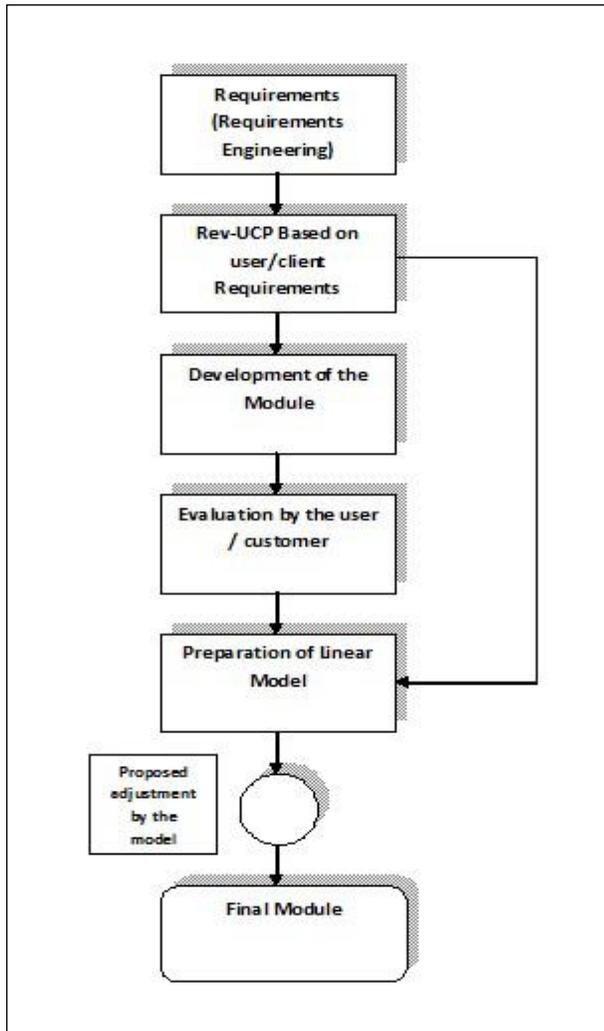


Fig. 1. Block diagram of the steps in the development of study.

This algorithm is repeated with each module or use case, and would be adjusted as software development advances.

This linear algorithm was chosen because its scalability is better to those with feedback, ie, the response times are much better and more tailored to customer needs.

In this study, it has three possible scenarios:

- Existing conditions given by labor and programming resources.
- Ideal conditions given by the Rev-UCP and requirements analysis
- The final conditions of the product are given by acceptance testing by the customer / user.

Being the analysis of software programming of large scale, it was decided to segment the application in modules which

will show to the user for evaluation through a form which will have a weighting on each stage of software development. Evaluating the results provided by the user on the results obtained by the programming team can establish a linear relationship which comes from the method of average line adjustment.

H. Calculating Rev-UCP for each use Case as Ideal Conditions

To start the investigation, the study takes as reference various methodologies which were tested with different scenarios associated with the same large-scale software development, which is a system for operational management of a clinical laboratory based in the cloud. Was chosen the method of Rev-UCP which throws the study with great accuracy which is the effort required to develop such software, the first step was to identify, from customer requirements, what are the use cases on each module as an integral part of the system. The following format was used to identify and classify each use case, as assigned in Table 5:

TABLE V. USE CASE FORMAT

Catalog Information			
Project	Operative System for Private Hospitals		
Author	Fahad		
Version	0.1	Status	Development
Use Case Definition			
Code	Use Case 01		
Title	Enter patient data		
Objective	Enter name, identity card number, date of birth, address, height, weight, medical history, photography.		
Description	Entering via the keyboard, the data mentioned above.		
Actors	Client/user		
Prior Conditions	Client/user must be authorized for this action, database is able to accept this data.		
Main Scenario	(A) The user opens the patients form. (B) Entering patient details. (C) Check that everything is correct before accepting. (D) Accept the entered data. (E)The system checks if exists previous data related to the identity card. (F) The system drops a message with satisfactory transaction.		
Alternative Scenario	(A) The system tells the user that the identity card already exists and gives the possibility to modify any data if required. (B) The user modifies some data and accepts. (C) The user closes the form.		
Exception Scenario	(A) The system tells the user that the identity card already exists and gives the possibility to modify any data if required. (B) The user delete all the information. (C) The user closes the form.		
Success Condition	All data entered is saved and organized successfully and displayed through a flat pdf format.		
Hypotheses	When you delete data from a patient, what happens with the clinical history done in the laboratory?		

Using this format, and meeting customer requirements, there were 85 cases of use identified and listed below with their respective calculations based on the Rev-UCP method, note the

study decided to break down each use case and apply the methodology for a more accurate perspective of the curve of effort required by the software to develop, as assigned in Table 6:

- Use Case 1: Enter Patient Data

TABLE VI. USE CASE 1: ENTER PATIENT DATA

Enter Patient Data	
UAW	3
UUCW	5
UUCP	8
TF	37
TCF	0.97
EF	29.5
ECF	0.515
UCP	3.99
Effort	79.8

The above calculation yields the following segmentation in terms of timely dedication of the use case, as assigned in Table 7:

TABLE VII. DISTRIBUTION IN PROJECT STAGES OF USE CASE POINTS

Enter Patient Data		
Stage	Percentage	H/M
Analysis	10	7.98
Design	15	11.97
Programming	40	31.92
Tests (Functionality)	5	3.99
Tests (Errors)	5	3.99
Tests (Efficiency based in exec time)	5	3.99
Benchmarking (PC's Resources)	5	3.99
Tests (Database)	5	3.99
Tests (Overload and Tuning)	5	3.99
Tests (Running)	5	3.99
Total	100	79.8

I. Existing Conditions of Labour Resources and Delivery Time

The workforce of the group under study in this paper consists of one project leader, one quality expert, two programmers analysts, one GUI designer and two senior programmers. Clearly each module, section or segment of the software has its own characteristics and the team to develop them may vary over time. However organizational behavior can be modeled linearly under the requirements of effort given by the Rev-UCP method. The following Table 8 shows the time available for the project for each position:

TABLE VIII. WORK TEAM

Code	Quantity	Description	Years of Experience	Hours/Day
PL1	1	Project Leader	15	2
QE1	1	Quality Expert	12	1
PA1	2	Programmer Analysts	3	4
GD1	1	GUI Designer	8	3
SP1	2	Senior Programmer	10	4

Using the following formula the study can obtain the total hours/man available for the project:

$$HM = \sum (Code_{Quantity} * HD) \tag{21}$$

Where:

HM= Hours/man a day.

Code: Type of staff.

Quantity: The number of people of a type available for the project.

HD: Hours a day.

For example, for a time span of 40 days for delivery of the product it has a total of:

$$TotalHM = 40 * 22 = 880Hours/man \tag{22}$$

The total work of the development team for Use Case 1 is reflected in the following Table 9:

TABLE IX. DISTRIBUTION IN PROJECT STAGES OF REAL PROGRAMMING PROGRESS

Enter Patient Data		
Stage	Time per Stage	Σ
Analysis	6	6
Design	9	15
Programming	55	70
Tests (Functionality)	5	75
Tests (Errors)	2	77
Tests (Efficiency based in exec time)	4	81
Benchmarking (PC's Resources)	8	89
Tests (Database)	6	95
Tests (Overload and Tuning)	12	107
Tests (Running)	1	108

Clearly, if the team requires more time than stipulated by the Rev-UCP method may impact on the real costs of software and should optimize this feature through a linear regression for a series of standardized points on a plot where the horizontal axis are values estimated by the Rev-UCP method and the vertical axis are the actual values provided by the development team.

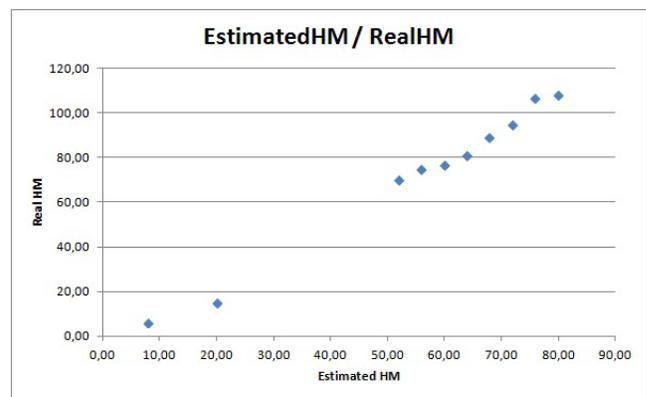


Fig. 2. Estimated HM Vs. Real HM in scattered form.

Because the data are scattered as shown in Fig. 2, must do a linear quadratic regression approach explained in the

theoretical basis for finding the best line that fits the data. If properly apply linear regression equations, then yields the following result:

$$F_{real}(x) = 1.474x - 9.472 \quad (23)$$

And the plot is shown in Fig. 3:

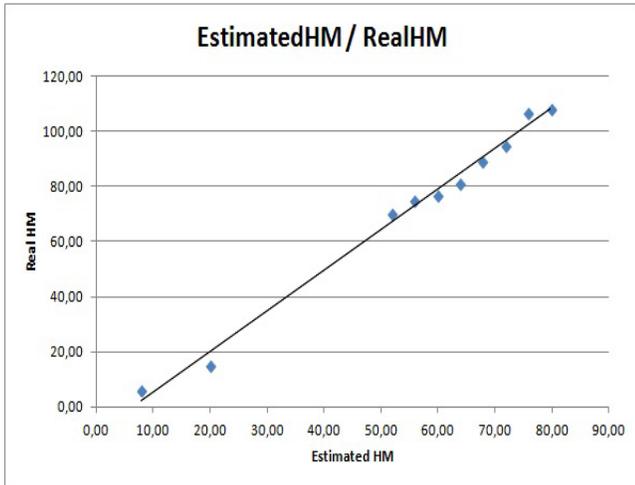


Fig. 3. Estimated HM Vs. Real HM With linear approximation.

J. Conditions of Evaluation and Acceptance by the Customer/User

While it is true that the calculation of the estimated effort through the Rev-UCP method is a fairly accurate approximation, the study finds that user or client preferences differ somewhat from those estimates, even may differ medium or largely from real effort applied to the development of the module to be evaluated. In the case study of this research, the study find this feature because it is obvious that is very difficult to model accurately and precisely the behavior, tastes and human preferences.

In this section, Fogg says that can be used to design technological channels influence the behavior of a user over the use of software, however, people do not understand what factors lead to change behavior and that's why some persuasive design fails [27].

In order to rate the acceptance and validation of client/user, the study used a table that automatically weighs each stage of the process, one by one, and thus can establish a linear relationship to the effort estimated by the Rev-UCP method.

As was discussed above in the introduction, to this applies an alpha test type by the customer in development site. The user naturally observing and recording errors and problems of use. This test was conducted in a controlled environment, as summarized in Table 10.

TABLE X. SURVEY THAT THE USER MUST FILL OUT WHEN TO ALPHA TEST

Description	Value Given By User
Is the prototype performing the agreed and expected functions correctly?	85
Is the prototype achieving specific goals?	93
Does the prototype has the appropriate set of functions for specified tasks?	95
Does the system showing actual transaction?	98
Does the user can interrupt an operation without affecting the normal operation of the prototype?	75
In case an error occurs, the prototype is still functioning normally?	85
Is the prototype able to return to a stable state after an error occurred?	65
Do users perform their tasks properly in the shortest possible time?	90
Is it appropriate the size of the text?	80
Does the physical space used is appropriate?	85
The amount of information is well distributed?	95
Does the application enables the user to feel comfortable?	100
Is there default values?	88
Do the actions can be performed simply in a few steps?	92
Is there clarity of the elements of the interface?	78
Are the messages properly notifies the action that the user is going to carry out?	66
Are the controls properly selected for each function?	79
Is it easy to recognize quickly and clearly what actions the user can perform on an interface?	91
Are there elements that show the progress of a transaction?	93
Are the controls interfaces, provide help or information from its use?	87
Do the data is displayed complete and easily?	100
Can You easily perform actions on the data?	100
Can you search and access data quickly?	99
Is it editable the content entered by the user?	78
Is the correction of errors in input data allowed?	86
Do actions can be canceled without detrimental effects to normal operation?	86
Is the prototype can be adapted to the needs of different users?	88
Does the design is consistent across all screens of the prototype?	92
Are the controls of the same type maintain the same behavior?	99
Are the controls always kept in the same position of the interface?	100
There are mechanisms for validating input data provided?	94
There are mechanisms that facilitate the user to input data provided?	95
Do error messages represent clearly and concisely the error occurred?	85
Do error messages suggest a solution to the problem occurred?	68
Do help messages are clear and concise?	79
Do background colors used in the elements of the user interfaces are always the same?	78
Can foreground elements (either text or images) easily distinguished background?	85
Are there non-aligned or disorderly elements?	86
Are the sections where the interface is divided, remain uniform throughout the application (prototype)?	87
Are the actions and tasks designed to perform as fast and intuitive as possible?	96

The value given by the user corresponds to the following classification, as demonstrated in Table 11:

TABLE XI. WEIGHTING GIVEN BY THE USER

Not fulfilled	Poorly Fulfilled	Mildly Fulfilled	Fulfilled	Totally Fulfilled
to 20	21 to 40	41 to 60	61 to 80	81 to 100

Each question has a direct impact based on percentage on some stages of development. Tables 12 and 13 below are shown an example of how the weighting is calculated, the study must add that these tables are entirely empirical and developed based on field experience of authors.

TABLE XII. WEIGHTING GIVEN BY THE USER PART 1

Question	Value Given By User	Analysis	Design	Programming
	85	17		34
	93	9,3		37,2
	95	9,5	9,5	19
	98	9,8	19,6	9,8

TABLE XIII. WEIGHTING GIVEN BY THE USER PART 2

Functionality	Errors	Efficiency	PC Resources	Database	Tuning	Running
25,5		8,5				
27,9		18,6				
38					9,5	9,5
29,4	9,8			9,8	9,8	

Once the survey is completed weight / total value of each stage of the process is calculated using the following formula:

$$ValueStage_i = \sum_j^n W_j \quad (24)$$

Thus, the forty questions involved in the survey have their weightings in each stage of the process until the following total weight, as summarized in Table 14:

TABLE XIV. TOTAL WEIGHTING FOR STAGE OF THE PROCESS

	Values Obtained	Expected Values	Rate
Analysis	301,9	330	91,48%
Design	617,7	710	87,00%
Programming	425,8	480	88,71%
Functionality	448,7	510	87,98%
Errors	245,2	300	81,73%
Efficiency	236,3	270	87,52%
PC Resources	341,2	400	85,30%
Database	305,7	330	92,64%
Tuning	282,6	320	88,31%
Running	295,9	350	84,54%

Once the relationship between Obtained Values and Expected, proceed to establish a new relationship, now, between user perception and the real effort used for the development team in programming the module, using the following Table 15:

TABLE XV. RATE USER EVAL VS. ESTIMATED HM

	Real	User Perception %	Rate from real
Analysis	6	91,48%	5,49
Design	9	87,00%	7,83
Programming	55	88,71%	48,79
Tests (Functionality)	5	87,98%	4,40
Tests (Errors)	2	81,73%	1,63
Tests (Efficiency based in exec time)	4	87,52%	3,50
Benchmarking (PC's Resources)	8	85,30%	6,82
Tests (Database)	6	92,64%	5,56
Tests (Overload & Tuning)	12	88,31%	10,60
Tests (Running)	1	84,54%	0,85

And then the study proceeds to represent these values, by way of summation in a graph whose horizontal axis (X axis) is the values obtained through the use of Rev-UCP method, as is shown in Fig. 4:

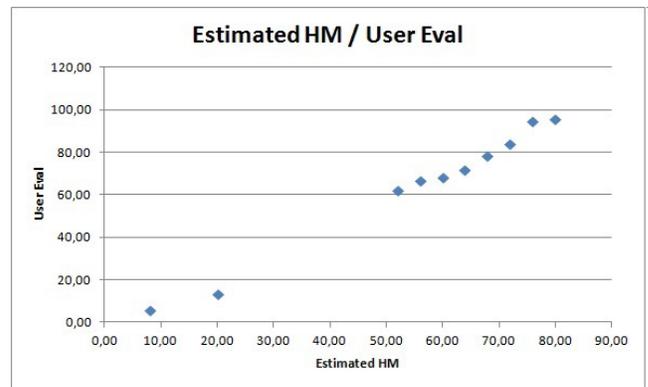


Fig. 4. Estimated HM Vs. User Perception.

And this data optimization depicted in a scattered way is also given by a linear regression based on the method of least squares, and whose equation is:

$$F_{user}(x) = 1.301x - 8.174 \quad (25)$$

And the plot is shown in Fig. 5:

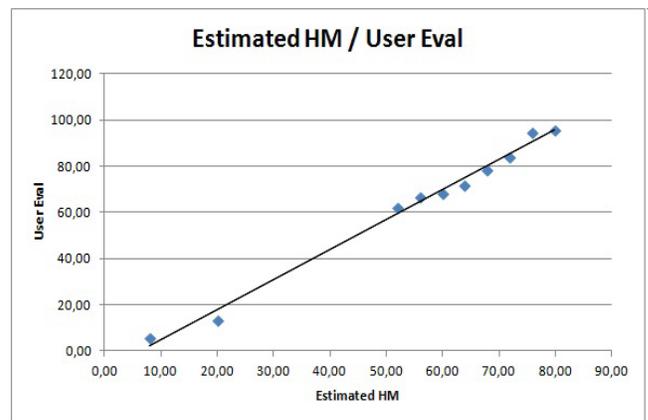


Fig. 5. Estimated HM Vs. User Perception.

K. Prediction of Required Programming Effort using a Linear Mathematical Model

The average linear equation (excluding errors) is as follows:

$$F_{average}(x) = \frac{(1.474+1.301)}{2}x + \frac{(-9.472-8.174)}{2} \quad (26)$$

However, the study must now consider the error produced by the semidifference:

$$F_{average\Delta}(x) = (1.3875 \pm 0.0865)x + (-8.823 \pm 0.649) \quad (27)$$

To graph the lines of maximum and minimum slope need to calculate the centroid using equation (20), Fig. 6 shows it.

$$Cent = (7.5069, 1.5925) \quad (28)$$

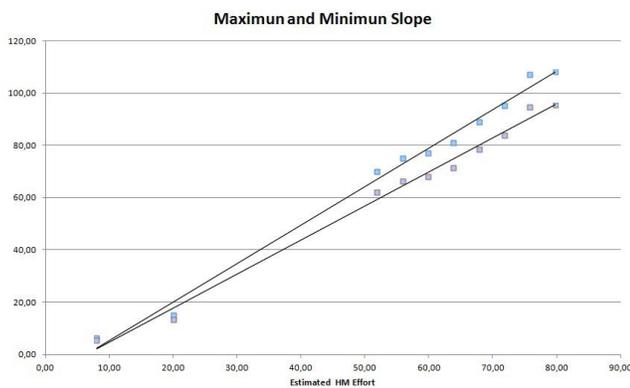


Fig. 6. Maximun and minimun slope.

IV. DISCUSSION OF RESULTS, CONCLUSIONS AND RECOMMENDATIONS

With the results obtained in this study, produced a model of linear approximation to determine the effort required in large-scale software programming, this was done thanks to the modularization and segmentation of all software and as they develop the different modules it can be applied and, in fact, adjusting the linear model very accurately.

The main reasons for the development of this model is to consider the validation and acceptance of the software by the user without impacting significantly on the costs of programming. As is known that, excessive application of hours/man in an activity directly affects the final cost of the software obtaining virtually the same result, thereby decreasing the efficiency of the development team.

While it is extremely difficult to model the tastes and preferences of a user regarding a software, the linear approximation even dependent requirements, fits quite well with the objectives of this study.

However it should be noted that in the development of software, especially large scale, both teams programming and users can vary greatly throughout the life of the project, which implies that adjustments must be made provided when necessary or at least the start of the programming of each module.

A way to future studies might include further aspects such as organizational behavior, psychology client/user and design persuasive way to minimize errors in the calculation of the linear model.

The software studied in this study is still in development stage approximately 70% complete. Below is Table 16 with the percentages of global acceptance by the user of some modules and estimated by the proposed model calculation:

TABLE XVI. RESULTS OF APLIED MODEL IN SOME MODULES

	Inserting Clinical Analysis	Daily performance report	Billing
Analysis	92,00%	89,00%	97,00%
Design	93,00%	98,00%	94,00%
Programming	89,00%	98,00%	96,00%
Tests (Functionality)	95,00%	99,00%	95,00%
Tests (Errors)	94,00%	96,00%	89,00%
Tests (Efficiency based in exec time)	88,00%	97,00%	89,00%
Benchmarking (PC's Resources)	96,00%	85,00%	90,00%
Tests (Database)	97,00%	98,00%	93,00%
Tests (Overload & Tuning)	92,00%	93,00%	92,00%
Tests (Running)	95,00%	89,00%	95,00%

As its clear that the results are quite satisfactory considering that it is taking into account the same user that was used to calculate the model.

It is also necessary to analyze this result from the pragmatic point of view because for non-productive modules prototypes were used, however, they were basis for developing the final module required by the client.

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My deepest acknowledgements to the University of Shaqra for the support received during the preparation of this study, and that made possible its successful completion. Thank you for promoting this study, which is part of my growth as a professional and that in turn, such research will contribute to the overall knowledge of software engineering.

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Repository of Static and Dynamic Signs

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Abstract—Gesture-based communication is on the rise in Human Computer Interaction. Advancement in the form of smart phones has made it possible to introduce a new kind of communication. Gesture-based interfaces are increasingly getting popular to communicate at public places. These interfaces are another effective communication medium for deaf and dumb. Gestures help conveying inner thoughts of these physically disabled people to others thus eliminating the need of a gesture translator. These gestures are stored in data sets so we need to work on developing an efficient dataset. Many datasets have been developed for languages like American sign language; however, for other sign languages, like Pakistani Sign Language (PSL), there has not been done much work. This paper presents technique for storing datasets for static and dynamic signs for any sign language other than British Sign Language or American Sign Language. For American and British Sign Languages many datasets are available publicly. However, other regional languages lack public availability of data sets. Pakistan Sign Language has been taken as a case study more than 5000 gestures have been collected and they will be made part of a public database as a part of this research. The research is first initiative towards building Universal Sign Language as every region has a different Sign Language. The second focus of the research is to explore methodologies where a signer communicates without any constraint like Data gloves or a particular background. Thirdly, the paper proposes use of spelling based gestures for easier communication. So the dataset design suggested is not affected by constraints of any kind.

Keywords—Data gloves; feature extraction; human computer interaction; image segmentation; object recognition

I. INTRODUCTION

According to the reports by World Health Organization around 360 million people around the world are deaf. Noise pollution might affect a huge number of young people who are in 12–35 year age range. The sufferers use hearing aids and sign language; and other forms of educational and social support. This number surpasses 1.25 million deaf children in Pakistan, yet very few attend school.

Whenever there is a community of humans, a sign language gets evolved. Many deaf mostly learn sign language from their parents. Usually 90% of the parents of deaf are normal hearing parents. These are the children who get formal sign language education. 6,909 spoken and 138 sign language are known so far [1], [2].

Among them American Sign Language (ASL) and British Sign Language (BSL) are based on English language [3], [4] [5] whereas, German Sign Language (GSL) [6], Argentinian Sign Language (ArSL) [7], Indian Sign Language (ISL) [8],

Persian sign language [9], Arabian Sign Language [10] and Chinese Sign Language (CSL) [11] are also among the well-known sign languages. However very little work has been done on PSL (Pakistan Sign Language) [12], [13].

Several surveys have been done to address the topics related to datasets. These surveys have covered vision based human-activity recognition to detect abnormality in video streaming, full body activity recognition, action recognition pose estimation and tracking, hand gestures for human computer interaction and the sign language itself etc. Databases for gesture recognition require natural gesture set, size of set and recording of data set with multiple sensors.

However, most algorithms are dependent either on typical background, or use of sensors or wearing of special kind of gloves or dresses. Sometimes use of Kinect and sometimes some special type of camera is used to capture input. The proposed dataset uses ordinary cameras of mobile or laptop, to capture input. The videos and images in dataset also come from ordinary cameras. This results in tradeoff between efficiency of the system whereas at the same time giving flexibility to the system.

First of all, we start with evolution of sign language, then we discuss the guidelines for a good data set. Materials and methods sections provides details how the static and dynamic signs will be stored. Results section discusses how the data set can facilitate on research on static and dynamic signs.

II. EVOLUTION OF SIGN LANGUAGE

Whenever there is a community of humans, a sign language gets evolved. There are very few deaf in any society. Their source of learning sign language is their parents. Usually 90% of the parents of deaf are normal hearing parents.

Sign language is just like natural languages, they meet all social and mental functions of spoken languages. However their medium of communication differs entirely from vocal auditory spoken languages.

Here we take Pakistan Sign Language (PSL) as a case study for this paper. The same approach can be applied to sign languages other than English Language based sign languages.

We find traces of PSL initiated by Syed Iftikhar Ali [13]. The dictionary of PSL created by him contained 750 signs. This was first step in this direction. 2nd contribution was by “Anjuman-e-Behbood-e-Samat-e-Atfal” (ABSA) for the development of PSL. This group worked on standardization of PSL. A special authority named “National Institute of Special Education” (NISE) runs special education centers. An NGO

named “Pakistan Association of the Deaf” (PAD) has realized the need of a standardized sign language. Their effort resulted in a book and a learning tool on Grammar for PSL.

First ICT assisted learning tool was funded by USA. It was started in 2002 by Sabahat. They have provided lessons for learning and a CD containing practice for the sign language. This project targeted to improve learning of PSL among deaf. Along with development of sign language, people have also provided their effort for learning. A very recent advancement is the development of categorical PSL learning resource. The researchers at PSL Deaf Reach Program have designed 5000 videos, a mobile app and a book containing 1000 PSL signs. Boltay Haath is another project related to PSL. However this project is dependent on use of data gloves, it uses statistical template matching. The accuracy of the system is from 70 – 80%. Sumaira has proposed another system using data gloves but this time the use of colored ones is proposed by Sumaira et al. She uses fuzzy classifiers to identify gestures [14], [15].

Ahmed et al has developed PSLIM. PSLIM takes voice input and convert it into sign/gesture of PSL. They have built several interfaces. Their product accuracy is almost 78%. They have added to the PSL vocabulary. They have also improved speech recognizer along with Translator component. [14].

Asif Ali suggested a system which uses Haar’s Algorithm and takes input in both forms text and image of sign and convert it into other form without using any special camera. Khan et al has introduced techniques for deaf to teach them programming and Farooq et al. has introduced DWT based technique using ordinary RGB camera with an accuracy of about 86%. Their system can process the changes in hand pose also but only for static and single hand gestures. Sami et al [9] has proposed another technique using computer vision. They have used cross correlation with an accuracy of 75% [14].

III. GUIDELINES

Before creating a dataset we must keep few guidelines in our mind. Usually our end user is either a researcher who uses data set to test his/her algorithms, or a developer who uses this data to produce solution and to test it before using it in an actual real life situation. The dataset creation involves selection of tasks, requirements by the algorithm, types of gestures to be covered and the classes in the data set if any [16].

Creating a dataset is also a complex task which involves many hours of work. The researcher creating a dataset should always keep in mind the possibility of releasing the dataset publicly at the end of his work. It should provide all possible support for image analysis and segmentation. Indeed the time spent to record a dataset may quickly become very long and the dataset could be valuable to other researchers [20]. Fig. 1 shows us images of basic alphabets from Pakistan Sign Language. Fig. 2 shows signs of numerics from 0-9.

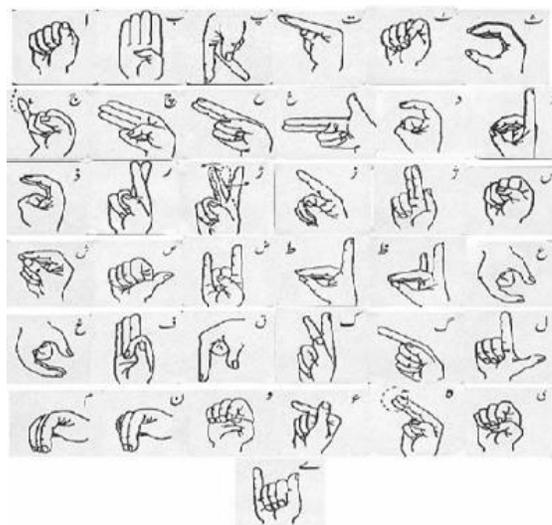


Fig. 1. The complete PSL alphabets.

The data set should have **Careful design** covering all the desired characteristics and recording conditions. The data set is build using an appropriate framework. Acquisition of data is quite time consuming. We should acquire data with highest possible quality. Next step is to verify the data using well known algorithms. Once tested for public use it can be released in lower quality. Lastly a good documentation and description of the dataset is important for a public release of the dataset elaborating the data acquisition in detail [17]-[19].

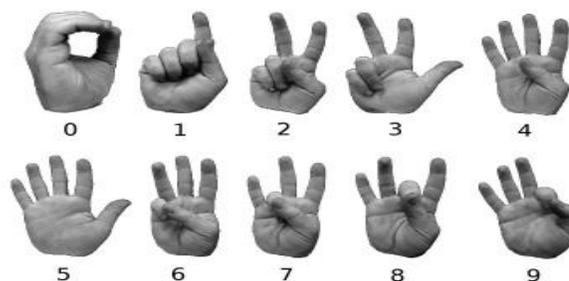


Fig. 2. The complete PSL numeric.

IV. MATERIALS AND METHODS

Urdu has been written in Urdu font as well as Roman Urdu. Initially British introduced the concept of Roman Urdu but now it is commonly used for text-messaging and Internet services. A person from Islamabad chats with another in Delhi on the Internet only in Roman Urdu. They both speak the same language but with different scripts. In addition to this Oversees Pakistanis, mostly their kids also use Roman Urdu [17]. The following Table 1 tells us about some Urdu language alphabets and their Roman Urdu substitutes.

TABLE I. SOME ALPHABETS OF URDU LANGUAGE

Letter	Name of letter	Letter	Name of letter
1. ا	alif	2. ر	ré
3. ت	té	4. ژ	zhé
5. ٹ	té	6. س	sīn
7. ث	sé	8. ش	shīn
9. ج	jīm	10. ص	su'ād
11. ذ	zāl	12. ف	fé

Table 2 lists few Urdu language words, their English and Transliteration of the Urdu language words.

TABLE II. URDU LANGUAGE WORDS WITH ENGLISH TRANSLATION

English	Urdu	Transliteration
Hello	السلام علیکم	assalāmu 'alaikum
Good Bye	خدا حافظ	khudā hāfiz
yes	ہاں	hā ⁿ
no	نا	nā

This research work has been inspired by the work of **Deaf Reach Program** in Pakistan [22]. There are two ways to use dynamic gestures in all sign languages.

- 1) *Word based dynamic gestures(existing)*
- 2) *Spelling based dynamic gestures (Proposed)*

All over the world, the dynamic gestures are word based i.e. every word has its own gesture. These gestures may use one or two hand. It means a language that has very rich vocabulary, will require more effort to learn its sign language. Fig. 3 shows word based gesture for Joota (shoes).

Alphabets make meaningful words and sentences [21]. The proposed spelling based gestures are more closer to computer based processing. They may also use one hand or two hand gestures, but here they are using one hand gestures only. Although communication through these gestures will be slow, but these dynamic words are easy to learn as they are using existing static gestures. Fig. 4 and 5 show spelling based dynamic gesture for Joota (shoes) and Khatt (letter) respectively.

This paper presents slightly different technique for storing the videos for continuous signs in PSL. The data set has been stored in MS SQL. For this initially a data repository has been used. The structure of the repository is as shown in Table 3:

TABLE III. REPOSITORY STRUCTURE

Roman Urdu	English	Urdu script	Link
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In Fig. 3, few entries have been added to show how videos and images are stored in the repository. Urdu words are selected from different categories. بلی (cat) is stored as BILLI.

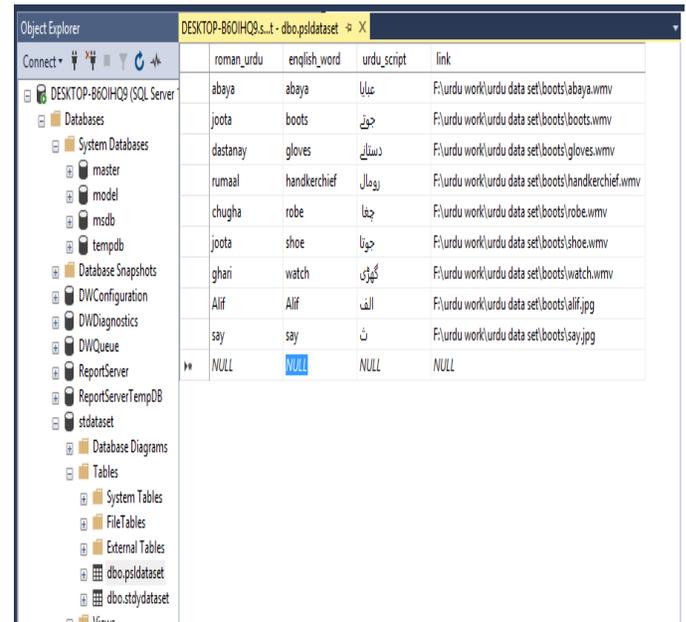


Fig. 3. A view of repository.



Fig. 4. Word based gestures for word shoe (joota).

تا (dog) is stored as KUTTA. However there is still clash of few words e.g. ام (Mango) عام (Ordinary) both have been spelled as aam. As a starting point, Urdu words have been selected from Categories mentioned below:

- Common adverbs and adjectives, public places, electronic appliances, Buildings, educational institutes, offices, clothes, computer grammar edible items, families and their norms, law and order, Agriculture, professions Sports, etc.

Urdu is then coded in Roman Urdu. While converting these words in roman Urdu, all the rules for pronouncing the Urdu words are followed. A few resources like Urduworld.com provide facility to carry on English to Urdu, Urdu script to English and from Roman Urdu to English translation [2].

When we will switch to any other sign language like Chinese Sign Language, we will use Roman Chinese in place of the attribute Roman Urdu. Urdu Script attribute will be replaced with Chinese Script attribute in the repository.

V. RESULTS AND DISCUSSION

Alphabets are stored in the form of pictures. Words are stored in the form of videos which are converted to images using any appropriate tool whether it is an online tool or a program segment written in MATLAB or any other visual language.

To present words using spelling based gestures, videos have been recorded using ordinary mobile or laptop camera. For alphabets images have been captured. Only one hand gestures have been used.

Fig. 5 shows selected frames from the video of spelling based gesture of the word “shoe” while Fig. 6 shows selected frames from video of the word “letter” in Pakistan Sign Language. Simplicity of this technique is that no special gloves, clothes, or any other electronic gadgetry is required. This makes system even more flexible.

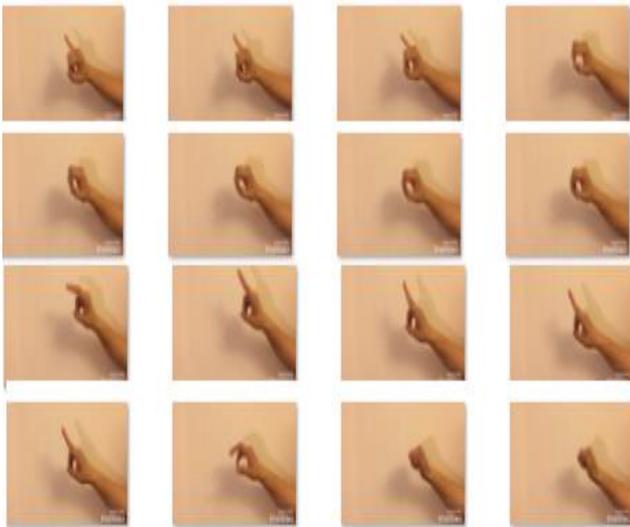


Fig. 5. Spelling based gestures for the word shoe (Joota).

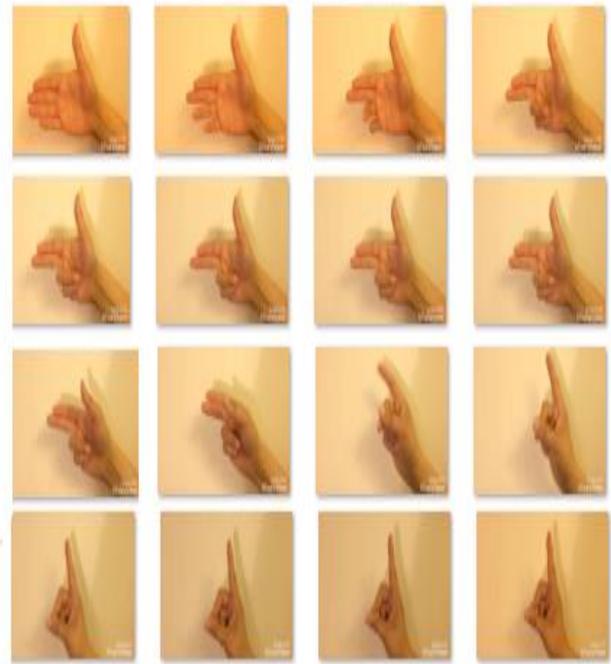


Fig. 6. Frames from video of Urdu word letter (Khatt).

VI. CONCLUSION

This paper proposes a simple method to store static and dynamic gestures. Many groups are working on PSL static and dynamic gestures. Words have been chosen for all walks of life. Emphasis is to create a touch free interface. Future work may include making this dataset publically available. Some datasets are available but they have not been following any algorithm so they cannot be used in interaction with computer based systems very efficiently.

Few guidelines have also been provided about the main facts researchers should keep in mind when selecting or creating datasets for research. Future work includes design of a Universal Sign Language and replacement of word based gestures with spelling based gestures.

ACKNOWLEDGMENTS

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Lightweight Internet Traffic Classification based on Packet Level Hidden Markov Models

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Abstract—During the last decade, Internet traffic classification finds its importance not only to safeguard the integrity and security of network resources, but also to ensure the quality of service for business critical applications by optimizing existing network resources. But optimization at first place requires correct identification of different traffic flows. In this paper, we have suggested a framework based on Hidden Markov Model, which will use Internet Packet intrinsic statistical characteristics for traffic classification. The packet inspection based on statistical analysis of its different characteristics has helped to reduce overall computational complexity. Generally, the major challenges associated with any internet traffic classifier are: 1) the limitation to accurately identify encrypted traffic when classification is performed using traditional port based techniques; 2) overall computational complexity, and 3) to achieve high accuracy in traffic identification. Our methodology takes advantage of internet packet statistical characteristics in terms of its size and their inter arrival time in order to model different traffic flows. For experimental results, the data set of mostly used internet applications was used. The proposed HMM models best fit the observed traffic with high accuracy. Achieved traffic identification accuracy was 91% for packet size classifier whereas it was 82% for inter packet time based classifier.

Keywords—Hidden Markov model; traffic classification; network security; deep packet inspection; internet traffic modeling; Internet of Things

I. INTRODUCTION

Rapid developments in multimedia and broadband applications have made traffic classification a difficult subject, but over the years it has drawn significant importance [1]-[5] among researchers. Use of non-standard ports, user privacy and huge traffic load on the network is creating major bottlenecks to some of the developed techniques. Traditional port based classification techniques are not reliable and cannot identify encrypted traffic. Statistical analysis based deep packet inspection approaches have proven to be more robust and efficient to handle encrypted traffic, which have made it a fertile research area.

Network traffic classification is fundamental to number of network activities, including its management, security, planning and quality of service provisioning [6]. The prerequisite for Internet traffic classification is packet inspection. However, strict privacy policies and heavy network load coupled with high processing and

infrastructure requirements for deep packet inspection engines have made it difficult to implement. Statistical analysis based packet inspection approaches have been very effective for encryption and protocol obfuscation. But still real time traffic classification and complexity of existing solutions is a big challenge. The debate for optimal technique for traffic classification is still open and with the emergence of new multimedia broadband applications, like Peer to Peer, Internet Protocol based Television and online Games, it has become very difficult for traditional classifiers to identify different traffic flows [7], [8]. The researchers have responded to this difficulty by working out different methods of internet traffic classification based on application level usage patterns and customer behavior. The authors [9], [10] have modeled internet traffic by using a stochastic process in which internet traffic has a self-similar character in nature. The overall behavior for this model was observed for different traffic flows in various network architectures.

II. RELATED WORK

In port based identification techniques, each application is having a unique port number at the server side, and various applications are detected by doing analysis of TCP and UDP [27] traffic. But before applying any traffic engineering rules, the captured port numbers are compared against their default ports [28] in order to validate correct port identification. But the rapid advancements in various applications, some authors have assigned port numbers other than their default port numbers. Bit-torrent [29] is one of such applications which use different port numbers. Due to such cases, the port based detection could not identify 30% of Internet traffic [30]-[32]. Table 1 below shows some examples of different ports assigned to different application by Internet Address Assignment Network Authority.

TABLE I. IANA ASSIGNED PORTS TO VARIOUS APPLICATIONS

Assigned Port	Application
20	FTP Data
21	FTP Control
22	SSH
23	Telnet
53	DNS
80	HTTP
110	POP3
123	NTP
161	SNMP

Nguyen and Armitage [11], covers the detailed and comprehensive work about traffic classification up to 2008. But due to the failure of two main packet classification techniques: 1) mapping of transport layer source and destination ports; and 2) payload signature based recognition, the researchers have focused their work on traffic classification using statistical and Machine Learning techniques. Nguyen, Thuy TT and Grenville Armitage [11] used machine-learning technique to analyze interactive IP traffic. W. Li and A. W. Moore [12] have suggested machine learning approach based on Naive Bayes and C4.5 decision tree algorithms, which accurately classify internet traffic by collecting different features at the start of internet traffic flows. There are number of packet scanning applications which are implemented across different networks, and they are capable of doing packet inspection, like SNORT [24], [25] and Linux L-7 (Layer-7) filter. One very important key area is Network security, where the intrusion takes place to take over system resources and causing denial of service for end users. To mitigate such attacks, authors [26] have suggested passing over the entire traffic through a firewall where all rules have been defined. The implementations [14], [15] works on statistical properties of different flows, i.e. IPT (Inter packet time) and PS (Packet size). Similarly, HMM implementation [16] covers the comparative analysis of different HMMs with other techniques of traffic classification. The researchers also applied other statistical methods [17], [18] to address the problem of traffic classification in IP networks.

III. HIDDEN MARKOV MODEL

These are stateful statistical models which are based on statistical principles of Markov Chain, which is a stochastic process where one state depends on the other state and are linked with each other through state transition probabilities. HMM can be represented at a high level by following variables:

1) The hidden variables with their temporal evolution follow a Markov chain, i.e. $x_n = s_1, s_2 \dots, s_N$ represents the (hidden) state at discrete time n with N representing the number of states.

2) The observable variables which stochastically depends on the hidden state, i.e. $y_n = O_1, O_2 \dots, O_M$, it represents the observable variables at discrete time n with M being the number of observable variables.

$\lambda = (\mu, A, B)$ represents key characteristics of Hidden Markov Model, Where

- 1) μ is the initial state distribution, i.e. $\mu_i = P(x_i = s_i)$
- 2) A is $N \times N$ transition Matrix, where N is representing number of states $1, 2, \dots, N$.
- 3) B is $N \times M$ observable generation Matrix, where M is the observation matrix and it could be discrete or continuous in nature. Each observation can be described by different distributions and all these distributions are log-concave in nature.

The probability of being in any specific state while considering the same Markov Chain λ at a certain time t is as under

$$P(s_t = i | s_{t-1} = j, s_{t-2} = k, \dots, \lambda) = P(s_t = i | s_{t-1} = j, \lambda) \quad (1)$$

HMM based estimation model was developed by using HMM estimation capabilities (learning, modeling, and prediction) [19], both for PS and IPT separately. The traffic classification model [9] recognizes the distinct behavior patterns of various flows. In HMM implementation [13], first few packets are used to train the model and to classify each flow at an early stage. The basic HMM structure learns the characteristics of initial packets of different flows and afterwards, the statistical properties of the complete sequence are determined by observing packet size and inter packet time. Following four mostly used application classes:

- 1) Live streaming (YouTube)
- 2) Email services
- 3) Online game
- 4) Voice services (Skype) were used to develop the model.

IV. METHODOLOGY AND APPROACH

In order to Model different traffic flows, we focused four mostly used applications. These applications were represented by four different states based on their statistical properties, i.e. packet size and inter packet time. These applications were selected based on their usage and complexity. The classifier block diagram is as under.

The related traffic was generated from dedicated network machines and it was captured on a server placed in Network Operation Center. The considered traffic statistical parameters, i.e. packet size and inter packet mean and standard deviation was calculated using MATLAB and is shown in Table 2.

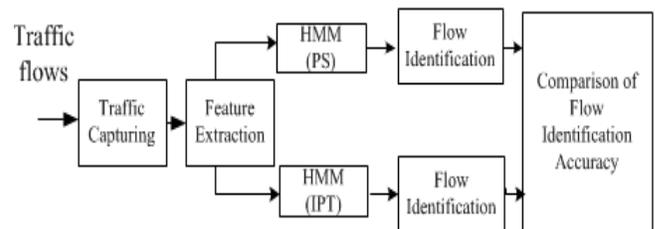


Fig. 1. Classifier block diagram.

TABLE II. CONSIDERED TRAFFIC STATISTICS

App	IPT (dBμ) (mean)	IPT (dBμ) (std. dev)	PS (B) (mean)	PS (B) (std. dev)
YouTube	33	5	89	57
Email	31	11	210	343
Skype	32	10	93	159
Game	31	6	134	241

A. Modeling and Mathematical Framework

HMM is composed of hidden state variables, $x[m] = [s1, s2, \dots, sm]$, and two dimensional observable variables, $x[m] = (v1[l], v2[l])^T$, where m is representing the number of states in HMM and s is representing hidden traffic class as a state, $v1[l]$ and $v2[l]$ are inter packet time and packet size respectively. IPT can be calculated by using (2).

$$v_1[l] = 10 \log\left(\frac{IPT}{1 \mu sec s}\right); \quad (2)$$

where, $v_2[l]$ =packet size of mth packet

IPT and PS were assumed to be statistically independent variables. The conditional probability density functions (pdf's) for inter packet time and size are given in (3) and (4).

$$f_i^{(t)}(v_1) = \frac{(v_1 / w_i^{(t)})^{(g_i^{(t)} - 1)} \exp(-(v_1 / w_i^{(t)}))}{w_i^{(t)} \Gamma(g_i^{(t)})} \quad (v_1 > 0) \quad (3)$$

$$f_i^{(p)}(v_2) = \frac{(v_2 / w_i^{(p)})^{(g_i^{(p)} - 1)} \exp(-(v_2 / w_i^{(p)}))}{w_i^{(p)} \Gamma(g_i^{(p)})} \quad (v_2 > 0) \quad (4)$$

Where, $v_1 = v_1[1], v_1[2], \dots, v_1[L]$ is representing IPT values, and $v_2 = v_2[1], v_2[2], \dots, v_2[L]$ is representing PS values. The Forward variable α and the backward variable β were computed using Forward-Backward algorithm [20]. These variables are mentioned in (5) and (6).

$$\alpha_j[l] = \sum_{i=1}^K a_{i,j}[l-1] A_{i,j} f_j^t v_1[l] f_j^p v_2[l] \quad (5)$$

$$\beta_i[l] = \sum_{j=1}^K A_{i,j} f_j^t v_1[l+1] f_j^p v_2[l+1] \beta_j[l+1] \quad (6)$$

The likelihood for Inter packet time and packet size were computed by using (7), which is given as under

$$\lambda = P(Y / F) = \sum_{i=1}^K \alpha_i[l] \beta_i[l] \quad (7)$$

Test traffic was generated from known sources of YouTube, email, Skype and online game. The overall traffic in terms of bytes collected is shown in Table 3.

Delay was calculated both for PS and IPT traffic flows and their group delay for trained and training data is shown in Fig. 2. It shows that initially there was

considerable delay (gap) between trained and training data but after eight iterations both started matching each other.

TABLE III. TOP FOUR APPLICATIONS TRAFFIC

Application	Amount [MB]	% of total traffic	No of flows
YouTube	548692	69	8156202
Email	52365	9	125425
Skype	25436	10	256354
Game	125425	9	354875

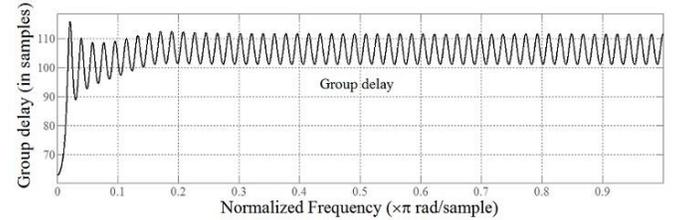


Fig. 2. Training and trained data set group delay.

PS and IPT probability density functions of these four set of traffic flows (YouTube, email, Skype & game) are shown in Fig. 3 to 6.

Fig. 3 shows that YouTube average packet size is 90 bytes and its IPT is 32 bytes. Variance between PS and IPT validates that they are two independent data sets.

As compared to YouTube traffic Fig. 4 shows that email average packet size is 200 bytes and its IPT mean is almost in the same range as that of YouTube traffic, i.e. 32 bytes. Variance between PS and IPT validates that they are two independent data sets.

Fig. 5 also validates the same variation between PS and IPT values for Skype traffic as it was observed for YouTube and email. Fig. 6 shows the variation for online game traffic.

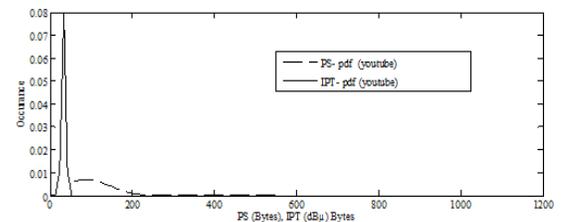


Fig. 3. PS, IPT Pdf's of YouTube.

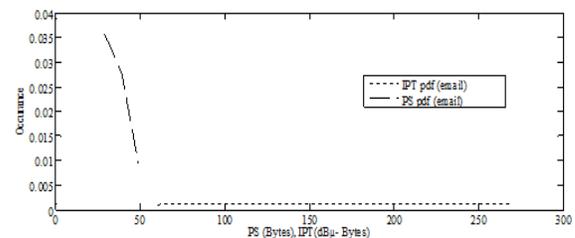


Fig. 4. PS, IPT Pdf's of email.

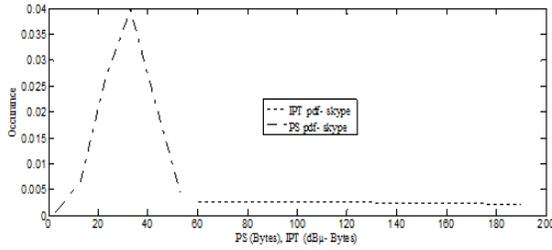


Fig. 5. PS, IPT Pdf's of Skype.

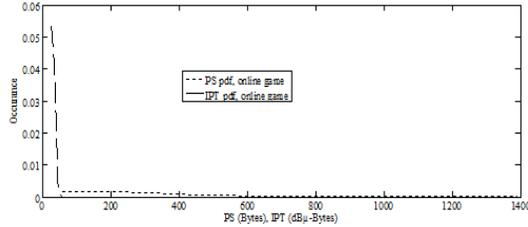


Fig. 6. PS, IPT Pdf's of online game.

TABLE IV. TRAINING SET STATISTICS

Application	IPT (dBμ) (mean)	IPT (dBμ) (std. dev.)	PS (B) (mean)	PS (B) (std. dev.)
YouTube	37	8	107	104
Email	38	9	95	68
Skype	45	9	67	25
Game	49	8	236	415

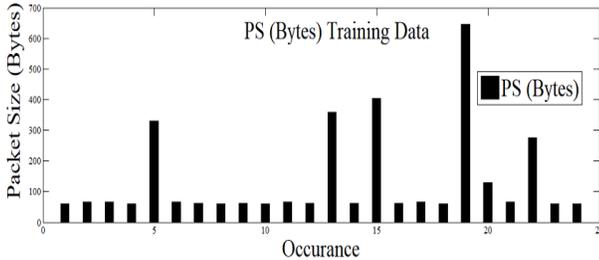


Fig. 7. PS (packet size) training data.

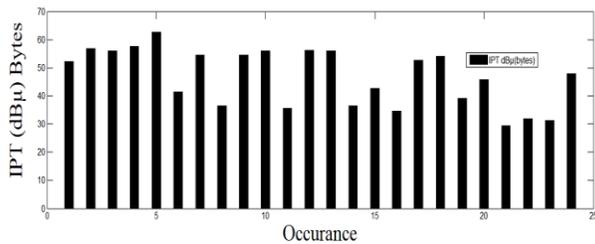


Fig. 8. IPT (inter packet time) training data.

For these models, the training data statistics are shown in Table 4. It comprises of 945 initial packets of YouTube, email, Skype and online game.

The bar plot of training data of PS and IPT is shown in Fig. 7 and 8. PS mean value of these applications is almost double as compared to the mean value of IPT. Similarly, PS and IPT standard deviation validates the distinct nature of PS and IPT traffic data.

V. ESTIMATING FLOW PARAMETERS AND RESULTS

For estimating HMM parameters, Baum-Welch introduced an iterative algorithm [21], which kept refining HMM parameters (π, A, B) until it converges to a local minimum. The Baum-Welch algorithm seeks to optimize λ via an auxiliary function $\lambda^t = (\pi^t, A^t, B^t)$, which satisfies either $\lambda = \lambda$ or $P(O/\lambda) < P(O/\lambda^t)$. It is also represented in below equation:

$$Q(\lambda^t, \lambda) = \sum_q P(O, q | \lambda^t) \log P(O, q | \lambda) \quad (8)$$

$Q(\lambda^t, \lambda)$ will converge to a local optimal solution, provided that the below condition is fulfilled.

$$Q(\lambda^t, \lambda) \geq Q(\lambda^t, \lambda^t) \Rightarrow P(O | \lambda^t) \geq P(O | \lambda) \quad (9)$$

$P(O/\lambda)$ give in (10) yields the results in terms of HMM parameters.

$$P(O, q | \lambda) = \pi_{q_0} \prod_{t=1}^T \alpha_{qt} -_{qt} \prod_{K=1}^M b_{qtk} (O_t k) \quad (10)$$

Independent maximization of Baum auxiliary functions [21] yields a new set of model parameters given in (11), (12), and (13).

$$\bar{\pi}_i = \frac{P(O, q_0 = i | \lambda)}{P(O | \lambda)} \quad (11)$$

$$\bar{a}_{ij} = \frac{\sum_{t=1}^T P(O, q_{t-1} = 1, q_t = j | \lambda)}{\sum_{t=1}^T P(O, q_{t-1} = i | \lambda)} \quad (12)$$

$$\bar{b}_{ik}(x) = \frac{\sum_{t=1}^T P(O, q_t = j | \lambda) P(O_{ik} = x)}{\sum_{t=1}^T P(O, q_t = i | \lambda)} \quad (13)$$

By using α, β , above equations were rewritten as under in (14) whereas parameters re-estimation in terms of α and β is as under in (15).

$$P(O, q_t = i | \lambda) = \alpha_i(i) \beta_i(i), P(O / \lambda) = \sum_{i=1}^N \alpha_i(i) \beta_i(i) \quad (14)$$

$$\bar{\pi}_i = \frac{\alpha_0(i) \beta_0(i)}{\sum_{j=1}^N \alpha_0(j) \beta_0(j)} \quad (15)$$

$$\bar{a}_{ij} = \frac{\sum_{t=1}^T \alpha_{t-1}(i) a_{ij} \beta_t(j) \sum_{k=1}^M b_{jk}(O_{tk})}{\sum_{j=1}^N \alpha_{t-1}(i) \beta_{t-1}(i)} \quad (16)$$

$$\bar{b}_{ik}(x) = \frac{\sum_{t=1}^T \alpha_t(i) \beta_t(i) b_{ik}(O_{tk})}{\sum_{t=1}^T \alpha_t(i) \beta_t(i)} \quad (17)$$

The above equations represent new sets of estimated parameters learned with the help of Expectation Maximization algorithm.

A. Traffic Flows Estimation

HMM Viterbi was applied to find out the most likely path for the hidden Markov model as specified by the state transition matrix (A), and emission matrix (B). Model parameters were iteratively improved by using Viterbi Algorithm. PS and IPT states state transition as shown in Fig. 9 and 10 were used to optimize likelihood of each state.

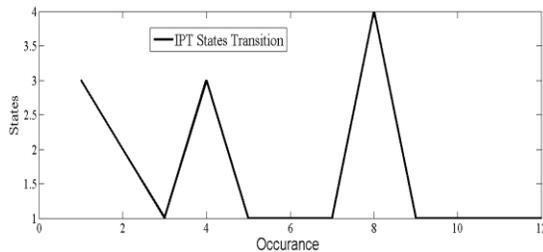


Fig. 9. States transition (IPT).

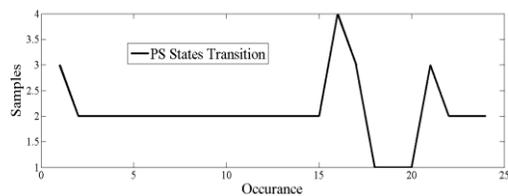


Fig. 10. States transition (PS).

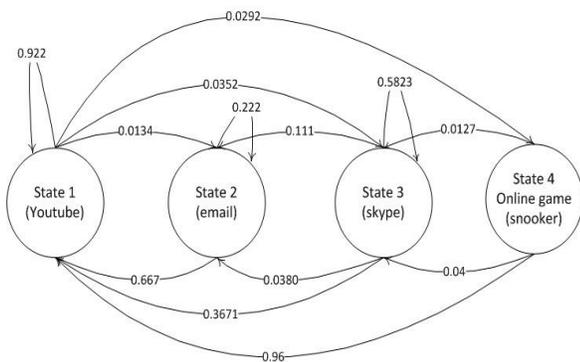


Fig. 11. State transition diagram (PS).

These figures indicate that YouTube was the mostly found state both for PS and IPT transitions. It also matches with actual traffic which was generated from different traffic sources. After computing YouTube, email,

Skype and online game, their state transition probabilities are shown in Fig. 11. It shows that YouTube has 92.2% probability to stay within the same state, which reflects that overall traffic is mostly dominated by YouTube, and there are higher chances that the YouTube state probability always remains very high as compared to other flows.

The traffic flow identification accuracy results for PS and IPT are shown in Table 5. The traffic identification accuracy PS was up to 92%, whereas for IPT, the achieved accuracy was 87%.

The modeling results of YouTube, email, Skype and game for PS and IPT are shown in Table 6 and 7. The results are shown through a confusion matrix. All correct classification were shown italic in below tables.

TABLE V. PS AND IPT ACHIEVED ACCURACY COMPARISON

No of Packets (training data)	Accuracy Achieved (PS)	Accuracy Achieved (IPT)
5	80%	60%
12	91.67%	75%
946	92%	87%

TABLE VI. CLASSIFICATION RESULTS CONFUSION MATRIX (PS)

Application	YouTube	Email	Skype	Game
YouTube	<i>91.93%</i>	6.5%	1.2%	0.37%
Email	5.4%	<i>84.20%</i>	1.54%	8.86%
Skype	3.54%	5.48%	<i>81.25%</i>	9.73%
Game	4.58%	6.54%	9.34%	<i>79.54%</i>

TABLE VII. CLASSIFICATION RESULTS CONFUSION MATRIX (IPT)

Application	YouTube	Email	Skype	Game
YouTube	<i>81.00%</i>	9.0%	3.0%	7.0%
Email	8.0%	<i>73.20%</i>	8.00%	10.80%
Skype	9.00%	8.00%	<i>69.00%</i>	14.00%
Game	8.00%	9.00%	11.00%	<i>72.00%</i>

Row 1 in Table 6 shows that for YouTube application achieved accuracy for PS based modeling was 91.93%, whereas 6.5% of the YouTube traffic had been classified as email, 1.2% as Skype, and 0.37% had been classified as online game. This shows that accuracy of classifier was up to 91.93% for YouTube, 84.20% for email, 81.25% for Skype and 79.54% for online game. Similarly, in case of IPT, the Table 5 shows that accuracy of classifier for YouTube traffic was 81%, for email 73.2%, for Skype it was 69% and for online game, it was 72%. For different flows, we considered traffic in one direction only and that could be one of the reasons that to a certain extent, the accuracy was 69% for Skype. Considering traffic in both directions may improve the accuracy.

VI. CONCLUSION

With rapid advancements in Internet of Things, the network resources are no more unlimited, and bandwidth hungry multimedia applications are consuming the major part of available bandwidth. Traffic classification is key to network security solution and management architectures [22], [23]. In this paper, a novel HMM based modeling

technique has been proposed that can classify internet traffic based on their statistical properties, i.e. PS and IPT. The traffic classifications have been done by using minimum number of statistical parameters, which reduced computational complexity and overall load on network systems. The comparative analysis of PS and IPT shows that achieved classification accuracy for PS based model was 92% and for IPT it was 81%. The achieved accuracy suggests that proposed modeling framework can be part of a multi traffic classifier system. Moreover, PS and IPT combination could also result in better accuracy and can be an area of future work on traffic classification.

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Efficient K-Nearest Neighbor Searches for Multiple-Face Recognition in the Classroom based on Three Levels DWT-PCA

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Abstract—The main weakness of the k-Nearest Neighbor algorithm in face recognition is calculating the distance and sort all training data on each prediction which can be slow if there are a large number of training instances. This problem can be solved by utilizing the priority k-d tree search to speed up the process of k-NN classification. This paper proposes a method for student attendance systems in the classroom using facial recognition techniques by combining three levels of Discrete Wavelet Transforms (DWT) and Principal Component Analysis (PCA) to extract facial features followed by applying the priority of k-d tree search to speed up the process of facial classification using k-Nearest Neighbor. The proposed algorithm is tested on two datasets that are Honda/UCSD video dataset and our dataset (AtmafaceDB dataset). This research looks for the best value of k to get the right facial recognition using k-fold cross-validation. 10-fold cross-validation at level 3 DWT-PCA shows that face recognition using k-Nearest Neighbor on our dataset is 95.56% with $k = 5$, whereas in the Honda / UCSD dataset it is only 82% with $k = 3$. The proposed method gives computational recognition time on our dataset 40 milliseconds.

Keywords—Multiple-face recognition; DWT; PCA; priority k-d tree; k-Nearest Neighbor

I. INTRODUCTION

Facial recognition performance is influenced by several variables, including pose, expression, lighting, and occlusion (namely, glasses, mustaches, beards, headgear, etc.) [1].

Many educational institutions in Indonesia continue to use attendance sheets, allowing students to cheat by asking friends to sign their names. The use of attendance sheets has proven to be time-consuming, unreliable, inaccurate, and inefficient. Based on this issue, we propose a combination of face recognition methods using three levels of Discrete Wavelet Transforms (DWT) and Principal Component Analysis (PCA) to extract facial features followed by applying k-d tree to accelerate the process of facial classification using k-NN. The k-NN process with Euclidean distance is used to identify students' presence through pictures or video of a student's face. By using this approach, it is possible that automatically integrated systems between IP camera and pc or notebooks will

determine whether each student is present or absent and will be recognized in the group of courses followed.

The contributions of this paper include: 1) combining three levels of 2D DWT-PCA for feature extraction; 2) we adapted approximate nearest neighbors search algorithm using the priority of k-d tree to find some (k) nearest neighbors from a certain query point (q) efficiently [2]

The paper is structured as follows: Section 2 consists of related research discussions, Section 3 consists of the proposed research method, Section 4 presents the results of research and analysis, and Section 5 offers some conclusions.

II. RELATED WORKS

Human facial recognition plays an important role in biometrics. The eigenvector-based method of facial recognition was first introduced by [3], and then expanded upon by [4] and [5]. The eigenvector-based method extracts the low-dimensional subspace, which tends to simplify the classification process. Chitaliya and Trivedi [6] developed a facial recognition model that used wavelet-PCA for feature extraction, then used Euclidean distance and neural networks for classification. In this study, Level 1 discrete wavelet transform (DWT) was used. They were able to attain up to 93.3% accuracy.

In 2012, Rao [7] proposed a facial recognition system using discrete wavelet transform (DWT) and eigenvectors, showing an average of 3.25% improvement in recognition performance.

Research on attendance management in the classroom proposed by [8], using the haar cascade method for face detection. While the face recognition using eigenface method. This face recognition approach achieves an accuracy of 85%.

Research on improving facial recognition was proposed by [9], who used a wavelet-PCA decomposition method with mahalnobis classification. The results of this study improved recognition by 95.7%. Recognition results using Euclidean classification reached 93.8% accuracy, with a computing speed of 8.501 milliseconds.

In 2014, Mao [10] conducted research into multiple face detection, tracking, and recognition in the classroom using a Honda/UCSD dataset of videos. In the experiment, the student dataset consisted of 16 and 39 people in the classroom. Fifty-nine videos were used: 20 for training and 39 for testing. The study used the Haar cascade facial detection method. For facial recognition, this study used eigenfaces, LBP+K-mean. The average precision and recall values in this study were more than 90%.

The combination of methods for student attendance systems in the classroom was proposed by [11] using facial recognition techniques by incorporating Discrete Wavelet Transforms (DWT) and Discrete Cosine Transform (DCT) to extract the facial features of students followed by applying Radial Basis Function (RBF) to classify face objects. The success rate of the proposed system in recognizing facial images of students who sit in the classroom is about 82%.

In 2017, Sayeed [12] presented an automated attendance monitoring system with face recognition in a real-time background world for with a database of student's information by using Principal Component Analysis (PCA) algorithm. The testing results have been tested and taken from few different environment backgrounds. Basically is during the day and night time with lights either on or off. Average successful rate of the proposed system are about 2.43 to 2.81.

K-nearest neighbor (k-NN) is a simple and effective classification method. Samet [13] proposed a k-nearest neighbor algorithm using MaxNearestDist, while the k-NN repair method had been proposed by [14]-[16]. The weakness of k-NN algorithm, namely the process of calculating the similarity to be done on all existing training data [17]. If training data increases in number, the time for classification will also increase proportionately. The problem can be solved if using k-d tree data structure [18]-[21]. It can be used with a k-nearest neighbor (k-NN) approach to match facial features

efficiently and search for the location of the nearest neighbors. K-d tree data structure has been used as a data structure for overcoming increased processing times caused by the addition of features into the database. An alternative approach is establishing a balanced k-d tree, as proposed by [22]. The nearest neighbor search algorithm using the k-d tree data structure can be found in [23]. In their research, they only found one nearest neighbor. We integrate the priority k-d tree search and best bin first method (BBF) to find the nearest neighbors, and the Euclidean distance is utilized as similarity measure.

In our study, the nearest proposed neighbor search algorithm uses a data structure called a priority queue that stores the list of closest neighbors k with some distance to the query point q. The priority queue has a fixed upper limit on the number of elements (or points) that can be stored, which is the number of nearest neighbors k. Each time a new element is added to the queue, if the queue is at a predetermined capacity, the element with the highest priority value (the longest distance) is removed from the queue.

III. PROPOSED METHOD

In order to make the framework, the proposed method in this study used was the method from related research and then we developed them to be tested on our dataset. The research method used in this article consisted of several stages, as shown in Fig. 1.

A. Face Database Training Stage

1) Single Face Image

In this stage, facial images of students were captured using a digital camera. Facial data from 1,014 individuals was collected; each individual had nine images taken from different angles. A set of student facial images as training data is presented in Fig. 2.

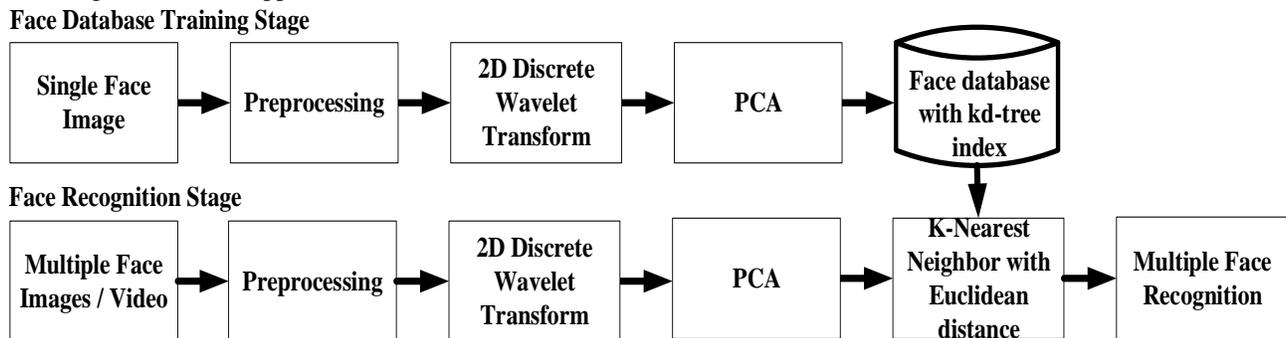


Fig. 1. The proposed method.

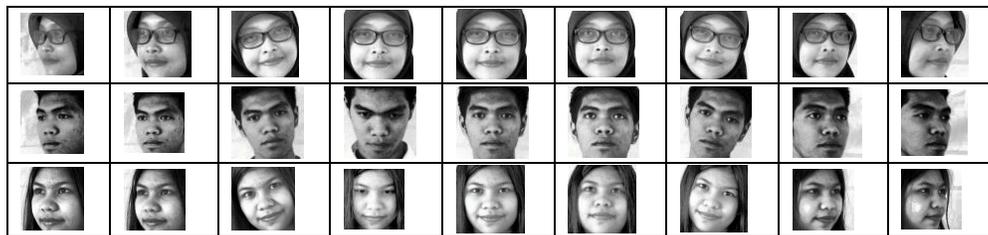


Fig. 2. A set of student facial images as training data.

2) Preprocessing

In the preprocessing stage, the following steps were conducted:

- a) Facial cropping, the detection and localization of the face in a square area using the Viola-Jones method [24]
- b) Changing the facial image from RGB to grayscale mode.
- c) Resizing the facial image to 128x128 pixels.
- d) Normalizing color brightness using a histogram equalization process.

The preprocessing stage of this research is shown in Fig. 3.

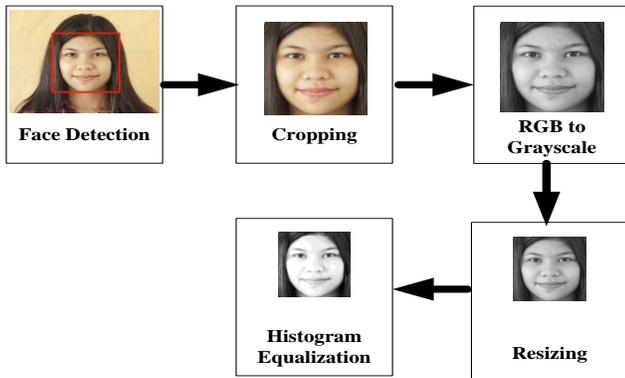


Fig. 3. Preprocessing stage.

The Viola-Jones method was used to detect faces in the images taken by digital cameras. Facial images were then stored in the database. After the detection process, images of students' faces were manually registered in the database by name and identity code. The process of registering students' faces is shown in Fig. 4.

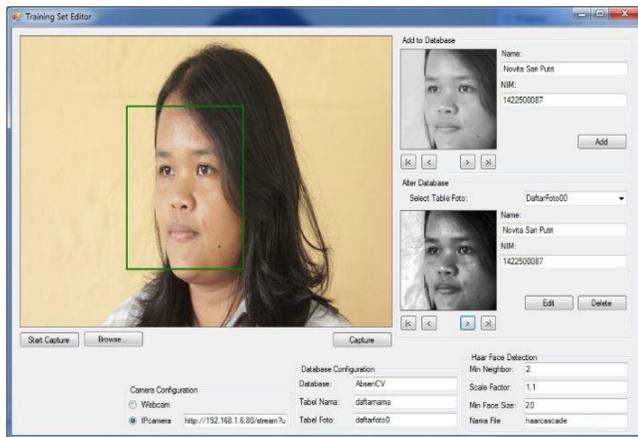


Fig. 4. The process of registering students' faces.

3) 2D Discrete Wavelet Transform

Wavelets are defined as small or short waves. The wavelet transform converts a signal into a series of wavelets. This is the basic function at a different time. Wavelets result from the scaling function. Certain wavelets are also called mother wavelets, as other wavelets result from their scaling, dilation, and shift.

Discrete Wavelet Transform (DWT) is a discrete form of the wavelet transform, consisting of a signal sampling process based on the scaling and shifting of parameters [25]. It is systematically defined by the following equation [26]:

$$DWT_{x(n)} = \begin{cases} d_{j,k} = \sum x(n)h(n-2^j k) \\ a_{j,k} = \sum x(n)g(n-2^j k) \end{cases} \quad (1)$$

The coefficient $d_{j,k}$ refers to the detailed component of the signal $x(n)$ and it is suited to the function of the wavelet, while $a_{j,k}$ refers to the approximation components of the signal. The functions $h(n)$ and $g(n)$ are the coefficients of high-pass and low-pass filters, respectively, while parameters j and k show the scale of wavelets and translational factors.

In this research, the mother wavelet used for feature extraction is the Haar wavelet. The image produced through preprocessing is decomposed at three levels. At each level, DWT was first performed in a vertical direction, followed by a horizontal direction. After the first level of decomposition, four sub-bands were obtained: LL1, LH1, HL1, and HH1. For each level of decomposition, the sub-band LL from the previous level was used as the input. The sub-band LL1 was only used for DWT calculation in the next scale. To calculate the wavelet features in the first stage, the wavelet coefficients were calculated on sub-band LL1 using a Haar wavelet function. For the second level of decomposition, DWT was applied to band LL1 by decomposing it into four sub-bands: LL2, LH2, HL2, and HH2. For the third level of decomposition, DWT was applied to band LL2 by decomposing it into four sub-bands: LL3, LH3, HL3, and HH3. LL3 contained the low-frequency band, while LH1, HL1, and HH1 contained the high-frequency band.

The face image size was 128x128 pixels obtained from the pre-processing results was then decomposed to 64x64 pixels on the wavelet level 1, then the 64x64 pixel face image was decomposed to 32x32 on the wavelet level 2, and the last was the 32x32 pixel face image decomposed using wavelets level 3 to 16x16 pixels. These three levels of facial image decomposition were used in the experiment to find the right size for the recognition process. Experiments were performed on all three levels of wavelet decomposition to find the right level of accuracy of recognition of many faces. Third face image of wavelet decomposition process will be processed by PCA (principal component analysis). The illustration of the 3-level 2D-DWT decomposition process is shown in Fig. 5.

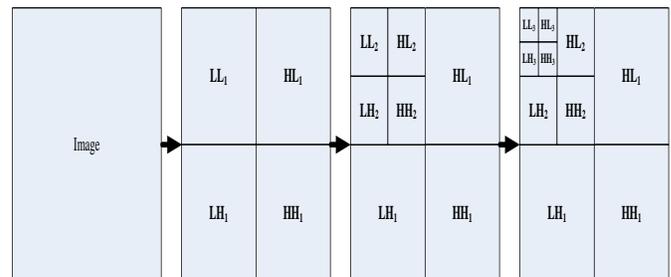


Fig. 5. The Illustration of three-level 2D-DWT decomposition.

4) Principal Component Analysis

Imagery produced through three-level 2D-DWT decomposition was subjected to the PCA process, as shown in Fig. 6. This is very significant for feature extraction, as it reduces dimensions and thus reduces the complexity of computation.

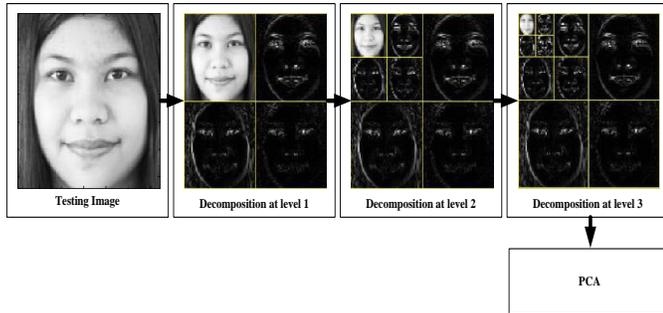


Fig. 6. Three level 2D DWT and PCA decomposition process.

PCA was used to obtain vectors, also known as principal components that could provide information regarding the maximum variance in the facial database. Each principal component is a representation of a linear combination of all training face images that have been reduced by the image mean. Combinations of facial images are known as eigenfaces; these facial images are those that will be recognized.

PCA aims to find the principal components of faces collected in the database. The significant features are termed eigenfaces and obtained from the eigenvector—a feature that describes the variance between face images—of a covariance matrix of images in the database. Each location on the face contributes to each eigenvector. Each face in the database can be represented by a linear combination of these eigenfaces. The number of eigenfaces is the same as the number of faces stored in the database. Facial images can be identified with the best eigenface (i.e. that which has the largest eigenvalue) that has most of the facial variations in the database. By taking some of the principal (most important) components, the calculation of eigenfaces may be efficient [27]. The steps to identify eigenfaces are as follows [28]:

- a) Determine the dimension of the matrix of facial images which will be used.
- b) Arrange the matrix of facial images into the vector of column Ψ with the size $m \times n$
- c) Diminish every facial image Γ_i by the average of matrix Ψ and store the result in variable Φ_i

$$\Psi = \frac{1}{M} \sum_{i=1}^M \Gamma_i \quad (2)$$

$$\Phi_i = \Gamma_i - \Psi \quad (3)$$

d) Calculate the covariance of matrix C by finding the eigenvector e_i and eigenvalue λ_i :

$$C = \frac{1}{M} \sum_{n=1}^M \varphi_n \varphi_n^T = AA^T \quad (4)$$

$$Ce_i = \lambda_i e_i \quad (5)$$

e) Obtain the eigenvector e_i and eigenvalue λ_i by finding the eigenvector and eigenvalue of matrix $C_1 = A^T A$ (dimension $M \times M$). If v_i and μ_i is the eigenvector and eigenvalue of matrix $A^T A$, then:

$$A^T A v_i = \mu_i v_i \quad (6)$$

Multiply both sides of equation (5) with A from the left, obtaining:

$$AA^T A v_i = A \mu_i v_i$$

$$AA^T (A v_i) = \mu_i (A v_i)$$

$$C(A v_i) = \mu_i (A v_i) \quad (7)$$

f) Sequence the eigenvector in columns based on the eigenvalue, from largest to smallest.

g) By selecting the eigenvector with the largest eigenvalue, the principal component is obtained from the early matrix and can form the feature vector. By forming a new matrix E, then every e_i vector is the column vector. The dimension of this matrix is $N \times D$, with D being the desired eigenvector number. This is used for the data projection of matrix A and the calculation of vector y_i matrix $Y = (y_1, \dots, y_m)$

$$Y = E^T A \quad (8)$$

Every original image can be reconstructed by adding the average of image Ψ by summing the weights of all vectors of e_i .

- 1) Change the training image being sought to find vector P, diminished by the average Ψ and projected by the matrix of eigenvectors (eigenfaces):

$$\omega = E^T (P - \Psi) \quad (9)$$

The extracted features were reduced from 16384 to 256 by the DWT procedure. However, 256 was still too large for calculation. Thus, PCA was used to further reduce the dimensions of features. The curve of the cumulative sum of variance versus the number of principal components was shown in Fig. 7.

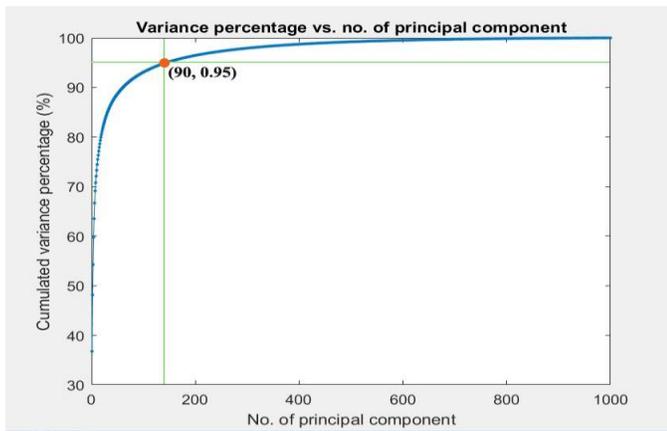


Fig. 7. The curve of variances against number of principle components (here we found that 90 features can achieve 95.03% variances).

The variances versus the number of principal components showed that only 90 principal components (bold font in the figure), which were only $90/256 = 35.15\%$ of the original features, could preserve 95.03% of total variance.

Feature (principal component) with the highest percentage (variance) selected to be used in the process of correspondence among feature of face images[29].

5) Feature Representation

After the face image was projected into the face space, the next task was to determine which face image would be most similar to the image in the database [30]. In this research, the eigenvector with the largest eigenvalue was projected into the PCA space. This projection was stored as a k-d tree structure, indexed, and stored in a database [31]. This projection was later used in the testing stage and compared with the unknown image projection.

A k-d tree is a structure of partition space data used to set points in k-dimensional space based on the key values in the nodes [32], [21]. Components of K-d tree node in this research consisted of vector key or k-dimensional points, descriptor features, or pointers known as Left LINK and Right LINK (left subtree and right subtree). The sizes of the images used in this study after preprocessing were 64x64 pixels, 32x32 pixels, and 16x16 pixels. Each node on the K-d tree consists of key records. These nodes can be seen as points in a dimensional space. In addition, the nodes in K-d tree can also represent sub-regions of the entire space.

A feature which is the eigenvector with the value of variance percentage of PCA dimension reduction process as much as 90 principal components will be indexed. These eigenvectors were then deposited into k-d tree, with K in the k-d tree being the dimension of the template. The number of nodes in k-d tree is the same as the number of templates in the input files inserted into the tree [20].

Before constructing the tree, the data point x_i must be played through the mapping of U^T to align the main axis with the coordinate axis. Given a sample there was $\{x_i | i = 1, \dots, N\}$ which was the set of R^d . Then eigenvector $A = \sum_{i=1}^N x_i x_i^T$. Eigenvector A is the principal axis of the data set, and eigenvalue is called the principal moment. If $A = U \Lambda U^T$ is

the eigenvalue decomposition of A and column U is the eigenvector (orthogonal), then $x_i \rightarrow U^T x_i$ mapping the dots to the principal set of an axis that is aligned with the axis coordinates. If $U_{1:k}$ are the matrix consisting of the dominant k eigenvector, then the projection of $U_{1:k}^T$ is the set of points arranged into spaces stretched by k principal axis of the data. In general, if the data is aligned through the rotation of dimension U^T , the data is divided into the k-d tree and will be selected between k principal axis from the data. k is the depth of the tree. In building k-d tree, all data stored in the k-d tree must have the same dimension as the existing dimension in face space. The data consists of the dominant eigenvector and has been projected into the space stretched by the principal axis of the data k. In building or reconstructing k-d tree, all data stored in the k-d tree must have the same dimension as the existing dimension in face space. The k-d tree construction is performed using a recursive method with parameters at each iteration of arrays from points and depth. Depth value can be used to determine axis value. The initial value of arrays is all points and the depth value is 0. The Algorithm to construct k-d trees is shown in Algorithm 1.

Algorithm 1 The Algorithm to construct k-d trees

The Algorithm to construct k-d trees

Input: Set / Set of vectors $\{x_i\} \in R^d$

Output: k-d tree

1. Begin
 2. Calculate the axis value with the formula, axis = depth mod 2
 3. Sort array data based on axis value, if axis is smaller afterward sort done to the left, if the axis is larger, then sorting done to the right
 4. Calculate the median coordinates, by:
 - (1) index_median = number of coordinates div 2 and
 - (2) coordinates_median = coordinates [index_median]
 5. Determine the node: node = coordinates [index_median]
 6. Specify left node and right node using new iteration. Next iteration use the following parameters:
 - (1) array coordinates = sub array coordinates = coordinates [0]
 - (2) array coordinates = sub array coordinates = coordinates [index_median + 1] [coordinate number]
 7. End
-

B. Facial Recognition Stage

1) Multiple Face Images from Video

Images of multiple student faces in the classroom were captured from videos using an IP camera (Zavio F320). Images of students' faces had previously been registered with students' names and identification codes in the database. Five classrooms were used in this recognition stage. Each classroom consisted of forty students; as such, the total dataset used for the test consisted of 200 face images. Face images captured from video streams using an IP Camera were extracted frame-by-frame until the 60th frame [33]. Five video samples in AVI (Audio Video Interleave) format with a resolution of 1920x1080 was used. These videos had a frame rate of 30 fps [34] and duration of two minutes. The computer system in this study has a detection and facial recognition software installed on a personal computer (PC) or notebook and the lecturer should run it at the beginning of each class in the course group that has been determined on schedule. The layout system is shown in Fig. 8.

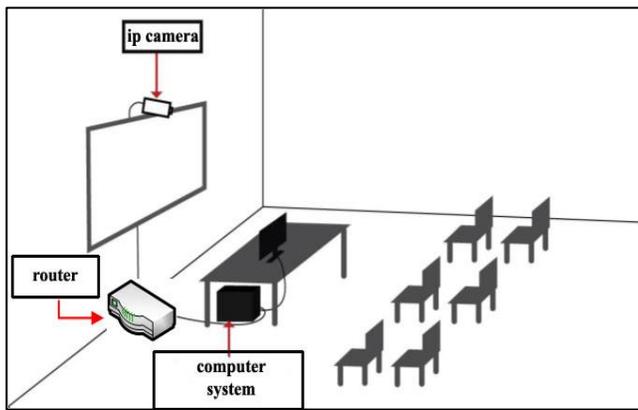


Fig. 8. The Layout System.

2) Preprocessing

The following steps were involved in the preprocessing stage:

- a) Faces were cropped using multiple face detection on each video frame. Face detection was implemented based on Haar-like features using the Viola-Jones method [24], which quickly detects multiple faces in the classroom (Fig. 9).
- b) Faces were changed from RGB to grayscale mode.
- c) Faces were resized to 128x128 pixels
- d) Images of faces were normalized using a histogram equalization process



Fig. 9. Sample of Multiple Face Detection Results in the Classroom (detected faces are marked by green rectangles).

The preprocessing stage of the multiple-face images in this research is shown in Fig. 10.

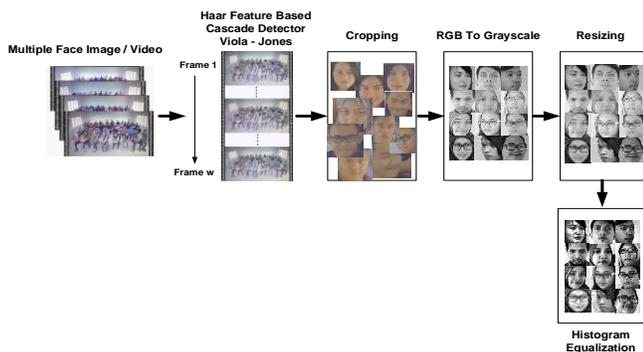


Fig. 10. Multiple face image preprocessing.

3) 2D Discrete Wavelet Transform

The 2D Discrete Wavelet Transform (2D DWT) process uses the same process as the face database. Images resulting from preprocessing were decomposed at three levels. At each level of decomposition, DWT was first performed in a vertical direction, followed by a horizontal direction. After performing the first level of decomposition, four sub-bands were obtained: LL1, LH1, HL1, and HH1. For each level of decomposition, the sub-band LL from the previous level was used as input. Sub-band LL was only used for DWT calculation in the next scale. To calculate the wavelet features in the first stage, wavelet coefficients were calculated on sub-band LL1 using a Haar wavelet function. For the second level of decomposition, DWT was applied to band LL1 by decomposing it into four sub-bands: LL2, LH2, HL2, and HH2. For the third level of decomposition, DWT was applied to band LL2 by decomposing it into four sub-bands: LL3, LH3, HL3, and HH3. LL3 contained low-frequency bands, while LH1, HL1, and HH1 contained high-frequency bands. The face image size was 128x128 pixels obtained from the pre-processing results was then decomposed to 64x64 pixels on the wavelet level 1, then the 64x64 pixel face image was decomposed to 32x32 on the wavelet level 2, and the last was the 32x32 pixel face image decomposed using wavelets level 3 to 16x16 pixels. Experiments were performed on all three levels of wavelet decomposition to find the right level of accuracy of recognition of many faces. Third face image of wavelet decomposition process will be processed by PCA (principal component analysis).

4) Principal Component Analysis

This stage was the same as the face database stage, with images resulting from the three levels of decomposition applied in the PCA process. This is very significant for feature extraction due to the reduction in dimensions, which leads to the reduction of computation complexity. For the recognition process, a test image (the image presented to the system for the recognition process) has the same dimension as the training image presented to the system. The test image is then extracted by multiplying by the eigenvector of the training image, and producing a feature vector containing the main component having the same dimension as the vector of the training image feature. Once the feature vector was obtained from the test image, the next process was to compare the feature vector of the test image with the feature vector of the training image. The results of this PCA process will then be used in the classification stage.

5) K-Nearest Neighbor Search using Priority K-d Tree

In this section, the calculation of similarity was done by calculating the level of similarity (distance) between test data and training data. The calculation of similarity level in this research was done by using Euclidean Distance shown in equation [35].

$$d(x, y) = \sqrt{\sum_{i=1}^n (x_i - y_i)^2} \quad (10)$$

From (10) it can be explained that $d(x, y)$ is the level of similarity between the test data (x) and the training data (y), x_i is the i feature value of the test data and y_i is the i feature value of the training data. n is the number of x and y features.

In Fig. 11(a) shows an example of a nearest neighbor priority queue that has a maximum size of five and has five elements, A-E. Suppose the nearest closest neighbor that is put into the priority queue is element F with a priority or a distance of 0.50. Since the priority queue has a maximum size of five, Element F is entered into the priority queue, while element E with the longest distance is removed from the priority queue.

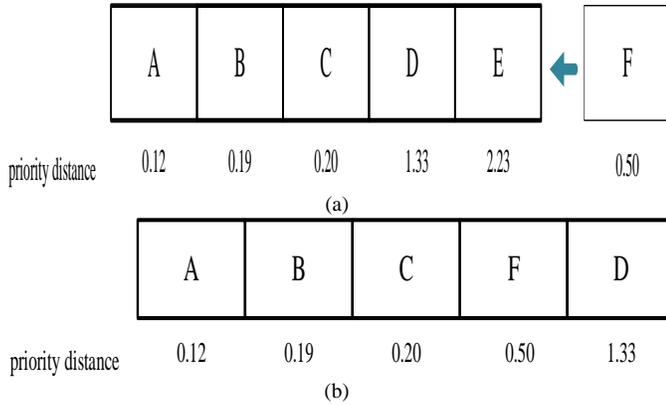


Fig. 11. An example of a nearest neighbor priority queue.

We use 10 test features in two dimensions as an example to illustrate the process of building k-d tree. Fig. 12(a) shows how the feature space is divided into hyper-rectangles iteratively, where the red points are test features and the blue one is the query feature. The tree structure in two dimensions is illustrated in Fig. 12(b).

Pseudocode for closest neighbor search using the priority k-queue is described in Algorithm 2.

Algorithm 2 The k-d tree nearest neighbor search

The k-d tree nearest neighbor search Algorithm

Input : node, currNode, INode, IDist, currDist, euclideanDistance, value, q, min_dist, k, neighborList
Output : nearest neighbor data points // distance //nearest distance between the query point and the data points

1. Begin
2. INode=NULL; /* last node null value */
3. IDist=Max_val; last distance with maximum value
4. If neighborlist.size > 0 then /* Calculate the Euclidean The distance between the last node in neighborList and the query point */
5. INode = neighborList.last ();
6. IDist = euclideanDistance (INode.value, value);
7. End
8. IDist = euclideanDistance (INode.value, value); /* Calculate the Euclidean distance between the current node and the query point. */

9. currDist = euclideanDistance(curr.value, value); /* Add the current node to the neighbor list if necessary. */
10. if currDist < IDist then
11. if neighborList.size == k AND INode ≠ NULL then
12. neighborList.remove(INode);
13. end
14. neighborList.add(curr) ; /* Add the current node to neighborList. The neighbor list is automatically sorted when the current node is added to the list. */
15. else if currDist == IDist then
16. neighborList.add(curr) ; /* Add the current node to neighborList. Note: The neighbor list can have more than k neighbors if the last nodes have equal distances in our implementation. */
17. else if neighborList.size < k then
18. neighborList.add(curr); /* Add the current node to neighborList. */
19. end
20. INode = neighborList.last();
21. IDist = euclideanDistance(INode.value, value) ; /* Calculate the Euclidean distance between the last node in neighborList and the query point. IDist is equivalent as r in Equation (11). */
22. axis = curr.depth % k ; /* Get the current axis. */
23. left = curr.left ; /* Get the current node's left child. */
24. right = curr.right ; /* Get the current node's right child. */
25. if left ≠ NULL AND !checked.contains(left) then search the left child branch
26. checked.add(left) ; /* Add the left child to the examined list. */
- /* Calculate the difference between the splitting coordinate of the query point and the current node. difference is equivalent as $|q_i - x_i|$ in Equation (11). */
27. if axis == X_AXIS then
28. difference = abs(value.x - curr.value.x) ; /* abs is absolute operator. */
29. else if axis == Y_AXIS then difference = abs(value.y - curr.value.y);
30. else if axis == T_AXIS then
31. difference = abs(value.t - curr.value.t);
32. end
33. intersection = (difference < IDist); ; /* Determine if the splitting plane intersects the hyper-sphere using Equation (11). */
34. if intersection then continue down the left branch
35. searchNode(value, left, k, neighborList, checked);
36. end
37. end
38. if right ≠ NULL AND !checked.contains(right) then search the right child branch checked.add(right) ; /* Add the right child to the checked list. */
39. if axis == X_AXIS then
40. difference = abs(value.x - curr.value.x);
41. else if axis == Y_AXIS then
42. difference = abs(value.y - curr.value.y);
43. else if axis == T_AXIS then
44. difference = abs(value.t - curr.value.t);
45. end
46. intersection = (difference < IDist); ; /* Determine if the splitting plane intersects the hyper-sphere using Equation (11). */
47. if intersection then continue down the right branch
48. searchNode(value, right, k, neighborList, checked);
49. end
50. end

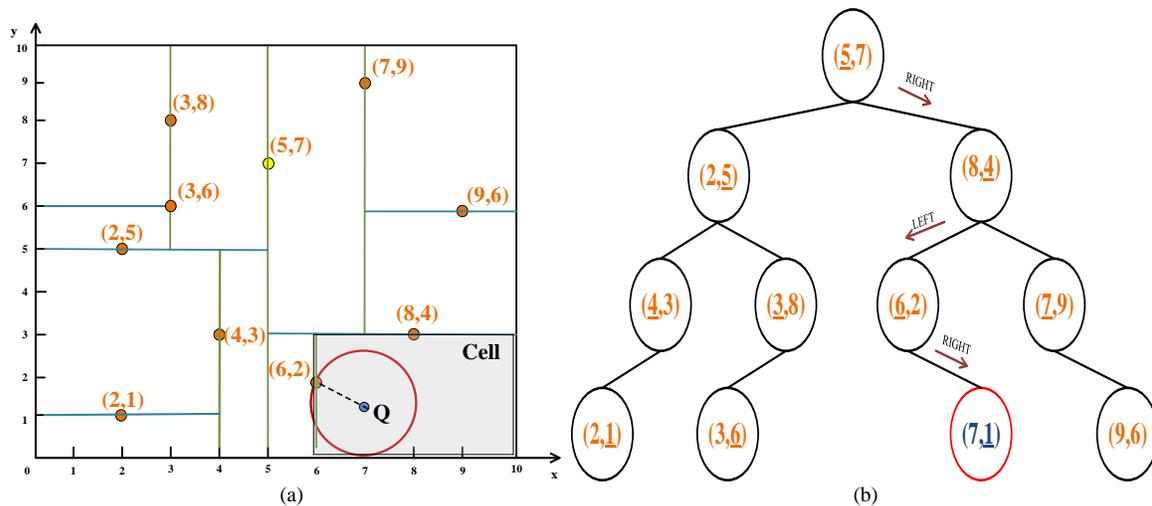


Fig. 12. (a) The feature space is divided into hyper-rectangles iteratively; (b) the tree structure in two dimensions.

In Algorithm 2, the first step is to input the k-d tree that is already constructed with the target point is $x_i = (x_i^{(1)}, x_i^{(2)}, \dots, x_i^{(k)})^T$, $i = 1, 2, \dots, n$, it is explained that the algorithm gives a query point first To find the nearest neighbor in k-d tree, then the k-NN algorithm looks for similarity of features in k-d tree by traversal determines the proper branches to explore. Each branch in k-d tree represents the space partition. This is intended to explore partitions closer to the query point. Partitions closer to this query point contain features that are similar to the nearest neighbors. The nearest neighbor search algorithm works by starting from the root node and running down the k-d tree recursively to find the query point. Once the algorithm reaches the leaf node in the k-d tree, the node is stored as the closest neighbor for the moment. The algorithm performs recursion and checks the tree again. Checks are performed on each node to find a better node with the nearest neighbor. The algorithm performs recursion and checks the tree again. The leaf node contains the target node x in the k-d tree. To find the nearest neighbor in the k-d tree, the algorithm gives Q query point first as shown in Fig. 12(a), then the k-NN algorithm search similarity features in the k-d tree by traversal by specifying the right branch to explore. When the priority search descends and reaches a sub-tree, sibling of the subtree is added to the sorted list. The subtree in the sorted list is then saved. The stored subtree has a distance between the query feature and the hyperrectangle corresponding to each subtree. If the coordinates of the current point x coordinates are less than the coordinates of the cut-point, the search is performed to the left sub-node. If the current point x point coordinates are greater than the cut-off point, the search is performed to the right sub-node. Until the child's node is a leaf node. If the instance stored on the node is closer than the current closest point to the query point, the instance point is considered the current closest point. The algorithm forms a hyper-sphere centered at the query point

with the radius of the circle being the distance (in this study is the Euclidean distance) which is calculated between the nearest best query point and current neighbor. The current nearest point should be in the region corresponding to the sub-node. Hyper-sphere candidates are formed by centering on the query point $q (q_0, q_1, q_2, \dots, q_{k-1})$ and through the point of the current node. The nearest neighbor node point to the request point should be within the hyper environment. The equation for determining the hyper-sphere candidate in the hyper environment is indicated by

$$|q_i - x_i| < r \quad (11)$$

q is the query point, x is the node, r is the radius and i is the i -th dimension.

IV. RESULT AND ANALYSIS

In this study, static and video images from the classroom were taken for the training process using a digital camera and an ip camera for testing process. A total of 9,126 facial data were collected from 1,014 people and stored in the database. Every individual had nine face poses with different angles. Tests were conducted to evaluate performance of proposed algorithm. Tests carried out with two face dataset which are Honda/UCSD [36] (Fig. 13) and AtmafaceDB dataset (Fig. 14). To test the accuracy of images, a total of 1350 face images were used. An Intel Core i5-7200U CPU @2.50 GHz was used to process this experiment. The experiment was conducted to compare the level of recognition using different levels of discrete wavelet decomposition. First, preprocessing was applied by cropping faces for face detection and applying localization processes in a rectangular area using the Viola-Jones method. Face images that had been cropped or cut were converted from color images into grayscale images. Facial images were then resized to 128x128 pixels. The images brightness was then normalized using histogram equalization.

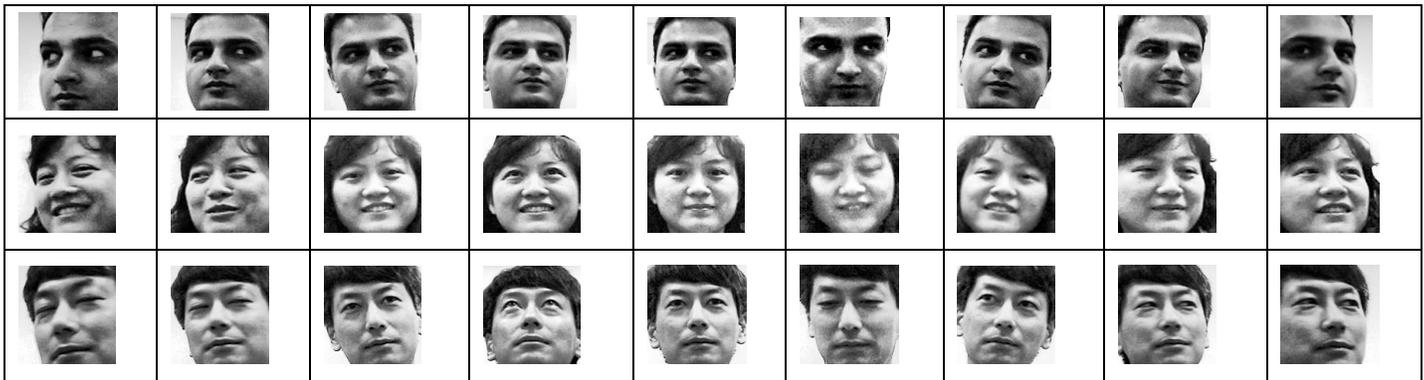


Fig. 13. Several samples of Honda/UCSD Dataset.

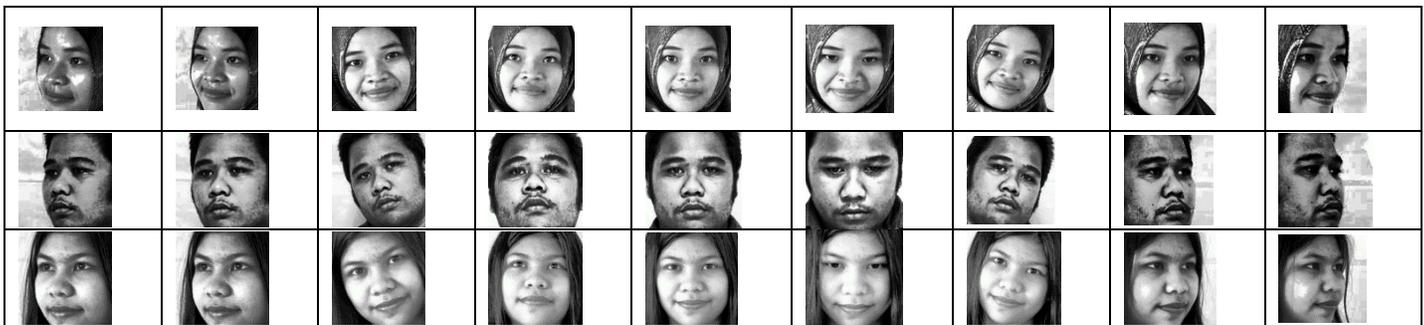


Fig. 14. Several samples of AtmafaceDB Dataset (Our Dataset).

Second, the 2D DWT-PCA method was applied. It was used for feature extraction using the face images resulting from preprocessing. After that, the result of student facial feature extraction was applied by k-d tree method. K-d tree was used to accelerate the process of facial classification using k-NN. The face recognition algorithm applied in this research is shown in Algorithm 3.

Algorithm 3 Multiple Face Recognition Algorithm

The Multiple Face Recognition Algorithm

- Input: Face Images
Output: Multiple Faces Recognized
1. Face Detection
 2. Face Image Preprocessing
 3. n level of 2D DWT application on face images
 4. Sub-band LL of 2D DWT application on PCA, followed by generation of feature vectors
 5. Storing of feature vectors in the database
 6. Indexing feature vectors in the database using k-d tree
 7. Finding the distance between the testing sample and all training samples using a Euclidean distance algorithm
 8. Sequencing of all training samples using nearest neighbor approach based on the minimal distance taken

In this study, the optimal choice of K was determined by 10-fold cross-validation [37]. Optimal K based on research from [35], [38] was used in this study. Each experiment was done 10 times, then the result was calculated from the average of 10 times of the experiment. In the k-d tree data structure was done several times of testing with different k values, namely k = 1, k = 3, k = 5 and k = 7. In this research, the time taken to calculate the result of classification with k-NN.

Based on Table 1, k-NN performs the best accuracy on k equal to 3 on the 3rd level wavelet for the Honda/UCSD

dataset, while the best accuracy on k equal to 5 on the 3rd level wavelet for the AtmafaceDB dataset. This shows that k-NN gives 82.00% on 600 Honda/UCSD faces and 95.56% on 1350 AtmafaceDB faces. K equals 5 on our dataset would be used in the next test because the best result.

TABLE I. K-NN Face ACCURACY

K Value	Average Accuracy (%)	
	Honda dataset	AtmafaceDB dataset (our dataset)
K=1	79.75	93.40
K=3	82.00	95.33
K=5	81.43	95.56
K=7	80.86	95.33

Table 2 shows the accuracy and timing of recognition on three levels of 2D DWT-PCA using k-d tree on AtmafaceDB dataset.

TABLE II. ACCURACY OF FACE RECOGNITION THREE LEVELS OF 2D DWT-PCA USING K-D TREE (K=5)

Level of Decomposition	Recognition Accuracy	Recognition Time (ms)
1 (64x64)	89.49%	98
2 (32x32)	90.00%	69
3 (16x16)	95.56%	40

Comparison of computing time for facial recognition at each level of 2D DWT-PCA using k-d tree is shown in Fig. 15.

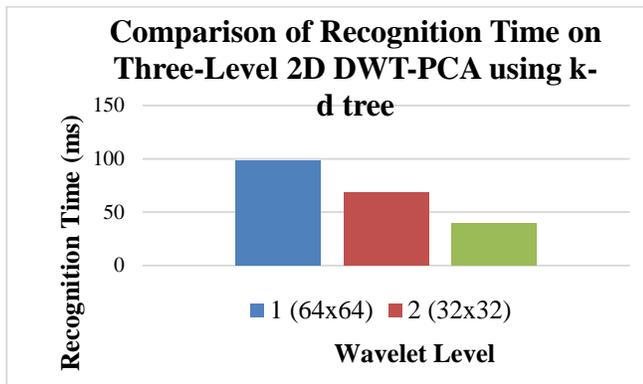


Fig. 15. The comparison of recognition time on three-levels of 2D DWT-PCA using k-d tree.

V. CONCLUSION

This paper proposes an attendance management system based on multiple face recognition combining the 2D DWT-Principal Component Analysis method with the k-Nearest Neighbor (k-NN) classification. Indexing using the k-d tree technique is conducted to speed up the classification process using a k-nearest neighbor (k-NN) approach. 2D DWT was decomposed into three levels. From the experimental results, k-Nearest Neighbor face recognition delivered best accuracy 95.56% on $k=5$. At each wavelet level, computational time for recognizing faces was compared. The three-level 2D DWT-PCA facial recognition method proposed shows good results. Research results show that this method reaches 95.56% accuracy, with a computing time of 40 milliseconds required for facial recognition. From the test results, it can be concluded that the use of data structure of k-d tree can reduce the time required when performing classification by using the method of k-nearest neighbors. The time required for classification using k-d tree also changes due to the facial image size of different wavelet decompositions. The future work of this research is to utilize GPU (Graphical Processing Unit) on detection of tracking model using KLT method and utilizing MBR (Minimum Bounding Rectangle) on k-d tree method with the aim of increasing accuracy of multiple-face recognition in classroom.

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Optimization and Evaluation of Hybrid PV/WT/BM System in Different Initial Costs and LPSP Conditions

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Abstract—A modelling and optimization study was performed to manage energy demand of a faculty in Karabuk University campus area working with a hybrid energy production system by using genetic algorithm (GA). Hybrid system consists of photovoltaic (PV) panels, wind turbines (WT) and biomass (BM) energy production units. Here BM is considered as a back-up generator. Objective function was constituted for minimizing total net present cost (TNPC) in optimization. In order to obtain more accurate results, measurements were performed with a weather station and data were read from an electricity meter. The system was also checked for reliability by the loss of power supply probability (LPSP). Changes in TNPC and localized cost of energy (LCOE) were interpreted by changing LPSP and economic parameters such as PV investment cost, WT investment cost, BM investment cost, and interest rates. As a result, it was seen that a hybrid system consisted of PV and BM associated with an effective flow algorithm benefited from a GA meets the energy demand of the faculty.

Keywords—*photovoltaic (PV)/wind turbines (WT)/ biomass (BM); hybrid system; optimization; sizing; cost-effective; reliability; genetic algorithm*

I. INTRODUCTION

Recently, as energy demand increases, fossil-based energy sources are running out. Usage of renewable energy sources such as solar, wind and hydroelectric, become widespread as an alternative to the depleting fossil resources [1]. Despite the widespread use of renewable energy sources, they are still not cost-effective as conventional energy sources [2]. For this reason, some economic and reliability calculations must be taken into consideration before investment.

Renewable energy sources are used as hybrid systems to reduce investment costs and increase system reliability. Because, when they are used individually, some disadvantages arise due to their stochastic properties whereas, these disadvantages disappear when they are used as hybrid systems [3], [4]. If renewables are used as hybrids, optimum sizing

studies can be done according to the variable load. During sizing studies, the objective function is constituted, and mathematical calculations are performed to obtain the lowest value of this function [5].

In sizing studies, objective function is generally considered as cost equations. Total net present cost (TNPC), total annualized cost (TAC) and localized cost of energy (LCOE) are the most common economic evaluation methods. TNPC is sum of net present cost (NPC) of the components. These components are initial investment cost (IC), operating and maintenance costs (OM), fuel costs (FC) and salvage values (S) [6]. TAC expresses the annual cost of TNPC [7]. LCOE is energy cost per kWh [6]. Economic analyses such as TNPC [8]-[10], TAC [11] and LCOE [9] are frequently used in literature.

In hybrid energy generation systems, high reliability of the system is as important as cost-effectiveness. Meeting of load by generated energy refers to a reliable system. Loss of power supply probability (LPSP) is a reliability evaluation method and was proposed by [12]. Researchers are frequently using LPSP for reliability of hybrid systems [9], [11]. Other reliability parameters such as loss of energy expectation (LOEE) used in [8] and energy index of reliability (EIR) used in [10] study.

Most of hybrid systems consist of PV panels, WT, batteries, diesel generators and fuel cells are evaluated according to economy and reliability. Optimization problems in these studies were solved by different meta-heuristic methods such as artificial bee colony, genetic algorithm, harmony search and particle swarm optimization [4], [8], [13], [15]. In literature, small number of studies includes BM. [14]-[20]. In addition, optimization problems were solved by ready-software such as HOMER [16]-[20]. For instance, in the studies [14], [15]; mixed integer linear programming and harmony search were used to solve optimization problem. In

these studies wind energy was not included in the hybrid system.

However, HOMER has some disadvantages such as usage of a single objective function to reduce net present cost to minimum, usage of non-sorted results by LCOE when doing an evaluation according to NPC, performing without considering depth of discharge for batteries and ignoring hourly changes [21].

Suganthi et al. express that in recent years optimization studies involving solar and wind energy systems have been frequently performed. In addition, despite the start of bioenergy studies with solar and wind energy, there is still a large gap in researches about optimization of hybrid energy systems including bioenergy [22].

In this study, PV/WT/BM were hybridized and optimized with GA for the first time. For this purpose, number of PV panel, sweeping area of WT and power of biogas (BG) generator were selected as optimization parameters due to the major effects on the total system efficiency. BM based PV/WT hybrid energy production system was optimized according to the minimum value of TNPC to meet variable load. Results were also evaluated in terms of LCOE and cost per kWh was calculated. In addition, reliability was controlled by setting LPSP to maximum 0.1. Furthermore, results for TNPC and LCOE were interpreted with different LPSP values under the operating conditions with different economic parameters such as different initial cost of PV, WT, BM, and interest rates.

This paper was organized as follows: Section 2 described scientific fundamentals and experimental studies consisting of weather and electrical measurements to prepare the required data for the simulation input. Section 3 presented and evaluated the optimization results according to the different economic parameters. Finally, conclusion was conferred in Section 4.

II. METHODOLOGY AND MATHEMATICAL MODELLING

In this section, measurement values, constant values and mathematical models of PV/WT/BM were revealed for optimization study. In addition, mathematical models of economic evaluation method were suggested to determine

objective function. Work flow of optimization study was presented to understand system working principle.

A. Obtaining of Data

Hourly radiation, temperature and wind speed was obtained from the weather station and instantaneous changing of the load was taken from electricity meter of Faculty of Economics and Administrative Sciences which shown in Fig. 1. For biomass source of the hybrid system, waste of student and staff dining hall of Karabuk University, waste of dining hall of Kardemir Corporation, waste of Training and Research Hospital dining hall of Karabuk University and grass quantity of campus area were used. Possible waste quantity per person and rate of methane for these wastes were taken from [23] and [24]. Biogas production potential of these wastes was given in Table 1.

Table 1 shows the number of meals, amount of waste, produced BG and methane. The number of meal was taken from dining halls personnel and produced amount of BG and methane were taken from [24]. In addition to food wastes BG production of grass wastes were given as in Table 2.

Table 2 shows the amount of grass wastes, produced BG and methane. Annual amount of grass wastes in campus area was taken from technical personnel of university and produced amount of BG and methane were taken from [25], [26].

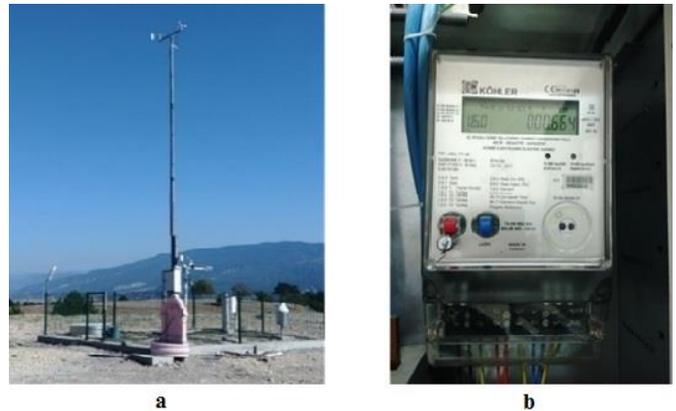


Fig. 1. Weather station (a) and electricity meter (b).

TABLE I. BIOGAS PRODUCTION POTENTIAL OF WASTES

Location	Number of meals (piece/year)	Total amount of waste (kg/year)	Produced amount of biogas (m ³ / year)	Methane ratio in biogas [24]	Produced amount of methane (m ³ /year)
Dining Halls	3699286	350026.44	85756.46	64%	54884.13

TABLE II. BIOGAS PRODUCTION POTENTIAL OF GRASS WASTES

Location	Obtained quantity (kg/year)	Produced biogas (L) [25-26]	Produced amount of biogas (m ³ /year)	Methane ratio in biogas [26]	Produced amount of methane (m ³ /year)
Grass on Campus	165000	82500000	82500	70%	57750

TABLE III. TECHNICAL AND ECONOMIC PARAMETERS OF HYBRID SYSTEM

Parameters	Unit	Value
Interest Rate (i)	-	0.1
Lifespan of Project (N)	year	25
Inflation Rate	-	0.0805
Escalation Rate of PV System	-	0.09
Escalation Rate of Wind Turbine	-	0.09
Escalation Rate of Biogas System	-	0.05
Investment cost of PV System (α_{pv})	(\$/piece)	385.71
Operating and Maintenance Cost of the PV System	(\$/piece/year)	$0.011 \times \alpha_{pv}$
Salvage Value of PV System	(\$/piece)	$0.2 \times \alpha_{pv}$
Maximum power temperature coefficient (K_p)	(%/°C)	-0.42
Temperature in Standard Test Condition (T_R)	(°C)	25
Investment cost of Wind Turbine α_{wt}	(\$/m ²)	480
Salvage Value of Wind Turbine	(\$/m ²)	$0.1 \times \alpha_{wt}$
Annual Operating and Maintenance Cost of the Wind Turbine	(\$/ m ² /year)	$0.0109 \times \alpha_{wt}$
Investment cost of Biogas System α_{bg}	(\$/kW)	2438.45[27]
Fixed Operation and Maintenance Cost of Biogas System	(\$/kW/year)	$0.045 \times \alpha_{bg}$
Variable Operation and Maintenance Cost of Biogas System	(\$/kWh/year)	0.0351
Fuel Cost of Biogas System	(\$/m ³ /year)	0.1657
Salvage Value of Biogas System	(\$/kW)	$0.3 \times \alpha_{bg}$
Efficiency of Biogas Generator	-	0.41
Methane ratio in biogas	-	0.64
Lower Heating Value of Biogas	(kWh/m ³)	6.4
Number of PV Panels (N_{module}^{max})	Piece	1000
Maximum Area for Wind Turbines (A_{wt}^{max})	(m ²)	1000
Maximum Power of Biogas Generator (P_{bg}^{max})	(kW)	100
Maximum LPSP ($LPSP^{max}$)	-	0.01

Simplified diagram of hybrid system was shown in Fig. 2. Relative frequency of radiation (W/m²), wind speed (m/s), weather temperature (°C) and load period (W) were given in Fig. 3. Technical and economic parameters of hybrid system were listed in Table 3. The parameters were taken from literature [15], [24], [27]-[30].

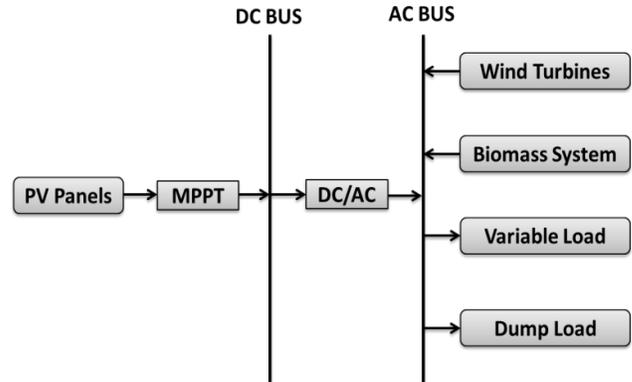


Fig. 2. Simplified diagram of hybrid system.

B. Modelling of PV Power

Power generating systems can be represented by different mathematical methods. In this study, following equations were utilized for power model of PV panel.

$$T_C(t) = T_A(t) + \frac{NOCT-20}{800} R(t) \quad (1)$$

$$P_{pv}(t) = N_{module} \cdot V_{mpp} \cdot I_{mpp} \times \frac{R}{1000} \left[1 - \frac{K_p}{100} (T_C(t) - T_R) \right] \quad (2)$$

Where, $T_C(t)$ is cell temperature, $T_A(t)$ is ambient temperature, $R(t)$ is radiation and NOCT is nominal operation cell temperature in (1). $P_{pv}(t)$ is power in maximum power tracking point, N_{module} is number of total modules, K_p is maximum power temperature coefficient (%/°C), T_R is cell temperature in standard test conditions, and maximum power point voltage and current are V_{mpp} and I_{mpp} , respectively in (2).

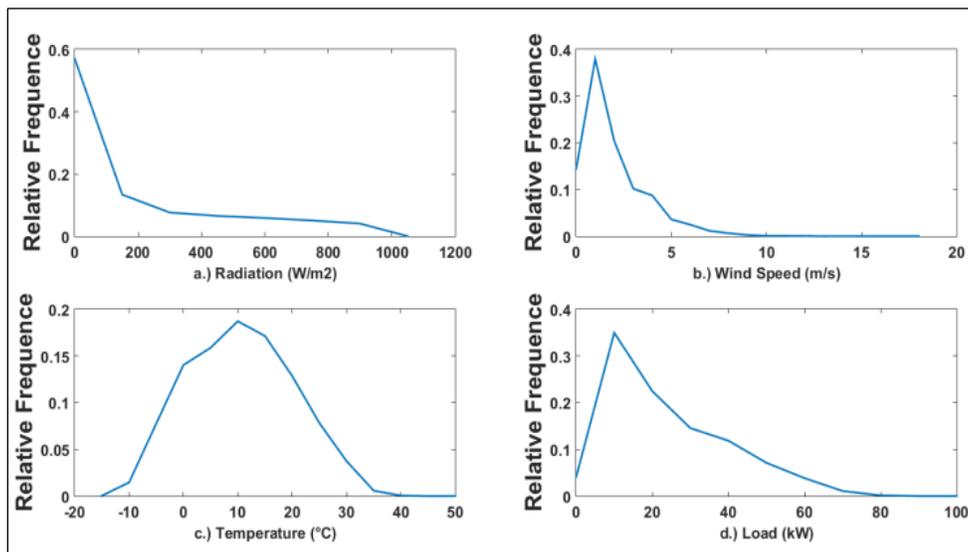


Fig. 3. Relative frequency of radiation (W/m²) (a), wind speed (m/s) (b), ambient temperature (°C) (c) and load period (W) (d).

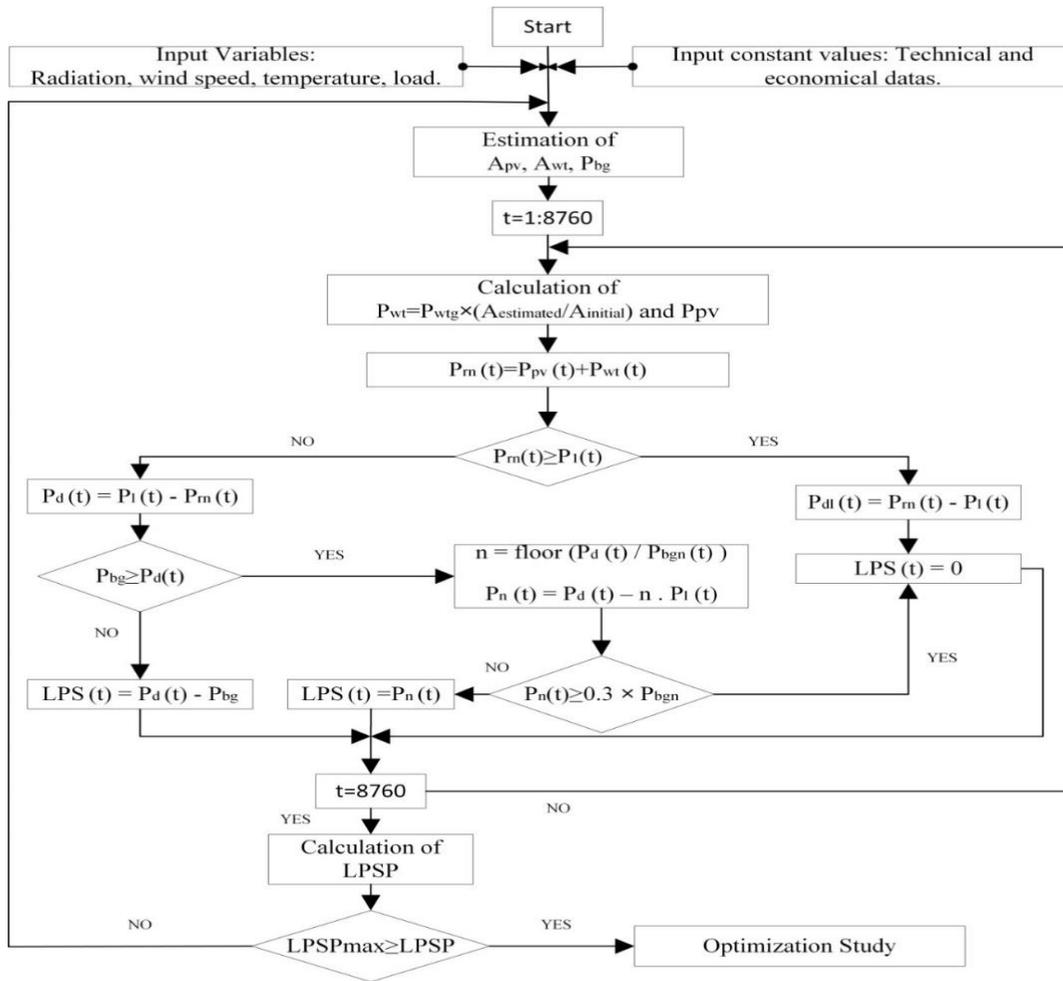


Fig. 4. Work flow of optimization.

C. Modelling of Wind Turbine Power

For the modelling step of WT power, (3) was used. In (3), P_r is nominal power of WT, A_{wt} is sweeping area of turbine, V_r is speed in nominal power. ρ_{air} indicates air density and was taken as 1.225 kg/m^3 .

$$P_r = \frac{1}{2} \times \rho_{air} \times A_{wt} \times V_r^3 \times Cp \quad (3)$$

In order to obtain power of WT (P_{WTG}) more accurately under different wind speed conditions, (4) was used as given below. In (4), V_{ci} is cut in speed for turbine (m/s) and V_{co} is cut out speed for turbine (m/s) [31].

$$P_{WTG} = \begin{cases} 0, & V < V_{ci} \\ a \times V^3 - b \times P_r, & V_{ci} \leq V < V_r \\ P_r, & V_r \leq V \leq V_{co} \\ 0, & V > V_{co} \end{cases} \quad (4)$$

a and b coefficients were given below:

$$a = \frac{P_r}{V_r^3 - V_{ci}^3} \quad b = \frac{V_{ci}^3}{V_r^3 - V_{ci}^3} \quad (5)$$

Output power of WT is updated according to the estimated sweeping area of turbine. P_w (W) shows the updated output power of turbine and takes a new value in every iteration.

$$P_w = P_{WTG} \times \left(\frac{A_{wt}}{A_{initial}} \right) \quad (6)$$

In (6), $A_{initial}$ is initial sweeping area of turbine (m^2) and A_{wt} is sweeping area (m^2) of WT estimated by genetic algorithm.

D. Modelling of Biogas Generator Power

In this study, when energy production from PV panels and WT became insufficient, a back-up BG generator runs. A mathematical model to determine the dimensions of BG generator was developed as given in (7) [15], [32].

$$P_{bg}(t) = \eta_{bg} \times Q_{bg}(t) \times LHV_{bg} \quad (7)$$

Where, P_{bg} is power of biogas generator (W), η_{bg} is efficiency of generator, $Q_{bg}(t)$ is amount of biogas consumption (m^3/h), and LHV_{bg} is lower heating value of biogas (kWh/m^3).

According to the hourly working power of generator, required amount of biogas was calculated as follows:

$$Q_{bg}(t) = \frac{P_{bg,h}(t)}{\eta_{bg} \times LHV_{bg}} \quad (8)$$

Where, $P_{bg,h}(t)$ is power of biogas generator at t hour.

Technical information of PV panels, WT and BG generator were shown in Table 4.

TABLE IV. TECHNICAL INFORMATION OF PV PANEL, WT AND BIOGAS GENERATOR

PV Panel	PV Panel Manufacturer	Yingli Solar
	Model	YL265P-29b
	Rated Power (W)	265
	Panel Area (m ²)	1.63
	Nominal Operation Cell Temperature (°C)	46 +/-2
Wind Turbine	Wind Turbine Manufacturer	Halbes
	Wind Turbine Efficiency (%)	31.9
	Pr (kW)	10
	Vr (m/s)	11
	Vci (m/s)	2.5
	Vco (m/s)	25
	Rotor Diameter (m)	7.5
Biogas Generator	Generator Manufacturer	NPT
	Model	10GFT
	Alternator Manufacturer	MBH(Germany)
	Nominal Power (kW/kVA)	10/12.5
	Rated Speed (r/min)	1500
	Power Factor	0.8

E. Total Net Present Cost (TNPC) of Hybrid System

TNPC economic analysis method was used for economic evaluation of the hybrid energy system. TNPC is sum of net present costs of all costs over lifetime of the hybrid energy system as given in (9).

$$TNPC = IC + OM + FC - S \quad (9)$$

Here, IC is investment cost, OM is NPC of operating and maintenance costs, FC is NPC of fuel costs, S is NPC of salvage value of hybrid systems.

The TNPC for PV system, WTs and BG system were shown in (10)-(12), respectively. Fuel cost was not written in TNPC equation due to not existence fuel consumption in PV systems.

$$TNPC_{pv} = IC_{pv} + OM_{pv} - S_{pv} \quad (10)$$

$$TNPC_{wt} = IC_{wt} + OM_{wt} - S_{wt} \quad (11)$$

$$TNPC_{bg} = IC_{bg} + OM_{bg} + FC_{bg} - S_{bg} \quad (12)$$

In contrary to PV systems, fuel cost must be considered in BM systems. In addition, both fixed and variable costs were considered for operating and maintenance costs in BG system.

F. Loss of Power Supply Probability

Reliability of hybrid system was tested by LPSP method. It is one the most common reliability test and was shown in (13) [18]. Calculation of hourly LPS was explained in "methodology of optimization process".

$$LPSP = \frac{\sum_{t=1}^T LPS(t)}{\sum_{t=1}^T P_l(t)} \quad (13)$$

G. Objective Function and Constraints

Objective function of optimization study was given in (14). Number of PV panels, sweeping area of WT and power of BG generator were the parameters of optimization study. When these values were optimized, the objective function was expected to get the lowest value.

$$\text{Min.TNPC} (N_{module}, A_{wt}, P_{bg}) = \sum_{i=pv,wt,bg} TNPV_i \quad (14)$$

Constraints of optimization were given in (15)-(18). Estimated values of N_{module} , A_{wt} , P_{bg} should be remain the following limits:

$$N_{module}^{min} \leq N_{module} \leq N_{module}^{max} \quad (15)$$

$$A_{wt}^{min} \leq A_{wt} \leq A_{wt}^{max} \quad (16)$$

$$P_{bg}^{min} \leq P_{bg} \leq P_{bg}^{max} \quad (17)$$

$$LPSP^{min} \leq LPSP \leq LPSP^{max} \quad (18)$$

H. Localized Cost of Energy (LCOE)

At the end of the optimization, the energy cost per kWh was calculated by LCOE (\$/kWh) as given in (19). Here, E_l is energy consumption of faculty per year.

$$LCOE = \frac{TNPC \times CRF}{E_l} \quad (19)$$

Capital recovery factor (CRF) was calculated as in (20):

$$CRF = \frac{i \times (1+i)^N}{(1+i)^N - 1} \quad (20)$$

In Fig. 4, work flow of optimization can be seen.

I. Optimization Algorithm and Software

For optimization, GA which is meta-heuristic optimization algorithms was used. GA uses rules which contain probability and it gives successful results when the solution space is discontinuous and complex. For parameters of GA; the number of populations was taken 50, the probability of crossing was taken 0.8, the probability of mutation was taken 0.05, and function tolerance was taken 10e-6. Here, function tolerance was used as stopping criteria.

J. Methodology of Optimization Process

In order to meet the load during the flow of the process, the PV and WT energy were preferred firstly, and when these sources were insufficient, BG generator run. Obtaining of hourly LPS(t) and its methodology were as follows:

1. Situation:

$P_{rn}(t) \geq P_l(t)$: $P_{rn}(t)$ is the sum of energy produced by PV and WT and $P_l(t)$ is load. If produced energy is enough for meeting consumption, $LPS(t)$ will be zero.

$$P_{rn}(t) = P_{pv}(t) + P_{wt}(t) \quad (21)$$

$$LPS(t) = 0 \tag{22}$$

$P_{dl}(t)$ is the dump load and occurs when $P_{rn}(t)$ is much more than load.

$$P_{dl}(t) = P_{rn}(t) - P_l(t) \tag{23}$$

2. Situation:

$P_{rn}(t) \leq P_l(t)$: When $P_{rn}(t)$ is insufficient to consumption, deficit load is occurred as $P_d(t)$.

$$P_d(t) = P_{rn}(t) - P_l(t) \tag{24}$$

2.1. $P_d(t) \geq P_{bg}(t)$, When $P_{rn}(t)$ and $P_{bg}(t)$ cannot meet to consumption together, LPS(t) become as difference between $P_d(t)$ and $P_{bg}(t)$.

$$LPS(t) = P_d(t) - P_{bg}(t) \tag{25}$$

2.2. $P_d(t) \leq P_{bg}(t)$, If energy produced by BG generator is more than deficit power, following situations occurs.

$$n(t) = \text{floor}\left(\frac{P_d(t)}{P_{bgn}}\right) \tag{26}$$

$$P_n(t) = P_d(t) - n \times P_{bgn} \tag{27}$$

$P_n(t)$ defines the required energy when total energy supply from the hybrid system was not sufficient. If $P_n(t) \geq 0.3 \times P_{bgn}$, working BG generator power ($P_{bg,h}(t)$) will be equal to $P_d(t)$. Otherwise, $P_{bg,h}(t) = n \times P_{bgn}$ and $P_n(t)$ will be equal to $LPS(t)$. P_{bgn} is the nominal power of BG generator. BG generator cannot work well when load is less than 30% of generator nominal power. So, loading coefficient of 0.3 was taken as multiplier.

III. RESULTS

Optimization of hybrid systems involving biomass energy in existing studies shows that it is usually done with packet programs. In our study, the inclusion of wind energy in the hybrid system and the evaluation of the LCOE beside TNPC are different from previous studies.

Sizing of the hybrid system was repeated for different economic parameters during the study. MATLAB was used for coding of optimization algorithm. An i7 processor computer consisting of 16 GB ram and 2 GB graphics card was utilized to perform optimization process. According to the iteration, changes in TNPC value were given in Fig. 5.

Optimization results were given in Table 5. N_{module} , A_{wt} and P_{bg} are optimization parameters. As a result of optimization made by the GA, 597 PV panels and 6 pieces of 10 kW biogas generators must be used. The power equivalent of the panels was given in Table 5.

TABLE V. OPTIMIZATION RESULTS

Energy Source	Optimized Parameter	Result	Power (kW)
PV	N_{module} (pieces)	596.429	158.205
WT	A_{wt} (m ²)	0	0
BM	P_{bg} (W)	63790.795	60

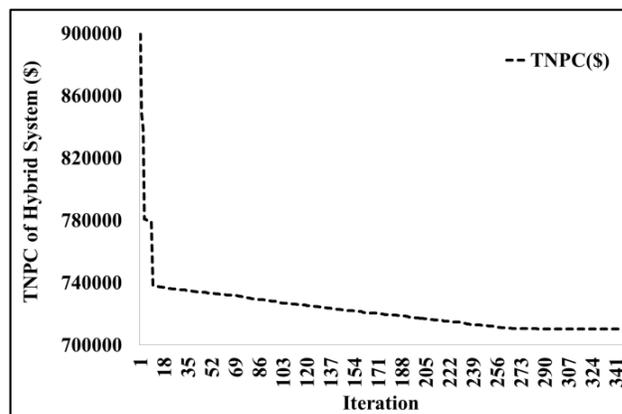


Fig. 5. Changes in TNPC values according to the iteration number.

As shown in Fig. 6, 71% PV, 29% BM and 0% WT were recommended after optimization. As a result of the optimization made by the GA, the WT was not selected as an energy source because the wind speed around Karabuk University is not suitable for investing for efficient wind energy production.

Fig. 7 shows values of TNPC and LCOE, according to the different LPSP values changing between 0.01 and 0.02. When LPSP increases 1%, LCOE and TNPC increase 24.11% together. The characteristics of slopes for TNPC and LCOE show increasing trends according to decreasing LPSP values towards to 0. Hence, when LPSP reached to 0, TNPC and LCOE values expected to be much higher.

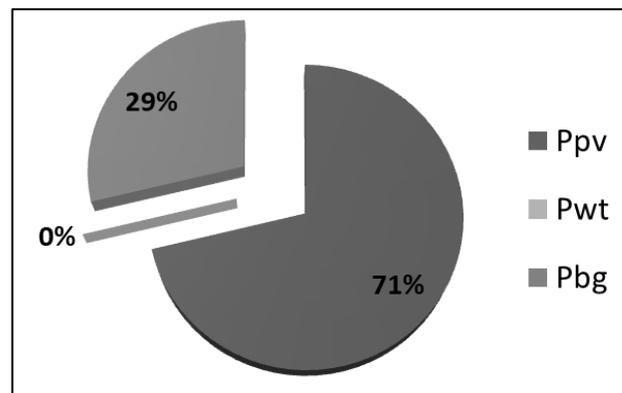


Fig. 6. Rates of power distribution according to the energy sources.

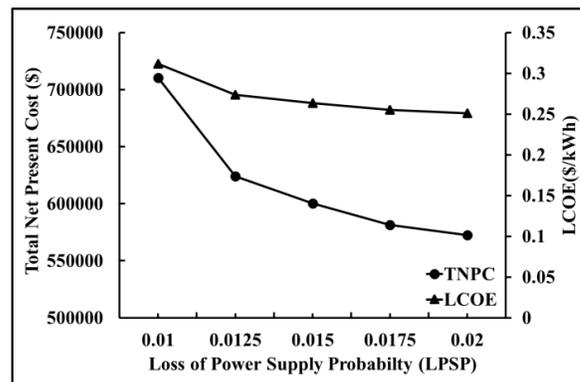


Fig. 7. Changes of TNPC and LCOE values in different LPSP.

Interest rate in undeveloped and developing countries is not stable as in developed countries. Since Turkey is a developing country, changes in interest rate have an impact on investment costs. Values of TNPC and LCOE, according to different interest rates, were shown in Fig. 8. As interest rate increases from 7% to 13%, LCOE increases from 0.2778 \$/kWh to 0.3421 \$/kWh and TNPC decreases from \$813085 to \$629685. In addition, according to the Fig. 8, it's observed that the LCOE is directly proportional to the interest rate, however the TNPC is inversely proportional with interest rate. Furthermore, a 6% increase in interest rate provided and increase in LCOE values by 19.5% and caused a decrease TNPC values by 22.5%.

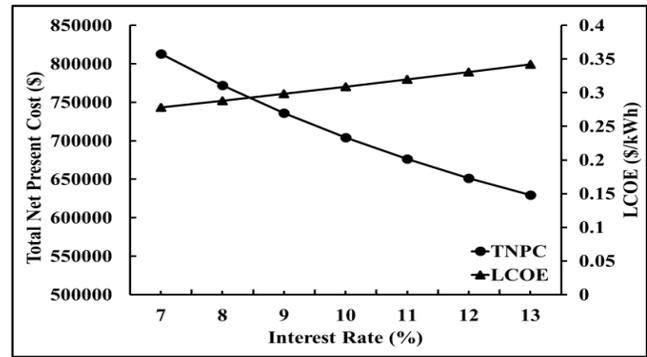


Fig. 8. Values of TNPC and LCOE in different interest rate.

TABLE VI. RESULTS FOR DIFFERENT INITIAL COST OF PV PANEL

Initial Cost of PV (\$/piece)	TNPC _{pv} (\$)	TNPC _{wt} (\$)	TNPC _{bg} (\$)	OM _{pv} (\$)	OM _{bg} (\$)	TNPC (\$)	LCOE (\$/kWh)
315	240085	0	415628	52611	162605	655714	0.2877
340	245620	0	427057	53825	166917	672657	0.2951
370	251223	0	445228	55051	175117	696428	0.3055
400	267694	0	448657	58662	176660	716342	0.3143
430	285665	0	452800	62600	178834	738485	0.3240

TABLE VII. RESULTS FOR DIFFERENT INITIAL COST OF BIOMASS SYSTEM

Initial Cost of BM (\$/kW)	TNPC _{pv} (\$)	TNPC _{wt} (\$)	TNPC _{bg} (\$)	OM _{pv} (\$)	OM _{bg} (\$)	TNPC (\$)	LCOE (\$/kWh)
1700	251257	0	386857	55060	141562	638114	0.28
2000	257585	0	401000	56445	150225	658600	0.2889
2300	258154	0	430857	56571	166828	689028	0.3023
2600	260797	0	460457	57151	183534	721257	0.3164
2900	264928	0	487571	58057	199054	752485	0.3301

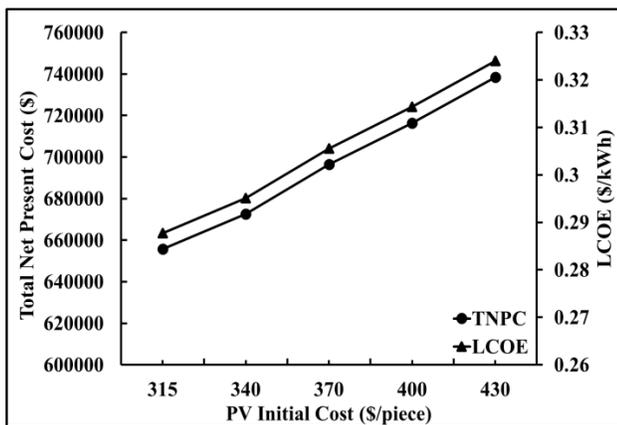


Fig. 9. TNPC and LCOE values according to the changing PV panel cost.

The variation of PV panel investment cost versus LCOE and TNPC was shown in Fig. 9. According to the Fig. 9, when initial cost of PV panel decreases from \$ 430 to \$ 315, LCOE decreases from 0.3240 \$/kWh to 0.2877 \$/kWh and TNPC decreases from \$ 738485 to \$ 655714. When initial cost of PV panel decreases 26.7%, LCOE and TNPC decrease 11.2% together. According to this result, changes in PV panel initial cost have a serious impact on TNPC and LCOE.

In Table 6, TNPC of PV panel, WT, BM system, and operation and maintenance cost of each system for different initial costs of PV panels were listed. According to Table 6, changes in initial cost of PV panel effects the TNPC strongly. It was seen that the investment cost and usage rate of PV panel in hybrid system are inversely proportional. Besides, when PV panel initial cost increases, usage rate and of BG generator and TNPC_{bg} increases.

In Fig. 10, it was seen that as investment cost of the BG system increases, TNPC and LCOE values increases together. When the initial cost of BM system decreases from \$ 2900 to \$ 1700, LCOE decreases from 0.3301 \$/kWh to 0.28 \$/kWh and TNPC decreases from \$ 752485 to \$638114. When initial cost of BM system decreases 41.4%, LCOE and TNPC decrease 15.2% together. As the cost of BM system investment increases, the results tend towards PV energy usage, so the number of solar panels and TNPC_{pv} values increases.

In Table 7, TNPC of PV panel, WT, BM system, and operation and maintenance cost of each system for different initial costs of BM system were demonstrated.

According to Table 7, changes in initial cost of BM system effects to TNPC. The increase in investment cost of the biomass system increased both TNPC_{bg} and TNPC_{pv}. Because when initial cost of BM system increases, usage rate of PV panel increases.

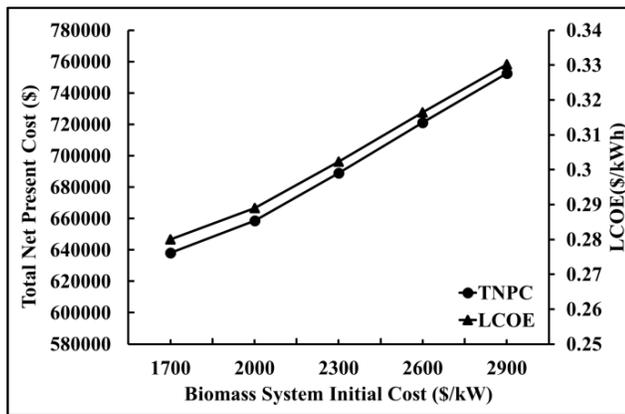


Fig. 10. TNPC and LCOE values according to the changing BM cost.

IV. CONCLUSION

In the study, size optimization was performed according to the lowest cost and highest reliability to meet the energy requirement of a faculty in Karabuk University Campus with BM supported PV/WT hybrid energy system. GA which is one of the meta-heuristic optimization algorithms was used in current optimization study. TNPC and LCOE values were demonstrated according to the interest rate, PV and BM initial cost. As a result, WT energy was not considered as a profitable energy source by GA due to the insufficient wind speed around Karabuk University for an efficient wind energy production. When LPSP was set to 0.1, recommended sizes of PV power, BM power and WT power were determined as 71%, 29% and 0%, respectively by GA. In optimized system, power of PV and BM system were determined 158.205 kW and 63.791 kW, respectively. The TNPC value was \$710285 and the LCOE value was 0.3117 \$/kWh. As a result, even if WT was not selected as an energy producer by GA, it was proven that supplying the energy demand of faculty by PV and BM effectively is possible. We hope this study will be a favourable case for researchers and engineers who study in hybrid energy and optimization topics. In future studies, optimization of hybrid systems containing biomass energy in terms of economy and reliability can be realised using hybridized meta-heuristic algorithms.

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A Web based Inventory Control System using Cloud Architecture and Barcode Technology for Zambia Air Force

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Abstract—Inventory management of spares is one of the activities Zambia Air Force (ZAF) undertakes to ensure optimal serviceability state of equipment to effectively achieve its roles. This obligation could only be made possible by automating the current manual and paper based inventory system. A web based inventory management system using cloud architecture and barcode technology was proposed. A literature review was conducted on three technologies used in the inventory management that is Radio Frequency Identification (RFID), Barcode Technology and Near Field Communication (NFC). A review was also undertaken on the related works to identify the concept that could be adopted in the proposed system. A baseline study was performed to understand the challenges faced by ZAF in the inventory management of spares. The results of the baseline study were analyzed and found that the challenges were attributed to the current manual inventory management system mainly due to human errors, incorrect inventory reporting and pilferage of items. The proposed prototype system was developed and tested and proved to be faster, efficient and more reliable than the manual and paper based system.

Keywords—Zambia Air Force (ZAF); inventory system; barcode technology; Radio Frequency Identification (RFID); Near Field Communication (NFC); cloud computing; web based application

I. INTRODUCTION

Inventory management of aircraft spares is one of the activities Zambia Air Force (ZAF) carries out to ensure that the state of the equipment is serviceable to effectively achieve its primary and secondary roles. To ensure the maintenance of equipment is up to date, ZAF procures so many types of spares that come in different sizes for various categories of aircraft as shown in Fig. 1. Among other spares that ZAF procures are Garmin Audio Control 340, Directional Gyro, Compressor Bleed, HF Receiver Exciter, HF Controller, AMP Coupler, KX165 VHF COMM/NAV, Marker Beacon Receiver, KN6ZA, Computer, Radar Altimeter, Isolation Amplifier, ATC Transponder, Pictorial NAV Indicator, Weather Radar, Transceiver, Flap Train, Access GPS, Slave Accessory, Transmitter, Slave Accessory, Radar sensor, Split Pin, Altimeter Pressure, Ignition Exciter, Indicator temperature AC Sealed Relay and High current Fuse. Some of these spares are very small in size and fuses are a good example. Therefore, it is so complex to store and track these small spares in the

warehouse using a manual and paper based system. The manual and paper based system of inventory that is in place does not provide the needed efficiency and effectiveness to the maintenance of equipment. So, in order for ZAF to effectively achieve its roles, it is necessary to automate the current manual inventory business processes and adopt it for its operations as Information and Communication Technology (ICT) has become an integral component in all organizations. Most large companies and organizations in developing countries are adopting web-based applications to do their business efficiently and effectively by taking advantage of Internet presence that has rapidly spread around the world [1].

The study's focus is on computerizing inventory management processes by using cloud architecture and barcode technology. The barcode technology will make use of one-dimensional barcodes, and a long-range wired barcode scanner [2], [3]. Barcode technology was preferred to other technologies such as Radio Frequency Identification (RFID) and Near Field Communication (NFC) because it is a mature technology, cheaper and simple to use.

This paper is organized as follows: The second section is literature review which covers technologies used in the inventory management and cloud computing. The third section is related works, which looks at the systems that have previously been designed and implemented to solve challenges of the similar nature. Fourth section presents the methodology. Fifth section brings out the results and the discussion of the baseline study conducted to identify challenges in the inventory management that ZAF faces, and the last section presents the conclusion.



Fig. 1. Aircraft spares.

II. LITERATURE REVIEW

Mwasele and Sichona [4] define inventories as dormant stocks of items that are stored in the warehouse waiting to be utilized. The management of inventory involves systems and processes that identify inventory requirements, set targets, provide replenishment techniques, report actual and projected inventory status and handle all functions related to tracking and management of material. Managers, now more than ever before, need reliable and effective inventory control to reduce costs and remain competitive [5]. According to Dobler and Burt [6], inventory alone account for as much as 30% of the organization-invested capital. Victoria and Ukpere [7] suggest that inventory control enhances profitability by reducing costs associated with storage and handling of materials. RFID, Barcode technology, NFC and related works are discussed in the subsequent sections.

A. Radio Frequency Identification

RFID is an automated system that utilizes wireless technology to uniquely identify and track tagged objects in the form of a unique serial number [8]. It gathers data about an object without the need to touch or see the data carrier. A typical RFID system is composed of four basic components including RFID tags, readers, antennas and a central node computer system which houses the database server and management software (middleware) [8]. The RFID tag or transponder is the data carrier that transmits information to the RFID reader (the transceiver) within a given range through a microchip and antenna embedded in it [8], [9]. The second component in an RFID system is the reader. Its role is to query a tag and receive data from it [10]. The antenna generates radio signals to activate the tag and read or write data to it [8]. The middleware at the central node manages incorporation of data received from the reader [10]. The middleware manages the information exchange between the reader and the backend database server [10]. A computer database server mainly completes the data storage, management and read-write control of the radio frequency tags. They provide the data obtained from the reader to the software application.

The advantages of RFID include: automatic non-line-of-sight [11], [12], ability to withstand harsh environments [12], the data capacity of RFID tags permits them to vary in size, from holding only a few bits to thousands of bits [11], [12], the technology is secure [11], it provides real-time information as it is quite challenging for those organizations managing large yards to know precisely what goods and their quantity are and on which truck without first unloading the truck, which also makes it complex to direct the truck to the right drop off or parking yard location [11] and it is cost saving [12].

The disadvantages of RFID include: it is expensive compared to barcode technology and the price of RFID tags has traditionally been a significant obstacle to its widespread deployment in Supply Chain Management (SCM) [11], [12], because RFID uses the radio spectrum to transmit its signals, it is susceptible to interference that leads to the hampering of its ability to transmit clear and reliable information to RFID readers [11], it is difficult to position tags on a varying range of products to gain the most successful read rates [12], it is difficult to read multiple items when a pallet contains different

items to be read, as the reader needs to be aware it is reading multiple types of items and the current RFID protocols are designed to offer the most optimal performance between readers and tags, but neglecting to address consumer privacy concerns. Privacy advocates are worried that if RFID tags are placed in common items, the product may be tracked once purchased by consumers [12].

B. Barcode Technology

The barcode technology is used in various areas of applications in computerizing the operations for the purpose of achieving efficiency, effectiveness and realizing optimal benefits from the business by scanning the inflow and outflow of barcoded items using a scanner [13]. The technology comprises of barcodes and barcode readers also known as scanners.

Barcodes are printed symbols of machine-readable data that contain information about an item to help facilitate the item's identification and tracking [13]. Sarika and Imran [2] define a barcode as an optical machine-readable representation of data that is capable of storing the physical object information in digital form to which they are attached or fixed. There are three types of barcodes that are used in enterprises: linear (1D), two-dimensional (2D) and three-dimension (3D) barcodes. A linear barcode is the first generation, one-dimensional barcode that is made up of lines and spaces of various widths that create specific patterns. These patterns represent stock-keeping unit (SKU) numbers, which are easily and quickly read by computer scanners. The usage of linear barcodes is much cheaper and quite simple. Linear barcodes are widely used and they come in different types such as UPC, CodaBar, Code 25, 39, 128 and European Article Numbering (EAN) [2]. The 2-Dimensional barcodes are more powerful and store more information compared to 1-Dimensional and these are in two types which include stacked 2D barcode and matrix 2D barcode [14]. The durability of 2D barcode is much high as compared to that of 1D barcode. Information is stored in two directions, which are horizontal as well as vertical. In 2-dimensional barcodes, many thousand alphanumeric characters can be placed in a single symbol [15]. One of the most important advantages of 2D barcode is that large amount of data can be read easily and written accurately [15]. The 3-dimensional barcodes are composed of an array of 3D cells, called modules, and each can be either filled or empty, corresponding to two possible values of a bit. They are just like 2D barcodes because they can contain different types of information such as pricing, height, weight and other product information. These barcodes were designed mostly to avoid the problems of high temperature, chemicals and solvents that would destroy any barcode in linear or 2-dimensional barcodes [16].

The barcode reader is an electronic tool that scans printed bar codes on items for sale or on other labels for identification purposes. It is used to extract information optically from the barcode [17].

The advantages of barcode technology include: since the main two components used to produce barcodes are paper and ink, therefore, barcodes are relatively less expensive compared to RFID technology that makes use of silicon chips [12], it is

easy to use [11], it is scalable [12], it is reliable and accurate than manual data collection and it provides real-time information [12].

The disadvantages of barcode technology include: because barcode readers use a direct line of sight to the printed barcode when scanning a barcode, it makes the technology difficult and impractical in various industrial environments and the ordinary barcodes can only store a small amount of static information, normally around 20 characters [11].

C. Near Field Communication

NFC is one of the latest short-range wireless communication technologies [18]. It provides safe communication between electronic gadgets. NFC-enabled devices can just be pointed or touched by the users of their devices to other NFC-enabled devices to communicate with them. This act of communication is called tap-in or to tap and go. With NFC technology, communication is established when an NFC-compatible device is brought within a few centimeters of another which is around 20 cm theoretically and 4 cm in practical [19]. The immense benefit of the short transmission range is that it prevents eavesdropping on NFC-enabled dealings. This technology enables several innovative usage scenarios for mobile devices. It works on the basis of RFID technology that uses magnetic field induction to commence communication between electronic devices in close vicinity. Sharing of files between phones, service discovery and getting information by touching smart phones are possible applications of NFC using smart phones [18], [19]. Currently, NFC has many applications, which mostly focus on the field of Identification and authentication, ticketing systems in public transport such as trains and buses as well as contactless Electronic Point of Sales (EPOS) terminals at shopping centers. NFC has also shown promise in being used for data transfer or data beaming in applications such as smart posters or simplifying the setup of more complex communication methods such as Wi-Fi [19].

NFC technology defines two types of devices and two modes of operations. One is an initiator device and the other is the target device. The initiator device is one that initiates the communication and controls the data exchange. The target device is the one that responds to the initiator device. Active and Passive are the two operating modes of NFC. In active mode, both the initiator and the target generate the RF signal on which the data is carried. While in passive mode, only the initiator generates RF signal, and the target communicates back to the initiator using a technique called load modulation [20]. What makes the communication between the devices so easy is that, NFC protocol provides some features not found in other general-purpose protocols [21]. First of all, it is a very short-range protocol. It supports communication at distances measured in centimeters [21]. The devices have to be literally almost touching to establish the link between them [22]. The advantage of this is that: Devices can rely on the protocol to be inherently secured since the devices must be placed very close to each other. It is easy to control the two devices to communicate by simply placing them next to each other or keeping them apart [23]. Procedure of establishing the protocol is inherently familiar to people. If you want something to communicate to, touch it. This allows for the establishment of

the network connection between the devices to be completely automated and happens in a transparent manner. The whole process is fulfilled if devices recognize each other by touching and then connect to each other once touched [23]. Another important feature of this protocol is the support for the passive mode of communication [22].

D. Cloud Computing

Cloud computing is proving itself as an emerging technology in IT world which provides a novel business model for organizations to utilize software, applications and hardware resources without any upfront investment [24]. Cloud is a metaphor to describe web as a space where computing has been preinstalled and exist as a service; such as information, infrastructure, applications, storage and processing power on the web ready to be shared [24]. The cloud computing system consists of the front end and back end components. These components connect to each other through a network, usually the Internet. The front end is the side of the computer user or client whereas the back end is the cloud section of the system. The front end includes the client's computer or computer network and the application required to access the cloud computing system. Cloud computing comprises of three types of service models which include: Infrastructure as a Service (IaaS), Platform as Service (PaaS) and Software as a Service (SaaS). Cloud computing also comprises of four types of deployment models and these include: public, private, hybrid and community models.

In the infrastructure as a service model, the cloud providers offer cloud services such as hardware resources, storage and network infrastructure services. The virtualization is the base of this model [24]. In the platform as a service model, the cloud service providers provide application development platform for developers. They also deliver a set of APIs for developers to develop and launch their own customized applications. There is no need for them to install any development tools on their local devices and machines and the software as a service model facilitates for customers to access the applications hosted on the cloud. Instead of installing the applications on their own machines, users access these applications installed on the cloud using their own browsers [25].

The public computing model is used by the general public, which includes individuals, corporations and other types of organizations. Third party vendors essentially administer the public clouds over the Internet and services are offered on pay-per-use basis. The advantage of this model is that it is widely used in the development, deployment and management of enterprise applications at an affordable cost. It also allows organizations to deliver highly scalable and reliable applications rapidly at a more affordable cost. Its limitation is the security, which is a significant concern in public clouds [25]. In private computing model, the computing resources are operated exclusively by one organization. Private clouds are actually more secure than public clouds since their users are trusted individuals inside the organization. It emulates the concept of cloud computing on a private network [25]. Hybrid computing model is a composition of two or more cloud deployment models, linked in a way that data transfer takes place between them without affecting each other. This can be a combination of private, community or public clouds which are

linked by a proprietary or standard technology that provides portability of data and applications among the composing clouds. These clouds would typically be created by the enterprise and management responsibilities would be split between the enterprise and the cloud provider. In this model, a company can outline the goals and needs of services [26]. A well-constructed hybrid cloud can be useful for providing secure services such as receiving customer payments, as well as those that are secondary to the business, such as employee payroll processing. The major drawback to the hybrid cloud is its difficult aspect in effectively creating and governing such a solution. Services from different sources must be obtained and provisioned as if they originated from a single location, and interactions between private and public components can make the implementation even more complicated [26]. The community cloud model is the type of cloud computing in which the infrastructure is shared by several organizations for a shared cause and may be managed by them or a third party service provider and it is rarely offered cloud model. These clouds are normally based on an agreement between related business organizations such as banking or educational organizations. A cloud environment operating according to this model may exist locally or remotely. The best example of a community cloud is the Facebook [26].

E. Related Works

Chandrasekharan et al. [27] developed an integrated barcode system for event management to ensure smooth and quick registrations of participants, real time stocktaking of consumables and providing exclusive secured venue-access during events.

Mathaba et al. [28] developed an inventory control system using an integration of Internet of Things (IoT) with RFID technology and web 2.0 technologies for identifying stock levels on shelves, loss prevention and as an enabler for locating misplaced stock, anti-counterfeiting of stock, stock validity and many others.

Boyinbode and Akinyede [10] developed an RFID Inventory Control system for Nigerian supermarkets to effectively detect and capture response signals transmitted from the RFID tags attached on each item that passes through the scanning zone.

Jamal et al. [29] developed a cloud computing system in which data from the scanning system is provided to the Electric Product Code (EPC) Information System that is implemented on cloud as SaaS (Software as a Service). The transmitted data is stored and managed on the cloud and is made available in a reliable manner to any application that requests it.

Some of the solutions provided by applications in the related works would be of great benefit if adopted in the inventory management of aircraft spares in ZAF. The concept of barcode technology and cloud architecture implemented in the related works would be adopted in the design of the proposed prototype. The rationale of using barcode technology is to keep track of how much stock is going out, how much remains on shelves and in the warehouse, giving commanders a real time picture of what is happening. The system would ensure that the institution does not hold much stock than is

necessary in order to avoid unnecessary incurring of holding cost. The idea behind optimum stock level is to ensure that the cost is kept as low as possible.

III. METHODOLOGY

A. Baseline Study

The purpose of the baseline study was to establish the challenges faced by ZAF with regards to inventory management of spares. A Mixed Methods Research Methodology was used in this study.

1) *Study Population:* The target population for the study included ZAF employees who work under stores management, Senior Officers in charge of procurement, aircraft engineers and technicians.

2) *Sample Size and Sampling Procedure:* The study was conducted in three (03) Zambia Air Force Bases located in three different provinces, namely, Lusaka, Southern and Central. The three ZAF Bases were purposively sampled because the target was personnel who had the knowledge and experience about the information of interest by virtue of them working in the warehouses and proving aircraft maintenance.

3) *Research Instrument:* The research instruments were tailored with the sole purpose of meeting the objective of the baseline study. The instruments included the following:

- Questionnaire for ZAF employees who work in the warehouses or stores.
- Questionnaire for ZAF employees who provide aircraft maintenance.
- Interview guide for ZAF employees.

4) *Data Collection:* The researcher was granted authority by ZAF Command to collect both quantitative and qualitative data from ZAF employees with regards to inventory management of aircraft spares. Questionnaires were distributed to 45 respondents in the affected bases and they were given ample time to respond to the questions for qualitative data collection. The interviews were equally conducted to gather quantitative data. The whole process of data collection was done in two weeks' time.

5) *Data Analysis:* The quantitative data that was gathered by use of questionnaires was analyzed using IBM Statistical Package for the Social Sciences (SPSS). The results were presented in the form of tables and charts.

B. System Design

The system requirements specification and model design phase of the research study employed the use of qualitative data from interviews that ZAF personnel supplied. The interviews with the stores personnel and personnel who service the equipment provided the qualitative data needed to come up with the current business process and thereafter design the automated inventory business process and the system architecture.

1) *Current Business Process:* The current business process is shown in Fig. 2. It is derived from interviews that were

conducted. In the business process, Aircraft Maintenance Unit (AMU) provides maintenance to equipment to ensure that it is in a serviceable state. When a particular spare part on the equipment is defective, it is indicated on Form 700 and forwarded to Technical Control to make a demand. The Officer Commanding Technical Control raises an internal demand to technical stores on ZAF Form 674 also called Internal Demand and Issue Voucher. The details that are required to be filled on this form include: part number, description of the equipment, purpose for which the spare part is required, quantity and the inventory number. The technical stores personnel issue out the spare part when it is available in stores on Form 674. If the spare part is not available, an external demand is raised to source for the missing item from Central Equipment Depot (CED). The baseline study revealed that the current process of managing inventory of aircraft spares makes extensive use of forms.

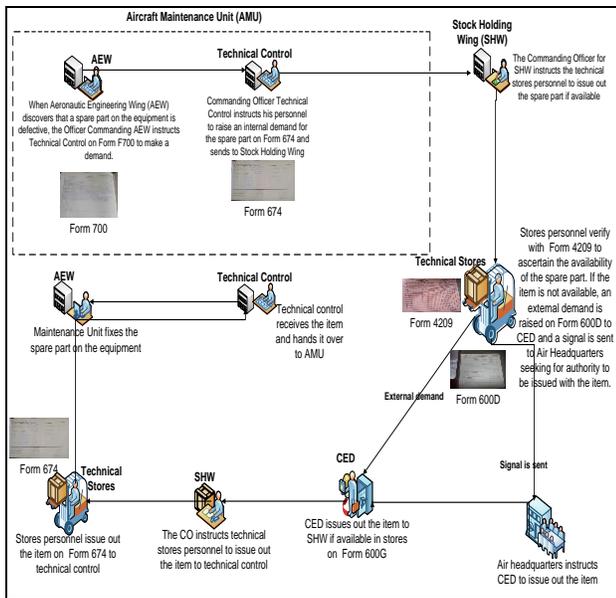


Fig. 2. Current business process.

2) *Proposed Business Process:* The proposed automated demand business process depicted in Fig. 3 is derived from the current demand business process methodologies as described by the stores personnel in Fig. 2. Automating manual and paper based phases in the processes is the change that is proposed here. Barcode technology was a preferred technology to be used in the proposed inventory business process because it is a mature technology, relatively cheaper, easy to implement and simple to use compared to radio frequency identification and near field communication.

The centralized database stores all the information about the spares, suppliers and employees. The application links the barcode readers to the centralized database server. The spares that are received in the warehouse already come with barcodes. Once the barcode reader scans the item, the barcode transmits information to the scanner and the scanner reads out the information and transmits the information read from the

barcode to the software. The application then interprets the numbers from the barcode and then writes the information in the database. Equally, when issuing out the spares the barcode reader scans the item and transmits the information read from the barcode to the application. The application then interprets the numbers from the barcode and matches those numbers with the information in the database indicating the type of spares they represent. For instance, if the information is for a fuse for category 826Y, it will be able to show its description and there will be an instant reduction in the number of fuses for category 826Y in the database. If the minimum number of fuses in that category is reached, the system will automatically send a message to the management to reorder that particular item. This allows the stores personnel to track which spares have been issued out with a handheld scanner. Specialized software keeps track of how much stock is going out the door via issuance and how much remains on shelves and in the warehouse, giving managers a real time picture of what is happening. The software analyzes the data and makes recommendations for reordering strategies. The Closed Circuit Television (CCTV) is incorporated in the proposed business process to monitor how business is conducted in the stores.

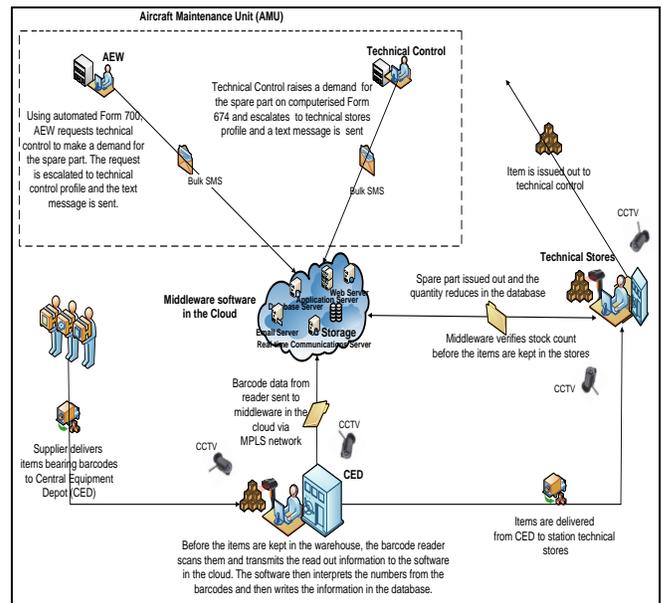


Fig. 3. Proposed business process.

3) *Proposed System Architecture:* The proposed system architecture utilizes the private cloud infrastructure and barcode technology to manage inventory of aircraft spares via the web interface. As the baseline study showed that the current system is tedious hence the proposed model would help reduce costs and time it takes to conduct business. The proposed system architecture is shown in Fig. 4.

ZAMTEL, the largest telecommunications company in Zambia provides the MPLS network while ZAF provides the private cloud services. The MPLS backbone comprises of fiber and microwave. ZAF exclusively operates computing resources in the cloud. There are a number of servers installed in the cloud such as Email server, Database server, Application server, Web server, Real-time communication server and other

services, like Data storage and Backup storage. The rationale herein is to provide services to remote bases without the hassles of the hardware, software and security of information. This kind of cloud computing is more secure than public clouds since their users are trusted individuals inside the organization. It allows users to have the benefits of cloud computing without some of the pitfalls. ZAF would have complete control over how data is managed and what security measures are to be put in place. This leads to users having more confidence and control over the system.

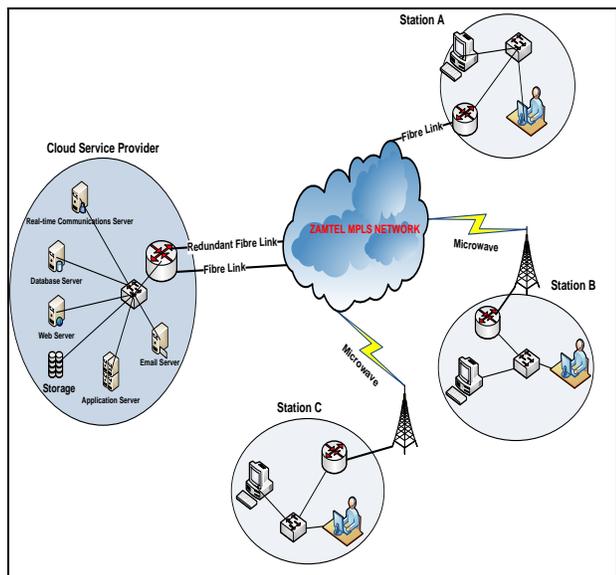


Fig. 4. Proposed system architecture.

C. Use Cases

The Use Case diagrams in Fig. 5 shows the interactions between the actors and the system in the system implementation. The main actors of the system were the middleware, reader and application users. The barcode reader is responsible for recording inventory stock items by scanning barcodes attached to items and sending data read to the middleware. The barcode middleware sits between the barcode reader and the backend database. It is responsible for managing exchange of information between the reader and the backend system. The users at the application interface first log into the system and then perform transactions, view inventory data and generate reports.

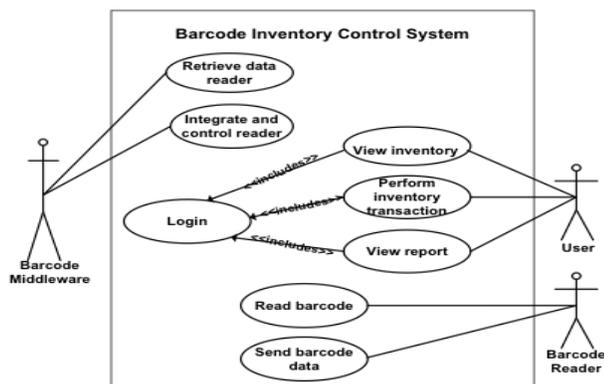


Fig. 5. Use case diagrams.

D. Sequence Diagram

Fig. 6 shows a sequence diagram for the “Read Barcode” from Reader Use Cases. The reader firstly monitors barcode activity. The user interface (UI) starts and then the control object is instantiated. The control object reads the barcodes as the stock items are scanned. Upon reading data from barcodes, the reader retrieves the data and sends to middleware for processing.

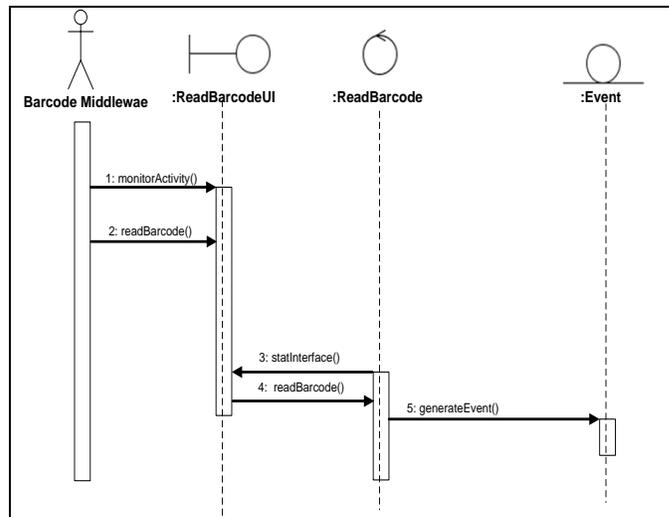


Fig. 6. Sequence diagram.

E. Class Diagram

The class diagram notations describe the structure of the proposed system by indicating system’s classes, and their attributes, operations or methods, and the relationships among the classes. The class diagram in Fig. 7 illustrates the common components of classes, class attributes and class operations.

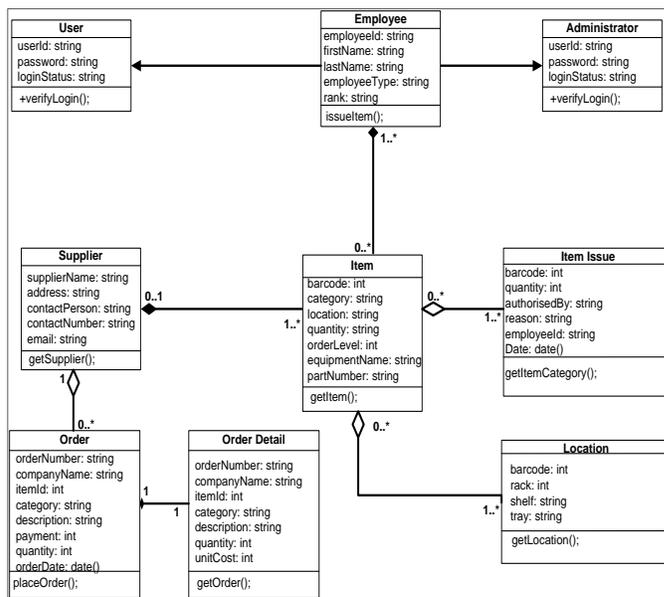


Fig. 7. Class diagram.

F. Entity Relationship Diagram

Fig. 8 shows an Entity Relationship (ER) model diagram for the barcode inventory system. The ER model provides a representation of user reality. It consists of entities, attributes and relationships that have been reasonably assumed for the proposed system. The assumptions are derived from the requirements that have been gathered from the survey and interviews.

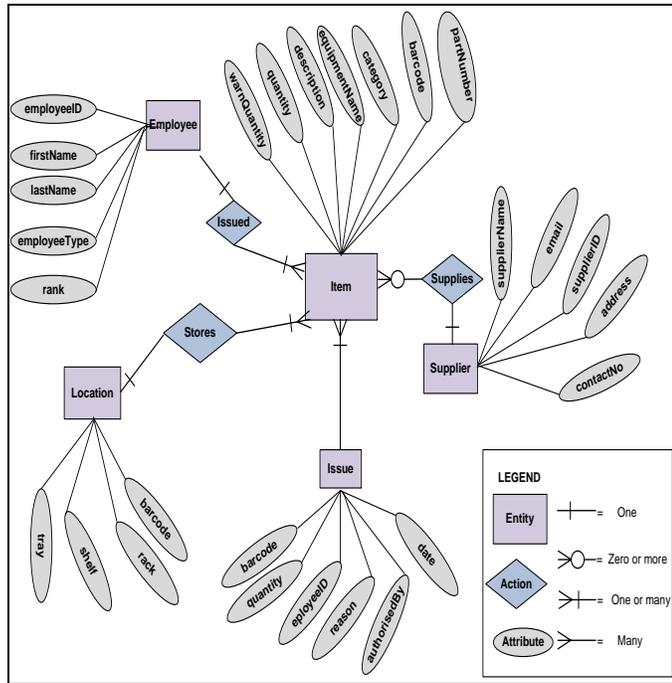


Fig. 8. Entity relationship diagram.

G. System Prototype Development

The system consists of frontend and backend components. The frontend was developed using HyperText Markup Language (HTML) for formatting of text in the document, JavaScript for interactivity in the web pages and Cascade Style Sheet (CSS), which provides the look and feel of the web pages. The backend is the server-side component of the system. The system runs on apache webserver and the database is designed using MySQL, which is a structured query language. The software was developed using Hypertext Processor (PHP) programming language for dynamic web applications.

IV. RESULTS

The results obtained from the baseline study and system prototype development and testing are presented in this section. The main purpose of conducting the baseline study was to ascertain the challenges that ZAF faces regarding inventory management of aircraft spares. The proposed prototype application was developed show as proof of concept of how the fully implemented system would work to alleviate the challenges currently faced by ZAF.

1) *Baseline Study:* The data collected from the baseline study was analyzed using descriptive statistics and the results were presented in form of charts. When the respondents were

asked if verification of stock count is done physically, 79% agreed and 21% were not sure. When asked if there was any loss of service during business time, 61% reported that there was loss of service due to wrong inventory reporting where the storesman reported that there was no spare part in the stores when it is available and 39% said there was no loss of business. When the respondents were asked if there was late delivery of service with the current system, 58% confirmed and attributed this to circumstances where the storesman reports availability of the spare part which is not available while 42 respondents said there was no late delivery of service. When asked if there was pilferage of spares, 76% said there was pilferage due to lack of effective tracking system of spares while 24 respondents said there was no pilferage. When asked if the introduction of the automated inventory system could mitigate the aforementioned challenges. 91% of the respondents recommended the introduction of the automated system and 9% did not recommend the introduction of the automated system. Fig. 9 shows the summary of the results from the baseline study.

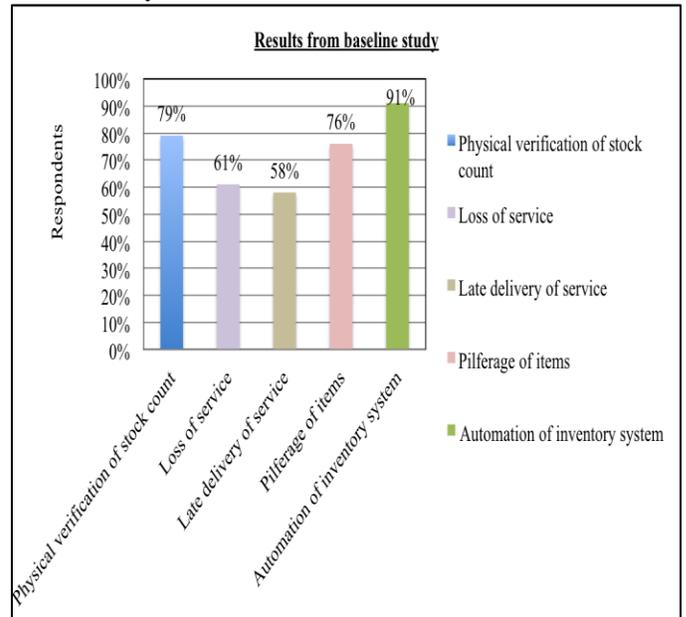


Fig. 9. Baseline study results.

2) *System Prototype Development:* As already outlined in the previous section, the prototype application named Stock and Inventory Management System (SIMS) consists of the web components which is the frontend and the server-side component which is the backend. The system administrator creates and manages users in the system. The user is registered in the system for them to be able to access the web based system modules. This helps to track every activity performed by specific users in the system. To create a new user account in the system the administrator logs in first and then enters the credentials of the user. Fig. 10 shows the screenshot for the administrator’s menu.

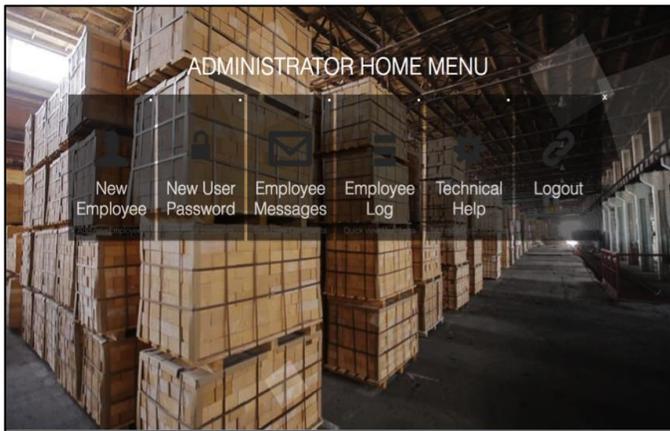


Fig. 10. Administrator Menu.

The administrator can create another administrator and users in the system by giving them user names and default passwords which can later be changed. The passwords are encrypted using MD5 algorithm. Fig. 11 shows the screenshot for registering users.

Fig. 12 shows the login screen for the system, which requires users to provide their usernames and passwords.

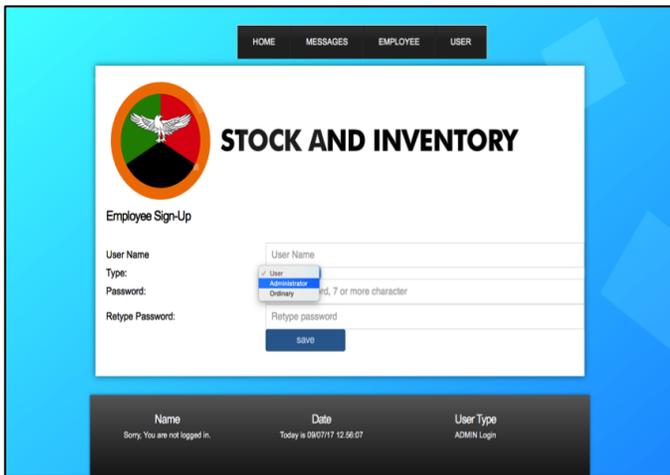


Fig. 11. User registration.

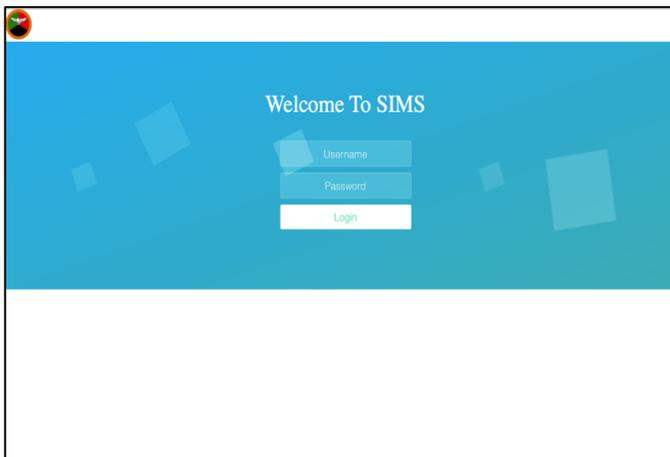


Fig. 12. Login screen.

Fig. 13 shows the main screen. When a user logs in the system, is taken to the main screen. This screen presents a number of options to the user to choose from what task to perform such as add item, add new supplier, transfer item, issue item, print or view reports and many other options.

Fig. 14 and 15 show a web page for adding details of new spares in the system using a barcode reader. The barcode reader scans the barcode on the item and captures the barcode number in the barcode field on the form and then other details related to the item are also entered and written to the database.

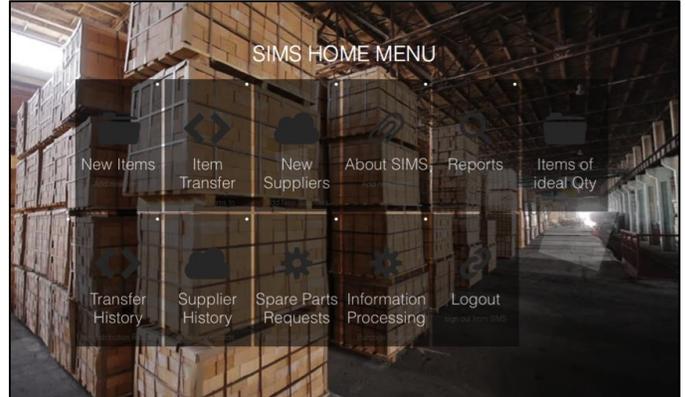


Fig. 13. Main Menu.

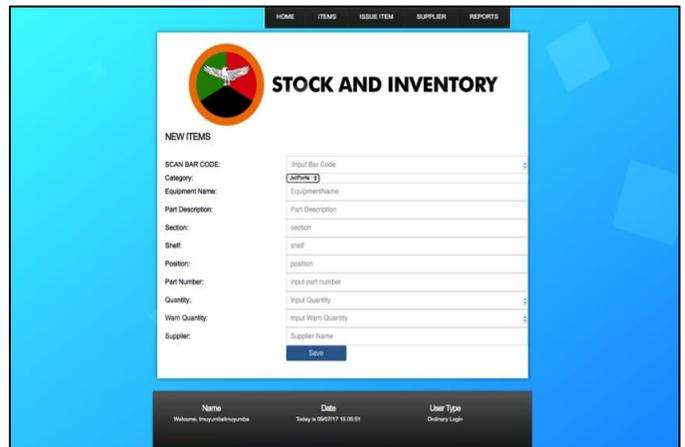


Fig. 14. Adding details of new spares.



Fig. 15. Adding spares by using barcode reader.

Fig. 16 shows a web page that is used for issuing out of aircraft spares. When issuing out spares, they are again scanned with the barcode reader. Each spare part that is scanned the quantity reduces in the database. This helps to track the inflow and outflow of spares in the stores.

Fig. 17 shows a screenshot for the results of the report generated for the spare parts that have been issued out. It shows the description of the spare part, category, number of spares issued out, date of issue and the name and rank of the employee who collected the items.

Fig. 18 shows a report of aircraft spares that are below warn quantity.

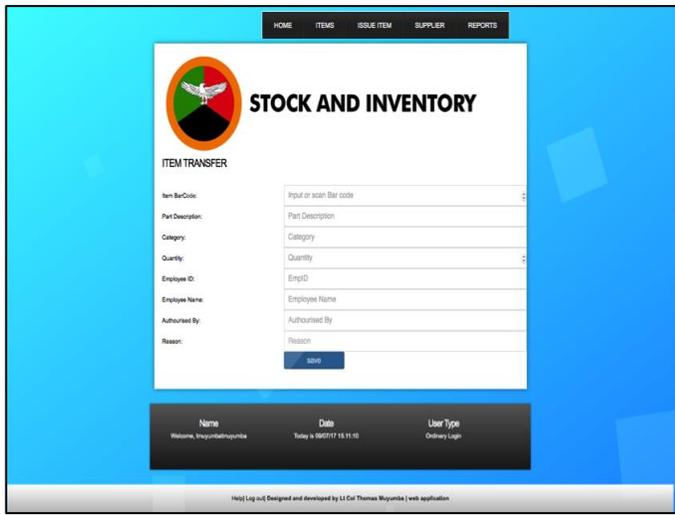


Fig. 16. Issuing spares.

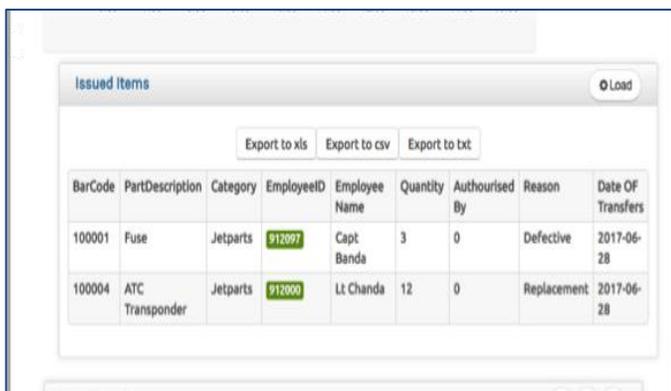


Fig. 17. Issued out spares.

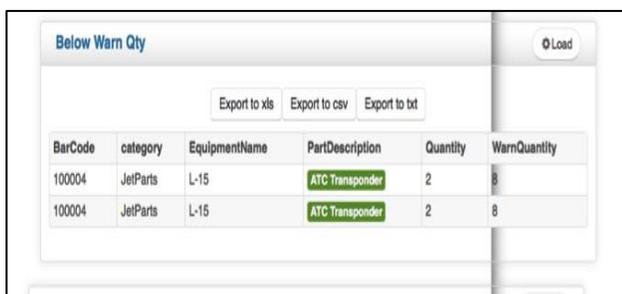


Fig. 18. Below warn quantity.

3) *Efficiency Comparison:* The one tailed paired t-test was conducted in Microsoft Excel 2013 using the data that was collected showing in Fig. 19 in order to have the scientific evidence of the hypothesis which states that the automated inventory system performs better than the manual and paper based system using the significance level of $\alpha = 0.05$. Results of the analysis are shown in Fig. 20. Comparing the two inventory systems, the time used by the manual inventory had a significantly higher average time ($M=41.9$, $SD=32.261$) than the time used by the barcode inventory system ($M=6.4$, $SD=7.351$), $t(9) = (-4.214)$, $P = 0.001$. This result leads to the rejection of the null hypothesis (H_0) which states that there is no difference in performance between the two systems at the 95% confidence level, which means that statistically there is sufficient evidence that the barcode inventory is more than 95% efficient considering the obtained probability value of $p = 0.001$.

TIME TAKEN TO COMPLETE A TASK (MINUTES)		
TASK	AUTOMATED INVENTORY	MANUAL INVENTORY
Locating a spare part in the stores	1	10
Check issued spares	2	7
Checking Below warn quantities	1	60
Checking existing spares	2	30
Generating a comprehensive report	5	60
Checking spares by category	6	45
Stock taking	20	90
Stock verification	4	20
Process of issuing a spare part	3	7
Process of receiving spares in the stores	20	90
Mean	6.4	41.9
Standard Deviation	7.351492668	32.26091547
N	10	10

Fig. 19. Collected data.

t-Test: Paired Two Sample for Means		
	AUTOMATED INVENTORY	MANUAL INVENTORY
Mean	6.4	41.9
Variance	54.04444444	1040.766667
Observations	10	10
Pearson Correlation	0.812089822	
Hypothesized Mean Difference	0	
df	9	
t Stat	-4.214229176	
P(T<=t) one-tail	0.001129317	
t Critical one-tail	1.833112933	
P(T<=t) two-tail	0.002258635	
t Critical two-tail	2.262157163	

Fig. 20. T-test analysis results.

V. DISCUSSION

The main aims of this study were to establish challenges that ZAF faces regarding inventory management of spares and to design a model for an automated barcode inventory management system. From the baseline study conducted, it was discovered that there were a number of challenges that were identified which are highlighted in the results section. The current business processes were mapped as indicated in Fig. 2 and a model based on cloud architecture and barcode technology was developed as indicated in Fig. 3 in order to

address the challenges that were discovered in the baseline study. A web based inventory prototype was developed using a model based on cloud architecture and barcode technology to mitigate or resolve the challenges faced by ZAF in inventory management. The prototype was tested locally and remotely via MPLS VPN network in which stores personnel were able to add information of spares to the database, issue out spares, verify inventory and generate reports. The following observations were noted during the testing phase of the system:

- The testing that was conducted showed that the bar code scanner was 95% more efficient and over three times faster than the current method used to manage the inventory in ZAF. This was evidenced by the paired t-test that was conducted.
- The scanning was extremely reliable, with no errors in any of the tests completed. The study supported the possibility of a better means to track spares of the organization in the warehouses.
- It was discovered that the bar code scanners could become the gap filler needed to provide a means of timely and accurate inventories to commanders.
- To address the challenge of pilferage of items, Closed Circuit Television (CCTV) was implemented. IP Cameras were installed in all the warehouses and linked to the cloud network and monitoring is done by sentries on duty in various control centres located in sentry points. The Network Video Recorder (NVR) records the information that is captured by cameras to make it possible to check on previous incidences.

VI. CONCLUSION

The baseline study was conducted and a number of challenges were identified in the current system such as late delivery of service, loss of service, pilferage of items, high costs and duplication of inventory data. The current business processes were mapped and a model based on cloud architecture and barcode technology was developed in order to address the challenges that were discovered in the baseline study. With the challenges identified and the overwhelming response of 91 percent who recommended that the inventory process be automated, a web based inventory prototype was developed using barcode technology and cloud model to address the challenges. To fully address the challenge involving pilferage of items, CCTV was integrated in the cloud network in which IP cameras were installed in the warehouses. The barcode web based inventory prototype system was fully appreciated by the users in the organization because of its efficiency and effectiveness as evidenced by the t-test that was conducted.

VII. RECOMMENDATIONS AND FUTURE WORKS

A. Recommendations

The study has revealed that the automated inventory system is desirable and therefore this system should be fully implemented in order to realize its full benefits.

B. Future Works

The proposed future works, which should be done on this system, is to migrate from barcode technology to radio frequency identification technology, integrate bulk SMS technology, automate the entire procurement processes and incorporate a module for inventory management of uniforms as well.

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A Model for Forecasting the Number of Cases and Distribution Pattern of Dengue Hemorrhagic Fever in Indonesia

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Abstract—Dengue Hemorrhagic Fever (DHF) outbreaks is one of the lethal health problems in Indonesia. *Aedes aegypti* type of insect prolefration as the main vector of DHF has affected climate factors, such as temperature, humidity, rainfall, and irradiation time. Therefore, to project the number of DHF cases is a very important assignment for the Ministry of Health to initiate contingencies planning as a prevention step in confronting the increasing number of DHF cases in nearby future. This study aims in developing a forecasting model in anticipating the number of cases and distribution pattern of DHF with multivariate time series using Vector Autoregressive Spatial Autocorrelation (VARSA). VARSA model uses multivariate time series, such as a number of DHF case, minimum temperature, maximum temperature, rainfall, average humidity, irradiation time and population density. This modeling is done in two steps: Vector Autoregressive modeling to predict the number of DHF cases and Local Indicators of Spatial Association (LISA) method to visualize distribution pattern of DHF based on the spatial connectivity of the number of DHF cases among the neighboring districts. This study covers 17 districts in Sleman Yogyakarta, resulting in low errors with Root Means Square Error (RMSE) of 2.10 and Mean Absolute Error (MAE) of 1.51. This model produces smaller errors than using univariate time series methods, such as Linear regression and Autoregressive Integrated Moving Average (ARIMA).

Keywords—Dengue Hemorrhagic Fever (DHF); Vector Autoregressive Spatial Autocorrelation (VARSA); forecasting; multivariate time series; Local Indicators of Spatial Association (LISA)

I. INTRODUCTION

Dengue Hemorrhagic Fever (DHF) is an acute and endemic disease which periodically causes outbreaks and even epidemics. DHF is widely found in tropical and sub-tropical areas [1]. Data from around the world shows Asia ranks first in the number of DHF patients each year. Meanwhile, from 1968 to 2009, the World Health Organization (WHO) listed

Indonesia as the country with the highest dengue fever case in Southeast Asia [2].

DHF is a disease caused by dengue virus that is transmitted from person to person through the bite of *aedes aegypti* mosquitoes [3]. This disease is caused by the dengue virus of the genus flavivirus, flaviviridae family. Dengue transmitting mosquitoes are present in almost all corners of Indonesia, except in places with an altitude of more than 1000 meters above sea level. Several factors that influence the occurrence of DHF include low immune status and a population density of infectious mosquitoes due to mosquito breeding places that usually occur in the rainy season [4].

The number of DHF cases in 34 provinces in Indonesia based on data from the Ministry of Health in 2012 recorded as many as 90,425 cases and 816 people died. In 2013 recorded as many as 112,511 cases and 871 people died, In the year 2014 recorded as many as 71,668 case, and 641 people died, In the year 2015 recorded as many as 129,650 case, and 1,071 people died [5].

Preventive program namely the eradication of mosquito nest has been widely conducted nationally and regionally. This preventive activity is carried out by draining, closing, burying water reservoir and applying larvicide, keeping larvae fish and using a mosquito net, examination and eradication of larvae periodically no more than three months, and fumigation.

Nevertheless, those preventive actions have not been able to reduce the number of DHF patients nationally. The low ability in preventing of dengue fever is due to some factors. The first is the unpredictable time, place and number of events. The second is the unavailability of index and vulnerability maps of the region based on the time of the incident. The third is the unavailability of reliable model for forecasting DHF cases. Forecasting the number of DHF cases is very important for public health service to anticipate

affirmative planning for the prevention of the increasing number of DHF cases in the nearby future. Anticipated planning is needed to avoid problems such as unnecessary or delayed precautions, or even with the increased casualties and lack of spaces and personnel for handling DHF patients.

In previous related studies the process of forecasting numbers of DHF cases were done by using ARIMA method [6] and SARIMA method [7]. Unfortunately, those studies focused on predicting the number of DHF cases without considering the spatial connectivity between an area and its neighborhoods. Moreover, this study aims to predict the number of case and distribution pattern of DHF using a combination of vector autoregressive and spatial autocorrelation (VARSA) model. This study is expected to help the public health service, especially for Sleman regency, Yogyakarta in the preventing the increasing numbers of Dengue Hemorrhagic Fever cases in the future.

The remaining of this paper is organized as follows. Section two deals with previous studies related to this study. The proposed method is presented in section three. The experiments study are discussed in section four, and the last section contains conclusion and recommendation for the future work.

II. RELATED WORKS

The purpose of applying time series, in general, is to understand future behavior through measurement of attribute data in a past time series by using trend, cyclic and seasonal indicators. [8]-[12]. The study of forecasting the number of dengue fever cases using the ARIMA method has been done by [13]-[16] and the SARIMA Method [17]-[21].

The study using the VAR method to predict the number of DHF cases has been done by [22]. The main advantage of VAR is that multivariate variables are both explained and explanatory variables. Hence, this model performs more accurate predictions using the relations between multiple variables [23].

This model is very popular in economics and explains the underlying causal mechanisms by using granger causality test [24], [25]. This test determines whether past variables can provide predictive information.

Forecasting time series analysis has been a major tool in many applications in meteorological phenomena, such as rainfall, humidity, and temperature [26], [27]. The development of the forecasting model by estimating the weight parameters by the least squares method on the hybridizing exponential smoothing model with neural network does not give optimal results [28]. This is because square errors in the emerging model will shift the fit curve to another point to reduce the accuracy of the forecasting result.

From the forecasting field review, the number of dengue cases can be analyzed that the application of the VAR method for forecasting the number of DHF case short-term and long-term (one or twelve periods) has good accuracy with low errors and meets the parsimony principle (simplicity) to be applied.

III. PROPOSED METHOD

Fig. 1 shows the proposed forecasting the number of case and distribution pattern of DHF using the VARSA model. The model starts from the input data in the form of climate, a number of DHF case and population density data. The climate variable data consists of such as minimum temperature, maximum temperature, average temperature, average humidity and irradiation time. All data then do the preprocessing to eliminate the missing value and equalize the data period. The preprocessed data is then processed to forecast the number of DHF cases using the VAR method. The model is then tested using the RMSE and MAE methods, to see prediction errors compared to actual data. Forecasting results are then visualized using spatial autocorrelation by obtaining a digital district map data in Sleman. Visualization in this study using Local Indicator Spatial Association (LISA) method to see patterns of the distribution pattern of DHF case based on spatial connectivity among neighboring districts.

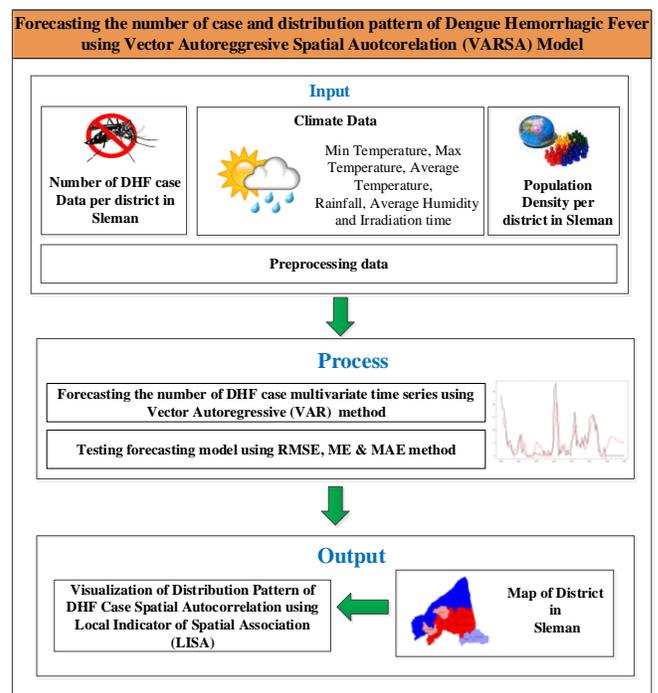


Fig. 1. Forecasting the number of case and distribution pattern of DHF using VARSA model.

Fig. 2 shows the research steps of forecasting the number of cases and distribution pattern of DHF using VARSA model. This model consists of four steps namely preprocessing data, create forecasting model, evaluation forecasting model and visualization distribution pattern of DHF with spatial autocorrelation.

In the first step, the preprocessing data, there are three kinds of data, namely, climate data, the number of DHF cases and population density data. Those data were collected from the district in Sleman, Yogyakarta-Indonesia, from 2010 to 2015. The climate data consist of minimum temperature,

maximum temperature, average temperature, humidity, rainfall and irradiation time variable. Firstly, the activities of climate data preprocessing are replacing the missing value using interpolation smoothing spline method, the correlation test to find out the influential climate variables using Keyser Meyer Olkin (KMO) method, and aggregating daily data of those influential climate variables into monthly. Secondly, the number of DHF cases is preprocessed by aggregation of data per incident into monthly data per district. Thirdly, the preprocessing of population density data is done by dividing the yearly data into monthly data per district.

After all data are clean and have the same period, then the second step is to build multivariate time series forecasting model using VAR method. The third step is to evaluate the forecasting model using MAE and RMSE method compared with actual data. The fourth step is to visualize the distribution pattern of DHF cases using Local Indicator of Spatial Association (LISA) method. This method is used to visualize the distribution patterns of DHF cases based on spatial connectivity between one district to its neighbors.

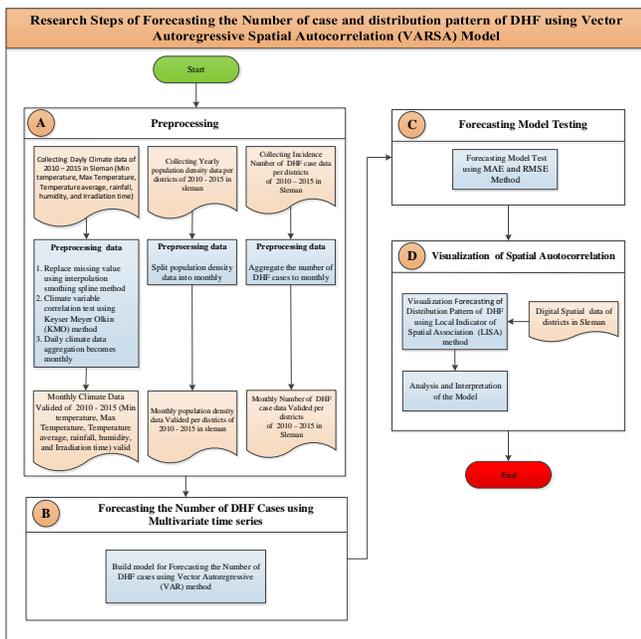


Fig. 2. Research steps of forecasting the number of case and distribution pattern of DHF using VARSA model.

A. Preprocessing

The preprocessing the climate data in Sleman regency Yogyakarta, the data used in this research is sourced from <http://dataonline.bmkg.go.id> the result of post measurement of geophysical station Yogyakarta. The research uses the district climate data (with a monthly period) from 2010 to 2015 consisting of minimum temperature, maximum temperature, average temperature, humidity, rainfall and irradiation time. The use of monthly data for climate forecasting is based on literature studies [10], [11], [13]. The more periods of the month used the data patterns will be more easily analyzed to determine the correct forecasting method. The climate data consisting of 17 districts in the Sleman included Moyudan,

Minggir, Seyegan, Godean, Gamping, Mlati, Depok, Berbah, Prambanan, Kalasan, Ngemplak, Ngaglik, Sleman, Tempel, Turi, Pakem, and Cangkringan.

The preprocessing data experiments were performed for all missing values of the total of 2,037 climate data. The missing value consists of unmeasured data reaching 5.1% for minimum temperature, 8.20% for maximum temperature, 17.43% for average temperature, 17.48% for average humidity, 3.29% for rainfall and 3.58% for time irradiation. From the results of climate data analysis is required preprocessing stage to obtain data quality, with data input quality (noise free) will be obtained an output that has the validity and high accuracy. The process that will be done is cleaning data replacing missing value to clean climate data from noise and distortion value. Starting with checking the input data whether it has an empty / tuple value, if there is an empty value for the attribute, the empty value can be filled with the new value using linear interpolation method [29]. Eliminating the missing value of the initial climate data done in linear regression and smoothing spline method. Interpolation using smoothing spline is given by can be seen in (1):

$$S(x) := \begin{cases} S_0(x) & x \in [x_0, x_1] \\ S_1(x) & x \in [x_1, x_2] \\ \vdots & \vdots \\ S_{n-1}(x) & x \in [x_{n-1}, x_n] \end{cases} \quad (1)$$

which each $S_i(x)$ is a polynomial of degree k .

The next process after the net climate data was correlation test to see the correlated variables using Keiser Mayer Olkin Factor Adequacy (KMO) method. Correlation test using KMO method is given by can be seen in (2).

$$KMO_j = \frac{\sum_{i \neq j} r_{ij}^2}{\sum_{i \neq j} r_{ij}^2 + \sum_{i \neq j} u_{ij}^2} \quad (2)$$

Where,

$R = [r_{ij}]$ is the correlation matrix and

$U = [u_{ij}]$ is the partial covariance matrix.

B. Creating of Forecasting Model of DHF Multivariate Time Series using Vector Autoregressive.

The vector autoregression (VAR) model is one of the most successful, flexible, and easy to use models for the analysis of multivariate time series. It is a natural extension of the univariate autoregressive model to dynamic multivariate time series. The VAR model has proven to be especially useful for describing the dynamic behavior of economic and financial time series and for forecasting. It often provides superior forecasts to those from univariate time series models and elaborate theory-based simultaneous equations models. Forecasts from VAR models are quite flexible because they can be made conditional on the potential future paths of specified variables in the model [22]. Vector Autoregressive in (3):

$$Y_t = c + \sum_{i=1}^p \Phi_i y_{t-i} + \varepsilon_t \quad (3)$$

Where, y_t is the vector of *response* time series variables at time t . y_t has n elements. c is a constant vector of offsets, with n elements. Φ_i are n -by- n matrices for each i . The Φ_i are autoregressive matrices. There are p autoregressive matrices, and some can be entirely composed of zeros. ε_t is a vector of serially uncorrelated innovations, vectors of length n . The ε_t are multivariate normal random vectors with a covariance matrix Σ .

C. Evaluation Forecasting Model

The evaluation forecasting model, is done to find the best forecasting method to be used for forecasting the number of DHF cases. Evaluation model using Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) to find the value of forecasting results, the smaller the error value than the more accurate forecasting results.

The Mean Absolute Error (MAE) is a quantity used to measure how close forecasts or predictions are to the eventual outcomes. MAE is given by can be seen in (4). RMSE is a quadratic scoring rule that also measures the average magnitude of the error. It's the square root of the average of squared differences between prediction and actual observation. RMSE is given by can be seen in (5). Assuming that the difference or error is obtained using the Root Mean Square Error [28] :

$$MAE = \frac{1}{n} \sum_{j=1}^n |y_j - \hat{y}_j| \quad (4)$$

Where, y_i is actual data, \hat{y}_i is predicted data and n is the total number of data.

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (P_i - O_i)^2}{n}} \quad (5)$$

Where, P_i and O_i are the predicted and observed values, respectively; O is the average of O_i , and n is the total number of data.

The accuracy of the method is a measure to show how appropriate the method used to reproduce the data in the coming period, the smaller the error value, the better and the right method used.

Data forecasting results of the VAR method will be used to determine the pattern of DHF deployment. The model can be used for determination of dispersion pattern. Data forecasting results of the Vector autoregressive method will be used to determine the pattern of DHF deployment.

The model can be used for the determination of DHF

dispersion pattern because it can perform Short and long-term Dengue forecasting (1-12 months) with a minimum error value.

D. Visualization of DHF Distribution Pattern using Spatial Autocorrelation

Spatial Autocorrelation (SA) is defined as the correlation between observation areas in the form of spatial patterns. The SA outline can be positive if the value of the observed region is similar to its neighbor's value and negative if the value of the observed region has a low degree of similarity with its neighbor.

The concept of spatial Autocorrelation indicator is divided into two methods of analysis namely the Global Indicator of Spatial Association (GISA) method and the Local Indicator of Spatial Association (LISA) method. GISA is used to determine the correlation within the entire set of observed data whereas LISA is used to determine the extent of spatially dependent variable data on the area around the observed location. In this research visualization pattern of dengue disease spread using LISA method.

The Local Indicator of Spatial Association (LISA) is a tool for the determination of spatial associations in each research area. The LISA method can indicate the region of centralization or the introduction of spatial phenomena in a region. LISA is as it is denoted in (6).

$$I = z_i x \sum_{j=1}^n w_{ij} z_j \quad (6)$$

Which, z_i and z_j are deviations determined by (7).

$$Z_i = \frac{x_i - \bar{x}}{\delta} \quad (7)$$

Value of W_{ij} is the weight matrix element determined by (8).

$$\sum_{i=1}^n \sum_{j=1}^n W_{ij} = n \quad (8)$$

The observed value of 'I' can be compared with the data distribution with the null hypothesis, it has no autocorrelation spatial, for example when the value of z_i is independent of the value of z_j ($i \neq j$) in its neighbor region.

IV. EXPERIMENTAL RESULTS

Experimental results and model evaluation Forecast dengue hemorrhagic fever will be analyzed in Section IV.

A. Prapreprocessing Experiment Climate Data

In this experiment interpolation of climate data is performed with two methods of linear regression and smoothing spline. Graph of rainfall data and humidity of Sleman regency in 2010 until 2015 after preprocessing using linear regression method is presented in Fig. 3 and 4. In linear regression noise method is not seen on the chart with missing value but line connected does not follow curve pattern so it looks does not connect.

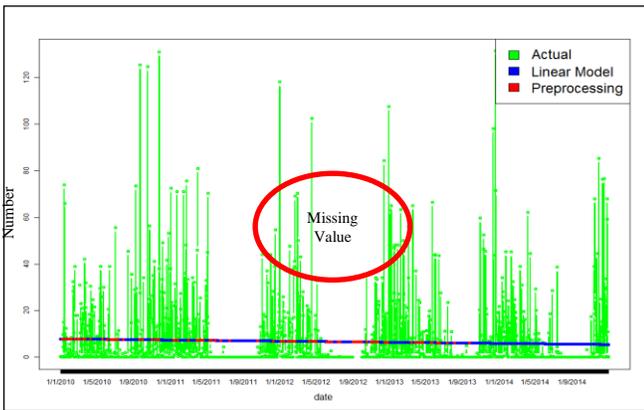


Fig. 3. Rainfall graph of 2010 until 2015 using linear regression after preprocessing.

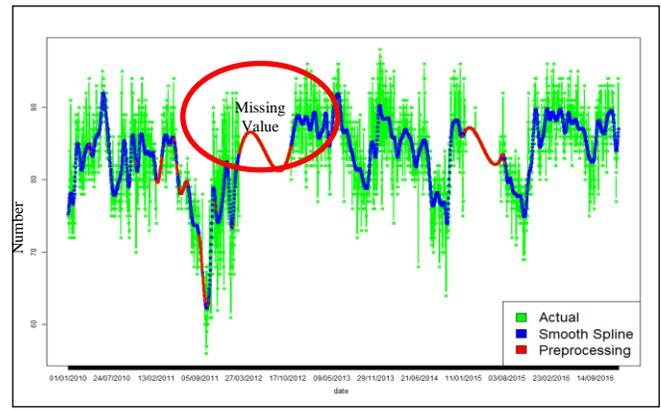


Fig. 6. The average humidity graph of 2010 to 2015 using smoothing spline method after preprocessing.

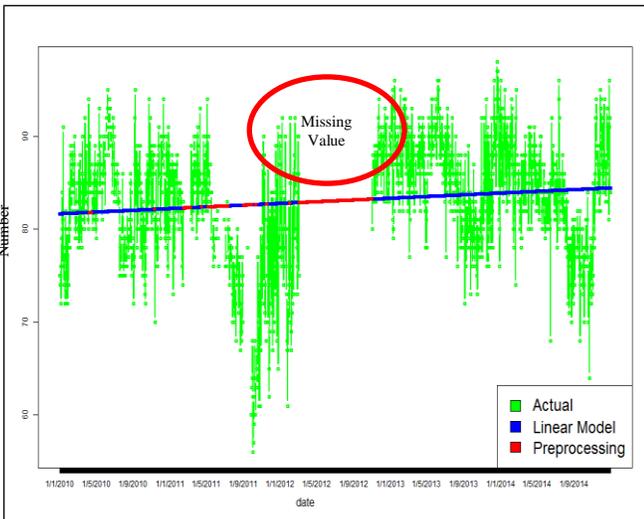


Fig. 4. Graph of humidity in 2010 until 2015 using linear regression method after preprocessing.

The second method uses smoothing spline method. In this method noise is not visible on the graph with has missing value with the connecting line connecting rainfall data and average humidity while maintaining the smoothness of the curve as shown in Fig. 5 and 6.

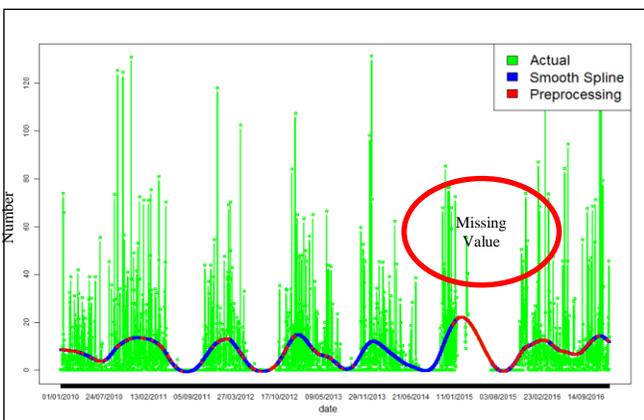
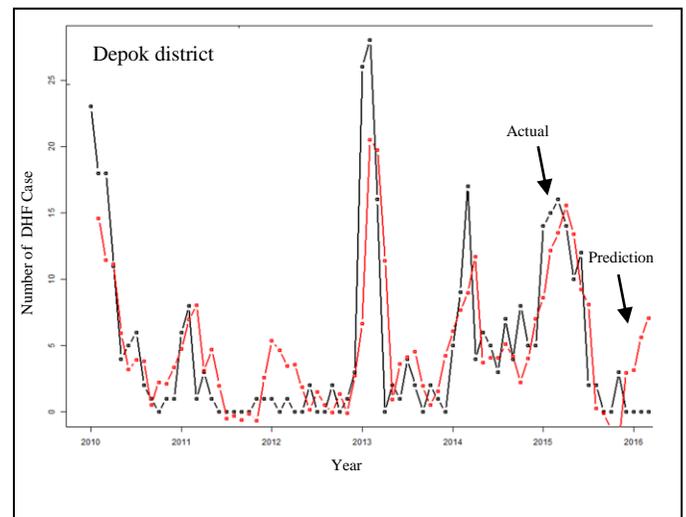


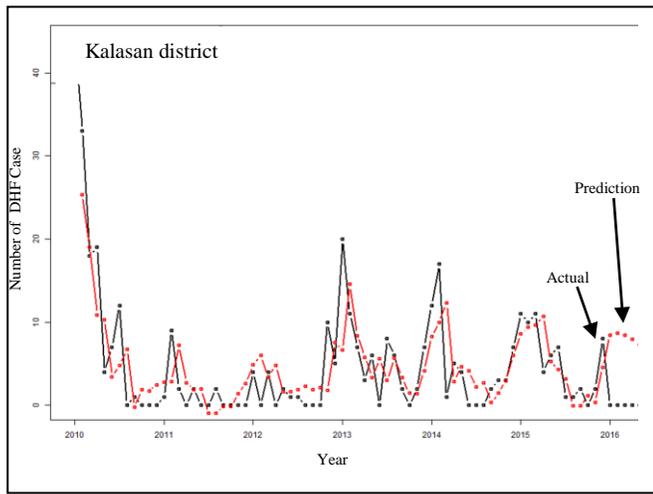
Fig. 5. Rainfall graph of 2010 until 2015 using smoothing spline method after preprocessing.

B. Experimental Forecasting Model the Number of DHF Cases using Vector Autoregressive Method

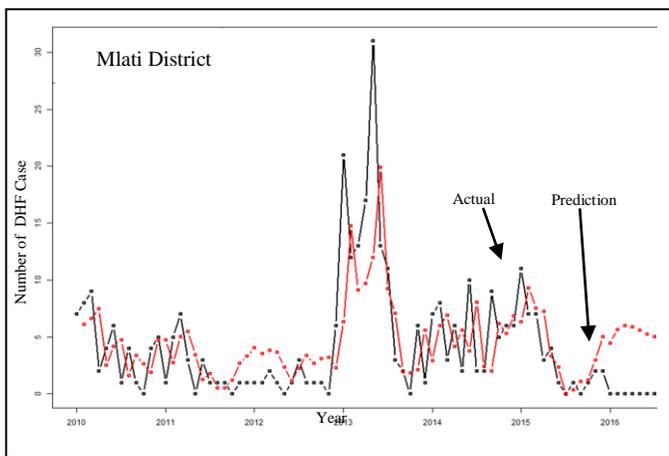
Fig. 7 shows predicted number of DHF cases in 2016 for Depok district (Fig. 7(a)), Kalasan District (Fig. 7(b)) and Mlati district (Fig. 7(c)). The Graph shows variation pattern of predicted data cycle of DHF cases from 2010-2015 following the previous period and according to the actual data cycle variation pattern. The graph shows a prediction point (red lines) almost equal to the actual point (black line) across almost the entire observation line. An important analysis of predictive experiments with the vector autoregressive method is that the 2016 prediction line shows a trend of seasonal patterns, the pattern indicates conformity with historical data patterns (actual data of previous years). Prediction pattern analysis shows that the corresponding vector autoregressive method is used to predict data on the number of DHF cases for the pattern of disease spread because the prediction pattern is seasonal. The analysis also shows the tendency of the vector autoregressive algorithm to be appropriate for short-term and long-term predictions.



(a)



(b)



(c)

Fig. 7. Forecasting the Number of DHF case in 2016 at Depok (a), Kalasan (b), and Mlati District, (c) using Vector Autoregressive method.

The next step are to experiment the correlation test to determine the effect of each climate variable by using Keiser Mayer Olkin factor adequacy method as Table 1.

TABLE I. RESULT CORRELATION TEST KMO METHOD

No.	Variable	KMO Value
1	Min Temperature	0.48
2	Max Temperature	0.62
3	Average Temperature	0.61
4	Average Humidity	0.55
5	Rainfall	0.69
6	Irradiation Time	0.70

From the results, KMO Test selected Variables that have a Value > 0.6 so that the variable of minimum temperature and average humidity removed [30].

C. Evaluation Forecasting Model

The results of experimental forecasting the number of DHF cases using VAR model for 17 Districts in Sleman, Yogyakarta-Indonesia showed a good suitability. This shows the conformity of the predicted data pattern of the number of

dengue cases with the actual data. Table 2 shows the relatively small RMSE and MAE values.

TABLE II. AVERAGE COMPARISON OF ERROR FITTING VALUES BETWEEN VECTOR AUTOREGRESSIVE ALGORITHMS WITH LINEAR REGRESSION, AND ARIMA ALGORITHMS FOR 17 DISTRICTS IN SLEMAN

No	Size test	Linear regression	ARIMA	VAR
1	RMSE	2.79	2.81	2.08
2	MAE	2.04	2.06	1.50

Evaluation fitting results the number of DHF cases in 17 districts using the VAR method has a low error, for the RMSE value of 2.08 and the MAE value of 1.50.

Comparison of error measurement between time series VAR algorithm with univariate time series algorithm using linear regression and ARIMA method for a number of DHF case in 2010 until 2015 for predicted data of 2016 could be seen in Table 3.

TABLE III. AVERAGE COMPARISON OF ERROR FORECASTING VALUES BETWEEN VECTOR AUTOREGRESSIVE ALGORITHMS WITH LINEAR REGRESSION, AND ARIMA ALGORITHMS FOR 17 DISTRICTS IN SLEMAN

No	Test Size	Linier Regression	ARIMA	VAR
1	RMSE	3.49	3.55	3.16
2	MAE	2.71	2.68	2.47

The results of the predictive data test of the number of DHF cases using linear regression algorithm for the RMSE value of 3,49, and MAE value of 2,71. ARIMA method for the RMSE value of 3.55 and MAE value of 2.68.

The comparison of test size values between time series univariate algorithms with the proposed time series multivariate model for 17 districts in Sleman Regency in Table 3 shows that the proposed model has lower Error value compared with linear regression and ARIMA methods.

In this study forecasting the number of cases will be used to determine the distribution pattern of DHF so that required model that can make a prediction of the short-term or long-term a number of DHF case (minimum 1-12 months) with a minimum error value. Recommendation based on analysis of experimental results, the model for forecasting the number of DHF cases appropriate for the planning needs of prevention of the spread of DHF disease is vector autoregressive spatial autocorrelation.

D. Visualization of Forecasting the Distribution Pattern of DHF Case using Spatial Autocorrelation

Fig. 8 shows districts that have hotspots are in Gamping, Depok and Mlati districts. The hotspots area indicates that the districts have the potential to spread DHF diseases so that the control of the spread needs to be done. While the districts that have coldspots are Moyudan, Minggir, Seyegan, Sleman, Ngemplak and Prambanan. Coldspots areas have the potential to become vulnerable to the spread of dengue fever which is transmitted by the surrounding area is high.

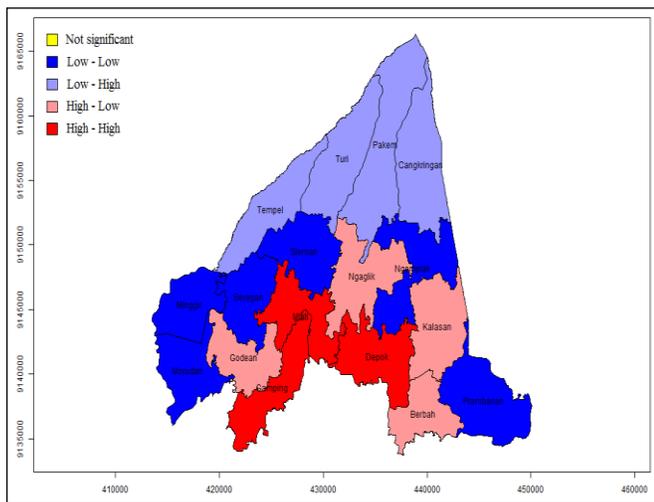


Fig. 8. LISA plot of DHF case forecasting.

Spatial autocorrelation analysis showed three districts in Sleman regency significant to High - High (HH) in 2010 until 2015; the area is Depok, Mlati, and Gamping District. This indicates that controlling the number of DHF case need to be done by the public health service in the three districts.

The hotspots (HH) area is a connectivity of areas with high dengue fever cases in the study sites.

V. CONCLUSION

Forecasting DHF using the vector autoregressive spatial autocorrelation (VARSA) model is proven to perform both short and long-term forecasting with relatively lower error values than linear regression and ARIMA method. This model can also see the pattern of the spread of dengue cases, based on the spatial connectivity of the number of dengue fever cases among the neighboring districts.

Spatial autocorrelation analysis showed three districts in Sleman regency significant to High - High (HH). the area is Depok, Mlati and Gamping district. This indicates that controlling the number of DHF patients needs to be done by the public health service in the three districts.

Future research is recommended and suggested to expand the scope of the research study area (scope of DI Yogyakarta or all provinces within Indonesia). Subsequent research includes the addition of variables forecasting the number of cases of dengue fever with socioeconomic data and population density as well as conducting a comparative study of forecasting methods in are needed this research using artificial neural network method.

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An AHP Model towards an Agile Enterprise

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Abstract—Companies are facing different challenges in order to adapt to their environmental context. They should be aware of the changes on the social, political, ecological and economical levels. Moreover, they should act in an efficient and rapid manner by leveraging new and reconfigurable resources. Organizational agility is the firm's key dynamic capability which enables it to deal with changes and exploit them as opportunities. Firms' objective is thus to attain a higher degree of agility which can help them to perform durably. In this article, a new model based on analytical hierarchy process (AHP) method is proposed. This can help companies to raise their agility level by deploying the most suitable agility enablers which can be either general or specific when related to information technologies. They can thus develop the most appropriate strategy towards agility regarding their internal and external contexts.

Keywords—Organizational agility; analytical hierarchy process; information technology; agility enablers

I. INTRODUCTION

The international context of companies is characterized by increased competition due to globalization, free trade and low cost labor in Asian and other emerging countries.

In addition, the local environment for companies is rapidly changing as countries are adopting new laws regularly, adapting their monetary/fiscal policies and facing social challenges.

Companies should in this rapidly changing environment, adapt their strategies regularly in order to manage risks and to create a competitive advantage.

They should thus be agile regarding their current and future environmental challenges.

Organizational agility is the firm's dynamic capability which allows it to combine the features of chaos and flexibility with a minimum of order, control, and predictability [1], [2].

It is the ability of the firm to sense changes in its environment and to respond in an adequate and rapid manner [3], [4].

The aim of companies is to enhance their agility's level continuously. They should be able to detect key levers and develop thus a strategy towards agility.

In this paper, a new model based on multi criteria method (AHP) is proposed. It allows the company to define a global strategy by leveraging agility's enablers based on their weights. Then, the IT levers of agility are highlighted. The company can activate them and integrate them into its IT strategy in order to

be more agile. The presented model is original as previous works have proposed methods in order to assess firm's agility without proposing a detailed strategy for improvement [5].

The structure of this work is organized as follow. Section II is dedicated to the definition of AHP method, its advantages and main applications. In Section III, the organizational agility concept is defined. Then, the adopted methodology and the AHP model are described. Section IV allows illustrating the application of the proposed model. It presents the global and IT specific methods for enhancing enterprise agility. Finally, Section V provides a brief conclusion of this article and the future research perspectives.

II. AHP

A. Definition

AHP is a multi-criteria approach for decision making based on the definition of a goal as a top priority and on a decision hierarchy from the highest to the lowest criteria in term of importance [6].

AHP starts from the judgments of decision makers to form a decomposition of problems into hierarchies. The problem complexity is represented by the number of levels in the hierarchy which combine with the decision maker's model of the problem to be solved.

Decision making process through AHP requires two phases: design and evaluation.

Design, as described earlier, is reaching a consensus about the hierarchy model.

Evaluation is based on pair wise comparison. The criterions on the same level of the hierarchy are compared with each others, and with other elements on the level above [7].

The pair wise comparison is accomplished thanks to the use of a square matrix. As in (1), the rows and columns represent the criterions which are compared and the entries of each cell of the matrix represent the weight of an element of the matrix when compared to another element.

$$A = \begin{bmatrix} a_{11} & \dots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \dots & a_{nn} \end{bmatrix} = \begin{bmatrix} 1 & \dots & w_1/w_n \\ \vdots & \ddots & \vdots \\ w_n/w_1 & \dots & 1 \end{bmatrix} \quad (1)$$

Where, $a_{ij} = w_i/w_j$ and a_{ij} represents the importance of the weight w_i over w_j .

The matrix A has positive entries everywhere and satisfies the reciprocal property $a_{ji} = 1/a_{ij}$. This kind of matrix with this property is called a reciprocal matrix.

Saaty, 1977 proposed a hierarchical decomposition in which the elements are grouped in classes of about 7 elements each, in order to limit the number of comparisons required and to minimize the number of errors that could arise. Thus, a 1-9 scale is used in order to assign weights to each criterion (Table 1). In the case of this article, a linear scale is used [8]-[10].

There are other scales for comparisons in the literature [10]- [17] (Table 2).

TABLE I. THE LINEAR SCALE FOR COMPARISONS (SAATY, 1977) [10]

Intensity of importance	Description
1	Equal Importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values
Reciprocals	Values for inverse comparison

TABLE II. THE DIFFERENT SCALES FOR COMPARISONS (ISHIZAKA & LABIB, 2009) [10]

Scale Type	Values								
Linear (Saaty 1977) [10]	1	2	3	4	5	6	7	8	9
Power (Harker and Vargus 1987) [12]	1	4	9	16	25	36	49	64	81
Geometric (Lootsma 1989) [13]	1	2	4	8	16	32	64	128	256
Logarithmic (Ishizaka, Balkenborg et al. 2006) [14]	1	1.5 8	2	2.3 2	2.5 8	2.8 1	3	3.1 7	3.3 2
Root square (Harker and Vargus 1987) [12]	1	1.4 1	1.7 3	2	2.2 3	2.4 5	2.6 5	2.8 3	3
Asymptotical (Dodd and Donegan 1995) [15]	0	0.1 2	0.2 4	0.3 6	0.4 6	0.5 5	0.6 3	0.7 0	0.7 6
Inverse linear (Ma and Zheng 1991) [16]	1	1.1 3	1.2 9	1.5	1.8	2.2 5	3	4.5	9
Balanced (Salo and Hamalainen 1997) [17]	1	1.2 2	1.5	1.8 6	2.3 3	3	4	5.6 7	9

The Eigenvalue method is used in order to derive priorities among criterions/sub-criterions. Thus, priorities' vector is the principal eigenvector of the matrix. It is a vector ω of order n such that $A\omega = \lambda\omega$. For such a matrix, ω is said to be an eigenvector and λ is an eigenvalue [18].

The largest eigenvalue λ_{max} of the comparison matrix is used to calculate the consistency index. The difference between λ_{max} and n is an indication of the inconsistency of the judgments. The consistency index (CI) can be calculated using (2) [19].

$$CI = (\lambda_{max} - n) / (n - 1) \tag{2}$$

Then, the consistency ratio (CR) is calculated by dividing the consistency index (CI) and the random index (RI) (3).

$$CR = \frac{CI}{RI} \tag{3}$$

Saaty, 1980 describes average RI values of randomly generated matrices of different sizes.

Moreover, he suggests that if the consistency ratio (CR) exceeds 0.1, the set of judgments may be too inconsistent to be reliable. In practice, CRs of more than 0.1 have to be sometimes accepted [20].

Finally, the global priority is obtained by multiplying the priorities values of the criterions/sub-criterions across the hierarchy.

B. Advantages and Applications

AHP is an intuitive and flexible method. It allows, in addition, checking the inconsistencies in judgments [21].

It has applications in several domains. For example, in operations management, AHP can be used for "make or buy" decisions, project risk analysis [22], supplier selection [23] and strategic solutions for alternate energy/emissions management [24].

In addition, AHP can be used in software selection based on technical and managerial considerations [25].

Wei et al., 2005 proposed an AHP-based approach to select the most suitable ERP system which allows the company to enhance its performance and competitiveness [26].

Other applications proposed by Melvin, 2012 are related to choosing among different strategies for improving safety features in motor vehicles or for evaluating the quality of research and investment proposals [27].

III. PROPOSITION OF AN AHP MODEL FOR AN AGILE ENTERPRISE

A. Organizational Agility

The history of agility began in the USA in order to help the American industry to regain the leading position which was lost during the 70s and 80s in favor of Japanese and European industries.

Organizational agility is the capacity of a company to adapt itself to the changes in its environment and to exploit it as opportunities of development and growth through fast and innovative responses [28].

Organizational agility enables firms, by sensing changes in the environment, to prioritize and choose the best solution among the possible alternatives, to reconfigure business processes and to customize real-time response [29].

There are two main distinct components of agility: 1) sensing; and 2) responding.

Sensing is related to scanning the environment through exploring and incorporating new knowledge [30].

The second component refers to responding to changing market conditions in a reactive or proactive manner [31].

These sensing and responding components should be aligned in order to maximize the impact of agility on firm's performance [32].

B. The Methodology

Fig. 1 below describes the methodology adopted for this study. First, the AHP hierarchy is defined by setting the goal, the criteria and sub-criteria.

Then, based on pair wise comparisons, the weights of each criterion and sub-criterion are calculated.

Finally, a threshold is fixed which and allows selecting the general agility's levers and the specific IT levers of agility.

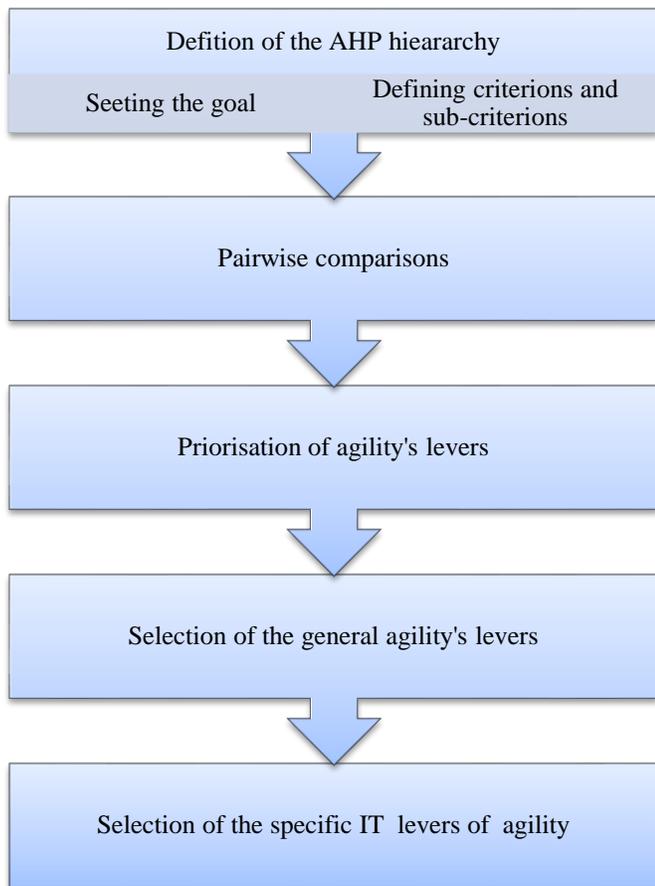


Fig. 1. The adopted methodology.

C. AHP Model proposition

The proposed model has three levels (Table 3):

- The goal is to achieve the firm's agility.
- The criteria and sub-criteria include the main agility enablers. They belong to six groups: IT, human resources, process, knowledge management, organizational structure and innovation [33].

TABLE III. THE PROPOSED HIERARCHY

Level (0) Goal	Level (1) Criterion	Level (2) Sub-criterion
Agile enterprise	IT	IT resources
		IT skills
		IT acceptance
		IT innovation
		Knowledge management systems
	Human resources	Mindset
		Behavior
		Planning
		Training
		Evaluation
	Process	Motivation
		Flexible process
	Knowledge management	Efficient decision making
		Capitalizing knowledge
		Balance in managing knowledge and change
	Organizational structure	Learning organization
		Adaptable structure
		Independent/multidisciplinary business units
Innovation	Self-organization	
	Introduction of new products	
		Entering new markets

IV. ILLUSTRATION : PRACTICAL APPLICATION OF THE MODEL FOR THE DEFINITION OF A GLOBAL AND IT STRATEGY TOWARDS AGILITY

The purpose of the proposed model is to allow companies to prioritize the most relevant attributes enabling them to be more agile.

The global approach is based on the by classification of the sub-criteria related to six enablers groups: IT, HR, process, knowledge management, organizational structure and innovation. Then, a specific approach related to IT is proposed.

The data is used below for illustration purposes of the proposed model.

The PriEST software, which is an open-source priority estimation tool developed by Sajid Siraj is adopted [34].

A. Pairwise Comparisons

First, a first pair wise comparison of the six criterions of level (1) is made.

Fig. 2 below presents a graph view of this pair wise comparison using the PriEsT tool (CR=2,5% < 0,1).

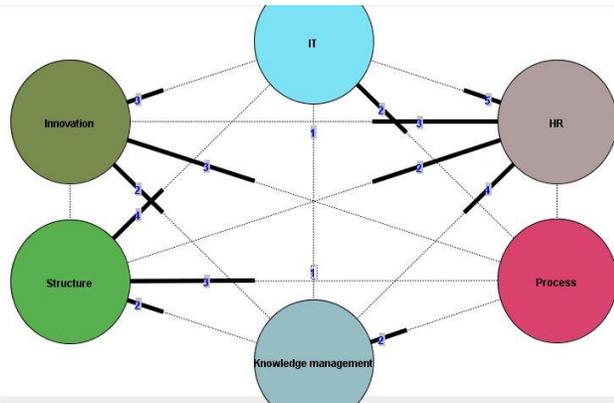


Fig. 2. Graph view of pair wise comparison between the six criterions.

B. Prioritization of Agility's Levers

Then, a pair wise comparison between sub-criterions of level (2) is performed (CR=7,7% < 0,1).

This allows calculating the priorities (column on the right) among agility's levers using the BPMSG AHP Online System which apply the eigenvector method [35] (Fig. 3).

Decision Hierarchy				
Level 0	Level 1	Level 2		Glb. Prio.
Agile enterprise	IT	IT resources	0.0816	0.6 %
		IT skills	0.3887	2.9 %
		knowledge management systems	0.0892	0.7 %
		IT acceptance	0.2793	2.2 %
		IT innovation	0.1818	1.4 %
		IT	0.0782	
	HR	Mindset	0.3367	12.8 %
		Behavior	0.2854	9.7 %
		Planning	0.0727	2.8 %
		Training	0.1098	4.2 %
		Evaluation	0.0992	2.6 %
		HR	0.381	
	Process	Motivation	0.1584	6.0 %
		Process	0.0802	
	Knowledge Management	Flexible process	0.8667	4.0 %
		efficient decision making	0.3333	2.0 %
		Knowledge Management	0.0946	
	Organizational Structure	Capitalizing knowledge	0.1172	1.1 %
Balance in managing knowledge and change		0.2884	2.5 %	
Organizational Structure		0.2046		
Innovation	Learning organization	0.8144	5.8 %	
	Adaptable structure	0.2493	5.1 %	
	Innovation	0.1818		
	Independent Business Units	0.1871	3.2 %	
	self-organization	0.5938	12.1 %	
	Introduction of new products	0.8667	12.1 %	
	entering new markets	0.3333	6.1 %	
			1.0	

Fig. 3. Prioritization of agility's levers.

C. Global Approach towards Agility

In order to select the most influencing levers on which the company should focus, a threshold is calculated as (4):

$$\text{Threshold} = 1/NB(\text{agility's levers}) \quad (4)$$

As presented in Table 4 below, the agility's levers with a priority which is higher or equal to the previous threshold are selected.

In this example, Threshold = 1/19 = 0,047619.

TABLE IV. SELECTION OF THE MOST INFLUENCING AGILITY ENABLERS

Agility's enablers	Priority	Selected agility's enabler
IT resources	0,006368	No
IT skills	0,028816	No
knowledge management systems	0,006946	No
IT acceptance	0,021835	No
IT innovation	0,014198	No
Mindset	0,128275	Yes
Behavior	0,097312	Yes
Planning	0,027706	No
Training	0,041726	No
Evaluation	0,026379	No
Motivation	0,059589	Yes
Flexible process	0,040139	No
efficient decision making	0,020069	No
Capitalizing knowledge	0,011075	No
Balance in managing knowledge and change	0,025359	No
Learning organization	0,05805	Yes
Adaptable structure	0,051008	Yes
Independent Business Units	0,032131	No
self-organization	0,121451	Yes
Introduction of new products	0,121045	Yes
entering new markets	0,060522	Yes

In conclusion, in order to enhance its agility, the focus should be in this example on employee's mindset, their behavior, their motivation, on having an adaptable/ learning and self-organized structure, and on innovation (introduction of new products, entering new markets).

D. The IT Specific Approach towards Agility

In the rest of this article, the agility's levers related to information technology (IT) are highlighted.

A third level is then added to the AHP model (Table 5 below).

TABLE V. THE EXTENDED HIERARCHY RELATED TO IT LEVERS OF AGILITY

Level (0) Goal	Level (1) Criterion	Level (2) Sub-criterion	Level (3) Sub-criterion
Agile enterprise	IT	IT resources	IT architecture(SOA)
			Cloud computing
			Interoperability
		IT skills	Mastering IT resources
			Use of HRIS
		IT acceptance	Perceived ease of use of IT
			Usefulness of IT
		IT innovation	3D printing
			Robotics
			RFID
			IoT
		Knowledge management systems	Mobile
			Use of groupware and workflow Tools
			Use of Intranet/extranet
			Use of DMS
			Use of CMS
Decision support systems			
Big data analytics			
Manage knowledge using AI			

Then, a pair wise comparison allows prioritizing the IT levers of agility based on their weights (the column on the right in Fig. 4 below) (CR=6,6%<0,1).

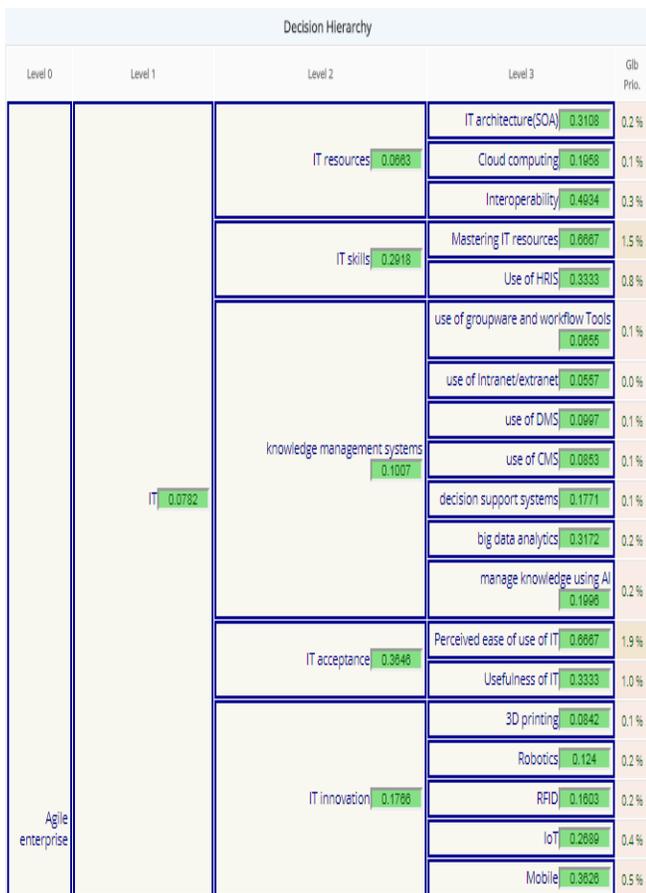


Fig. 4. Prioritization of IT levers of agility.

An IT threshold is calculated as the mean of the IT agility levers priorities (5).

In this example,

$$IT \text{ Threshold} = \sum IT \text{ levers of agility priorities} / 19 \quad (5)$$

$$IT \text{ Threshold} = 0,004113$$

Then, the most influencing IT levers of agility are selected (Table 6 below).

TABLE VI. SELECTION OF THE MOST INFLUENCING IT LEVERS OF AGILITY

IT levers of agility	Priority	Selected IT levers of agility
IT architecture(SOA)	0,00161	No
Cloud computing	0,001014	No
Interoperability	0,002556	No
Mastering IT resources	0,015204	Yes
Use of HRIS	0,007602	Yes
use of groupware and workflow Tools	0,000515	No
use of Intranet/extranet	0,000438	No
use of DMS	0,000785	No
use of CMS	0,000671	No
decision support systems	0,001394	No
Big data analytics	0,002496	No
Manage knowledge using AI	0,001571	No
Perceived ease of use of IT	0,019001	Yes
Usefulness of IT	0,0095	Yes
3D printing	0,001162	No
Robotics	0,001712	No
RFID	0,002213	No
IoT	0,003712	No
Mobile	0,005006	Yes

In this example, company should focus on using mobile, on IT acceptance (Usefulness and perceived ease of use of IT), and developing IT skills (mastering IT resources and using HRIS) among employees.

V. CONCLUSION AND FUTURE PERSPECTIVES

The current article has allowed the proposition of a new model based on the AHP method. It may help companies to enhance their agility's level by selecting the most appropriate enablers regarding their context.

It can be improved and adapted to the company's internal and external environment. Thus, criteria and sub-criteria may be added or removed according to the company's resources or activity sector.

Future research will focus on the application of the model in a real case through an action research methodology aggregating the pair wise comparisons across company's experts by using an appropriate survey.

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Ghanaian Consumers' Online Privacy Concerns: Causes and its Effects on E-Commerce Adoption

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Abstract—Online privacy has gradually become a concern for internet users over the years as a result of the interconnection of customers' devices with other devices supporting the internet technology. This research investigates and discusses the factors that influence the privacy concerns faced by online consumers of internet services and the possible outcomes of these privacy concerns on the African online market with Ghana being the primary focus. Results from this study indicated that only 10.1% of respondents felt that the internet was safe for purchase and payment transaction in Ghana. However, respondents were willing to shop online if e-Commerce was the only means of getting their products. Respondents also had a high sense of perceived vulnerability and their perceived vulnerability to unauthorized data collection and misuse of personal information could affect Ghanaian e-Commerce platform adoption. The perceived ability of users of e-Commerce platforms in Ghana to control data collection and its subsequent use by other third parties was also found to negatively impact customers' willingness to wholly transact and share their personal information online. The perceived vulnerability was found to be affected by the high levels of internet illiteracy while the perceived ability to control the collection of information and use was influenced by both the internet literacy level as well as the level of social awareness of the Ghanaian internet consumer.

Keywords—E-Commerce; technology adoption; online privacy; perceived vulnerability; perceived control

I. INTRODUCTION

Internet, which is defined as the linkage of networks, is used by a wide variety of people. From its early concept, it was supposed to be used by only the military and the government but now it has now extended in terms of usage to billions of people from all walks of life [1]. Since the inception of the world-wide web, the number of people who have been using the internet has grown exponentially. The internet has further changed a number of ways we do things from how we communicate, to the advancement of research and how businesses are transacted [2]. Thus, the internet has turned the

earth planet as we know it into a “global village” whereby information has been made readily available to everyone.

The internet is rapidly evolving and two aspects have made the evolution a reality, that is, the breakthrough of mobile technology and the introduction of social networking. The internet never ceases to be the pinnacle of a new beginning and will undoubtedly continue to play an unprecedented role in our life. A report from authors in [3] points out that the number of users of the internet were roughly 16 million in 1995 and in 2017 the number is now 3.732 billion which represents 49.6% of the entire world's population.

The ever increasing number of users of the internet technology however creates one major concern and that is privacy. UNESCO defines privacy as the right of any citizen to control his or her own personal information and to decide what that information can be used for, thus, to keep or disclose [4]. Privacy invasion comes into the picture when the personal information is being disseminated, used and released without being restrained. With the rapid expansion of the world-wide web, consumers have raised concerns regarding their personal privacy whilst they are either online or even offline.

The internet in spite of its numerous advantages has paved way for a cleverly systemized way of collecting data. The online footprints of consumers can easily be tracked in a unique way that the person will not even become aware of it. Virtually every single information about the person stemming from the person's interest, preference and some private information can easily be accessible to other third parties for them to use in their own way. Studies done by the Federal Trade Commission (FTC) discovered that 90 percent of web sites were gathering at least one type of identifiable information about their users such as name, e-mail address, location, while 57 percent were obtaining at least one type of demographic information, for example, gender and preferences with some websites going to the extent of gathering very

sensitive details such as social security number and credit card details [5].

The sale of information has become very prevalent with the introduction of the dark web and here is a summary of how much some information gathered costs online from a TrendMicro research [6]:

- Very sensitive data such as banking credentials will cost around \$1000. Health record and social media accounts sells for around \$50 per record.
- Some basic information such as name, age, location, typically the kind of data that you need when registering for a site goes for about \$0.50.

Even though this might not seem much, it must be noted that a number of these information floating around the dark web make it a very profitable venture for hackers, organizations and other people to use it to their advantage. It is clear that the financial reward of these kinds of information testifies to the reason why online gathering of consumer's data has taken an interesting turn for a lot of online services. And it is as a result of this that consumers now have a fear of how their private information is being used online.

With the release of Edward Snowden papers by WikiLeaks, it has been observed that the number of people using Virtual Private Networks (VPN) and browsers that ensure users anonymity online such as The Onion Router (TOR) and ZOHO have increased dramatically because as released by the WikiLeaks papers, these are the browsers that the NSA had major problems in decrypting [7].

When ex-CIA programmer Snowden released the classified files in 2013, in August alone the number of people using TOR skyrocketed from 500,000 users to 1,200,000 users [8]. Further studies which also show the ever-increasing number of users world-wide of TOR has been presented in [9]. Events like these have led to many people who initially were not interested in online privacy concerns to now question security practices of governments' branches that deal with the practice of looking into private lives of people by the use of the internet. Some governments are willing to prioritize the privacy of their citizens over the economic wellbeing of their citizens. For example, it was revealed recently that Verizon, a mobile telecommunication network gave US agencies backdoor access to be able to invade on the privacy of their users. The US agencies used this opportunity to spy on Angela Merkel, who is the German chancellor. Merkel cancelled Germany's partnership with Verizon which resulted in economic loss [10] when this vulnerability was uncovered. This proves how far governments are willing to go in order to protect the privacy of its people.

As a result of these occurrence, there have been a massive rise in technological start-ups companies that specialize in ensuring the anonymity or preventing the infringement of privacy of users. Experts encourage start-ups in this era of information technology to focus on solving problems on privacy. With an increasing number of devices and complex interconnectivity between them, attention is being shifted from how the data will be created and stored to how secure the data is. Consumers need to be able to dictate the use of their private

data. The introduction of internet of things (IOT) which is defined as the inter-networking of physical devices, vehicles, buildings, and embedded systems such as electronics, sensors, actuators, and network connectivity which enables these objects to collect and exchange data has made the discussion on online privacy more imminent.

The Ghanaian telecom sector has seen an increasing number of mobile phones and other handset that can easily access the internet. This is as a result of the huge reduction in the cost of internet services. Internet has now become part of the everyday life of every Ghanaian. Ghana has a literacy rate of 71.5%. There are about 21 million educated people in Ghana and a survey conducted by researchers in [11] suggests that 51% of the people in Ghana use mobile phones. This is to say that getting access to internet is not too expensive for the average Ghanaian.

Research conducted from the user statistics of TOR, summarized in Fig. 1, shows the increase in the average Ghanaian internet consumer privacy since 2013 [12]. The later part of 2016 saw a spike in TOR usage. This could mainly be attributed to the cautious nature of the citizens during the presidential election period. The result in Fig. 1 supports the hypothesis that a concern has grown amongst the Ghanaian public about their online privacy and even though some experts might argue that citizens in third world countries like Ghana may not be concerned about online privacy, this data clearly tend to show otherwise that irrespective of the developmental stage of a country, privacy infringement is still a problem and hence Ghana is no exception to the rule.

The issue of online privacy in Ghana has become very important because businesses are now targeting Ghanaian consumers for e-Commerce transactions in their advertisements of business products and services. In most cases, consumers provide personal information during online transactions when registering on transactional websites such as Tonaton, OLX, Amazon, eBay, Alibaba and social media platforms like Facebook, Twitter, Instagram.

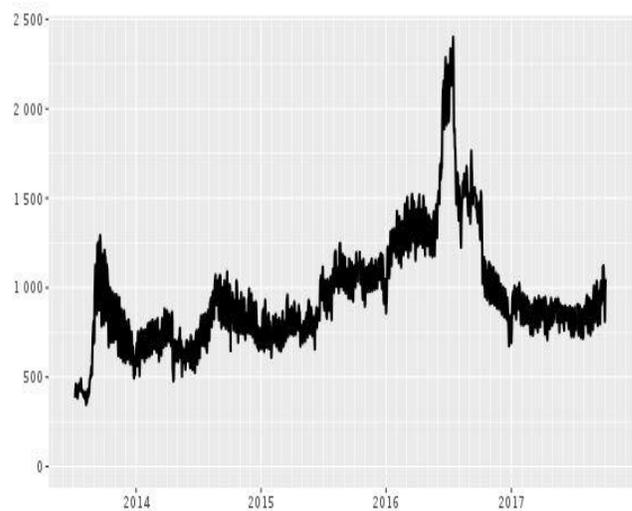


Fig. 1. A graph showing the number of TOR browser users in Ghana [12].

Perkins and Annan [13] in their research work on evaluating factors that affects the adoption of online banking in Ghana found out that cookies in browsers provided personal information of customer when tracking customer's online surfing activities. They could not however evaluate the extent to which this breach of privacy affected online banking adoption by clients. This research seeks to investigate the extent to which the privacy concerns of online users in Ghana affect their willingness to share information online. The research also seeks to study if there is any relationship between the privacy concern and their willingness to transact business online.

A. Principles of Privacy Development

The development of online privacy policies must address the perceived vulnerability of the online user and the perceived ability of the user to control his personal information online. The perceived ability to control is creating a condition for the consumer to believe that they can withhold personal information from being released online and also control what is being shared of them. This allows consumers to exercise their right to privacy. The perceived ability to control private information flow with consumers reduces their sense of vulnerability and their online privacy concerns [14].

The Federal Trade Commission addresses these issues with five core principles to promote privacy policy development by online content vendors [15]. These core principles are:

- Notice: Consumers ought to be made mindful of a Website's capacity to gather data and utilization practices before data is gathered.
- Choice: Consumers ought to be allowed to pick whether to partake or decline the collection of their own data.
- Access: Consumers ought to approach their own data and ought to have the capacity to rectify incorrect data.
- Security: There ought to be approaches to guarantee the respectability of information and as such, the anticipation of abuse of data ought to be set up.
- Redress: Enforcement ought to be set up to guarantee the above standards are maintained. Illustrations are self-controls (by the buyers) and government directions.

These guidelines allow online consumers to control the usage of their personal data. If these rules are met, the consumers will then feel safe and convinced to trust such websites to collect their personal information. Another way for consumers to trust websites to collect their information is the use of third-party seals of approval programs. Examples of such third parties are TRUSTe and Verisign. These programs confirm the website's respect for personal privacy [16].

II. METHODOLOGY

This section investigates how the average Ghanaian online consumer uses the internet and how privacy issue affects the customers' willingness to use these online services again. The research further conducts a study on understanding how the new generation of internet users in Ghana perceives internet privacy and how it affects their internet usage.

The preferred method of information gathering was the questionnaire. Questions posed in the questionnaire were not compulsory, that is, respondents were free to ignore the question if they did not feel like answering. This idea was implemented as a way of making the answers as true as possible. No one was forced to answer any question. Respondents were also free to edit their answers. This was to allow answers that were selected in haste be reconsidered and changed at a later time. The disadvantage of this approach is that, it could lead to a lot of outliers and this could complicate data analysis.

About 120 individuals were invited of which 104 responded. The sample space comprised of Students and the working class adults who were avid internet users. This group was chosen because the young generation are the people who use the internet the most according to Perkins and Annan [13]. This category of users were also selected because of the need to get responses from people who were regular internet users, and that would mean they understood what exactly the research was about.

The main subject of the study was to evaluate how consumers are impacted by their perceived vulnerability to unauthorized gathering and use of personal information, and their perceived ability to control the manner in which their personal information is collected and used online. In view of this, the questions focused on the consumers' frequency of sharing information, what kind of information they shared and how safe they think their information is. Their response served as the basis to evaluate how Ghanaian consumers' perceived vulnerability affected their willingness to use the internet for e-Commerce transactions.

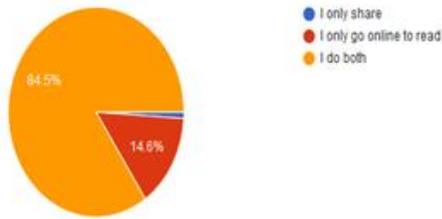
III. RESULT AND DISCUSSIONS

As consumers' concerns about their online privacy grows rapidly, most activities on the internet could be eventually affected, thus, from e-Commerce to providing personal data and even general browsing/surfing on the internet. The first part of our study sought to find out how respondents share and look for information online. The results from the question were very conclusive that all of the people in the sampled class were internet users on various social platforms. They shared and received various types of information on the internet. Respondents indicated that, as seen in Fig. 1(a), they used the internet as their primary means of looking for information. 84.5% of respondent admitted that, they shared and researched for information online. When asked what kind of information they shared as summarized in Fig. 2(a), surprising, 99 responded to sharing information which contradicted the total number of 88 people who agreed to sharing information online. When the respondents were asked which kind of information they liked to share, 40 out of the 99 respondents indicated they liked to share personal information. Respondents were allowed to choose more than one option when submitting their response to this particular question. The major thing respondents seemed to like sharing was news with 69 out of 99 respondents indicating this preference. From Fig. 2(b), it is easy to notice that most of the things shared online by the sample group were non-personal details.

This was expected since the sample group was mostly young people who usually use the internet for reading news and browsing multimedia applications. The questions were further focused on details that had to do with their online vulnerability, that is, information shared that contained personal information. The responses are summarized in Fig. 3 and can be seen that 71.8% indicated they provided their personal details online. However, 72% of those who responded Yes to providing personal details online said that, they only provided it because that was the only means through which they could get access to the e-Commerce platforms they wanted to use.

Do you share information, go for information or both on these platforms?

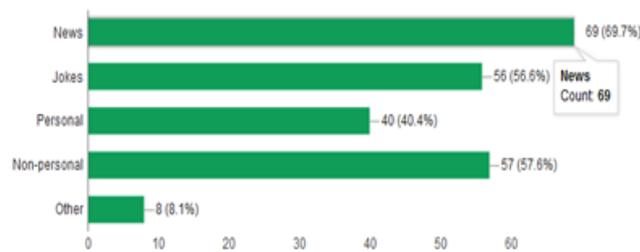
103 responses



(a)

What kind of information do you share?

99 responses



(b)

Fig. 2. (a) Information sharing; (b) Information sharing by the sampled group.

Do you provide personal details to websites?

103 responses

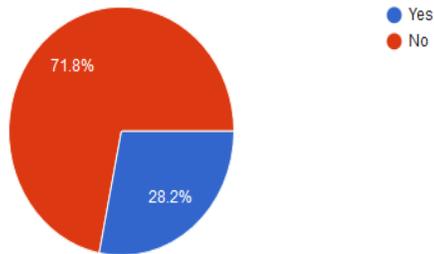


Fig. 3. Personal details.

When the respondents were asked about their perceived vulnerability, 93.2% indicated that, the fear of the information they share been compromised online make them hesitant in sharing information. From the results summarized in Fig. 4 and 5, it is clear that most of the respondents were weary of the internet. They were afraid of what their information would be used for. This information differs from the assumptions some experts in literature make that internet users in third world countries don't care about their online privacy. It was assumed that the average Ghanaian did not care what kind of information they shared online, but from the results, it can be concluded that the new generation of Ghanaian internet users are aware of the dangers of the internet as supported by over 65% of respondents indicating their uncertainty of the safety of the internet (refer Fig. 5(a)) and as such their willingness to limit their information sharing (refer Fig. 5(b)).

Has the fear of it becoming known to the public hindered you from sharing information?

103 responses

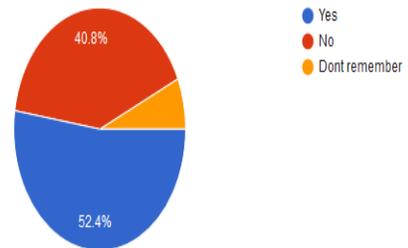
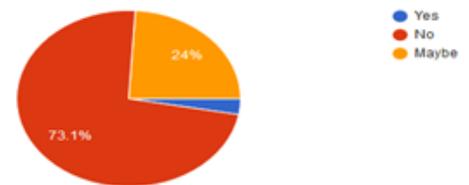


Fig. 4. Perceived vulnerability.

Do you think personal information shared online is safe?

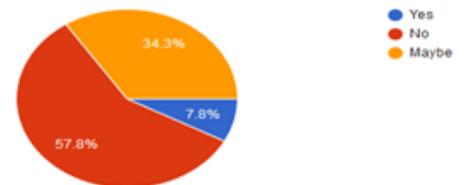
104 responses



(a)

In general, do you think the internet is safe?

102 responses



(b)

Fig. 5. (a) Information sharing perspectives; (b) Perceived vulnerability concerns.

The respondents were further questioned on their knowledge of digital marketing and e-Commerce. Over 50% of them had heard of the phrase “Digital Marketing” but did not know exactly what it was while 70% had heard of e-Commerce and showed brilliant understanding of its concept.

After learning of their views on perceived vulnerability and their understanding of e-Commerce, it was decided to study how their perceived vulnerability affected their use of the internet. This part of the research questions sought to mainly inquire how the perceived vulnerability affected their interactions with e-Commerce websites and platforms that required them to share personal information in order to use their services. From the response gathered, 59.8% of respondents indicated they had made an online payment or transaction before as shown in Fig. 6 but only 10.1% of respondents felt that the internet was safe for making purchase orders and payment transactions as shown in Fig. 7(a).

Respondents were however, willing to shop online if e-Commerce was the only means of getting their products.

Have you ever made a purchase online?

102 responses

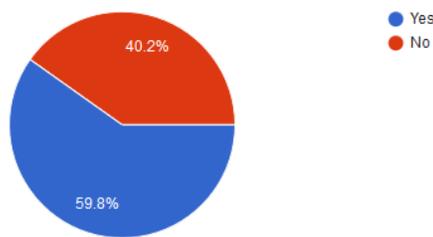
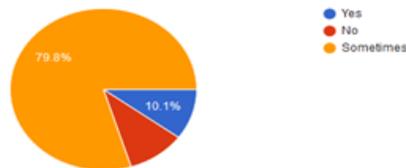


Fig. 6. Online purchasing responses.

Do you think online purchases are safe?

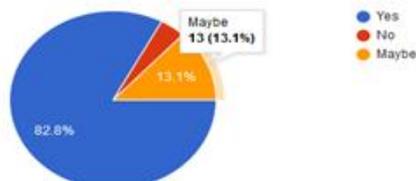
99 responses



(a)

Would you shop online if it was the only way to get a product?

99 responses



(b)

Fig. 7. (a) Views on the safety of e-Commerce; (b) Online purchasing responses.

In Fig. 7(a) and (b), there is a noticeable contrast in responses when it comes to the safety of e-commerce systems. In a bid to simplify the results, all ‘Maybe’ and ‘Sometimes’ answers were considered as negative answers. From this we can see that when asked about the safety of e-commerce platforms, most people did not trust them but when it was the only way to get a product most people said they would use them since they had no option.

Some of the reasons respondents gave for not trusting online e-Commerce sites were:

- Because such sites do not general feel safe for them to provide them with sensitive personal information.
- The respondents couldn’t entirely trust online shops since they are unable to determine who is behind them.
- Some respondents also felt it was risky and that information provided could be used for something else. They therefore would prefer to deal directly with a supplier.

The results from this study show that Ghanaian users of e-Commerce platforms are highly concerned with their online privacy. About 71% of respondents are less willing to disclose personal information online. Despite their high privacy concerns and unwillingness to provide their personal information to websites, online privacy concerns did not negatively affect Ghanaians consumers’ willingness to engage in e-Commerce transactions if the only means of getting the products was through an online transaction. Analysis of our questionnaire further indicated that this privacy concern of respondents could lead to three categories of internet users in Ghana, namely,

- *Users who are ready to provide their personal data:* In this case, users will not be required to enter or provide their personal details that the website requests from them. This may result in some surfing only through websites which do not request personal information or even in the cases where personal information is required, these users may provide false personal information in a bid to remain anonymous while using the website.
- *User who decline to adopt e-Commerce platform as a means of transacting business in Ghana:* Where their personal data will be required most of the time leading to an increase in the perceived vulnerability of internet users in Ghana. The possible increasing privacy concerns which could arise may affect negatively on e-Commerce transactions.
- *Users who refuse to use the internet and e-Commerce platforms:* This could be the worst case scenario where users would be unwillingness to use the internet and e-commerce platforms. This could happen when internet users have the feeling that even when they don’t provide information, some attributes of theirs could still be tracked online. There are some users who could be extremely concerned about online privacy and would not even voluntarily use the internet.

People have tried to come out with frameworks that will reduce online privacy concern and through their analysis and study of the online privacy problem, a lot of strategies and measures have been suggested to solve or minimize the online privacy concerns including using an integrated whole of government approach [17] and framing a new internet regulatory regime [18].

This research would also propose some measures in addition to what have been proposed by Perkins and Annan [13] to address the online privacy concerns of the Ghanaian internet user.

The privacy concern can be reduced by increasing the users' perceived ability to control the collection and use of his sensitive personal information. This can be positively supported by the users' level of internet literacy and his level of awareness of social issues involving internet usage. The perceived control of user can be increased when businesses and legitimate marketers in Ghana who collect consumers' personal information obey the Privacy Law Act of Ghana which has been clearly stipulated in the constitution. This can be enhanced by online vendors by posting a comprehensive or detailed privacy policy conspicuously on the home page of their Website. This measure will increase the social awareness and alertness of internet users in Ghana. This could help in increasing the consumers' perceived ability to control information.

The procedural fairness in the collecting and usage of personal data collected from users by these e-Commerce platforms must also be made known to the users. This would further help increase users' trust in using these e-Commerce and online platforms [19]. Consumers should also be allowed to decide whether to choose to participate or be excluded in the collection of personal information before being taken. Consumers should have access to their own personal information and should be able to correct erroneous information. Policies to ensure the integrity of information and prevention of misuse of them should be clearly spelt out in the laws of Ghana.

Another way of reducing Ghanaians consumers' online privacy concerns, which could be derived from the implication of the results in this study, is by reducing the perceived vulnerability to information misuse and its consequences in e-Commerce. This can be achieved when users' perceived ability to control information collection and usage is increased as discussed early on. Since factors such as, accidental disclosure of personal information, hacking into networks and systems, weak identification and authentication systems and spam that require personal details, could affect users' perceived vulnerability. Users must be educated on these factors to improve their internet literacy levels. Data obtained from respondents in this study show that, only 5% of respondents knew about cookies and firewalls. It is therefore very important for online marketers and businesses in Ghana to educate online users of their platforms on the options and measures available for protecting their personal information.

IV. CONCLUSION

From the study, it can be seen that Ghanaian consumers are highly concerned with their online privacy and they are less willing to disclose personal information online. Most of the respondents in this study indicated their preparedness to stay away from websites that require them to submit personal details such as bank account information and location information online. Even though their high privacy concern and unwillingness to provide their personal information to websites has not negatively affected the willingness to engage in e-Commerce transactions for now, their concerns about their online privacy could grow rapidly and this could adversely affect how they will adopt these ever-increasing e-Commerce platforms in Ghana in the long term if these concerns are not addressed soon.

The implication of the results in this study supports the need for online marketers and businesses to carefully study and understand these factors that increase online privacy concerns in Ghana and address them appropriately and urgently. Future research could develop and test a comprehensive privacy framework for the Ghanaian internet space. This is very crucial and critical because if not properly considered, online transactions and e-Commerce can lose its value and its impact on the Ghanaian economy would be adverse.

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Expert System of Chili Plant Disease Diagnosis using Forward Chaining Method on Android

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Abstract—This research was conducted to make an expert system that is able to diagnose disease in chili plants based on knowledge that provided directly from the experts. This research uses classical probability calculation method in calculating the percentage of diagnoses and implemented on the Android mobile device. This research consisted of 37 symptoms data, 10 data of chili disease caused by fungi, and 10 rules. This expert system uses forward chaining inference method. Test results shows: (1) Functional testing using the Black Box Equivalence Partitioning (EP) method give the results as expected on the test scenario on each test class. (2) Expert testing by comparing the results of manual and system calculations matches and run well. (3) User acceptance test is done to 53 respondents which is divided into four groups of respondents. The first respondents group that is consisting of experts of chili disease give average score of 85.14% (excellent). The second group that consist of Agriculture Department students give score of 84.13% (excellent). The third respondent group that consist of Computer Science Department students give score of 84.28% (excellent) whereas the last group (chili farmers) give a score of 86% (excellent).

Keywords—Android; classic probability; expert system; forward chaining; likert scale

I. INTRODUCTION

Chili is one of the important horticultural crops in Indonesia. Chili is classified as fruit and vegetable crops that have protein to be developed and have high economic value [1]. The production of chili during 2011-2013 tends to decrease [2]. The reduction of chili production is followed by high consumer needs. Fig. 1 is a graph of the development of chili production in Lampung province, Indonesia. At rainy season, the production of chili is reduced, while the demand is constant and continuous every day, even increase in certain seasons. One cause of decreased production is disease of chili plants.

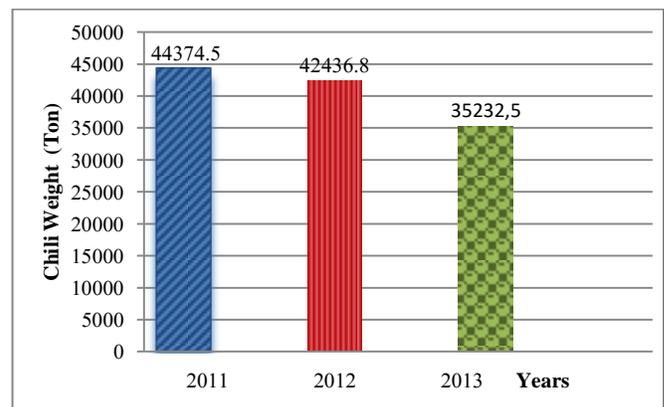


Fig. 1. Development of chili production of Lampung Province, 2011-13 [2].

The presence of disease attacks that attack chili plants can lead to crop failure. Therefore, the right control is needed to avoid that. The right control is not only when the attack is already happened, but the most important is the act of prevention. The late diagnosis process is caused by the lack of farmers' knowledge about the types of diseases that attack chili plants [3]. The diagnostic process needs an experienced expert in order to deliver the right conclusion. However, limited expert's available time become an obstacle for farmers to consult. In this case, expert system can be consulted as the second alternative in solving the problem. Based on the described explanation, the expert system that is able to diagnose chili plants disease is needed.

In this paper, we propose an expert system that can diagnose the chili plants disease. By developing the expert system, we hope the system can help farmers or field instructor in getting information about symptoms, chili disease and the way of handling the symptoms.

II. LITERATURE REVIEW

A. Chili

Chili plant is one of the horticultural commodities that are categorized as season crops. Chili plants are estimated to be about 20 species that mostly grow in place of its origin, America. The classification of chili plants is as follows [4]:

Kingdom	: <i>Plantae</i>
Division	: <i>Spermathophyta</i>
Sub division	: <i>Angiospermae</i>
Class	: <i>Dicotyledoneae</i>
Subclass	: <i>Metachlamydeae</i>
Order	: <i>Solanales</i>
Family	: <i>Solanaceae</i>
Genus	: <i>Capsicum</i>
Species	: <i>Capsicum annuum L.</i>

B. Disease on Chili Plants

The chili disease caused by fungi is as follows [5]:

1) Sprout Bee or Damping off

Pathogen: One of *Rhizoctonia solani*, *Pythium* spp. *Fusarium* spp. *Phytophthora* sp. or *Colletotrichum* spp.

Symptoms: Chili seedlings fail to grow, seeds that have germinated die suddenly or dwarfed seedling because rootstock or root neck rot and dry. In the nursery place appear bald sprouts or chili pepper sporadically and spread irregularly.

Prevention and control:

a) Media for seeding using sub soil coating (1.5-2 m below ground level), fine mature manure and river sand in a ratio of 1: 1: 1. This media mixture is pasteurized for 2 hours.

b) Infected seeds should be removed and destroyed, and the contaminated soil media should be disposed.

c) The nursery shade is gradually opened so the sunlight will reach the plants and the plants will become stronger.

d) Use of selective fungicides with the lowest dose limits.

2) Anthracnose

Pathogen: *Colletotrichum* spp.

Symptoms: Dead shoots that continue to the bottom. Leaves, twigs and branches dry rot blackish brown. On the trunk of acervuli the fungus is seen as a lump.

Prevention and control:

a) Balanced Fertilization, with Urea 150-200 kg, ZA 450-500 kg, TSP 100-150 kg, KCl 100-150 kg, and organic fertilizer 20-30 tons per hectare.

b) Chili intercropping in the highlands can reduce pest and disease attacks and increase yields.

c) The use of silver plastics mulch in the highlands, and straw in the lowland reduces Anthracnose infestation and soil diseases, especially in the rainy season.

d) Anthracnose disease caused by *Colletotrichum* spp. controlled with chlorotalonyl fungicide (Daconil ® 500 F, 2 g / l) or Propineb (Antracol ® 70 WP, 2g / l). Both of these fungicides are used interchangeably.

e) To reduce the use of pesticides ($\pm 30\%$), it is advisable to use fan nozzles that spray granules are mist and evenly distributed.

C. Expert System

Expert system is a system that seeks to adopt human knowledge to the computer, so that the computer can solve problems as usually done by experts. A good expert system is designed to solve a particular problem by imitating the work of the experts. With expert system, even common people can solve quite complex problems that can only be solved with the help of an expert. For experts, this expert system will also assist its activities as a highly experienced assistant [6].

The characteristics of expert systems are as follows:

- 1) Have a reliable information facility.
- 2) Easy to modify.
- 3) Can be used in various types of computers.
- 4) Have the ability to learn to adapt. [6]

Expert system consists of two main parts: the development environment and the consultation environment. The development environment is used as a builder both in terms of component and knowledge base. The consulting environment is used by the common people to consult. Expert system components can be seen in Fig. 2.

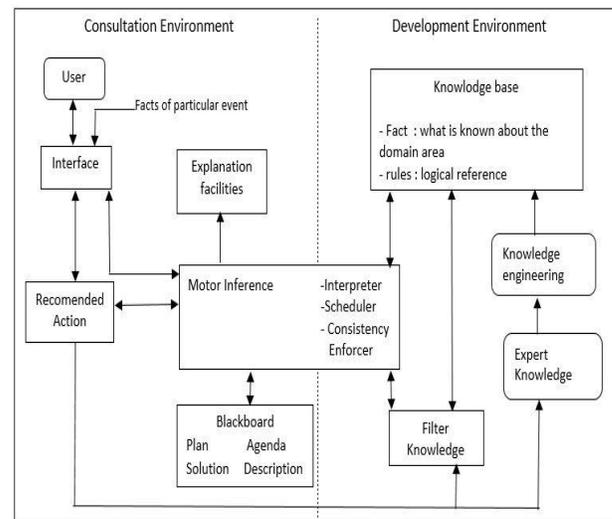


Fig. 2. Expert system structure [6].

D. Classic Probability

Probability is a quantitative way related to the existing uncertainty. Classic probability is also called a priori probability because it relates to a game or system. As mentioned earlier, the term a priori means "before" [7]. This probability is considered a kind of game, like throwing dice, card games, and tossing coins.

The general formula for classical probabilities is defined as the probability $P(A)$ with n is the number of occurrences, $n(A)$ represents the number of results getting A . Relative frequency the occurrence of A is $\frac{n(A)}{n}$ then [7] :

$$P(A) = \frac{n(A)}{n} \quad (1)$$

This classic probability is used to procure the probability of disease, so to calculate the percentage of illness is:

$$\text{Percentage (A)} = P(A) \times 100\% \quad (2)$$

III. METHODOLOGY

A. Research Stages

The steps in this study are problem identification, problem formulation, data collection, system design, system development, and system testing. This research stage can be seen in Fig. 3.

1) Problem Identification

This stage is the process of formulating and limiting the problem to be studied. The formulation and limitation of the problem is needed in order to further lead the researcher in making the system so that the research done does not come out of the predetermined limits.

2) Data Collections

Data collection is done by using two methods, through literature reviews and interviews.

a) Literature review

At this stage data is collected through literature such as books, journals, or documents relating to research themes.

b) Interview

Interviewing experts aims to obtain data that could not be found in the literatures.

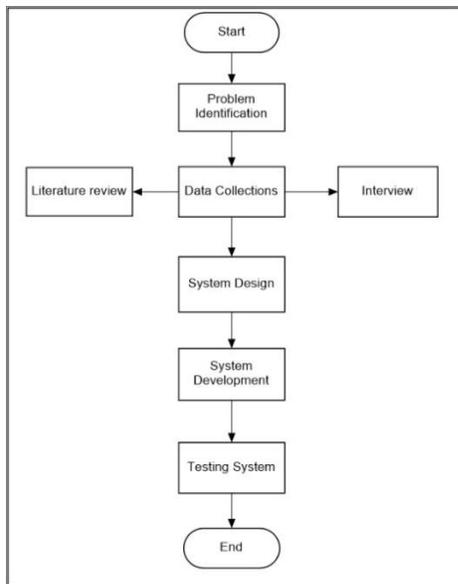


Fig. 3. Research stage.

3) System Design

System design is done by modeling the problem in the form of UML diagram (use case diagram). Design of use case diagram is presented in Fig. 4.

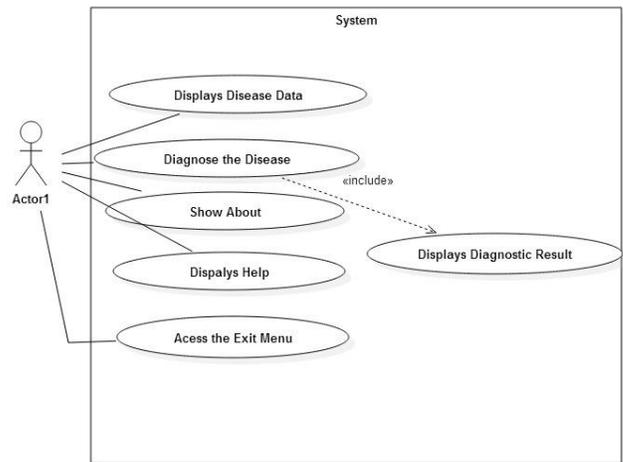


Fig. 4. Use Case diagram.

B. Discussion

1) Data Requirement Analysis

Data required on this expert system include symptom data and disease data on chili caused by fungi. Information on chili symptoms and diseases and their handling solutions come from consultation result with chili disease experts. It is found there are 37 types of symptoms and 10 types of chili disease caused by fungi. The list of symptoms and names of diseases in this expert system is coded “G” for symptom data and “P” for disease data.

2) Percentage Analysis of Illness

Percentage calculations in the expert systems are based on classical probability theory. This probability is used to procure opportunities for disease. For example, to calculate the percentage of diagnosis of Damping Off disease in Appendix 1 with four symptoms and one rule:

1. Chili seedlings fail to grow
2. Germinated seeds are dead
3. Dwarfs
4. Symptoms of Sporadic

The rule: “**IF** the Chili Seeds fail to grow **AND** the seeds are germinated dead **AND** The dwarfs and the symptoms in the sporadic seedbed **THEN** Damping Off.”

Then the Calculation is:

If the user does consultation and provide the facts that the chili plant experiencing: 1) Chili paste failed to grow; 2) Germinated seeds are dead; 3) Little Pygmy; Then get $n = 3$; $n(A) = 4$; $P(A) = 0.75$. Then the percentage of Damping Off is 75%. So, based on the facts given the user can be concluded the diagnosis of Damping Off disease with the level of possible illness is 75% (almost sure).

3) Expert System of Diagnosis Chili Disease Application

The screenshots of expert system application of chili disease diagnosis implemented on android can be seen in Fig. 5, 6 and 7.



Fig. 5. (a) Spalsh screen, (b) Home page.

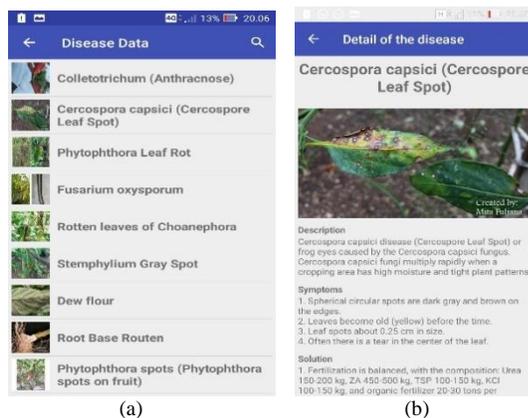


Fig. 6. (a) Disease data, (b) Disease detail.

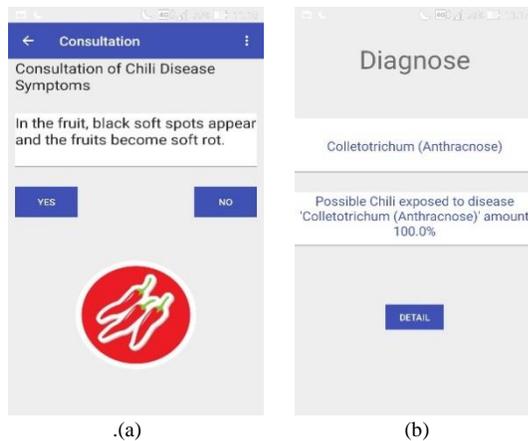


Fig. 7. (a) Symptom consultation, (b) Diagnostic results.

4) Testing

Testing of This expert system are conducted in two tests: internal testing and external testing. Internal testing is done to test the functional of the system and test the expertise of the system based on the facts given.

a) Functional testing

Functional testing is used to find errors on the system that has been built. Functional testing in this study uses Black Box Equivalence Partitioning (EP) method. The functional testing

process gets the expected results according to the test scenario in each test class.

b) System expert testing

Experimental test system aims to see the expert system's ability in the application in identifying the type of chili disease based on the facts of symptoms given. Testing was done with 12 cases.

c) External testing

External testing is done by collecting questionnaires filled by randomly selected respondents. This external test involved 53 respondents to get a direct assessment of the resulting system. These respondents were categorized into four categories with the aim of comparing the assessment results of chili disease respondents, who studied chili disease, who did not study at all about chili disease, and chili farmers. Categories of respondents in this study are as follows:

- 1) *Category of Respondents I: Experts on chili diseases, with details of 5 lecturers' faculty majoring in Agriculture.*
- 2) *Category of Respondents II: People who learn about chili disease, which is 18 students of Agriculture Department.*
- 3) *Category of Respondents III: People who do not learn about chili disease, which is 20 students Computer Science Department.*
- 4) *Category of Respondents IV: People who grow chili are 10 farmers.*

In this respondents are asked to access the application directly and provide an assessment of the application by filling out a questionnaire. Assessment categories consist of:

- Very Good (SB), with the value of 5.
- Good (B), with the value of 4.
- Good enough (CB), with the value of 3.
- Less Good (KB), with the value 2.
- Not Good (TB), with the value 1.

The formula for determining percentage of criterion-based valuations on the Likert Scale is to use the following mean arithmetic formulas [8]:

$$P = \frac{Xi}{n(N)} (100\%) \quad (3)$$

Description:

P = Percentage of statements

Xi = Total qualitative value

n = Number of respondents

N = Value of the best statement category

To analyze the questionnaire results, criteria of the assessment index is needed to facilitate the interpretation of the conclusion of the questionnaire results. Criteria of the assessment index is categorized into five categories, which is very good, good, good enough, less good, and not good. The following is the calculation of index criteria:

$$I = \frac{100\%}{K}$$

$$I = \frac{100\%}{5} \tag{4}$$

$$I = 20\%$$

Based on the calculation of the above interval, obtained interval value is 20%. Criteria index of respondents' assessment of the system is presented in Table 1.

Fig. 8 is a graph of the test results of the questionnaire.

TABLE I. CRITERIA ASSESMENT INDEX RESULT QUESTIONNAIRE

Answer	Description
0%-19.99%	Not Good
20%-39.99%	Less Good
40%-59.99%	Good Enough
60%-79.99%	Good
80%-100%	Very Good

Results of Questionnaire Testing

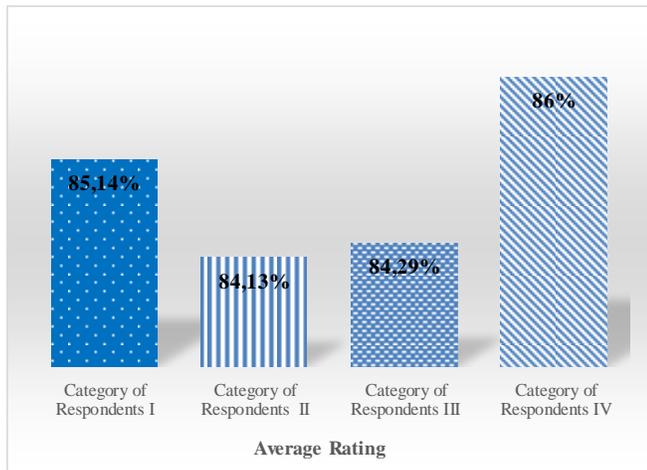


Fig. 8. Average values of questionnaire testing results.

Based on the questionnaire result, it can be concluded that the application “Expert Chili App” obtained an average percentage of appraisal of 85.14% (very good) according to respondent group I (the lecturer of agriculture), 84.13% (very good) according to respondent group II (student of agriculture), 84.28% (very good) according to respondent group III (student of computer science), and 86% (very good) according to respondent group IV (chili farmers).

IV. CONCLUSIONS

Based on the results of research that has been done, it can be concluded that:

- 1) The application of “Chili Expert System” has been successfully developed to assist the general public and farmers in identifying diseases caused by fungi based on the symptoms given.
- 2) The built expert systems is useful for public and farmers to find out information about chili diseases.
- 3) The results of functional testing indicate that the expert system built has been running as expected.
- 4) Based on the assessment of the use of the application through the questionnaire, it can be concluded that “Expert Chili App” obtained “very good” - “excellent” result.

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Cross-Organizational Information Systems: A Case for Educational Data Mining

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Abstract—Establishing a new organization is becoming more difficult day by day due to the extremely competitive business environment. A new organization may not have enough experience to survive in the competitive market; which in turn may push down the reputation of the organization and the trust of the investors. The goal of this research project work is to design a framework for the cross-organizational information system for assessment and decision making using machine learning with the emphasis on the educational sector. In the proposed framework, organizations share information (even raw data) with each other and machine learning tool will be utilized for shared data analysis for decision making for a particular organization. A framework like this can help new organizations to get benefit from the experience of other ‘older’ organizations and institutions. Such knowledge-based machine learning system helps to improve the organizational capability of newly established institutions. As an implementation of the framework, we build a fuzzy system that can effectively work as a cross-platform system for educational entities.

Keywords—Information system; machine learning; cross-organization; decision making; education; fuzzy matching; data mining

I. INTRODUCTION

A cross-organizational information system is a kind of information system that allows association, communication, and shared interactions. Such a system helps taking decisions for the organizations to get the competitive advantage in business [1], [2]. A cross-functional information system is an information system that is designed to allow different organizations share information and get benefits as the system allow the coordination between the business organization process activities [3]. Designing a cross-organization information system, sharing information and getting benefit become the main challenge for the business organization professional in today’s environment. The purpose of developing a cross-organizational information system is to assist a new organization to use information from various other organizations to take right decisions.

Various types of decisions taken while establishing a new organization should be correct, accurate and beneficial for the organization. Otherwise, badly assessed decisions may lead to the loss of the trust of the investors. In this scenario, we can imagine a cross-platform system to assist such organizations

and that can work as a supporting tool for a new organization. A new organizations can take the benefits from the ‘experiences’ of the older organizations, where these ‘experiences’ are actually derived using data mining techniques on the data shared by other organizations. Thus, in this paper, we address the key challenge to making a framework that can help an organization to communicate with the other similar organizations, share information and get the benefit of the experiences of the most renowned organizations.

Of course, the ability of such a system is limited by the amount of data shared by various organizations. Generally, organizations have public and protected data; the public data can be accessed by other entities and protected data can be accessed by only the authorized person. The protected data can be accessed by the following organization policies through the interference rules [4], [5]. In addition, in an amicable situation (such as country-wise public university system), sharing data may be more feasible, as the entities in such a system serve some common goals (building the competent workforce, for example). Therefore, the case study presented in this work for the proposed cross-organizational system focuses on educational data mining. The main contributions of this work can summarize as follows:

- Initial independent data mining systems for each organization.
- Cross-matching of ‘trend curves’ from similar organizations to measure comparative evaluation.
- Identify points of weakness for a ‘lagging’ organization from the trend lines of the best (or established) organization.

While building such a cross-organizational system, a number of issues need to be considered in the framework. We need to consider distributed database system with security issues, as various organizations apply their own rules and data structure. In such a scenario, protecting the privacy of the data of an individual organization is important. In addition, the data mining tool need to normalize the data sources in order to build proper matching models.

As an implementation of the proposed framework, we build a system for educational data mining using fuzzy trend line matching. The goal is to build a system that can help a new educational institution assess the quality of their education compared to other older institutions. Data in such a

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system are mainly students' records which are highly private data that cannot be publicly shared. Therefore, a cross-organizational system that ensures the privacy of shared data, while providing a platform for assessing qualities is highly sought. This paper exactly seeks to achieve this goal.

The rest of this paper is organized as follows. Section 2 deals with the discussion of the related work. In Section 3, we present our cross-organizational framework. The case study and corresponding model are presented in Section 4. Section 5 deals with the discussions of the experimental results. Finally, Section 6 is the conclusions.

II. RELATED WORK

In this section, we briefly present some existing works related to our research. We first review some works which are related to cross-organizational systems. We then evaluate works that focus on educational data mining.

A. Multi-Source Systems

To the best of our knowledge, little work has been done on building a decision-making system that involves multiple organizations. Rather, many researchers have focused on 'multi-source' information systems [16]-[20]. For example, Poli et al. [16] discussed the possibility of integrating the precepts from *multiple non-communicating observers* as a means of achieving better joint perception and better decision making. Their approach involves the combination of brain-computer interface (Bel) technology with human behavioral responses.

Multi-source of information doesn't necessarily come from distinct sources. In cases, information can be categorized into distinct classes, where each class represents different aspects of the information. Such a case can be found in the evaluation of consumer decision process. In [17] the authors utilized an agent-based conceptual and computational model of consumer decision-making based on culture, personality, and human needs. They used a five-factor model to formulate the utility function, to process and update the agent state, and to build recognition and action estimation modules for the consumer decision process.

Another way for utilizing a 'multi-source' system is to adopt multiple layers of decision making, where each layer is responsible for deciphering different aspects [18]. In [18], the multilayer data mining approach was focused on e-business activities to provide the high level of business intelligence for enterprises. The conversion model is used to create distinct layers of data mining structures, where these mining structures act as the platform for applying the multilayer data mining models. Brodsky et al. [19] used the concept of Decision-guidance management systems (DGMS) and proposed an initial data model and then an integrated DGMS query language, DG-SQL. Their approach supports seamless integration of construction of learning sets, learning, probabilistic prediction and simulation; and stochastic or deterministic optimization. In [20] another work, integrated decision support systems with data mining and multiple criteria decision making.

B. Educational Data Mining Systems

The case study considered in this paper involves performance evaluation systems based on data from multiple educational organizations. Such a system can be broadly categorized as an Educational Data Mining System (EDMS). Therefore, in the following, we discuss some existing approaches for EDMSs. More details on EDMS can be found at [19].

Many researchers have worked on EDMS with a number of goals in mind. Some works focus on measuring student performance [6], [12], [13], others target selecting the best educational and learning methods [10], [11], [14], [15]. In addition, as we discussed in the previous section, some EDMS do utilize multi-source systems to serve their goals [7], [8].

A predictive data mining model to identify the difference between high and slow student learners was proposed in [6]. Records of 300 students were used to construct a Bayesian classification model. Guruler et al. [12] explored the factors having an impact on the success of university students. They used a decision tree classification as a data mining technique for prediction of dropout and retention for motivating engagement in learning activities and consequently increasing students' satisfaction. In [13], four types of predictive mathematical models, i.e. multiple linear regression, multilayer perceptron network, radial basis function network, and support vector machines are used to predict students' academic performance in engineering disciplines.

As for the learning perspective of EDMS, the impact of Learning Analytics (LA) on EDMS Educational Data Mining (EDM) was studied in [9], [10]. Bienkowski et al. [11] used adaptive learning systems for measuring objectives, methods, knowledge discovery processes. Levy and Wilensky discussed [14] behavior modeling and students' exploratory actions with computer-based multi-agent models when their goal is to construct an equation. They suggested that engaging students in constructing symbolic representations may provide a bridge between frequently disconnected conceptual and mathematical forms of knowledge. Moridis and Economides demonstrated how the various kinds of evidence could be combined so as to optimize inferences about affective states during an online self-assessment test [15]. They used a formula-based method for the prediction of students' mood. The method was tested using data emanated from experiments made with 153 high school students from three different regions of a European country.

Works that utilize multiple sources of information include the research carried out by Siemens et al. [7]. Here, EDM with Learning Analytics and Knowledge (LAK) is utilized with the support of two distinct research communities. Formal communication and collaboration between these two communities in order to share research, methods, and tools for data mining and analysis in the service of developing both LAK and EDM fields. Romero et al. [8] used various web-based courses as learning content management systems for knowledge discovery.

III. A CROSS-ORGANIZATIONAL SYSTEM: THE FRAMEWORK

In this section, we present our framework in a more abstract form. A proper implementation of the framework will be discussed in the next sections. Therefore, the discussion in this section is less technical and addresses only the key issues in the framework.

The main components of the proposed framework are illustrated in Fig 1. The whole process starts with a data fetching module that ensures data privacy, adequacy, and relevancy. Once enough data is there, normalization of data is performed (like scaling, of course, grades). In this phase, extreme data points are also identified and filtered. In the third phase of the proposed framework, data mining tools are used to build models that are later compared to infer results. The concept of building models is to construct ideal cases (or best cases) scenarios for different queries that a new organization may have. In the final module of the framework, data from the new (or enquiring) organization compares its data with the models built from the previous phase to assess the performance of the organization.

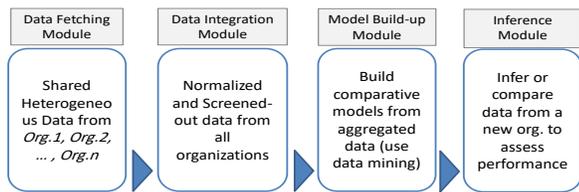


Fig. 1. Overall structure of the cross-organizational information system for inference, assessment and decision making.

It is important to note here that the first module of the framework consists of several sub-modules, where each sub-module is implemented for each individual database. The reason behind sub-modules is that individual databases may have their own structures and privacy policies; hence it might be difficult to devise uniform rules to screen out relevant data for later stages of the framework. A more detailed illustration of the data fetching sub-modules of individual databases and their relationship with the data integration module of the framework is depicted in Fig. 2.

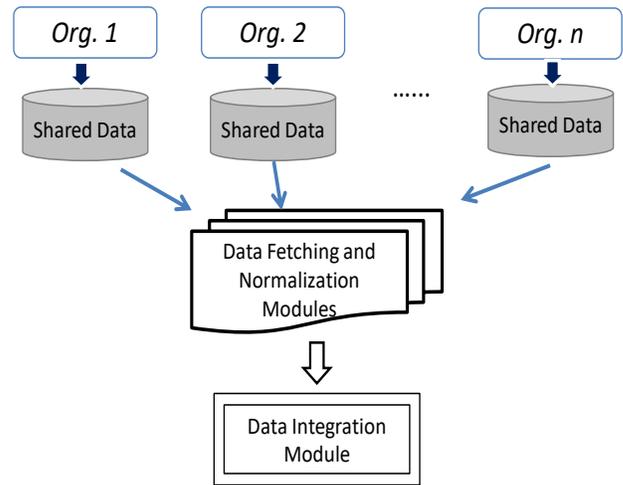


Fig. 2. Data normalization and integration modules in the framework.

IV. A CASE STUDY

The framework proposed in this paper is evaluated for a case study in educational data mining. In the framework described above, the ‘organizations’ now refer to educational institutions. In this work, we use data collected from three different departments of the authors’ current institution. Although the case study is completed using data from the same institution, the process described below is generic and can be readily applied to multiple institutions.

We have collected data of students’ results in several courses for three different departments. For the purpose of privacy, the names of the departments and corresponding courses will not be mentioned here. Rather, we will refer to the three departments as *Dept.A*, *Dept.B* and *Dept. C*. Each course under study will be referred to *Dept.X Sub.Y*, where $X = \{A, B, C\}$ and $Y > 0$ is an integer. For example, *Dept.BSub.3* refers to the third course in department *C*. In this work, data from a total of 28 courses containing 585 students’ records are analyzed. Each student’s record is a tuple of the form $\langle \text{Dept.}; \text{Semester}; \text{Course}; \text{Student ID}; \text{Semester marks}; \text{Final Marks}; \text{Total Marks}; \text{Grade} \rangle$. Table 1 shows some samples of data used in this case study.

TABLE I. SAMPLES OF DATA USED IN THE CASE STUDY (STUDENTS IDS ARE KEPT HIDDEN FOR PRIVACY)

Department	Semester	Course Code	Subject	Semester marks	Final Marks	Total	Grade
IT	351	IS-125	Database	50	30	80	B
IT	351	IS-125	Database	45	21	66	D+
IT	351	IS-125	Database	40	14	54	F
IT	351	IS-125	Database	36	24	60	D+
IT	351	IS-125	Database	34	12	46	H
IT	351	IS-125	Database	17	15	32	H
IT	351	IS-125	Database	47	28	75	C+
IT	351	IS-125	Database	47	31	78	C+
IT	351	IS-125	Database	45	27	72	C

The overall process of the data mining tasks carried out in this work is outlined in Fig 3. *Raw Data* refers to the students' records as stored as is in the Students Affairs database. The filtering module takes this data and applies some operations like a removal of students' names/IDs (assuring privacy), aggregation of data of several semesters for the same course, normalization of data values, etc.

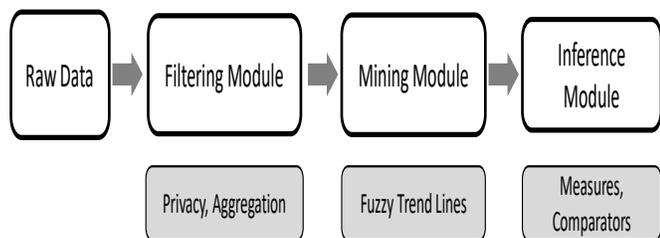


Fig. 3. Phases of educational data mining process.

Data mining module in Fig. 3 refers to the machine learning operations carried out on the filtered data from the previous module. In this work, this module is responsible for generating fuzzy trend lines as described later. Finally, *inference module* takes various trend lines and compares them so as to derive decisions. Methodology for comparing trend lines will be discussed later.

A. Problem Formulation

In this section, we describe the metric we evaluate through the data mining module. Suppose, the filtered data for *Dept.X* ($X \in \{A, B, C\}$) contains information for n courses, where $count_i$ refers to the number of records in course i , $i = 1, 2, \dots, n$. Let Thr_i be the minimum mark (out of 100) that students need to obtain to pass the i -th course. Suppose, $SG_{i,j}$ refers to the value of the semester mark in the j -th record in i -th course.

Now, let be $Prob_{i,t}$ the probability that a student in i -th course can have his total grade $>Thr_i$, given that the student's semester grade is less than or equal to t . For example, $Prob_{i,40}$ refers to the probability that a student in course i can eventually pass the course, while his semester grade is less than or equal to 40 (out of 100). Estimating this probability $Prob_{i,t}$ can be rendering several benefits. As an example, a high value of $Prob_{i,t}$ for a low t may indicate that the final exam was relatively easier, especially if the probabilities for the same group of students in their other courses are lower than this particular course.

The probability $Prob_{i,t}$ can be estimated for a course as follows. Suppose, $count_{i,t}$ is the number of students in course i , whose semester grades is less than or equal to t . Then, $Prob_{i,t}$ is estimated as the ratio of $count_{i,t}$ and $count_i$. Now, let $Prob_{X,t}$ be the probability that a student can pass *any* course in department X given that the student's semester grade is less than or equal to t . In the following section, we describe how $Prob_{X,t}$ can be formulated as a fuzzy number and how values $Prob_{X,t}$ of two different departments can be compared.

B. Fuzzy Modeling and Trend Lines

The easiest and straightforward approach to estimate $Prob_{X,t}$ is to treat it as an average value of all. $Prob_{i,t}$, $i = 1, 2, \dots, n$. However, average value is well known to destroy the *trend* in a set of values and thus is not a good representative. A better approach, as adopted in this work, is to represent as $Prob_{X,t}$ a fuzzy number that can capture some variability in students' performance across a number of courses over several semesters.

In modeling $Prob_{X,t}$, we describe the value of $Prob_{X,t}$ as a fuzzy probabilistic measure. Fuzzy probabilistic measures are fuzzy sets that have membership functions similar to those of fuzzy numbers that are characterized by possibility distributions. In our representation of $Prob_{X,t}$, a fuzzy probabilistic measure is a π number [21], denoted by $\pi = (p_1 / \beta_1; \theta; p_2 \setminus \beta_2)$, where $p_1 = \theta - \gamma_1$, $\gamma_1 > 0$ and $p_2 = \theta + \gamma_2$, $\gamma_2 > 0$. Fig. 4 illustrates the concept of π numbers. In a π number, the membership value is 1 in $[p_1, p_2]$, and decreases linearly in $(p_1, p_1 - \beta_1]$ and $(p_2, p_2 + \beta_2]$.

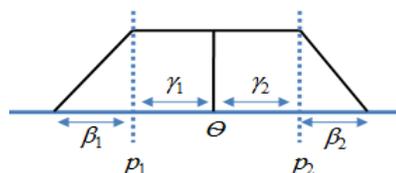


Fig. 4. Illustration of fuzzy probabilistic measure.

We now describe how $Prob_{X,t}$ is calculated as a fuzzy probabilistic measure in this work. Suppose, $T_{X,i}(t)$ is a discrete function where $T_{X,i}(t \leftarrow k) = Prob_{i,k}$, for department X and $t = 0, 1, 2, \dots, S_i$. Here, S_i is the maximum semester grade that a student in department X can score in course i . Fig. 5 illustrates the functions $T_{X,i}(t)$ for a number of courses of a single department. The dotted line in Fig. 5 is calculated as the average of all $T_{X,i}(t)$ and is denoted by $T_X(t)$. This function $T_X(t)$ is called a *trend line*, and has a fuzzy description as explained below.

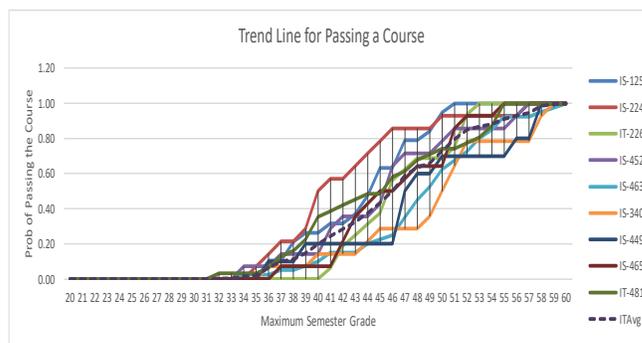


Fig. 5. Estimation of fuzzy trend line: an example for a number of courses.

As an illustration of the estimation of the fuzzy trend line $T_X(t)$, consider Fig. 6. The solid dot in Fig. 6 refers to the average value calculated as:

$$T_X(t \leftarrow k, \theta) = \frac{\sum_{i=1,2,\dots,n} Prob_{i,k}}{n} .$$

This refers to the value of θ in the π number described above. In our formulation, the two width values (γ_1 and γ_2) are taken equal and estimated as:

$$T_X(t \leftarrow k, \gamma) = STDEV(Prob_{i,k}), i=1,2,\dots,n .$$

Here, $STDEV(.)$ is the function to calculate the standard deviation. Therefore, $T_X(t \leftarrow k) = \langle T_X(t \leftarrow k, \theta), T_X(t \leftarrow k, \gamma) \rangle$ is a fuzzy probability measure which measures the probability that a student in department X can pass any course in that department with a semester grade less than or equal to k . As, for the ranges β_1 and β_2 , they can be taken as zero for simplicity of calculation.

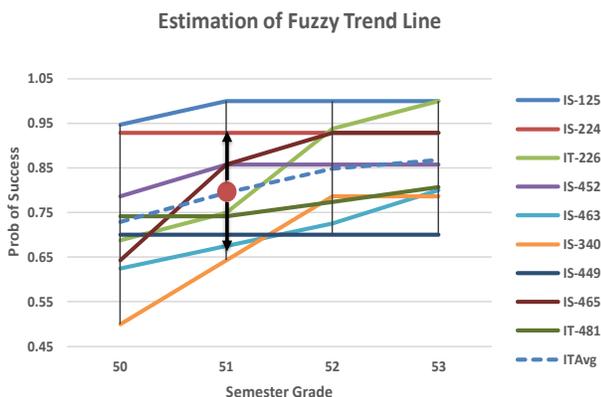


Fig. 6. Estimation of fuzzy trend line at the department level.

C. Fuzzy Matching

In this section, we describe how trend lines can be compared and inferences can be made. Fig. 7 refers to the plot of two trend lines: $T_A(t)$ and $T_B(t)$ for two departments in the authors' current institution. Note that, semester grades range from 20 to 60, since in these two departments, the total 100 degrees of a course is divided into 60% for semester grades and 40% for the final exam. As shown in Fig. 7 students, whose semester grades are generally low, have more probabilities to succeed in Dept. B. compared to Dept. A. This does not necessarily mean that student in Dept. A perform poor, as the trend lines in Fig. 7 are both fuzzy and the differences that can be seen in Fig. 7 may not be significant. Therefore, in the following, we describe how $T_A(t)$ and $T_B(t)$ can be compared so as to find that whether students' performances in two departments are comparable or not.

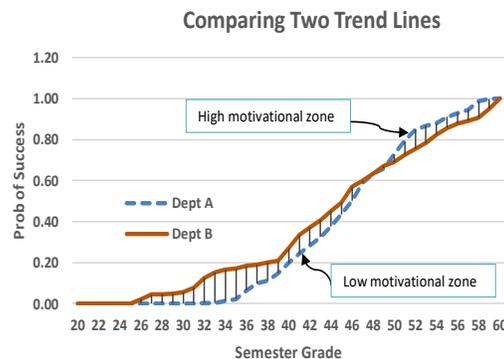


Fig. 7. Illustration of trend lines for two departments (or two institutions).

Let, $\theta_X(s)$ be the continuous function generated from the discrete-valued function $T_X(t)$. The function $\theta_X(s)$ is defined as:

$$\theta_X(s) = T_X(s), s = 0,1,2,\dots,60 \text{ and } \theta_X(s + \delta) = \theta_X(s)$$

Where, $s = 0,1,2,\dots,60$ and $0 < \delta < 1$. Now, matching $T_A(t)$ and $T_B(t)$ is essentially matching $\theta_A(s)$ and $\theta_B(s)$. The dissimilarity measure $d(\theta_A, \theta_B)$ of $\theta_A(s)$ and $\theta_B(s)$ is defined as follows: $d(\theta_A, \theta_B) = \left(\int_0^l |\theta_A(s) - \theta_B(s)|^l ds \right)^{1/l}$,

Where, l is the maximum obtainable semester grade.

Now for L_2 metric, the integral $\int_0^l |\theta_A(s) - \theta_B(s)|^2 ds$ is computed by adding up the value of the integral within each strip. Here a strip is defined by a consecutive pair of discontinuities (in this case, the at the integer values of s) in $\theta_A(s)$ and $\theta_B(s)$. The integral within a strip is computed as $w_{strip} \times d_{strip}^2$, where w_{strip} is the width of the strip (which is 1 here) and d_{strip} is the 'fuzzy' difference between $\theta_A(s)$ and $\theta_B(s)$ within that strip. To compute d_{strip} , assume that, within a strip $\theta_A(s) = \varphi_1$ and $\theta_B(s) = \varphi_2$. Here, φ_1 is a π number $(p_1 / \beta_1; \theta; p_2 / \beta_2)$. Here, d_{strip} is used as the dissimilarity measure for fuzzy probabilities of success and is computed as follows.

$$d_{strip} = 0, \text{ if } \varphi_2 \in [\theta - \gamma_1, \theta + \gamma_2] \quad \text{\{Case 1\}}$$

$$1, \quad \text{if } \varphi_2 > (\theta + \gamma_2 + \beta_2) \text{ or } \varphi_2 < (\theta - \gamma_1 - \beta_1) \quad \text{\{Case 2\}}$$

$$\frac{\varphi_2 - p_2}{\beta_2} \quad \text{if } p_2 < \varphi_2 < p_2 + \beta_2 \quad \text{\{Case 3\}}$$

$$\frac{p_1 - \varphi_2}{\beta_1} \quad \text{if } p_1 - \beta_1 < \varphi_2 < p_1 \quad \{\text{Case 4}\}$$

V. DISCUSSION

The measure $d(\theta_A, \theta_B)$ essentially compares students' success rates for two departments. As a generalization, $T_A(t)$ and $T_B(t)$ need not the trend lines from the same educational institutions. Rather, they can be from two different institutions. For example, a trend line from the Computer Science Dept. from one university can be compared to the trend line of the same department from another university. However, data values may need to be normalized before the dissimilarity measures can be used. A general guideline for using a measure like $d(\theta_A, \theta_B)$ in a cross-organizational setting can be given as follows:

- *Highly Similar.* In the case of the educational institution, if the value of $d(\theta_A, \theta_B)$ is quite low (say close to zero), where *Dept. A* is well-reputed, and then *Dept. B.* can be described as functioning satisfactorily.

- *Highly Dissimilar.* Here, the value of $d(\theta_A, \theta_B)$ is high and thus indicates issues in performance in *Dept. B.* A high dissimilarity value can lead to several observations (ref. Fig. 7). It is possible to identify two zones: highly motivational zone and low motivational zone, as shown in Fig. 7. An existence of low motivational zone may refer to the group of students who may not exert sufficient effort to pass a course. Identification of such a group is essential for an institution, as improving the performance of these groups of students can improve the overall performance of the institution.

For a newly established institution, trend lines provide means through which a program can set up its various parameters. For example, difficulty levels in the final exam can be monitored through trend lines and an appropriate level can be set. Programs can even generate trend lines of individual courses and identify the courses where students generally perform worse. In this way, a number of queries essential to an education department addressed, like identifying courses having worst results, courses whose performances are co-related, etc.

VI. CONCLUSION AND FUTURE WORK

Nowadays, for successful establishing of a new institution, a cross-organizational information system for assessment may be needed. Decision support technology is also sought in order to handle decision-making problems. In this area, machine learning and data mining can play an important role to extract relevant information. In this paper, we design a framework for the cross-organizational information system for assessment and decision making using machine learning with the emphasis on the educational sector. In the proposed framework, organizations share information (even raw data) with each other and machine learning tool will be utilized for shared data analysis for decision making for a particular organization. A framework like this can help new organizations to get benefit from the experience of other

'older' organizations and institutions. Such knowledge-based machine learning system helps to improve the organizational capability of newly established institutions. In future work we will implement this framework for multiple universities.

ACKNOWLEDGEMENT

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A Comparative Study between Applications Developed for Android and iOS

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Abstract—Now-a-days, mobile applications implement complex functionalities that use device's core features extensively. This paper realizes a performance analysis of the most important core features used frequently in mobile application development: asynchronous multi-threaded code execution, drawing views/elements on the screen and basic network communications. While multiple mobile platforms have emerged in recent years, in this paper two well-established and popular operating systems were considered for comparison and testing: Android and iOS. Thus, two basic applications featuring the same functionality and complexity were developed to run natively on both platforms. Applications were developed by using development languages and tools recommended for each operating system. This paper aims to highlight the differences between the two operating systems by analyzing core feature performance metrics for both functionally identical mobile applications developed for each platform. Results obtained could be further used for guiding the optimization of application's development process for each considered operating system.

Keywords—Android; iOS; mobile application development; mobile device core features; common scenario performance comparison; development optimization

I. INTRODUCTION

The rapid development of the mobile devices industry has culminated with the rise of modern operating systems, specifically optimized to use the advantages and limits of the hardware environment in order to interface with the user.

While many mobile operating systems have been developed in the recent years, in today's market, the most widely adopted are Android [7], developed by Google and iOS [8] developed by Apple.

Being open-source software, Android has been extended and used by some of the major mobile device manufactures, being advantageous from the development cost perspective and offering a great level of customization.

Apple's approach to a mobile operating system was quite different, as iOS was developed to run on a very specific set of devices, which feature an established list of hardware

components. The close relationship between the hardware setup and the operating system development have tied the success of iOS platform to the popularity of its host devices. This approach, however, also represents an advantage, as iOS was optimized to have a responsive and fast interface, designed specifically around its hardware limitations.

The comparative study developed in this paper will concentrate on the analysis of three important core system features that are used extensively in every modern mobile application: asynchronous multi-threaded code execution, drawing views/elements on-screen and basic network communications.

A specific architecture together with several tests was developed to measure the time needed for the operating system to perform tasks that involved each feature. The observed performance differences for individual tasks are expected to be relatively small, with only a few milliseconds separating one device from another. These discrepancies will, however, become noticeable in real-world applications, where core features are combined and used recurrently to introduce new functionalities.

The performance measurements were applied on a basic application developed to run on Android and iOS. During the development phase, the recommended development languages and tools were used: for the Android operating system, the Android Studio [9] environment was used to develop the application and the main programming language chosen was Java [10]; the application authoring tool XCode [11] was used for the iOS implementation alongside the Objective C [12] language.

Finally, an exhaustive analysis of obtained results was made and several guidelines for application development optimization were presented.

II. RELATED WORK

While several comparison studies between the two operating systems exist in the literature, they are merely

focused on comparing existing features and architectures than taking into consideration application development issues.

For example, a comparison related to various factors that influence security on both platforms, such as application provenance, application permissions, application isolation, and encryption mechanisms is presented in [1], [2], [6]; [3], [4] present a comparison of the two operating system architecture together with provided features and frameworks for application development; several tools for cross-mobile application development are proposed in [5]; also, a comparison based on availability and capabilities of different set of UIs is described in [6].

Moreover, several papers in the literature realize comparisons based on detailed analysis of market share of smart phones having different mobile operating systems [3], but also on advertisement and overall impact on the consumers [6].

With the general complexity of both operating systems expanding on each new version iteration, more features become available for application developers. In this context, analyzing from the performance point of view of the most important core features used in mobile application development for both operating systems could be very helpful for further application development processes. Consequently, the paper approaches a very important aspect, by guiding the optimization process to potential slow or inefficient parts of the application specifically on each device.

The paper is structured as follows: next chapter presents the two mobile applications developed for each operating system together with the web platform used by both applications for receiving HTTP requests and sending JSON responses. Chapter IV describes the developed testing architecture and the performance tests carried on. Based on the results of the comparisons, several conclusions regarding optimization issues for application development are drawn and presented in the conclusion chapter.

III. PRESENTATION OF THE MOBILE APPLICATIONS

A native mobile application was developed for each operating system (Android and iOS) in order to study the performance and development differences. Both mobile applications feature the same functionality and scene structure, with differences only being visible at the user interface level, where some elements diverge in order to respect the design guidelines recommended by each operating system manufacturer.

The mobile applications are complemented by a web platform built on top of the Laravel [13] framework. The platform receives signed data requests through the HTTP protocol and it then sends back responses containing JSON [14]-encoded structured data that is extracted and compiled from a MySQL [15] database.

From a functionality standpoint, each application allows the user to view promoted commercial locations and related events or picture galleries for a specific geographical area. The web platform provides the data, which is displayed within the mobile applications, allowing registered users to perform

CRUD operation over the datasets representing the locations, events and galleries.

The mobile applications were designed to use a hierarchical navigation system that guides the user to the desired content. Using this approach, different category and entry lists were created for each data type alongside shortcut paths that allow the user to reach the content in an efficient manner. The general structure of the scenes is described in Fig. 1.

In recent years, several frameworks such as Xamarin [16], Cordova [17] or React Native [18] were created, allowing the development of mobile applications that run on multiple operating systems using a single codebase solution. Using the hybrid application development approach, while it does have its advantages, was not preferred in this case because the purpose-built frameworks introduce another layer over the native code, making testing much more difficult and the results inaccurate.

Therefore, a native approach was chosen for the application development process on each platform, using the tools recommended by each operating system manufacturer. This allowed each codebase to exploit the advantages of its operating system separately, emphasizing the major differences in implementation and optimization between the platforms.

Both applications followed similar MVC (Model-View-Controller) architectural pattern [19], having clear delimitations between classes and code sections that handle the application behavior, the user inputs and the information representation form. Model classes were created to describe and handle the structured data displayed using the user interface.

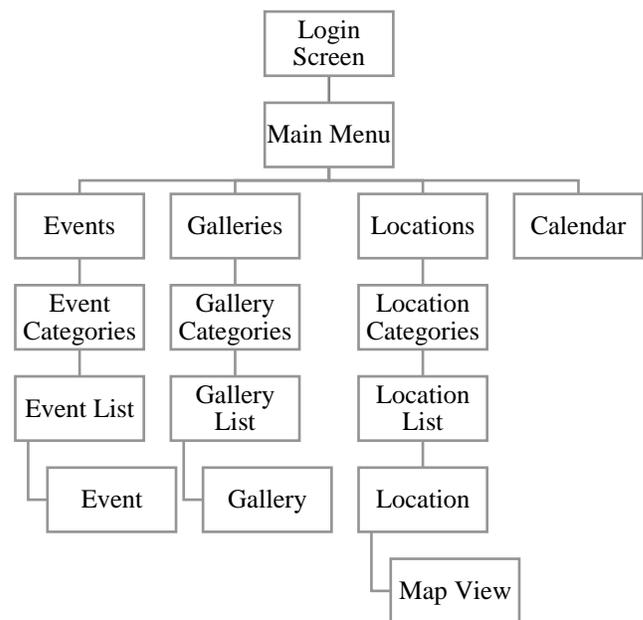


Fig. 1. The application scene structure 1.

A. Android Application Development

For the Android operating system, the choice for the development language was straightforward as only the Java language is supported natively. The visual structure for each scene was built using the default method of declaring UI elements in separate XML [20] files.

Since the Android application development process lacks a tool for scene navigation management, the rules that define the order of scenes were described within the *Activity* and *Fragment* derived classes [7].

The responsiveness of the user interface was facilitated by isolating all long-lasting or complex operations in secondary threads. This approach reduced the amount of workload on the main thread, which was then able to handle user interface updates and input detection without further delays.

Slow operations, such as establishing a network connection or data decoding, were implemented by deriving the *AsyncTask* class from Java [10]. Once a data set is prepared, the main thread is notified of this change using the observer design pattern optimized for multiple listeners.

Activities were created for each section context, leaving all subsequent scenes to be handled by using Fragments. For scenes that involved grids and lists, the application took advantage of the reusable item view approach, minimizing the amount of memory used to store complex arrays of data.

B. iOS Application Development

The iOS application authoring tool XCode offers two native options regarding the main development language: Objective C and Swift. Currently, Swift is being promoted for the development of new application that run in the Apple ecosystem. But, for this implementation process, Objective C was chosen as it is much more mature language with clearly outlined best practices, coding styles and an existing suite of well tested and stable third-party libraries.

Unlike the approach used by Android Studio, the visual structure of the whole application can be managed in a single file using the Storyboard [21] environment. Each individual scene was constructed using static View Controllers for standalone pages and Collection View Controllers to list structured data [12].

The navigation paths between the main scenes (*segues*) were described using the graphical user interface and references were created inside the header files for each view controller, allowing for scene transitions to be performed automatically for events triggered when a background task is complete or for user inputs.

Asynchronous tasks were handled using *NSOperation* [12] instances that notified the main application thread once all the processing stages were completed. The network connections were managed using the *AFNetworking* [22] library that extends and simplifies the networking abstractions already available in Cocoa [23], the application development environment for iOS and OS X.

IV. PERFORMANCE TESTS

After developing the mobile applications, the differences between iOS and Android were highlighted by analyzing the specific performance metrics and signature. Since both applications were created using the native tools and development languages, they take advantage of optimizations offered by each operating system.

A. Testing Architecture

From a development standpoint, each application uses the advantages of multi-threading, an approach which improves the responsiveness of the user interface. Standalone long-lasting tasks such as network downloads, data decoding and image conversions were executed in separate threads, leaving the operating system to decide which hardware cores to use in order to perform each operation.

Within the applications, the most computational intensive section was used to highlight the differences between the operating systems. As such, a predefined *location* scene was loaded on each tested device. The data received from the server represents a JSON-encoded string containing the location information; the full data size is 1 MB total, including HTTP headers. The amount of time required to complete each test is expected to be directly proportional to the size of the source data.

The user interface for the *location* scene was created using the following native graphical elements available on both operating systems: adjustable text labels, an image view and structural layout groups. The components of the user interface were displayed prior to running each test in order to maintain the computational cost low for each draw cycle.

At the time of writing this paper, there are no official devices that offer support for both operating systems, meaning that the hardware components must also be taken into consideration while interpreting the results. The discrepancies at a hardware level were minimized by also emulating real devices in a shared environment.

For each device, a total of three tests were performed, measuring the time needed to complete each specific task. The tests were performed on the following physical devices running the latest versions of their respective operating system: Samsung Galaxy S8+ (using Android 7.0) and Apple iPhone 7 Plus (using iOS 10.0). Well-established and leading benchmarking tools, such as GeekBench [24], position both devices very close to each other from a performance perspective.

The iOS device is roughly 72.5% faster in single-core operations however it loses its edge in multi-core tasks where it is 8.6% slower than the Android counterpart. Table 1 presents the most relevant hardware differences between the two devices.

TABLE I. THE PHYSICAL DEVICES USED IN THE TESTING PHASE

Device	Samsung Galaxy S8+	Apple iPhone 7 Plus
CPU (cores)	8	4
CPU (clock)	4 x 2.35 GHz 4 x 1.9 GHz	4 x 2.34 GHz
RAM Memory	3GB	4 GB
GPU	Mali – G71	PowerVR Series7XT Plus

In an effort to reduce the hardware differences to a minimum, the performance tests were also executed on emulated devices. For the emulation process, the devices with the most advanced specifications were chosen from the available options, ensuring several criteria such as memory size or display resolution remained consistent.

For the Android platform, a virtual device that used the Google Pixel definition file was created by using the native tools embedded in Android Studio. For iOS, a Simulator [25] instance was launched from the XCode environment for the iPhone 7 Plus device.

The emulated devices and the web-based platform that supplies data for the mobile applications used a host computer with the hardware/software setup presented in Table 2.

TABLE II. HARDWARE ARCHITECTURE OF THE SERVER

CPU	Intel 3570K
CPU (cores)	4
CPU (clock)	4x4.4 GHz
RAM Memory	16GB
GPU	AMD Radeon 280x
Network Link State	1000 Mbps, Full Duplex
Storage Type	SSD

Network related delays and issues were minimized by constructing a local network where only the server and the tested device were able to interact. The mobile devices were connected to the local network using 802.11n standard over the 5GHZ band (Wi-Fi). For the emulated devices, a bridged connection over the host computer adapter was used in order to connect to the local network. The testing architecture components are described in Fig. 2.

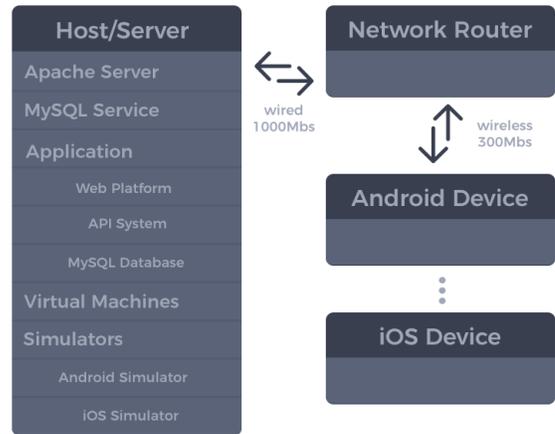


Fig. 2. The testing architecture.

B. Testing Results

Before running each test, the mobile devices were restarted and all non-essential background processes and applications were closed.

The time needed to perform an operation was determined by analyzing the timestamp values echoed in the development platform console. This approach allows accurate measurements down to 1ms as it relies on the mechanisms used by the operating systems. Each test was performed several times ($p=10$) in order to obtain the average values.

The first test measures the time needed to establish a connection with the server and to retrieve the location information. The data payload is small in order to prevent any network related delays.

The values obtained by running the first performance test can be visualized in Table 3 and Fig. 3.

TABLE III. NETWORK PERFORMANCE RESULTS

Device	Transfer Time (ms)		
	MIN	MAX	AVG
Physical devices			
Samsung Galaxy S8+	165	183	171.5
Apple iPhone 7 Plus	187	382	272.5
Emulated Devices			
Google Pixel XL	173	252	206.5
Apple iPhone 7 Plus	347	517	401.5

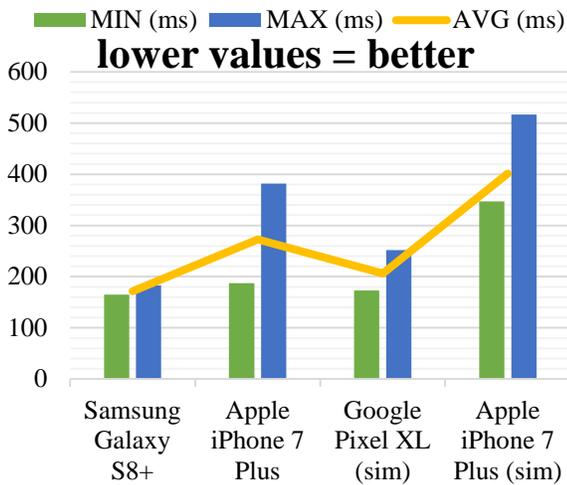


Fig. 3. Network performance results chart.

By analyzing the average values for each device, it can be observed that the Android platform is faster by a small margin in terms of data download times. One aspect that must be emphasized is that on iOS, establishing the initial connection to the server took longer than expected on each device, only with subsequent network calls being more consistent. The implications of using emulated devices become clear as substantial performance differences (slower by more than 30ms) are measured, even in such cases, where the host computer has more computational power than the original device.

Once the data is downloaded and available, a second test is executed, measuring the time needed to transform the raw JSON data into string values that are processed afterwards into model instances. The test results are highlighted in Table 4 and Fig. 4.

The JSON parsing task is launched in a new thread in order to minimize any interference with the main thread that controls the user interface.

Several conclusions can be drawn from the second test results. Since both operating systems allow for tasks of other applications to persist in the background, the performance of the current task is directly controlled by the available core count and the efficiency of the operating system's task scheduler. The multi-threaded approach taken during the development phase has improved the performance on devices that are advantaged by a high number of physical cores.

For both real and emulated devices, the iOS platform had faster average execution times and lower limits. In a simulated environment, Android needed twice the amount of time to process the same amount of data.

The developed application processes structured data in small bursts meaning that higher core clocks do not necessarily improve the overall performance.

TABLE IV. JSON ASYNCHRONOUS PARSING PERFORMANCE RESULTS

Device	Processing Time (ms)		
	MIN	MAX	AVG
Physical devices			
Samsung Galaxy S8+	16	29	24.2
Apple iPhone 7 Plus	10	21	14.25
Emulated Devices			
Google Pixel XL	10	14	12.75
Apple iPhone 7 Plus	5	7	6

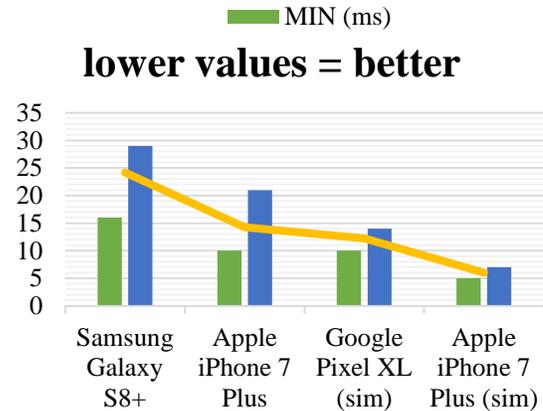


Fig. 4. JSON asynchronous parsing performance results chart.

With the location data downloaded and processed, the third test measured the time needed to update the UI elements on the screen. This actually measured the time needed to display only static data, ignoring elements, which still have to be handled asynchronously, such as image downloads.

From a structural perspective, the location scene has a container element, a *RelativeLayout* on Android and a *ViewController* on iOS. Inside the container, there is a scroll view that enables all the child elements to be visible on the screen. The relevant data is displayed using a set of labels and a single *ImageView* [7]. For the purpose of this test, we did not take into account the time needed for the image to be displayed, since this would require additional network transfers.

TABLE V. DRAW PERFORMANCE RESULTS

Device	Draw Time (ms)		
	MIN	MAX	AVG
Physical devices			
Samsung Galaxy S8+	19	25	22.5
Apple iPhone 7 Plus	13	20	16
Emulated Devices			
Google Pixel XL	13	19	17
Apple iPhone 7 Plus	3	5	4

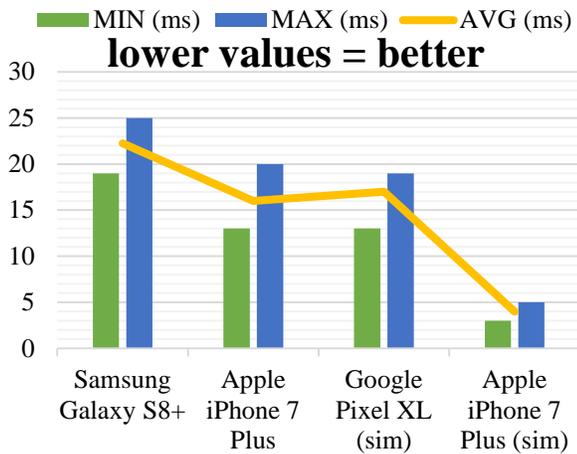


Fig. 5. Draw performance results chart.

The results of the third test, displayed in Table 5 and Fig. 5, show a distinct advantage of the iOS platform over Android for the time needed to draw a scene. The performance difference can mainly be attributed to optimizations at the operating system level for GPU-accelerated UI elements draws.

On physical devices, the time needed to update the UI was relatively close to one display frame, with Android being slower. Tasks which require more than 16ms (60 frames/second = 16.67ms) will affect the fluidity of the user interface. When tested in a simulated environment, the iOS device was significantly faster, taking advantage of the host hardware.

V. CONCLUSIONS

A set of two basic applications featuring the same functionality and complexity was developed to run natively on Android and iOS platform. The tests that were performed and presented in this paper analyze several important core features by creating, for each feature, a particular scenario in the implemented applications and architecture. Tests have not outlined any operating system to be more efficient than the other, at least not from an overall application developer perspective, each platform being more efficient and excelling for different tasks.

For network related tasks, Android had a clear edge over iOS, however the time difference was spent mostly on establishing the connection to the server, while the relevant data was retrieved in a similar time frame on both operating systems.

The JSON parsing and decoding test was intended to display the efficiency of the task scheduling part of the operating system and the processing speed of big strings. The results of this test also reflected the hardware differences between real devices, however, in the end, both platforms performed similarly, with iOS being ahead by only a few milliseconds.

On the draw performance test, iOS was clearly faster than Android with views and UI elements being drawn on the

screen within the time frame limit to not cause user interface fluidity issues. The emulation process also proved to be much more efficient with iOS devices.

The design constraints of each application might create a situation that would benefit more from the device hardware and the software advantages or limits of one platform over the other. For example, according to the performed tests, an application that relies heavily on views being drawn on the screen as soon as possible will perform better on iOS, while other application that use a lot of network communications will behave better on Android.

Consequently, the developed performance tests and their results can be used to anticipate where the slow or inefficient parts of the application will be on each device. Developers can then author applications that will behave and perform similarly on both operating systems, either by optimizing their source code or by designing functionality around these limits.

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Recognizing Human Actions by Local Space Time and LS-TSVM over CUDA

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Abstract—Local space-time features can be used to make the events adapted to the velocity of moving patterns, size of the object and the frequency in captured video. This paper purposed the new implementation approach of Human Action Reorganization (HAR) using Compute Unified Device Architecture (CUDA). Initially, local space-time features extracted from the customized dataset of videos. The video features are extracted by utilizing the Histogram of Optical Flow (HOF) and Harris detector algorithm descriptor. A new extended version of SVM classifier which is four time faster and has better precision than classical SVM known as the Least Square Twin SVM (LS-TSVM); a binary classifier which use two non-parallel hyperplanes, is applied on extracted video features. Paper evaluates the LS-TSVM performance on the customized data and experimental result showed the significant improvements.

Keywords—Motion detection; human action recognition; LS-TSVM; GPU Programming; Compute Unified Device Architecture (CUDA)

I. INTRODUCTION

Action recognition from video objective is to recognize the action and goal by analyzing the series of frames and their relationship that define the classification of the action. The pose estimation is an element of computer vision to transform 3D looking objects into 2D images from the video feeds to detect the corners and edges by using free-form contours [1]. Mostly it uses multiple methods and combine them consecutively to prevent the limitations of each. The pose assessment and action reorganization, both are vital elements of vision based human motion understanding. They are used in many applications like intelligent surveillance system, learning humanly moves in games and human interaction with computer systems [2], [3].

Another very important use of action recognition and pose estimation could be the storage of video as an abstract data like the human brain does. Harris detector algorithm is very efficient approach for corner detection in image processing. Motivation for the Harris detection is matching problem during the motion of pictures, pitch problem to find the best patch from first image to second. Histogram of Optical Flow (HOF) is used to detect edges from the images, it also supports the gradient structure which has property of photometric transformation, human detection, local shape, relatively invariant to local geometric transformation coarse spatial sampling and fine orientation sampling works best [4], [5].

Support Vector Machines (SVM) is used to perform classification in a nonlinear manner. It can also be worded as function estimation, with the optimization of convex accompanied by the primal-dual interpretation and distinctive solution [6]. Whereas, the LS-TSVM can be used as both linear and nonlinear classification including function estimation, solving linear systems, regularization networks, link with Gaussian processes and valid in primal-dual optimization formulations and high dimensional input spaces [7], [8], kernel versions of Fisher Discriminant Analysis (FDA) and Sparse approximation and robust regression [9].

Finally, LS-TSVM uses two non-parallel hyperplanes in such a manner that each of the hyperplane is close to the one of the other classes and leaves the existing concurrently. TWSVM proves itself four times faster than a normal SVM by solving two smaller size two smaller-sized Quadratic Permutation Polynomial (QPPs). SVM and TWSVM are initially developed for solving the binary classification problems. Yet, classification of the multi-class problems is usually come across in real-world situations. That's why extension to multi-class classification problems from classical SVM and TWSVM are still ongoing research. Nevertheless, there are two serious problems in SVM for multi-class classification problems. One is the how fast a machine can learn a model and other is methods for handling potential unbalance of samples in dissimilar classes. For two different classes, the purposed LS-TSVM method, solves the unbalance problem by using different variable. Henceforth, solving linear equation system, enhanced the model learning speed and turn out to be faster. On the basis of this analysis, the paper aims to expand from SVM to LS-TSM in HAR. Linux system with GPU installed and programming was done over CUDA to increase the algorithm performance.

II. REPRESENTATION

To represent the corner detection paper uses Harris detection method which uses a gradient formulation to detect response at any shift (x,y) [5].

$$E(u, v) = \sum_{x,y} w(x, y) [I(x + u, y + v) - I(x, y)]^2 \quad (1)$$

If E(u,v) is close constant patches, it will be near 0. E(u,v) will be higher provided unique patches. It is clear that E(u,v) should be higher. In this work, bilinear approximation for small shifts [u, v] is used and is shown below.

$$E(u, v) \cong [u, v]M \begin{bmatrix} u \\ v \end{bmatrix} \quad (2)$$

In the above equation, M is 2x2 matrix that is calculated by following image derivations equation:

$$M = \sum_{x,y} w(x,y) \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix} \quad (3)$$

Calculating a weighted sum (simple case, w=1) which is windowing function where I_x, I_y are the product of components of gradient and the calculating the corner response by:

Measure or corner response:

$$\begin{aligned} R &= \det M - k(\text{trace} M)^2 \\ \det M &= \lambda_1 \lambda_2 \\ \text{trace} M &= \lambda_1 + \lambda_2 \end{aligned} \quad (4)$$

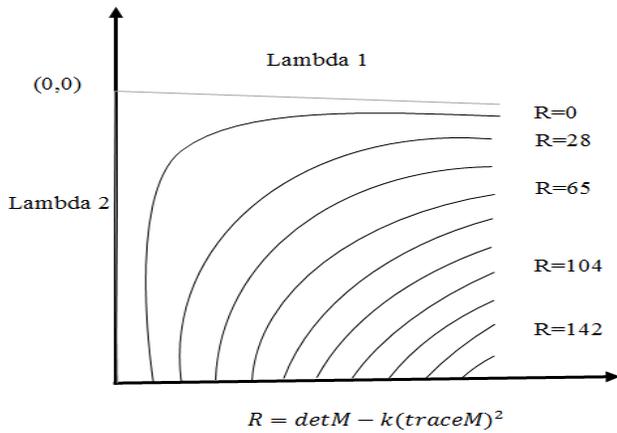


Fig. 1. Corner response map.

The 'k' is empirically defined constant, whose value is $k = 0.04-0.06$

'R' only depends on eigenvalues of M, for a corner R is higher, with higher edge magnitude R is negative and for a flat region |R| is small [3], [5] as shown in Fig. 1.

Joint angles are parsed out from the captured video feeds and all the theoretical methods of action recognition are applied to them. There are so many challenges are involved while applying such approaches to the video feeds including accurately and precisely detecting and extracting joints, tracking the joints with limitation of visual, variations in size, scale, pose etc. In the field of object reorganization, the paper suggests the idea of using optical flow in motion sequence is very much efficient, based on the research and successful feature histogram results extraction. Yet, as it is known that the size of the descriptor or the number of pixels in person varies eventually. Also, there are some issues involve in using optical flow to minimize the background noise of the image and in computation as well, abnormality in scale changes, problem with direction of motion. To prevent these problems, the optical flow distribution is used. It is obvious that when the object moves with a fixed background in scene, it creates a very specific profile of optical flow. For example, a sample for waving hand sequence depicts optical flow

patterns; the optical flow profile will be different at different scales of same motion or activity such as zoom-in and zoom-out. In case of zoomed out the magnitude of OF vector would be smaller and vice versa. Likewise, if the waving person direction changes, the OF examined would be an image in the vertical axis to that examined. Therefore, based on optical flow, work has computed the feature that depicts the activity profile at every instance of time, which does not affect by the change of scale or direction of movement [10], [11].

Work uses local space time feature [12] to handle the moments of non-constant motion by primitive events belonging to progressive two dimensional images.

Authors build its scale-space representation $L(\cdot, \sigma^2, \tau^2) = f * g(\cdot, \sigma^2, \tau^2)$ to find the local features in a sequence of images $f(x,y,t)$. this paper uses Gaussian convolution kernel $g = \exp(-(\mathbf{x}^2 + \mathbf{y}^2)/2\sigma^2 - t^2/2\tau^2) / (2\pi)^3 \sigma^4 \tau^2$ for gradients of spatiotemporal image representation $\nabla L = (L_x, L_y, L_t)^T$ is used to computer second moment matrix[13].

$$\mu(\cdot; \sigma^2, \tau^2) = g(\cdot; \sigma^2, \tau^2) * \nabla L (\nabla L)^T \quad (5)$$

where in order to allocate position of feature using the local maxima of $H = \det(\mu) - k \text{trace}^3(\mu)$ over (x, y, t) .

In space and time, Gaussian kernel associated spatial and temporal scale parameters (σ, τ) , are used to define spatiotemporal feature neighborhood. By the help of automatically selecting scales parameters (σ, τ) , it is feasible to adopt the feature size to match the spatiotemporal [14], [15] level of original image structure.

Also, shape of the feature can be varied according to the speed of local patterns which makes the feature more steady and stable along with the use of dissimilar number of camera motions [16]. In order to gain scale invariance, ineffectiveness of velocity of the camera motion, paper uses both of these methods.

III. CLASSIFICATION LEAST SQUARE TWIN SUPPORT VECTOR MACHINE

LS-TSVM is four time faster and has better precision than classical SVM in binary classification. LS-TSVM uses the classical SVM and Twin SVM to prevent the limitations of each by using two non-parallel hyperplanes.

A system of linear equations can be used to solve:

$$D = \{(x_1, y_1), (x_2, y_2), \dots, (x_l, y_l)\} \quad (6)$$

Where the R is the n-dimensional real space containing the x and y the i^{th} data sample and $y_i \in \{+1, -1\}$ is the class label. Likewise number of patterns are 'l'.

Decision function to classify the patterns used by SVM:

$$f(x) = \text{sgn}((w \cdot x) + b) \quad (7)$$

SVM uses hyper-plane to separate pattern of two classes, illustrated in Fig. 2.

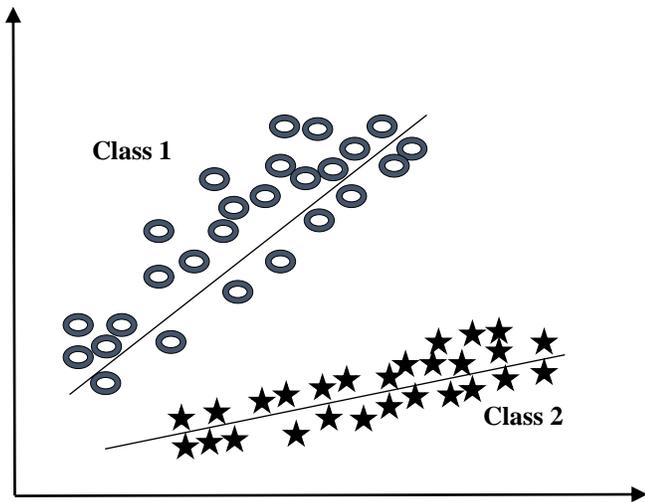


Fig. 2. Geometric representation of binary support vector machine.

The equation of hyper-plane is:

$$w \cdot x = b = 0$$

Following are the planes in with above hyper-plan lies:

$$w^T \cdot x + b = 1 \text{ and } w^T \cdot x + b = -1 \quad (8)$$

Here, R is the normal vector in n -dimensional Real Space and $b \in R$ is a bias term. To find R SVM solves QPP:

$$\min_{w,b,\xi} \quad \frac{1}{2} \|w\|^2 + C \sum_{i=1}^l \xi_i \quad (9)$$

$$y_1((w \cdot x_i) + b) \geq 1 - \xi_i \text{ and } \xi_i \geq 0 \quad (10)$$

Where $C > 0$ represents slack variables and ξ_i is the penalty parameter similarly $i = 1 \dots l$. how much the data sample is misclassified is defined by the slack variable and QPP mentioned above is solved using the dual form. SVM dual formulation changes according to the amount of patterns in the dataset. Complexity for the 1 training pattern is $O(1^3)$ [6].

In order to perform classification of the patterns of two classes Twin SVM uses below mentioned decision function

$$f(x) = \operatorname{argmin}_{i=1,2} \frac{|w_i \cdot x + b_i|}{\|w_i\|} \quad (11)$$

By optimization of a pair of QPP TWSVM can attain two non-parallel hyper-planes in order to execute classification task. QPPs are:

$$\min(w_1, b_1, \varepsilon) \quad \frac{1}{2} \|x_1 w_1 + e_1 b_1\|^2 + c_1 e_2^T \xi \quad (12)$$

$$\text{s.t. } (x_2 w_1 + e_2 b_1) + \xi \geq e_2, \xi \geq 0$$

$$\min(w_2, b_2, \eta) \quad \frac{1}{2} \|x_2 w_2 + e_2 b_2\|^2 + c_2 e_1^T \eta \quad (13)$$

$$\text{s.t. } (x_1 w_2 + e_1 b_2) + \eta \geq e_1, \eta \geq 0$$

where patterns of positive c_1 comes from matrices $x_1 \in R^{l_1 \times n}$ and negative c_2 from $x_2 \in R^{l_2 \times n}$ and know that c_1 and $c_2 > 0$ which represents the penalty parameters for misclassification of the data sample.

Two hyperplanes defined by Twin SVM which are not parallel in n -dimensional space is as follow

$$x^T w_1 + b_1 = 0 \text{ and } x^T w_2 + b_2 = 0 \quad (14)$$

In order to solve smaller size QPPs, Twin SVM used the pattern of one class to provide its' constraints. Where the complexity of the Twin SVM is $O(2x(1/2)3)$ provided that number of patterns in both classes is almost 1/2. Hence, by the above Fig. 3, it is proved that the Twin SVM is 4x speedy than simple SVM.

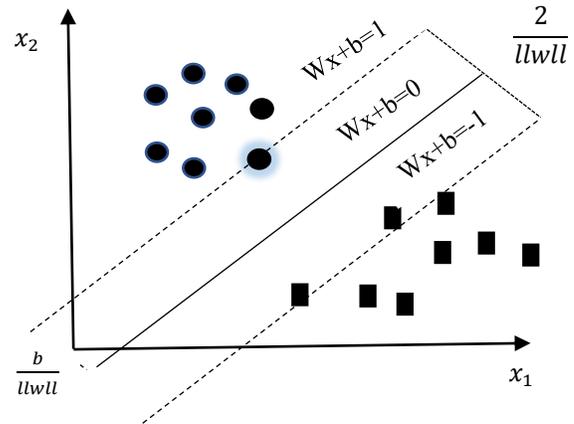


Fig. 3. Geometric representation of binary twin support vector machine.

IV. EXPERIMENTS

First it detected the video feed and converted each frame into the grayscale. Then converted grayscale images into the threshold values to start analyzing image data with Harris detection and HOF to take care of the video changing effects. After that, apply two methods for motion detection and recognition one is LS-TSVM which works mutually with motion descriptor called local features (LF) and Optical Histogram local feature. Then, paper compares both methods for performance evaluation to different approaches for classification.

V. METHOD

This work enhanced algorithm performance by using CUDA programming, with the high-performance GPU with 8 core CPU and 12 GB of RAM.

Harris Detection method is used to detect edges using the intersection of two edges and point of intersection represents direction of change in two edges. In order to detect it, high distinction of gradient of the image play a vital role. HOF method is used to detect edges from each frame of video [9], it also supports the gradient structure which has property of photometric transformation, human detection, local shape, relatively invariant to local geometric transformation coarse spatial sampling and fine orientation sampling works best. Finally, LS-SVM is used for classification of the actions. It uses the both linear and nonlinear classification and function estimation. It improves the performance and efficiency by providing the two hyperplane and finding the least distance between each hyperplane for classification.

VI. RESULTS

Program can detect human activities including hand waving, clapping and walking with high accuracy. CUDA programming is implemented over the GPU to enhance the rendering speed of the image processing algorithms.

Experiments results are show in the Fig. 4. In part (a) images show recognition of the hand waving, in part (b) images show the recognition of clapping and in part (c) images show the detection of human walking activity. This work has implemented different methods to perform recognition like simple SVM but LS-SVM proved to be the best.

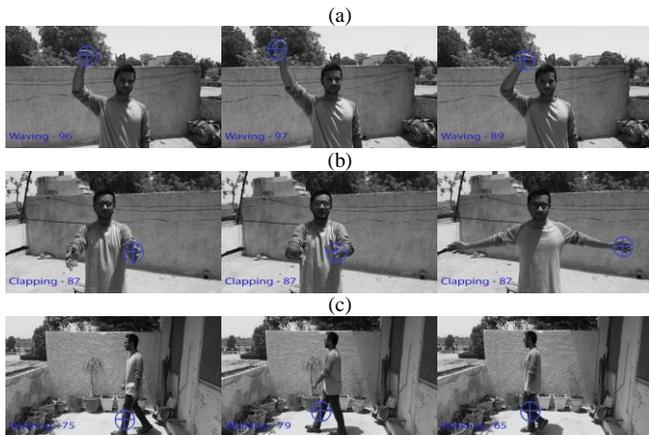


Fig. 4. Demonstration of human activity recognition.

VII. CONCLUSION

In the field of human action recognition and pose estimation, paper has demonstrated the LS-TSVM feature by analyzing the motion patterns over CUDA. This paper has implemented a novel method over GPU for action recognition using the both methods motion descriptor term as Local feature and Histogram Local Feature with LS-TSVM which proves much efficient and effective than the other approaches. In order to evaluate, it uses customized video dataset in human action recognition system.

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A Generic Methodology for Clustering to Maximises Inter-Cluster Inertia

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Abstract—This paper proposes a novel clustering methodology which undeniably manages to offer results with a higher inter-cluster inertia for a better clustering. The advantage obtained with this methodology is due to an algorithm that showed beforehand its efficiency in clustering exercises, MC-DBSCAN, which is associated to an iterative process with a potential of auto-adjustment of the weights of the pertinent criteria that allows the reclassification of objects of the two closest clusters through each iteration, as well as the aptitude of the auto-evaluation of the precision of the clustering during the clustering process. This work conducts the experiments using the well-known benchmark, 'Seismic', 'Landform-Identification' and 'Image Segmentation', to compare the performance of the proposed methodology with other algorithms (K-means, EM, CURE and MC-DBSCAN). The experimental results demonstrate that the proposed solution has good quality of clustering results.

Keywords—MC-DBSCAN; iterative process; inter-cluster inertia; unsupervised precision-recall metrics

I. INTRODUCTION

Nowadays, Data Mining [1] is imposed as one of the effective techniques for searching and retrieving information from very large databases. Like other search traditional operations, data mining is in the same vein. It aims to analyze a set of raw data in order to extract information that can be considered part of knowledge, and therefore, become exploitable. However, the data mining field specifically supplies solutions targeting the problematic of description, estimates, prediction, association, segmentation, classification and clustering [2]-[4]; To that end, the state of art shows that clustering and classification are both the most fundamental tasks in Data Mining.

The supervised classification always depends on a pre-constituted database reference. On the other hand, the exploitation of dataset without reference classification, unsupervised classification techniques called 'clustering' are

unconditionally used [5]. For Clustering techniques [6], there is a choice among the methods based on the partition [7], hierarchical methods [8], [9], methods based on the grids [10], methods using models [11] and methods based on the density [12]. In that sense, Jain suggests, in his recent works, that 'There is no best clustering algorithm' [13], [14]. Furthermore, the practice shows that the performance of an algorithm depends on the tool choice and adaptation in accordance with the problem constraints.

The present paper proposes a generic methodology leading to an iterative process, that allows to improve in an optimal way the results of a clustering exercise. To that end, the density algorithm MC-DBSCAN [15] was used as the main clustering algorithm. This is justified by the fact that the MC DBSCAN showed its performance towards problems of multi-criteria in clustering. Specifically, in an earlier study, the MC-DBSCAN algorithm has given respectively the Accuracy values [17], [18] 93% and 34% with databases 'Vehicle-Silhouettes' and 'Iris' [15]. Although accuracy levels are high, some elements more or less misclassified are detected.

For this purpose, the performance of the solution proposed by this work will have as an assessment element for comparison, the results from the 'clustering' achieved with algorithms MC-DBSCAN [15], CURE [8], EM [19] and K-Means [20] each respectively representing a particular clustering category, clustering algorithms density, hierarchical clustering, clustering from clustering model and partitioning.

The outline of this article focuses successively on the presentation of MC-DBSCAN algorithm, the methodology governing the proposed solution; the treatment and comparing results obtained; and a conclusion.

The next part of this work, after the first section where the theme was introduced, is divided into five sections: Section 2, describing the original MC-DBSCAN algorithm; Section 3 presenting the proposed new generic methodology of clustering

in detail; Section 4, explaining the experimental results and discussions; Section 5, drawing conclusions.

II. MC-DBSCAN ALGORITHM

MC-DBSCAN is an improved version of DBSCAN [16] for the purpose of solving the problem of multi-criteria in clustering. The multi-criteria data is defined on different scale types with varied weights according to the importance of each criterion. This capacity has largely influenced the algorithm choice for the needs of this work, since MC-DBSCAN offers a possibility to adjust the weight of pertinent criteria in each iteration.

The MC-DBSCAN algorithm is composed of the following steps:

- Selection of an arbitrary object from a set of objects $alt_i \in D$;
- Calculation of similarity (Table 1/ function 1) and strong dissimilarity (Table 1/ function.3) of this object alt_i with each object from the set D ;
- Calculation of weighted similarity (Table 1/ function 2) of this object alt_i ;
- Calculation of overall similarity (Table 1/ function 4) of this object alt_i ;
- The test of the value of overall similarity (Table 1/ function 4) and the presence of strong dissimilarity (Table 1/ function 3) allow the determination of the object which is considered to be a neighborhood of the object alt_i ;
- The retrieval of each object density-connected to the object alt_i according to the parameters of overall similar (Table 1/ function 4) and the parameter $MinPts$;
- If alt_i is a core object, a cluster is formed;
- If alt_i is a point of border, therefore no point can be density-connected to alt_i and the algorithm visits the following object of the set D .

TABLE I. FUNCTIONS OF MC-DBSCAN ALGORITHM

Functions	Meaning
Similarity: $Similarite_i(alt_1, alt_2):$ $D \times D \rightarrow \{-1,0,1\}$	$Similarite_i(alt1, alt2) = \begin{cases} +1 \text{ si } alt1_1 - alt2_1 \leq \sigma_i \\ -1 \text{ si } alt1_1 - alt2_1 \geq \sigma_i \end{cases}$
Weighted similarity: $SP(alt1, alt2):$ $D \times D \rightarrow [-1,1]$	$SP(alt1, alt2) = \sum_{i=1}^n p_i * Similarite_i(alt1, alt2)$
Strong dissimilarity: $DF(alt1, alt2):$ $D \times D \rightarrow \{0,1\}$	$DF_i(alt1, alt2) = \begin{cases} 1 \text{ if } alt1_1 - alt2_1 \geq \delta_i^+ \\ 0 \text{ elseif} \end{cases}$
Similarities: $GS(alt1, alt2):$ $D \times D \rightarrow [-1,1]$	$GS(alt1, alt2) = mm(SP(alt1, alt2), -DF_1(alt1, alt2), \dots, -DF_m(alt1, alt2))$
Min and Max: $mm: [-1,1]^q \rightarrow [-1,1]$	$mm(p_1, \dots, p_q) = \begin{cases} \max(p_1, \dots, p_q) \text{ si } p_i \geq 0 \\ \min(p_1, \dots, p_q) \text{ si } p_i \leq 0 \\ 0 \text{ sin on} \end{cases}$

III. PROPOSED METHODOLOGY

The proposed solution is a generic methodology that can use other types of clustering algorithms. However, for the raised reasons in the previous parties, the MC-DBSCAN is proved to be the appropriate tool. In substance, the methodology is a model operating in an iterative manner to achieve the clustering. The iterative process of this model is tributary to the quality of the concluded clusters from the previous iteration. In other words, the process's continuity relies on the automatic comparison of the quality of the two consecutive iterations results. The solution consists of three principals steps.

The first phase leads to the MC-DBSCAN algorithm's intervention, which, first of all, uses the default values of inputs parameters for the preliminary classification. In this way, the obtained clusters serve as input data for the next stage, which is a procedure of the iterative classification.

The second phase represents the analysis and assessment stage of the obtained results in order to detect the similarity between the different achieved clusters. The analysis and assessment of the classification quality is done by calculation of the similarity between the clusters; in the sense that hence, the two clusters presenting a high similarity rate, show in contrast, an inter-class inertia [21] value less elevated (1). This situation would be a result of two possible scenarios, either the objects constituting two closest classes should belong to the same class, or an error is produced in the classification of certain objects that would belong normally to a class whereas they were found in the other class and vice versa.

The proposed model overcomes these classification anomalies by identifying the pertinent criteria (2), which would amplify the similarity between two classes, while taking back into consideration their weights in the following classification by using the AHP method [22], [23].

$$d(A, B) = \frac{p_A * p_B}{p_A + p_B} d_2(G_A, G_B)^2 \quad (1)$$

p_A and p_B are respectively the weights of the two clusters A and B ,

G_A and G_B are respectively the centers of the two clusters A and B .

$$R_{(ij, Criterion_k)} = \frac{I(C_i) + I(C_j)}{I(C_i, C_j)} \quad (2)$$

$I(C_i)$ and $I(C_j)$ represents the respectively average distance between the elements and center of class 'i' and class 'j'.

$I(C_i, C_j)$ represents the average distance between the two classes' centers 'i' and 'j'.

The third phase purpose is the evaluation of the two consecutive iterations. It concretely allows a comparison of the quality of the obtained results in the two last iterations in such a manner that the results' quality of the iteration (i) is better than the iteration (i-1). In this case, the process of classification continues in order to improve the classes precision; if not, it restores and considers the issued results of the previous iteration (i-1) to complete the classification process.

For the purpose of assessing the overall quality of the results, the art of state offers several metrical approaches, which can be grouped into two categories. The first category are methods depending on the availability of a reference database. And the second category includes methods that do not use the reference database [24], this is namely inertial methods [21], Dunn [25], DB [26], Silhouette [27] and so on.

However, these preceding methods are limited in the evaluation of the results' quality in some clustering cases as mentioned in the work of Kassab [28].

To overcome this dilemma, Lamiel and other [29]-[32] have proposed improvements of the subsequent methods (Recall, Precision and F-Measures) based on reference classification, by making them adequate and relevant to unsupervised classification.

Nevertheless, the suggested method has been previously adapted for the clustering applied to text data.

However, the present paper proposes also the improvements of the following unsupervised methods: Recall, Precision and F-Measures, for being adaptable to all different types of data.

The principle of this work relies on the fact to be able to measure the classes' homogeneity by studying the distribution of intervals of each criterion within these classes. Consequently, each class is characterized by a set of intervals, in which the ratio of their weights inside the considered class and those in the partition should be maximal.

The global values of unsupervised Recall (4), Precision (5) and F-measure (6) are calculated as follows (Table 2):

$$Recall_{Unsupervised} = \frac{1}{|\bar{P}|} \sum_{C \in \bar{P}} \frac{1}{S_C} \sum_{Int_{i,j} \in S_C} \frac{|C_{Int_{i,j}}|}{|P_{Int_{i,j}}|} \quad (4)$$

$$Precision_{Unsupervised} = \frac{1}{|\bar{P}|} \sum_{C \in \bar{P}} \frac{1}{S_C} \sum_{Int_{i,j} \in S_C} \frac{|C_{Int_{i,j}}|}{|C|} \quad (5)$$

$$F1_{Unsupervised} = 2 \cdot \left[\frac{1}{Recall_{Unsupervised}} + \frac{1}{Precision_{Unsupervised}} \right] \quad (6)$$

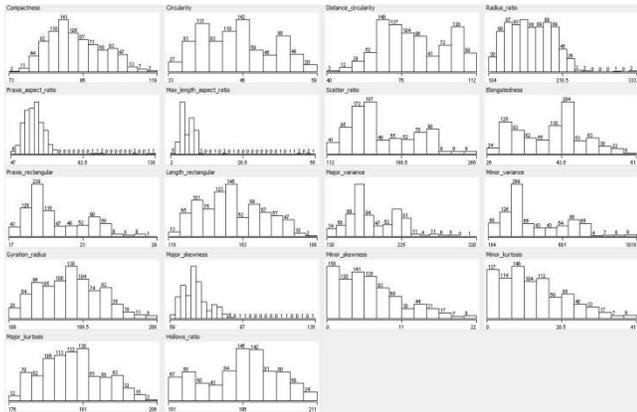


Fig. 1. Exemplary set of intervals of each criterion.

TABLE II. PROPERTIES OF UNSUPERVISED RECALL AND PRECISION

Properties	Meaning
Set of criteria that describe the data.	$E = \{Criterion_1, Criterion_2, \dots, Criterion_m\}$ (7)
Values of each criterion are presented as a set of intervals (Fig. 1).	$Criterion_i = \{Int_{i,1}, Int_{i,2}, \dots, Int_{i,k}\}$ (8)
Partition resulted from a clustering.	$P = \{C_1, C_2, \dots, C_k\}$ (9)
S_c Represents all intervals of each criterion that have a maximal value of weight in class $C \in P$ in relation to other classes.	$S_c = \left\{ \begin{array}{l} Int_{i,j} \in Criterion_i, \\ Criterion_i \in E \mid \bar{W}_c^{Int_{i,j}} = \max_{C \in P} (\bar{W}_c^{Int_{i,j}}) \end{array} \right\}$ (10) $\bar{W}_c^{Int_{i,j}} = \frac{N_c}{N}$ (11)
N_c	Number of appearance of $Int_{i,j}$ within class C .
N	Number of appearance of $Int_{i,j}$ within the other classes.
$C_{Int_{i,j}}$	Set of objects of class C possessing the property $Int_{i,j}$.
$P_{Int_{i,j}}$	Set of objects of the partition P possessing the property $Int_{i,j}$.
\bar{P} : Set of proper classes.	$\bar{P} = \{C \in P \mid S_c \neq \emptyset\}$ (12)

The following chart summarizes the process of the proposed methodology (Fig. 2).

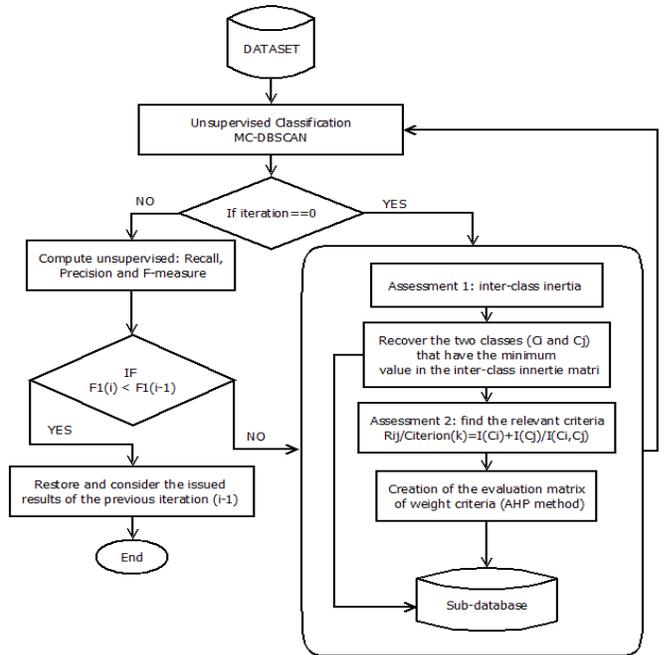


Fig. 2. Proposed methodology.

IV. RESULTS AND DISCUSSION

A. Databases Used

The performance of the proposed generic methodology and those of other algorithms namely EM, Cure, K-means and MC-DBSCAN are evaluated using the well-known reference databases, 'Seismic', 'LandformIdentification' and 'Image Segmentation' (Table 3). The three databases are from the great platform of data 'UCI Machine Learning Repository'.

TABLE III. DESCRIPTIONS OF DATASETS

Data Set	Instances	Criteria	Number of Classes
Seismic	2584	19	2
LandformIdentification	300	6	13
Image Segmentation	2310	19	6

B. Assessment Measures

To evaluate and compare the proposed methodology performance, we use the standard metrics: 'Precision: number of objects correctly assigned divided by total number of objects assigned', 'Recall: number of objects correctly assigned divided by the total number of objects that should be assigned' and 'F-measure: harmonic mean of precision and recall' which use the confusion matrix.

The precision scales the clusters in terms of the proportion of data that contain the specific properties of these first. Consequently, the more the data associated with a cluster have specific common properties, the more they are similar to each other, and therefore the criterion of homogeneity within the clusters is strengthened.

The Recall 'Recall' allows to measure the completeness of the clusters' contents, linked to the presence of specific properties that are specific to them. The more a cluster has a set of specific properties that are exclusive, the more it differs from other clusters, and therefore the criterion of heterogeneity between clusters is strengthened.

The F-measure which combines the precision and the recall is their harmonic average, named F-measure or F-score.

C. Results and Discussion

The Table 4 below includes and shows the results of different performed tests (Precision, Recall, F-measure) with the three test databases (a), (b) and (c). In these tests, the input parameters of the three first algorithms (EM, Cure and K-means) have default values except the parameter that represents the clusters' number which is fixed according to the issued information of reference databases.

TABLE IV. NUMERICAL RESULTS OF EM, CURE, K-MEANS, MC-DBSCAN AND THE PROPOSED METHODOLOGY

	Precision	Recall	F1
EM	75,52	76,19	75,85
CURE	53,36	57,5	55,35
K-MEANS	22,81	100	37,15
MC-DBSCAN	83,49	82,5	82,99
Proposed methodology	89,66	95,38	92,43

^aWith dataset: Seismic

	Precision	Recall	F1
EM	32,18	43,21	23,96
CURE	41,27	47,63	35,75
K-MEANS	30,83	45,22	21,02
MC-DBSCAN	63,54	38,90	48,26
Proposed methodology	84,73	83,68	84,20

^bWith dataset: Landform- Identification

	Precision	Recall	F1
EM	54,307	55,85	52,80
CURE	66,00	55,71	60,42
K-MEANS	58,62	54,27	56,36
MC-DBSCAN	73,35	62,58	67,54
Proposed methodology	83,53	81,98	82,75

^cWith dataset: Image Segmentation

The proposed 'Precision' factor for appreciating this work's results shows an important contrast between the achieved results of the propounded methodology and those of other existing algorithms. The suggested methodology presents respectively values 83,5%, 84% and 89% with databases 'Image Segmentation', 'Land form Identification' and 'Seismic'. In the other hands, the three other algorithms present fluctuating values between 23% and 83%, knowing that the number of clusters are pre- defined in these algorithms.

On one hand, these results lead to note that the precision's levels of achieved clusters are superior to 80% (required values for a sufficient homogeneity of clusters). This outcome illustrates or lets us foresee a high homogeneity within the given clusters from the proposed methodology. On the other hand, this methodology permitted an improvement of results of MC-DBSCAN algorithm with regard to its exclusive use. It allowed an improvement of the of clusters homogeneity varying between 6% and 21% in accordance to the used 'test databases'.

Regarding the 'Recall' factor, the suggested methodology gives an average of 87% for the three test databases. However, it points out respectively the average values of 61%, 66%, 53% and 57% for MC-DBSCAN, K-means, Cure and EM algorithms. Exceptionally, in the third database 'Seismic', the value of the 'Recall' factor, issued from K-means algorithm, has shown the existence of clusters that present a set of specific properties that are exclusive for them. This means that The 'Recall' shows a value of 100% (against 95% for the proposed methodology).

Moreover, the improvement provided by the proposed methodology is important and considerable. It is 26% in comparison to the result given by the MC-DBSCAN algorithm. This improvement emanates from the inclusion of iterative corrections, which allow a re-classification of misclassified items in previous iterations.

Overall, the harmonic average of the two factors 'Precision' and 'Recall' on the three test databases has demonstrated an improvement respectively of 20%, 48%, 35% and 36% compared to the MC-DBSCAN, K- means, Cure and EM algorithms, which highlights the relevance and pertinence of the proposed methodology.

V. CONCLUSION

Due to the recurring difficulty that rises in the evaluation of the quality of a clustering, many approaches are used in the performance estimation in a clustering exercise results. The state of art puts forward approaches of appreciation based on

the judgment of an expert, the use of the labeled data when available, the comparison with the references classification or the computation of various indices generally relying on the relations of intra\extra distances clusters. Even though those approaches offered results that are relatively satisfying in some projects, it still reveals its limits in certain clustering exercises. However, the proposed methodology seems to be an alternative solution to overcome the limitations faced with the approaches mentioned above. The methodology leading to an iterative process, that allows to improve in an optimal way the results of a clustering exercise with a higher inter-cluster inertia. To that end, MC-DBSCAN algorithm was used as the main clustering algorithm.

As a minimum, it would be important to mention that this methodology highlighted the improvement of the inter-class inertia; nevertheless, in order to achieve a better precision of clusters, it is better and significant to include a parallel evaluation, which would allow an optimized intra-cluster quality and a better homogeneity.

In addition, the proposed methodology could also contribute, beyond the MC-DBSCAN algorithm, to the improvement of the performance and to the precision of other multi-criterion assistance with the decision algorithms, as long as it offers the possibility to adjust the weights of the criteria's from iteration to the other.

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Software Migration Frameworks for Software System Solutions: A Systematic Literature Review

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Abstract—This study examines and review the current software migration frameworks. With the quick technological enhancement, companies need to move their software's from one platform to another platform like cloud-based migration. There are different types of risks involved during migration. By performing migration activities correctly these risks might be reduced. Due to the absence of resources, such as workforce, time, budget in small organizations, the software migration is not performed in optimized way. Therefore, many functionalities are not implemented exactly after migration. In this paper, we have described different methods and frameworks which provide guideline for developers to enhance software migration process.

Keywords—Software migration; frameworks; system migration; cloud migration; migration risk

I. INTRODUCTION

According to different researchers migration can be done on small scale or large scale. Migration of the single system is the example of small scale where large scale migration involves more than one system. A number of migration types such as code migration, platform migration, operating system migration, database migration, user interface migration, programming languages migration, architecture migration and infrastructure migration. Mostly organization migrate their software products from one existing system to target system to get benefit of rapid variations of development tools and techniques.

The legacy systems are normally 10 to 30 years old, during this period they became critical and mature enough that their establishment required huge investment for several organizations. Software systems that have multi millions lines become very difficult to migrate because of their large scale, inconsistent documentation, aging implementation technologies and incomplete specifications. During a system's life, it may have to be modified to run in different environments.

Software migration is a complex process involving different stakeholders, performing migration activities at different point in time. It requires understanding of existing system, developing contingency plans to risk mitigation and ensuring that the application will continue to work in the purposed environment.

Due to the critical nature of software migration, it requires a systematic process prescribing (1) migration activities,

(2) roles performing the activities, (3) migration phases (4) work products and (5) guidelines.

The main purpose of this study is to explore current existing frameworks that are useful for software migration, identify risks in migration, migration challenges and their solutions. In the remaining paper, Section 2 presents research methodology and Section 3 describes related work. The rest of paper presents a background material on software migration frameworks and discussed their challenges. Further we discuss risks in migration. Finally, we end the paper with comparison of different frameworks, discussion on our findings, conclusion and direction for future work.

II. RESEARCH METHODOLOGY

In our research process, we followed the guideline proposed by Kitchenham and Charters [49]. We formed research questions, search strategies, defined inclusion criteria, exclusion criteria and Data Extraction and Assessment of Study Quality. In order to fulfil the goal of the study, we have collected data through Research papers and followed the systematic literature review process for the identification of QAs in software migration.

A. Research Questions

We have designed the following research questions (RQs):

RQ1: Identifying the existing challenges in software migration frameworks?

RQ2: What are the frameworks used in Software Migration?

RQ3: Identifying the real world practices in Software Migration?

B. Search Strategy

1) Identifying Search Terms

From research questions, we extract major terms and check their synonyms for obtaining related research papers. These terms verified in relevant papers. OR operator is used for concatenation of synonyms words. AND operator is used for concatenation of major terms.

2) Search Strings

("Software Migration" OR "System Migration" OR "Software Modernization" OR "Legacy Modernization" OR "Software Migration Maintenance") AND ("Framework" OR

“Process Models” OR “Activities” OR “Task” OR “Factors” OR “Challenges” AND (characteristics OR features OR barriers OR risks OR problems OR “issues”).

3) Trial Search

We search related data from the following electronic data sources which are presented in Table 1.

TABLE I. TRAIL SEARCH RESULTS

S.No	Digital library	Search	Conduction Date
1	IEEE Explore	144	1 May 2017
2	ACM Digital Library	118	10 May 2017
3	Google Scholar	101	20 May 2017
4	Science Direct	12	30 May 2017
5	Site Seer Digital Library	11	10 June 2017
6	Springer link	8	10 July 2017

C. Study Selection Criteria

With the help of search strategies used above, we took an enormous amount of products listed in databases. Inclusion criteria used to find the related peer reviewed material (conference proceedings and journal papers) by using different search terms.

1) Included Criteria

Studies that are described theoretical concepts in the context of software migration. Studies that are described software migration in the context of information technology or part of their migration issues. Studies that describe software migration and studies that directly answer one of the research questions.

2) Excluded Criteria

It includes the studies that are described software migration without the scope of software engineering such as manufacturing studies that are part of websites. Studies that are described software migration but not in software engineering at all.

3) Data Extraction and Assessment of Study Quality

As our inclusive criteria is defined, that data which is relevant to our research, fulfill our requirements and defining the scope of our research, will guide us for quality study. Relevant data is gained and now assessment started for quality study.

III. RELATED WORK

Different types of software migration described by different researches like Migration of Legacy Software Systems into Web Service-based Architectures [50], SOA migration [51], Cloud Migration Research [54], a comparative evaluation of cloud migration optimization approaches [52], Exploring the factors influencing the cloud computing adoption [53], A Fresh Perspective on Total Cost of Ownership Models for Flash Storage in Datacenters [55], Understanding Performance of I/O Intensive Containerized Applications for NVMe SSDs [56], AutoReplica: Automatic Data Replica Manager in Distributed Caching and Data Processing Systems [57], FiM: Performance Prediction Model for Parallel Computation in Iterative Data Processing Applications [58], Accelerating Big Data

Applications Using Lightweight Virtualization Framework on Enterprise Cloud [59], GREM: Dynamic SSD Resource Allocation in Virtualized Storage Systems with Heterogeneous IO Workloads [60], Improving Virtual Machine Migration via Deduplication [61], Improving Flash Resource Utilization at Minimal Management Cost in Virtualized Flash-based Storage Systems [62], eSplash: Efficient Speculation in Large Scale Heterogeneous Computing Systems [63], SEINA: A Stealthy and Effective Internal Attack in Hadoop Systems [64], AutoPath: Harnessing Parallel Execution Paths for Efficient Resource Allocation in Multi-Stage Big Data Frameworks [65] and EA2S2: An Efficient Application-Aware Storage System for Big Data Processing in Heterogeneous Clusters [66].

Service oriented introduced as solution for rehabilitation of legacy system. SOAs are associated to business, so it should be compulsory to clearly understand about business as what is business vision, their actors, business use cases and processes, goals and key performances and their customers. The current study provides SOA migration approaches and activities to produce that approaches like categorization. Also, derive a reference model, called SOA migration frame of reference [51].

In [50] the grouping of legacy software migration procedure performed which highlighted at least one advantage and disadvantage of each procedure in term of their benefits. Also it describe the way migration process should carried out to limit the bottlenecks, where wrapping the existing system source code directly to generate web services.

Ideal environment for provisioning applications, engineering and hosting is called cloud computing. Legacy applications have unique characteristics such as modernization and migration to cloud environments. The cloud migration is advancing but is not mature enough that is still in early stages of research. This review explore the needs of migration frameworks, how to enhance trust in cloud migration, less number of tools to automate migration task, describe the self-adaptive cloud-enabled systems and needs for their architecture [54].

In [52] the current cloud migration optimization approaches are identified and classified. It also performs comparison between them that show the gap in current approaches and highlight the future directions.

[53] This literature review provides clear understanding of cloud migration security framework. Also the need of secure cloud migration model is identified so it can be trusted by organizations and at the end a conceptual model for cloud migration is proposed.

A. Risks in Software Migration

Software projects are classified in three categories: development, maintenance and migration. In migration different transformational phase perform by different researchers. Changing the existing system involved many types of risks during transforming. Table 2 presenting the different types of risks associated during migration process, which are extracted and highlighted by several researchers during different studies they conducted.

TABLE II. DIFFERENT TYPES OF RISK IN DIFFERENT STUDIES

Sr. #	The Researcher(s)	Risks
1	(Boehm, 1991) [39]	Requirements understanding, less expertise, scope change, computer capacity, performance of products
2	(Barki, Rivard, & Talbot, 1993) [40]	Less expertise, technological advancement, size of application, Application complexity and environment of organization
3	(Nidumolu, 1995) [41]	Coordination in project
4	(Wallace, 1999) [42]	Environment of organization, Users and Development team
5	(Oz & Sosik, 2000) [43]	Leadership faults, inappropriate communication, absence of skills, less project management and deviation from actual scope line
6	(Schmidt, 2001) [44]	Project Management, Relationship Management, Scope, Planning, Development process, Requirements, Funding, Scheduling and Technology
7	(Tesch, 2007) [45]	Relationship Management, Ownership, Funds and Schedules, Scope and Requirements

B. Different Concepts Related to Migration used by Different Research Eruations

Different researchers purposed different techniques for migration for an instance virtualization. This approach refers to the ability for running an application within a virtual space that we can manage as an individual item. This approach is considered well for those applications that have relatively small data centre. Virtualization is a good way to repurpose aging servers [1]. To minimize the risk factors associated in this approach, incremental approach is used [7] where different components of generic information system are migrated. New approaches like network centric computing, user interface technology and so on in software engineering are establishing day by day. Due to the enhancement of these technologies, it's become very difficult to estimate the effects of these technologies. Different studies show that data management strategies can be applied when we perform migration. In recent age software systems were being used in high integrity and high security environments. Software systems used to provide support to our society's services such as electric utility, healthcare field, and communication over the internet, services in banking and finance area which are very critical. These systems will provide services continuously. Keeping services in running situations provide a sensible level of insurance that a framework will helps in gaining goal in required time and reduce chances of failure [8].

Software modernization is refer to the technique where old legacy system is converted or rewrite in new libraries, protocols, programming language or hardware platforms. The meaning of recollecting is to increasing the value of legacy systems through migration, which transform it into new structure. After the first release of software, software systems are constantly developed to fulfil the varying requirement of the users. For the sake of correcting changes, counting new

functionality and implementing new one technologies software originators are doing variations in the source code. Unluckily, Lehman's laws of evolution described that the quality decreases of evolving program due to coding structure and turn into higher difficulty [2]. For that reason, legacy system becomes very complex to understand. If we cannot understand the system than its maintenance cannot be performed, the reason being that after many years of evolution due to little understanding about it. If we want to span legacy system lifecycle, we have to follow the object oriented platforms instead of procedural systems [3]. Migration of software requires deep knowledge and expertise in the application domains. A powerful knowledge representation technique called ontology [4] that deals with correct and more accurate specification of shared conceptualization of a domain. It provides facility in sharing of knowledge and software reuse in Artificial Intelligence. Domains of many applications make use of ontologies [5], [6]. In this situation where failures occur services will be still given using new platform. Service migration is used for the purpose of suspending the current state of a service on existing system and running this service to another system. It is also involve in the movement of core services program to different platform and freezing where the computation was ceased on the newer platform. For various critical safety systems, migration is known as the heart of the structural design of software [9]. Migration is considered an important strategy for system survivability service. In those conditions where we have seen that reproductions of a system is very difficult or may go outside the boundary of budgetary constraints service migration will be valuable for system migration. Fault tolerance is survivability techniques which can be used for damage avoidance and mask providing. In the compression of these services with service migration various problems found in above techniques which are very costly or may be impossible for large scope and high complexity systems [10].

The way of computing, storage and networking means are changed in Clouds [11]. These services are purchased and consumed by services providers across the cloud stack layers [12]. In everyday life the services such as social network, web content access and ecommerce plays important role in our lives. Mostly data centres host a large amount of these services that are managed by live VM migration in an effective way with the enhancement of server virtualization. The administrators of a network in live VM migration transfer the services to various servers over the network for better load balance. Due to VM migration, we can control load balance and save energy without carrying any services disturbance. Moreover the network administrator has many data centres by a single organization such as cloud bursting [13] via live VM migration across data centers.

C. EPSS-Electronic Performance Support System

A French company developed a system for software migration named as EPSS (Electronic Performance Support System), where front-end was coded in JAVASCRIPT, AJAX and HTML and data management was coded in JAVA/J2EE. On other side server was coded using JAVA language where client side was coded in AJAX. The main purpose of this is to make EPSS fully compatible with Oracle E-business.

Drawbacks:

- No proper method for migration was defined.
- Poor visibility towards goal.
- The functional coverage of the system was not properly defined.
- It does not have the source analysis model.

D. FASMM-Fast and Accessible Software Migration Method

To avoid all EPSS drawbacks there proposed a new framework named as FASMM. This method involves some functional actors which are business analyst. The main purpose is to define the goal of the user that project is likely to achieve. This method mainly describes five intentions. [22]

- Getting model
- Migration of functionality
- Validation
- Describing rules of transformation
- Improvement of dictionary

Getting Model: Basic purpose is to define the border of the function which is to be migrated. For getting modelling two different techniques used.

- Functional Modelling
- Technical Modelling

Migration of functionality: After this, developers need to validate functional modelling and technique modelling by consensus. For this two strategies are identified.

Validation: Check the validity of use case diagrams. Perform functional validation.

Discover rules of transformation: The rules for transformation will be defined by experience, by code review / heuristic, by problem identification and by model analysis.

Improvement of dictionary: In this step, the developer has to ensure the improvement of the dictionary.

E. SOMA-Service-Oriented Modeling and Architecture

In [17] a Service Oriented System was designed and implemented by use of an incremental process. Basically SOMA defines, planning of software system, designing of software system, implementation of the software system and installation of the SOA system.

F. Quality Driven Software Migration framework

Non-functional requirements play an important role in software development process. This paper defines a systematic and quantitative approach through which quality of software system produce due to the direction of migration process. It will enhance the software properties like reusability and higher maintainability etc. In such quantity driven process of migration three main issues are defined.

- Quality goals which are compulsory in under development system.

- Operationalize these goals during migration process.
- Validation of these specific goals in under development system

The first problem is resolved by getting domain knowledge, interviewing the customer and documentation. Second issue is resolved by identifying a set of transformation. To get desire results they suggest a controllable methodology.

Advantages: This model enables the coalition of system qualities (specific) with source code also it allow selection as well as the application of transformation rules[3].

G. A Framework for Process Migration in Software DSM Environments

Migration scheme is evaluated by Trademarks, which is a commercial product that basically presents the state of art in the realism of software DSM system [24]. Migration Framework is a part of COROL project. This paper discusses the difference between single process migration and parallel process migration. Ivan Zoraja [25] compares three monitoring systems developed at LRR-TUM Munchen which address different programming paradigms.

According to the structure of shared address space, following breakdowns can obtained.

- Paged based system
- Fine grained system
- Object based system

H. Software Engineering Challenges for Migration to the Service Cloud Paradigm [26]

- SEA-Service Architecture Engineering [27]
- SOAD-Service Oriented Analysis and Design [28]
- Gartner Research developed SODA (Service Oriented Development of Applications). That is appropriate for software reuse.
- SOMA (Service Oriented Modelling and Architecture) [17] developed by IBM.

Key Problems for Migration to the Service Cloud Paradigm: [26]

- Context establishment
- Software architecture modernization
- Modernize data
- Managing the quality of non-functional requirements services in cloud
- Validation and verification should perform in cloud
- Introduce the quickness in migration process
- Advance business models

I. Java based Applications Migration with Variety of Software Solutions

The system that provides many solutions for Business operations can be considered as information system. Business solution provided by these systems can be deployed on various platforms to fulfill the demands of the users. With the use of these information systems, that actually provide business operations has now become standard model. The proposed solutions mostly adopted in enterprise software solution for commercial support, open source application servers support and databases liked named AAMS (Authentication & Authorization Management System) support. Here we compare AAMS with different servers and databases [29].

Implementation of AAMS: AAMS is on the paper in java programming language it has following modules:

- Authentication
- Authorization
- Account Management

Migrating the Enterprise: Here they introduce a new concept called, E-stack, which is used to track the management architecture and execution of business of any company. We will follow E-stack and examine the four possible migration options. We will also familiarize a set of matrices which will be used to select the correct option [30].

Problems and their solutions: Constructed E-stack serve as the base to identify the key components in the migrating system. These components can either be integrated or can be individually deliver services to application or can support as administrator of the application.

During migration following problems can occur:

- Full attention is provided to the component of application.
- The software that is being built does not have effectiveness and capability to fulfil business requests.
- We do not find compatible platform to migrate software from one infrastructure to other infrastructure.

J. SNOW-Software Systems for Process Migration in High-Performance Heterogeneous Distributed Environments

SNOW[31] is basically Scalable Network of Workstation that supports client level process migration. It uses large scale distributed systems for process migration in a heterogeneous environment. When we transfer a process between two systems containing different software and hardware aspects it is called process migration of heterogeneous systems. Memory state, Communication state and Execution state are three main challenges faced in heterogeneous systems for migration process. SNOW facilitates in migration of all states. A compiler is used in execution state of migration which is done through analysis of source code. Memory pieces are referred as memory block. For this purpose they define memory space representation (MSR).

K. ARTIST Methodology and Framework: A Methodology used for Migrating the Legacy Software System on Cloud

In EU Project, a model driven transformation and movement proposed. For legacy application migration ARTIST suggested a “one stop shop”. It is big issue in cloud environments for all participated entity to transform and adaptation of legacy system. Not only regarding technical point of view as well as it’s a critical issue for business level in the following the commercial procedures and representation of transformed application [32].

Artist Migration Methodology

Pre-migration: It is a step in which a knowledge about the practical and financial availability will be accomplished.

Migration: In this step migration process will be carry out with the help of reverse engineering (RE) and forward engineering (FE) for the purpose of implementation of legacy system in the cloud.

Post-migration: The parts of transformed application will be implemented on the destination environment and then it will be tested.

Migration Artifacts Reuse & Evolution: In this step all those events are performed regarding maintenance after transformation to the cloud.

Development Phase: The main conceptual level of many steps comprising the methodology.

Disciplines: Every step and task will be recognized as practical, procedure or commercial.

Migration Phase:

- Detection of model and its understanding.
- Requirements of objective environment Model Driven Forward Engineering (MDFE) can be used for transforming and implementing the migration into the destination cloud.

Migration Artifacts Reuse & Evolution Phase: The major determination of this step is to adoptive reprocess of ARTIST artifacts and provides more efficient evolution of software to a many cloud supplier if they desired.

L. Search based Migration of Model Variants to Software Product Line Architectures [33]

Feature Traceability (Set of UML class diagrams): In this phase traceability links between each feature are extracted automatically.

Reverse Engineering of Feature Model: Set of different features which denote collection of features provided by variant.

PLA construction: The production of class diagrams with smarty notation is the key purpose of this phase.

M. OPTIMA: An Ontology based Platform Specific software Migration Approach

Ontology known as a standout amongst the capable learning representational techniques which gives a formal

representation and express detail about imported conceptualization of a domain. In which requirement had been formed for computerized reasoning to encourage learning imparting in reuse. A few requisition domains would settling on utilization of ontologies will include those learning measurement to their devices. A specific platform based on Ontology used for the software migration is called OPTIMA [34]. Maintainers requires more attempts to perform programming migration operations, system APIs will be cause of critical situation during migration activities. On restricted down the inspection difficulty in that study, these technique adopts in interface determinations concerning illustration the fundamental detail method to highlight three reasons:

Firstly: Interfaces are drawn cheaply from system models as well as from legacy systems.

Secondly: Interfaces might be used to isomorphic partner speak to both framework models that are architected throughout the ahead building phase, What's more legacy wrappers that would obtained throughout the reverse building phase and specifying the conceptual benefits represented by these legacy frameworks.

Thirdly: The establishment of mappings between ontology and source code, they might clearly converted under parameterised parts that holds their major aspect for running ahead legacy wrappers.

N. ProfMig-A Framework for Flexible Migration of Program Profiles across Software Versions

Offline programs cost more in term of frequent update. Here proposed a systematic solution for profile migration between different cross-version programs. Cross version program behavior profile migration is efficiently reduce valid profiles of old version into a new version which is introduced by them. The idea seems natural and has only been preliminary explored. Before design of the migration system it is the need to comprehend the factor affecting the system. The main source of complexity is bad behavior of program & analysis of scope changing code.

Complexities from program behavior:

- Behaviour unit
- Order and Nesting

Complexities from profile formats:

- Level of abstraction
- Meta data

Complexities from impact analysis: Change impact analysis [35] is technique in which information about code change impact analysis in the most recent adaptation of software.

Solution of complexities: Among the listed complexities some just need reasonable design consideration while other includes analysis of impact factors in the behavior. Here describe the solution of the problem by presenting a general framework named ProfMig. [36]

O. Incorporating Quality Requirements in Software Migration Process

As the software product released it constantly being evolved to fulfill the varying requirement form the user side. Software developer as well as software maintainer are executing changes in the source code that is being used by the user to remove faults, to add some new features and to make sure that software will work in new technologies. If they don't do these things there are so many chances of software uncontrolled. The value of a developing program cause the failure and program construction leads to higher complexity as highlighted by Lehman's laws of evolution. Due to these reasons legacy systems become very difficult to understand and difficult to maintain after many years of continuous development. A synthesized domain model for a different procedural language like COBOL, Pascal, C and FORTRAN presented here. Mutual features between these languages such as functions types, procedures and sub procedures can be showed by XML also, we can put on standardized conversions over systems written in a diversity of procedural language with the use of this model. Furthermore, it suggest a significant framework that will observe and assess software qualities at every step of the reengineering process [37].

- The quality was not maintained previously.
- Scope was not defined properly.
- Previous method cannot maintain the lifecycle of legacy systems.
- Previous method doesn't include the non-functional requirements of system.

P. Moving and Relocating-A Logical Framework of Service Migration for Software System Survivability[38]

- Moving and Relocating
- System model and service migration
- The logic constraint solving and proof search

A detail comparison of different software migration frameworks expresses in Table 3. In this table framework name, migration phases, migration activities, roles performing the activities, work products, future guidelines and migration type explain in different columns.

TABLE III. DIFFERENT FRAMEWORK/ PROCESS/ TECHNIQUES FOR MIGRATION AND THEIR CHALLENGES

Frame Work Name	Migration phases	Migration activities	Roles performing the activities	Work products	Future guidelines	Migration type
ARTIST Migration Methodology and Framework	<ol style="list-style-type: none"> 1) Pre Migration <ul style="list-style-type: none"> • Technical feasibility analysis • Business feasibility analysis 2) Migration <ul style="list-style-type: none"> • Application discovery and understanding • Target environment specification • Modernization 3) Post Migration <ul style="list-style-type: none"> • Scale • Multitenant • Monitor able • Bill automatically • Highest security standards 	<ol style="list-style-type: none"> 1) Pre-Migration <ul style="list-style-type: none"> • Technical & business evaluation • Technical & business feasibility analysis • Decide whether to migrate or not 2) Migration <ul style="list-style-type: none"> • Methodology customization • Verification of behavioural equivalence • Verification of non-functional requirement • Certification of the migrated product • Migration artefacts reuse and evolution 3) Post Migration <ul style="list-style-type: none"> • Capture changes • Detect inconsistencies • Resolve inconsistencies • Implement Changes 	Application owner and developer	ARTIST ARCHITECTURE ARTIST Methodology Process Tool	Enhance their applicability and impact in real business scenarios	Legacy application to modern cloud environment
FASMM (Fast and accessible software migration method)	<ol style="list-style-type: none"> 1) Get model <ul style="list-style-type: none"> • Functional Modelling • Technical Modelling 2) Migrate functionality 3) Validate 4) Discover transformation rule 5) Enrich dictionary 	<ol style="list-style-type: none"> 1) Get model <ul style="list-style-type: none"> • Reviewing existing model • Reverse engineering • Reviewing existing code • By experience • Identify reusable parts • Validation • Identify unsatisfactory part 2) Migrate functionality <ul style="list-style-type: none"> • Semi-automatic strategy • Manual strategy 3) Validate <ul style="list-style-type: none"> • Functional test • Technical test 4) Discover transformation rule <ul style="list-style-type: none"> • Model analysis • Problem identification • Heuristic and code review • By experience 5) Enrich dictionary <ul style="list-style-type: none"> • Correction • Invalidation • Creation 	Developers	FASMM approach for any company wants migration towards new technology	Can build a component base to store FASMM components for improve the migration methods knowledge	Migration of software from one source to target technology

<p>Software defined line virtual machine migration</p>	<ol style="list-style-type: none"> 1) Pre-migration stage 2) Migration stage 3) Post migration stage 	<ol style="list-style-type: none"> 1) Pre-migration stage <ul style="list-style-type: none"> • Migration condition verify • Migration iterations • Establish network path for migration • Coordinate to establish cross data centre network path 2) Migration stage <ul style="list-style-type: none"> • Storage and memory migration • Analysing activities flaws • Calculating new flaws table • Pre-update flaws table • Coordinate the controller to finish pre-network state update 3) Post migration stage <ul style="list-style-type: none"> • Shutdown the original VM • Start the VM in the new location • Update the VM location information 	<p>During development implemented by developers</p>	<p>Dynamically reallocation VMs providing various services to different servers for better load balance and energy saving etc.</p>	<p>Motivated by the paper the future work can be increased</p>	<p>Virtual machine (VM) migration</p>
<p>SNOW Software systems for process Migration in High Performance</p>	<ol style="list-style-type: none"> 1) Execution state migration 2) Memory state migration 3) Communication state migration 	<ol style="list-style-type: none"> 1) Execution state migration <ul style="list-style-type: none"> • Developed a pre-compiler • Determine poll-points • Recognize of process migration • insert macros in the source code 2) Memory state migration <ul style="list-style-type: none"> • present a logical memory model 3) Communication state migration <ul style="list-style-type: none"> • Protocols are selected 	<p>Coded by developer</p>	<p>Process migration methodology for stack based languages in a heterogeneous network environments</p>	<p>The better understanding of data structure and data size can reduce the cost of migration</p>	<p>Process migration of a software system</p>
<p>Model driven software migration into service oriented architectures [23]</p>	<ol style="list-style-type: none"> 1) Business Modelling 2) Solution management 3) Service identification 4) Service specification 5) Service realization 6) Service implementation 7) Service deployment 	<ol style="list-style-type: none"> 1) Business Modelling <ul style="list-style-type: none"> • All possible information and state of company is analysed 2) Solution management <ul style="list-style-type: none"> • Select a technique to solve project specification problems. 3) Service identification <ul style="list-style-type: none"> • Identify a business process service 4) Service specification <ul style="list-style-type: none"> • Description of service design 5) Service realization <ul style="list-style-type: none"> • Take decision of which services will be implemented 6) Service implementation <ul style="list-style-type: none"> • Provide detail how to implement them. • Implementation of a service 7) Service deployment <ul style="list-style-type: none"> • Acceptance test are performed 	<p>Developer</p>	<p>Described a model driven approach to migrate legacy systems. Extended IBM's SOMA method.</p>	<p>The approach will be tested and adapted in industrial scale project in future</p>	<p>Legacy system into Service Oriented Architecture (SOA)</p>

<p>OPTIMA An ontology-based Platform specific software migration approach</p>	<ol style="list-style-type: none"> 1) Instance based definition 2) Application specified design 3) API based classification 4) Behaviour cantered organization 5) Cardinality restricted relations 6) Understanding aimed naming 7) Aspect oriented restructuring 8) Multi layered structure 	<ol style="list-style-type: none"> 1) Instance based definition <ul style="list-style-type: none"> • Define rules that one instance has one definition. 2) Application specified design <ul style="list-style-type: none"> • Definition of concept. 3) API based classification <ul style="list-style-type: none"> • Concepts in the ontology are divided into three categories <ol style="list-style-type: none"> I. Code level concept II. Code behaviour level concept III. Code attributes level concept IV. Behaviour cantered organization • Concepts organized according to their behaviour. 4) Cardinality restricted relations <ul style="list-style-type: none"> • Introduced Cardinality 5) Understanding aimed naming <ul style="list-style-type: none"> • Determine names of concepts, relations and instance 6) Aspect oriented restructuring <ul style="list-style-type: none"> • Check whether Ontology design process support restructuring or not 7) Multi layered structure <ul style="list-style-type: none"> • Making sure that Ontology design support with multi layered structure 	<p>Applications owner or Developer</p>	<p>An OPTIMA approach is proposed to provide understand ability, specifications, reusability, knowledge acquisition and reliability for software migrations</p>	<p>Adding knowledge dimension to software migration approach will be feasible way to facilitate software migration process by making it more efficiently and accurately</p>	<p>RTOS specific software migration (RT Linux to Thread)</p>
<p>ProfMig A frame work for flexible Migration of program profile across software versions</p>	<ol style="list-style-type: none"> 1) Relation between profiles and change impact analysis 2) Analyse the effect of various factor of program 3) Propose a simple norm of identity 4) Development of ProfMig 5) Introduce a set of metrics 	<ol style="list-style-type: none"> 1) Relation between profiles and change impact analysis <ul style="list-style-type: none"> • Perform change impact analysis. 2) Analyse the effect of various factor of program <ul style="list-style-type: none"> • Perform analysis of factors and its complexities 3) Propose a simple norm of identity represent of multiple profile migration steps into cohesive process 4) Development of ProfMig <ul style="list-style-type: none"> • Developed ProfMig framework 5) Introduce a set of metrics <ul style="list-style-type: none"> • Test which framework is best 	<p>Developer</p>	<p>The ProfMig framework is proposed for migration of profile of different versions of a software. On the behalf of experiments, it proved that profile migration is feasible in practice</p>	<p>The result indicates some opportunities for future improvement. It suggests the need for better impact analysis techniques to be developed in the future.</p>	<p>Cross-version program profile Migration</p>
<p>Reverse Engineering strategies for software migration</p>	<ol style="list-style-type: none"> 1) Re documentation 2) Restructuring of source code 3) Transformation of source code 4) Abstraction of recovery 5) Reimplementation 	<ol style="list-style-type: none"> 1) Re documentation <ul style="list-style-type: none"> • Capture change • Document change 2) Restructuring of source code <ul style="list-style-type: none"> • Understanding of code • Understanding its functionality 3) Transformation of source code <ul style="list-style-type: none"> • Migration of source code from one language to another language 	<p>Developer</p>	<p>Reverse Reengineering strategies server business needs better and migration them to modern architectures</p>	<p>Given the tremendous software asserts in many corporation reengineering these asserts to serve business need better and migrating them to modern architectures will be easy</p>	<p>Legacy system to Modern Architecture</p>

		<p>4) Abstraction of recovery</p> <ul style="list-style-type: none"> • Abstract of recovery steps are performed <p>5) Reimplementation</p> <ul style="list-style-type: none"> • Reimplementation in performed. 				
Moving and Relocating: A Logical framework of service migration	<p>1) The logic language</p> <p>2) Representing a service migration</p> <p>3) Logic interference rules</p>	<p>1) The logic language It includes</p> <ol style="list-style-type: none"> Entities Platform Service Actions Event Time points Time interval etc. <p>2) Representing a service migration</p> <ul style="list-style-type: none"> • Describe how to use a logic to represent a service migration process <p>3) Logic interference rules</p> <ul style="list-style-type: none"> • Present it using sequent calculus 	Developer / maintainer	Logical framework for service migration	The requirements for dependable, robust and resilient software systems have increased with the society's growing dependency on the critical systems	Service migration of a software system
A Best Practice of java based application migration with variety of software solutions	<p>Migration Principles of Application Server</p> <ol style="list-style-type: none"> System property file Adopt JNDI (java naming and dictionary interfaces) Encode parameter Development descriptor <p>Migration Principles for Database Sever</p> <ol style="list-style-type: none"> Database reversed words Common data types Common SQL syntax Common SQL style System time 	<p>Migration Principles of Application Server</p> <ol style="list-style-type: none"> System property file <ul style="list-style-type: none"> • Gain knowledge about systems files Adopt JNDI (java naming and dictionary interfaces) <ul style="list-style-type: none"> • Provide description about AAMS implementation and JNDI • Provide detail about mechanism to Adopt JNDI Encode parameter <ul style="list-style-type: none"> • Encoded all the parameter Development descriptor <ul style="list-style-type: none"> • Development descriptor are described <p>Migration Principles for Database Sever</p> <ol style="list-style-type: none"> Database reversed words <ul style="list-style-type: none"> • Select compounds words to name for database tables and fields. Common data types <ul style="list-style-type: none"> • Select common data type of database fields and tables. Common SQL syntax <ul style="list-style-type: none"> • Follow the SQL syntax Common SQL style <ul style="list-style-type: none"> • Use SQL common SQL style System time <ul style="list-style-type: none"> • Obtain the system time by using java implementation 	programmers	The paper proposed some common principles of system migration and system design rules. The paper proposed an instance of A&A (authentication and authorization) management system(AAMS) to migrate different kind of application servers and databases	In the future, it will be application servers and relational databases added to raise the migration flexibility and make the common principles of migration more robust	Java base application migration from one server to another and from one database to another database

<p>Incorporating quality requirements in software migration process [37]</p>	<ol style="list-style-type: none"> 1) Access quality status 2) Identify critical quality bottlenecks 3) Establish quality objective 4) Construct quality models 5) Quality measurements 	<ol style="list-style-type: none"> 1) Access quality status <ul style="list-style-type: none"> • Analysis are performed using different perspectives <ol style="list-style-type: none"> I. Characteristics II. Strengths III. Weakness 2) Identify critical quality bottlenecks <ul style="list-style-type: none"> • Error prone area are identified • Selection of key bottleneck 3) Establish quality objective <ul style="list-style-type: none"> • Selection of quality objectives • Selection of target application scenarios 4) Construct quality models <ul style="list-style-type: none"> • Different quality models are built and represented. 5) Quality measurements <ul style="list-style-type: none"> • Selection of a set of metrics to compute the quality measurements 	<p>Developers</p>	<p>A prototype software toolkit is developed This toolkit developed a system segmentation algorithm to break a large system into a set of smaller working area</p>	<p>A plan to focus on extracting behaviour model for the original systems and to trace these behaviours in the migrated systems</p>	<p>Legacy system to modern object-oriented platform</p>
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IV. DISCUSSION

Different migration techniques and frameworks are described in this paper. The characterization of software migration process and comparison of systematically selected studies by highlighting existing study gaps is the main concern of this study.

Software migration is the data movement from one database system to any other types of database system. Using software migration tools we have done migration of working software from source to targeted PC. Due to fast changes and inventions in technologies, the need of migration is increasing in old systems. For example, Transforming set of programs or guidelines like PLC (programmable logic controller) programs from one platform to another. Shifting a live process from one system to another system like migrate a process from lower specification system to higher specification system is called migration process. The two systems may have different specification. To acquire sharing of resources, data access locality, load distribution, fault resilience and mobile computing can perform process migration. In large scale distributed surroundings like computational grids [14], we perform runtime process migration for resource utilization from lower to higher specification system. This thing leads to improve performance in individual application and also to produce high throughput for distributed systems. Different methods are defined for migration of software system or legacy systems [15]-[17].

An incremental approach for migration of complete systems is defined [7]. Another general migration technique towards migration projects are proposed by the reengineering factory [18]. SMART approach [19] and Butterfly approach [16] both support Data migration. Using [20], we can get more detailed overview about strategies of migration. Reference

Migration Process provided a general process model for software migration [20]. IBM's SOMA method is one of the best known strategies according to martin [21]. SOMA process model for SOA development and evolution that used as a methodological framework for recognising and encompassing migration activities and their technological support. For identification, specification and implementation services seven different phases are being used that move iteratively [17].

V. CONCLUSION

The key finding of this study is to elaborate current research knowledge about software migration. Software migration in simple words we can say moving of application to their desire place in the datacenter. We can use different way to migrate software. We can migrate software using outsourced and external hosting as well. Normally, whenever someone purchases large application, he may like to host it for the purpose that the maintenance of the application will be easy. Regarding migration purpose, we keep in mind that what services the vendor may be able to provide better or at a lower cost, so it could prove to be more cost effective option in the future.

The main areas, we have explored in software migration are framework, process, activities, challenges and their solutions. A detailed comparison of different selected studies is performed in this paper to point out the existing research gap as well as to explore future directions of work.

- Core migration frameworks with distinct activities which describe planning and migration process in different scenarios are extracted.

- Different methods and technique that are used in software migration described in detail. Following steps taken by researchers for achieving required output.
- Planning: Analyze and plan for migration strategies.
- Execution: modification of code, retrieval and transformation of data.
- Evaluation: deployment, testing and validation.

For further field development we believe that software migration and software engineering researchers have to propose a common framework.

VI. FUTURE WORK

Here, we used AAMS which is proposed system for migrating business operation cross platform because it reduces time and lower construction cost during migration process. A common framework for software migration can be helpful for understanding the data structure and data size effectively that can reduce the cost of migration, also it will enhance the applicability and impact in real business environment. There will be a time in near future when common principles will be made more robust and also for raise in flexibility of migration more databases and application servers will be there [29].

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Comparison of Machine Learning Algorithms to Classify Web Pages

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Abstract—The ‘World Wide Web’, or simply the web, represents one of the largest sources of information in the world. We can say that any topic we think about is probably finding it's on the web. Web information comes in different forms and types such as text documents, images and videos. However, extracting useful information, without the help of some web tools, is not an easy process. Here comes the role of web mining, which provides the tools that help us to extract useful knowledge from data on the internet. Many researchers focus on the issue of web pages classification technology that provides high accuracy. In this paper, several ‘supervised learning algorithms’ evaluation to determining the predefined categories among web documents. We use machine learning algorithms ‘Artificial Neural Networks (ANN)’, ‘Random Forest (RF)’, ‘AdaBoost’ to perform a behavior comparison on the web pages classifications problem.

Keywords—Web page classification; artificial neural networks; random forest; adaboost

I. INTRODUCTION

In the computer world, data represent an interesting area. It is constantly increasing and expanding exponentially, and it is important for us to find useful information from this massive data. The overall process of analyzing data to find understandable and useful information is called data mining. In the last few years, most enterprise-owned data have been stored in structured data stores such as relational databases [1] These data are easily accessible for exploratory purposes using several data mining techniques. However, the nature of the data has changed dramatically since the advent of the Internet, which has characteristics that make it different from structured data. Some of these characteristics are The huge volume on the web and growing exponentially, The web contains various types and formats of data. This includes structured data, such as the table, semi-structured data such as XML documents, unstructured data such as text on web pages, and multimedia data such as images and movies, the incompatibility of information on the Internet urge the researchers from around the world are involved in building web content. As a result. We may find pages with similar or identical content.

In addition, web data have hyperlinks, which means that web pages are linked together so that anyone can navigate through pages within the same site or across different sites that make the Information noise. The reasons for this are two issues. First, the typical web page usually contains much information such as the main body of the page, links, ads, and much more. Thus, the page does not have a specific structure.

Second, there is no qualitative control over information, meaning that anyone can upload content on the web, regardless of its quality, finally, A large portion of the content on the web is considered dynamic, meaning that the information is updated frequently and continuously. For example, weather information is updated continuously.

All these characteristics make data extraction on the web more challenging while giving us opportunities to discover useful and valuable knowledge from the web. Because of a wide range of data types, the traditional techniques to extraction data have become inadequate. This has led to the crystallization of a need to develop new techniques and algorithms aimed at data mining on the Internet. The rest of this research paper is structured as follows. In Section 2, Related work is discussed; Section 3 describes Machine Learning Algorithms. Data Collection and preprocessing is discussed in Section 4, Section 5 explained Entropy Term Weighting Schema, Experimental Results and Discussion are shown in Section 6. Concluding remarks are given in Section 7.

II. RELATED WORK

WPC techniques use concepts from many fields like Information filtering and retrieval, Artificial Intelligence, Text mining, Machine learning techniques and so on. In the machine-learning model, a classifier was given training with already classified examples and it learns the rules for classification during this training phase. Then this classifier is used for classification of the new pages. Much work has been previously begun on WPC. Mention some of them:

I. Anagnostopoulos, et al. [2] suggested a system to identify and categorize web pages, based on information filtering. The system is a three layer Probabilistic NN (PNN) having biases and radial basis neurons in the middle layer and competitive neurons in the output layer. This is an eCommerce area study domain. Thus, PNN hopes to identify eCommerce web pages to classify them to respective type based on a framework describing commercial transactions fundamental transactions on the web.

In the same direction, Feng Shen, et al. in [3] proposed a new deep learning based text classification model to solve the problem of Chinese web text categorization of dimension reduction by use away way to learn the data feature from massive data is to use deep learning NN structure. Deep learning network has the excellent feature learning ability. It

can combine objects of low-level features to form advanced abstract representations of the object which will be more suitable for classification.

J. Jagani and et al [4] M.S. Othman and et al [5] the authors discuss the result of classifying web documents using the extraction and machine learning techniques. Six web document features have been identified which are text, meta tag and title (A), title and text (B), title (C), meta tag and title (D), meta tag (E) and text (F). The Support Vector Machine (SVM) method is used to classify the web document while four types of kernels namely: Radial Basis Function (RBF), linear, polynomial and sigmoid kernels was applied to test the accuracy of the classification.

E. Sarac and et al [6] introduced that increase in the amount of information on the Web has caused the need for accurate automated classifiers for Web pages to maintain Web directories and to increase search engine performance. Every tag and every term on each Web page can be considered as a feature there is a need for efficient methods to select the best features to reduce the feature space of the WPC problem. The aim is to apply a recent optimization technique, namely the firefly algorithm (FA) to select the best features for Web page classification problem. The firefly algorithm (FA) is a metaheuristic algorithm, inspired by the flashing behavior of fire flies. Using FA to select a subset of features and to evaluate the fitness of the selected features J48 classifier of the Weka data mining tool is employed. Another related work M.Klassen [66] and J. Jagani J. Jagani and K. Patel [7] where the authors are extract useful knowledge from large web data, and handle those data and achieve various functionalities. They going to discuss a new technique that will work on hierarchical as well as multi pass approach that is having the advantages of both multi pass and hierarchical approach by combining the benefits of both and designed a new algorithm, the discussion is based on various neural network learning algorithms that help to handle large web data as well as better classification and clustering of data with less number of errors. Self-Organizing Maps called SOM and Learning Vector Quantization known as LVQ are very constructive learning algorithms that classify and cluster the web data. MLVQ and HLVQ techniques are following a concept of multi pass in which more than one pass can be performed on the same model using different algorithms.

A. Herrouz and et al [8] authors used techniques Apriori Algorithm and implementation of Naive Bayes Classifiers. Apriori Algorithm finds interesting association or correlation relationships among a large set of data items interesting association or correlation relationships among a large set of data items, relationships among huge amounts of transaction records can help in many decision making process and use Naive Bayes Classifier to calculate probability of keywords among a large data item sets The Naive Bayes Classifier uses the maximum a posterior estimation for learning a classifier.

III. MACHINE LEARNING ALGORITHMS

A. Artificial Neural Networks (ANN)

An interconnected set of virtual neurons created by software programs similar to the work of a biological neuron or

electronic structures (electronic chips designed to simulate the work of neurons) using the mathematical model to process information based on the communicative method of computing. Neural networks generally consist of simple processing elements that do a simple job, but the overall behavior of the network is determined by the connections between these different elements called the neurons and the indicators of these elements [9]. The first suggestion of the idea of neural networks comes from the mechanical action of brain neurons that can be likened to electrical, biological networks to process the information contained in the brain.

Artificial neural networks are composed of nodes called neurons or processing elements, which are connected together to form a network of nodes. Each contact between these nodes has a set of values called weights which contribute to the determination of the values resulting from each processing element based on the input values of that element. Neural network arranged in layers of artificial cells [10]: input layer and output layer and layers between them called hidden layers. Each cell in one of these layers relates to all the neurons in the next layer and all the neurons in the layer preceding it. All connections between a neuron and another is characterized by a value called weighting, it is the importance of the connection between these two elements.

The neurons multiply each input value from the previous layer neurons with the weight of the communication by these neurons and then multiply the multiplication outcomes, The conversion is different with neuron type, the output of the transformation considers the output of the neuron which is transferred to the neurons of the next layer. The feed forward-back propagation neural network is adapted as the classifiers. The activation of these input units is propagating forward through the network, and finally, the value of the output unit determines the categorization decisions.

B. Random Forest

Random Forest [11] is the one of a Machine Learning Algorithm work as a large collection of the correlated decision tree. The random forest lies in one of those Class of Machine Learning Algorithms which does 'ensemble' classification. By Ensemble, Collective Decisions of Different Decision Trees. RF is making a prediction about the class not based on One Decision Tree, but by an (almost) Unanimous Prediction, made by Decision Trees.

The training algorithm for random forests applies the general method of bootstrap aggregating, or bagging, Each tree is trained on a bootstrapped sample at each node of training data, the algorithm searches across a random a subset of the variables to determine a split, this procedure leads to best model performance because it decreases the variance of the model, without increasing the bias. This means that the predictions of a single tree are very sensitive to noise in its training set, To classify an input feature vector in random forests, the vector is submitted as an input to each of the trees in the forest. Each tree gives class and it is said that the trees vote for that class. In the classification time, the forest chooses the class that has the most votes.

C. AdaBoost

AdaBoost, abbreviated "Adaptive Boosting", is a "machine learning meta-algorithm" produced by Yoav Freund and Henry Martyn Robert Schapire, it is a type of "Ensemble Learning" where varied learners are employed to construct a stronger learning algorithm. AdaBoost is one of the most efficient supervised learning algorithms of the last years [12]. it has to be inspired learning theoretical developments and also provided solid theoretical foundation, very accurate prediction, great simplicity building and easily explainable modeling that proved successful in wide applications, It is used in most cases with several alternative types of learning algorithms to enhance their performance by which combined the output of the other learning algorithms ('weak learners') into into a weighted addition that represents the ultimate output of the boosted classifier, but it is sensitive to noising data and outliers in some cases, it may be less oversensitive to the overfitting problem than other learning algorithms.

AdaBoost works by choosing a base algorithm (e.g. Decision trees) and iteratively improving it by accounting for the incorrectly classified examples in the training set.

IV. DATA COLLECTION AND PREPROCESSING

Data collection is a process used to crawling the web page from a website, We can get updated data and maintain this document for later processing by storing in the database. In this paper, The type of data in the database is a health data includes Diseases information, the dataset used in this experiment collecting randomly from search engines.

The web pages consist varied information like nouns, stop words, navigation, image, link structure, Advertisement, and lay out all of these are unnecessary in classification in order to achieve a standard representation of all documents must be applied preprocessing. The preprocessing contains three steps (lexical analysis, string tokenizer, stop words elimination and stemming) as Fig. 1.

The lexical URL analysis technique used to enhance the classification accuracy of web classifiers, the system uses the tools of lexical analysis to reduce the amount of data by removing any Useless word and can get the Stream of useful words that could be used in the next steps of the preprocessing. Identify words in the plain text using, tokenization, which processes represented each word as a token.

After the string tokenizer process is applied the stop words, elimination is done, which means the pronouns, prepositions like "to", "the", etc. and conjunctions are removed from the document because these words don't have any meaning or indications about the content. Thus affecting the quality of classification, Finally, The last part of preprocessing is stemming, Stemming is a technique used to minimize the words to their grammatical roots. The stemming process is applied to remove suffixes like "Ed", "ing", "ly", etc. by removing these suffixes we can reduce the terms in the document and lessen the complexity and also it is necessary to do text analysis to make information retrieval efficient in especially in data mining applications.

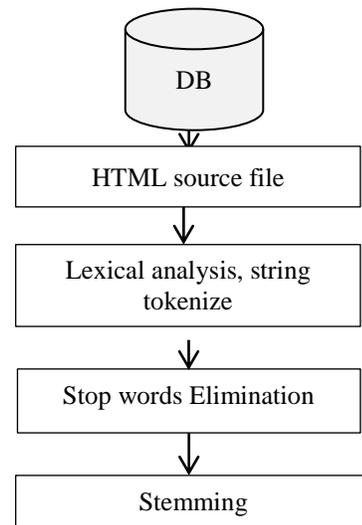


Fig. 1. Preprocessing steps for web page.

After the preprocessing of all web pages document, the database has been created and contains all the unique words in each page. The number of unique words (25769) represents distinctive words that appeared several times in the page. Each word represents one feature vector. This feature vector contains the document terms weight. The Term weight calculated by using the entropy term weighting scheme

V. ENTROPY TERM WEIGHTING SCHEME

A process that identifies most regular words in each class or category, as well as calculating the weights of them by implementing the term weighting scheme, Entropy method is based on a probabilistic analysis of the texts. It provides a more accurate weight. Calculate term weighting from two aspects which are local term L_{jk} weighting and global G_k . Entropy term weighting scheme on each term is calculated as $L_{jk} \times G_k$ calculate from two formulas [13]

$$L_{jk} = \begin{cases} 1 + \text{Log } TF_{jk} & (TF_{jk} > 0) \\ 0 & (TF_{jk}=0) \end{cases} \quad (1)$$

And

$$G_k = \frac{1 + \sum_{k=1}^n \frac{TF_{jk}}{F_k} \text{Log } \frac{TF_{jk}}{F_k}}{\text{log } n} \quad (2)$$

(n) is the number of documents in a database and $TF_{(jk)}$ is the term frequency of each word in Doc j as F_k is a frequency of the term k in the entire document collection. Term weight input to principal components algorithm "PCA" which use to reduce the original data vectors to a small number of relevant features and it calculates the eigenvectors of the covariance matrix, after that projects the testing data onto a lower dimensional feature space which is defined by the eigenvectors

VI. EXPERIMENTAL RESULTS AND DISCUSSION

The experiments were carried out to show the effectiveness of these algorithms and difference between them. The data type used is web pages that are randomly downloaded from search engines yahoo, google, etc. and divided to eight categories, namely Respiratory, Hearts, liver, cancer, diabetes, dermatology, joint, digestive, 269 web page was used contain information about this Diseases, this dataset divided into 70% for training phase and 30% for testing. It was evaluated the classification performance using the standard information retrieval measures (F. Measures), it considers both the precision and the recall as below:

$$\text{Precision} = TP / (TP + FP) \quad (3)$$

$$\text{Recall} = TP / (TP + FN) \quad (4)$$

$$F.\text{Measures} = 2 * TP / (2 * TP + FP + FN) \quad (5)$$

Where the precision for a class is the number of true positives (i.e. The number of pages correctly labeled as belonging to the positive class) divided by the total number of pages labeled as belonging to the positive class (i.e. The sum of true positives and false positives which are pages incorrectly labeled as belonging to the class).

Recall in this context is defined as the number of true positives divided by the total number of pages that actually belong to the positive class (i.e. The sum of true positives and false negatives, which are pages which were not labeled as belonging to the positive class but should have been). The experiments were conducted using three algorithms and test the accuracy and efficiency for each of them; results are shown in Table 1 and Fig. 2:

TABLE I. COMPARISON RESULTS OF THREE CLASSIFIERS

Algorithm	Precision	Recall	F.Measures
Random forest	92.94%	82.24%	87.26%
Artificial neural networks	90.33%	79.93%	84.82%
AdaBoost	82.6%	82.4%	81.7%

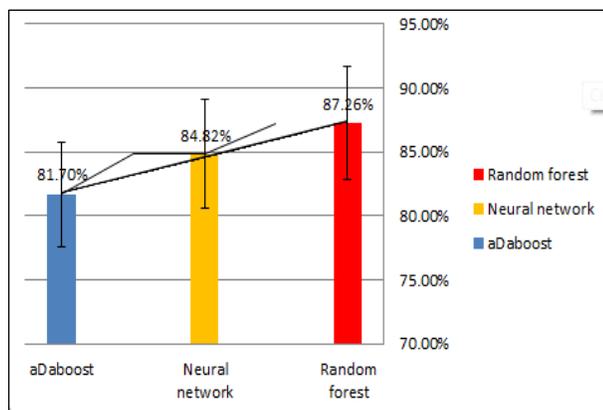


Fig. 2. Performance of RF, NN and adaBoost algorithm.

The results above show that the random forest has a higher precision than neural network and ADABOOST. The value of F. Measures are also greater from Other in the classification. But the NN has the best competitive performance with ADABOOST. A bagging algorithms model rather than a boosting algorithm. A too complex model has a low bias, but large variance, while a too simple model has low variance, but large bias, both leading a high error, but two different reasons. One powerful modeling algorithm that makes good use of bagging is Random Forests. Random Forests work by training numerous decision trees each based on a different resampling of the original training data. In Random Forests the bias of the full model is equivalent to the bias of a single decision tree (which itself has high variance). By creating many of these trees, in effect a "forest", and then averaging them the variance of the final model can be greatly reduced over that of a single tree. In practice the only limitation on the size of the forest is computing time as an infinite number of trees could be trained without ever increasing bias and with a continual (if asymptotically declining) decrease in the variance.

AdaBoost weak learners have high bias and low variance. To reduce the bias of a large number of 'small' models with low variance by building up one learner at the top of another, the boosting ensemble tries to decrease the bias, for a little variance. While the result of random forest nearly with a neural network, both algorithms have strength and weakness points. Here we are going to focus on the positive side of random forest compared to the neural network. The RF faster, usually finishes within minutes and it Easier to train, RF has less hyper-parameter to tune, In contrast, in NN have huge numbers of parameters to choose from like the number of layers, a number of neurons in each layer, activation function, learning rate, etc.

VII. CONCLUSION

From the testing phase, the accuracy of RF classifier is 87.26 %, NN is 84.82% and AdaBoost is 81.7 % According these results, we found that RF can classify more accurately than the ANN and AdaBoost classifiers. The value of F1 is greater from Other when classifying the pages. But the ANN has the best performance compared with AdaBoost. Finally, RF Can handle small data most NN architectures require big data to generalize very well, and the number of documents should be a much larger from a number of features. While RF could give a proper accuracy with a small number of documents even with too many features.

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GDPI: Signature based Deep Packet Inspection using GPUs

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Abstract—Deep Packet Inspection (DPI) is necessitated for many networked application systems in order to prevent from cyber threats. The signature based Network Intrusion and Detection System (NIDS) works on packet inspection and pattern matching mechanisms for the detection of malicious content in network traffic. The rapid growth of high speed networks in data centers demand an efficient high speed packet processing mechanism which is also capable of malicious packets detection. In this paper, we proposed a framework GDPI for efficient packet processing which inspects all incoming packet's payload with known signature patterns, commonly available is Snort. The framework is developed using enhanced GPU programming techniques, such as asynchronous packet processing using streams, minimizing CPU to GPU latency using pinned memory and zero copy, and memory coalescing with shared memory which reduces read operation from global memory of the GPU. The overall performance of GDPI is tested on heterogeneous NVIDIA GPUs, like Tegra Tk1, GTX 780, and Tesla K40 and observed that the highest throughput is achieved with Tesla K40. The design code of GDPI is made available for research community.

Keywords—Packet processing; Graphic Processing Units (GPUs); deep packet inspection; network security; parallel computing; heterogeneity; CUDA

I. INTRODUCTION

Deep Packet Inspection (DPI) is a challenging task which involves network packet filtering mechanism. The incoming packets specially the payload part is inspected for malicious content. The payload of packet is processed in order to determine the authenticity of the packet at application layer. This process of payload inspection needs to be effective and efficient in terms of speed. The packet payload inspection is performed repeatedly for every incoming packet. Considering the wide scale usage of DPI application, a significant high speed packet processing mechanism is needed.

Existing techniques of DPI systems use Graphic Processing Units (GPUs) [1]–[3] for performance improvement in terms of high throughput. Despite of its speedup and performance efficiency, deployment of DPI method over GPUs using CUDA C-programming platform is quite thought-provoking for developers. GPUs are also used in various computation-intensive applications like IP lookup, general packet classification [9] and pattern matching for DPI systems. Pattern matching consumes 70% [5] of the execution time which can be reduced by exploiting parallelism in GPUs. Various algorithms have been proposed for pattern matching [4]–[6] such as Rabin Karp [7],

Knuth-Morris-Pratt (KMP) [8], [9] developed with CUDA C programming platform.

Most of the DPI systems such as Gsnort [10], and other system are not open source [11] that can be used. There is an extensive need for efficient DPI mechanism which fully exploits GPU functionality using modern GPU programming techniques. The DPI system must consists of modular programming approach so newer pattern matching algorithms can be integrated to check the efficiency and should be available for further investigation.

In this paper, the research is motivated with above mentioned challenges and requirements. To this end, a framework is proposed named “GDPI” for deep packet inspection. The general architecture of GDPI is briefly shown in Fig. 1. The caching [12], [13] of incoming network packets boost the network performance as stream of packet is transferred from CPU memory to GPU memory. The asynchronous call of CUDA functions increases the transfer speed as CPU is not locked while streams are transferred to GPU memory for further packet processing. The framework used two common methods for packet transfer that is pinned memory and zero copy mechanisms. The packets are processed to identify malicious contents in the payload of packet using known patterns or signatures. We used an open source SNORT [14] database for known malicious patterns or signatures. The incoming packet's payload is inspected using open source CUDA based pattern matching algorithms, KMP and Rabin Karp. The framework is designed considering modular programming approach in a way that either of pattern matching algorithms, KMP or Rabin Karp can be selected for the patterns to be matched. The modular approach facilitates the integration of different pattern matching algorithms as per need. The memory coalescing technique is used for patterns residing in GPU shared memory to be matched with incoming packets, which also reduces the read operations and increases the overall packet processing speed. If packet payload contains malicious content, it is dropped or discarded otherwise forwarded to the next hop. Table 1 briefly elaborates the research challenges, goals and research contributions of this paper. The main contribution of this paper are:

- Developed an efficient and effective open source GPU based DPI solution for research community.
- Used a modular programming approach considering the selection of either of pattern matching algorithm

TABLE I. CHALLENGES, GOALS, RESEARCH CONTRIBUTIONS

S.No	Challenges	Goals	Research Contributions
1	High throughput	To develop network application based on hardware accelerators using GPUs which is capable of processing network traffic in an efficient way	The use of graphics processing units ensures the high level of parallelism
2	Prevention from malicious content	To inspect all incoming network traffic in order to prevent from cyber threats	Deep Packet Inspection to examine incoming packet payload
3	Use an efficient pattern matching algorithms for Deep Packet Inspection	To analyze the efficient pattern matching algorithm that can be integrated with the framework in order to observe the overall performance	Modular approach used to develop the GDPI
4	Parallel processing of packets using GPUs	To use enhance GPU programming techniques in a effective way	GPU programming techniques such as stream processing, zero copy,memory coalescing is incorporated
5	Availability of program code for GPU based DPI	Research community can access it for further investigations	Open Source

such as KMP or Rabin Karp in this case.

- Enhanced GPU programming techniques like asynchronous stream processing, zero copy, memory coalescing used to fully exploit parallelism.
- Performed extensive experiments using heterogeneous NVIDIA GPUs like Jetson Tk1, GTX 780, and Tesla K40.

The rest of this paper is organized as follows: Section II consists of related work which discusses the recent trends in high performance intrusion detection systems, regular expression matching methods for deep packet inspection, packet processing techniques on GPUs, pattern matching algorithms for DPI and machine learning methods used for DPI. Section III contains the proposed Methodology which includes packet capturing, packet transfer from CPU memory to GPU memory and pattern matching. Finally, Section IV includes the experiments performed using different NVIDIA GPUs. Section V follows with conclusion and future work.

II. RELATED WORK

We divide the related work in four broad categories.Each category briefly elaborates the approaches used in DPI systems. The categories are: high performance intrusion detection, regular expression matching for DPI, packet processing using GPUs, pattern matching algorithms over GPUs, and machine learning methods for DPI. Table 2 briefly explains the feature comparison of proposed framework with existing solutions.

A. High Performance Intrusion Detection

Network Intrusion Detection systems (NIDS) are well known source for monitoring inbound and outbound network traffics in order to prevent from DDOS and other types of attacks. Numerous solutions are available for the detection of malicious content in network monitoring systems like Snort [15], Suricata, BRO [16] are widely used NIDS.Due to continuous growth in network applications, high throughput is needed for the processing of network applications. The emergence of graphics processing units has increasingly in demand for every aspect in network processing [17] applications. A GPU based intrusion detection system, Gnorm, Kargus [18] has been developed to accelerate packet processing speeds in NIDS.

The research is inspired with these existing solutions and designed a framework for signature based DPI using GPUs. Gnorm and other GPU based DPI solutions are not open source,so we are not aware of its performance comparison with our framework which is open source and available for the research community. We developed it using modular approach which facilitates the integration of any pattern matching algorithm to improve its performance. Our framework is tested on different types of kepler architecture of NVIDIA GPUs like Tegra Tk1, GTX780, Tesla K40.

B. Regular Expression Matching for Deep Packet Inspection

In order to improve the efficiency of signature based NIDS, numerous automaton approaches has been adopted for its effectiveness. Deterministic finite automata (DFA) and non-deterministic finite automata (NFA) are two popular methods used in NIDS. In both approaches, regular expression string matching is done but with different performance and memory usage properties.Regular expression matching on deterministic finite automata (DFA) [19] is used for fast packet processing at wire speed.The researchers proposed DFA estimator and a regular expression based grouping algorithm. The DFA estimator calculates size based on regular expression and grouping algorithm without building actual DFA and showed improvement in terms of memory size and speed. For further enhancing speeds in string matching while controlling memory expense, a finite state machine (FSM) based scheme is developed which scans multiple characters in parallel by running small sized FSMs. This approach reduced the memory consumption cost and thus increased its efficiency. Tunable finite automata (TFA) [20] has solved state explosion and prediction performance problem. TFA allows multiple concurrent active states unlike DFA which allow only one active state, and achieved 98% reduction in memory consumption. The head body finite automaton [11] used multicore general purpose processors (GPP) for parallelism and single instruction multiple data (SIMD) operations. The head body matching is based on pre-defined DFA depth value and head size for partitioning and parallel processing and observed 58% significant increase in throughput.

The research is motivated with the generalized DPI methods [21] and used string matching based on hashing approach using general purpose graphics processing units (GPGPUs).The hashing method calculates the hash value of each string of currently inspected incoming payload. The hash

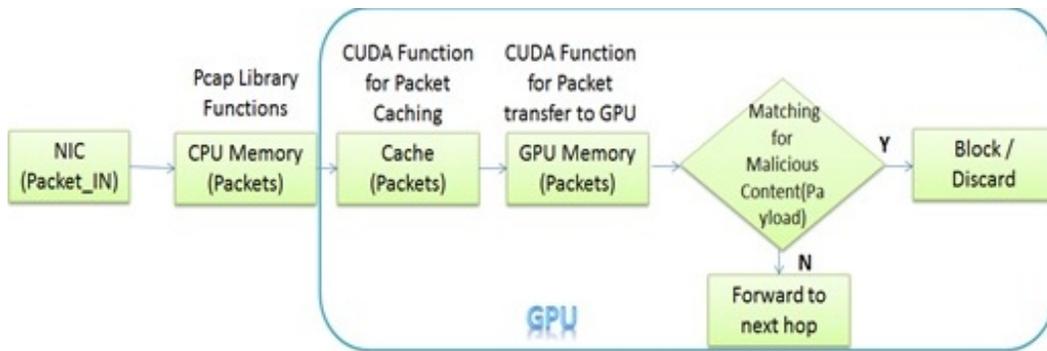


Fig. 1. General architecture of GDPI.

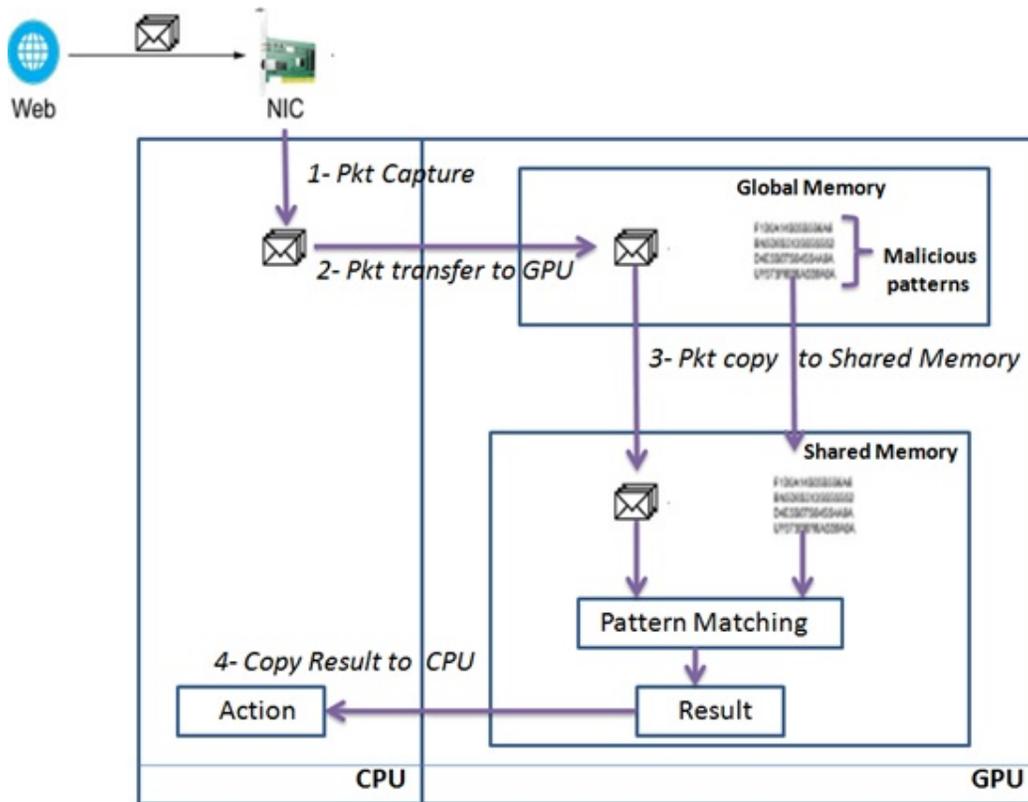


Fig. 2. Modular process flow of proposed framework GDPI.

value of payload is compared (binary search can be done for matching) byte by byte with the precomputed hash value of corresponding signature patterns. The other approach includes string search algorithm which looks for the occurrences of strings and compared with signature patterns.

C. Packet Processing using GPUs

GPU computing [22] has become an integral part of computing systems. There has been remarkable increase in throughput and performance capabilities of network applications as well. GPUs brought the new prospects for packet processing by offloading [23], [24] computation needs to the GPUs as it offers extreme thread level parallelism on hundreds of core. Packets are processed in a batch [25] to

reduce per packet memory management overhead. Effective packet processing for network application has complex operations like TTL decrement, checksum recalculation, broadcast management, handling of IP options like ICMP or ARP. The network operations needed modular pipeline processing [26] for synchronous and asynchronous packets with in-order execution by leveraging GPUs. The growth of virtualization for network appliances lead the use of software based virtual switches. These virtual switches needed high packet iO rate and a classification scheme for high throughput as the size and dimension of forwarding table is continuously growing in case of SDN. The packet classifiers attained high throughput by ensuring the coalesced memory [27] access in order to reduce latency for off chip memory.

The research is highly inspired with enhanced GPU based CUDA programming techniques which can be used for fast and effective packet processing. We used CUDA function APIs for batch processing of packets. This helped us to increase the packet transfer rate from CPU memory to GPU memory. The batch of packets are sent to GPU memory instead of sending single packet per thread improves the overall performance. The packet offloading from CPU to GPU memory using page locked or pinned memory via asynchronous CUDA functions increased the transfer rate. Another CUDA technique for CPU to GPU transfer is Zero Copy [28], [29] in which space is allocated to both CPU and GPU and does not have to transfer the data, reduces CPU cycles and save memory bandwidth. The memory accesses for pattern matching is coalesced which decreased memory access latency and speedup the packet processing capabilities of the framework.

D. Pattern Matching Algorithms over GPUs

String matching is an important technique for various applications. Traditional string matching algorithms requires backtracking and the comparison process [30] repeatedly effects the efficacy of the algorithm. There are various algorithms for Pattern matching such Aho-Corasick [31], Boyer-Moore [32]. Middlebox services for network applications typically inspects for known patterns which can be present anywhere in payload. The Aho-Corasick algorithm constructs a DFA and provides an optimal performance as it frequently refers memory and causes large number of cache misses. DFC algorithm [17] resolved this problem by minimizing CPU stalls and maximizing CPU level parallelism. The computation time for processing large number of patterns has been sufficiently decreased by using high end parallel SIMD architecture of GPUs. KMP and Rabin Karp, etc. showed the speedup for pattern matching when integrated with these high end GPUs.

Another GPU based algorithm HMPA [33] outperformed CPU only and GPU only implementations as it adopted the hybrid approach. The packet filtering and full pattern matching is performed by CPU and GPU respectively, but overall performance is limited. For this purpose, a variant of HMPA is designed known as CHMPA [3] which estimates CPU and GPU processing capabilities and self allocates the process at runtime. The varying payload length also become a bottleneck which is resolved by LHMPA [11]. It restricts those packets whose payload length exceeds predefined length bound. The variable length payload for pattern matching is resolved by using a probabilistic data structure bloom filter [1] using multiple hash functions.

The research is encouraged with the recent and efficient algorithms for pattern matching. We used CUDA based KMP and Rabin Karp algorithm. KMP is a single pattern matching algorithm but we developed it as a variant of KMP for multi-pattern matching. The hashing method for DPI is fulfilled by Rabin Karp algorithm. The GDPI framework used a modular approach that either of algorithm can be selected to identify the overall performance and efficacy of the framework.

E. Machine Learning Methods for DPI

Network traffic classification has become significantly important with rapid growth of current internet network and on-

line applications. Advance Machine Learning techniques provide a new dimension for detection of attacks at various levels. The machine learning techniques such as naive bayes, support vector machine (SVM), C4.5 decision trees have been used for the classification of attacks and observed high accuracy factor with C4.5 [34] classifier. The flow based anomaly detection systems adopted a deep learning approach know as deep neural network [35] and observed 75.5% accuracy and has high potential in software defined network (SDN) environment. The network traffic characterization and application identification can also be achieved through convolutional neural network (CNN) [36] with both encrypted and unencrypted network traffic.

We are highly motivated with this new paradigm for classification of attacks from cyber threats prevention. In this paper, we have not used any machine learning or deep learning techniques but we can incorporate these techniques in our future work.

III. METHODOLOGY

This section explains development design of GDPI using CUDA C programming platform. CUDA is a parallel computing application platform developed by Nvidia to use CUDA enabled graphics processing unit.

A. Packet Capturing at NIC

The packets are generated by an open source network traffic generator tool Ostinato at Network Interface Card (NIC). Fig. 2 shows that the stream of packets are created using `cudaStream()` API. The API creates stream of packets at CPU memory. The stream of packets is transferred to GPU memory for further processing and reduces the overhead of sending single packet per thread. It increased the packet transfer rate and also decreased the CPU to GPU latency due to asynchronous CUDA function operations.

B. Packet Transfer from CPU to GPU Memory

The CUDA based application framework manages concurrency by executing asynchronous functions for stream processing. The stream of incoming packets is transferred from CPU memory to GPU memory in two ways: the first method is to transfer by using page locked host memory also called pinned memory. The CUDA API is `cudaMemcpyAsync()` which is a asynchronous transfer and helps improved the transfer rate and reduce the latency from CPU to GPU memory. The second method is to transfer the stream of packets using Zero copy mechanism. The Zero Copy is a way to map host memory and access it directly over PCIe without doing an explicit memory transfer as it allows CUDA kernel to directly access host memory, instead of reading data from GPU global memory. The CUDA API for zero copy is `cudaHostGetDevicePointer()` creates a memory to access the data between CPU and GPU. We used both methods to transfer the incoming packets and open source signatures to the GPU memory.

C. Pattern Matching

The open source SNORT signature's database is used for the detection of malicious content in packet payload. The

TABLE II. FEATURE COMPARISON OF EXISTING SOLUTIONS WITH GDPI

S.No	Feature Set	Snort	Bro	Suricata	Kargus	Gnort	GDPI
1	GPU based system	-	-	✓	✓	✓	✓
2	Open source	✓	✓	-	-	-	✓
3	Modular approach	-	-	N/A	-	N/A	✓
4	Enhance GPU programming techniques	N/A	-	N/A	-	N/A	✓
5	Evaluation on heterogeneous GPUs	N/A	-	N/A	-	-	✓

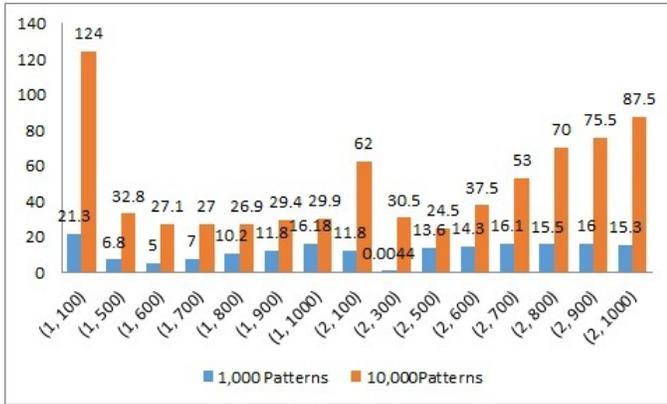


Fig. 3. Packet processing time with varying no. of threads and blocks on group of pattern sets.

hexadecimal format of malicious signature is loaded into CPU memory. The string matching algorithms used for pattern matching are KMP and Rabin Karp. The preprocessing includes the computation of prefix table and hash values of signature over GPU, while using KMP or Rabin Karp, respectively. The modular approach is used and either of the algorithms can be selected for pattern matching. By copying preprocessed signature patterns to GPU's shared memory, reduces read operations while searching using memory coalescing mechanisms. For patterns p_1, \dots, p_n , and GPU grid consisting of threads t_1, \dots, t_k , each thread i iterates j times, assigned pattern $p_i + (j * n)$ which then applies the searching algorithm on it.

The packet payload is compared by using string matching algorithms developed for GPUs such Rabin Karp and KMP. After the packet is transferred to the GPU memory, a kernel is launched with 4 Blocks of 512 threads by default (unless configured otherwise). Each thread in a grid scans for a specific malicious signature using the selected algorithm KMP or Rabin Karp and then returns the action to be performed on the packet. The performance is increased due to coalesced memory access technique together with shared memory. The results are copied back to host. The respective stream managing thread then analyze the result. In case of malicious content found in payload of the packet, the connection is closed by sending a reset control signal TCP_RST and TCP_FIN to both end points to finally close the connection.

IV. EXPERIMENTS

The framework is initially tested on NVIDIA Tegra TK1, a mobile embedded system with 192 cores and 2GB of memory. We also evaluated GDPI on commodity hardware with Ubuntu server 14.0.4 with linux kernel installed on it. The supported programming platform CUDA 7.5 is installed for GPU programming. These machines are equipped with NVIDIA GTX

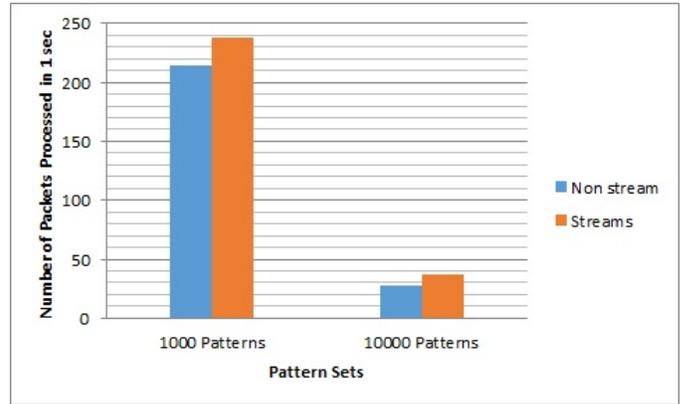


Fig. 4. Number of packets processed for pattern matching on group of pattern sets.

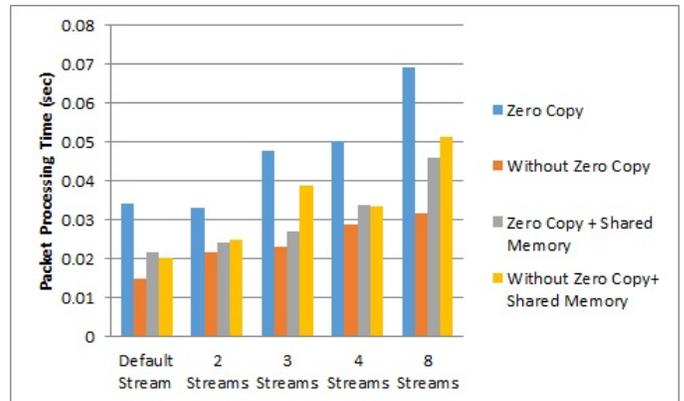


Fig. 5. Packet processing time with and without zero copy and shared memory.

780 with 2304 cores and NVIDIA Tesla K40c with 2880 cores. The memory installed in these commodity hardware is 8GB.

A. Packet Streams

Initially, the incoming packets is sent to GPU using single packet per thread by varying grid configuration (blocks, threads). Fig. 3 shows the packet processing time with different number of blocks and threads configuration of a grid. We observed the time taken for packet processing on signature pattern set of 1000 and 10,000. Initially, the grid is launched with single block and 100 threads and then gradually the grid configuration is varied. The packet processing speed is gradually increased and showed improved performance as shown in Fig. 3.

After that we implemented stream processing through asynchronous CUDA function API `cudaStream()`. The API created the stream of packets and then transfer to GPU memory.

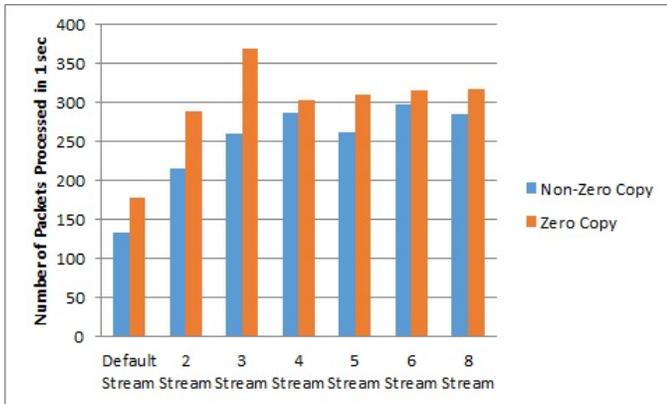


Fig. 6. No. of packets processed with coalescing memory.

The stream processing of packets showed the performance improvement when compared with single packet per thread. Fig. 4 shows the number of packets processed per second on pattern set of 1,000 and 10,000, respectively. The processing time of packet streams reduced the overhead of sending single packet per thread. The packet streams have clearly shown a significant increase in packet processing time.

B. Packet Transfer using Pinned Memory and Zero Copy

The incoming packets stream transferred from CPU to GPU memory using pinned memory and zero copy mechanism. The packet stream transfer rate is improved using zero copy. The incoming packets and pattern sets are in shared memory of GPU. Fig. 5 shows that multiple streams are sent to the GPU shared memory for comparison with pattern sets. The packets processing time using zero copy with shared memory showed an increase in performance as compared to non-zero copy.

C. Pattern Matching using Memory Coalescing

The signature patterns were copied from device global memory to shared memory for patterns to be compared with incoming packet streams. When malicious signature patterns copied to shared memory. Fig. 6 shows that the memory coalescing technique together with zero copy and patterns reside in shared memory increased the overall performance of packet processing.

D. DPI Module Performance on Heterogeneous GPUs

Fig. 7 shows the single packet processing time is evaluated on CPU cores and different NVIDIA GPUs kepler architecture like, Jetson Tk1, GTX780 and Tesla K40 with pattern matching algorithms, KMP and Rabin Karp. GDPI framework showed improved results on Tesla GPU with Rabin Karp algorithm.

V. CONCLUSION AND FUTURE WORK

This paper proposed a framework GDPI for signature based deep packet inspection using GPUs. The framework GDPI scans incoming packet for the detection of malicious content in the payload of packet using Snort signatures. The framework is designed using a modular programming approach so any of the pattern matching algorithm can be integrated to observe the performance improvements. The implementation is mainly

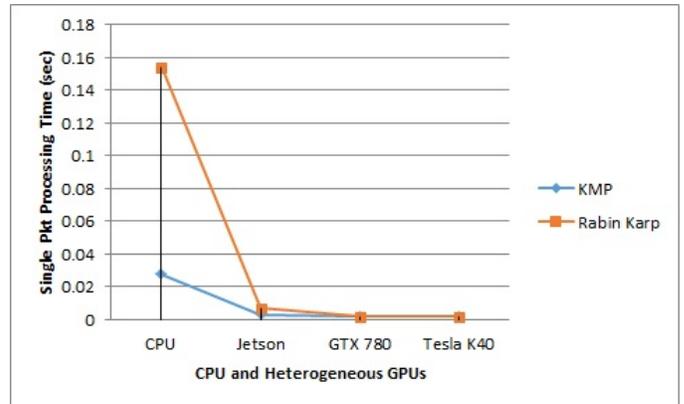


Fig. 7. GDPI performance on CPU and Heterogeneous GPUs.

focused on the recent GPU programming techniques such as stream processing, memory overlapping methods zero copy, etc. and observed speedup in packet transfer from CPU to GPU memory. The asynchronous nature of CUDA operations violates the serialization process. The use of shared memory where patterns and packets are copied reduced read operations from global memory. The memory coalescing technique also resulted in reduction of bandwidth and thus speedup the matching process which is considered as main bottleneck in DPI systems. The framework is tested on heterogeneous kepler architectures of NVIDIA GPUs such as Tegra Tk1, GTX 780 and Tesla K40. The experiment results achieved maximum speed of packet processing when tested over Tesla K40 with Rabin Karp algorithm. The GDPI framework is open source for research community for further investigation.

As network security is of vital concern for cloud and bigdata applications. The research community is continuously working on recent methods and practices for deep packet inspection. Machine learning (ML) and deep learning (DL) techniques providing a new paradigm to Network Intrusion Detection Systems. ML and DL techniques are used for the classification of attacks in order to prevent from cyber threats. Network intrusion detection systems performance needs improvement in terms of accuracy, which can be achieved with the use of deep learning techniques for intrusion or fraud detection. These systems can be implemented and tested in real time SDN environment to evaluate the effectiveness of the system in terms of accuracy, latency, and throughput. The proposed GDPI framework is not using any machine learning or deep learning classification techniques such as support vector machine and deep convolutional neural network (DNN). The incorporation of these techniques can significantly increase the effectiveness of the proposed framework in real time environment.

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Multi-Target Tracking Using Hierarchical Convolutional Features and Motion Cues

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Abstract—In this paper, the problem of multi-target tracking with single camera in complex scenes is addressed. A new approach is proposed for multi-target tracking problem that learns from hierarchy of convolution features. First fast Region-based Convolutional Neural Networks is trained to detect pedestrian in each frame. Then cooperate it with correlation filter tracker which learns target's appearance from pretrained convolutional neural networks. Correlation filter learns from middle and last convolutional layers to enhances targets localization. However correlation filters fail in case of targets full occlusion. This lead to separated tracklets (mini-trajectories) problem. So a post processing step is added to link separated tracklets with minimum-cost network flow. A cost function is used, that depends on motion cues in associating short tracklets. Experimental results on MOT2015 benchmark show that the proposed approach produce comparable result against state-of-the-art approaches. It shows an increase 4.5 % in multiple object tracking accuracy. Also mostly tracked targets is 12.9% vs 7.5% against state-of-the-art minimum-cost network flow tracker.

Keywords—Multi-target tracking; correlation filters; convolution neural networks

I. INTRODUCTION

Multi-target tracking task is to estimate number of targets and their trajectories across multiple frames. It is a crucial problem in the field of computer vision. Also it is highly demanded in many computer application such as surveillance, human behavior analysis and augmented reality. Mainly it consists of two components: detection and data association between detections across frames. Data association step is challenging due to many reasons such as missed or faulty detections, short and long term occlusions and interactions between targets in crowded scenes. Most recent approaches in multi-target tracking have followed tracking-by-detection approach, where object detectors output are linked to build targets trajectories.

Recently, convolutional neural networks (CNN) have gained a lot of attention. CNN demonstrated the state of the results in various computer vision tasks such as object recognition, semantic segmentation and object detection. Due to it's ability to capture a generic feature representation from visual data. However, CNN rarely used in multi-target tracking. As CNN require collecting large number of training positive and negative samples, which is not always available. Also dealing with ambiguity in the decision boundary between positive and negative samples. As sampling is done near target which lead to high correlation between positive and negative samples.

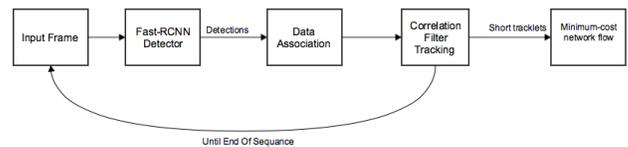


Fig. 1. Overview of our multi-target tracking system.

On the other hand CNN learned features have outperformed hand crafted features in many vision problems. As stated in previous work in single object tracking task [1] features from last convolutional layer encode target semantic information and more robust to handle appearance change in the target. However they have low spatial details which is necessary in target localization task. On the other hand features in earlier layers have high spatial details. So it's more helpful in localization but less invariant to target appearance change.

In this paper Fast Region-based Convolutional Neural Networks (Fast RCNN) detector is integrated with correlation filters tracker. The proposed multi-target tracking algorithm is based on correlation filters that learn from hierarchical convolutional features of a pretrained CNN. Also cosine similarity is used between convolutional features along with Euclidean distance as association measure between previous frame tracklets and current detection. Then a post processing step is added with minimum-cost network flow tracker to recover target after long occlusions. Overview of our proposed approach is shown in Fig. 1.

The following three contributions are made. First Fast RCNN is integrated with correlation filters tracker. Using Fast RCNN to detect pedestrians in each frame. Also Fast RCNN is cooperated with correlation filters to handle targets disappearance. Second new data association metric is proposed between detections and trajectories that describe the path of target instances over time. Data association is based on measuring cosine similarity between middle convolutional layers. Third a fix for occlusion problem in correlation filters is proposed. Using min-cost network flow to avoid short tracklets and high identity switch rate.

This paper is organized as follow: In Section II, previous work is discussed. In Section III, The proposed approach details are discussed including basic idea of Fast R-CNN, mathematical concept for correlation filters tracker, data association metrics strategy and min-cost network flow. In Section

IV, evaluation of proposed approach on MOT2015 benchmark is presented. Comparison against state-of-the-art approaches is shown. In Section V, advantages, limitations of proposed approach and future work are discussed. In Section VI, conclusion for the work done in the paper is presented.

II. RELATED WORK

A. Object Detection

Recently deep convolutional neural networks have made a huge progress in object detection. RCNN [2] is a detector that classify proposal regions with a deep convolutional neural networks. RCNN first compute region proposals using separated algorithm such as selective search [3]. Then it feeds the candidate regions to convolution neural networks to classify selected regions. However RCNN is slow as it doesn't share computation while performing forward pass. It process each proposal separately. Girshick proposed Fast RCNN [4] an end-to-end architecture with shared convolutional layer. Fast RCNN improved train and test speed while also gained higher detection quality.

B. Multi-target Tracking

Due to the importance of multi-target tracking in computer vision, a large number of sophisticated approaches have been developed to handle this challenging task. Specially in case of crowded scene where occlusion and false positive are common. Most work in multi target tracking follow tracking by detection approach [5, 6, 7], where it can be divided into two steps. First detect all targets in each frame. Then link these detections to form trajectories. Processing detections can be done online, where only past and current frames are considered in building tracklets. Different approaches have been proposed in handling data association in online tracking. Early approaches handled data association by using recursive Bayesian filters such as: Kalman filter[8], Particle filter [9] which depends on first-order Markov assumption. Another direction in association is to match between objects at consecutive frames using similarity measure, where only local features are considered such as object appearance, distance between detections and size. However local association that considers consecutive frame have limitation in handling false positive and missed detections.

On the other hand other approaches in multi-target tracking adopt batch learning approach [10, 11, 12, 13, 14], where future detections are also considered and data association construct targets trajectory globally. The Association between detections is then formulated as minimization of cost function. Data association problem can be formulated to achieve global optimum by using linear programming relaxation [10, 15] or minimum-cost flow [11, 16, 17].

C. Deep Learning Multi-Target Tracking

Recent multi-target tracking algorithms based on CNN [18] or Recurrent Neural Networks have been proposed. They show higher performance when compared to handcrafted features. A Siamese CNN [18] was used to estimate likelihood if two pedestrian belong to same entity using images and optical flow as model input. Then they used gradient boosting to combine

features from Siamese CNN features with contextual features. An end-to-end learning with Long Short-Term Memory (LSTM) was proposed in [19] for online tracking. Although this work was the first fully end-to-end learning method based on deep learning. Its performance did not achieve the accuracy of the state-of-the-art methods.

D. Tracking with Correlation Filters

Another recent approach in tracking is based on correlation filters. It starts with a cropped image of the tracker from a given position. After initialization, from every new frame an image patch is cropped from the estimated position. Features is extracted from the cropped image and a cosine function is applied for smoothing the discontinuities at boundary. Afterwards a correlation is computed between input and trained filter in frequency domain. Then apply inverse Fourier transform on correlation to get confidence map which give high values at the estimated target position and low values to the background. These filters can be considered as simple linear classifiers.

A new approach was proposed in [20], where all translated samples collected from target will be used in training the classifier. This enhanced training performance, without sacrificing much speed. Enhancement was done by exploiting circular structure of the kernel matrix. Extended Kernel Correlation Filter was proposed in [21] using both depth and color features. Also depth distribution was used to identify scale changes and reflect these changes in the Fourier domain. Depth was used to detect occlusion based on checking if there are sudden changes in target depth histogram. This approach achieved real time performance as it work on 35 fps. A fast Scalable Kernel Correlation Filter was introduced in [22]. This approach used Gaussian window function to deal with fixed size limitation in the kernelized correlation filter. So it allowed target scale changes and provide better separation around the target. An extensive survey on correlation filters is available at [23], where experiments have been conducted on correlation filters to evaluate the effectiveness and efficiency of different algorithms.

III. PROPOSED ALGORITHM

Taking inspiration from previous approaches in multi-target tracking. The proposed approach is subdivided into two modules: multi-target detection and two step tracking. First step in tracking is based on correlation filters tracker for each target in scene. Each correlation filters learn from hierarchically of convolution features. Second step minimum-cost network flow is applied to link short tracklets from previous step. Our goal is to obtain entire trajectory for each target in the scene. Also each target will be associated with unique ID. Overview of our approach is shown in Fig. 2. Algorithm 1 summarize the proposed approach.

A. Fine-Tune Multi-Target Detector

An end-to-end multi-object detector is adopted which called Fast RCNN. Fast RCNN was trained on PASCAL VOC dataset. Since 2DMOT2015 benchmark is based on pedestrian. A fine-tune step is applied to consider pedestrians only. So softmax layer is changed to only consider two classes: pedestrians and non pedestrians.

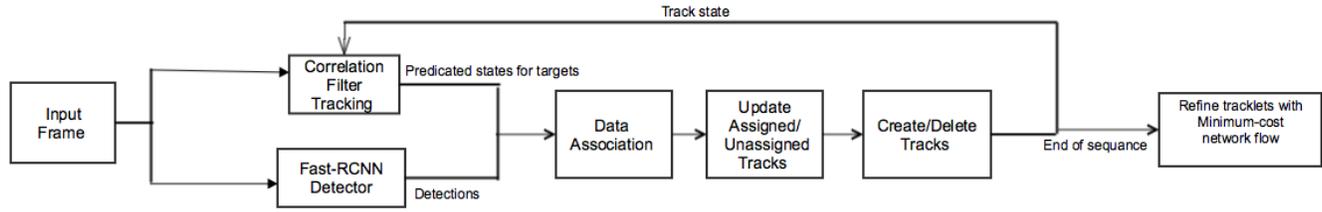


Fig. 2. Detailed description for our system using correlation filter and minimum-cost network flow.

A selective search algorithm is used to generate region proposals for the network. Object detector will measure each proposal region and give each detection a score. Only detections with a score higher than a threshold will be considered as valid. High predefined threshold = 0.9 will cause most pedestrians to remain undetected. However decreasing detection threshold will cause an increase in false positive, which is more severe than missed detections. Final step non-maximal suppression is applied based on bounding box overlap between detections in order to suppress redundant boxes.

B. Correlation Filters Tracking

As mentioned above. Many possible targets states remain undetected. Correlation filters tracking is applied to improve detection. Correlation filters (CF) have attracted a lot of attention in recent years for speed and accuracy. Due to analyzing frames in Fourier domain which lead to faster processing. It has the ability to update appearance model at every frame. CF is a discriminative classifier that learns to separate target from its background. The main idea behind CF tracker is that a learned filter is used to predict target position by searching maximum value in correlation response map. We follow the same mathematical model in model learning [1]. CF learns from features that were extracted from VGG-Net-19 [24] which was trained on imageNet [25]. The proposed algorithm in [1] used output from conv 3-4, conv 4-4 and conv 5-4. Due to pooling operation in VGG-net-19 which cause gradual decrease in spatial resolution. This lead to imprecise target localization. For example convolution feature size of pool4 is 14x14 and in pool5 is 7x7. In order to solve this problem Convolution feature is resized to fixed larger size using bilinear interpolation.

A correlation filter W^l is learned from each convolution map to generate response map, where l indicate number of convolutional maps. Feature vector of l -layer of size $M \times N \times D$ is denoted as x , where M, N and D indicate width, length and height. Output from applying Gaussian function to the circular shifts of x along the M and N dimensions is denoted as y . Each W^l is updated in frame t from previous frame $t-1$ using the numerator A^l and the denominator B^l through the following equations:

$$A_t^l = (1 - \eta)A_{t-1}^l + \eta Y \odot \bar{X}_t^d; \quad (1)$$

$$B_t^l = (1 - \eta)B_{t-1}^l + \eta \sum_{i=1}^D X_t^i \odot \bar{X}_t^i; \quad (2)$$

$$W_t^l = \frac{A_t^d}{B_t^d + \lambda} \quad (3)$$

The capital letters refer to Fourier transformed signals. \odot indicate element wise multiplication and η is a learning rate and λ is a regularization parameter.

The a correlation response map is calculated given new image patch that contain target with the following equation:

$$F^l = IFFT\left(\sum_{d=1}^D W^d \odot \bar{Z}^d\right); \quad (4)$$

where IFFT symbol for inverse Fast Fourier transform .Then target new position can be deduced by searching maximum value of correlation response map.

C. Detection Guidance

We propose cooperation between Fast RCNN detector and CF tracker to handle CF disadvantages such as: scale variation and model drifting problem. As CF doesn't handle scale variation well. We add CF predicted bounding box of targets to region proposals of Fast RCNN. Then use predicted scales to updated targets appearance model. This way the detector will validate CF predictions. Also we use Fast RCNN detector to discover if target disappeared from point of view. We consider detector score, if it's less than predefined threshold. We know that target state is inactive and stop update its appearance model. So this step will prevent model drift that may occur to the tracker. As shown in Fig. 3 and 4.



Fig. 3. Frame i-1.



Fig. 4. Frame i.

Example of detection guidance in our model. At frame $i-1$ we have three targets each assigned an ID and target with ID '1' appear to be leaving the view. At frame i the target '1' disappears. So bounding box disappears.

D. Data Association

Data association goal is to associate between current frame detections and tracks that describe targets paths. This lead to updating each target state and identify the new detections. Each target can belong to a single state. Target state can be one of the following: assigned, unassigned, lost and new.

Hungarian assignment algorithm [26] is used to achieve this task. According to the assignment algorithm results we can determine the following: assigned detections with tracks, unassigned tracks and new detection. In each frame we apply Hungarian algorithm and use cosine similarity as cost measure between current frame detections and predicted target position from CF. Highly overlapped bounding boxes are considered in the association. The cosine similarity is calculated between middle convolution features from output of conv 3-4 layer. Since the middle layer has higher spatial detail which is useful in differentiating between targets. The overlap function between two bounding boxes A,B is calculated as follows:

$$Overlap = \frac{A \cap B}{A \cup B} \quad (5)$$

E. Minimum-Cost Network Flow

This is done as post processing step after the proposed multi-target correlation filters tracking. The integration between Fast RCNN with correlation filters handle low missed detection rate and increase tracker precision. Also our proposed approach can handle some cases of occlusion such as targets occluded by non pedestrian objects or leaving scene. On the other hand we still need to handle recovering target after long occlusion. Also we need to handle the case where target is occluded by other pedestrian. All these issues may cause wrong association and false target model update. We follow batch learning approach to handle these issues, where we can use future detections. Multi-target tracking is formulated with minimum-cost network flow. Matching between detections is solved jointly for all tracklets.

We used modified version of minimum-cost network flow in [12] to refine the resulted tracklets. As it depends on motion cues in the association between detections. Given initial set of tracklets that consists of a set of ordered detections. Motion cues are used to refine those tracklets and link separated short tracklets.

For every detection d in tracklet. Two sets of detections is defined. The first set contains all tracklet detections before d. The second set contains all tracklet detections after d. These two sets are used to determine linear regression coefficients that can predict forward and backward target position. Then cost function that considers residual between the predicted and actual tracklet positions is computed. Finally a minimum-cost network flow solution is computed to produce the final tracklets.

IV. EXPERIMENTS

In the evaluation step 2DMOT2015 [29] benchmark is used to evaluate our multi-target tracking algorithm. A common reference in multi-target tracking task. 2DMOT2015 benchmark is composed of training and testing sets. Training set consists of a 11 sequence with a 40,000 bounding box, while testing

Algorithm 1: Pseudocode of our Proposed Approach

INPUT: Video

OUTPUT: tracklets + bounding box with ID

```
1: for each frame in video do
2:   Detect pedestrian using Fast RCNN
3:   Apply non-maximal suppression
4:   for each correlation filters tracker do
5:     Update target location from proposed regions
6:   end for
7:   Data Assignment based on updates states
8:   for each detection in unassigned detection do
9:     Initialize new correlation filters tracklet
10:  end for
11:  for each tracklet in assigned tracklets do
12:    Update target model from convolutions maps
13:  end for
14:  for each tracklet in unassigned tracklets do
15:    Run Fast RCNN to the predicted location
16:
17:    if detector confidence = Threshold then
18:      Update target model from convolutions maps
19:    else
20:      Delete tracklet
21:    end if
22:  end for
23: end for
24: for each tracklet do
25:   Refine tracklets using motion cue LP optimization
26: end for
```

set consists of 11 sequence with 60,000 boxes. 2DMOT2015 benchmark contains sequences with high target motion variation, camera motion, a different views and person density. Also for fair comparison in tracking task, 2DMOT2015 provide public detections, given by Aggregate Channel Features (ACF) pedestrian detector [30]. In order to be able to compare the proposed work with others, public detections are used as region proposals for the Fast RCNN detector.

The widely accepted CLEARMOT evaluation metrics [31] are employed by 2DMOT2015. To summarize multi-object tracking (MOT) performance the following measures were reported: MOT accuracy (MOTA) measures jointly three errors: false positives (FP), false negatives (FN) and identity switches (IDSwitch). MOT precision (MOTP) measures the misalignment between the detected target locations and ground truth. Also mostly tracked and mostly lost targets percentages (MT and ML) are reported. Furthermore, the IDSwitch ratio between targets is reported.

A. Analysis on MOT Validation Data

In order to train Fast RCNN detector to detect pedestrians. Training data in 2DMOT2015 benchmark are split into two parts to fine-tune our detector: train and validation. Training data include the following sequences: TUD-Stadtmitte, ETH-Bahnhof, ADL-Rundle-6, PETS09-S2L1 and KITTI-13. While testing data include TUD-Campus, ETH-Sunnyday, ETH-Pedcross2, ADL-Rundle-8, KITTI-17 and Venice-2

TABLE I. COMPARISON WITH STATE-OF-THE-ART APPROACHES. THE BEST SCORE ARE BOLDFACED. ARROW UP INDICATE HIGHER IS BETTER. WHILE ARROW DOWN INDICATE LOWER IS BETTER

Algorithm	MOTA \uparrow	MOTP \uparrow	MT \uparrow	ML \downarrow	FP \downarrow	FN \downarrow	IDSswitch \downarrow
oICF [27]	27.1	70.0	6.4 %	48.7 %	7,594	36,757	454
TBX [28]	27.5	70.6	10.4 %	45.8 %	7,968	35,810	759
RNN_LSTM [19]	19.0	71.0	5.5 %	45.6 %	11,578	36,706	1,490
Siamese CNN [18]	29.0	71.2	8.5 %	48.4 %	5,160	37,798	639
ELP [12] (Baseline)	25.0	71.2	7.5 %	43.8 %	7,345	37,344	1,396
Ours multi CF	25.5	71.9	9.3 %	34.4 %	12,344	31,378	2,064
Ours multi CF+minimum-cost n/w	29.5	73.1	12.9 %	36.3 %	11,866	30,474	976

B. Evaluation on MOT Testing Data

In order to be fair in comparing with other approaches. During testing phase, public detections are used which were provided by benchmark as region proposals for Fast RCNN detector. So Fast RCNN will only filter 2DMOT2015 public detections and eliminate false positive. **Baseline comparison** The proposed approach is compared with minimum-cost network flow in [12]. To show the progress achieved by the proposed multi-target tracking algorithm in improving precision and restoring undetected targets states.

The proposed approach is compared against state-of-the art deep learning based approach such as Siamese CNN in [18] and recurrent neural network in [19], as shown in Table.I. Also the proposed approach is compared against approaches based on handcrafted features in [27, 28].

The results show that cooperating Fast RCNN with multi-correlation filters tracker produce high precision and low missed detection rate. Also the benefit of using motion cue with minimum-cost network lowered identity switch which improve the mostly tracked targets rate.

V. DISCUSSION

Training correlation filters with hierarchy of convolution features improves tracker robustness and accuracy. Also cooperating correlation filters with Fast RCNN helps tracker from drifting and scale estimation problem. These lead to low missed detection rate and high tracker precision. The last step in the proposed approach is refining the tracklets while considering motion similarity. However refining tracklets with linear velocity assumption may fail in case of random motion patterns, which lead to false association and increase identity switch between targets. Non linear motion patterns will be considered in future work.

VI. CONCLUSION

In this paper, multi-target tracking algorithm is proposed that exploit features from pretrained convolutional neural network. First Fast RCNN is trained to detect all pedestrians in the scene. Then a correlation filters tracker is proposed to learn target appearance. It learns from hierarchy of convolution features. As middle convolution layers are useful for target localization while last convolutional layer are more robust in handling target appearance changes. Also cosine similarity is used between convolution features in data assignment between tracklets and detections.

Finally to handle correlation filters failure in case of occlusion a minimum cost network is proposed to link short tracklets. Experimental results demonstrate that the proposed algorithm provides competitive performance on the 2DMOT2015 benchmark.

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Machine Learning for Bioelectromagnetics: Prediction Model using Data of Weak Radiofrequency Radiation Effect on Plants

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Abstract—Plant sensitivity and its bio-effects on non-thermal weak radio-frequency electromagnetic fields (RF-EMF) identifying key parameters that affect plant sensitivity that can change/unchange by using big data analytics and machine learning concepts are quite significant. Despite its benefits, there is no single study that adequately covers machine learning concept in Bioelectromagnetics domain yet. This study aims to demonstrate the usefulness of Machine Learning algorithms for predicting the possible damages of electromagnetic radiations from mobile phones and base station on plants and consequently, develops a prediction model of plant sensitivity to RF-EMF. We used raw-data of plant exposure from our previous review study (extracted data from 45 peer-reviewed scientific publications published between 1996-2016 with 169 experimental case studies carried out in the scientific literature) that predicts the potential effects of RF-EMF on plants. We also used values of six different attributes or parameters for this study: frequency, specific absorption rate (SAR), power flux density, electric field strength, exposure time and plant type (species). The results demonstrated that the adaptation of machine learning algorithms (classification and clustering) to predict 1) what conditions will RF-EMF exposure to a plant of a given species may not produce an effect; 2) what frequency and electric field strength values are safer; and 3) which plant species are affected by RF-EMF. Moreover, this paper also illustrates the development of optimal attribute selection protocol to identify key parameters that are highly significant when designing the in-vitro practical standardized experimental protocols. Our analysis also illustrates that Random Forest classification algorithm outperforms with highest classification accuracy by 95.26% (0.084 error) with only 4% of fluctuation among algorithm measured. The results clearly show that using K-Means clustering algorithm, demonstrated that the Pea, Mungbean and Duckweeds plants are more sensitive to RF-EMF ($p \leq 0.0001$). The sample size of reported 169 experimental case studies, perhaps low significant in a statistical sense, nonetheless, this analysis still provides useful insight of exploiting Machine Learning in Bioelectromagnetics domain. As a direct outcome of this research, more efficient RF-EMF exposure prediction tools can be developed to improve the quality of epidemiological studies and the long-term experiments using whole organisms.

Keywords—Machine learning; plants; prediction; mobile phones; base station; radiofrequency electromagnetic fields; RF-EMF; plant sensitivity; classification; clustering

I. INTRODUCTION

Mobile phone technology has exhibited remarkable growth in recent years, heightening the debates on the changes in plant growth due to non-thermal weak radio-frequency electromagnetic fields (RF-EMF). In order to preserve green living

and biodiversity, one of the major ground-level concerns is environmental damage and its effects on plants. Modeling plant sensitivity due to RF-EMF is an important task for both agriculture sector and for epidemiologist, on the other hand, it is a useful tool to assist a better understanding of this phenomenon and eventually advance it. Reported studies showed significant effects on plants that exposed to the radiofrequency radiation or plant sensitivity to the RF-EMF [1].

The fields of machine learning and big data analytics helps to extract high-levels of knowledge from raw data and improve automated tools that can aid the health domain. Machine learning is a key tool in analytics, where algorithms iteratively learn from data to discover hidden insights [2]. It is quite challenging for experts to overlook the important details of billions of data, hence, alternatively, use of automated tools to analyze raw data and extract stimulating high-level information is exceptionally important for the decision-makers [3].

Machine learning techniques have been used in big data analysis; nonetheless, the challenge is to build a prediction model for the data with multiple variables. The raw-data grasps crucial information, such as patterns and trends, which can be used to advance decision-making and optimize achievements. This paper uses machine learning in bioelectromagnetics; that consequently, develops a prediction model of plant sensitivity to RF-EMF.

The controversy or the contention exists about the physiological and morphological changes that affect sensitivity in plants due to the non-thermal weak radio-frequency electromagnetic fields (RF-EMF) effects from mobile phones and base station radiation. On the other hand, the world has been challenged with recent environmental concerns and the loss of green living that has caused dilemma and re-evaluation of implications, especially in agriculture. While developing the country economically, citizens expect political measures to be taken for a greener environment. Nonetheless, one of the major ground-level concerns is external environmental effects on plants. There is a need to understand the trends and patterns that occur in the non-thermal weak radio-frequency electromagnetic field (RF-EMF) and its effects caused by mobile phones and base station radiation activities on plants and trees. Also, it is important to understand the significance of environmental attributes which have impacted the classification algorithm for better prediction. There is no single study that sufficiently covers machine learning concept in bioelectromagnetics domain yet.

This study tries to demonstrate the usefulness of Machine Learning algorithms for predicting the possible damages of electromagnetic radiations on plants and consequently, develops a prediction model of plant sensitivity to RF-EMF. hence, this proposes a novel solution to apply machine learning concepts and techniques by using raw data from our previous review study. Similarly, this study will replicate the former study to validate former study and to perform predictions extracting high-levels of knowledge from raw data using different classifications and clustering algorithms. This study will also presents and outline the following: 1) development of optimal attribute selection protocol to identify key parameters that should be used in in-vitro laboratory experiments; 2) K-mean clustering algorithms to analyze and predict what conditions will RF-EMF exposure impacts plant of a given species may not produce an effect; 3) which frequency and electric field strength values are safer; 4) classification algorithms for prediction of RF-EMF effect on plants species; and 5) the verification of the performance of the classification and clustering algorithms.

II. CLASSIFICATION ALGORITHMS, CLUSTERING ALGORITHMS AND PERFORMANCE EVALUATION METHODS

This section discusses 1) classification framework; 2) classification algorithms (Bayesian Network Classifiers, Naive Bayesian Model Classifier, Decision Table, JRip, OneR, J48, Random Forest, Random Tree); 3) test modes (k-fold Cross-validation, Data Percentage Split Criteria); 4) performance evaluation of classification algorithms (Percentage of Correct Classifications, Root-mean-square error, Confusion Matrix, Time Performance); 5) clustering algorithms (K-Means Clustering, Cannopy Clustering, Expectation Maximization (EM) Clustering, Filtered Clustering, Hierarchical Clustering); 6) performance evaluation of clustering algorithms (Cluster Sum of Squared Error, Silhouette coefficient); 7) data collection; and 8) data analysis, that we used for our analysis.

A. Classification Algorithms

A classification algorithm is used to train a data sets to build a model that can be used to assign unclassified records into one of the defined classes. Classification algorithms are most appropriate for predicting or labeling new data sets (test data) with numeric, binary or nominal categories (nominal data types that represent the text data and ordinal data types that represent the data with pre-defined options). The classification algorithms or techniques are used in this study to predict the expected outcomes are Bayes Net, Nave Bayes, Decision Table, JRip, OneR, J48, Random Forest and Random Tree.

The list of symbols are defined in Table 1. Consider n -dimensional attribute vector $\vec{X} = (X_1, X_2, \dots, X_n)$. Let there be m classes variables $C = \{c_1, c_2, \dots, c_j, \dots, c_m\}$.

1) **Bayesian Network Classifiers (Bayes Net)**: The learning task consists of finding an appropriate Bayesian network [4] given a data set D over \vec{X} .

Using the Bayes theorem ($P(c_j|\vec{X}) = P(c_j)p(\vec{X}|c_j)/\left[\sum_j P(c_j)p(\vec{X}|c_j)\right]$), Bayesian classification, C_{BN} or (h_b) is given by

$$C_{BN} = h_b(\vec{X}) = \arg \max_{j=1, \dots, m} P(c_j)p(\vec{X}|C_j) \quad (1)$$

TABLE 1. LIST OF SYMBOLS AND DESCRIPTIONS

Symbol	Description
D	Dataset
N	Number of labels
C	Number of class variables, i.e., $C =$ (changed, unchanged)
\vec{X}	Attribute vector $\{F, SAR, P, E, T, p\}$
\vec{X}_1	$\{F_1, SAR_1, P_1, E_1, T_1, p_1\}$, First instance
\vec{X}_2	$\{F_2, SAR_2, P_2, E_2, T_2, p_2\}$, Second instance
Ω_x	Map x^{th} instance (data point)
Ω_c	Value of c^{th} classifier (class label)
h_c	Hypothesis that correctly predict classification
c_j	j^{th} classifier
D_i^t	Training data set
s	Cross-validation number (e.g. $S \in 5, 10, 20$)
D_i	i^{th} data partition for cross validation
a_i	Actual value of i^{th} instance
p_i	Predicted value of i^{th} instance
F	F-measure or harmonic mean
r	Recall or sensitivity
p	Precision
K	The number of clusters
E_{ss}	Cluster sum of squared error
cl_K	Centroid off the K^{th} cluster
s_i	Set of objects in the i^{th} cluster
x_i	An object or i^{th} attribute vector
μ_i	Center point of the i^{th} cluster
M	Maximization step
E	Expectation step

where $P(c_j)$ is “a priori” or prior probability distribution and $p(\vec{X}|C_j)$ is the conditional probability density. For example, for 2 class problem (c_1, c_2) Bayes rule is given by:

$$C_{BN} = \begin{cases} c_1 & P(c_1|\vec{X}) > P(c_2|\vec{X}) \\ c_2 & \text{otherwise.} \end{cases}$$

2) **Naive Bayesian Model Classifier (Naive Bayes)**: This is based on the Bayesian theorem and uses the method of maximum likelihood for attribute estimation. Naive Bayesian Model classifier (Naive Bayes) [5] requires a small amount of training data to predict the data attributes. The Naive Bayes classifier predicts whether \vec{X} belongs to class c_i , if $p(c_i|\vec{X}) > p(c_j|\vec{X})$ for $1 \leq j \leq m$. Using Bayes’ theorem, the maximum posteriori hypothesis is given by $p(c_i|\vec{X}) = p(c_i)p(\vec{X}|c_i)/p(\vec{X})$. This maximize $p(c_i)p(\vec{X}|c_i)$ and $p(\vec{X})$ is a constant. If we have many attributes, it is computationally costly to evaluate $p(\vec{X}|c_i)$. Hence, Naive assumption of “class conditional independence” is given by $p(\vec{X}|c_i) = \prod_{k=1}^n p(X_k|c_i)$.

3) **Decision Table**: Decision table classification algorithm can be efficiently used to decide the most important attributes

in a given dataset [6]. This evaluates feature of subsets by using best-first search and cross-validation mode that can be used for evaluation. In this method, attributes are not considered as an independent that is differentiated, from a verified model.

4) **JRip**: This classification algorithm implements a propositional rule, “Incremental Pruning is to Produce Error Reduction” (RIPPER), which uses sequential covering algorithms for creating ordered rule lists [7]. The algorithm goes through a few stages: building (growing, pruning), optimization and selection [7].

5) **OneR**: A simple classification algorithm that produces one rule for each predictor in the data and uses the minimum-error attribute for prediction [8].

6) **J48**: The J48 is a classification algorithm generates decision tree which generates a pruned or unpruned C4.5 decision tree [9] and is used for the classification of the data.

7) **Random Forest**: Random forests classification algorithm considers amalgamation of tree predictors (each tree depends on the independent values of a random vector sampled) and uses similar distribution for all trees in the forest [10]. When a number of trees in the forest become large, the generalization error for forests converges to a limit. This error of the forest tree classifiers depends on the vigour of the individual trees as well as the correlation between them [11].

8) **Random Tree**: Random Tree classification algorithm [12] uses a class for building a tree, which considers x randomly chosen attributes at each node and it does not perform pruning. Furthermore, it has an option to estimate the class probabilities established on a hold-out set or back-fitting.

B. Test Modes

Cross-validation is a technique used for estimating the error (accuracy) of the algorithm. This works by splitting the data into k subsets of approximately equal size. The performance evaluation method of eight classifiers or classification algorithms (described above) were obtained by using two different test modes: k -fold cross-validation and percentage split. Hence, for this paper, 10-fold cross validation and data percentage split criteria are used for model assessment.

1) **K-fold cross-validation (k -foldcv)**: The k -foldcv splits the data set D in s equal parts D_1, \dots, D_s , where typical values for s are 5, 10 and 20. Here training data set D_i^t is given by removing i^{th} data portion, D_i from D with $s = N$, k -fold cross-validation. Each data point used once for testing and $s - 1$ times for training. When $s = N$, k -fold cross-validation becomes $loo - cv$. For an example, in this work, we use k -fold cross-validation ($k = 10$) method. Hence, these splits the data into 10 equal parts then uses first 9 parts for training and the final fold is for testing purposes.

2) **Data percentage split criteria**: The data percentage split mode is a mode that splits the dataset into training data and testing it with different percentage ratios. In this test mode, the identified percentage of the train data: test data split ratio, e.g., 90%:10%, 80%:20%, etc.

C. Performance Evaluation Methods of Classification Algorithms

Outputs are then compared to understand the classifier performances using: 1) percentages of correctly classified instances (PCC); 2) mean absolute error (MAE); 3) root-mean-squared error (RMSE); 4) confusion matrix; and 5) computational time or CPU time (sec). For the confusion matrix we considered True Positive (TP) Rate, False Positive (FP) Rate, Precision (p), Recall (r) and F-measure (F).

1) **Percentage of correct classifications (PCC)**: The classification algorithms are frequently evaluated using the percentage of correct classifications (PCC) and this is denoted as:

$$\Psi(i) = \begin{cases} 1 & \text{if } a_i = p_i \\ 0 & \text{else} \end{cases}$$

where a_i denotes the actual value and p_i denotes the predicted value for the i^{th} instance. Using $\Psi(i)$, PCC is defined,

$$PCC = \sum_{i=1}^n \Psi(i) / N \times 100\%. \quad (2)$$

2) **Mean absolute error (MAE)**: In this analysis, we calculated the average of the absolute errors: MAE, where is the prediction forecasts and the true value. If the prediction instances are p_1, p_2, \dots, p_n and actual values are a_1, a_2, \dots, a_n . Mean absolute error of testing data value is given by $(p_i - a_i) +, \dots, +(p_n - a_n) / n$ for n different predictions.

3) **Root-mean-square error (RMSE)**: The root mean squared error (RMSE) is a popular metric [13]. A large PCC (i.e. near 100%) suggests a suitable classifier, while a regressor should exist a low global error (i.e. RMSE close to zero). Root-mean-square error (RMSE) = $\sqrt{\sum_{i=1}^n (p_i - a_i)^2 / n}$ for n different predictions.

4) **Confusion matrix**: We also calculated the rate of each classifier that we used to predict the actual plant sensitivity and see if it changes using test data. Moreover, the weighted average of precision (p), recall (r) and F-Measure (harmonic mean) are obtained by using the 10-fold cross-validation approach.

Prediction model is defined using Confusion Matrix [14] as, 1) true positive, TP or correct hit (actual plant sensitivity changes in instances that were correctly classified), 2) true negative, TN or correct rejection (non-sensitivity changes in instances that were not classified as changes), 3) false positive, FP or the false alarm (non-sensitivity changes instances that were classified as changes, Type II error), and 4) false negative, FN or a miss (actual plant sensitivity changes in instances that were not classified as changes, Type II error). For prediction, p is the percentage of predictive items that are correct where $p = TP / (TP + FP)$; and 2) recall or sensitivity, r is the percentage of correct items that are predicted where $r = TP / (TP + FN)$. The F -measure, the harmonic mean of p and r , can be calculated as $F = 2pr / (p + r)$.

5) **Time performance (CPU time)**: CPU time, in this case, the time taken to build a model [14], was calculated for every algorithm (both clustering and classification). Time taken to build model was observed to identify their characteristics in

the tool. Classification algorithms are used to train a data set to build a model, and then the model can be used to allocate unclassified records into one of the well-defined classes. A test set is used to decide the accuracy of the model. Usually, the given data set is divided into the training data and tests data sets. The training set is used to build the model and test sets are then used to validate it.

D. Clustering Algorithms

Clustering is the task of grouping a set of data instances in a way that it assigns the data instances to the same group (intra-cluster) that is more alike to each other than to those in other groups (inter-clusters) [15]. Clustering is a common form of unsupervised learning, where no human expert who has assigned data to clusters ever before. Moreover, unsupervised learning methods do not construct a hypothesis prior to this analysis [16]. The clustering algorithms or techniques used in this study are: Simple K-Means, Cannopy, EM, FathestFirst, Filtered Clusterer and Hierarchical Clutterer. These are to create clusters with a set of similar behavioral points that are consistent internally.

1) **K-Means Clustering:** Here we use K-Means clustering algorithm to discover sensitive plants to RF-EMF. Consider a set of instances (attribute vector) x_1, x_2, \dots, x_n and K clusters where $\vec{K} = (K_1, K_2, \dots, K_r)$. Denote the centre of the clusters (centroids) as cl_1, cl_2, \dots, cl_K , where cl_K is centroid of K^{th} cluster. Initially, each centroid will be randomly placed. The Euclidean distance between i^{th} data point, x_i , in cluster and cluster centre cl_j is $\arg \min_j \|x_i - cl_j\|$ to calculate nearest centroid where x_i is the i^{th} data instance (attribute vector) in K^{th} cluster. For each cluster $j = 1, \dots, K$ we calculate cluster centre

$$cl_j(a) = \frac{1}{n_j} \sum_{x_i \rightarrow c_j} x_i(a)$$

for $a = 1, 2, \dots, d$. Hence, each instance (e.g. attribute vector X_1) will be assigned to a cluster with the nearest centroid. Each centroid will be moved to the mean of the instances assigned to it. The K-Means clustering algorithm [17] continues until no data point changed the cluster membership, and then we stop the algorithm as it has converged. After the clustering is completed, we calculate the distance between a data point and a cluster centroid.

2) **Cannopy clustering:** The canopy clustering algorithm is an unsupervised pre-clustering algorithm that is usually used as the pre-processing step for the Hierarchical clustering algorithm or K-Means algorithm. This algorithm speeds up clustering procedures on large data sets [18].

3) **Expectation Maximization (EM) clustering:** The EM iteration swaps between performing an expectation (E) step and a maximization (M) step. During the step E it constructs a function for the expectation of the log-likelihood using the current estimate for the attributes. During the step M it calculates attributes maximizing the expected log-likelihood discovered during the step E [19]. This expectation maximization is used to establish the distribution of variables and continues until it gets the optimal value.

4) **Filtered clustering:** This clustering method uses an arbitrary clusterer on data that has been approved through an arbitrary filter. The structure of the filter is totally based on the training data points and test data points that will be managed by the filter without changing their structures [14].

5) **Hierarchical clustering:** This method [20] follows a collection of closely related clustering algorithms that produce a hierarchical clustering by merging two closest clusters until it becomes a single set. This divides a data set into the sequence of nested partitions.

E. Performance Evaluation Methods of Clustering Algorithms

We then evaluate the performance of how well each data point places within its cluster using each clustering algorithm by using three methods: 1) Cluster Sum of Squared Error (E_{ss}); and 2) Silhouette coefficient; and 3) Time performance (CPU time). The evaluation is based on log-likelihood, if clustering scheme creates a probability distribution [21].

1) **Cluster Sum of Squared Error (E_{ss}):** Given a set of data points, cluster sum of squared error (E_{ss}) is given by

$$E_{ss} = \sum_{i=1}^K \sum_{\beta \in s_i} \|\beta - \mu_i\|^2$$

where s_i set of objects in the i^{th} cluster ($i = 1, 2, \dots, K$) and μ_i is the center point of the i^{th} cluster, β is a data instances in cluster s_i .

2) **Calculate Optimal Number of Clustering using Silhouette Coefficient:** Silhouette signifies to a method of explanation and justification of consistency within clusters of data and it is a quantitative method to evaluate the quality of a clustering. The algorithm provides a concise graphical representation of how well each data point places within its cluster [22]. Data points to a high silhouette value are considered satisfactory clustered, oppose to, the data points with a low value could be outliers. This method works well with K-Means clustering, and it is also used to define the optimal number of clusters, hence, we use this method for cluster evaluation.

III. MATERIALS AND METHODS

This section discusses materials and methods used for this study: 1) classification framework; 2) data collection; 3) data analysis; and 4) statistical analysis. Fig. 1 shows the steps by step procedure to analyze the dataset (Algorithms 2 and 3), and how machine learning could implement in Bioelectromagnetics that are used. This is further explained in Algorithm 2 (an adaptation of classification algorithm) and Algorithm 3 (an adaptation of clustering Algorithm) for plant sensitivity to RF-EMF. The list of symbols is defined in Table 1 and attributes that we used for this analysis are shown in Table 2.

As explained in our previous review study (Halgamuge, 2016), in this study, physiological or morphological effects of plants (bio-effects) or plant response (changed/unchanged or effect/no effect) due to exposure to weak radiofrequency radiation from mobile phones and base station is defined as the changes in 1) plant growth rate; 2) seed germination rate (primary shoot and root length); 3) thermographic imaging;

4) carbohydrate metabolism; 5) oxidative damage/stress; 6) gene expression; 7) DNA damage; 8) reactive oxygen species (ROS); 9) cell function, enzyme activities; 10) mitotic index and mitotic abnormalities; 11) mutation rates and genomic stability; 12) pigmentation (chlorophyll concentration); and 13) chromosomal aberrations and micronuclei.

TABLE 2. ATTRIBUTE DESCRIPTION USED FOR ANALYSIS

Attribute	Symbol	Type	Description (Domain)
Plant	p	Nominal	29 different plant types
Frequency	F	Numeric	00 - 8000 (MHz)
SAR	SAR	Numeric	0 - 50 (W/kg)
Power Flux Density	P	Numeric	0 - 50 (W/m ²)
Electric Strength	Field E	Numeric	0 - 100 (V/m)
Exposure Time	T	Numeric	0 - 6 years
Response	R	Binary	Changed or Unchanged

The list of symbols is defined in Table 1 and attributes that we used for this analysis are shown in Table 2.

A. Classification Framework

One of the key machine learning tasks is classification. The main task of classification is learning a target function f which maps each attribute sets and mapping an input attribute set Ω_x into its appropriate class label Ω_c . Although the classification is made by generating a predictive model of data, interpreting the model normally offers information for distinguishing labeled classes in data [13]. In this paper, we used 2 class variables: plants growth responses that are changed or unchanged due to non-thermal weak RF-EMFs.

Consider a data set D with N labeled and C classifiers. Then the data split into two parts: training data (used to train the classifier) and test data (used to estimate the error rate of the trained classifier). Train data is used to learn the algorithm and to test data set that will only be accessible during the classifier prediction. Classifier is a mapping method from unlabeled instances (new data points) to classes (in our case, 2 class variables: changed or unchanged). Hence, define a classifier as a function (f) assigns a class variables $C \in \Omega_c = \{c_1, c_2, \dots, c_m\}$ to objects described by a set of attribute variables such that $\vec{X} \in \Omega_x = \{X_1, X_2, \dots, X_n\}$ (n dimensional attribute vector), then map $f : \Omega_x \rightarrow \Omega_c$, (x^{th} instance to c^{th} classifier). The classification can be divided into two phases: learning phase to train data and classification phase for test data. A classifier $h : \Omega_x \rightarrow \Omega_c$ is a function that maps an instance of Ω_x to a value of Ω_c . Now consider the classifier or the hypothesis (h_c) that can correctly predict the classification of the new scenario and its a function that maps an instance $h_c : \Omega_x \rightarrow \Omega_c$ ($\vec{X} \rightarrow y$).

The classifier is learned or becomes proficient from a data set D consisting of samples, (Ω_x, Ω_c) . Given the probability $P(c_j|\vec{X})$ where x belongs to a certain class rather than a simple classification. Here \vec{X} is a n -dimensional attribute vector. Then we map $\vec{X} \rightarrow P(C|\vec{X})$, $j = 1, \dots, m$

$$\lim_{j=1, \dots, m} P(c_j|\vec{X})$$

where c_j is the j^{th} classifier. Finally, classification is defined as

$$C = h_c(\vec{X}) = \arg \max_{j=1, \dots, m} P(c_j|\vec{X}). \quad (3)$$

Example: Consider attributes: frequency (f_1), specific absorption rate (SAR_1), power flux density (p_1), electric field strength (E_1), exposure time (T_1), biological material (m_1). So, consider two new data attributes vectors: $\vec{X}_1 = \{f_1, SAR_1, p_1, E_1, T_1, m_1\}$ and is the first instance and $\vec{X}_2 = \{f_2, SAR_2, p_2, E_2, T_2, m_2\}$ in the second instance. The binary type of class variables, i.e., $C =$ changed, unchanged will be used. Now, considering the classifier that can correctly predict the classification of the new scenario then the classification could be selected as one of the two class variables (changed, unchanged) to allocate to each instances \vec{X}_1 and \vec{X}_2 , based on how classification algorithm calculates the probabilities of predicting that option.

B. Data Collection

The raw-data holds crucial information, such as patterns and trends, that can be used to improve decision-making and optimize the achievements. This paper used raw-data of plant exposure from our previous review study [1] (extracted data set from 45 peer-reviewed scientific publications (1996-2016) with 169 experimental observations carried out in the scientific literature, e.g. [23] and performed prediction extracting high levels of knowledge from raw data using different classification algorithms and performance evaluation methods. Moreover, we used these data sets for clustering algorithms. The collected dataset comprises of 8 attributes and 169 experimental case studies or instances.

C. Data Analysis

In our analysis, we considered the class variables, attributes (characteristics), classification algorithms, performance evaluation methods of classification algorithms, clustering algorithms, performance evaluation methods of clustering algorithms, as shown in Table 3.

D. Statistical Analysis

The statistical significance is a technique that does not vary in outcome when applying it to the same dataset. All studies require a statistically significant method to analyze their data to come up with the final analysis of whether the hypothesis of the radio frequency radiation affects the plants or not. In order to detect whether or not a frequency may have an effect on plant sensitivity, we performed clustering algorithms, as outlined in Section II. We perform cluster analysis tests to observe whether *intra-cluster-variance* (V_{intra}) of some data points are smaller compared to *inter-cluster-variance* (V_{inter}). We consider variability among mean of the sum of squared distances within groups which are smaller than distances between the groups. Hence, the null hypothesis (H_0) in this analysis is that there are no subsets of observed data that are more alike to each other than the rest of the data, in other words, cluster analysis tests whether *intra-cluster-variance* (V_{intra}) of some data points are small compared to *inter-cluster-variance* (V_{inter}). The alternative hypothesis (H_A) is that the probabilities are statistically different. In

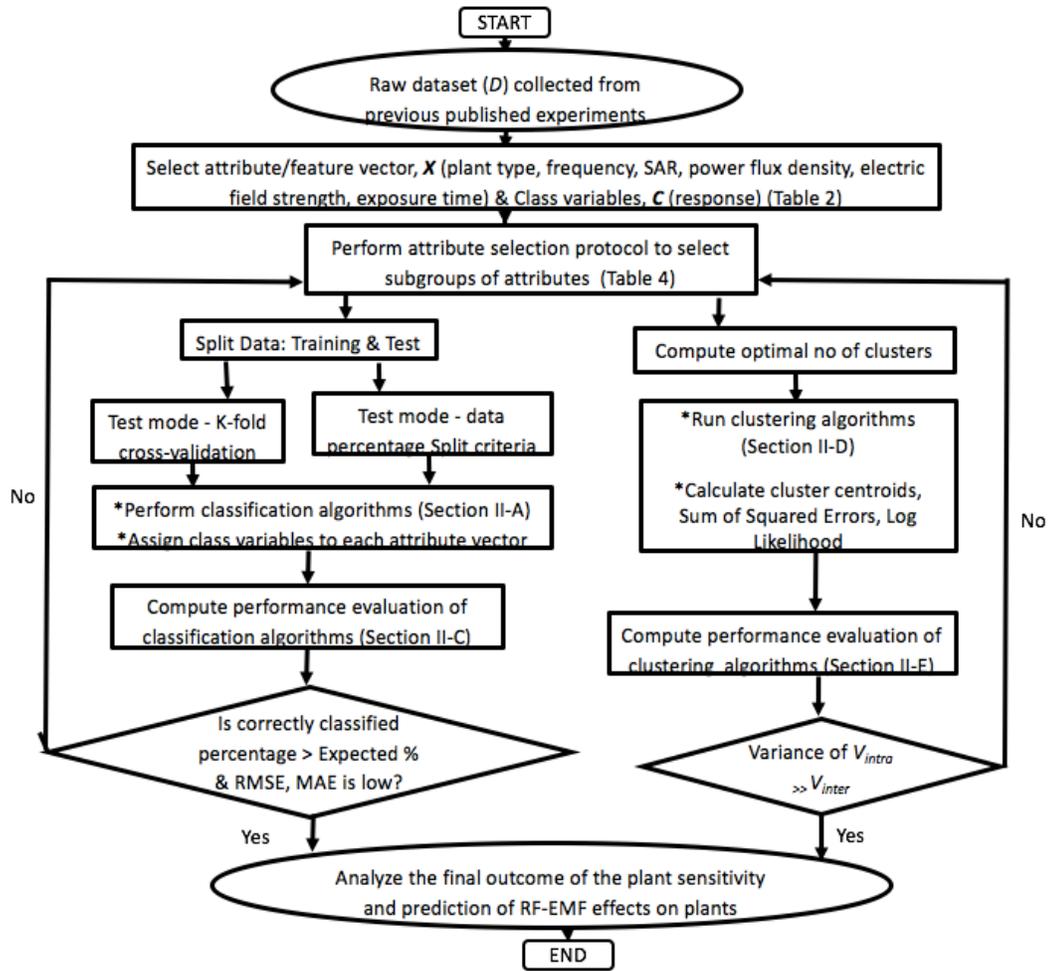


Fig. 1. Plant sensitivity to RF-EMF analysis and prediction tool (Tables 2, 3, and 4)

TABLE 3. LIST OF PARAMETERS USED IN THE PROPOSED RF-EMF DATA ANALYSIS

Type	Number	Description
Data Instances	169	Data from 169 published studies gathered in our previous work [1]
Class variables	2	Changed, Unchanged
Attributes	6	Plant, frequency, SAR, power flux density, electric field strength, exposure time
Classification algorithms	8	Bayes net, NaiveBayes, Decision Table, JRip, OneR, J48, Random Forest and Random Tree
Performance evaluation methods of classification algorithms	5	Percentage of Correct Classifications (PCC), Mean absolute error (MAE), Root-mean-square error (RMSE), Confusion Matrix, Time performance (CPU time)
Clustering algorithms	6	Simple K Mean, Cannopy, EM, FathestFirst, Filtered Clusterer, Hierarchical Clutterer
Performance evaluation methods of clustering algorithms	2	Cluster Sum of Squared Error (E_{ss}), Time performance (CPU time)

Algorithm 1 : Optimal Attribute Selection

- 1: **Load** raw Dataset D
- 2: **Split** Data into \Rightarrow *Training : Test*
- 3: **Load** $\vec{X} \in \Omega_x = \{f, SAR, P, E, T, p\}$ (complete attribute vector)
- 4: **Find** all compulsory attributes \Rightarrow in-vitro experiments
- 5: **Select** sub-set of attribute vector $\vec{x}_j < \vec{X}$ (e.g. Case A, Case B)
- 6: **Select** classification algorithm
- 7: **Perform** attribute selection protocol to select subgroups of attributes
- 8: **for** $\forall \vec{x}_j$ **do**
- 9: **Run** classification algorithm
- 10: **Evaluate** both test modes **do**
- 11: Select Test mode: *K-fold cross-validation*
- 12: Select Test mode: *Data Percentage Split Criteria*
- 13: **end for**
- 14: **Select** attribute set \Rightarrow Training : Test score is minimized
- 15: **Allocate** model type (Case A, Case B) for each attribute vector, \vec{X}
- 16: **End**

TABLE 4. EXPERIMENTAL PROTOCOL FOR SELECTION OF SUBGROUPS OF APPROPRIATE ATTRIBUTES (ALGORITHM 1): THE VARIOUS SCENARIOS OF ATTRIBUTES SELECTION (PARAMETER) FOR CLASSIFICATION AND CLUSTERING ANALYSIS

Model Type	Plant	Frequency	SAR	Power Flux Density	Electric Field Strength	Exposure Time
Case A	Yes	Yes	Yes	Yes	Yes	Yes
Case B	Yes	Yes	Yes	Yes	Yes	Yes
Case C	-	Yes	Yes	Yes	Yes	Yes
Case D	Yes	Yes	-	Yes	Yes	Yes
Case E	Yes	Yes	Yes	Yes	-	Yes
Case F	-	Yes	-	Yes	-	Yes
Case G	-	Yes	Yes	Yes	Yes	Yes
Case E	Yes	Yes	-	Yes	Yes	Yes
Case I	Yes	Yes	Yes	Yes	-	Yes
Case J	Yes	Yes	-	Yes	Yes	Yes

this analysis, 95% of confidence level ($p < 0.05$) to estimate statistical significance. The null hypothesis is rejected if $y < 0.05$ i.e. at confidence level ($p < 0.05$). This study we use cluster sum of squared error (E_{ss}), hence, the hypothesis is given as

$$H = \begin{cases} H_o & \text{if } V_{intra} \text{ of } E_{ss} \gg V_{inter} \text{ of } E_{ss} \\ H_A & \text{otherwise.} \end{cases}$$

The MATLAB (MathWorks Inc., Natick, MA, USA) R2015b, one-way ANOVA procedure in SPSS Statistics (Version 23) and Weka tool (Waikato Environment for Knowledge Analysis, Version 3.9) have been used to carry out analysis on a computer with an Intel Core Intel Core i7 CPU.

IV. RESULTS

This section briefly explains the results and the aim of this study to develop a tool using machine learning to analyze data in bioelectromagnetics domains. In order to measure plant sensitivity to non-thermal weak RF-EMF, the different classification and clustering algorithms are used. We have used extracted data from the 45 peer-reviewed scientific publications published between 1996-2016 with 169 experimental case studies carried out in the scientific literature with 6 attributes and 2 class variables to analyze the prediction performance of algorithms. For our evaluation, we used 8 classification algorithms specifically using 2 test modes, 5 performance evaluation methods of classification algorithms, 6 clustering algorithms, 2 performance evaluation methods of clustering algorithms.

A. Attribute Selection

Our proposed attribute selection protocol (ten different cases, as shown in Table 4) and performed it under 10 different scenarios to observe the highest important attribute that demonstrates certain aspects of the proposed method. Tables 4 and 5 demonstrates *Case C* (frequency, SAR, power flux density or electric field strength and exposure time) attribute group is the more appropriate parameter group to predict most correctly classified instances. The optimal attribute selection protocol is beneficial to identify key parameters that should be used in in-vitro laboratory experiments.

Algorithm 2 : Adaptation of Classification Algorithm for Plant Sensitivity to RF-EMF

- 1: Collect raw dataset D with C classifiers
- 2: Select attribute vector, $\vec{X} \in \Omega_x = \{f, SAR, P, E, T, p\}$
- 3: Select class variables $C \in \Omega_c = \{c_1, c_2, \dots, c_m\}$
- 4: Select classification algorithms, a_1
- 5: Perform attribute selection protocol to select subgroups of attributes
- 6: **Repeat**
- 7: **for** all attribute selection protocols Class A to Class J **do**
- 8: **for** classification algorithms $a_1 = 1, 2, 3, \dots, p$ **do**
- 9: **for** both test modes **do**
- 10: Select Test mode: *K-fold cross-validation*
- 11: Select Test mode: *Data Percentage Split Criteria*
- 12: **for** all dataset D **do**
- 13: **Split** Data into \Rightarrow *Training : Test*
- 14: Perform classification algorithm
- 15: Assign class variable using classifier to each attribute vector, $h : \Omega_x \rightarrow \Omega_c$
- 16: **end for**
- 17: **end for**
- 18: Compute Percentage of Correct Classifications (PCC)
- 19: Compute Mean absolute error (MAE)
- 20: Compute Confusion Matrix
- 21: Compute Time Performance (CPU time)
- 22: **if** PCC < 80%
- 23: **else if** MAE > 1
- 24: **else if** CPU Time > 1 sec **then**
- 25: **stop**
- 26: **end for**
- 27: Select next attribute set
- 28: **end for**
- 29: **until** there is attribute selection protocol to test

B. Classification

In this subsection, we further analyze RF-EMF sensitivity it caused on the plants using classification algorithms. Ten test cases (as in Table 4) were designed to demonstrate certain aspects of the proposed method. After carrying out the Multi-variate Analysis of plants, six classification algorithms (Bayes

Algorithm 3 : Adaptation of Clustering Algorithm for Plant Sensitivity to RF-EMF

```
1: Collect raw dataset  $D$ 
2: Select attribute vector,  $\vec{X} \in \Omega_x = \{f, SAR, P, E, T, p\}$ 
3: Select clustering algorithms,  $a_2$ 
4: Perform attribute selection protocol to select subgroups of
   attributes
5: Repeat
6: for all attribute selection protocols Class  $A$  to Class  $J$  do
7:   for classification algorithms  $a_1 = 1, 2, 3, \dots, q$  do
8:     Compute optimal number of clusters using silhouette
       coefficient
9:     Calculate cluster centroid,  $cl_1, cl_2, \dots, cl_K$  where
        $\arg \min_j \|x_i - cl_j\|$ 
10:    Calculate distances between data points and a cluster
      centroid
11:   for No of Clusters  $K = 1, 2, \dots, K$  do
12:     Compute Cluster Sum of Squared Error ( $E_{ss}$ )
13:     Compute Time Performance (CPU time)
14:     if  $V_{intra}$  of  $E_{ss} \gg V_{inter}$  of  $E_{ss}$  then
15:        $H_0$ 
16:     else  $H_A$ 
17:     end if
18:   end for
19: end for
20: Select next attribute set
21: end for
22: until there is attribute selection protocol to test
```

Network, J48, JRIP, Naive Bayes, OneR and PART) were used to make the best predictions for the given dataset. In order to test each algorithm, mainly three different testing techniques were used: using 1) full training set; 2) cross-validation with 10 folds; and 3) percentage split. Table 5 shows the correctly classified percentages of each classification algorithm.

This study has found that the Random Forest algorithm shows a high percentage of accuracy by 95.26% (0.084 error) with only 4% of fluctuation among algorithm measured. We also used Nave Bayes algorithm and found the least classification percentage. Hence, we removed it from tables. We developed an optimal attribute selection protocol and performed it under 10 different scenarios to observe the most important attribute (parameter) for classification and clustering. This is vital to identify key parameters that are highly significant in the in-vitro laboratory experiments. The protocol of various scenarios is described in Table 4. The optimal attribute selection protocol is vital to identify key parameters that are highly significant when designing the in-vitro practical standardized experimental protocols.

1) Changed or unchanged prediction: k-fold cross-validation of raw data method: This work has used k-fold cross-validation ($k = 10$) method. This method splits the data into 10 equal parts and then uses the first 9 parts for training, and final fold is for testing purposes. The classification model performance uses a confusion matrix-10-folds cross-validation method (Table 6) shows a comparative study between the classifiers to obtain which classifier is the best for the given dataset. Computational time seems to be low due to the smaller sample size. The obtained results reveal that (Table

5) the Random Forest algorithm is the most accurate and most suitable classification algorithm to be used in effect of the plant for their further data analysis and predictions. Random Forest classification algorithm outperforms with highest classification accuracy by 95.26% (0.084 error) followed by JRip with 94.08% (0.235 error) and Bayes Net with 94.08% (0.2349 error) (Table 5). Table 6 shows a comparative study between the classifiers. The weighted average values of changed or unchanged prediction were considered by using “Case C” parameter selection, as shown in Table 4.

2) Changed or unchanged prediction: percentage split of raw data method: The dataset was verified by splitting the data into different percentages whereas Train%: Test%. In this technique, the model will be trained and constructed with a certain percentage of data and then tested with the rest of the percentage. Table 7 shows the correctly classified percentage of each classification algorithm. The bold values are marked as the best within the classification type. According to this analysis, Bayes net and Random Forest algorithms show the high percentage of accuracy. Our results suggest to disregard differentiating plant type (i.e. tomato, soybean) then the classification prediction accuracy is the highest (Table 5). The classification results (PCC values (%)) and RMSE values are in the bracket, underline is the best model, bold values are the best within the classification type (Table 7). The “Case C” data set has been used for this analysis (Test mode: Percentage Split test method (Train Data: Test Data)).

Considering the classification of algorithms, Random Forest gives the best results with a strong connection among attributes. Nevertheless, the overall of all eight algorithms demonstrates good results. For instance, results show that the fluctuation among the correctly classified percentages of algorithms is less than 4%.

C. Clustering

In this sub-section, we try to find data points from our datasets with similar behaviors in groups. Six clustering algorithms were used to cluster the data sets from 169 experimental records. Evaluation of different clustering algorithms is shown in Table 8. It is visually clear that there are three distinct clusters. Moreover, we visualized the potential clusters using Simple K-Means clustering algorithm. The K-Means is the simplest clustering algorithm among all the clustering methods. Hence, we used it for visualizing the clusters. Table 8 shows 1) the cluster instances and percentages of 2 clusters; 2) CPU time, a number of iterations, log-likelihood value, and cluster sum of squared error (E_{ss}) for the different clustering algorithms. The optimal number of clusters were obtained using Silhouette value. Our analysis gives optimal results when $K = 3$ (Fig. 2 and 3). Cluster sum of squared error (E_{ss}) for K-Means clustering was 148.08 and Filtered cluster method also shows the same error. Log-likelihood value for Expectation Maximization clustering (EM) method was -37.42.

Table 9 shows Duckweed is the most common plant species that is very sensitive to RF-EMFs in any given number of clusters. We also observed that when $K = 4$, Duckweed species repeatedly shows the sensitivity to RF-EMF in more than one cluster. Using optimal clustering ($K = 3$, silhouette plots (Fig. 2 and 3)), our data showed Duckweeds, Mungbean,

TABLE 5. CLASSIFICATION RESULTS (PCC VALUES (%) AND RMSE VALUES ARE IN BRACKET, UNDERLINE IS THE BEST MODEL, BOLD VALUES ARE THE BEST WITHIN THE INPUT SETUP. TEST MODE: 10-FOLD CROSS VALIDATION METHOD)

Classification Type	Case A	Case B	Case C	Case D	Case E	Case F	Case G	Case H	Case I	Case J
Bayes net	93.49% (0.2370)	92.89% (0.2447)	94.08% (0.2349)	93.49% (0.237)	94.08% (0.2298)	93.49 % (0.2295)	87.57% (0.2587)	92.89% (0.2447)	92.89% (0.2385)	92.89% (0.2447)
NaiveBayes	73.96% (0.4204)	55.62% (0.5216)	59.17% (0.5201)	77.51% (0.408)	92.89% (0.2654)	88.16% (0.3300)	44.37% (0.6212)	54.43% (0.5188)	90.53% (0.2947)	54.43% (0.5188)
Decision Table	92.31% (0.2522)	92.89% (0.2431)	93.49% (0.2465)	92.30% (0.2522)	92.30% (0.2524)	94.08% (0.2377)	94.08% (0.2375)	92.899% (0.2431)	92.89% (0.2433)	92.89% (0.2431)
JRip	94.08% (0.2345)	94.08% (0.2347)	94.08% (0.235)	92.89% (0.2525)	94.67% (0.2224)	94.67 % (0.2234)	94.08% (0.2355)	94.08% (0.2347)	94.08% (0.2351)	94.08% (0.2347)
OneR	88.16% (0.344)	88.16% (0.344)	93.49% (0.2551)	88.16% (0.3440)	88.16% (0.3440)	94.67 % (0.2308)	94.67% (0.2308)	88.16% (0.344)	88.16% (0.3440)	88.16% (0.344)
J48	93.49% (0.2457)	94.67% (0.2233)	92.30% (0.2686)	93.49% (0.2457)	93.49% (0.2469)	94.67 % (0.2224)	94.67% (0.2224)	94.67% (0.2233)	93.49% (0.2461)	94.67% (0.2233)
Random Forest	94.08% (0.2222)	94.08% (0.2243)	<u>95.26%</u> (0.084)	94.08% (0.2251)	94.08 % (0.2232)	94.67 % (0.2291)	94.67% (0.2272)	93.49% (0.2269)	94.08% (0.2263)	93.49% (0.2269)
Random Tree	93.49% (0.2478)	92.89% (0.2595)	92.89% (0.2556)	94.08% (0.2382)	94.67 % (0.2249)	91.12 % (0.2858)	91.12% (0.2908)	93.49% (0.2475)	94.08% (0.2374)	93.49% (0.2475)

TABLE 6. CLASSIFICATION MODEL PERFORMANCE USING CONFUSION MATRIX (WEIGHTED AVERAGE). TEST MODE: 10-FOLD CROSS VALIDATION METHOD USING CASE C DATA SET

Classifier	PCC (%)	MAE	RMSE	TP Rate	FP Rate	Precision (p)	Recall (r)	F-Measure (F)	CPU Time (sec)
Bayes net	93.49%	0.0725	0.2345	94.1%	37.3%	93.6%	94.1%	93.7%	0.02
NaiveBayes	76.33%	0.2681	0.4068	59.2%	30.7%	86.7%	59.2%	67.2%	0.00
Decision Table	92.30%	0.1263	0.2521	93.5%	47.7%	92.9%	93.5%	92.7%	0.05
JRip	94.08%	0.0980	0.2345	94.1%	42.5%	93.6%	94.1%	93.5%	0.01
OneR	89.94%	0.1006	0.3172	93.5%	47.7%	92.9%	93.5%	92.7%	0.00
J48	93.49%	0.1092	0.2458	92.3%	47.9%	91.5%	92.3%	91.7%	0.02
Random Forest	94.08%	0.0824	0.2242	95.3%	31.9%	95.0%	95.3%	95.0%	0.20
Random Tree	91.71%	0.0841	0.2786	92.9%	37.4%	92.6%	92.9%	92.7%	0.00

TABLE 7. CLASSIFICATION RESULTS (PCC VALUES (%) AND RMSE VALUES ARE IN BRACKET, UNDERLINE IS THE BEST MODEL, BOLD VALUES ARE THE BEST WITHIN THE CLASSIFICATION TYPE. TEST MODE: PERCENTAGE SPLIT TEST METHOD (TRAIN DATA: TEST DATA) USING CASE C DATASET)

Classification Type	Train 90% : Test 10%	Train 80% : Test 20%	Train 70% : Test 30%	Train 60% : Test 40%	Train 50% : Test 50%	Train 40% : Test 60%	Train 30% : Test 70%	Train 20% : Test 80%	Train 10% : Test 90%
Bayes net	88.23% (0.2971)	94.12% (0.2801)	94.12% (0.2631)	94.12% (0.2503)	94.04% (0.2454)	94.05% (0.2422)	94.91% (0.2249)	95.55% (0.2260)	94.07% (0.2341)
NaiveBayes	64.70% (0.4487)	73.52% (0.4641)	72.54% (0.5082)	70.58% (0.4849)	72.61% (0.4568)	76.23% (0.4351)	94.06% (0.2489)	93.33% (0.237)	94.07% (0.2428)
Decision Table	94.11% (0.2473)	94.11% (0.2480)	94.11% (0.2473)	94.11% (0.2379)	92.85% (0.2570)	93.06% (0.2543)	94.06% (0.2351)	94.07% (0.2326)	90.13% (0.3059)
JRip	94.11% (0.2359)	94.11% (0.2407)	94.11% (0.2363)	92.64% (0.2690)	92.85% (0.2584)	93.06% (0.2565)	94.06% (0.2369)	94.07% (0.2395)	94.07% (0.2433)
OneR	94.11% (0.2425)	94.11% (0.2425)	94.11% (0.2425)	94.11% (0.2425)	92.85% (0.2673)	93.06% (0.2633)	94.06% (0.2436)	94.07% (0.2434)	94.07% (0.2433)
J48	94.11% (0.2353)	94.11% (0.2358)	94.11% (0.2351)	92.64% (0.2466)	94.04% (0.2390)	94.05% (0.2417)	92.37% (0.2762)	94.07% (0.2395)	86.18% (0.3717)
Random Forest	94.11% (0.2469)	94.11% (0.2471)	94.11% (0.2390)	92.64% (0.2349)	92.85% (0.2375)	93.06% (0.2448)	93.22% (0.2322)	94.07% (0.2209)	95.39% (0.2245)
Random Tree	88.23% (0.2953)	94.11% (0.2425)	88.23% (0.3430)	92.64% (0.2716)	90.47% (0.3124)	92.07% (0.2743)	94.06% (0.2473)	93.33% (0.2553)	93.42% (0.2484)

TABLE 8. CLUSTERING RESULTS (PERCENTAGE OF INSTANCES IN EACH CLUSTER, CPU TIME, LOG LIKELIHOOD, CLUSTER SUM OF SQUARED ERROR (E_{ss}) USING CASE C DATA SET)

Clustering Algorithm	Cluster 1	Cluster 2	Cluster 3	CPU Time	Log Likelihood	E_{ss}
Simple K Mean	55 (33%)	65 (38%)	49 (29%)	0.05	-	148.08
Cannopy	66 (39%)	70 (41%)	33 (20%)	0.01	-	-
EM	17 (10%)	62 (40%)	85 (50%)	0.06	-37.42	-
FathestFirst	154 (91%)	13 (8%)	2 (2%)	0.01	-	-
Filtered Clusterer	55 (33%)	65 (38%)	49 (29%)	0.01	-	148.08
Hierarchical Clusterer	165 (98%)	3 (2%)	1 (1%)	0.10	-	-

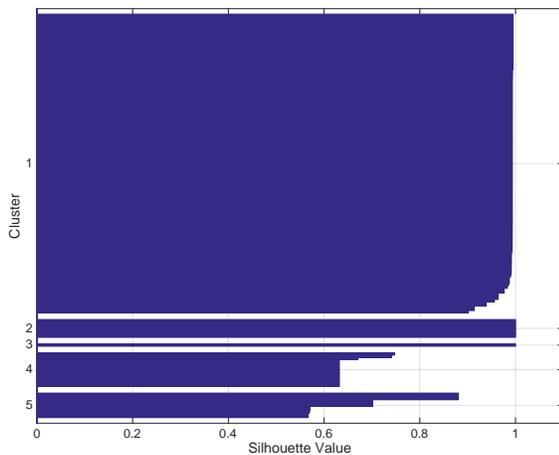


Fig. 2. Silhouette coefficient to determine optimal number of clusters - Calculating the silhouette plots.

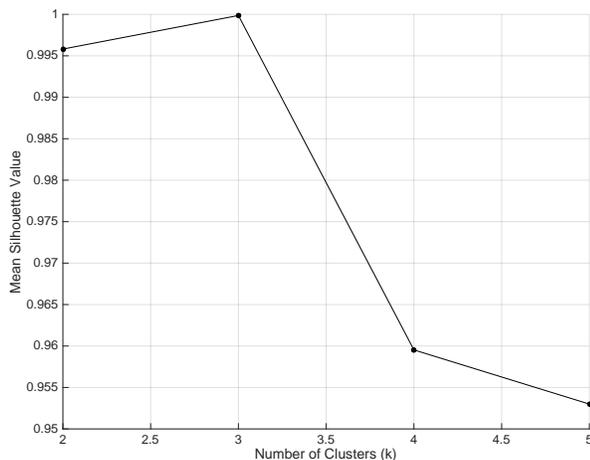


Fig. 3. Silhouette coefficient to determine optimal number of clusters - The optimal Silhouette value is obtained when $K = 3$.

TABLE 9. COMPARISON OF DATA ANALYSIS FROM OUR PREVIOUS METHOD AND SIMPLE K-MEAN CLUSTERING USING SAME DATASET [1] USED BY OUR PREVIOUS STUDY

Study/ No of Clusters	Sensitive Plants for RF-EMF
Analysis from our previous Study [1] where $p < 0.05$	Duckweeds, Mungbean, Pea, Broadbean, Maize, Fenugreek, Roselle, Tomato, Onions
K-Mean clustering $K = 1$	Duckweeds
K-Mean clustering $K = 2$	Duckweeds, Mungbean
K-Mean clustering $K = 3$, Optimal clustering using silhouette plots (Fig. 2 and Fig. 3), $p < 0.009$	Duckweeds, Mungbean, Pea
K-Mean clustering $K = 4$	Duckweeds, Maize, Pea, Mungbean
K-Mean clustering $K = 5$	Duckweeds*, Mungbean, Roselle, Onions
K-Mean clustering $K = 6$	Duckweeds*, Mungbean, Roselle, Onions, Fenugreek
K-Mean clustering $K = 7$	Duckweeds*, Mungbean, Roselle, Broadbean, Maize, Fenugreek
K-Mean clustering $K = 8$	Duckweeds*, Mungbean, Pea, Broadbean, Maize, Fenugreek, Roselle

Pea species are more sensitive to RF-EMFs ($p < 0.0001$). These values were then compared with the results from our previous review study [1] and observed similar behaviors. In our previous review, we found Maize, Roselle, Pea, Fenugreek, Duckweeds, Tomato, Onions and Mungbean plants are more sensitive to RF-EMF ($p < 0.0001$). In this paper, we used simple K-Means clustering algorithm and observed Pea, Mungbean, and duckweeds plants are more sensitive to RF-EMF ($p < 0.0001$).

To interpret the clusters, we compared our previous analysis of electric field strength values (effect or no effect) for different frequencies (raw data from 45 case studies) (Fig. 4(a)) [1] and clustering using K-mean algorithm (Fig. 4(b)). As clearly shown in the figure, we observed the robust connection using the K-mean clustering and it is clearly grouped no-effect data instances. This proves that K-mean clustering algorithms can be successfully used in Bioelectromagnetics to observe which frequency and which electric fields strengths are more sensitivity (bio-effects) or more effective on plants (Fig. 4). Hence, this paper provides the useful insights about under

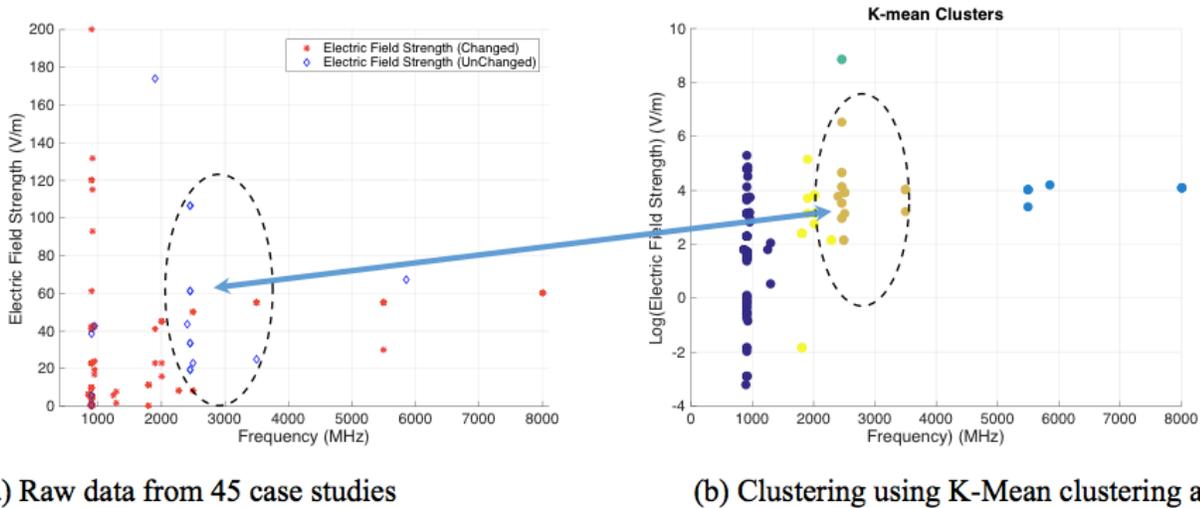


Fig. 4. K-Mean clustering algorithm to data from plants exposed to RF radiation in experiments that reported results (plant sensitivity response (changed/unchanged or effect/no effect)) from 45 publications describing 169 experimental observations to detect the plant sensitivity changes in plants due to the non-thermal RF-EMF effects from mobile phones and base station radiation. Please note that due to identical exposure conditions there were overlaps of data points. This figure demonstrates the robust connection using the K-mean clustering and it is clearly grouped no-effect data instances. This shows that K-mean clustering algorithms can be successively used to observe which frequency and which electric fields strengths are more sensitivity (bio-effects) or more effective on plants.

what conditions will RF-EMF exposure of given plant species may not produce an effect. Ultimately, the observational data for this study agrees with our earlier study, and suggest that Machine learning is an important tool, as it verifies some unexplained correlations in bioelectromagnetics domain.

V. DISCUSSION

In order to preserve green living and biodiversity, one of the foremost ground-level concerns is environmental damage and its effects on plants. Modelling plant sensitivity due to RF-EMF is an important task for both agriculture sector and for the epidemiologist. It is also a beneficial tool to assist a better understanding of this phenomenon and ultimately advance it. On the other hand, mobile phone technology has exhibited remarkable growth in recent years, heightening the debates on the impact and changes it causes in plant growth due to non-thermal weak radio-frequency electromagnetic fields (RF-EMF). Nonetheless, mobile phone technology is updated and upgraded every day. Consequently, the importance of combining the importance of conserving plants, and technology, guarantees sustainability by identifying the effects of RF-EMF on plant species. As the diversity changes and the requirement of its understanding increase, at the same time of technology, it assists people to find more precise responses quicker than ever. Hence, using the technology, machine learning algorithms gives a better understanding of diversity. This study has developed a prediction tool to investigate the effect of RF-EMF to plant species in order to identify key variables that affect plant sensitivity (bio-effect). This approach shows changed/unchanged levels by using big data analytics and machine learning concept in bioelectromagnetics domain to reveal hidden patterns and unknown correlations. We used raw-data of plant exposure from our previous work [1] (extracted data from 45 peer-reviewed scientific publications published

between 1996-2016 with 169 experimental case studies carried out in the scientific literature) and performed predictions, obtaining high-level of knowledge from raw data.

The number of mobile phones usage boosted in a drastic way due to the 1) decreasing communication cost; 2) excessive usability of web services, send and receive emails; and 3) using services from entertainment, education, banking, and medicine. With the remarkable advancement in the use of this technology, the controversy remains to exist about the physiological and morphological or bio-effect in the plants due to non-thermal weak RF-EMF effects from mobile phones and base station radiation. Our results suggest that a good predictive accuracy can be succeeded, if the information is provided about the frequency, SAR, power flux density, electric field strength, and exposure time. Hence, optimal attribute selection protocol to identify key parameters that are highly significant when designing the in-vitro practical standardized experimental protocols. Nevertheless, for the field of bioelectromagnetics and medical science accuracy is the key objective as they deal with sensitive data and a single error that can lead to the wrong conclusion. The advancement of Information Technology, and interest in big data analytics, machine learning has led to exponential growth of business organizational databases. This data holds beneficial information, such as trends and patterns, consequently, can be utilized to improve decision making that inadvertently optimizes success. Experts overlooked important details from billions of data which are quite challenging, thus, alternatively, using automated tools to analyze raw data and obtain stimulating high-level information for the decision-maker is quite significant [3].

Machine learning concepts have also been used in many research communities, including medicine [24], [25], crime prediction [26] and education [3]. However, no single study

exists which adequately covers machine learning concept in bioelectromagnetics domain. Due to attributes that influence (in our case, attributes are: frequency, SAR, power flux density, electric field strength, exposure time and plant type) to RF-EMF effects on plant sensitivity, it is very challenging to predict the growth of changes with high accuracy. On the other hand, machine learning concepts have not been generally accepted due to their inherent stochastic behavior [24]. Consequently, the results may not provide a sufficient reproducibility to adequately facilitate thoughtful scientific studies, as machine learning techniques use the probability approach. Therefore, it allows small fluctuation of incorrectly classified instances in different classifiers. However, with the advancement of technology, the reproducibility became sufficient to permit serious scientific studies [24]. On the other hand, advancement of the modern technology, intelligent data analysis will show a vital role due to the vast amount of information produced and stored [24]. To accommodate that, current machine learning algorithms provide sophisticated tools that can considerably help the science community to uncover new relationships in the data and its behavior.

Results revealed attributes set selected using the developed algorithm is consistent with in-vitro experiments. Once the raw data is fed, using K-Means clustering algorithm, demonstrated that the Pea, Mungbean, and Duckweeds plants are more sensitive to RF-EMF and statistical analysis revealed the same results evidencing precision ($p < 0.0001$). The cluster sum of squared error (E_{ss}) has been used to evaluate how well all the data points are clustered. To support these results, our previous research [1] found Maize, Roselle, Pea, Fenugreek, Duckweeds, Tomato, Onions, and Mungbean plants are more sensitive to RF-EMF ($p < 0.0001$). Additionally, this study shows that K-mean clustering algorithm can be successively used to predict what conditions will RF-EMF exposure given to plant species produce has an effect. Another possibility to obtain statistical significance (p-value) is using the Silhouette coefficient. We use the Silhouette coefficient to estimate the optimal number of clusters. Then, the ratio between intra-cluster-distances: inter-cluster-distances should be in-between -1 to $+1$. Clustering algorithms have been extensively used by research in areas for energy minimization [27], [28] that could also have been trained in this area as well. Similar to our results, the findings of previous research [29], [30] show that extensive thoughtful and computational attributes that can be used with K-Means clustering approach using medical data could be ideal. Their results have also suggested that K-Means have the potential to classify medical data.

Our results show that in bioelectromagnetics domain, the various classifiers are accomplished the same way, and the similar outcomes were obtained by another group of physicians in medical data obtained similar outcomes [24]. However, we cannot generalize this as we had a small sample size. In different classifiers who have different explanation capability [24], suitable for each classifier which could depend on the explanation that fits our own data. We used 7 different classification algorithms to select the best classifier for our data. This idea was supported by a previous research. Selecting a single best classifier that could be an option, nonetheless, the best solution could also be to use all of them and combine their judgment when solving a new problem [24].

In bioelectromagnetics domain, obtaining of SAR data is generally difficult and time-consuming. Therefore, it is appropriate to have a classifier that is able to consistently identify with a less amount of data about some attributes. Our results show that getting the appropriate subgroup of attributes could play a significant role in obtaining the high percentage of correctly classified instances. This observation was also supported by [2], whereas, selecting an appropriate subgroup of attributes (parameters or characteristics) is a key thing when using machine learning algorithms [2], as the selection is completed during the learning.

Despite its benefits, there is no single study that adequately covers machine learning concept in bioelectromagnetics domain yet, nonetheless, in the future, this technique might play a vital role to predict the potential effects of RF-EMF in order to study the possible interaction mechanism between RF-EMFs and living beings. Though this research was conducted only for in-vitro studies, it can be applied to in-vivo and epidemiology studies as well. Hence, as a direct outcome of this research, more efficient RF-EMF exposure prediction tools can be developed, in order to improve the quality of epidemiological studies and the long-term laboratory experiments using whole organisms (in-vivo). As a direct outcome of this research, more efficient prediction tools can be developed, reducing the environmental exposure and enhancing the quality of life using more raw data. More research is essential in order to understand whether and how some attributes (e.g. frequency, SAR, exposure time, power flux density) affect the prediction of effects/no-effects in plants. The difference between classification and clustering may not seem pronounced. Nevertheless, these two algorithms are fundamentally different, as the classification is a form of supervised learning while clustering is a form of unsupervised learning. In general, classification and clustering display to be a promising tool for weak radio-frequency radiation effect prediction on plants.

Machine learning technique also could be used to incorporate data from field observations in which appropriate variables are taken with an identical methodology (e.g. field strength, SAR, radiation frequency, damage types found, species affected, distance to radiation source etc.), however, more experiment records are needed for that analysis. Even without a thorough knowledge of plants or RF-EMF, it is promising to use machine learning algorithm in bioelectromagnetics domain. Nonetheless, its limitation is that it demands a large number of data to provide adequate results [2] and the quality of the predictions depends on the dataset. However, the results obtained by our study shows only 4% of fluctuation among correctly classified percentage, proving that the results are significant. Besides, the sample size of reported 169 experimental case studies, perhaps low significant in a statistical sense, nonetheless, this analysis still provides useful insight of using Machine Learning in Bioelectromagnetics domain. This investigation should be further analyzed with a bigger sample size (more data) in the future.

VI. CONCLUSION

Using mobile phone has triumphed as it has become a crucial part of our society, as it serves as a social and informative tool. Big data analytics and machine learning techniques allow a high-level extraction of awareness from

raw data which offers remarkable opportunities to predict the future trends and outcomes of the impact of handheld devices and its impacts on living beings. There is no single study that adequately covers machine learning concept in bioelectromagnetics domain. However, this paper has analyzed prediction models and their accuracies in order to identify the best classification algorithm to be used in analyzing data that shows environmental effects from mobile phones and base station radiation on plants. This analysis has helped us understand different types of attributes that have shown effects and impact on plants. Random Forest algorithm stands out producing better prediction among all the classification algorithms. Using K-Means clustering algorithm we found, Pea, Mungbean, and Duckweeds plants are more sensitive to RF-EMF. Moreover, this study shows that K-mean clustering algorithms can be successively used to predict conditions will RF-EMF exposure of given plant species are affected by RF-EMF (bio-effects). Moreover, this paper also illustrates the development of optimal attribute selection protocol to identifies key parameters that should be used when designing the in-vitro practical standardized experimental protocols. Our results show that clustering and classification are, in general, a promising prediction tool which can be practically used to predict plant effect changes due to non-thermal weak RF-EMF. Although this research was conducted only data from in-vitro studies, it can be applied to in-vivo and epidemiology studies. Hence, as a direct outcome of this research, more efficient RF-EMF exposure prediction tools can be developed, in order to improve the quality of epidemiological studies and the long-term laboratory experiments using whole organisms (in-vivo). Machine learning is an important tool, to validate some mysterious occurrences in bioelectromagnetics domains, which is not used by the community, so far, however, in the future, this might play a fundamental role to predict the potential effects of environment on plants and to study the possible interaction mechanism between RF-EMF and living being.

VII. DECLARATION OF INTEREST

The authors declare no conflict of interest.

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K-means Based Automatic Pests Detection and Classification for Pesticides Spraying

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Abstract—Agriculture is the backbone to the living being that plays a vital role to country's economy. Agriculture production is inversely affected by pest infestation and plant diseases. Plants vitality is directly affected by the pests as poor or abnormal. Automatic pest detection and classification is an essential research phenomenon, as early detection and classification of pests as they appear on the plants may lead to minimizing the loss of production. This study puts forth a comprehensive model that would facilitate the detection and classification of the pests by using Artificial Neural Network (ANN). In this approach, the image has been segmented from the fields by using enhanced K-Mean segmentation technique that identifies the pests or any object from the image. Subsequently, features will be extracted by using Discrete Cosine Transform (DCT) and classified using ANN to classify pests. The proposed approach is verified for five pests that exhibited 94% effectiveness while classifying the pests.

Keywords—Automatic plant pest detection; pest classification; Delta-E; discrete wavelet transform; support vector machine

I. INTRODUCTION

Enhancements and improvements in the modern computer science has helped us in my unique ways. This is helping us in many ways making our daily tasks easy and convenient for us. It helps us to reduce the time consumption of different activities. Agriculture is also a fundamental part of any country. While technology is also taking part to improve it and help us to make it more easier and easy for the farmers. However it require the continues observation of expert, which was done manually, so it is time consuming process and not much efficient and expensive in large farms. As it requires experts having a precise knowledge of pest management through different techniques like black light traps and sticky traps, and framers spray the pesticides which may also harmful for the crops as well as for the environment. To reduce the effect as technology is playing role in cropping, vigilance now it is being used in the field of pest control.

The main purpose of this work is to establish such a system which may help us to detect pests as well as classify them. This will help us in future in recognizing that whether a pest is a friend one or enemy, so we can decide whether it required a spray or not. As the previous researches has shown that image processing may also help to detect plant diseases by the presences of pest. On the other hand, there are some plants with no pests, but in past they were used by some pests. During

their stay many pests leave their larva over the leaves, which are more dangerous. The injuries effects of pest in plant affects the agriculture which shows the negative influence on economy of a country it. There are many pests, which badly effects the plants some are dangerous like snails, flies, caterpillar, fungal infections, while some are friendly for the crops like lady-birds, earwig and many more, so we need to identify them, because spraying blindly is very dangerous [1]. Prevention of plant from pest is more viable then to only detect and cure them after being effected by pests. For effective prevention precise knowledge about the pests management must be required before demonstration of maintaining pests. With a specific end goal to spare the work and ensure humans wellbeing, local and remote specialists have been inquired about on misusing the robot utilized for reaping products of the soil pesticides to plants in nursery diffusely [2]. If pest detection is not done, it will proceeds towards the reduction of crops, which results in increase of poverty. It is required to use a proper well organized pest detection methodology which may help us to reduce these pesticides and increase a healthy yields [3]. We have seen a typical thing that the vast majority of those models were proposed for some particular condition. Here and there these models are proposed for particularly for a solitary sort of pests in view of the colors or shape. While our condition incorporates creepy crawlies, mold, rodents, microscopic organisms and other such creatures. While a couple of these are valuable to individuals from numerous points of view, others are hurtful in nature [4]. Automatic detection of pest and determine the pests on plant through image processing and classify them on different properties of image is the best technique for accruing pest detection. To have the feasible pest control by using automatic pest detection through k-mean clustering which help to determine the pest invasion on the regular basis.

II. RELATED WORK

Earlier in this field some work has already been done. [5] has proposed a model to detect 3D position of the detected object, they have discussed that this model was proposed only for red colored pest and tested on red colored models. In [6] has explained a proper way to identify an infected area on the leaves. This approach shows that if there are some effected leaves there must be some pests. It involves some color

transformations from the RGB to l3a, l3b, H space. After this some thresholding functions were used to identify the affected area. In [4], author focused on a surveillance system, data was collected by using a binocular. This was a stereo system, which is using to control the sprays by robotic device. Some researchers used existing old traditions, like sticky materials, or pheromones, or attractive fragrances to attract the pesticides towards traps.

In [7], author has proposed a method, in which he has used some traps with sticky materials. Pests with the help of some smelly materials get attracted towards these traps. Where they get stuck, but this is a special way to reduce pests, it will not help about those pests which cannot fly, or which are at initial level. There are some common techniques to detect pests where some used clustering. Clusters basically divide an image on behalf of multiple factors, like colors, geometries, distances etc. A proposed method to detect objects from an image, where they have transformed an RGB image to another color space. Than by applying C-Mean Clustering they identify the different objects. The said technique have been used to detect effected areas in human body even from different diseases.

In [8], [9], authors proposed a novel technique to detect the pests at some initial stages. This idea was an excellent approach towards the detection of pests, but with some limitations. It only detects the White flies a specific pest. It will not work for the others. Similarly it is a vision dependent, system which depends upon the angle of vision. If this angle changes results of the said system will get damaged. In [10], author used the MATLAB neural network system toolbox to develop the forecast framework about natural product tree infections and bug bothers in light of the Backpropagation neural network as per the climate data and the event status of organic product tree illnesses and creepy crawly bugs in plantations. The history record information were used to prepare the information. Toward the end they think about both the anticipated esteems and unique information in the preparation set for the bug, or plant infection. From the outcomes we can check climate framework is performing precisely or suddenly. The applications that predicts organic product tree infections and pests irritations can use the framework.

In [3], author presented a crop based detection technique. Authors has developed a cotton crop pest's dataset. Further they have applied a thresholding function on this raw data. They have used multilayer ANN for the classification of pests. An other vision based technique used for the pest detection by [11], which was an SVM based technique used for the indoor green house. It was a yield dependent technique which is based upon the color variation. It uses very high definition images which results into more high processing and calculations. These images may not be suitable in real-time environments. In [12], author explained the uses of ANN and Bayesian, for correctly identifying a rice fields pest named as Yellow Stem Borer. They have used a dataset specifically designed for the rice field which was compiled by collecting the data over the duration of 12 years, for different climates. Earlier they have collected all the data and classify it using ANN, while after this the results collected by the ANN were further predicted using Bayesian. This methodology was well organized, but was dependent over a specific dataset [13]. There are several systems which are available among them

some are color based or pest based which are presented by different researchers, among them some are [14], [15].

Reviewing the existing work it was observed that most of the models were color, yield or pest dependent. It was necessary to design a generic detection and classification technique which should not be dependent on colors or yields [1].

III. MATERIAL AND METHODOLOGY

This methodology is based upon three different steps, on initial stage pest will be detected. Pest detection consist of pre-processing to reduce noise and to prepare the image for further processing. After pre-processing this image will be segmented using k-mean clustering. Second step is to extract the features of detected pest. Third step is classification of the pest on the behalf of extracted features. A brief flow and working of the system shown in Fig. 1. At first step system will acquire the image using different technique or devices. These earlier level images are not a suitable thing for the classification. It will be preprocessed. To enhance the appearance base intensity variations we have used the Gaussian filter described in (1).

A. Image Pre-processing

To prepare the image to for the system for main operation image was preprocessed. Pre-processing consist of the steps like: I) Smoothing filter II) Color transformation.

B. Smoothing Filter

Due to different factors during capturing the image it is possible that some sharp edges appears. These sharp edges and lightening effects may cause the local maxima during our segmentation process. This could affect our system's performance. That's why this was essential to remove these edge and smooth the image. For this purpose we will use Gaussian filter. It will consider a point on the image as a center and smooth the image as per given equation.

$$G(x, y) = e^{-(x^2+y^2)/\alpha} \quad (1)$$

Gaussian filter required a Gaussian center, which is taken at (0,0), while α is showing the Standard deviation.

C. Color Transformation

After smoothing images will be transformed to from RGB to L*, a*, b* color space. This process was taken to take the maximum values of L*, a*, b*, which were further be used as threshold. After pre-processing images will be as shown in

D. 2 K-mean clustering

For detection purpose here it was used k-mean clustering algorithm. It was earlier used by some of the researchers but existing techniques were facing some problems with green colored pests. In our proposed model the k-mean clustering is applied sequentially. Initially on the image was clustered using k-mean clustering. K-mean clustering technique decide on behalf of distance between two instances. We have used Euclidean distance to decide about any point on the picture.

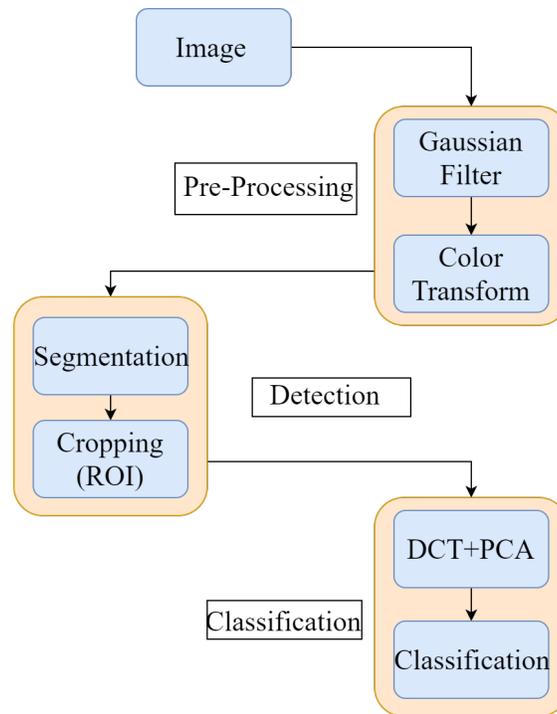


Fig. 1. A complete flow of proposed model.

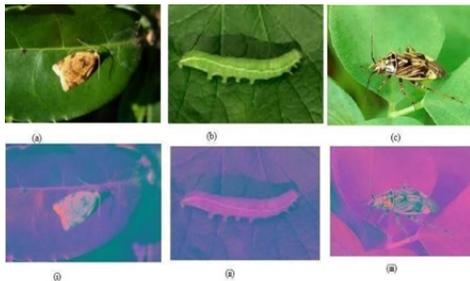


Fig. 2. Input images and their corresponding preprocessed images.



Fig. 3. Input images and their cropped images.

To overcome the colored problem we have improved the working of this detection algorithm. Our algorithm make the segments on the behalf of initially on the number of colors than remaining will be clustered in the behalf of distance. Due to this detection results were based upon the number of colors we used to classify. We selected 5 number of colors in which image has to be segmented. This threshold value was selected on the experimental results observed by us. K-means clustering is a technique from vector quantization. Basically, it is a Signal processing technique, which was utilized in Data Mining for the data clustering. K-mean Clustering normally measure 'n' Observations, then categorized in k Clusters. This decision will be made on the behalf of nearest matched clusters. It normally takes a set of observations $X_1, X_2, X_3, \dots, X_n$, where each observation from this set is a p-dimensional real vector. The said techniques actually categorize the sample in k number of classes as $S_1, S_2, S_3, \dots, S_k$ where $(k_j=n)$. Actually the combinations are combined using Euclidean distance, the objects having the minimum distance will be clustered in one class. While the distance of the clusters will be calculated from

the center which were selected earlier.

E. Classification

Segmented images will be cropped on the next step. At this step the area of interest will be cropped as per shown in Fig. 2.

Fig. 3 shows Input Images and their cropped images. These are the results when number of colors are taken 3. After this cropping we have extracted the features using DCT. Feature set was too much large almost of 50×50 . As such high dimensions need a complex ANN. While on the behalf of results it was seen that some of the features were not effecting the results in both ways. So we had decided to reduce the dimensionality using PCA (Principal Component Analysis). PCA returned a set of 1×32 set of features. On behalf of this a neural network of 32 input neurons was constructed. This ANN was consisting of one hidden layer. ANN was using a parallel classifier as we were working one out of 10 classes. To improve the results and

TABLE I. SEGMENTATION RESULTS OF DIFFERENT NUMBER OF CLUSTERS

Color (n)	Correctly segmented		Incorrectly segmented	
	Images	%age	Images	%age
1	0	0	64	100
2	23	35.9375	36	56.25
3	30	46.875	31	48.4375
4	42	65.625	17	26.5625
5	58	90.625	1	1.562
6	31	48.4375	21	32.8125
7	20	31.25	35	54.6875

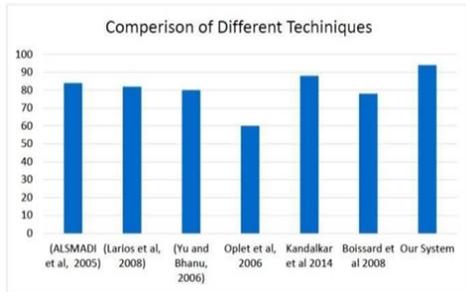


Fig. 4. Comparison of different techniques.

validate them we have used a 10 cross fold validation method.

If we conclude the whole process in a broader way than we can say that this whole methodology depends upon the three major steps: 1) preprocessing; 2) detection; and 3) classification which is shown in Fig. 1. While each Sub category contain more discrete steps for a specific operation. Like preprocessing include the loading of plant pest image which will pass through the Gaussian filter and creating the color transformation or color space changing structure applying the cluster technique further which will passes to the segmentation and create the corresponding 360^o angular filter using training image known as cropping (ROI) technique to detection while classification contain Feature Extraction, Set the tuning parameter to determine input images and recognized the best matches. Normalized of images for different viewing angles known as Feature Reduction, and Classification phase.

We have tested the crafted features with three different Classifiers, KNN (K-Nearest Neighbor), SVM and ANN. Complete results of the system along with comparison of different techniques have been shown in Table IV. It has been compared with the results of different features combinations along with different classifiers. It also conclude that we have reached to highest results with suitable technique, which was the core objective of our work.

IV. RESULTS AND DISCUSSION

When we have observed the initial detection results it was observed as seen in Table I. It was seen that the detection phase has shown some good results when total number of clusters have been taken as n=5.

For classification for testing the accuracy of system we have selected four classes. Dataset for training and testing our system was taken by [16]. They have applied some different feature extraction and classification techniques and collected the results shown in Table IV. He has discussed the working

TABLE II. CLASSIFICATION RESULTS

Pest	Accuracy%age		AverageAccuracy%
	1st Fold	2nd Fold	
Assassin Bug	79	89.42	84
T. Plant Bug	66.7	75	70.85
Convergent Lady Beetle	75	92	83.5
White Flies	87.5	100	93.75

TABLE III. BRIEF COMPARISON OF DIFFERENT TECHNIQUES

Reference	Method	ACC%
ALSMADI et al., 2005 [17]	Grey Level Co-occurrence Matrix+ ANN	84
Larios et al., 2008 [12]	Histogram + Appearance Base	82
Oplet et al., 2006[18]	Scale-invariant feature transform	60
Kandalkar et al., 2014[19]	Discrete Wavelet transform(DWT) + ANN	88
Boissard et al., 2008[7]	Knowledge Base Mappin	78
Our System	DCT + ANN	94

of different feature extraction techniques with two classifiers. The results for the classification are as given below. If we make a comparison of different Feature and classifying techniques with our methodology we can see that it has improved results. Result has been collected very precisely, and shown in Table II. We have shown a brief comparison of the Results with some existing benchmark techniques in Table III.

Setup used by [16] has been extended to check the accuracy of the said database with ANN (Artificial Neural Network). It shows a remarkable results on each class of he given dataset, which shows the robustness of the system. This extension contains one more classifier and a features technique. Results of each combination have been shown in Table IV, and graphically illustrated in Fig. 4.

TABLE IV. COMPARISON OF RESULTS WITH DIFFERENT CLASSIFIERS AND FEATURE TECHNIQUES [16]

Features	Classifier		
	KNN	SVM	ANN
Scale-Invariant Feature Transform (SIFT)	46.5	63.5	70.1
Speeded-Up Robust Features (SURF)	53.0	72.5	60.3
Histograms Of Oriented Gradient (HOG)	73.5	81.0	82
HOG + SIFT	75.0	84.0	85.0
HOG+ SURF	76.5	89.5	90.2
DCT + PCA Our	92.3	90.5	94

V. CONCLUSION

The result shown above in this paper were impressive and improved than previous techniques. The proposed technique is based on image-processing and k-mean clustering methodology. When a pest will be recognized by using four main phases that which pest is this, after we can classify we can recognize it as a friend or enemy pest. We were very much accurate that we have achieved our results, but still this work could be extended in future, which will be more direction oriented to reduce the pesticide usage. Still by introducing the Deep learning techniques we can improve our results. In future this method can be used to develop an automated spraying system which will spray only those pests which need a spray else it will skip it.

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Deployment Protocol for Underwater Wireless Sensors Network based on Virtual Force

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Abstract—Recently, Underwater Sensor Networks (UWSNs) have attracted researchers' attention due to the challenges and the peculiar characteristics of the underwater environment. The initial random deployment of UWSN where sensors are scattered over the area via planes or ships is inefficient, and it doesn't achieve full coverage nor maintain network connectivity. Moreover, energy efficiency in underwater networks is a crucial issue since nodes utilize battery power as a source of energy and it is difficult and sometimes impossible to change or replenish these batteries. Our contribution in this research is to improve the performance of UWSNs by designing UW-DVFA, an underwater 3-D self-distributed deployment algorithm based on virtual forces. The main target for this work is to stretch the randomly deployed network in the 3-D area in a way that guarantees full area coverage and network connectivity.

Keywords—Deployment algorithm; underwater wireless sensor network; virtual force; coverage; connectivity

I. INTRODUCTION

Nowadays, the growing interests toward exploring and monitoring oceans due to the broad application prospects, such as natural disaster detection and prevention, oil and mineral discovery and extraction, and military surveillance, have drawn the attention toward Underwater Wireless Sensors Networks (UWSNs) [1]. Unlike terrestrial sensor networks that rely on radio signal communication channels with high bandwidth and low propagation delay, UWSNs employ acoustic signals for underwater hop by hop node communication. The reason behind the designing of this stand is the peculiar characteristic of the underwater environment which attenuates the radio signal and makes it inefficient to be directly applied in UWSN. However, employing acoustic signals into UWSN can lead to many challenges and difficulties such as the large propagation delay and limiting bandwidth with high transmission loss. Furthermore, the inevitable movement that caused by the water current induces the Doppler Effect, which affects the signal intensity [2].

Therefore, researchers have become recently interested to explore other aspects of UWSNs such as the deployment of the network, sensors allocation and synchronization, power management and routing protocols. One fundamental task that is common to all these aspects is the network deployment which needs to be urgently addressed due to its direct impact on the other aspects.

In UWSNs, sensors must be deployed properly to collaborate with each other in three-dimensional space to perform monitoring and collecting information tasks according to the application requirements. Deployment of UWSN has attracted significant attention recently due to its tangible impact on

the other aspect of UWSN. The deployment in UWSN can be classified as static and distributed deployment [3]. In static deployment, nodes are deployed manually in predefined positions and cannot move once they are deployed. However, distributed deployment considered the mobility capability of sensors and assumed the initial deployment is randomly done using planes or ships to cover the desired area.

Sparse node distribution faces many challenges such as inefficient area coverage and lack of network connectivity. Moreover, reducing the deployment energy consumption to increase network lifetime is a major issue in UWSNs [4]. There are two aspects of energy consumption: one is related to the movement and communication between nodes during the deployment phase, the other is related to the difficulties raised from recharging the power of nodes. Hence, recharging underwater sensors can be time-consuming and expensive due to the need of imposing special underwater vehicles into the network for such purpose.

Different deployment algorithms such as clustering, connected tree, Practical swarm, Voronoi, and Virtual force are proven to success in the deployment of 2-D terrestrial sensor networks. Some of them are modified to be used in UWSN as we can see in the literature. Virtual Force is one of the known algorithms that is used in deploying wireless sensor network [5], [6]. It is based on the idea from the potential field and disk packing where sensors behave as a source of forces that are exerting among other. In this work, we will consider adopting this algorithm in UWSN.

The rest of the paper is organized as follows. Section II presents the state of the art related to UWSN deployment. In Section III, we present the basic underwater network architecture along with the models we used for coverage rate, acoustic propagation, and energy consumption. In Sections IV and V, we present the underwater distributed virtual force algorithm (UW-DVFA) and the performance evaluation of it, respectively. Finally, we conclude this paper with a summary of our contributions in Section VI.

II. RELATED WORK

The fundamental task on UWSN deployment is to correctly locate each node in order to monitor the whole area. Different studies were aiming to find the best 3-D deployment techniques for UWSN. One technique is by filling a pre-calculated space with polyhedron and manually deployed sensors in each polyhedron for achieving 100% 3-D coverage and connectivity [8], [9]. For instance, Felamban et al. [9] deployed nodes in ways that form truncated octahedron with the objective

of minimizing the transmission loss under a given monitored volume and number of sensor nodes.

Another technique is presented in [10] where the deployment algorithm partitions the monitored volume into layers and clusters and then determines and selects the best cluster shape for manual deployment.

All these approaches are considered static and manual. They are centralized and require pre-knowledge about the monitored area which is not practical in an underwater environment where the water current and wind change the shape of the topology frequently. Moreover, the static manual deployment is not feasible due to accessibility and time constraints, especially in large monitoring volume. Therefore, distributed deployment where nodes can adjust their underwater positions through mobility after the random initial deployment is highly needed for most of the underwater applications.

Different studies were focused on how to stretch the randomly deployed 2-D network topology on the surface or at the bottom of the ocean in a distributed manner to form a 3-D network. According to the mobility of sensors, node distributed deployment techniques are falling into two main categories which are movement-assisted deployment [7] and sensor-self deployment [11]. In the former, the free mobility of special kind of sensors (Robots) is used to assist other sensor nodes in fulfilling the network requirement [12], [13], [14]. Despite its success in achieving coverage and connectivity, the use of these robots leads to very high network deployment cost and energy consumption.

On the contrary, the latter exploit the mobility of the sensor and can be classified into two categories: self-depth adjustment, and freely movement deployment. In self-depth adjustment, nodes are anchored to the ground or at the surface of the oceans and can adjust their depth by controlling the anchored wire and moving vertically along the z-axis in 3-D space [15], [16]. In freely movement deployment, nodes are attached to buoy that allow them to move freely in each direction by following deployment algorithm. In the following subsections, we present some research works related to the sensor-self deployment in UWSN.

A. Self-depth Adjustment Technique

Regarding the depth-adjustment deployment [18], [17], Akkaya et al. [19] propose an algorithm for adjusting the position of sensor nodes after their initial deployment to reduce coverage overlaps between neighbor nodes based on clustering and Graph Colouring. However, this algorithm create small coverage holes between each two nodes which affect the whole connectivity in the topology.

Two other approaches for adjusting nodes position that are randomly deployed on the surface of the ocean are presented in [20], [21]. Both approaches implementing Voronoi Diagram to adjust the nodes position based on the density of sensor nodes. Although this algorithm is operated in a centralized manner, the authors claim that the algorithm can be applied in a distributed way. However, in this case, each node needs to know all the location of all nodes in the network which imply a very high cost in term of message control transferring.

Senel et al. [22] propose a node position adjustment algorithm based on the connected dominating set (CDS) where the nodes are deployed initially on the surface of the ocean. The algorithm first determines the CDS in the 2-D network and establishes a connected backbone of nodes. In this algorithm, the number of iterations increases when the number of nodes increases, thus the complexity of the algorithm increases considerably. Hence, the deployment duration may be significantly high.

All the above techniques restrict the movement of the sensors by adjusting the depth vertically. However, in this work, we will focus on the self-deployment strategies that take into consideration the mobility of the sensor nodes.

B. Freely Movement Deployment Technique

Many techniques exploit the free mobility of sensor in all direction. For instance, Xia et al. [23] present a particle swarm inspired sensor self-deployment algorithm which simulates the flying behavior of bird flocking or fish schooling. The introduced algorithm aims to cover the area with high density of events and make the distribution of sensors (particles) match that events. Indeed, a group of random particles fly across the region and search for the optimal position. In case an event is in the sensing range of a particle, the particle will obtain the event location and send its location information to the nearest particles.

Similar to this approach Feng et al. [24] presents the underwater sensor network redeployment algorithm based on wolf search (RAWS) to obtain a fair underwater network coverage. The idea of the algorithm is based on the simulation of preying and escaping from predators. Indeed, the authors invoke the wolf search algorithm where wolves exhibit three typical behaviors: preying initiatively, preying passively, and escaping.

Thus, after the initial deployment, the coverage is initially calculated. Then, the first iteration of the algorithm begins such that each node will follow one of three scenarios. The first one is Active Coverage, when node $s(i)$ detect a target coverage point $p(i)$, that fall in the sensing range of that node, the node $s(i)$ will move in the same direction of the coverage point $p(i)$ and maintain its position. The second case is the Passive Coverage, when node $s(i)$ does not have any coverage point within its sensing range. In such case, if the node $s(i)$ have a one-hop neighbor $s(j)$, and the neighbor node $s(j)$ have more point to cover, then the node $s(i)$ will move to the direction of that neighbor node. Otherwise, the node $s(i)$ will move in any direction. The last one is Escape Mechanism, where in case of the existence of obstacles, the node moves in a random direction with a distance larger than it sensing radius to avoid those obstacles. The algorithm continues the iterations until the coverage is achieved. In this algorithm, each wolf has an independent search capability, thus increasing the diversity of the search space.

These two approaches were mainly focused on achieving the needed coverage despite the connectivity. Also, it suffer from computational load.

Jiang et al. [25] were concerned about achieving best connectivity and they present a Guaranteed Full Connectivity

Node Deployment algorithm where nodes are divided into two types either coverage nodes or connectivity nodes. Consequently, the coverage nodes used first to guaranty fully area coverage using the greedy iterative strategy. Then, the connectivity nodes used to improve the network connectivity in an area with disconnection.

To summarize, the primary target of the underwater self deployment algorithms is to maximize the sensors area coverage while maintaining the connectivity given a limited number of the sensors by spreading nodes in the whole area following a specific mathematical approach.

The virtual force (VF) algorithm is one of the algorithms that is used in terrestrial sensor network that utilize the concept of Artificial Potential Field. The virtual force (VF) algorithm is proven to have a faster convergence compared to the other algorithms in WSN and node deployment. In the [27], the authors introduce the 3-D VF, an extended version of the known virtual force algorithm, to be used on 3-D areas. However, with the complication of the underwater environment, it needs to be modified in order to be effectively applied in oceans. In this work, we will adopt the existing algorithm to create underwater distributed virtual force algorithm UW-DVFA.

III. NETWORK ARCHITECTURE AND MODELES

A. Network Architecture

UWSN consists of a large number of underwater sensors that are capable of forwarding and receiving acoustic waves. As shown in Fig. 1, these sensor nodes detect and collect ambient data over a 3-D space and transmitting it to surface sink nodes via a multi-hop path. The surface sink nodes offload the collected data to an on-shore station through radio communication.

The initial deployment of these sensor nodes is generally random. Our target is to cover all the monitoring area by the needed number of sensor nodes following our redeployment algorithm while maintaining the connectivity toward the sink node.

B. Underwater Acoustic Propagation Model

The acoustic propagation in the underwater environment affects the transmission from node to node propagated through the ocean at the sound speed (1500 m/s). In this section, we will present the underwater attenuation, noise, and the related signal to noise ratio that we utilized in our algorithm.

1) *Underwater attenuation*: The attenuation (dB/m) modeled as the signal loss over a distance (d) in meter that associated with frequency (f) in kilohertz as:

$$10 \log_{10} \left(\frac{A(d, f)}{A_0} \right) = k 10 \log_{10} d + \frac{d}{10^3} 10 \log_{10} \alpha(f) \quad (1)$$

Where A_0 is normalizing constant, K is the spreading factor ($k = 1$: Cylindrical, $k = 1.5$: Practical, $k = 2$: Spherical) and $\alpha(f)$ is the Absorption Coefficient which is derived by Thorp Formula [28] as:

$$10 \log_{10} \alpha(f) = 0.11 \frac{f^2}{1 + f^2} + 44 \frac{f^2}{4100 + f^2} + 2.75 \times 10^{-4} f^2 + 0.003 \quad (2)$$

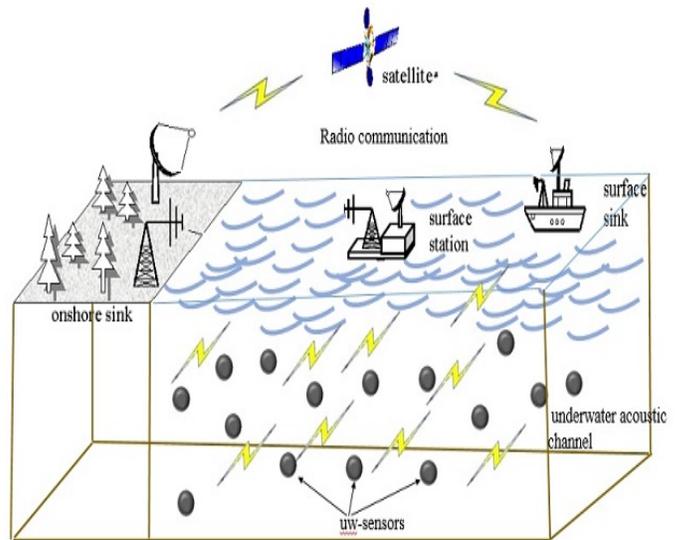


Fig. 1. UWSN architecture.

2) *Noise and signal to noise ratio*: There are four main sources of noise in the oceans which are the turbulence, shipping, wind driven waves and thermal noise that influences different frequency region. The power spectral density (p.s.d.) can be expressed as the following formula:

$$10 \log_{10} N(f) = \eta_0 - 18 \log_{10} f \quad (3)$$

Where f is the frequency in kilohertz. The constant level η_0 is adjusting according to the specific deployment site.

The Signal to noise ratio can be expressed as a function of both attenuation and noise as:

$$SNR(d, f) = \frac{S(f)\Delta f}{N(f)\Delta f} = \frac{S(f)}{A(d, f)N(f)} \quad (4)$$

Where $S(f)$ is the p.s.d of the transmitted signal. Δf is the narrow frequency around f .

C. Energy Model

There are many causes of energy depletion for the sensors in the UWSN such as sensing, processing, communication, overhearing, etc. Moreover, the mobility of sensors in the underwater area is one of the principal sources of energy consumption. The influence of some of these sources is considered smaller than the other. Indeed, the communication between nodes and the mobility of sensor nodes consider the primary sources of energy depletion. Thus, in this paper, we only consider studying the energy consumption that is due to data transmission and reception and the movement during the deployment phase while neglecting the others.

Therefore, the energy spent in transmitting one packet of length P_l bits over a distance d is given by

$$E_{tx} = P_{tx} \times T_{tx} \quad (5)$$

Where P_{tx} is the transmission power, and T_{tx} denotes the transmission time that given by

$$T_{tx} = \frac{P_l}{r} \quad (6)$$

Where r is the transmission rate of the information packet.

Correspondingly, the energy spent in receiving one P_l bits packet is given by

$$E_{rx} = P_{rx} \times T_{tx} \quad (7)$$

Where P_{rx} is the electronics power of the reception, and T_{tx} denotes the transmission time.

The energy consumed due to the movement by distance d is given by

$$E_m = d \times e_{mu}(d) \quad (8)$$

Where e_{mu} is the energy consumption per movement distance.

Thus, the total energy consumed can be calculated by:

$$E_{total} = E_{tx} + E_{rx} + E_m \quad (9)$$

Where E_{tx} and E_{rx} depend on the amount of data transmitted and received, respectively. E_m depends on the distance traveled by the sensor during its lifetime. Hence, the number of messages sent and received by the algorithm reflect the energy consumed by the transmission and reception of the packets. Moreover, the distance traveled during the deployment algorithm reflect the energy consumed by the movement of the sensors.

D. Coverage and Connectivity Rate

Considering a specific volume of water described as a , b and c area of the interested field and N number of randomly deployed sensors in the given area. This specific area to be covered is called the region of interest. The coverage problem can be described as the positioning of nodes such that their sensing zones all together cover the region of interest.

More precisely, each sensor has a sensing range R_s and transmission range R_t . For each sensor S_i who deployed in (x_i, y_i, z_i) , and for each point P_i with the coordinate (x, y, z) , we can obtain the coverage $C_{P_i}(S_i)$ of the P_i by the sensor S_i following the binary equation:

$$C_{P_i}(S_i) = \begin{cases} 1, & \text{if } \exists S_i \mid d(S_i, P_i) < R_s \\ 0, & \text{if otherwise} \end{cases}$$

Where $d(S_i, P_i)$ is the Euclidean distance between S_i and P_i . Thus, when the coverage is equal to 1, it denotes a full coverage for this point.

Moreover, it is proven that when the following constraint $R_t \geq \sqrt{3}R_s$ is applied, the connectivity will be implied if the coverage is achieved. Thus we will focus on achieving the full area coverage following the above model.

IV. UNDERWATER DISTRIBUTED VIRTUAL FORCE ALGORITHM

A. Assumptions

This work is based on the following assumptions:

- Sensor nodes have the ability to change their position by moving freely in each direction of the 3-D space.
- Each sensor node knows its position by using one of the localization techniques such as the one presented in [26].
- Each node has spherical sensing range ' R_s ' and transmission range ' R_t ' where $R_t \geq \sqrt{3}R_s$.
- The first deployment is randomly done on the surface of the area either by planes or ships.

B. Virtual Force Algorithm Principle

The main principle behind this algorithm is to consider each sensor node as a source of forces that are exerted among its neighboring nodes. Hence, for each sensor S_i , the algorithm will calculate the force F_{ij} that is exerted by the neighbor sensor S_j . These forces are either attractive force or repulsive force depends on the distance between them. If the two neighbor nodes are too close to each other the repulsive force will be exerted to avoid node stacking. On the other hand, if the two neighbor nodes are far from each other, an attractive force will be exerted to maintain the complete homogeneity in the deployment and avoid coverage hole.

The main target of the algorithm is to reach the pre-determined distance threshold (D_{th}) between all neighboring nodes after numbers of iteration where in each iteration the nodes are moving to different locations according to the applied forces thus all nodes are equidistant.

Fig. 2 illustrates an example of these forces exerted on 4 nodes $S1$, $S2$, $S3$ and $S4$. The force F_{13} , exerted by $S1$ on $S3$, is an attractive force because the distance between these two sensors is bigger than D_{th} . However, the force F_{12} is a repulsive force since the distance between sensor $S1$ and $S2$ is smaller than D_{th} . The distance between $S1$ and $S4$ is equal to D_{th} hence the force F_{14} is null.

C. UW-DVF Algorithm

In order to extend the DVFA principle to be used in UWSN, some of the roles must be carefully tuned. First, most of the UWSN applications in the underwater environment requires the 3-D area monitoring and coverage. Hence, the distance threshold of the virtual force needed to be changed to harmonize with the area. Second, the existence of the water current force affect the deployment of the network in many aspects and need to be addressed. In the following subsections, we will explain the modification we applied regarding these issues.

1) *Distance threshold*: One of the significant roles in DVFA is choosing the D_{th} . In flat 2-D areas, the value of D_{th} depends on triangular tessellation where each neighbor is located at one of the vertexes of the triangular. Such arrangement is not accurate when it comes to 3-D underwater environment.

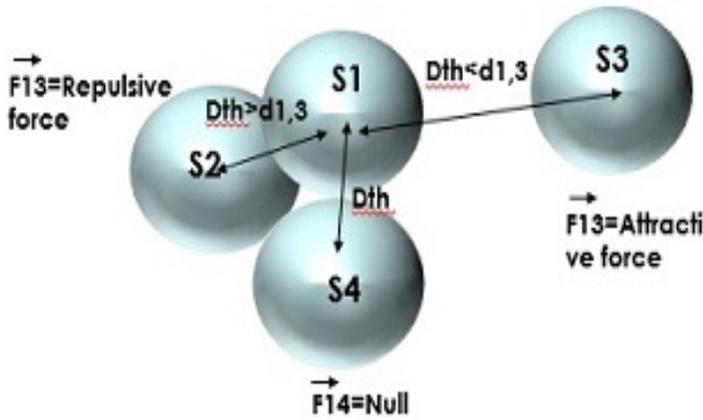


Fig. 2. An example of virtual forces exerted between nodes.

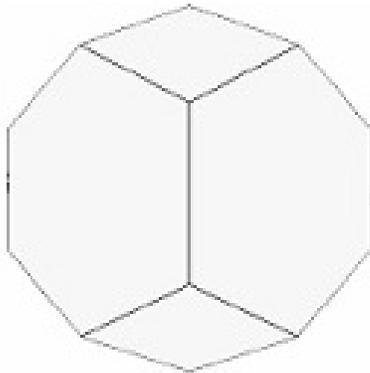


Fig. 3. A truncated octahedron.

According to [8], the best placement strategy for obtaining the optimal deployment in the 3-D environment is by filling the monitoring area with nodes to form truncated octahedron tessellation.

As illustrated in Fig. 3, the truncated octahedron has 14 faces, 8 of these faces are hexagonal, and 6 are square. Therefore, each node will have 14 neighbor nodes located at the faces of the truncated octahedron.

It means that nodes are not equidistance. Thus, if the node is located at one of the hexagonal faces, the D_{th} value will be expressed as $\sqrt{6}a$ where a is the edge length. However, if the neighbor node is located at one of the square faces, the D_{th} value will be expressed as $2\sqrt{2}a$.

However, in virtual force, the distance threshold must be a unique value for all the nodes neighbor. Thus, the truncated octahedron cannot be adopted. To overcome this issue, a regular dodecahedron is introduced in [27] to optimize the deployment in 3-D area instead of the truncated octahedron. As shown in Fig. 4, the node will be located at the center of the dodecahedron, and it will have 12 neighbors with the same distance. Therefore, the D_{th} will be equal to:

$$D_{th} = a\sqrt{\frac{5}{2} + \frac{11}{5}\sqrt{5}} \quad (10)$$

Where a is the edge length of a regular dodecahedron that can be calculated depends on the sensing range (R_s) for each node as:

$$a = \frac{4R_s}{\sqrt{3}(1 + \sqrt{5})} \quad (11)$$

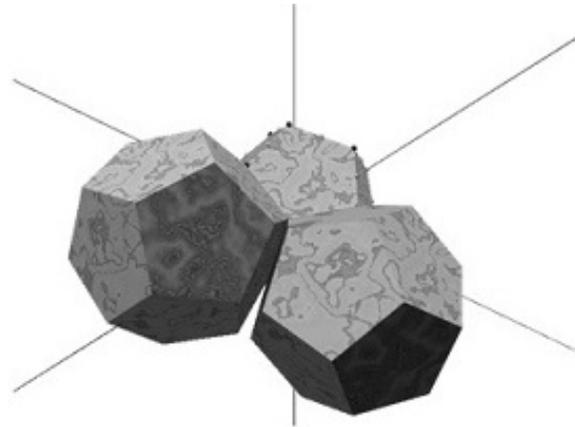


Fig. 4. Regular dodecahedron tessellation.

2) *Water current force*: The continued movement of the water current in the underwater environment have a crucial impact on the deployment process and hence the whole efficiency of the network. Indeed, the existence of water currents considers as an external force that is exerted on the sensors by the fluid media. Thus, we consider the effect of water current force in our algorithm.

According to the oceanography, oceans are stratifying with rotating characteristic. Hence the vertical movement can be negligible with respect to the horizontal one [29]. Thus, in our work, we consider the horizontal displacement of the water currents.

Moreover, the velocity of the currents is varying in each depth. Indeed, it keeps decreasing while we move down where it tends to be quiet in the deep of the oceans [30]. For instance, Fig. 5 shows the velocity profile for one of the fastest ocean currents in the world across the Gulf Stream at the Straits of Florida and Cape Hatteras. The velocity profile indicates that the maximum velocity is near to the surface around the top 200 meters. Velocity decreases with depth and the flow below 1000 meters is usually less than 10 cm/s [31]. In our work, we take into consideration the variation of water current velocity based on the depth of the area.

Consequently, the Force of the water current F_{wc} will be introduced along with the other virtual forces that are exerted by the algorithm where the total forces exerted on sensor S_i is:

$$\vec{F}_i = \sum_j \vec{F}_{ij} + \vec{F}_{wc} \quad (12)$$

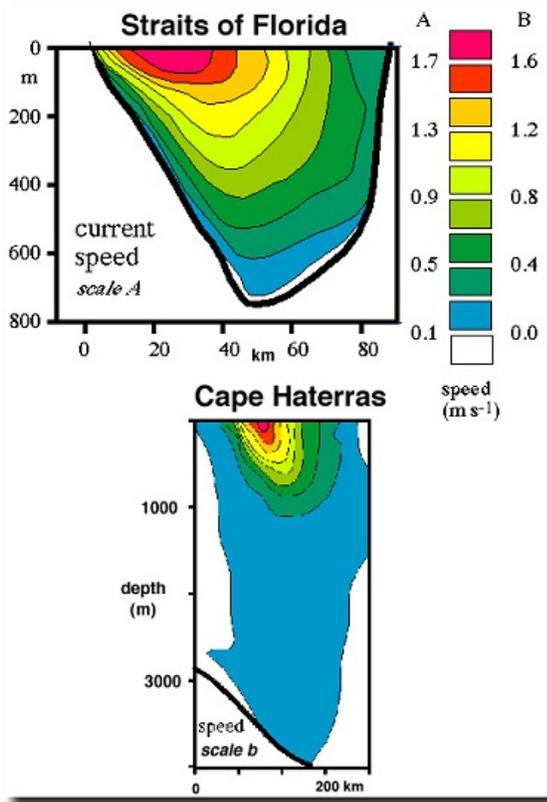


Fig. 5. The velocity of the water current in different depth.

Where, F_{wc} is the water current force and it will be varied depends on the z-axis and F_{ij} is the force exerted by the sensor S_j over the sensor S_i .

Thus, the UW-DVFA will initiate after the initial random node deployment, where each sensor node will send a Hello packet to all of its 1-hop neighbor that contain the position of the node to perform the initial neighborhood discovery. Then each node will calculate the Euclidean distance between its 1-hop neighbors such that for sensor nodes S_i and S_j the distance (d_{ij}) will be giving by the following formula:

$$d_{ij} = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2 + (z_j - z_i)^2} \quad (13)$$

After that, each sensor will compare the d_{ij} with the D_{th} which leads to three possible results:

- $d_{ij} > D_{th}$

In this case, the node S_j will exert an attractive force on S_i to reduce the distance between them and the force will be calculated according to the following formula:

$$\vec{F}_{ij} = K_a \cdot (d_{ij} - D_{th}) \cdot \frac{(x_j - x_i), (y_j - y_i), (z_j - z_i)}{d_{ij}} \quad (14)$$

Where K_a is the attractive coefficient.

- $d_{ij} < D_{th}$

In this case, the node S_j will exert a repulsive force on S_i to increase the distance between them and the force will be calculated according to the following formula:

$$\vec{F}_{ij} = K_r \cdot (D_{th} - d_{ij}) \cdot \frac{(x_j - x_i), (y_j - y_i), (z_j - z_i)}{d_{ij}} \quad (15)$$

Where K_r is the repulsive coefficient

- $d_{ij} = D_{th}$

In this case, no force will be exerted between these two nodes. Hence there will be no movement.

Therefore, the total force on S_i will be calculated with these formulas:

$$\vec{F}_{ix} = \sum_j \vec{F}_{ijx} + F_{wcx} \quad (16)$$

$$\vec{F}_{iy} = \sum_j \vec{F}_{ijy} + F_{wcy} \quad (17)$$

$$\vec{F}_{iz} = \sum_j \vec{F}_{ijz} \quad (18)$$

Noticing that the F_{wc} on the z axes is null. However, the variation of the depth on z-axis is considered.

Thus, the new position of the node S_i that is located originally at position (x_i, y_i, z_i) will depends on the resultant force on the node S_i such that $(x_i = x_i + F_{ix}, y_i = y_i + F_{iy}, z_i = z_i + F_{iz})$

V. PERFORMANCE EVALUATION

In order to evaluate the performance of UW-DVFA algorithm, we implemented the algorithm in Aqua-sim network simulator. It is a simulator based on the Network simulator NS2 to simulate the underwater environment.

A. Simulation Parameter

We conduct 20 different scenarios where nodes are randomly scattered at the surface of the monitored area. The simulation parameter we used are given in Table I.

TABLE I. SIMULATION PARAMETERS

Topology	Area size Sensor nodes Node speed	3km x 3km x 1km 300, 400, 500 10m/s
MAC Layer	protocol Transmission range R_t Sensing range R_s	Underwater Broadcast mac 500m 250m
Simulation	Result Simulation Time	Average of 20 simulation runs 1000s 1000s
UW-DVFA	K_a K_r Hello period D_{th}	0.004 0.25 20s 371.7
Water Current	Velocity in depth range (0-200 m) Velocity in depth range (200-400 m) Velocity in depth range (400-600 m) Velocity in depth range (600-800 m) Velocity in depth range (800-1000 m)	2m/s 1.7m/s 1.3m/s 0.9m/s 0.5m/s

B. Evaluation Criteria

The main goals for UW-DVFA are to obtain the full area coverage while maintaining the connectivity between nodes and to reduce the energy consumed in term of total distance travelled and number of messages exchanged.

Fig. 6 shows an example of the initial deployment. The final result of the deployment algorithm is shown in Fig. 7. The following sub-sections highlight the evaluation results of UW-DVFA.

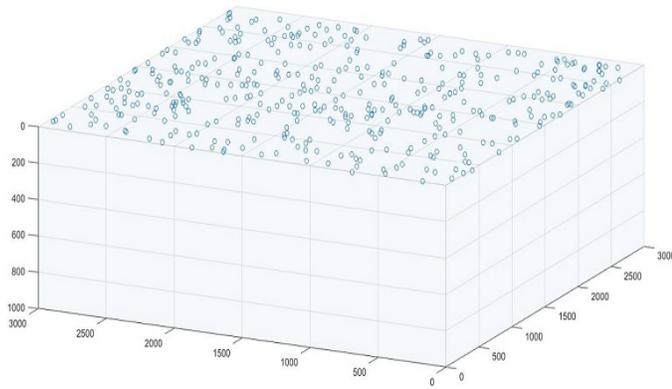


Fig. 6. Initial random deployment.

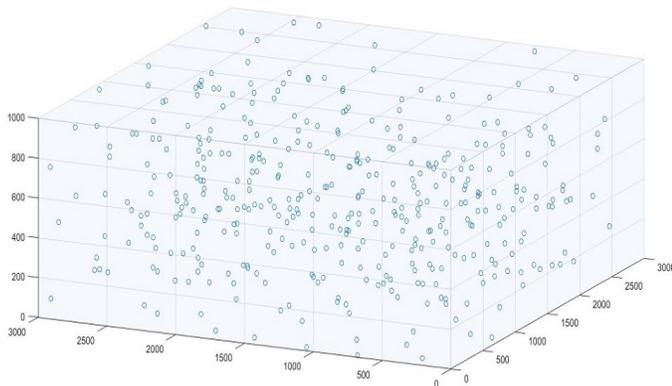


Fig. 7. Final deployment.

1) Coverage and connectivity rate: We conduct different simulation with a different number of nodes to evaluate the performance of the algorithm. First, we estimate the number of sensor nodes needed to cover all the area with length l , width w and height h based on the formulas given in [27]. These formulas don't provide the exact number of sensors needed to cover the monitoring area but give a lower bound and an upper bound of this number.

$$\begin{aligned} \text{Lowerbound} &= \frac{\text{Volume of the area}}{\text{Volume of the sphere}} \\ &= \frac{h \times l \times w}{\frac{4}{3}\pi(R_s)^3} \quad (19) \end{aligned}$$

Based on this formula, the lower bound for the area we were chosen is 138 nodes. Regarding the upper bound, the border of the area is taken into account: it is 6 faces and 12

edges.

$$\begin{aligned} \text{Upperbound} &= \frac{h \times l \times w}{\frac{4}{3}\pi(R_s)^3} \\ &+ 2 \frac{h \times l}{\pi(R_s)^2} + 2 \frac{h \times w}{\pi(R_s)^2} \\ &+ 2 \frac{l \times w}{\pi(R_s)^2} + 4 \frac{h}{R_s} + 4 \frac{l}{R_s} + 4 \frac{w}{R_s} \quad (20) \end{aligned}$$

Based on this formula, the upper bound for the area we were chosen is 404 nodes. In our simulation, we evaluate the network with a number of nodes around the upper bound using 300,400 and 500 nodes. Fig. 8 illustrates the coverage rate using three different number of nodes (300,400, and 500) for 20 different random deployment scenarios. As we can see, the UW-DVFA reaches 100% coverage rate in case of 400 and 500 nodes. The full coverage is reached within 250 seconds with 500 nodes for deployment while it takes 350 seconds with 400 nodes. This means that the deployment achieved the full coverage faster if the number of nodes is high. The coverage reaches 93% in case of 300 nodes. Fig. 9 illustrates a very important characteristic of UW-DVFA. In fact, the deployment algorithm maintains the initial connectivity and this connectivity between nodes is never lost during the deployment process.

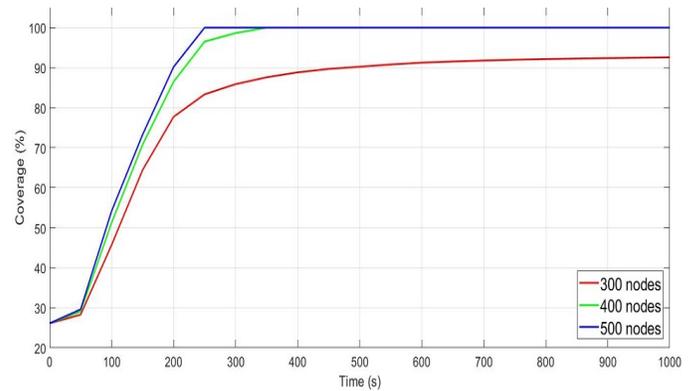


Fig. 8. Coverage rate as function of time.

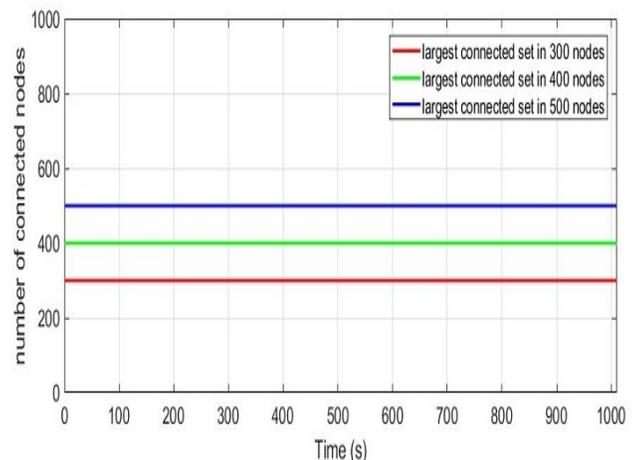


Fig. 9. Largest connected set as function of time.

2) *Distance travelled by nodes:* Fig. 10 presents the average, maximum and minimum distance traveled by nodes as a function of time. The values shown in the figure is the cumulative distance. As we can observe, the distance increased rapidly until the time around 300 seconds, where it reached the full coverage. After that, the distance continues growing slowly. We can notice that the distance traveled by nodes (maximum, minimum and average) increases if the number of the node increases. Hence, the energy consumed by node traveling to cover the area in the network with 500 nodes is higher than the energy consumed by nodes in a network with 400 nodes. As we see before, both cases reached the 100% coverage. Thus, in the rest of simulations, we only concentrate on the deployment with 400 nodes to evaluate the UW-DVFA overhead.

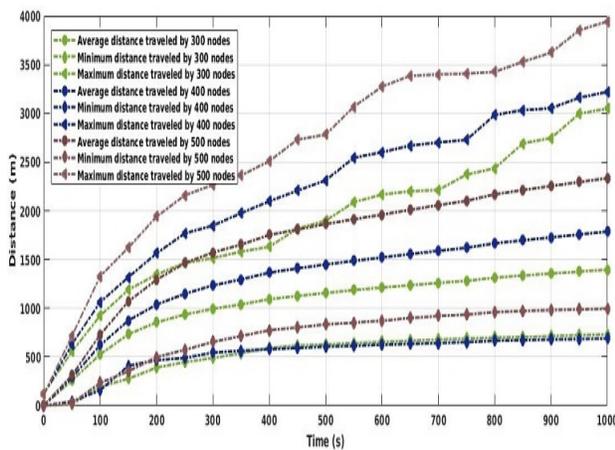


Fig. 10. The average, maximum and minimum distance traveled as function of time.

3) *Number of messages sent and received:* In order to compute the virtual forces, each node should send Hello messages periodically for neighborhood discovery. These messages permit to determine the 1-hop neighbors for each node. We notice that the performance of our deployment algorithm depends highly on the used Hello period. The reason behind this is the high propagation delay in the underwater environment due to the employment of acoustic signal. In the following simulation, we evaluate the effect of choosing different Hello period on the performance of our deployment algorithm. Fig. 11 and 12, show the number of messages sent and received with a variation of Hello period. As expected, the number of messages sent and received increase when the Hello period decreases. On the other hand, as shown in Fig. 13 the coverage rate is very low when using 5 and 10 seconds Hello period. This observation is logical due to the high propagation delay in the acoustic underwater environment. Hence, the information about the neighborhood of each node which the computation of virtual forces is not accurate. Nevertheless, in case of using 15 and 20 seconds of Hello period, the coverage rate reaches 100% in 450 and 350 seconds, respectively. Therefore, the best result is obtained when Hello period is 20 seconds since the deployment algorithm achieves the full coverage rate in shortest time with minimum overhead.

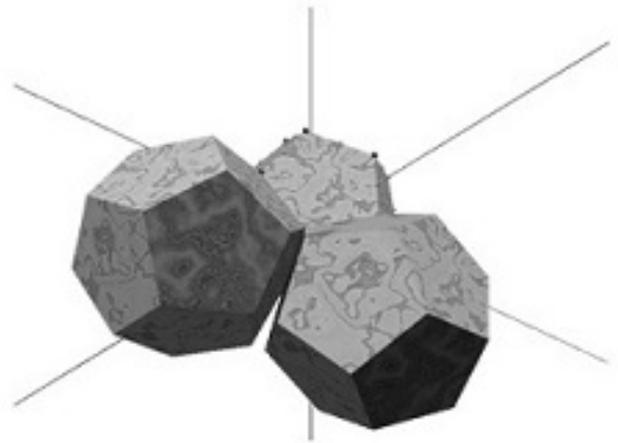


Fig. 11. Number of messages transmitted with different Hello interval.

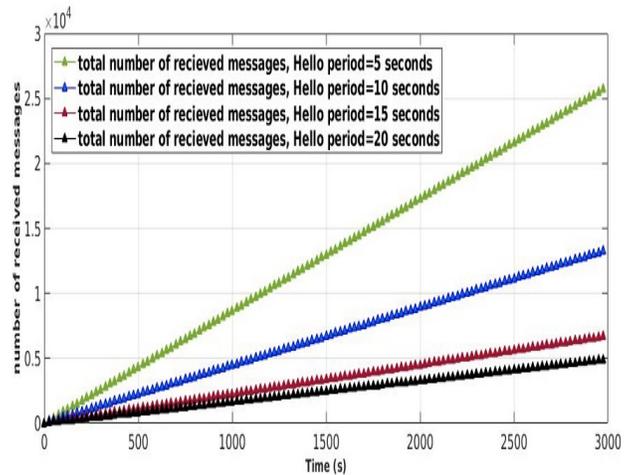


Fig. 12. Number of messages received with different Hello interval.

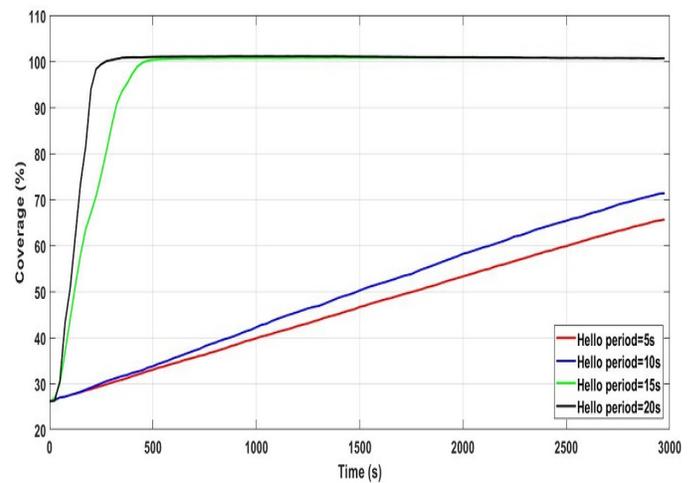


Fig. 13. Coverage rate with different hello interval.

VI. CONCLUSION

The existence of the Underwater Sensor Networks (UWSNs) applications and the interest in exploring and moni-

toring oceans motivate us into the field of UWSN deployment. In this paper, we have adapted the distributed virtual force algorithm into the underwater environment by taking into consideration the effect of the water current force. Our main target is to reach the full coverage of the region of interest with a reasonable number of nodes while maintaining the network connectivity. We showed that the full coverage is reached faster with a number of nodes around the maximum bound. Moreover, the network connectivity is never lost the entire deployment time. We strive to investigate the energy consumed during the deployment in term of the number of messages sent and received, and the distance traveled by nodes. In future work, we will show how the deployment algorithm can increase the network lifetime by covering coverage holes by replacing battery depleted nodes.

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FabricVision: System of Error Detection in the Manufacture of Garments

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Abstract—A computer vision system is implemented to detect errors in the cutting stage within the manufacturing process of garments in the textile industry. It provides solution to errors within the process that cannot be easily detected by any employee, in addition to significantly increase the speed of quality review. In the textile industry as in many others, quality control is required in manufactured products and this has been carried out manually by means of visual inspection by employees over the years. For this reason, the objective of this project is to design a quality control system using computer vision to identify errors in the cutting stage within the garment manufacturing process to increase the productivity of textile processes by reducing costs.

Keywords—Computer vision; histogram of oriented gradient; segmentation; object detection; image capture

I. INTRODUCTION

In the textile industry, quality control is required in manufactured products and this has been carried out manually by means of visual inspection by employees over the years, observing the product, analysing it, classifying it and discovering its imperfections. However, people may overlook several errors because of various external factors, in addition to the human visual inspection has drawbacks such as distraction and fatigue of the operators to be a repetitive task or they are simply very slow when doing the inspection, which generates losses of product replacement or a decrease in profits when selling the products at lower prices. It is necessary to evaluate methods to increase the efficiency of these processes, focusing on the use of automatic machines to find small details that those in charge of the inspection cannot observe, so that the quality control is a competitive advantage in the textile industry [1].

A system of quality control is proposed using computer vision to increase the precision in the inspection of the manufactured products and thus to achieve speed in the process of inspection and to increase the production.



Fig. 1. Raspberry Pi 3 embedded system.

As for the device being implemented for processing, it is an embedded system Raspberry Pi 3 (Fig. 1), which has an operating system based Linux, Raspbian, in which an application compiled in OpenCV or free software to make it possible the implementation of complete computer vision system [2], [3]. The Raspberry Pi 3 system has been chosen due to its hardware performance and the relative ease of using Raspbian for the intended implementation; some other development boards, such as Arduino, would force a more complex computer vision program with no apparent benefit compared to Raspberry Pi 3, in turn, the low consumption and small dimensions of the Raspberry Pi 3 make it ideal for its handling, assembly and operation, compared to a conventional computer.

For the acquisition of images use of a sensor with maximum resolution of 720 pixels and 24 bits of color depth is made.

II. HISTORICAL FRAMEWORK

With the success of the technological revolution or second industrial revolution in the late 19th and early 20th century, mankind has always sought to adopt technology to streamline its processes. Thus, with the advance of the creation of digital images that emerged in the decade of the twenties and continues to the present day, computer vision took a lot of interest in researchers and entrepreneurs. The idea of obtaining information through the analysis of an image revolutionized the way of seeing many processes, one of them, the process of detecting errors in quality control, which began to take increasing importance. During the time of the craft era in the nineteenth century, products had been sought to meet the quality attributes that the end-user desired, with the passage of time and increase in production volume, the piece-by-piece inspection became impossible to perform, in consequently, Harold F. Dodge and Harry Roming, quality researchers, implemented acceptance sampling, thus only inspecting several products within the total. However, this solution was not sufficient to obtain the total quality, although the costs for errors in the products were reduced significantly, still exist errors that represented costs for the companies. Technology applied to quality was necessary, so computer vision systems became important in quality control posts for the most delicate processes. From this background, a large variety of research and applications have been made on the use of computer vision and image processing for error detection. On the other hand, having food, clothing and a home to live are human physical needs. Clothing has been taking on more and more meaning for humanity, to the point of becoming

a representation of us, our personality and our way of life [4]. It is for this reason that the manufacture of garments has evolved notably from periods such as the Neolithic period. Currently the design and manufacture of garments not only covers the most basic needs of users, but also offers technologies ranging from waterproof fabrics to wearables, smart devices that can be worn. Being necessary even in the design and construction of automobiles and airplanes. Textile production has become essential. Therefore, the textile industry is one of the largest industries in the world at the sales level only behind industries such as tourism and information [5], [6], [7].

III. THEORETICAL FRAMEWORK

A. Basic Manufacturing Process in the Textile Industry

In order to carry out the fabrication process of textile products, various steps are represented by stages (Fig. 2).

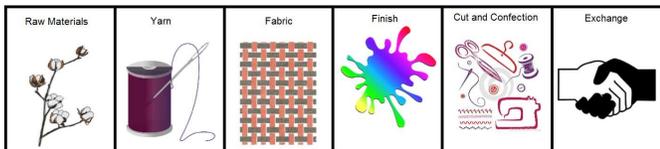


Fig. 2. Stages of the manufacturing process of textile products.

Raw Materials: These can be divided into natural fibers and synthetic fibers, such as cotton, wool, silk and nylon, polyester, rayon, respectively. Naturally, with the exponential growth of processes and the world population, the need for textiles has grown in the same way. It is believed that an economically stable person consumes between 20 and 25kg of textile products annually. This has created the need to produce more and more synthetic fibers to meet the needs.

Yarn: Process through which the fibers are either natural or synthetic are transformed into fine, resistant, flexible and extremely long thread that allows to create fabrics.

Fabric: This is a process that in essence has not changed since the origins of the first garments. However it is also the most complex due to the large number of fabrics that exist. It consists of four basic steps: Tissue organization, Positioning of tissues in parallel, Drawn, and Twisting. The process at its most basic level tries to organize the fibers strategically according to the type of fabric desired and to interlace them in such a way that they maintain a consistency throughout the process.

Finish: This process is responsible for three main tasks: 1) Remove impurities that may appear on the fabric. 2) Dyeing and stamping determined by the use that will be given to the fabric. 3) Modifications in the surface of the fabric, either to improve the physical properties of the product which translates into greater comfort or simply aesthetic improvements.

Cut and confection: It is the last stage of the manufacturing process of a textile product, in this, the fabrics treated in the previous stages are transformed into a final product, passing through sub-stages, such as:

Cutting: The goal of this stage is to turn the fabric into pieces with specific shapes to be joined later through the

sewing stage. Depending always on the type of technology used the cutting stage can be divided into seven basic steps:

- 1) A cut design is established for the parts of the product to be processed.
- 2) An optimization pattern is created to reduce waste as much as possible.
- 3) Prepare the fabric to cut.
- 4) Raw cuts are made that will serve for a next fine cut of contours.
- 5) A mark is made on the pieces that will aid in fine cutting. These marks are imperceptible in the final product.
- 6) Fine cuts are made. The piece takes the final shape.
- 7) Parts are prepared for future steps.

Sewing: It is made the union of the pieces in 2 or 3 dimensions that shapes the final product. At this stage the technology has been limited by the complexity that implies the union of pieces in 3 dimensions.

Detailed: Here you can apply the formulas (buttons, locks, etc.).

This process then comprises a systematic and orderly succession of steps, the last can not be performed without having done all the previous ones. This is why in processes as dependent as this is necessary to have a control of errors in each of the stages of the process, otherwise these errors would represent costs for manufacturing companies.

B. Analysis of a Digital Image

It is common to hear that the term quality is associated or used when talking about high definition images, however this is not totally true. While the current formats present large amounts of pixels, 980x720 pixels for the High Definition (HD), this does not guarantee the image quality. This is simply the size of the image. The true quality of the image is directly related to the color depth of each pixel, namely, its representation, the more bits to represent a pixel, the longer the color palette. This way our images will have as much quality as we want.

Also the quality of the image will depend on external factors, such as lighting, it is not the same to take an image in an open place where the irregularities of light are constant, that a closed place with lighting controls. To solve these problems of quality and thus extract the information of the image with more facility exist methods as they are the smoothing and enhanced. By one hand, the purpose of smoothing is to eliminate noise, which is presented as color irregularities between pixels. Some smoothing techniques are: Average neighborhood environment and Medium, fashion, maximum and minimum filtering. By the other hand Enhanced methods for the study of this work, these methods of improvement are not necessary, since being a quality control the lighting conditions will be optimal.

Furthermore, Histogram is a representation of an image in the form of discrete function, that is, with a finite number of values. This represents the number of pixels that are in the image according to its intensity level. For example, the histogram of a grayscale image whose intensity levels oscillate between 0 and 255, results in a bar graph from which we can obtain valuable information according to its distribution at the moment of analyzing digital images [8].

Finally, for the analysis of the image it is necessary of the segmentation that is the process through which we will obtain

the information of the edges and regions, being based in this way in the discontinuity and the similarity. An edge will be represented by a drastic change in intensity levels, i.e. there will be discontinuity in the image, in a region there will be similarity [9].

1) *Smoothing*: The purpose of this operation is to eliminate the noise, which appears as color irregularities between the pixels. Some smoothing techniques are:

- Averaged neighborhood environment.
- Filtering the median, fashion, maximum and minimum.

$$g(i, j) = \sum_{k,l} f(i+k, j+l) h(h, l) \quad (1)$$

From (1):

- $g(i, j)$ is the value of an output pixel.
- $f(i+k, j+l)$ is the sum of input pixel values.
- $h(h, l)$ is the kernel, the filter coefficients.

2) *Enhancing*: For the study of this thesis, these methods of improvement are not necessary, since when it is a quality control the lighting conditions will be optimal.

3) *Histogram*: It is a representation of an image in the form of a discrete function, that is, with a finite number of values. This represents the number of pixels that are in the image according to their intensity level.

As we observed in Fig. 3, the histogram of a digital image, in this case, at a gray scale whose intensity levels oscillate between 0 and 255, results in a bar graph from which we can obtain valuable information according to its distribution at the moment to analyze digital images.

IV. MAIN ALGORITHM

In the manufacture of garments, garments that go through the cutting process, come from a previous process of dyeing, so that the color posed a challenge in obtaining the correct image for analysis and detect errors. So, it is necessary to contrast the background with the garment in our acquisition of the image.

The block diagram of the project is shown in Fig. 4.

Thus, due to these color variations in the garments, it was necessary to add a dynamic background with RGB LEDs. The process is the following:

- 1) Acquisition of the image: The image of the garment is captured, Fig. 5.
- 2) Identification of the Region of Interest: The image is transformed to gray scale and binarized using an adaptive threshold. This works by comparing a pixel with a certain number N of pixels that surround it.

$$T_{dynamic}(x, y) = \begin{cases} 0 & g(x, y) < t(N(x, y)) \\ 0 & g(x, y) \geq t(N(x, y)) \end{cases} \quad (2)$$

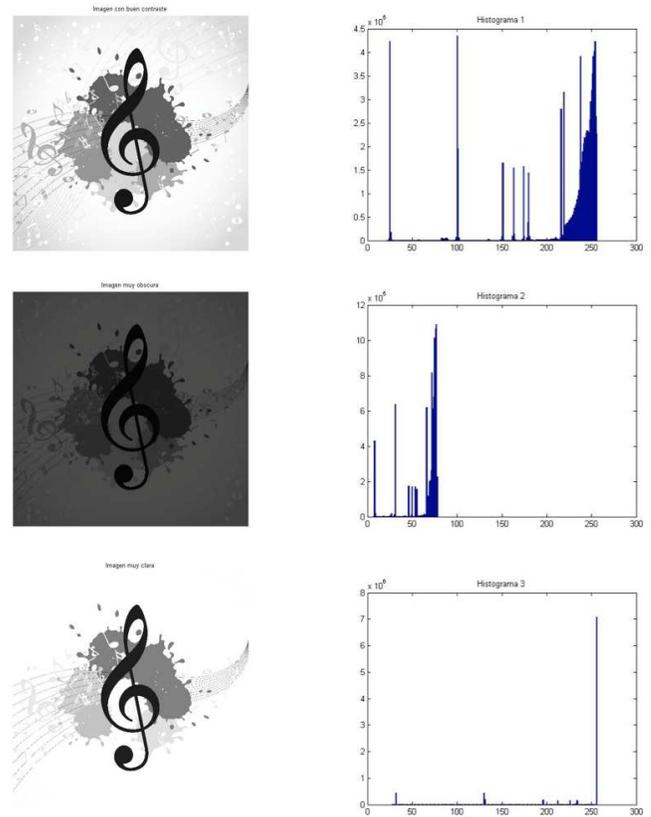


Fig. 3. Image with its histogram (a) Image with good contrast (b) Very dark image (c) Image with a lot of brightness.

then (2) calculates a threshold for each pixel individually. Once the image has been binarized, the edges are detected using the Canny algorithm, which consists of four steps:

- a) Noise reduction through a Gaussian filter.
- b) Identification of the intensity gradient in the image.
- c) Erasing pixels that do not constitute the edge.
- d) Edge thresholding to decide which meets the required intensity.

Once having the edges, it can establish the Region of Interest and work directly on it.

- 3) Average color of the Region of Interest: Each skin of each of the channels of the Region of Interest is averaged: red, green and blue. That is, we will have an average of the red, green and blue color present in the Region of Interest (Fig. 6).
- 4) Background color change: With these values the color less presented in the image is determined according to the values of Table I, this will be the new color of the background to increase the contrast (Fig. 7).

The number of RGB LED's in the matrix, 100 in our case, requires a certain current, each LED has a working current I_0 of 20mA, so our matrix needs to be fed with 2A of current to work properly, with a proper luminescence For our application. To achieve this luminescence it is necessary to adequately saturate the circuit, for that we used TIP100 transistors with current handling up to 8A. Considering a future expansion of

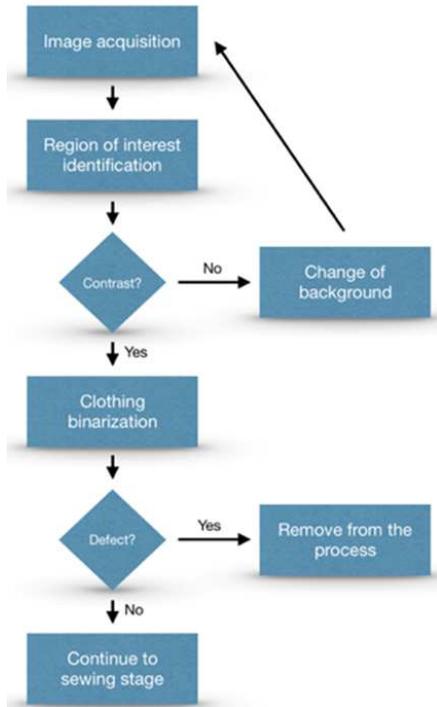


Fig. 4. Block diagram of the project.



Fig. 5. Acquisition of the image.

the LED array. In order to make possible the color change in the RGB matrix, it is necessary to have a control for each RGB primary color (red, green, blue), using the output ports of the Raspberry Pi 3 that must be connected to each Transistor to exert the switch function and power the circuit with the 2A current. However, a problem arises here, because the base-emitter voltage (V_{BE}) that most transistors handle is 5v and the maximum output voltage of the Raspberry Pi 3 is 3.3v. This prevents the saturation of the transistor and therefore represents a malfunction. The solution to this is the implementation of an photocoupler, which allows to use the 3.3v voltage level of the Raspberry Pi 3 as a switch to power the transistors

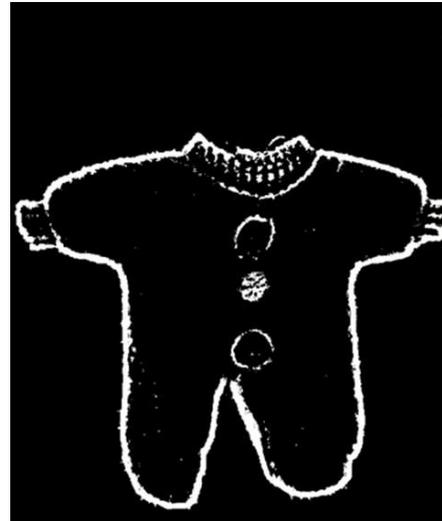


Fig. 6. Region of Interest.



Fig. 7. Background color change.

with a voltage level of 5v. The next step is the comparison of histogram and binarization. Then, any histogram analyzes pixel by pixel the intensity of the image, in our case, the acquired image will be transformed into grayscale, with intensity values from 0 to 255, i.e. with 8 bits of depth. The histogram shows us the concentration of pixels according to their tonalities, in our case the garment takes a dark tone due to the illumination, this helps us, since these dark colors will always be found at the beginning of the histogram (Fig. 8(a)). For each model,

TABLE I. COLOR COMBINATIONS IN RGB LEDs

Red	Green	Blue	Combination
0	0	0	Without lighting
0	0	1	Blue
0	1	0	Green
0	1	1	Cyan
1	0	0	Red
1	0	1	Magenta
1	1	0	Yellow
1	1	1	White

a mask is defined that represents the final pixel intensity value to be taken so that the garment is binarized and thus perfectly segmented from the color background (Fig. 8(b)). The comparison will then be made with two images that in theory should be the same, one will be the original model to repeat in the cutting process and another will be the garment in production line (Fig. 8(c)). A great advantage of using this method for the analysis is that a prior alignment of the garment is not necessary, since no matter the location within the image, the garment contributes the same amount of pixels. For this to be true care must be taken that the distance from the sensor to the garments is the same, otherwise, the objects in the image appear different sizes, changing the histogram.

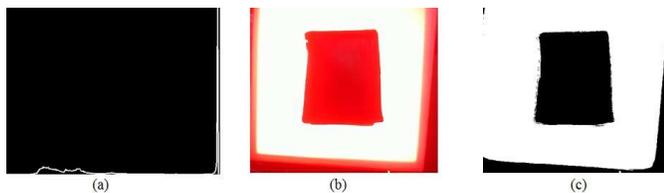


Fig. 8. (a)Histogram of the model; (b)Segmentation of the main image; and (c) Binarized image.

V. EXPERIMENTAL RESULTS

Thus the acquired image of the garment in production line is compared with the image of the model, stored in the system. The comparison will result in the following scenarios, depending on their similarity or difference expressed as a percentage:

1) Similarity between 100-95%: It is the ideal scenario and means that the garment in production line is exactly the same as the desired model. The percentage difference is due to lighting defects that come to be presented. So the process continues without interruption.

2) Similarity between 95-80%: In this scenario there is a clear difference, which can mean 2 errors: a) Garments of different sizes have been mixed. b) The garment presents bad cuts or ruptures in the fabric of previous processes. In this case, a check indicator is illuminated for the operator. This person will determine, depending on the severity of the error, the use of the defective garment.

3) Similarity less than 80%: Here the difference is remarkable and can represent 2 errors: a) The garment in production line has been mixed from another process, which explains the little similarity. b) The change of the model analysis has undergone some error, that is to say, there is a problem in the prototype, having thus to enter in the equation the operator.

In 3 cases, the proposed algorithm responds with a 98.07% of success. The errors were found when proposed algorithm processes a garment with similarity less than 80%, i.e. the third case.

VI. CONCLUSIONS

A broad investigation of the topics was developed within different areas that are related by this work, areas such as the textile, such as medicine and computational. A variety of resources such as books, internet articles and even image

editors were used in order to achieve a theoretical basis as robust as possible. Also Raspberry Pi 3 embedded system was implemented along with the Ubuntu operating system and the OpenCv compiler for the development of computer vision codes. It was possible to make a perfect segmentation of garments regardless of the color that was given them in previous processes within the textile manufacturing, this was possible thanks to the implementation of a dynamic opaque background composed of RGB LEDs that change color depending on contrast with the garment. The main process was based on the comparison of histograms of two images that in the ideal case should be exactly the same, one is the model to replicate within the production process and another is the garment in turn within the process. This analysis then represents a way of detecting not only whether the garment is the same to the model, but also to determine what the possible error is. The set of all these processes resulted in an extremely useful computer vision system for the cutting stage within the textile manufacturing process. The error detection performed by this system improves performance by finding errors that are difficult to detect by employees, which undoubtedly results in an improvement in the quality control of any company.

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An Efficient Method for Breast Mass Segmentation and Classification in Mammographic Images

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Abstract—According to the World Health Organization, breast cancer is the main cause of cancer death among women in the world. Until now, there are no effective ways of preventing this disease. Thus, early screening and detection is the most effective method for rising treatment success rates and reducing death rates due to breast cancer. Mammography is still the most used as a diagnostic and screening tool for early breast cancer detection. In this work, we propose a method to segment and classify masses using the regions of interest of mammographic images. Mass segmentation is performed using a fuzzy active contour model obtained by combining Fuzzy C-Means and the Chan-Vese model. Shape and margin features are then extracted from the segmented masses and used to classify them as benign or malignant. The generated features are usually imprecise and reflect an uncertain representation. Thus, we propose to analyze them by a possibility theory to deal with imprecise and uncertain aspect. The experimental results on Regions Of Interest (ROIs) extracted from MIAS database indicate that the proposed method yields good mass segmentation and classification results.

Keywords—Mammography; breast mass; mass segmentation; fuzzy active contour; mass classification; possibility theory

I. INTRODUCTION

Breast cancer is the most common form of cancer in the world. It has become the second cause of death by cancer in women after lung cancer. According to the World Health organization (WHO), in 2012, there were 1.7 million newly diagnosed breast cancer cases in the world [1]. Moreover, between the years 2008 and 2012, breast cancer incidence has increased by 20%, while mortality has augmented by 14%. Such statistics motivate researchers to design new tools for early detection and diagnosis of breast cancer.

Computer-Aided Diagnosis (CADx) systems have been developed to reduce the experts' workload and to help them in early detection of breast cancer [2]. Such systems involve generally four phases: preprocessing, segmentation, feature extraction and selection, and classification [3]. Each of these phases should be performed appropriately. In fact, the performance of each stage can affect that of the subsequent stages [4].

Breast masses are the most important indicators of malignancy that can be present in mammography. It is often difficult to distinguish this type of abnormality from the surrounding parenchymal. Thus, its automated segmentation and classification is a challenging task. There is extensive literature on mass segmentation methods. They can be divided

into several techniques such as: thresholding-based techniques, region growing-based techniques, clustering-based techniques and active contour-based techniques.

Thresholding-based techniques can be classified into global and local thresholding. Global thresholding focuses on global information such as the histogram of the mammograms [5]. When masses are sufficiently brighter than surrounding tissue, it is possible to use a global threshold. However, local thresholding determines a local threshold value for each pixel based on neighbor pixels intensity values. Thresholding techniques has been widely used for mammographic mass segmentation [6]–[8].

Region growing-based techniques start from initial seed point and regroup pixels of similar characteristics to divide the mammographic image into homogeneous regions. Cao et al. [9] proposed an adaptive region growing method with hybrid assessment function combined with maximum likelihood analysis and maximum gradient analysis. This method is used to segment mammographic masses. Berber et al. [10] proposed an extension of the classical seeded region growing for mass segmentation in mammographic regions of interest. In fact, in this work the threshold value is adjusted adaptively based on mass size estimation to prevent over- and under-segmentation.

Clustering-based techniques classify mammogram pixels by grouping those with similar properties into a set of clusters. Sampaio et al. [11] use cellular neural networks to develop a computational methodology for mass segmentation. In [12], the authors propose an extension of the K-means method. The disadvantage of Clustering-based techniques is that they need to set manually the number of clusters.

Active contours-based techniques can be classified into snakes and level sets. The difference between these two types is their mathematical implementation. In fact, the boundary in snake evolves explicitly. However, it evolves implicitly in level set. There are numerous studies on mass segmentation using level set methods [13]–[15].

Mass classification is a key technology in CADx systems. It is very useful in early breast cancer detection and it can prevent unnecessary biopsy [2]. Several researches have investigated mass classification. Gorgel et al. [16] use the support vector machine (SVM) method to classify the segmented masses as benign or malignant. The segmentation was performed using a local seed region growing (LSRG) algorithm. In [17], the authors combine both texture and shape features to classify

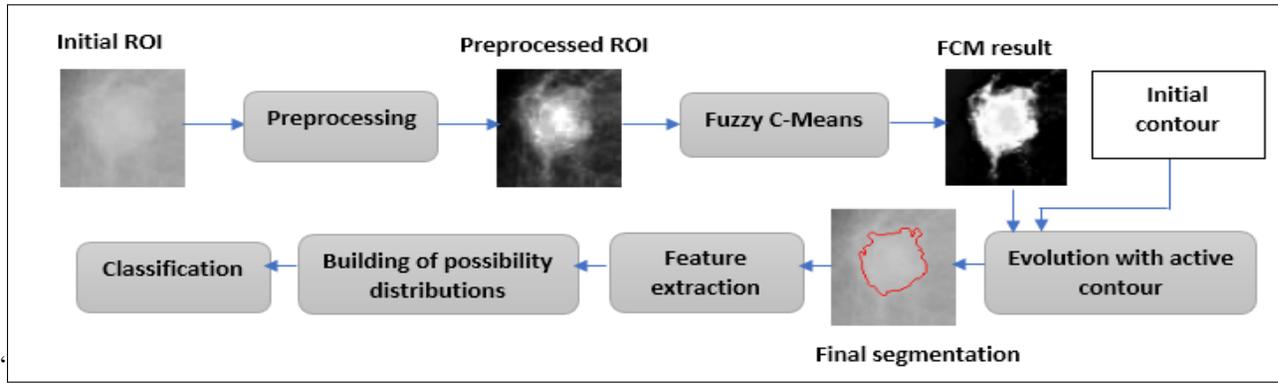


Fig. 1. Flowchart of the proposed method.

masses by using SVM and ELM networks with modified kernels. Liu et al. [2] performed mass classification using selected geometry and texture features, and a new SVM-based feature selection method.

In this paper, we propose a novel method for automatic mass segmentation and classification of mammographic masses. A general flowchart of the proposed method is outlined in Fig. 1. Mass segmentation is based on the Chan-Vese model. Considering the fact that masses have fuzzy boundaries, we propose to deal with this problem using fuzzy logic by integrating fuzzy membership values in the Chan-Vese model. This leads to a fuzzy Chan-Vese model. The estimation of the fuzzy membership values is performed using the fuzzy C-Means method.

The classification of the segmented masses depends essentially on their shape. In fact, benign masses are usually round and oval having smooth contours. Nevertheless, malignant masses have generally irregular shape with lobulated or spiculated margins. This knowledge suffers from imprecision and ambiguity. Thus, we propose to deal with the problem of mass classification using geometry features while taking into account the uncertainty linked to the degree of truth of the available information and the imprecision related to their content.

This paper is organized as follows: In Section II, we describe the proposed method for mass segmentation. In Section III, we present the extracted features from the segmented masses. In Section IV, we provide the followed steps to build a possibility knowledge basis and we present the used method for mass classification. In Section V, we provide the results obtained using the proposed method. Finally, Section VI presents a conclusion of this work.

II. MASS SEGMENTATION

The proposed mass segmentation method is based on the Chan-Vese active contour which is a region-based active contour capable of segmenting objects whose boundaries are not defined by gradient. Nevertheless, the disadvantages of this model are the problem of leaking which arises when the mass margins are fuzzy and ambiguous and the problem of increase of false positives in presence of tissue homogeneity. To overcome these problems, we propose a fuzzy version of the Chan-Vese model which is able to reject “weak” local minima

and to handle objects with discontinuous boundaries. The fuzzy C-Means method is used to build the fuzzy Chan-Vese model. In this section, we start by presenting the conventional Chan-Vese model and the fuzzy C-Means method.

A. Previous Methods and Background

a) *The Chan-Vese Model:* Chan and Vese [18] proposed an active contour model without edges which allows segmenting objects whose boundaries are not defined by gradient. This model assumes that the image is formed by two approximately piecewise-constant intensities [19]. The energy function of the model is defined as follows:

$$E(c_1, c_2, C) = \mu \cdot L(C) + \lambda_1 \int_{in(C)} |I(x, y) - c_1|^2 dx dy \quad (1)$$

$$+ \lambda_2 \int_{out(C)} |I(x, y) - c_2|^2 dx dy$$

where μ , λ_1 and λ_2 are fixed positive parameters; c_1 and c_2 are the mean values inside and outside the curve C , respectively.

b) *The Fuzzy C-Means method:* The Fuzzy C-Means [20] is an iterative unsupervised fuzzy clustering algorithm which uses the concepts of fuzzy set theory and fuzzy logic to provide a fuzzy partition of the image. It is based on minimizing the following objective function:

$$J = \sum_{j=1}^C \sum_{i=1}^N \mu_{ij}^m \|x_i - \nu_j\|^2 = \sum_{j=1}^C \sum_{i=1}^N \mu_{ij}^m D_{ij}^2 \quad (2)$$

Where,

- C is the number of classes and N is the number of pixels;
- μ_{ij} is the degree of membership of the pixel x_i to the class j ;
- $m \in [1, \infty[$ is a fuzziness factor which is used to control the fuzziness of the obtained partitions;
- D_{ij} is the euclidian distance between the pixel x_i and the class center ν_j .

Membership functions μ_{ij} and class centers ν_j are updated iteratively using the following formulas:

$$\mu_{ij} = \frac{1}{\sum_{k=1}^C \left(\frac{D_{ij}}{D_{ik}}\right)^{2/m-1}} \quad (3)$$

$$\nu_j = \frac{\sum_{i=1}^N \mu_{ij}^m x_i}{\sum_{i=1}^N \mu_{ij}^m} \quad (4)$$

The iteration will stop when the following condition is reached:

$$|J^{t+1} - J^t| \leq \varepsilon \quad (5)$$

The proposed mass segmentation method consists of mainly three steps: Firstly, the ROI is preprocessed to enhance the contrast. Next, two fuzzy membership values are estimated based on fuzzy C-Means algorithm. These fuzzy membership values are finally used to modify the energy of the Chan-Vese model and to perform the final segmentation.

B. Preprocessing

Since mammographic images are poor in contrast, a pre-processing step is necessary to enhance the contrast of ROIs. Thus, gamma correction which is a non linear transformation process is applied to change the luminance of these ROIs. The mathematical form of its transformation function is as follows [21]:

$$I_{out} = c.I^\gamma \quad (6)$$

where I is the input image, I_{out} is the output image, c and γ are parameters controlling the shape of the transformation curve. Fig. 2 shows how intensity values are mapped with different values of γ . From this figure, it can be seen that a γ value greater than 1 allows having an image with a higher contrast. In our experiment, we set the value of γ to 4.

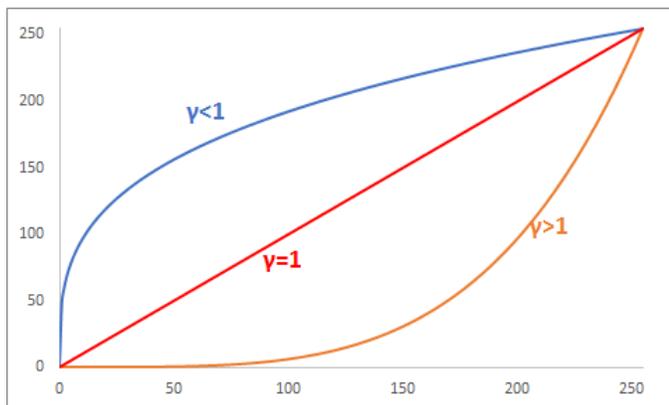


Fig. 2. Transformation curves with different values of γ .

C. Fuzzy Membership Estimation

The aim of this step is to determine the membership degrees $\mu_M(x, y)$ and $\mu_B(x, y)$ of each pixel of coordinates (x, y) to the class ‘‘Mass’’ and ‘‘Background’’. In this paper, we propose an estimation process based on Fuzzy C-Means

algorithm [20]. The followed steps to achieve this objective are:

- 1) Initialization of the fuzzy membership matrix μ_{ij} ;
- 2) Calculating the cluster centers using (4);
- 3) Updating the fuzzy membership matrix μ_{ij} using (3);
- 4) Return to Step 2 until convergence or maximum number of iterations is reached.

D. Segmentation using a Fuzzy Active Contour Model

After estimating the fuzzy memberships, the proposed method performs mass segmentation using a fuzzy active contour model. This model is based on the Chan-Vese model. In fact, the energy of each pixel which is formulated as $|I(x, y) - c_1|^2$ or $|I(x, y) - c_2|^2$ in the Chan-Vese model is weighted by the corresponding membership value $\mu_M(x, y)$ or $\mu_B(x, y)$ so that the formula of the energy formula becomes as follows:

$$E(c_1, c_2, C) = \mu \cdot L(C) \quad (7)$$

$$+ \lambda_1 \int_{in(C)} \mu_M(x, y) \cdot |I(x, y) - c_1|^2 dx dy$$

$$+ \lambda_2 \int_{out(C)} \mu_B(x, y) \cdot |I(x, y) - c_2|^2 dx dy$$

III. FEATURE EXTRACTION

Shape and margin features are the most important features to differentiate between benign and malignant masses. In fact, malignant masses have spiculated or microlobulated boundaries and irregular shape. However, benign masses appear smooth in the boundary and round in shape [22] (Fig. 3). In this

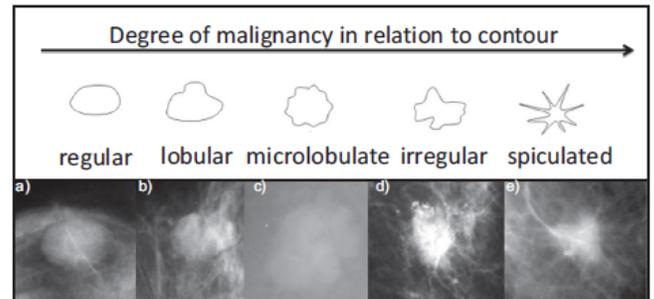


Fig. 3. Classification of breast masses according to their contours.

paper, nine shape features are extracted, including circularity, compactness, rectangularity, normalized radial length (NRL)-based features (mean, standard deviation, entropy, area ratio, zero crossing, roughness). These features are listed in Table I.

IV. BUILDING THE POSSIBILITY DISTRIBUTIONS OF THE FEATURES AND MASS CLASSIFICATION

In order to build a possibility knowledge basis, the mass description which is formulated by the extraction of shape and margin features should be transformed into a possibility description. Thus, a possibility distribution should be estimated for each feature and each class. In this work, the

TABLE I. EXTRACTED FEATURES FROM MAMMOGRAPHIC MASSES

Feature	Description	Equation
Circularity [23]	Represents how a mass is similar to a circle.	$C = \frac{A}{A_C}$ where A is the area of the mass given by the number of pixels inside its contour and A_C is the area of the circle having the same perimeter as the mass.
Compactness [24]	A measure of contour complexity versus the enclosed area.	$Com = \frac{P^2}{A}$ with P is the perimeter of the mass measured by summing the number of pixels on the contour's mass: $P = \sum_{pixels \in Contour} 1$ and A is its area.
Rectangularity [23]	Represents the degree of resemblance between the mass and a rectangle.	$Rect = \frac{A}{A_R}$ with A is the area of the mass and A_R is the area of the minimum bounding rectangle.
NRL Mean [25]	Mean of the Normalized Radial Length	$d_{mean} = \frac{1}{N} \sum_{i=1}^N d(i)$ where $d(i)$ is the Euclidian distance from the mass center to each of the boundary points normalized by dividing by the maximum radial distance.
NRL standard deviation [25]	Represents the variance of the NRL around a circle defined by NRL Mean as radius.	$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^N (d(i) - d_{mean})^2}$
NRL entropy [25]	A probabilistic measure determining how well the mass's radial length could be estimated. It includes both the idea of roundness and tumor roughness.	$E = -\sum_{k=1}^{100} p_k \log(p_k)$ where p_k is the probability of a NRL to the number of whole radials.
NRL area ratio [25]	Evaluates the percentage of the mass proportion located outside the circle defined by NRL Mean. Thus, it allows discriminating between masses with smooth and spiculated contours.	$AR = \frac{1}{d_{mean} \cdot N} \sum_{i=1}^N (d(i) - d_{mean})$
NRL zero crossing [25]	Represents the number of times the line plot crossed the mean NRL.	
NRL roughness [25]	Allows isolating the macroscopic mass shape from the structure of the fine contours.	$R(j) = \sum_{i=j}^{L+j} d(i) - d(i+1) $

generation of the initial possibility distributions, the choice of their shape and their parameters are performed based on the knowledge expressed by the expert. Fig. 4 shows the possibility distributions of the circularity feature.

The obtained distribution functions are then modified by considering the score feature evaluating its pertinence. Plenty of feature selection methods which use ranking criterion to score the features are available in the literature [26]. In our proposed method, the fisher score is used for feature selection due to its good performance. In fact, it evaluates each feature individually by measuring the degree of class separability with the following formula:

$$F(i) = \frac{\sum_{c=1}^C \eta_c (\mu_c^i - \mu^i)^2}{\sum_{c=1}^C \eta_c (\sigma_c^i)^2} \quad (8)$$

where, η_c is the number of elements belonging to the class c ; μ_c^i and σ_c^i are the the mean and the standard deviation of the i th feature in the class c , respectively; μ^i is the global mean of the i th feature.

The obtained Fisher scores are used to adjust the possibility distributions as follows:

$$\pi_i'(B) = \max(\pi_i(B), 1 - F(i)) \quad (9)$$

$$\pi_i'(M) = \max(\pi_i(M), 1 - F(i)) \quad (10)$$

After adjusting the possibility distributions, a fusion step is performed in order to combine all the information relative to extracted features and to obtain information of better quality. Thus, a conjunctive operator (minimum operator) is applied to the possibility distributions associated with the different features to get only one distribution for each class. The final possibility distributions are obtained as follows:

$$\begin{cases} \pi(B) = \pi_1'(B) \oplus \dots \oplus \pi_i'(B) \oplus \dots \oplus \pi_M'(B) = \\ \min(\pi_1'(B), \dots, \pi_i'(B), \dots, \pi_M'(B)) \\ \pi(M) = \pi_1'(M) \oplus \dots \oplus \pi_i'(M) \oplus \dots \oplus \pi_M'(M) = \\ \min(\pi_1'(M), \dots, \pi_i'(M), \dots, \pi_M'(M)) \end{cases} \quad (11)$$

The possibilistic decision can be made based on the maximum possibility measure, the maximum necessity measure or on the maximum confidence index. In this work, the decision-making is based on the maximum possibility value because it is the most intuitive and the most used decision in possibilistic classification.

V. EXPERIMENTAL RESULTS

A. Dataset

All the images used in this paper are belonging to a publicly available digital mammography dataset, which is the Mini Mammographic Image Analysis Society (MIAS) dataset [27]. It consists of 322 medio-lateral oblique (MLO) views of 161 patients. The images are digitized to 200 micron pixel edge and clipped/padded so that every image is 1024×1024 pixels.

A set of 57 ROIs were extracted from this dataset. These ROIs contain masses with different margin types such as CIRCumscribed (CIRC), SPICulated (SPIC), and MISClassified masses (MISC). Fig. 5 shows the distribution of the different mass margin types based on their severity. The contours of these masses were manually annotated by an expert radiologist to serve as ground truth (GTR).

B. Evaluation Metrics

We have used the accuracy, precision and sensitivity measures to evaluate the performance of the proposed segmentation and classification methods. These measures are defined as follows:

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN} \quad (12)$$

$$Precision = \frac{TP}{TP + FP} \quad (13)$$

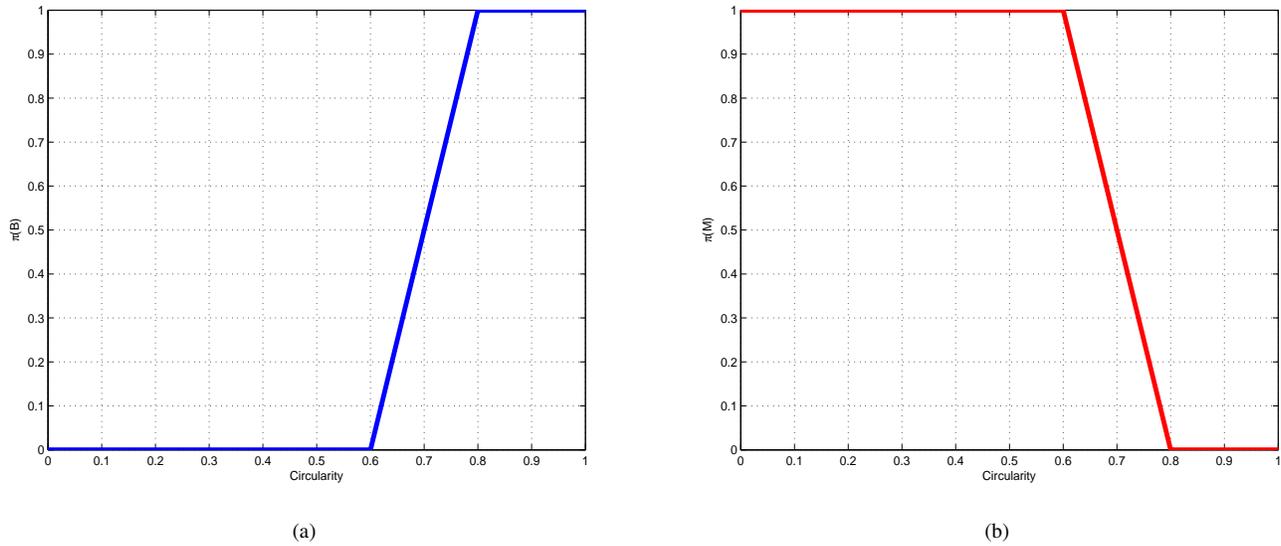


Fig. 4. Possibility distributions of the circularity feature (a) Possibility distribution of the class benign; (b) Possibility distribution of the class malignant.

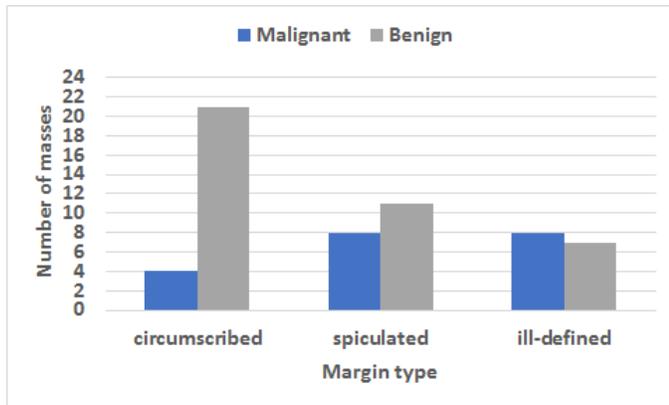


Fig. 5. Distribution of different mass margin types in the MIAS database.

$$Sensitivity = \frac{TP}{TP + FN} \quad (14)$$

where:

- True Positives TP: Pixels that are correctly segmented as Mass for the segmentation method ($SR \cap GTR$) and the number of malignant masses correctly classified as malignant for mass classification method.
- False Positives FP: Pixels that are segmented as Mass but they are not labeled so as in GTR for segmentation ($SR \cap \overline{GTR}$) and the number of benign masses falsely classified as malignant for classification.
- True Negative TN: Pixels that are correctly segmented as background for segmentation ($\overline{SR} \cap \overline{GTR}$) and the number of benign masses correctly classified as benign for classification.
- False Negative FN: Pixels classified as normal tissue in the SR but they are labeled as Mass in the GTR for segmentation ($\overline{SR} \cap GTR$) and the number

of malignant masses falsely classified as benign for classification.

C. Segmentation Results

Fig. 6 shows the results of preprocessing, the results of fuzzy membership estimation and also the final segmentation results of four ROIs extracted from the MIAS database. From this figure, we can note that the proposed method reduces the false positives. In fact, even though the benign tissue exhibits in-homogeneity, no noisy regions have been falsely detected outside of mass regions. The values of the quantitative evaluation measures for the ROIs are also given in this figure. We can notice that the proposed method gives satisfactory results both for benign masses (sample 2 and sample 4) and for malignant masses (Sample 1 and Sample 3).

To prove that the combination of the Chan-Vese model and the FCM method improves the segmentation results, we give in Table II the performance results on the whole database of the Chan-Vese model, the FCM method and the proposed method. We can note from this table that our proposed method has the highest accuracy and precision. However, the highest sensitivity is obtained by the Chan-Vese model. This can be justified by the overestimation of mass boundaries caused by this model.

TABLE II. OVERALL PERFORMANCE RESULTS OF MASS SEGMENTATION APPLIED ON MIAS DATABASE

Method	Accuracy	Precision	Sensitivity
Proposed segmentation method	94.66%	81.87%	78.94%
FCM	89.55%	69.37%	71.08%
Chan-Vese model	89.27%	61.22%	81.73%

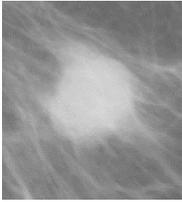
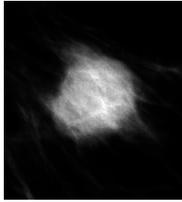
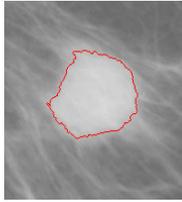
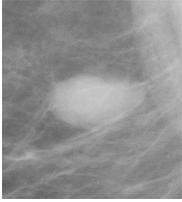
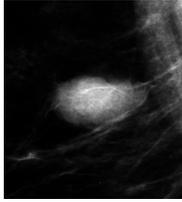
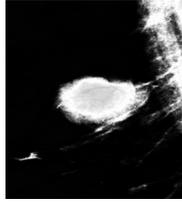
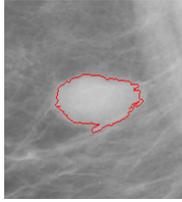
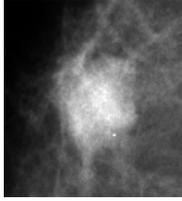
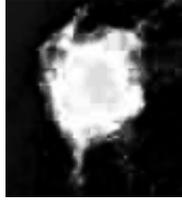
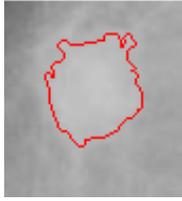
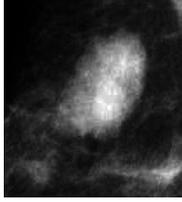
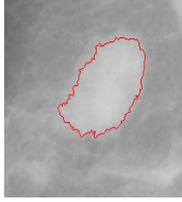
	Original ROI	Preprocessed ROI	FCM result	Final result
Sample1				 Accuracy=98.31% Precision=97.20% Sensitivity=91.73%
Sample2				 Accuracy=98.67% Precision=96.12% Sensitivity=89.43%
Sample3				 Accuracy=95.82% Precision=99.18% Sensitivity=83.73%
Sample4				 Accuracy=96.29% Precision=99.44% Sensitivity=79.59%

Fig. 6. Obtained results with the application of the proposed method on four samples.

D. Classification Results

Table III is a comparison between our proposed possibilistic classification method and other state-of-the-art classification methods. We can notice that our method outperforms the other methods in terms of accuracy when applied to MIAS database. The promising results should be due to the possibilistic reasoning which represents a means of simulating human reasoning.

TABLE III. COMPARISON BETWEEN THE PROPOSED MASS CLASSIFICATION METHOD AND THE STATE-OF-THE-ART METHODS

Reference	Method	Accuracy
Proposed classification method	Possibilistic classification using geometric features	91.52%
[28]	Classification using neural networks and shape and density features.	89.28%
[29]	Classification using SVM with directional features.	82.30%

VI. CONCLUSION

In this paper, we have investigated and have presented the results of segmentation and classification of breast masses with a data set of 57 ROIs extracted from MIAS database. The

proposed segmentation method estimates fuzzy membership values to the class Mass and the class Background. These values are then used to modify the Chan-Vese model. Thus,

the motion of the evolving contour will be guided by the pixel fuzzy memberships. This allows obtaining an accurate segmentation even for masses whose boundaries are not defined by gradient. The proposed mass classification method is based on the possibility theory which can handle the uncertainty inherent to the available knowledge.

The obtained results show that the proposed method represents an efficient tool that can automatically segment and classify masses in an accurate way.

A limitation of our method is related to the ROI detection which is not performed in an automatic way. Thus, as perspectives, we propose to deal with other stages of CAD systems such as automatic ROI detection. Furthermore, we will investigate the possibility of introducing other features such as intensity and textural features to improve the mass classification results.

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Collaborative Editing over Opportunistic Networks: State of the Art and Challenges

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Abstract—Emerging Opportunistic Networks (ON) are under intensive research and development by many academics. However, research efforts on ON only addressed routing protocols as well as data dissemination. Too little attention was given to the applications that can be deployed over ON. These are assumed to use immutable data (*e.g.*, photos/video files). Nevertheless, Collaborative Editors (CE) which are based on mutable messages are widely used in many fields. Indeed, they allow many users to concurrently edit the same shared document (*e.g.*, Google Docs). Consequently, it becomes necessary to adapt CE to ON which represents a challenging task. As a matter of fact, CE synchronization algorithms should ensure the convergence of the shared content being modified concurrently by users. In this work, we give an overview on ON and CE in an attempt to combine both states of the art. We highlight the challenges that could be faced when trying to deploy CE over ON.

Keywords—Opportunistic networks; collaborative editors; consistency maintenance; operational transformation approach

I. INTRODUCTION

With the increase of mobile devices use in the last years, Opportunistic Networks (ON) have become an important research field. Indeed, ON allow to ensure wireless communication between peer nodes in a flexible and high dynamic way. As a matter of fact, any node can join and leave the network at any time. The communication paths between senders and receivers are neither direct nor static since the network's topology can change frequently and dynamically according to nodes' movements [1], [2]. ON rely on the Store-Carry-and-Forward (SCF) approach [3] to transmit data between nodes. Each node has a range of neighbors to which it can forward messages. To reach a destination that resides outside the sender's range, the latter simply forwards the message to direct contacts. These take then the responsibility to forward the message using an opportunistic communication pattern till it reaches the destination [1], [2], [4]. Consequently, the communication between nodes is made simpler.

Most importantly, ON demonstrate to be effective in emergency situations caused either by natural catastrophes or even terrorist attacks where the network infrastructure is made unavailable or broken. It may be also the only way of ensuring communication in poor countries like India. In such situations, it is very important to allow users to be interconnected for security and rescue reasons [1]. This could be achieved through

the establishment of an ad hoc communication using mobile devices that are massively available nowadays.

Collaborative Editors (CE) provide a set of shared documents that may be modified at any time by geographically dispersed users [5], [6]. This kind of applications may be used in different situations where ON are established between many users. For instance, it is useful for participants during academic events (*e.g.*, conferences) or rescue teams in emergency situations to face the breakdown of the communications infrastructure.

To illustrate the importance of CE in ON, we consider the example depicted in Fig. 1 where a university faces a fire incident. We suppose that the infected area is separated into two operation sections: emergency area (EA) and First-Aids Area (FAA). EA represents the university buildings affected by the incident while FAA is reserved to give first aids to patients who will be then transported by ambulances towards hospitals according to their priorities and current status. It is crucial to record and share patients' information during and after the incident between the operation areas and also between rescue team members and hospitals. Thus, all required information such as the patients' status and what kind of first aids and medications they have received are available before their arrival at hospitals. Therefore, it is obvious that using CE instead of a pen-and-paper approach will improve the efficiency of the rescue operation. Indeed, it is easy to equip all rescue members with inter-connected mobile devices. Meanwhile, the communication infrastructure for such situations can't rely on traditional networks since they will be probably out of use during the incident. Thus, ON represent a very appropriate communication means since it only requires the use of Wi-Fi-equipped mobile devices.

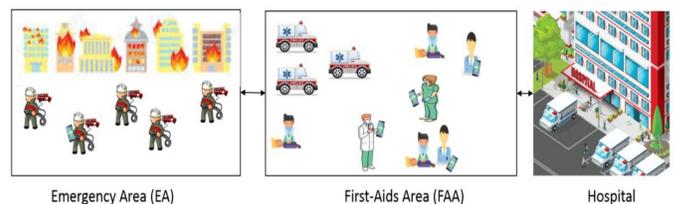


Fig. 1. Motivating the use of CE over ON.

However, the data handled by ON is generally supposed to be non modifiable like photos or video files. Too little attention was given to modifiable content over ON. Indeed, few researches have focused on how to adapt applications dealing with mutable content to ON [1], [7]. Indeed, combining CE with the high dynamic and mobility aspects of ON represents a real challenge. Moreover, ON require low storage capacity and low energy consumption.

Our paper aims at combining the state of the art of both CE and ON approaches and presenting the challenges faced when applying CE over ON.

First, this adaptation is motivated by the noticeable shift from desktop to mobile devices (laptops and smartphones, etc.). This phenomenon has lead to high mobility which is the basic motivation of ON. Since ON represent a new kind of networks, there is an urgent need to adapt many types of applications to ON.

Secondly, CE are more and more used nowadays due to their support of collaborative work, thus being useful for wide range of users in many fields. Adapting CE to ON is worthwhile because they allow opportunistic and ad-hoc teams to collaboratively edit the shared documents in a flexible way. Most importantly, CE are relevant for rescue teams. In [8], the need of adequate software tools in triage management was motivated which can be easily achieved by CE. Thus, CE are useful for disaster scenarios such as natural catastrophes (*e.g.*, hurricanes, earthquakes, etc.) or even human-generated network breakdowns. In fact, in such situations it is difficult to distribute critical notifications and rescue information to and among citizens [9]. CE can serve as a means of communication and collaboration in such situations.

Thirdly, CE should be allowed in ON since they are the only possible communication means in emerging countries that are disconnected from the global network (*e.g.*, countries in Africa or India) [1].

Finally, an interest to adapting CE over ON [1], [7] has emerged during the last years. However, the proposed solutions have many limitations. Thus, it is important to highlight the challenges faced when deploying CE over ON to help CE designers in taking the appropriate deployment and testing choices.

The main contribution of this survey is to provide an accurate study of both ON and CE. Therefore, we propose a set of comparison criteria between CE that take into account a possible deployment over ON. We highlight the challenges that might arise when adapting CE to an opportunistic context. To our knowledge, this is the first attempt to combine the literatures of CE and ON to provide a basic reference for CE designers and developers.

The remainder of this paper is organized as follows: First, we give an overview over ON in Section II. Second, we discuss CE types and properties in Section III. Afterward, we survey the most significant OT-based collaborative editing algorithms and compare between them in Section IV to raise the challenges that can be faced over ON. In Section V, we give an overview on existing CE models adapted to ON. Finally, we conclude in Section VI.

II. OVERVIEW ON OPPORTUNISTIC NETWORKS

ON are a kind of Delay Tolerant Networking (DTN) which has become popular in environments such as developing countries or disasters areas. Indeed, DTN is designed to support the disruption of connectivity and long delivery delays [10]. Precisely, ON are wireless ad hoc networks that represent an extension of mobile ad hoc networks [2]. ON represent an emergent solution for establishing communication even in the absence of any network infrastructure where routing depends on contact opportunities [10].

The key feature of ON is to be independent of any fixed network infrastructure. They ensure intermittent communication between peer nodes (or users) in a highly dynamic fashion, *i.e.*, there is no fixed topology and any node can join and leave the network at any time. More precisely, the sender and receiver do not need to be directly interconnected [1], [2].

A. Features of Opportunistic Networks

In ON, nodes are mobile devices with wireless networking capability [11]. There are three kinds of nodes: source, destination and intermediate. Indeed, ON nodes carry messages, store them in their local memories then forward them when a relevant opportunity occurs [10]. In ON, contacts are unpredictable since nodes do not have any knowledge about which node will enter in their ranges and when [10]. The message can be forwarded in ON when the nodes get an opportunity to send it (*i.e.*, when the intermediate nodes come in node's range that enables the sender to forward the message) [2]. Each node has a range of nodes with which it can communicate. When a sender node wants to send a message to any destination that resides outside its range, it relies on one of the closest intermediate nodes, *i.e.*, direct contacts. Next, the message is carried by and stored in intermediate nodes that wait for the appropriate opportunity to forward the message hop by hop till it reaches its destination. This process repeats until the delivery of the message [2].

ON represent a very appropriate communication means for scenarios where the network infrastructure is unavailable such as in sparsely populated areas. It is also very useful in large scale disasters due to the damage of network infrastructures. Finally, it may be the only communication mean in urban scenarios where the cellular network is overloaded or worse non-existing [12].

B. Deployment Constraints and Challenges

ON networks are characterized by the absence of any infrastructure. There are no predictable and fixed communication paths between nodes. Instead of direct transmission, the Store-Carry-and-Forward (SCF) approach [3] is used to transmit data and relies on the nodes mobility. Thus, the deployment constraints in ON are [4]:

- The links between nodes are temporary, so the network topology is highly dynamic [13].
- The routes are established dynamically by intermediate nodes that play the role of routers.
- The network is heterogeneous since it may house different kinds of devices (*e.g.*, cell phones, laptops, sensors, cameras, etc.).

- The connectivity is intermittent due to the high mobility of ON, the node can move, join and leave the network at any time which leads to network partitioning [14].

Accordingly, there are many challenges that need to be considered when designing an application to be deployed over ON including [2]:

- **High Mobility:** This leads to a lack of any previous knowledge about network information since any node can move in, join and leave the network freely.
- **Unpredictable Contact:** Any node in ON may contact any other node unpredictably due to the high mobility of nodes.
- **Storage constraint:** Intermediate nodes between source and destination require to have enough storage space for storing both routing and application messages until they make an opportunistic contact with another node or with the final destination.
- **Energy:** Managing energy in ON is a technical challenge due to the cost introduced by data transmission between nodes. Energy consumption rate increases when there are multiple replicated messages [15].

C. Routing Protocols

In ON, routes are built dynamically from the source node to the destination. Any node can be used opportunistically to deliver messages to the appropriate destination [10]. There are two approaches for routing in ON namely forwarding-based approaches and flooding-based approaches [2]:

The forwarding-based approach depends on the knowledge acquired by a node to take the decision of whether a message should be forwarded or not and to which node. This approach includes the following routing models [2]:

- **Direct transmission:** It consists in carrying the message by the sender itself till it meets the destination. It is a simple and trivial approach and reduces the communication overhead at the expense of very long delays.
- **Location-based:** It consists in exploiting additional information to forward a message. These information may include the proximity to the destination (*e.g.*, MobySpace protocol [2]).
- **Knowledge-based:** It consists in selecting the forwarding nodes based on its context information (*e.g.*, Context Aware Routing (CAR)).

As for the flooding-based approach, it is based on broadcasting messages to all neighbor nodes and it has two types:

- **Epidemic routing** [16]: It uses pair-wise exchange of messages between the nodes [2]. It is a well-known routing protocol that replicates all messages carried by any node to all the other nodes coming into its contact. It achieves high delivery probability since many nodes carry a copy of each message at the expense of network congestion. Epidemic with

ACK is one of Epidemic variations and it uses acknowledgment messages generated when the message is delivered to its destination. It eliminates multiple copies of any message once its ACK is received by the source. However, this version produces additional traffic overhead [10]. To avoid congestion due to flooding, the next family of protocols were proposed.

- **Estimate/prediction routing:** In this approach, estimation and prediction information like contact probabilities are used to decide about message forwarding [2]. The most known routing protocol that uses estimate/prediction routing is the Probabilistic Routing Protocol using History of Encounter and Transitivity (PRoPHET) [17]. It forwards messages based on encounters to estimate the probability of a given node to deliver a messages. Each node stores locally a probability value that is exchanged and updated with each contact. Thus, the message is only forwarded to nodes with higher contact probability with destination [10].

D. ON Applications

In the literature of ON, the applications that are well suited for an opportunistic context are [2]:

- **Recommender systems:** They give recommendations on various items by using the information collected from tracking user activities and mobility patterns.
- **Opportunistic computing:** To perform distributed tasks in ON, this application uses shared services, resources and applications.
- **Crisis Management (Emergency Applications):** ON are very appropriate to be used in emergency situations when there are unexpected disruptive events leading to the breakdown of traditional networks. Ensuring the messages and data generated in the disaster area is the most important objective in emergency cases in order to reach their destination. This is done without any loss and these messages contain information about victims as well as information for the global coordination of the emergency response [10].
- **Pervasive healthcare:** ON can be used to create an intelligent system in order to track patients as well as to monitor different parameters either physical or physiological.

E. Testing ON applications

To conduct tests and evaluate any application and/or routing protocol over ON, a testing framework is required. The most used simulation tools in ON are ONE [18] and MobEmu [19]. Both were used to test CE over ON in [1], [7]. Testing CE over ON by means of simulations requires to use either an appropriate mobility model or a real mobility trace.

Mobility Models. Node movements can increase the probability of message delivery and the opportunity for communication between the source and the destination. These movements are implemented through mobility models which are set of algorithms and rules that define the node movement patterns.

Mobility models are generally used to provide performance results and design high performance routing protocols. Indeed, they simulate the behavior of real mobile nodes and are used instead of real mobility traces that are more difficult to handle [20]. Examples of mobility models are:

- **Random Waypoint (RWP):** In this model, there is no restrictions on node mobilities where a random path is selected to forward the message to the destination. It creates zigzag paths within the network area because each node moves direct with a constant speed from the starting location to the next location. There is no algorithm used to select the shortest path where this results in taking less time to forward the message [15], [20].
- **Map based movement model:** In this model, nodes can move based on predefined maps for real cities where packets are forwarded to the destination depending on the path defined by the map [15].
- **Shortest Path Map Based Movement (SPMBM):** In this model, the node can specify the next destination by selecting any random point on the map. Then, the shortest path algorithm Dijkstra is used in order to find the shortest path to that selected point. This model is the best mobility model since nodes select the shortest path towards the destination [15], [20].

In CE area, the mobility models Modified Random Direction [21] and SMOOTH [22] have been used to test a revision control management system as a kind of CE [7].

Mobility Traces. Mobility traces reflect the real nature of vehicular and human mobility. They are used to validate new applications and protocols [23]. They may also include the node contacts and information about nodes' interests [1].

Though mobility traces are very similar to real movement patterns, they introduce a high deployment cost and time overhead in contrast to mobility models [23]. As for mobility models they allow to test a very high number of nodes thus achieving scalability compared to mobility traces [23].

Many real mobility traces were captured to test ON [23], but the most used trace in ON literature is Infocom [24]. In the area of collaborative editing, Infocom was used to test the work of [1] in addition to Sigcomm [25] and UPB [26] mobility traces.

After we have explained the principle of ON, we present in the following an overview on CE as useful and famous kind of applications that needs to be adapted and deployed over ON. We also discuss CE properties and problems.

III. OVERVIEW ON COLLABORATIVE EDITORS

CE have many benefits including improving the final result by reducing errors, getting different viewpoints and skills as well as shorting the production time of the final document [27]–[29]. CE are mainly used by communities that produce reports including scientists collaborating on a research project [27], software engineering teams designing and implementing software systems, contributors to wiki pages edition or musicians producing music scores, etc. As famous

CE examples, we cite Google Docs that enables many users in different locations to simultaneously collaborate on the same document [30] and Wikipedia that allows to write collaboratively the largest shared knowledge database.

According to the communication type offered by a Computer Supported Collaborative Work (CSCW) system, there are two kinds of editing systems [30], [31] (see Fig. 2):

- **Synchronous:** They allow users cooperation in real-time fashion, carry out the shared objects' updates and broadcast them to other users immediately. Any user can edit his/her local copy then forwards the updates of his/her local copy to other collaborators so that they can see the updates' effects immediately on their copies.
- **Asynchronous:** The enable users cooperation while updates may be observed with a delay at remote sites. Many tools support asynchronous communications such as Versions management tools like CVS [32] and file synchronizers like Unison [33]. For example, users can edit a shared file at different times using a file synchronizer. Then, their changes are merged later to get the same final view of the shared file.

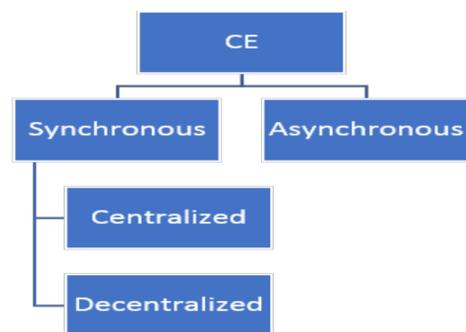


Fig. 2. Different kinds of collaborative editors.

In an opportunistic network, it should be possible to allow for both synchronous and asynchronous editing systems depending on the target application and the area hosting the opportunistic network. However, synchronous collaborative editors also known as Real-Time Collaborative Editors (RCE) are much more difficult to design and deploy over ON than asynchronous editors. Thus, we focus on RCE.

RCE are based on replicating the shared data to allow for high availability and to improve the performance of the editing system. Nevertheless, enforcing the data convergence (also known as consistency) of all replicas is hard to achieve. To solve this problem, many synchronization algorithms were proposed in the recent decades and can be classified into [30]:

- **Centralized algorithms:** This type requires the presence of a central server that is used to serialize concurrent users' updates as well as to get a unique and global order of operations execution (*e.g.*, GOT [34], COT [35], SOCT3 [36] and SOCT4 [36]).
- **Decentralized algorithms:** They allow requests that are concurrent to be executed in any order (*e.g.*,

SOCT2 [37], adOPTed [38], SDT [39], GOTO [40], ABTS [41] and OPTIC [6].

Collaborative editing systems are consistent if they always maintain the following properties [40]:

- **Convergence:** All copies of the shared document converge towards the same state at different sites. This should be achieved if all sites execute the same set of updates even though the execution of updates happens in different orders.
- **Causality preservation:** If an update depends causally on another one, it should be executed after it at all collaborating sites.
- **Intention preservation:** For any operation, its execution effect at every site shall be the same as the intention of its first execution.

In the following, we discuss RCE properties and requirements.

A. Real-time Collaborative Editors (RCE)

RCE provide simple text editor user interfaces, allowing viewing and editing of the same document for a group of users from different sites simultaneously [42]. All modifications at each site are propagated and displayed at other sites. Therefore, the user at one site can see the remote user's modifications. REDUCE and Hydra are examples of RCE providing many features, *e.g.*, undo operations, lock certain sections of the text, variable granularity of text propagation and color highlighting of text (used to indicate text inserted by various user). RCE can be used for documentation and communication in many tasks including design and engineering [43]. RCE have two advantages [44]:

- Providing an environment for contribution of multiple users to shared documents in an easy and fast manner.
- Providing a platform for all users that is ready-to-use and does not need to install heavy software bundle *e.g.*, Libre Office or Microsoft Office. This platform enables users to view and modify their documents on their web browsers.

RCE should take into account human factors as follows [45]:

- **High local responsiveness:** The system shall be as responsive as a single-user editor.
- **Unconstrained interaction:** At any time, the users shall be able to edit any part of the shared document.
- **Real-time communication:** For effective coordination, the user must be aware immediately of each remote update.
- **Consistency:** The final version of the shared objects must converge (*i.e.*, be the same after the reception of all updates).
- **Scalability:** RCE must enable a group to be dynamic in order to allow users to enter or quit the group at any time [30].

- **Decentralized coordination:** To avoid a single point failure, all concurrent updates must be synchronized without relying to a central unit [30].

Since many users are allowed to edit the same object concurrently, divergence situations may occur which represents one of the most important challenges when designing RCE applications [46]. To maintain consistency while updating concurrently the copies of the shared document, the Operational Transformation (OT) approach was proposed [5]. It relies on an optimistic replication technique and synchronizes divergent replicas to produce a converged view of the shared document. Many collaborative applications use OT approach such as CoPowerPoint (*i.e.*, slides creation and presentation system of the real-time collaborative multimedia), CoWord (*i.e.*, a collaborative word processor) and Joint Emacs (*i.e.*, a groupware based on Emacs as text editor) [6]. Recently, an OT-based collaborative graphical editor named CoWebDraw has been proposed in [47].

Another alternative method for consistency maintenance is the Commutative Replicated Data Types (CRDT). It relies on commutative operations defined on abstract data types. To ensure convergence, a unique and globally ordered identifier is associated to every object [1], [48]. Various algorithms of CRDT have been proposed such as WOOT [49], WOOTO [50], WOOTH [51], RGA [52], Logoot [53], LogootSplit [54] and Treedoc [55]. Though CRDT proposes efficient solutions in term of time complexity, OT remains more used than CRDT in existing collaborative frameworks probably due to the less space complexity it requires. Thus, in this paper we focus on OT-based CE since there is no prior research works to adapt such famous collaborative editing approach over ON.

B. The Operational Transformation (OT) Approach

OT is a technique that achieves causality and convergence preservation while increasing responsiveness. It represents the most efficient and safest method for maintaining consistency. The aim of OT is to ensure the convergence of copies although the updates of users are executed out of order on different sites [6].

In OT approach, it is assumed that all updates are buffered at every site locally in a local log stored at each collaborating site. This allows remote updates to integrate the effect of concurrent updates over shared content composed by a sequence of elements (*e.g.*, a XML node, a page, a paragraph, etc.) [6]. Updates can be either local which are executed immediately or remote which need to be transformed before they are executed [56].

OT uses generally two primitive updates as follows [42]:

- **Ins(p, e):** is used to add the element e at the position p .
- **Del(p):** is used to remove the element at the position p .

To illustrate the principle of OT approach, let us consider the shared textual document initially containing the string *efecte* and two updates $O_1 = \text{Ins}(2, f)$ and $O_2 = \text{Del}(6)$ performed by two different sites 1 and 2 concurrently, then the new states are *effecte* and *effect* respectively (see Fig. 3).

At site 2, when O_1 is executed, the state of the document is updated to *effect*. Meanwhile, at site 1, when O_2 is executed, it does not take into account O_1 that has been executed previously. Thus, the new state is *efece*. Consequently, the two sites have divergent states [6].

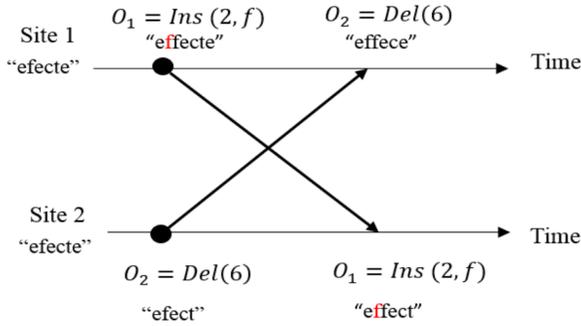


Fig. 3. Scenario of string operations without OT implementation.

To enforce convergence, OT relies on an algorithm called Inclusive Transformation (IT) [6], [30]. The effect of IT on the previous example leads to shift the deletion position of O_2 by 1 since the character *f* was inserted before O_2 is received at site 1. Thus, O_2 is transformed to $O'_2 = IT(del(6), Ins(2, f) = Del(7))$. The final resulting string at both sites is the same *effect* and consistency is achieved as shown in Fig. 4.

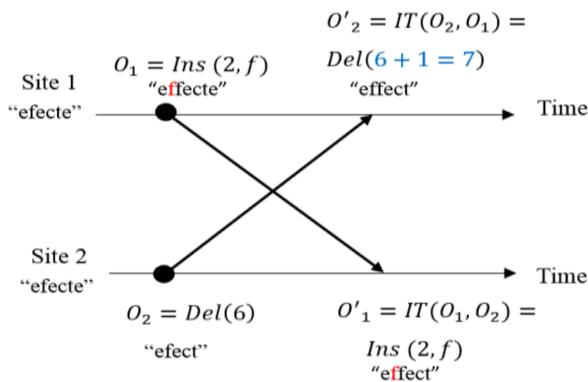


Fig. 4. Scenario of string operations with OT implementation.

OT defines another algorithm called Exclusive Transformation (ET) that allows to exclude the effect of an update from another one. ET is generally used to reorganize updates inside the log. Fig. 5 illustrates the ET function where O_1 is generated on the initial state *abc* and O_2 on the state produced by O_1 , that is *ac*. Then $O'_2 = ET(O_2, O_1)$ means that ET transforms O_2 against O_1 to exclude O_1 's effect. So, the result of O'_2 is *Ins(4, y)* as if O_2 was generated on the initial state *abc* instead of the state produced by O_1 [6].

To ensure convergence, OT must verify two properties Transformation Property 1 (TP1) and Transformation Property 2 (TP2).

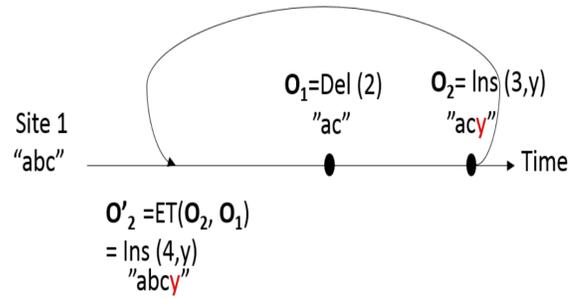


Fig. 5. Exclusive transformation example.

C. OT Properties

Two properties are required to achieve convergence using the OT approach [5], [36]:

- 1) **The first Transformation Property TP1:** This property was defined to ensure state identity, *i.e.*, if two sites begin the collaboration with the same initial state of the shared document, they must end with the same final state even if they execute the same updates but in different sequences. Formally, for any couple of sites having the same initial state S_0 . If they perform concurrently the updates O_1 and O_2 then exchange their updates such that $O'_1 = IT(O_1, O_2)$ and $O'_2 = IT(O_2, O_1)$, it must be that $S'_1 = S'_2$ where S'_1 is the new state of site 1 after executing O_1 followed by O'_2 and S'_2 is the new state of site 2 after executing O_2 followed by O'_1 .
- 2) **The second Transformation Property TP2:** This property defines updates identity and was defined to ensure that the transformation of any update let O_3 against equivalent update sequences (*i.e.*, two sequences including the same updates executed in different orders) must give the same result. It is formally defined as:

$$IT(IT(O_3, O_1), O'_2) = IT(IT(O_3, O_2), O'_1)$$

for any three concurrent updates O_1, O_2 and O_3 such that $O'_1 = IT(O_1, O_2)$ and $O'_2 = IT(O_2, O_1)$.

Fig. 6 presents an example that illustrates TP1, where there are two users sharing and editing the same document represented by a sequence of characters. At the beginning, the two copies contain the same string *abc*. At site 1, user 1 executes the update $O_1 = Ins(1, z)$ as a local update in order to insert the letter *z* at the position 1 and produces the string *zabc*. At the same time, user 2 performs $O_2 = Ins(2, y)$ as local update to insert the letter *y* at the position 2 and produces the string *aybc* at site 2. At site 2, when O_1 is received and executed as a remote update, the string *zaybc* is produced. At site 1, when O_2 is received and executed as a remote update, the new string *zaybc* is produced. Obviously, the final string at sites 1 and 2 is consistent and TP1 is achieved.

Fig. 7 presents example of TP2, where there are three users working on a shared document with the same initial string *abc*. At site 1, user 1 executes the update $O_1 = Ins(3, x)$ as a

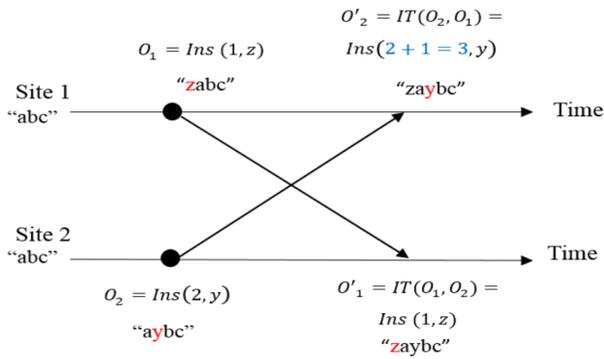


Fig. 6. TP1 example.

local update in order to insert the letter x at the position 3 and produces the string $abxc$. At site 2, user 2 executes the update $O_2 = Ins(1, z)$ as a local update in order to insert the letter z at the position 1 and produces the string $zabc$. At the same time, user 3 performs $O_3 = Ins(2, y)$ as a local update to insert the letter y at the position 2 and produces the string $aybc$ at site 3. TP2 is achieved at site 2 and site 3. In site 2, O_1 is transformed against O_2 and O'_3 to produce O'_1 on the state $zaybxc$. In site 3, O_1 is transformed against O_3 and O'_2 to produce O''_1 on the state $zaybxc$. Therefore, $O'_1 = O''_1$ and the final string at all sites is consistent.

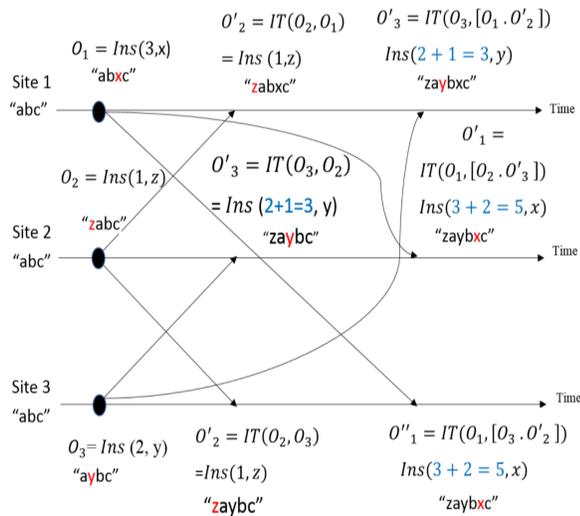


Fig. 7. TP2 example.

Though the OT principle is straightforward, many convergence problems may occur. Problems of OT approach will be presented in the following section.

D. OT Problems

There are three problems that can occur when applying OT approach in RCE:

First, the scalability issue consists in the ability of handling a high number of users efficiently. Indeed, dynamic groups

must be enabled in RCE where the user can join and leave the group at any time. Vector timestamp technique has been used in most OT algorithms to determine the concurrent and happened before relations between updates. It consists of a finite vector of size n such that n is the number of collaborating sites. As a consequence, it does not scale well since vectors size is limited [6].

Secondly, the convergence is difficult to achieve. A killer scenario referred to as TP2 puzzle was discovered by Sun *et al.* [34]. Most existing OT algorithms fail to meet TP2 property which leads to data divergence situations. The TP2 puzzle occurs when two insertions and one deletion are generated concurrently as shown in Fig. 8. In this scenario, TP2 is violated at sites 2 and 3. In site 2, O_1 is transformed against O_2 and O'_3 to produce $O'_1 = Ins(2, x)$ on the state $axyc$. In site 3, O_1 is transformed against O_3 and O'_2 to produce $O''_1 = Ins(3, x)$ on the state $ayxc$. Therefore, $O'_1 \neq O''_1$ and this leads to data divergence [6].

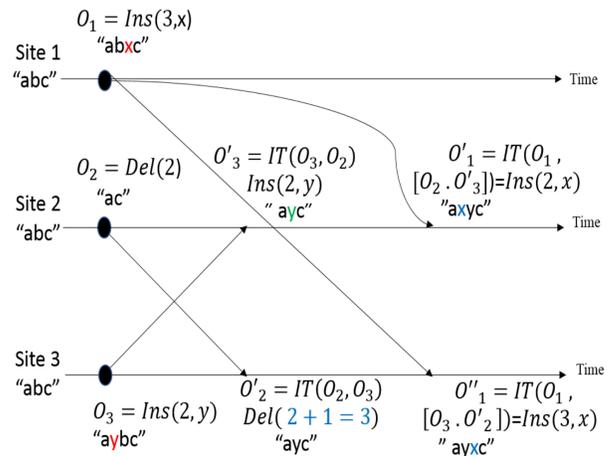


Fig. 8. Scenario of TP2 puzzle.

Lastly, the partial concurrency problem occurs when two or more causally dependent updates are generated concurrently to other updates. For example, if two sites begin the collaboration with the same initial state $fect$ and site 1 generates $O_1 = Ins(1, a)$ then $O_2 = Ins(2, f)$ to produce the $afect$ state while site 2 generates concurrently $O_3 = Ins(1, e)$ to produce the $efect$ state. Therefore, O_1 and O_3 are concurrent operations because O_1 none has seen the effect of the other while O_2 depends causally on O_1 . Obviously, O_2 and O_3 are generated from different states which leads to partial concurrency situation. When O_2 is received as remote operation at site 2, it is transformed directly against O_3 and leads to divergence. Indeed, IT was defined for two concurrent operations while O_2 and O_3 are partially concurrent operations.

In the following, we compare the main OT-based CE algorithms according to a set of criteria that we have defined to meet the characteristics of ON.

IV. COMPARING EXISTING OT-BASED ALGORITHMS

Independently of the semantics of the shared objects, the integration algorithm proceeds in the following steps:

- 1) Generate the local update and execute it directly on the state of document.
- 2) Store this update in the log of the site.
- 3) Propagate the local update to remote sites.

The steps of applying the integration algorithm when an update is received from a remote site are [6]:

- 1) Search in the local log for all concurrent updates.
- 2) Use the transformation functions to integrate the effect of these concurrent updates.
- 3) Execute the transformed form of the remote update at the current document state.
- 4) Store the transformed form in the site's log.

Therefore, the integration algorithm builds the local logs while preserving the causal relation between updates of different copies of the document. In the following, we present the main OT-based integration algorithms that were proposed in the literature.

Ellis and Gibbs [5] have proposed the earliest OT algorithm; the distributed OPeration Transformation (dOPT). It is character-wise and offers good responsiveness. Moreover, it does not rely on a central server as well as fulfills the precedence property. However, dOPT enforces TP1 only, the dOPT-puzzle *i.e.*, a scenario leading to divergence, has been discovered [1], [57]. Thus, dOPT is unable to ensure copies convergence and does not solve the partial concurrency problem [36].

Ressel *et al.* have proposed the adOPTed algorithm as an improvement of dOPT [38]. It requires an additional transformation property TP2. To keep the track of all valid paths of operation transformations in adOPTed, a N-dimensional interaction model graph is used. The adOPTed algorithm solves both the partial concurrency problem [36] and TP2 puzzle [6].

Suleiman *et al.* have proposed SOCT2 [37] that uses both IT and ET functions. It solves TP2 puzzle [6] and the partial concurrency problem. However, it is very expensive and leads to performance degradation because it requires reorganizations of the local log many times to integrate each remote update [6].

The Generic Operation Transformation (GOT) concurrency control algorithm has been proposed by Sun *et al.* [34]. It achieves convergence due to global total order. It defines an undo, do and redo scheme to integrate remote updates, thus avoiding TP2 puzzle [6], [58]. Indeed, out of order updates are first undone, then redone after the in-order updates are done. However, according to [1], GOT fails to provide correct results in some cases.

SOCT3 [36] uses a sequencer to maintain a global total order of execution via timestamps. The use of sequencer avoids TP2 puzzle by enforcing a continuous global order on updates [6], [58]. It depends on forward transposition and backward transposition (IT and ET). However, it does not scale well due to its client-server architecture [1], [6] and to the sequencer which represents also a single point of failure [39]. SOCT4 [36] is an improvement of SOCT3 that uses Forward Transposition (IT) only. Moreover, the partial concurrency problem has been solved [36].

Sun and Ellis [40] have proposed an optimization of GOT algorithm named GOT Optimized (GOTO). The new version ensures both TP1 and TP2. It has been tested in editing programs *e.g.*, CoMaya and CoWord. TP2 puzzle is solved [6]. It has been shown it solves the partial concurrency problem. Nevertheless, GOTO is very expensive and leads to performance degradation because it requires the reorganization of the local log many times to integrate each remote update [6].

Li and Li have proposed State Difference based Transformation (SDT) algorithm [39]. It is considered to be the first OT algorithm that is proved to converge in peer-to-peer group editors [57]. SDT has introduced the concept of update's effect relation and solves TP2 puzzle [6], [58].

Li and Li have also proposed the Admissibility-Based Transformation (ABT) [56] that does not require transformation functions to work. It depends instead on two correctness conditions that are formalized and proved: causality and admissibility preservation. The partial concurrency problem is solved by reorganizing the local log to integrate remote update [6].

Shao *et al.* [41] have extended the character-wise ABT algorithm to the Admissibility-Based Transformation with Strings (ABTS) algorithm which is string-wise. The correctness was formally proved and it has been shown ABTS does not need a total order and reversibility of updates to achieve convergence [41].

The Context-based OT (COT) algorithm [35] provides a framework for consistency maintenance and uniformed solutions for undo problems in distributed CE systems. Due to the nature of context vectors it uses, it may require extra memory space [59].

Imine [6] has proposed the OPerational Transformation with Intense Concurrency (OPTIC). OPTIC requires both IT and ET functions and introduces the semantic dependency for causality maintenance instead of state vectors. It scales naturally and is well-suited to manage highly dynamic groups. Moreover, OPTIC solves the TP2 puzzle using canonical logs (*i.e.*, special class of logs where insertions are stored before deletions). These logs enable transformation paths that lead to data convergence. Furthermore, OPTIC has a garbage collector mechanism [45], [60] to reduce appropriately log size without affecting the collaboration.

Based on the above discussion, we present an evaluation of the retained last version of most known CE algorithms in Table I. Our comparison is based on the following criteria that are of relevance in opportunistic context and allow for a correct deployment of CE over ON:

- **Correctness:** CE algorithms shall be correct to be deployed over ON. They shall ensure TP1 and TP2 and solve TP2 puzzle and partial concurrency problems.
- **Scalability:** To be easily deployed over ON, CE algorithms should be scalable to meet the high dynamic aspect of ON and be easy to use by an arbitrary number of users.
- **Decentralization:** Due to the high mobility and dynamic of ON, any proposed collaborative editing model dedicated to ON shall be completely decen-

tralized to take the benefits and keep the full potential of the opportunistic communication layer.

- **String handling support:** to reduce the communication overhead in ON, CE algorithms should be string wise. This is required to avoid the congestion problem.
- **Efficiency:** Since ON are constrained by the low storage and resources in peer nodes, the editing algorithm should not introduce additional memory and energy overhead. For this, we present in Table I the time and space complexities for each algorithm.

According to Table I, to achieve user intention preservation, all coordination algorithms use transformation of operations such as L-Transformation and multidimensional graph are used in adOPTed, Forward Transposition is used in SOCT4 and both IT and ET are used for other algorithms.

In order to achieve causality preservation, all the algorithms practically rely on state vectors except OPTIC which depends on semantic dependency relation.

To ensure copies convergence, algorithms adOPTed and GOTO refer to TP1 and TP2. SOCT4 refers to TP1 and continuous global order. SDT refers to IT, TP1 and TP2. ABTS uses admissibility preservation and causality preservation. Finally, OPTIC uses IT and ET algorithms, TP1, TP2, permutation function and canonical logs.

When it comes to the TP2 puzzle problem, all the algorithms presented in the table have succeeded to either solve or avoid the puzzle. Both ABTS and OPTIC use a special kind of logs called canonical logs in [6] that solves the TP2 puzzle.

As for the partial concurrency problem, GOTO solves this problem by reordering logs thus being expensive. The adOPTed algorithm solves the partial concurrency problem by constructing and memorizing a multidimensional graph in order to enable all the potential serialization orders to be retrieved. Also SOCT4 solves this problem thanks to deferred broadcast [36]. SDT solves this problem thanks to the effect relation between updates. ABTS uses admissibility preservation to ensure convergence and it has been formally proved. Lastly, OPTIC solves the partial concurrency problem thanks to the minimal dependency relation and avoids log reorganization before remote integrations.

Moreover, only OPTIC achieves the scalability property since it allows for unlimited number of users while the others are limited by the vector size.

Regarding to the decentralization criteria, all the algorithms are decentralized except SOCT4 since it relies on sequencer. Thus it is not well suited for ON.

The granularity of the shared object is very important. While the majority of proposed algorithms deal with characters, it is important for CE to allow for string handling in order to reduce the communication overhead over the network. As shown in Table I, all the algorithms support character except GOTO, ABTS and OPTIC since they can be easily extended to string elements.

Finally, the efficiency study shows all algorithms have linear time complexities except GOTO, SDT and ABTS that have a quadratic complexity, thus being inappropriate in ON.

As for space complexity, adOPTed, GOTO, SDT and ABTS require huge memory space since they rely on state vectors. As a matter of fact, they all have complexity equal to $O(|H| * S)$ which is greater or equal to $O(S^2)$ if we assume each site generates at least one operation. The other algorithms have linear space complexity $O(|H|)$ and then are favored over ON mainly OPTIC since it provides a distributed garbage collector to clean logs [45], [60].

V. OVERVIEW ON COLLABORATIVE EDITING IN OPPORTUNISTIC NETWORKS

In the last recent years, some research works have addressed CE over ON. In [7], a revision control system was adapted and developed over ON. The collaborative editing model was distributed and based on replicating shared documents. Each local copy contains the full history of previous versions. Two main approaches were proposed, namely adoption and merging in case a modified version of the content item is discovered. Adoption consists in adopting or discarding the modified version when two nodes carrying different versions meet opportunistically. Nodes receive modified versions from other peers then synchronize their copies as follows:

- The peer's version is ignored if it is a direct ancestor of the local version.
- The peer's version is adopted if it is a direct descendant of the local version.
- Otherwise, the merging is attempted.

Two decision making criteria are considered when selecting which version should be adopted or discarded: either the version presenting the latest changes is retained, or that providing the highest number of updates.

The merging approach is more complex and aims to generate a new version that takes into account all the updates performed on the shared data. A new version composed of the local version and the peer's version is produced or a conflict is issued. To proceed merge, the three-way merge approach, used in revision control systems, is used in order to automate merging. This approach, however, leads to conflicts when two versions cannot be combined. This occurs when users attempt to insert new content at the same position concurrently. To overcome the issue, it is required that the user interacts with the system to enforce convergence. Destructive and non-destructive conflict resolution are modeled. In the destructive model, only one set of modifications is selected while the other is discarded based on the version's length. Either the longer set among the two-conflicting change-sets is kept, or one of them is chosen arbitrarily but consistently if they have the same size.

In the non-destructive model, all the changes from both versions are retained by the node. Then, this node chooses to apply all changes from the first version then followed by the second version. This requires the application of these changes in the same order in all nodes to ensure consistency. An evaluation of merge and adoption was conducted to show that adoption performs well whereas merge outperforms adoption if the user intervenes in solving conflicts. There are many limitations in the proposed solution:

TABLE I. COMPARISON OF OT ALGORITHMS

Criteria/CE algorithms	adOPTed	GOTO	SOCT4	SDT	ABTS	OPTIC
Correctness	Intention preservation	L-Transformation and multidimensional graph [36]	Forward Transposition (IT) [36]	IT and ET [39]	IT and ET [41]	IT and ET [6]
	Causality preservation	State vectors [36]	Timestamps [36]	State vectors [39]	State vectors [41], [61]	Semantic dependency relation [6]
	Convergence	TP1 and TP2 [36]	TP1 and TP2 [36]	IT, TP1 and TP2 [39]	Admissibility preservation and Causality preservation [41]	IT and ET algorithms, TP1, TP2, permutation function and canonical logs [6]
TP2 Puzzle	Solved [6]	Solved [6]	Avoided [6], [58]	Solved [6], [58]	Solved using canonical logs [41]	Solved using canonical logs [6]
Partial Concurrency problem	Solved by constructing and memorizing a multidimensional graph in order to enable all the potential serialization orders to be retrieved [36]	Solved using reorder local log but it is very expensive and leads to performance degradation [6]	Solved thanks to deferred broadcast [36]	Solved thanks to the effect relation between updates [39]	Solved since characters order is respected in all sites [41]	Solved with minimal dependency relation and avoiding log reorganization [6]
Scalability	limited number of users	limited number of users	limited number of users	limited number of users	limited number of users	unlimited number of users [6]
Decentralization	Decentralized [30]	Decentralized [30]	Centralized [30]	Decentralized [30]	Decentralized [30]	Decentralized [6], [30]
String handling support	No [57]	Yes [57]	No [57]	No [57]	Yes [57]	Yes [6]
Time Complexity^b	$O(H)$ [58]	$O(H ^2)$ [58]	$O(H)$	$O(H ^2)$ [62]	$O(H ^2)$ [41]	$O(H)$ [6]
Space Complexity^c	$O(H * S)$	$O(H * S)$	$O(H)$	$O(H * S)$	$O(H * S)$ [41]	$O(H)$

^aTo evaluate the efficiency, we present time and space complexities for each algorithm in the worst case.

^b $|H|$ is the buffer (Log) size.

^c S is the number of sites.

- The case where users cannot solve merge conflicts consistently is not considered such as when there are different users performing different merge strategies or when users change their selection over time.
- Authors have argued that the merging can be fully automated while it requires user interaction to solve merge conflicts.
- No correctness proof on the data convergence of the solution has been done.
- Authors have assumed the interaction with the user solves the conflicts while it may cause divergence.
- The solution leads to a blocking situation since the user can not modify the document because of the accumulation of unsolvable conflicts in the network.

Another collaborative editing solution over ON was proposed in [1]. It is based on CRDT and proposes OpportunisticLogoot as an adaptation of Logoot [53] to ON. It is similar to LogootSplit [54] in supporting single identifier for a sequence of characters to achieve total ordering. It has been shown that OpportunisticLogoot reduces the metadata sent with each message and the metadata size of document to be deployed over ON. Two operations are supported by OpportunisticLogoot for modifying the application’s content and have the following syntax [1]:

- insert (*pos*, *base_element*) to insert a *base_element* at position *pos* where *base_element* is the smallest element in the application’s content like a character in a text editor or the whole message until the user presses Enter key in a chat.
- remove (*pos*) to remove a *base_element* stored at position *pos*.

The messages are ordered globally due to unique identifiers that are similar to identifiers in Logoot. These identifiers are generated in a densely ordered set and can be created between any two existing identifiers [1]. In order to ensure causality, the proposed algorithm can use external causal order algorithm like causal barriers [63] or vector clocks [64], [65]. OpportunisticLogoot algorithm uses a sequence of *base_elements* as content model instead of lines in Logoot. The definition of this sequence as pair $\langle id, sequence_content \rangle$ [1]:

- *id* is the unique identifier and is represented by a list of pairs $\langle x; s; l; r \rangle$ and a logical clock *clks*, where *x* is a priority number used to sort the characters, *s* is the unique site identifier, *l* is the identifier of the first *base_element* in the sequence (or the range left limit), and *r* is the identifier of the last *base_element* in the sequence (or the range right limit).
- *sequence_content* is a group of *base_elements*.

The identification system mentioned above ensures convergence without the need to transform updates. However, the proposed algorithm poses a series of limitations as follows:

- It relies on an identification system to ensure a total order between sequences. Though the authors have claimed the OpportunisticLogoot to reduce the memory space complexity, the solution still requires extra

memory to store identifiers since for each sequence in the document a new identifier is created.

- It depends on existing causal order algorithms to ensure the causality.
- There are two kinds of messages, mutable and immutable. Thus, leading to some temporary blocking situations since it is not allowed to alter immutable messages.

Table II shows the comparison between the two aforementioned CE models over ON. We mainly discuss the testing settings over ON and compare the efficiency of the two solutions.

TABLE II. COMPARING CE OVER ON

Criteria	Shared Content [7]	OpportunisticLogoot [1]
CE Algorithm	Revision control mechanisms	Logoot [53]
Simulation Tool	ONE [18]	MobEmu [19]
Mobility (Trace or Model)	Modified Random Direction model (MRD) [21] and SMOOTH mobility model [22]	Infocomm [24], Sigcomm [25] and UPB [26]
Routing Protocol	Epidemic [16] for MRD	ONside [66] and Epidemic [16]
Efficiency	Time consuming because the whole history of the document is checked in each contact	Space consuming because it requires additional space for storing identifiers.
Convergence	There are blocking cases	There are blocking situations and the convergence is not evaluated

VI. CONCLUSION

Opportunistic Networks (ON) are emerging networks that are being more and more popular due to the large scale availability and use of mobile devices. In this paper, Collaborative Editors (CE) over ON have been addressed.

The major challenges that might arise when deploying CE over ON have been discussed including high mobility, dynamic of nodes and network delays. Moreover, the last versions of the most known OT-based CE algorithms were compared according to a relevant set of criteria. Finally, the current state of the art of CE over ON has been reviewed.

We believe that this study will be very useful in the area of CE over ON. As a matter of fact, this survey is intended to allow for a correct future deployment of CE over ON. It provides the main deployment constraints as well as the testing environments that might be useful to design and evaluate CE over ON. Furthermore, it allows to well define future research directions on how to run effectively CE over ON. It might be possible to either change CE algorithms or ON routing protocols for a better CE deployment over ON.

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Realtime Application of Constrained Predictive Control for Mobile Robot Navigation

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Abstract—This work addresses the implementation issue of constrained Model Predictive Control (MPC) for the autonomous trajectory-tracking problem. The chosen process to control is a Wheeled Mobile Robot (WMR) described by a discrete, Multiple Input Multiple Output (MIMO), state-space and linear parameter varying kinematic model. The main motivation of the constrained MPC usage in this case relies on its ability in considering, in a straightforward way, control and states constraints that naturally arise in trajectory tracking practical problems. The efficiency of the presented control scheme is validated through experimental results on a two wheeled mobile robot using both STM32F429II and STM32F407ZG microcontrollers. The controller implementation is facilitated by the usage of the automatic C code generation and interesting optimization before real-time execution. Based on the experimental results obtained, the good performance and robustness of the proposed control scheme are established.

Keywords—Embedded C; STM32; microcontrollers; constrained model predictive control; optimization

I. INTRODUCTION

The gap between theory and practice has been discussed for many years across the spectrum of academia and industry [1]. One of the reasons that explains this gap is that control systems for the first time is often found too abstract and theoretical in nature; that is, too many mathematical equations as well as block diagrams. Furthermore, the use of control algorithms simulation only will not provide sufficient illustration of the real physical application of using control theory in solving engineering problems. The above shortcomings can be avoided throughout control system experimentation which is an important way to go through practical applications of control theory so as to overcome the above-mentioned difficulty. Hence real hands-on experiments or design problems are an alternative way of augmenting the conventional way of dealing with control theory, as it can be related to real engineering applications, such as modeling, controller design, and implementation.

Moreover, although some control algorithms has been found to be quite a robust type of control in most reported applications [2], [19], their implementation on low-cost system on chip solutions (such as microcontrollers) has been historically hindered by many restrictions and constraints [11]–[18]. Among these constraints are mathematical complexities, which are not a problem in general for the research control community but represent a drawback for the use in practice. The time-to-market delays and possible design errors if the algorithm is manually written in embedded C language on one side and the high computing and associated memory

demands of the algorithm on the other side are restricting the implementation of these control algorithms.

In fact, modern applications generally involve many computationally demanding iterations and have strong requirements on resource optimization. Therefore, the main drawback of complex control algorithms such as Model Predictive Control (MPC), is the need to solve mathematical program on line to compute the control action [3]. This computation prevents the application of MPC in several contexts, mainly because the computer technology needed to solve the optimization problem within the sampling time which is too expensive or sometime infeasible [5]. In fact, the resource constraints associated with embedded systems, combined with non-optimized software components used for their implementation, introduce non-determinism in the real-time system. For control systems this is of particular concern, since timing variations induced by the implementation degrade the control performance.

To cope with the above mentioned shortcoming and problems, the goal of this work is the implementation of constrained MPC algorithms on a fast system with no manual embedded C coding effort. The trade-offs between data size and computation speed, versus numerical precision and effectiveness of the computed control action is also focused on. By using MPC it follows that the tuning parameters are directly related to a cost function which is minimized in order to obtain an optimal control sequence; constraints on state, control inputs and control inputs deviation can be considered in a straightforward way [3]–[5], [7]. This objective is challenging especially in case of system with fast dynamics [6], system described with Multiple Input Multiple Output (MIMO) and parameter varying model. In this direction, the proposed control system is the nonholonomic two Wheeled Mobile Robot (WMR). The usage of the WMR as a plant is motivated by the following reasons: 1) The selected kinematic model of the WMR belongs to the class of MIMO, non-square, linear parameter varying which is challenging for control; 2) despite the apparent simplicity of the kinematic model of a WMR, the existence of nonholonomic constraints turns the design of stabilizing control laws for those systems in a considerable challenge [21]; 3) in recent years, autonomous mobile robots are finding widespread application in many areas and are at the heart of most modern control systems [22].

As a result, validating the proposed control framework in such a challenging systems will expand the number of addressable real time control applications.

On other hand, a general control system of two-wheeled robot usually has a complex structure due to plenty of sensors, which price is generally expensive. A control system with

DC motor driver is proposed instead, using low cost STM32 Discovery kits. These kits allow the controller implementation on high-performance MCUs with ARM Cortex-M4 core. Experimental results on a real WMR exhibit that the proposed control scheme yields some interesting results on autonomous trajectory tracking problem. In fact, compared to existing works such as [9] and [10], the proposed automatic C code generation saves time, avoids possible design errors with no C code manual coding effort. With regards to [3], the proposed implementation framework yields much more interesting results in term of execution speed.

The outline of this paper is as follows. In Section II, the kinematic robot model as well as the proposed MPC algorithm are presented. Implementation results demonstrating the good performance and robustness of the proposed controller are presented in Section III. Section IV concludes the paper.

II. MODEL PREDICTIVE CONTROL ALGORITHM

The basic idea of predictive control consists in calculating, at each sampling instant, a control sequence on a prediction horizon aimed at minimizing a quadratic cost function. The control algorithm is based on the following:

(i) The use of a model to predict, on a future horizon, the output of the process,

(ii) Computing the control sequence which minimizes a performance criterion which involves a sequence of the predicted output.

The following section states the robot model presentation followed by the proposed MPC algorithm investigation.

A. Robot model presentation

We consider a WMR made up by a rigid body and non-deforming wheels (Fig. 1). It is assumed that the vehicle moves without slipping on a plane, i.e., there is a pure rolling contact between the wheels and the ground [21], [22]. Referring to [21], we can write the kinematic model of the WMR as in the following system:

$$\begin{cases} \dot{x} = v \cos(\theta), \\ \dot{y} = v \sin(\theta), \\ \dot{\theta} = w. \end{cases} \quad (1)$$

or else, in a more simplified form:

$$\dot{\mathbf{x}} = f(\mathbf{x}, \mathbf{u}). \quad (2)$$

where \mathbf{x} describes the configuration (position and orientation) of the wheels axis's center, C , with respect to a global inertial frame $\{O, X, Y\}$. \mathbf{u} is the control input vector, where v and w are the linear and the angular velocities, respectively.

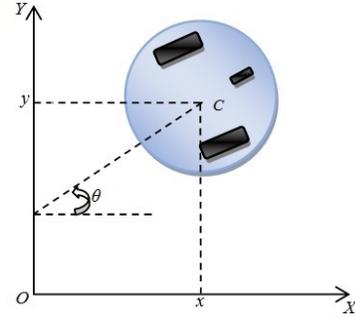


Fig. 1. Robot in (OXY) plan.

Now, considering a sampling period T_s , by applying the Euler's approximation to (1), one can obtain the following discrete-time model for the robot motion:

$$\begin{aligned} x(k+1) &= x(k) + v(k) \cos(\theta(k)) T_s, \\ y(k+1) &= y(k) + v(k) \sin(\theta(k)) T_s, \\ \theta(k+1) &= \theta(k) + w(k) T_s. \end{aligned} \quad (3)$$

or, in a compact representation,

$$\mathbf{x}(k+1) = f_d(\mathbf{x}(k), \mathbf{u}(k), T_s). \quad (4)$$

On the other hand, the problem of trajectory tracking can be stated as to find a control law such that:

$$\mathbf{x}(k) - \mathbf{x}_r(k) = 0. \quad (5)$$

Where, $\mathbf{x}_r = [x_r \ y_r \ \theta_r]^T$ is a known, pre-specified reference trajectory. It is usual in this case to associate to this reference trajectory a virtual reference robot, which has the same model than the robot to be controlled. A linearized discrete time model of the system, described by (6), is obtained by computing an error model with respect to a reference car. This is ensured by expanding the right side of (3) in Taylor series around the point $(\mathbf{x}_r, \mathbf{u}_r)$ and using forward differences.

$$\begin{aligned} \tilde{\mathbf{x}}(k+1) &= A(k) \tilde{\mathbf{x}}(k) + B(k) \tilde{\mathbf{u}}(k), \\ \tilde{\mathbf{y}}(k) &= C(k) \tilde{\mathbf{x}}(k). \end{aligned} \quad (6)$$

$$\text{with } A(k) = \begin{bmatrix} 1 & 0 & -vr \sin(\theta_r(k)) T_s \\ 0 & 1 & vr \cos(\theta_r(k)) T_s \\ 0 & 0 & 1 \end{bmatrix},$$

$$B(k) = \begin{bmatrix} \cos(\theta_r(k)) T_s & 0 \\ \sin(\theta_r(k)) T_s & 0 \\ 0 & T_s \end{bmatrix},$$

$C(k) = I_3$, I_3 is the (3×3) identity matrix. $\tilde{\mathbf{x}} = \mathbf{x} - \mathbf{x}_r$ represents the error with respect to the reference car, $\tilde{\mathbf{u}} = \mathbf{u} - \mathbf{u}_r$ is its associated error control input with $\mathbf{u}_r = [v_r \ w_r]^T$ and $\tilde{\mathbf{y}} = \mathbf{y} - \mathbf{y}_r$ denotes the system output. It is easy to see that when the robot is not moving (i.e., $v_r = 0$), the linearization around a stationary operating point is not controllable. However, this linearization becomes controllable as long as the control input \mathbf{u} is not zero [21].

B. MPC Direct Output Method

In this paper we consider the Model Predictive Control algorithm, where the objective function is rewritten as standard quadratic form. At that point, we target to solve the Quadratic Problem (QP) in using interior-point method, widely used in applications, to solve problems iteratively such that all iterates satisfy the inequality constraints strictly. By extending the output direct method equations provided in [20] to MIMO model process and if we consider (6) for the discrete state space model, the following output at time $(k + j)$ is obtained:

$$\mathbf{y}(k + j|k) = \mathbf{y}_r(k + j|k) + CA^j \mathbf{x}(k) - CA^j \mathbf{x}_r(k) + \sum_{i=0}^{j-1} CA^{j-1-i} B \mathbf{u}(k + i) - \sum_{i=0}^{j-1} CA^{j-1-i} B \mathbf{u}_r(k + i). \quad (7)$$

The MPC based on a state space model aims to minimize the quadratic criterion given by:

$$J = \sum_{s=1}^m \sum_{j=1}^{H_c} \lambda_1 [\mathbf{u}_s(k + j - 1)]^2 + \sum_{s=1}^n \sum_{j=1}^{H_p} \lambda_{2s} [\mathbf{y}_s(k + j|k) - \omega_s(k + j)]^2. \quad (8)$$

Here, H_p is the prediction horizon, H_c is the control horizon, $\lambda_1 = [\lambda_{1s}]_{s=1:2} = [\lambda_{11} \ 00 \ \lambda_{12}]$ is the input weighting matrix with $(m \times m)$ dimension.

The output error weighting matrix with $(n \times n)$ dimension is given by:

$$\lambda_2 = [\lambda_{2s}]_{s=1:n} = \begin{bmatrix} \lambda_{21} & 0 & 0 \\ 0 & \lambda_{22} & 0 \\ 0 & 0 & \lambda_{23} \end{bmatrix}, \omega = [\omega_s]_{s=1:n}^T$$

is the set-point and $\omega_s(k + j)$ denotes the set-point at time $(k + j)$, $\mathbf{u} = [\mathbf{u}_s]_{s=1:m}^T$ and $\mathbf{y} = [\mathbf{y}_s]_{s=1:n}^T$ denote the inputs and outputs, respectively.

It is assumed that there is no control action after time $(k + H_c - 1)$, i.e. $u(k + i) = 0$ for $i > (H_c - 1)$.

Since the MPC is a receding horizon approach, only the first computed control input \mathbf{u} is implemented.

In matrix presentation, the objective function can be expressed as:

$$J = U^T \Lambda_1 U + (Y - W)^T \Lambda_2 (Y - W), \quad (9)$$

in which $W = [\omega(k + 1), \dots, \omega(k + H_p)]^T$ is the set point matrix, Λ_1 is a weighting matrix with $(mH_c \times mH_c)$ dimension and Λ_2 is $(nH_p \times nH_p)$ matrix.

As in [20], the output sequence on H_p can be written as follows:

$$\tilde{Y} = L\tilde{U} + MA\tilde{x}(k), \quad (10)$$

where:

$$\tilde{Y} = \begin{pmatrix} y(k + 1) - y_r(k + 1) \\ \vdots \\ y(k + H_p) - y_r(k + H_p) \\ u(k) - u_r(k) \\ \vdots \\ u(k + H_c - 1) - u_r(k + H_c - 1) \end{pmatrix},$$

and $\tilde{U} = \begin{pmatrix} u(k) \\ \vdots \\ u(k + H_c - 1) \end{pmatrix}.$

The L matrix with the $(nH_p \times mH_c)$ dimension and M which is an $(nH_p \times n)$ dimensional matrix are given by:

$$L = \begin{pmatrix} CB & 0 & \cdots & 0 \\ CAB & CB & \cdots & 0 \\ \vdots & \vdots & \cdots & 0 \\ CA^{H_p-1}B & CA^{H_p-2}B \dots & \cdots & CA^{H_p-H_c}B \end{pmatrix},$$

$$M = \begin{pmatrix} C \\ CA \\ \vdots \\ CA^{H_p-1} \end{pmatrix}. \quad (11)$$

One can rewrite the objective function in a standard quadratic form:

$$J(U) = \frac{1}{2}U^T G U + g^T U + c_0, \quad (12)$$

where:

$$G = 2(L^T \Lambda_2 L + \Lambda_1),$$

$$g = L^T \Lambda_2 (M\tilde{x} - W),$$

$$c_0 = (MA\tilde{x} - W)^T (MA\tilde{x} - W),$$

$$\Lambda_1 = \text{diag}(\lambda_1 \dots \lambda_1),$$

$$\Lambda_2 = \text{diag}(\lambda_2 \dots \lambda_2).$$

In this way, the constrained MPC problem is formulated as a compact Quadratic Problem (QP) described by (12):

$$\min_{U \in R^{mH_c}} J(U) = \frac{1}{2}U^T G U + g^T U + c_0, \quad (13)$$

s.t.

$$F^T U \leq b.$$

G is $(mH_c \times mH_c)$ matrix, g is $(mH_c \times 1)$ vector, F is $(q \times q)$ matrix where q is the number of inequality constraints, q is equal to $(6mH_c)$ in our case, and b is a $(6mH_c \times 1)$ vector.

The QP problem is subject to linear inequality constraints on the system inputs, system inputs deviation ($\Delta u = u(k) - u(k-1)$) and system outputs as follows:

$$U_{\min} \leq U \leq U_{\max},$$

$$\Delta U_{\min} \leq \Delta U \leq \Delta U_{\max},$$

$$Y_{\min} \leq Y \leq Y_{\max}, \quad (14)$$

in which:

$$\begin{aligned} \Delta u_{\min} &= \begin{pmatrix} \Delta v_{\min} \\ \Delta w_{\min} \end{pmatrix}, \Delta U_{\min} = \begin{pmatrix} \Delta u_{\min} \\ \vdots \\ \Delta u_{\min} \end{pmatrix} \in \mathbb{R}^{mH_c}, \\ \Delta u_{\max} &= \begin{pmatrix} \Delta v_{\max} \\ \Delta w_{\max} \end{pmatrix}, \Delta U_{\max} = \begin{pmatrix} \Delta u_{\max} \\ \vdots \\ \Delta u_{\max} \end{pmatrix} \in \mathbb{R}^{mH_c}, \\ u_{\min} &= \begin{pmatrix} v_{\min} \\ w_{\min} \end{pmatrix}, U_{\min} = \begin{pmatrix} u_{\min} \\ \vdots \\ u_{\min} \end{pmatrix} \in \mathbb{R}^{mH_c}, \\ u_{\max} &= \begin{pmatrix} v_{\max} \\ w_{\max} \end{pmatrix}, U_{\max} = \begin{pmatrix} u_{\max} \\ \vdots \\ u_{\max} \end{pmatrix} \in \mathbb{R}^{mH_c}, \\ y_{\min} &= \begin{pmatrix} x_{\min} \\ y_{\min} \\ \theta_{\min} \end{pmatrix}, Y_{\min} = \begin{pmatrix} y_{\min} \\ \vdots \\ y_{\min} \end{pmatrix} \in \mathbb{R}^{nH_p}, \\ y_{\max} &= \begin{pmatrix} x_{\max} \\ y_{\max} \\ \theta_{\max} \end{pmatrix}, Y_{\max} = \begin{pmatrix} y_{\max} \\ \vdots \\ y_{\max} \end{pmatrix} \in \mathbb{R}^{nH_p}. \end{aligned}$$

Replacing Y in (14) by its value in equation (10), and by considering ΔU value at each iteration (k), we obtain:

$$\begin{aligned} Y_{\min} &\leq L\tilde{U} + MA\tilde{x}(k) - Y_{\text{ref}} \leq Y_{\max}, \\ \Delta U_{\min} &\leq u(k) - u(k-1) \leq \Delta U_{\max}. \end{aligned} \quad (15)$$

As a consequence, the following inequalities will be easily obtained:

$$U \leq (L)^+(LU_r + Y_{\max} + Y_{\text{ref}} - MA\tilde{x}(k)). \quad (16)$$

$$-U \leq -(L)^+(LU_r + Y_{\min} + Y_{\text{ref}} - MA\tilde{x}(k)). \quad (17)$$

$$U \leq \Delta U_{\max} + U(k-1). \quad (18)$$

$$-U \leq -\Delta U_{\min} - U(k-1). \quad (19)$$

The operator $(+)$ denotes the Moore-Penrose pseudo-inverse operator. Hence, we obtain:

$$\begin{aligned} F^T &= \begin{bmatrix} -I_c \\ I_c \\ -I_c \\ I_c \\ -I_c \\ I_c \end{bmatrix}, \\ b &= \begin{bmatrix} -U_{\max} \\ U_{\min} \\ -\Delta U_{\max} - U(k-1) \\ \Delta U_{\min} + U(k-1) \\ -(L)^+(LU_r + Y_{\max} + Y_{\text{ref}} - MA\tilde{x}) \\ (L)^+(LU_r + Y_{\min} + Y_{\text{ref}} - MA\tilde{x}) \end{bmatrix}, \end{aligned} \quad (20)$$

with $I_c \in \mathbb{R}^{mH_c \times mH_c}$ is the identity matrix.

C. Quadratic Problem: Interior Point Method

To set up the equations enabling the interior-point method design, we use the general theory on constrained optimization by defining a Lagrangian function and setting up Karush Kuhn-Tucker (KKT) conditions for the QP's that we wish to solve. The KKT-conditions (21) are conditions that must be satisfied for a vector U to be a solution of a given QP.

$$\begin{aligned} GU + g - F\lambda_l &= 0, \\ s - F^T U + b &= 0, \\ s_i \lambda_{li} &\geq 0, \end{aligned} \quad (21)$$

with λ_{li} is Langrange multiplier of the i^{th} inequality constraints, s_i is the i^{th} element of the slack vector s satisfying:

$$s = F^T U - b, \quad s \geq 0. \quad (22)$$

The full algorithm is stated in Fig. 2.

The algorithm requires a starting point (x_0, λ_{l0}, s_0) which does not need to be in the feasible region. In fact, this is accomplished by requiring that $(\lambda_{l0}, s_0) > 0$ and having the right hand side of (23) containing the residual vectors r_d, r_p and $r_{s\lambda}$ instead of zeros to prevent infeasibility [23].

Fundamental concepts related to this method such as central path, the stopping criteria, the predictor complementary measure for the computed Newton step μ_{aff} , the search direction $(\Delta x, \Delta \lambda_l, \Delta s)$, the complementary measure μ and the centering parameter σ are detailed in [23]. In the algorithm, the matrix $S = \text{diag}(S_1, S_2, \dots, S_m)$ in which S_i are the slack vectors, $\Lambda_l = \text{diag}(\lambda_{l1}, \lambda_{l2}, \dots, \lambda_{lm})$ is a diagonal matrix with the elements of the Lagrange multiplier on the diagonal, μ denotes the complementary measure, $(\Delta x_{aff}, \Delta \lambda_{aff}, \Delta s_{aff})$ is the affine scaling direction, λ_{aff} is the step length and $e = (1, 1, \dots, 1)^T$ is a $(m \times 1)$ vector containing ones.

For implementation, v_r is measured 0.2 m/s. Since we are dealing with nonhomolonic WMR, the saturation of the input control u should be considered. The maximum allowed values are $v_{max} = 0.4$ m/s and $w_{max} = 5$ rad/s while the minimum ones are $v_{min} = 0$ and $w_{min} = -5$ rad/s.

Off line treatment

Input (x_0, λ_{l0}, s_0) and G, F, g, b

Compute residuals and complementarity measure

$$r_d = Gx_0 + g - F\Lambda_{l0}$$

$$r_p = s_0 - F^T x_0 + b$$

$$r_{s\Lambda_l} = S_0 \Lambda_{l0} e$$

$$\mu = \frac{s_0^T \lambda_{l0}}{m}$$

Online treatment

While loop : terminate if stopping criteria (*) are satisfied

Predictor step:

Solve (23) to obtain an affine scaling direction $(\Delta x_{aff}, \Delta \lambda_{aff}, \Delta s_{aff})$ for setting up the right hand side for the corrector step and to obtain a good value of the centering parameter σ :

$$\begin{bmatrix} G & F & 0 \\ F^T & 0 & I \\ 0 & S & \Lambda_l \end{bmatrix} \begin{bmatrix} \Delta x_{aff} \\ \Delta \lambda_{aff} \\ \Delta s_{aff} \end{bmatrix} = - \begin{bmatrix} r_d \\ r_p \\ r_{s\lambda} \end{bmatrix}. \quad (23)$$

Compute α_{aff}

$$\lambda_l + \alpha_{aff} \Delta \lambda_{aff} \geq 0$$

$$s + \alpha_{aff} \Delta s_{aff} \geq 0$$

Compute μ_{aff}

$$\mu_{aff} = \frac{(s + \alpha_{aff} \Delta s_{aff})^T (\lambda_l + \alpha_{aff} \Delta \lambda_{aff})}{m}.$$

Compute centering parameter σ

$$\sigma = \left(\frac{\mu_{aff}}{\mu} \right)^3$$

Corrector and centering step:

Solve (24) to obtain search direction

$$\begin{bmatrix} \Delta x \\ \Delta \lambda_l \\ \Delta s \end{bmatrix} = - \begin{bmatrix} r_d \\ r_p \\ r_{s\lambda} + \Delta S_{aff} \Delta \Lambda_{aff} e - \sigma \mu e \end{bmatrix} \quad (24)$$

Compute α

$$\lambda_l + \alpha \Delta \lambda_l \geq 0$$

$$s + \alpha \Delta s \geq 0$$

Update (x, λ_l, s)

Update residuals and complementarity measure

$$r_d = GU + g - F\lambda_l$$

$$r_p = s - F^T x + b$$

$$r_{s\lambda} = S\lambda_l e$$

$$\mu = \frac{s^T \lambda_l}{q}$$

End while loop

Fig. 2. Interior point algorithm.

(*) Stopping criteria are:

- Reach Z which is the maximum number of iterations to ensure that the algorithm stops. Z belongs to $[50, 200]$,
- $\|rd\| \leq \varepsilon$ and $\|rp\| \leq \varepsilon$, with $\varepsilon = 10^{-16}$.

III. IMPLEMENTATION RESULTS

In order to demonstrate the effectiveness of the proposed controller scheme, the following section presents the MPC controller implementation steps on two wheeled mobile robot.

A. Implementation Software and Hardware Environment

The considered hardware environment is composed by:

- * Two wheeled mobile robot with 80 RPM as no-load rotating speed at 6 V, wheel diameter is equal to 65 mm and with width and weight respectively equal to 10.2 mm and 305 g.

Fig. 3 provides an overview of the used robot.

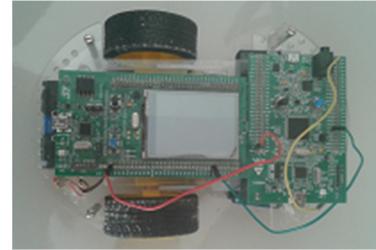


Fig. 3. WMR robot used for the implementation.

- * STM32F407 and STM32F429 32-bit are high performance MicroController Units (MCUs). they include ARM Cortex-M4 core, floating point unit and built-in single-cycle multiply-accumulate (MAC) instructions. The Adaptive Real-Time Accelerator combined with STMicroelectronics 90 nm technology provides linear performance up to 172 MHz. These MCUs includes 1 MB of on-chip Flash memory and 192 KB of SRAM. These features expand the number of addressable real time control applications.

- * STM32F4DISCOVERY and STM32F429DISCO are low cost kits based on STM32F407 and STM32F429 MCUs respectively and designed to help design engineers developing their applications easily. STM32F429DISCO integrates the gyroscope L3GD20 which is a low-power three-axis angular rate sensor includes a sensing element capable of providing the measured angular velocity $w = [w_x, w_y, w_z]$ to the external world through a digital interface Serial Peripheral Interface (SPI) in our cases. For efficient control, the angular velocity is generally coupled with the linear velocity for the WMR position calculation. That's why, the STM32F4DISCOVERY, embedding an ST MEMS accelerometer, is also considered.

- * Arduino Motor Shield based on the L298, is used to drive the two DC motors with control of the speed and direction of each one independently.

The software environment consists of:

- * MDK-ARM is a software development and debugging environment for ARM-based microcontroller devices. It is specially designed for microcontroller applications. Its C compiler is the only compilation tool co-developed with the ARM processors, and specially designed to optimally support the ARM architectures.

* Embedded MATLAB Coder works with Real-Time Workshop to convert code from a dynamically typed language (MATLAB) to a statically typed language (C).

B. Implementation Framework

Based on the measured angular velocity, the robot angular position output θ is calculated based on the following formula:

$$\theta(k) = \theta_0 + T_s \sum_{i=0}^k w(i), \quad (25)$$

with θ_0 is WMR angular position at $k=0$.

In order to measure x abscissa and y ordinate, the gyroscope sensor is combined with an accelerometer MEMS sensor in the STM32F407 Discovery kit aiming to provide the robot acceleration $a(k)$. The integration of the acceleration provides the linear velocity $v(k)$.

$$v(k) = v_0 + T_s \sum_{i=0}^k a(i). \quad (26)$$

in which v_0 is WMR linear velocity at $k=0$. Robot positions (x and y) are then calculated based on the following equations with x_0 and y_0 are respectively WMR abscissa and ordinate at $k=0$.

$$x(k) = x_0 + v(k)T_s \sum_{i=0}^k \cos(\theta(i)). \quad (27)$$

$$y(k) = y_0 + v(k)T_s \sum_{i=0}^k \sin(\theta(i)). \quad (28)$$

These equations allow the robot positions estimation from the real measurements obtained from sensors. However, it's known that accelerometers have an unwanted phenomenon called drift caused by a small DC bias in the acceleration signal. The presence of drift can lead to large integration errors. If the acceleration signal from a real accelerometer was integrated without any filtering performed, the output could become unbounded over time. That's why to solve the problem of drift, a pass-band filter is used to remove the DC component of the acceleration signal. The frequency response of the filter must have a very low and very high cutoff frequencies compared to the bandwidth of the signal. By filtering before integrating, drift errors are eliminated. The block diagram of the closed loop system is illustrated by Fig. 4.

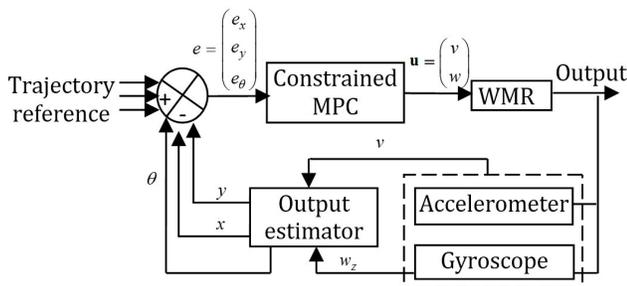


Fig. 4. WMR closed loop implementation diagram.

Fig. 5 and 6 summarize needed steps for the proposed controller implementation.

Steps executed during SysTick interrupt handler should not exceed the sampling time $T_s=0.01052$ s.

Hint: knowing that w_{max} and v_{max} parameters are subject of change according to battery depletion over time, terrain type,... we propose in this paper a real-time measurement of w_{max} parameter before trajectory tracking. This is done by turning the robot around (OZ) axis with maximum allowed speed and measuring the angular velocity which corresponds to w_{max} . v_{max} is then deduced given that a linear velocity is the product of the WMR radius r and angular velocity.

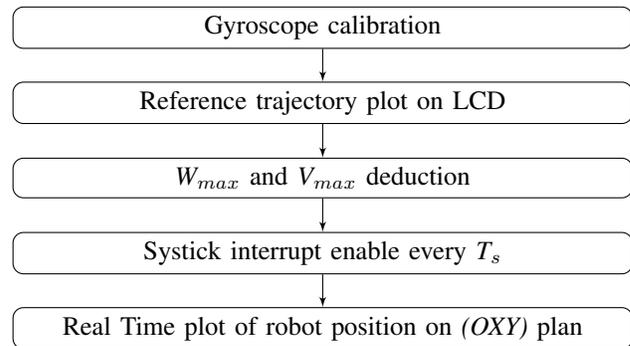


Fig. 5. SysTick handler treatment.

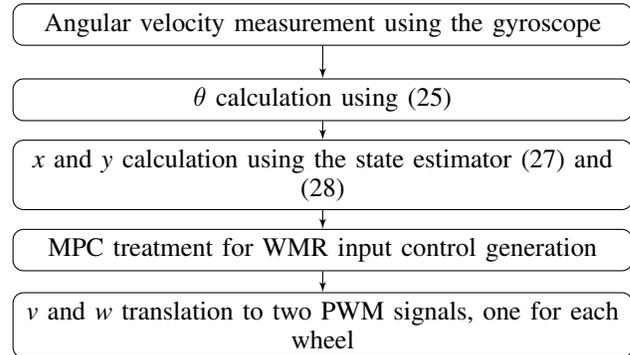


Fig. 6. Main program.

C. Automatic Code Generation for the Implementation

For code generation, Embedded Simulink Coder embeds many configuration options and advanced optimization for fine-grain control of the generated code's functions based on the processor architecture. These options allow control function boundaries, preserve expressions and apply optimization on multiple blocks to further reduce code size. The MDK-ARM tool integrates an ARM C compiler including a number of compiler optimization allowing code generation based on chosen microcontroller device and application area. The maximum level of performance optimization is chosen. Steps for automatic C code generation are detailed in [24].

D. Implementation Footprint and Execution Speed Optimization

Control algorithms implementation on system on chip solutions has been historically hindered by the high computing

and associated memory demands constraints. To overcome this problem, we propose some optimization hints detailed on [24] which results in a faster and more efficient system-development work-flow. MDK-ARM toolchain is used as development and debugging environment, Among these optimization hints, the usage of the simple precision floating type is particularly relevant. In fact, considering the hardware Floating Point Unit (FPU) of the STM32F429 device rather than the software double precision types (generated by default by MATLAB Embedded Coder) is an optimization hint for performance increase. In fact a simple addition of two variables, declared as double, requires 82 CPU cycles due to double software library call whereas in simple precision case, it requires only 2 CPU cycles to be executed thanks to the hardware FPU usage. To avoid the unnecessary type conversion or confusion, the letter “f” is assigned following the numeric value.

Results provided in Table 1 focus on execution speed results found after applying code optimization techniques on inputs constraints only and in the case of constraints on inputs and outputs.

TABLE I. OPTIMIZATION RESULTS

Constraints	Execution time per sample (ms)
Inputs constraints	2.66
Inputs and inputs deviation constraints	3.89
Inputs, inputs deviation and outputs constraints	4.80

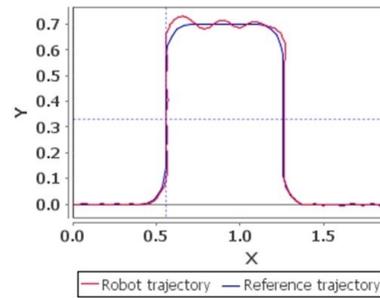
From Table 1, it is deduced that generated code is subject to very interesting execution time optimization. In fact, applying inputs, inputs deviation and outputs constraints does not exceed the half of the sampling period (10 ms) which reflects the effectiveness of the proposed control scheme.

E. Implementation Results: Inputs Constraints

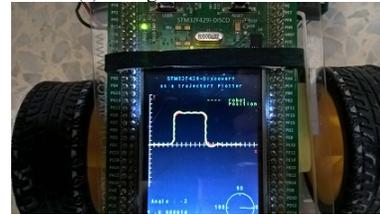
The robot trajectory is displayed using both LCD screen of the STM32 Discovery Kit and the STMStudio tool. This software tool is non-intrusive to the application code and used to monitor STM32 applications while they are running by reading and displaying their variables in real-time.

The maximum allowed linear velocity v_{max} is identified as 0.4 m/s and its minimal value $v_{min} = 0$ m/s. The angular velocities w_{min} and w_{max} are ± 5 rad/s. The linear input deviation Δv_{max} and Δv_{min} are measured and fixed to ± 0.25 m/s. Similarly, Δw_{max} and Δw_{min} are branded to ± 1 rad/s.

Fig. 7 shows that the robot tracks successfully the reference path. This is confirmed by the robot abscissa, ordinate and orientation errors with regards to the reference path presented in Fig. 8, 9 and 10.



(a) Using STMSTUDIO tool.



(b) Using LCD screen.

Fig. 7. WMR trajectory plot.

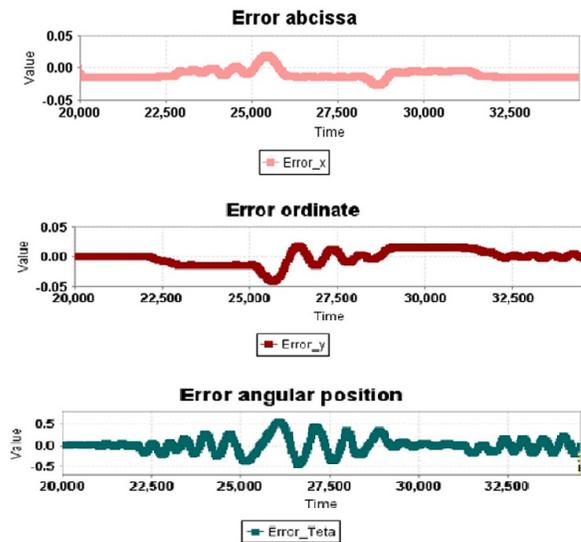


Fig. 8. WMR trajectory errors.

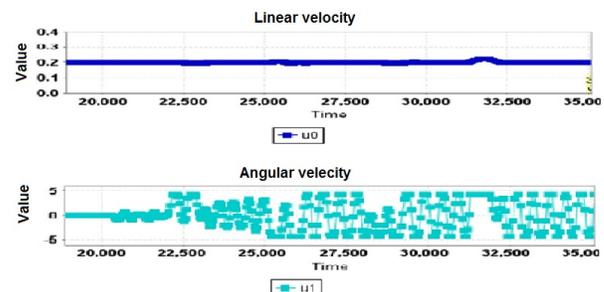


Fig. 9. Control inputs.

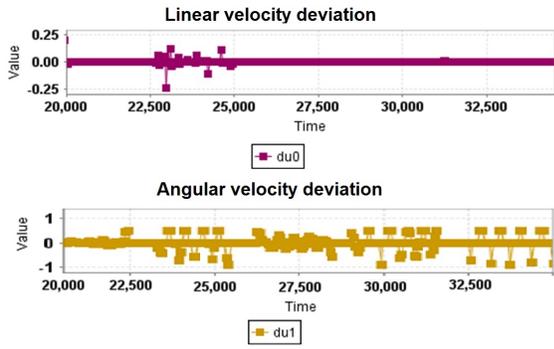


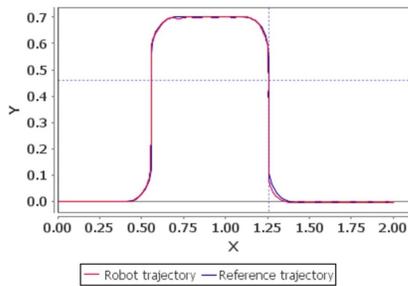
Fig. 10. Control inputs deviation.

F. Implementation Results: Inputs and Output Constraints

In addition to inputs constraints already defined in the previous paragraph, output constraints are also considered in this section. The output constraints are defined as $y_{min} = \omega - [0.01 \ 0.01 \ 0.25]$ and $y_{max} = \omega + [0.01 \ 0.01 \ 0.25]$.

Fig. 11 and 12 present the plot of the robot trajectory as well as the reference path. It is concluded from Fig. 11 and 12 that the output constraints are satisfied with errors very close to zero along the path.

From Fig. 11, 12, 13 and 14, it is established that inputs control and inputs control deviations constraints are satisfied and the proposed control method controls successfully the process with a very good set-point tracking.



(a) Using STMSTUDIO tool.

(b) Using LCD screen.

Fig. 11. WMR trajectory plot.

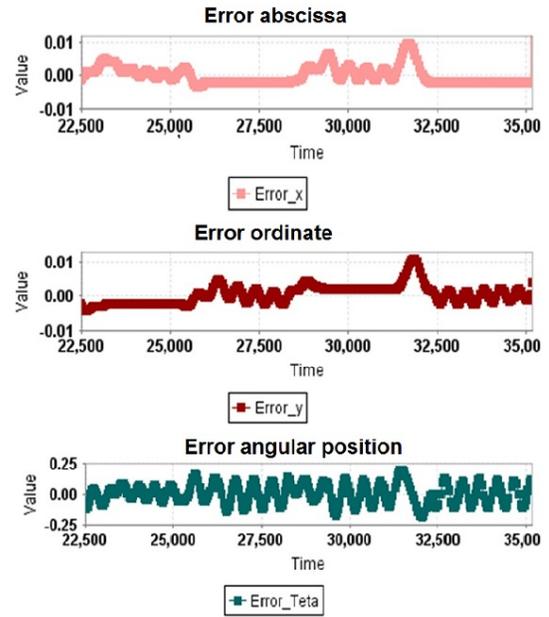


Fig. 12. WMR trajectory errors.

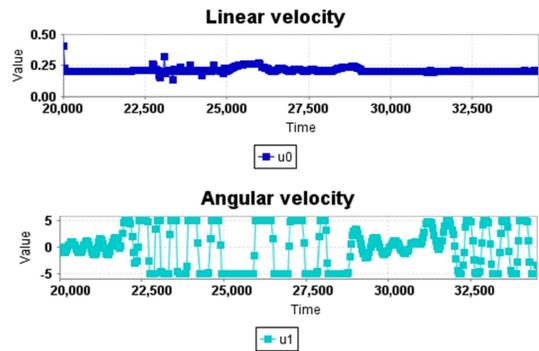


Fig. 13. Control inputs.

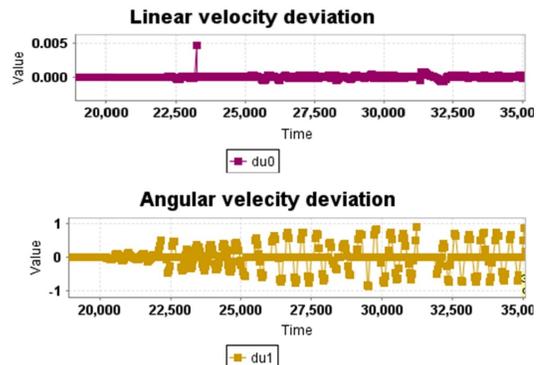


Fig. 14. Control inputs deviation.

IV. CONCLUSION

In this manuscript, Model Predictive Control implementation was focused on taking into account control inputs, inputs deviation and outputs constraints. The proposed control scheme exhibited suitable global performance when applied to wheeled mobile robots (WMR) for trajectory tracking problem.

Implementation results highlight the efficiency of the proposed design method. A framework for embedding MPC controller on a high performed STM32F429 microcontroller has been used. Optimization techniques have been applied to the generated code. Hence, an efficient implementation of the proposed control method yields a low computational burden with a high execution speed. Indeed, based on the experimental results, we noticed that the proposed method control successfully the process with a good set-point tracking.

In forthcoming article, we will focus on performance analysis comparison between the constrained MPC method proposed in this paper and a MIMO adaptive Proportional Integral Derivative (PID) regulator [8] for the trajectory tracking problem.

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Contextual Requirements for Mobile Native Applications

Contextual Requirements

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Abstract—Mobile apps have found wide acceptance in today's world which heavily depend on smart technology to access data over wide location. The apps are mostly of native type which can be used for accessing data even without the internet availability. In this paper the development of mobile native applications requires the assimilation of various analytical contexts depending on the requirement of users. We have done an empirical study of various papers based on ubiquitous systems and mobile apps for finding out the contexts in building mobile native apps and the mobile contexts are such as device context, user context, mobility context and social context. We have found that the overall weight of each mobile context is an empirical study. We have taken various activities which are performed among a user and mobile native apps and formed them into questionnaires which are sent to different mobile native app developers of different software industries. The mapping is done among these activities with the attributes and their associated mobile contexts. We have identified and obtained four contexts as main requirements for developing mobile native apps under any domain. The analysis of requirements is done modeling the contexts and their attributes through OWL DL language. We have determined from the empirical study that the overall weight of device context is more than the other contexts. Hence it is clear that the device context with its numerous features have a great impact on developing mobile native apps under any domain.

Keywords—Mobile contexts; pervasiveness; device usability; mobility interaction

I. INTRODUCTION

Mobile devices are the ubiquitous devices embedded with various sensors and powerful processors which provide information about any domain like agriculture, health care system and learning system. There are various platforms of mobile phones like ios phone, windows phone, android phone which are open for third party services. It means user can install third party applications from the central mobile application stores. These apps are stand alone in nature and don't always require the web services to access the data and hence are termed as mobile native apps. The mobile native apps are developed for smart phone applications that run specifically for native applications and don't require the internet connection for web services. These apps are written in 'objective C' or java programming languages depending upon the OS used by the mobile device. Mobile native apps are high performing and have a great deal of reliability for the

user. Since the mobile native apps are platform dependent, different versions are required to be developed for different platforms thereby increasing its cost of development. Context awareness in mobile apps discovers information based on contexts like device specific, user's activity specific and mobility specific. By enabling context awareness in mobile apps, these apps can provide information subject to any domain. Mobile context aware applications are more effective and adaptive due to the providing of required contextual information to users without taking so much attention of users. In generic domain, users need information about different domain specific entities. This information can be given to users through mobile apps with or without web services.

There also exist various frameworks or process models such as Mobile-D, Scrum, MASAM (Mobile Application Software Development using Agile Methodology) and SLeSS (Scrum Lean Six Sigma) which are used for building mobile native apps [1], [2]. But the requirement analysis phase in these frameworks or process models do not identify the requirements contextually under any domain. The word "context" is used to define and describe any entity based on different aspects. To build mobile native apps which can be used in any domain, it is necessary to identify the contexts of the mobile native apps. In this paper a study is done on the basis of the important context specific components of the mobile or ubiquitous device and from this study mobile context elements have identified as requirements for developing mobile native apps such as device context, user context, mobility context and social context. Its associated components and the commonalities are identified from the relationships among the contexts which give a clear idea to the developer of the native applications about the extent of its optimum usage by the user of a particular domain.

Here the research process is to identify the optimum context under mobile domain and identifying the overall weight of four contexts through empirical study. The four contexts are such as device context, user context, mobility context and social context which are referred to as mobile contexts in our research work. The overall weights of each mobile context have been determined. From the empirical study we have found that the overall weight of device context is more than other contexts. We have specified various activities and arranged them into questionnaires and send them to various mobile native app developers of different software

industries. These activities are the actions performed among a mobile native app user and mobile system. Further these activities are mapped with the mobile contexts under any domain. We have identified that most of the activities are mapped into device context and its associated attributes. Hence device context have a great deal in developing mobile native applications under any domain. The requirement specification described the contexts under mobile domain and its associated attributes. The requirement analysis describes the commonalities among mobile contexts under any domain.

The rest of the paper is organized as follows. Section 2 discusses related works on contexts in ubiquitous systems and context-awareness in mobile apps. Section 3 provides the research approach for the requirement specification. Section 4 discusses about empirical study and identification of requirements in mobile native apps. Section 5 provides requirement specification and requirement analysis for the development of mobile native apps. Section 6 provides discussion. Section 7 provides conclusion and future work, respectively.

II. BACKGROUND STUDY

A. Contexts and Context Awareness

Context is information which is used for identification of the situation of entities, that is whether a person, place or object is considered relevant to the interaction between a user and an application, including the user and the application themselves. Context [3] can be segregated into different dimensions such as external context and internal context or physical context and logical context. Context can [4] also be divided into four categories such as computing context, physical context, user context and time context. It is a fact that context has no uniform or standard definition. So everyone can give his understanding about context and it can be classified into any dimension. However in mobile computing area, the target of using context is to enable the device to better serve for people, either human computer interaction or context-aware mobile application or service.

Classification of context should establish the human-centric essence. It includes classification of context [5] into three dimensions such as physical context, internal context and social context. Physical context refer to the real world nearby user, making up physical things. Internal context is composed by abstract things inside people, such as feeling, thought, task, action, interest, goal, etc. which is very related to people. Social context means user's social surrounding, that is social relationship of user. This social context consists of persons related to user. The Generic Context Management Model consists of three basic components such as context semantics, context instance data and context related rules. Context semantics represents the semantics, concepts and relationships in the context data. It is formed by ontology that describes domain independent generic contexts and domain specific contexts. Context data represent instances of contexts. These are classified into various classes such as user context, device context, application contexts, network contexts, and resource context [6]. The rules represent derivation of axioms that are used by context aware systems to derive decisions and conclusions about the actions that follow. These rules have

two sources such as rules that are explicitly given by the users through the user interface and rules that are implicitly learnt by the system itself.

Mobile learning is the learning of different contexts. Mobile learning is unique in the sense that it is the combination of mobile technology and it's affordances that create a unique learning environment and opportunities which can span across time and place [7]. Content delivery, to the user should be based on their current context. Context plays an important role while designing the m-learning environment. The mobile learning context is where the situational and learning context meets in a learning environment. Contexts are created through mobile learning and classified as [8], learning context, situational context and learning environment context. The COMET [9], provides a semantic model for designing mobile learning applications and this model designs the mobile learning system into three aspects such as learner centric context, activity context and environment context. The learner centric context is segregated into profile, preference, physiological and cognitive abilities. The environment context is composed of many other contexts such as physical environment, social environment, virtual environment and computational environments. The activity context for mobile learning is composed of many activities such as physical exercise games, participatory simulations, field trip and visit, etc.

Context aware systems are able to adapt their operations to the current context without explicit user intervention and thus aim at increasing usability and effectiveness by taking environmental context into account. Due to the nature of context-aware applications, which often react to changes of the context during their execution, context server is provided a subscription-based push mechanism [10], which provides synchronous access to the context. Context data distribution [11], is the capability to gather and to deliver relevant context data about the environment to all interested entities connected to the mobile ubiquitous system. In fact, context data distribution is extremely significant from both the service and the middleware perspectives. The Muffin is a multi-sensory mobile device for providing context awareness to users. It is used as a prototype for extraction of different contexts. Here the contexts are categorized into three contexts [12], such as muffin terminal's context, user context and environmental context. Muffin's terminal context could be extracted accurately by using sensors and validating the output data. Furthermore muffin's state can be classified into exclusive classes and applies simple algorithms such as threshold analysis for finding the Muffin's state. In order to extract user context, a user has to carry Muffin in some ways. However available sensors and algorithms may change according to the position or situation in which Muffin mobile device is used. Environmental context such as air temperature and air pressure are directly extracted from sensors.

The Knotti project has designed and implemented a context aware platform for providing context aware services to mobile users. The platform enables the sharing of contexts and contextual contents. It provides the context aware services to users by segregating the contexts into various types [13], such as location, mood, mode of spending time, time and social

context, etc. The middleware platform [14] is developed to support context aware mobile apps development. It is capable of locating and extracting relevant context data from a large number heterogeneous data sources distributed over many different operating environments. This platform is designed as a service oriented architecture including various system functionalities as context data acquisition, reasoning, service registration and discovery. These are all designed and deployed as system services for developers and end-users to access. The middleware architecture consists of four logical layers such as physical space layer, context data management layer, service management layer and application layer. A mobile guide [15], is a mobile app that provides context dependent services, indoor and outdoor navigation to users operating on personal digital assistants (PDA) and smart phone applications. Mobile guide also provides [15], location awareness, map based navigation, bookmarking, collaboration, contextual information with multimedia mechanisms to users. The contexts in mobile guide are such as user, service, environment, system and social. Mobile guide architecture consists of three tier architecture such as application tier, middle tier and data tier. Mobile native apps can also be providing information about health care apps. For example mobile e-healthcare app [16] can be developed using HTML5 and provides context aware diabetes information to users or patients. For developing the e-health mobile apps, it uses various sensors such as accelerometer, low pass filter, magnitude filter for monitoring diabetes in the body when the user is in moving, walking or running stage.

III. RESEARCH APPROACH

In order to explore the issues around mobile native application requirement analysis processes and what characteristics are typically included in these requirement specifications, we have established three research questions (RQ1 to RQ3). These are as discussed below.

A. RQ1

How the requirement gathering is done in building mobile native apps under any domain?

This question RQ1 is established to identify, understand the attributes or elements under mobile domain which are included in the requirement specifications for mobile native applications.

B. RQ2

How the different attributes or elements under mobile native app development are identified in order to give effective requirement specification for building mobile native applications?

This question RQ2 is established to identify different attributes or elements under mobile domain with a particular focus on mapping of attributes with mobile contexts for building mobile native applications.

C. RQ3

How the requirement analysis is done in building mobile native applications under any domain?

This question RQ3 is established to specify the requirement analysis under any domain with a particular focus on establishing of commonalities among four mobile contexts for building mobile native applications.

IV. REQUIREMENT SPECIFICATION UNDER MOBILE DOMAIN

A. An Empirical Analysis on Context Elements under Mobile Domain

We have taken the contexts from the papers as mentioned in this study which is shown in Table 1 and assigned some values to these contexts. Here the assignment is done through taking a total of 100 values and dividing the total number of contexts from total value to get the desired value. This desired value is assigned to each context of papers in the study which is shown in Table 1. For example the contexts specified such as learner's personal status context, situational context and learning environment context in [8]. Hence the individual value for each context will be 33.33% that is 0.33 values. The context elements under the learner's personal context are learner's preferences, demographic information, and learner's history. So the value of each context element under this learner's personal status context will be assigned to the desired value as $33.33/3=11.11\%$ that is 0.11value. For example the learner's preferences, demographic information and learner's history context element will obtain the desired value as 11.11% that is 0.11value. Here the learner' history, demographic information and learner's history are identified and classified as user contexts in our proposed work.

TABLE I. AN EMPIRICAL STUDY ON CONTEXTS

Sl no	Authors of specified papers	Ref no []	Context specified in these papers	Context elements under these contexts of specified papers	Contexts classified in proposed work	% of Overall value of contexts in the proposed work
1	Genevieve Stanton and Jacques Ophoff	[8]	Learner's personal status context (33.33%) Situational context (33.33%) Learning environment context (33.33%)	Learner's preferences (11.11%) Demographic information (11.11%) Learner's history (11.11%) Social interaction (11.11%) Cultural surrounding (11.11%) Rules around communication (11.11%)	User context User context User context Social Context Social Context Social Context Device context Device Context Mobility Context	User context (19.71) Device context (48.67) Mobility context (22.72) Social context (8.87)

				Functional ability of the device (11.11%) Physical attributes (11.11%) Technical attributes (11.11%)		
2	Sohaib Ahmed and David Parsons	[9]	Learner centric context(33.33%) Activity context (33.33%) Environmental context (33.33%)	Learner's profile (8.33%) Learner's preferences (8.33%) Learner's physiological state (8.33%) Learner's cognitive state (8.33%) Physical exercise games (8.33%) Participatory simulations (8.33%) Field trips and visits(8.33%) Content creation(8.33%) Physical Environment (8.33%) Social environment (8.33%) Virtual environment (8.33%) Computational environment (8.33%)	User Context User context User context User context User context User context User context Device Context Social Context Mobility Context Device Context	
3	Dejene Ejigu and Marian Scuturici	[6]	User context (12.5%) Device context (12.5%) Application context (12.5%) Physical environment context (12.5%) Resource context (12.5%) Location context (12.5%) Network context (12.5%) Activity context (12.5%)	User's Identity (3.12%) User's preference (3.12%) User's activity (3.12%) User's location (3.12%) Processor speed (4.16%) Screen size (4.16%) Device location(4.16%) Vesion (6.25%) Availability (6.25%) Illumination (6.25%) Humidity (6.25%) Availability (4.16%) Size (4.16%) Type (4.16%) Inclusion of contents (12.5%) Minimum speed (6.25%) Maximum speed (6.25%) Start time (4.16%) End time (4.16%) Actor (4.16%)	User Context User Context Device Context Device context Device Context Device Context Device context Device context Mobility context Device context Device context Device Context Device Context Device context Device context Mobility Context Mobility Context Device Context Device Context User context	
4	Tetsuo Yamabe and Tatsuo Nakajima	[12]	Muffin terminal's context (33.33%) User context (33.33%) Environmental context (33.33%)	Device motion (11.11%) Device posture (11.11%) Placement (11.11%) User's activity (8.33%) User's physical condition (8.33%) Emotion (8.33%) Geographical information (8.33%) Air temperature (8.33%)	Device Context Device Context Device Context Device Context User Context User Context Device context Device Context Device context Device Context Device context	

				Air humidity (8.33%) Air pressure (8.33%) Ambient noise(8.33)		
5	Espoo	[13]	Location context (16.66%) Time (16.66%) Mood (16.66%) Mode of spending time (16.66%) Social context (16.66%) Virtual context (16.66%)	Fixed location (5.553%) Moving location (5.553%) Relative location (5.553%) Weekdays (5.553%) Weekends (5.553%) Seasonal Changes (5.553%) Relaxing (16.66%) Management board(5.553) Project meeting (5.553%) Economy committee (5.553%) Reminders (8.33%) Sending of personal messages (8.33%) Connection of mobile materials to virtual places (16.66%)	Device Context Device Context Device context Device Context Device context Device Context User Context User Context User Context User Context Device Context Device context Mobility Context	
6	MARGUERITE L. KOOLE	[7]	Device aspect (33.33%) Learner aspect (33.33%) Social aspect (33.33%)	Physical characteristics (5.55%) Input capabilities (5.55%) Output capabilities (5.55%) File Storage (5.55%) Error rates (5.55%) Processor speed (5.55%) Learner's prior knowledge (6.66%) Discovery learning (6.66%) Emotions and motivations (6.66%) Memory(6.66) Context and transfer (6.66%) Conversation and Cooperation (16.66%) Social Interaction (16.66%)	Device Context Device Context Device Context Device Context Device Context Device Context User Context User Context User Context User Context Device context Social Context Social Context	
7	Thomas Hofer and Wieland Schwinger	[10]	Time context (20%) Location (20%) Device (20%) User (20%) Network (20%)	Current time (20%) Current position of the device (20%) Device type (20%) Information content by user (20%) Available network (10%) Connection types (10%)	Device Context Device Context Device Context User Context Mobility Context Mobility Context	
8	Li Han and Salomaa Jyri	[5]	Physical Context (33.33%) Internal Context (33.33%) Social Context (33.33%)	Real world nearby user (16.66%) Making of physical things (16.66%) Feeling (8.33%) Thought (8.33%) Task (8.33%) Interest (8.33%) Social surrounding (16.66%)	Device Context Device context User Context User Context User Context User Context Social Context Social Context	

				Social interaction (16.66%)		
9	Karel-Henk Nijhuis	[32]	Context related to human factor (50%) Context related to physical environment (50%)	Information about the user (16.66%) User's social environment (16.66%) User's task (16.66%) Location (16.66%) Infrastructure (16.66%) Physical conditions (16.66%)	User Context Social Context User Context Device Context Device Context Device Context	
10	Jacqueline Floch and Svein Hallsteinsen	[27]	User context (50%) Network context (50%)	User mood and role (25%) User physical location (25%) Network capacity (25%) Accessed I/O devices (25%)	User context Device Context Mobility Context Device context	
11	Panu Korpipää and ä, Jani Mäntyjärvi	[28]	Location (20%) Time (20%) Environment (20%) User (20%) Device (20%)	Device/user location Time of the day Sound (5%) Temperature (5%) Humidity (5%) Light (5%) User's activity (20%) Device activity (10%) Application (10%)	Device context Device Context Device context Device context Device context Device context Device context Device context Device context	
12	Qusay H. Mahmoud	[29]	Location (25%) Time (25%) User's preferences (25%) Device capability (25%)	Device context (25%) Device context (25%) User context (25%) Device context (25%)	Device context Device context User context Device context	
13	PAOLO BELLAVISTA and ANTONIO CORRADI	[11]	Computing Context (25%) Physical Context (25%) Time Context (25%) User Context (25%)	Device capabilities (12.5%) Connectivity (12.5%) Device/user location (6.25%) Noise level (6.25%) Lighting data (6.25%) Temperature (6.25%) Time of a day (6.25%) Month (6.25%) Week (6.25%) Season of the year (6.25%) User's profile (8.33%) People nearby (8.33%) Current social situation (8.33%)	Device context Mobility context Device Context Device Context Device Context Device Context Device Context Device Context Device Context User Context Social Context Social Context	
14	Anind K. Dey and Gregory D. Abowd	[30]	Location (25%) Activity (25%) Identity (25%) Time (25%)	Device/user's location Device/user's activity User's profile Time of the day	Device Context Device context User Context Device Context	

15	George W. Musumba and Henry O. Nyongesa	[31]	Location (12.5%) Activity (12.5%) Identity (12.5%) Mood (12.5%) Social Context (12.5%) Physical Context (12.5%) Network Context (12.5%) Device Context (12.5%)	Device/user location (12.5%) Device/user activity (12.5%) User Profile (12.5%) User mood (12.5%) Relationship with people (12.5%) Lighting level (12.5%) Round trip time (12.5%) Device capabilities (12.5%)	Device Context Device Context User Context User Context Social Context Device Context Mobility Context Device Context	
16	Emmanouilidis, C., Koutsiamanis, R. A	[15]	User (20%) System (20%) Service (20%) Social (20%) Environment context (20%)	Emotional state (2.85%) User category (2.85%) Preferences (2.85%) History (2.85%) Activity (2.85%) Location (2.85%) Orientation (2.85%) Device characteristics (3.33%) Network conditions (3.33%) QoS constraints (3.33%) Privacy (3.33%) Security (3.33%) Energy consumption (3.33%) Available service (6.66%) Task sequence (6.66%) Constraint (6.66%) Relationships (6.66%) Group (6.66%) Interaction (6.66%) Crowding (6.66%) Time (6.66%) Noise readings (6.66%)	User context User context User context User context Device context Device context Device context Device Context Device context Mobility context Device context Device context Device context Device context Device context Social context Social context Social context Social context Device context Device context Device context	
17	Preuveneers, D., Berbers, Y.	[16]	Time (33.33%) Location (33.33%) Accelerometer sensor readings (33.33%)		Device context Device context Device context	

Here in Table 1, we have analyzed the contexts in papers and classified them under device context, user context, mobility context and social context in our proposed work. We have obtained the total number of device context element from various papers (17) that can be obtained as calculating sum of all the device contexts of various papers (17). This can be done using the formula, which is given below:

$$\text{The total number of device context element} = \sum_{i=1}^{i=17} \text{Devicecontext}(i)$$

Therefore the total number of device context elements is such as 9.38.

Similarly the total number of mobility context, social context and user context can be calculated using the formula as given above and are such as 4.38, 1.71 and 3.8, respectively.

After that all the four context elements are added to obtain a total value 19.27. Further the overall value of device context in our proposed work is calculated by using the formula (total number of device context elements / total value *100). The overall value of device context can be found as (9.38/19.27*100) and is obtained such as 48.67. Similarly the overall value of user context, mobility context and social context in our proposed work are 19.71, 22.72 and 8.87 respectively. In this empirical study we have obtained the four contexts such as device context, user context, social context and mobility context in mobile domain and these contexts are specified as requirements to develop mobile native apps in generic domain.

Here we have taken the total overall value as 100 and out of 100, the % (percentage) of overall value of device context is 48.67. Similarly the % (percentage) of overall value of mobility context, user context and social context are 22.72, 19.71 and 8.87 from 100. From these four contexts, the % of

overall value of device context is more than other contexts. Hence it is observed that, the device context with numerous and efficient features have a great impact in developing mobile native apps. After that mobility context has to be taken into account while developing mobile native apps under any domain. The user context and social context have a little impact on developing mobile native apps under any domain.

B. Identification of Requirements

We have taken numerous activities of various components in mobile native apps and organized them into a set of questions through Google forms and have sent to various mobile app developers of different software organizations for specifying the requirements under mobile domain. We have received their response and the requirements are determined based on their responses. Some of the questions are discussed below.

Q1. The native mobile app development requires what type of storage to save data?

- a. Shared preference
- b. Device memory or internal memory
- c. External storage
- d. Private database
- e. All

No of respondents for a=2

No of respondents for b=5

No of respondents for c=0

No of respondents for d=0

No of respondents for e=5

Q2. The app widgets require which layout classes?

- a. Linear layout.
- b. Relative layout
- c. Frame layout
- d. Grid layout
- e. All

No of respondents for a=0

No of respondents for b=0

No of respondents for c=2

No of respondents for d=0

No of respondents for e=8

Q3. Which gestures are used in mobile native app development, while interactions are done among user and mobile device.

- a. Drag
- b. Drag and Drop
- c. Pinch
- d. Zoom in and Zoom out
- e. All

No of respondents for a=0

No of respondents for b=0

No of respondents for c=0

No of respondents for d=0

No of respondents for e=10

Q4. Is it possible for a mobile device to be built, with all types of sensors to measure user's location, orientation and all types of environmental conditions?

- a. Yes
 - b. No
- No of respondents for a=10
- No of respondents for b=0

The questionnaire and responses are shown in bar graphs in Fig. 1 and 2, respectively.

Getting the responses from various mobile native app developers in various software industries, we have identified their attributes. Further these activities and their attributes are classified into contexts which are identified as requirements based on contexts for building mobile native application under any domain.

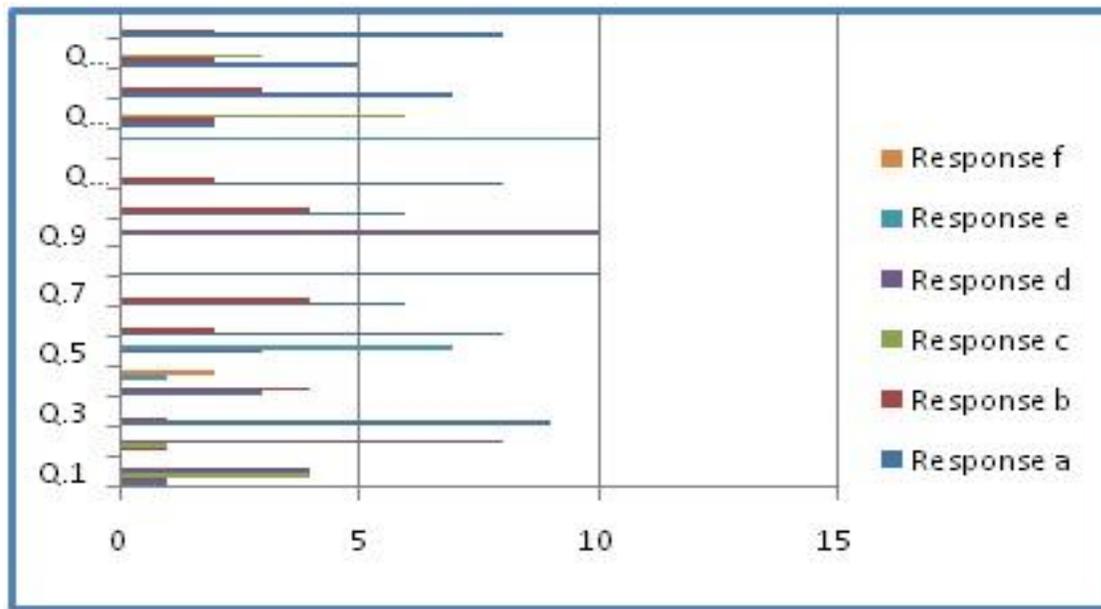


Fig. 1. A sample of questions Vs mobile native app respondents.

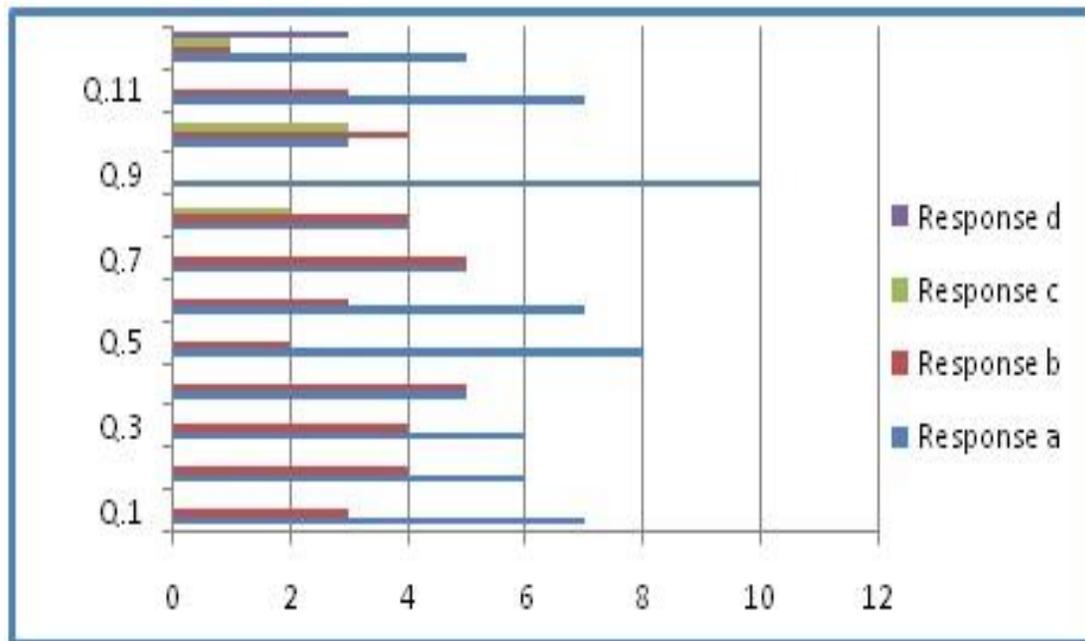


Fig. 2. A sample of questions Vs mobile native app respondents.

1) Mapping of Various Activities into Mobile Contexts

At first we have taken various activities which are done among mobile native user and mobile device and put them into a set of questions and collect the responses from various mobile native app software developers. Depending upon the responses, the activities are specified and classified into attributes and contexts under generic domain for mobile native apps. Further these activities are classified into different attributes and contexts which are shown in Table 2.

Here in Table 2, we have specified an activity, i.e. drag and drop and this activity is placed in form of question in

Google forms. This activity or question is shown as Question No. 3 as above in Section 4.2. We have identified its attribute such as gestures and this gestures attribute is mapped to device context as shown in Table 2. Similarly from the other we have identified the other attributes and mapped them to contexts such as user context, mobility context and social context.

Further these attributes under various contexts are identified as requirements for building mobile native apps and given in requirement specification as below.

TABLE II. MAPPING OF VARIOUS ACTIVITIES INTO CONTEXTS

Activity	Attributes	Context
Doing operations on screen of mobile device	Screen size and density	Device context
Doing operations on app widgets of a mobile app	Layouts or app widgets	Device context
Doing operations on menus of an mobile app	menus	Device context
Accessing the content of an mobile app	Content providers and content size	Device context
Saving the data in an mobile app	Storage	Device context
Providing controls to a user for selecting the input field	Input control elements	Device context
Extending the app widgets with the screen size	Margin	Device context
Drag and drop	Gestures	Device context
Finding location and weather data	Sensors	Device context
Connecting the mobile app with web server	WLAN	Mobility context
Connecting the mobile app with web server	GPRS	Mobility context
Connecting the mobile app with web server	EDGE	Mobility context
Retrieving information from the mobile app specified on user's role and task	Based on role	User context
Finding effectiveness on information from app	Based on preferences	User context
Finding efficiency on information from app	Based on preferences	User context
Finding ease of use on the mobile app	Based on usefulness	User context
Obtain trust on the retrieved information	Based on usefulness	User context
Accessing the audio and video files	Blogs	Social context
Sharing of information among users	Social networking	Social context
Searching relevant information	Wikis	Social context

V. REQUIREMENT SPECIFICATION

The requirement specification specifies different mobile contexts which can be applied to any domain area which are as follows in Sections (A-D).

A. Device Context

Device context includes features of mobile device through which user get information about any web domain area. Feature of a mobile device includes physical characteristics, functional characteristics and technical characteristics [7]. The physical characteristics [17], of a mobile device include screen size, screen resolution, overall physical dimensions, weight etc. The functional characteristics of a mobile device include input mechanisms, gestures and output mechanisms. The technical characteristic of a mobile device includes processor speed, sensors and storage capabilities. The motion, posture and placement of a mobile device can be extracted from various sensors [12], which includes 3D accelerometer, digital compass and skin resistance sensor. The device context parameters are taken from device context of mobile devices to use web apps are as follows.

1) *Sensors*: The sensors [18], form an important device context parameter of the mobile device. The sensors can be categorized as location, touch, proximity, environmental, data, motion and visual sensors. The location sensors sense the geographical position of the device in a particular area. The touch sensors are vital in accessing the touch screen technology in the modern smart phones. They sense the specific touch gestures on the screen which is sensitive to finger sensation in particular gestures. This touch gestures [19], is passed to the input component and is interpreted by the mobile operating system as a particular input. The proximity sensor senses and provides information on the distance, direction and area of the mobile device from that location point.

2) *Input output mechanisms*: The input mechanism device context parameter plays a key role of accepting input data in form of text, code or any other type of data to provide the input for possible and analyzing the data for the user of the mobile devices. The input mechanism can be facilitated by the most basic input device context parameters like the keyboard. The keyboard can be either touch based called the smart keyboard or physical key based called the standard keyboard.

The touch based keyboards are mostly present in the smart phones to efficiently enter the text based data to be used in numerous applications. The most common smart key boards are QWERTY keyboards and Swift Key keyboard. The output mechanisms of a mobile device includes speakers and screen display.

3) *Gestures*: Gestures form important device context parameters for smart and efficient input style for navigating web apps in smart phones. Gestures are the different typing or finger movements on the smart keyboard of the touch screen based smart phones for different input styles required for different applications. The various types of gestures used commonly in smart phones are touch, long press, swipe, drag, long press drag, double touch, double touch drag and pinch.

4) *High Screen Resolution*: High screen resolution is one of the essential requirements for data visualization of the smart phones. It is the ideal mix of sharpness, contrast and brightness of the screen for a comfortable and clear visualization of data.

5) *RAM size*: This is the data storage aspect which acts as an important device context parameter from the primary memory storage of the mobile devices. The larger the RAM size, the faster is the data loading rate for the web apps. This increases the efficiency of the usage of various native apps on the mobile device.

B. User Context

User context includes the user context parameters such as user's profile, role of user, preferences, process and task [8], associated with user from a general common social aspect. User and role holds context information related to user and its activity [6]. The user context also determines the belief of a user that interacting with the mobile system will enhance its task that is termed as usefulness [20]. The user context parameters are based on the involvement of the user with the native mobile apps considering certain important parameters which are classified into functional requirements and non-functional requirements such as Based on role, Based on preferences and Based on usefulness. These parameters are as follows:

1) *Based on Role*: The user context parameters are considered according to the basic roles they perform during their interaction with the native apps running on the mobile device.

2) *Based on Preferences*: The user context parameters according to the preferences of the user based on certain aspects of the mobile apps are effectiveness, efficiency, satisfaction and memorability [21]. The effectiveness shows the ability of a user to access the information in a particular context. The efficiency shows the extent of speed and accuracy of specific features of the mobile native apps used by the user. Satisfaction is the extent of fulfilment of the user's requirement by the usage of the mobile apps for a particular purpose by the user with the different aspects of mobile apps. Memorability is the ability to retain the step wise actions for accessing a specific feature of the mobile native apps.

3) *Based on Usefulness*: The user context parameters are analyzed on the basis of the extent of the usefulness of a native app user with the different contexts of mobile device like device contexts and social contexts. The parameters determining the aspect of usefulness are perceived ease of use, perceived usefulness, intention to use and trust [20], [22].

C. Social Context

Social context includes the concept of relevance of social media to the user context and the mobility context of the mobile apps. Web 2.0 includes the social media tools such as wikis, blogs, podcasting, micro-blogging, content hosting, social networking, e-Portfolios and social-bookmarking [23], [24]. Among them most of the social media tools include (www.unimelb.edu.au), wikis, content hosting, social networking, blogs and podcasting. The social context determines the relationship of the social media parameters with respect to its usefulness to fulfill the requirements the user intends to satisfy through the mobile apps. The social context parameter includes.

1) *Blogs*: Blogs are type of commentary or information dealing with a specific topic. It is an important social context parameter which acts as a medium to express user's information about a specific topic which is utilized by the user to benefit for a particular purpose.

2) *Content Hosting*: Content hosting is a social context parameter which enables the sharing of user's specific information by the public user of the content hosting sites to be viewed and used by the users using the web apps.

3) *Social Networking*: Social networking is the social context parameters through which a user can create and maintain a user profile for sharing the information on specific topics to be used by other users for their relevant requirements and purposes.

4) *Podcasting*: Podcasting is a social context parameter through which audio and video files can be accessed by the user through specific file formats compatible with specific devices to be listened or viewed or downloaded for offline usage purpose.

5) *Wikis*: Wikis are social context parameters which allow the users to contribute and edit the information available publicly to the community of users searching for their relevant information. Wikis provide information about specific topic which the users easily searches and views them. This social context parameter provide the user an easy access to almost every information and edit and add more information if they choose to.

D. Mobility Context

Mobility context is the flexibility and portability of a wireless mobile device in moving from one place to another and continuing to access the data connection network facility throughout its location inside the network zone. It plays an important role in the modern emerging wireless network technologies. Mobility brings freedom to personalize the computing experience and work satisfaction of a user and also empowering agility of a mobile device using any one wireless

standard, such as WLAN, GPRS and EDGE [25]. The mobility context determines the various parameters which are used by the social and device context parameters to access the information for a user using the mobile native apps. The complex mobility pattern can be implemented using a hierarchy of filters through GPS on a mobile device [26]. The mobile native applications for mobile devices are seen as inherently insecure due to their open interactions with other applications on the device. Hence these native apps should use standard built in OS browsers, (powering state and local mobility) for achieving mobility and interacting with outside world since they do not encrypt cookie, history or cache information.

1) *WLAN*: WLAN stands for wireless LAN which is a wireless network which links two or more devices using an interface like a network interface card for the wireless devices for a limited area of network access like the college campus, home ,office campus or business establishment.

2) *GPRS*: It stands for the general packet radio service which is a mobile data accessing service using the GSM technology on mobile phones. The GPRS provides the packet data rate of up to 172 kbps.

3) *EDGE*: EDGE stands for enhanced GPRS or enhanced data rates for GPRS evolution. IT provides 3 times faster speed than the original GPRS system. The data rate varies from 135 kbps to 473 kbps in 8 time slots which conserves these spectrum resources.

4) *Bluetooth*: Bluetooth is a common wireless network communication technology between the wireless mobile

devices to transfer or share data in form of data files of various types like text, picture graphics, audio or and video files.

5) *GPS*: Global positioning system or GPS is a navigation technology which is used for providing the time and location information of an object which can be a mobile device in all type of environmental conditions on the earth or within its atmosphere in a range close to its surface. GPS information is provided by GPS satellites which can be one or more a number providing images of the mobile device with in the unobstructed line of sight.

6) *Browser*: Browser is a mobility context parameter, which is used for mobile devices for accessing the information over the web by using the mobile web apps. Mobile browsers are optimized for the effective display of user friendly screen interface compatible to portable mobile devices.

E. Requirement Analysis

The requirement analysis is done through defining the commonalties among various contexts in a mobile domain for design and development of mobile native apps. The commonalties include device usability, pervasiveness, social interaction and mobility interaction. The device context, mobility context, social context and user context are taken into consideration to form mobile ontology. Here in this mobile system ontology, the device context and the other contexts are treated as classes. This mobile system ontology is built using OWL DL language in protégé 5.0 beta framework. The commonalties are built in mobile ontology through using property axioms among these classes. Here the device context and its components are treated as class and sub classes to build the mobile ontology. The mobile ontology is shown in Fig. 3.

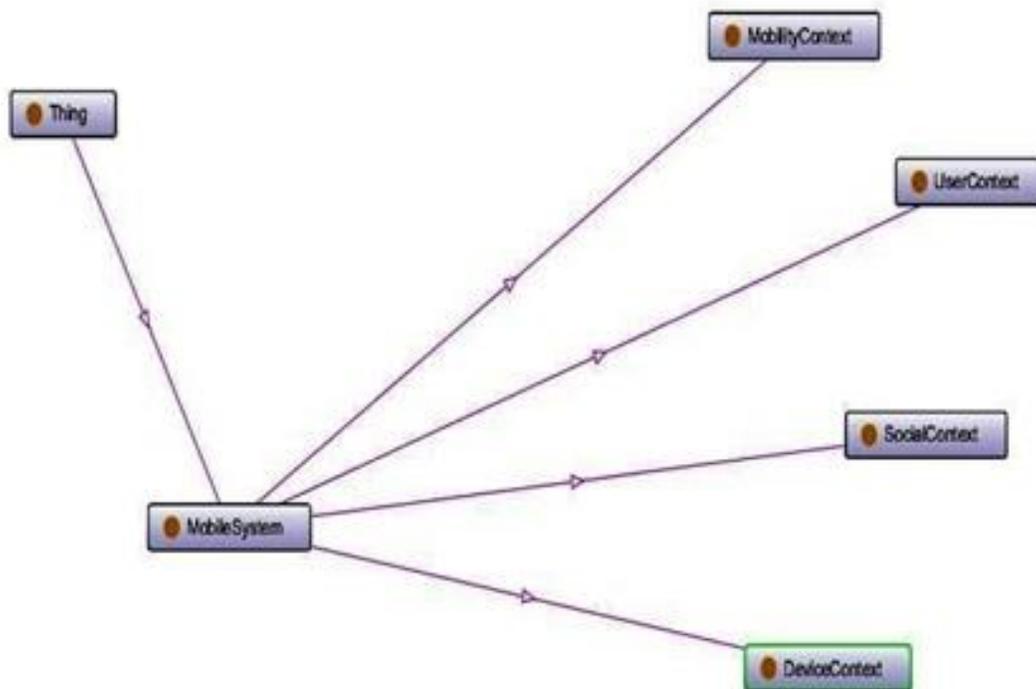


Fig. 3. Mobile system ontology.

1) *Device Usability*: The mobile device usability is the co relationship between the parameters of device context and the user context taking into view the commonalities which satisfy each other's criteria for a mobile device in accessing native apps over the mobile device.

2) *Pervasiveness*: Pervasiveness is the movement of the device inside the network area determined by the mobility context parameters. It shows the utilities of the device context parameters like sensors, gestures, input mechanism, high screen resolution and ram size inside the network area as shown by mobility context parameters.

3) *Mobility Interaction*: The mobility interaction is the usability of social context parameters in the mobile network area supported by the mobility context parameters showing the interaction between social context parameters.

4) *The social interaction*: It is the user interaction over the internet using social media web apps for sharing and transferring information from one user to another.

The classes under device context identified are as follows:

Device Context:

- SENSOR
 - Data sensor
 - Proximity sensor
 - Location sensor
 - Environmental sensor
 - Touch sensor

Visual sensor

- Gestures
- Keyboard
 - Swift key keyboard
 - Qwerty keyboard
- High screen resolution
- RAM size > 1

These subclasses under device context are modeled to form device context model through OWL DL in protégé 5.0 beta framework. The device context model is shown in Fig. 4 below.

Mobility Context: The classes under this context are as follows:

Mobility Context

- WLAN
- GPRS
- EDGE Bluetooth
- Browser
- GPS

These subclasses under mobility context are modeled to form mobility context model through OWL DL in protégé 5.0 beta framework. The mobility context model is shown in Fig. 5 below.

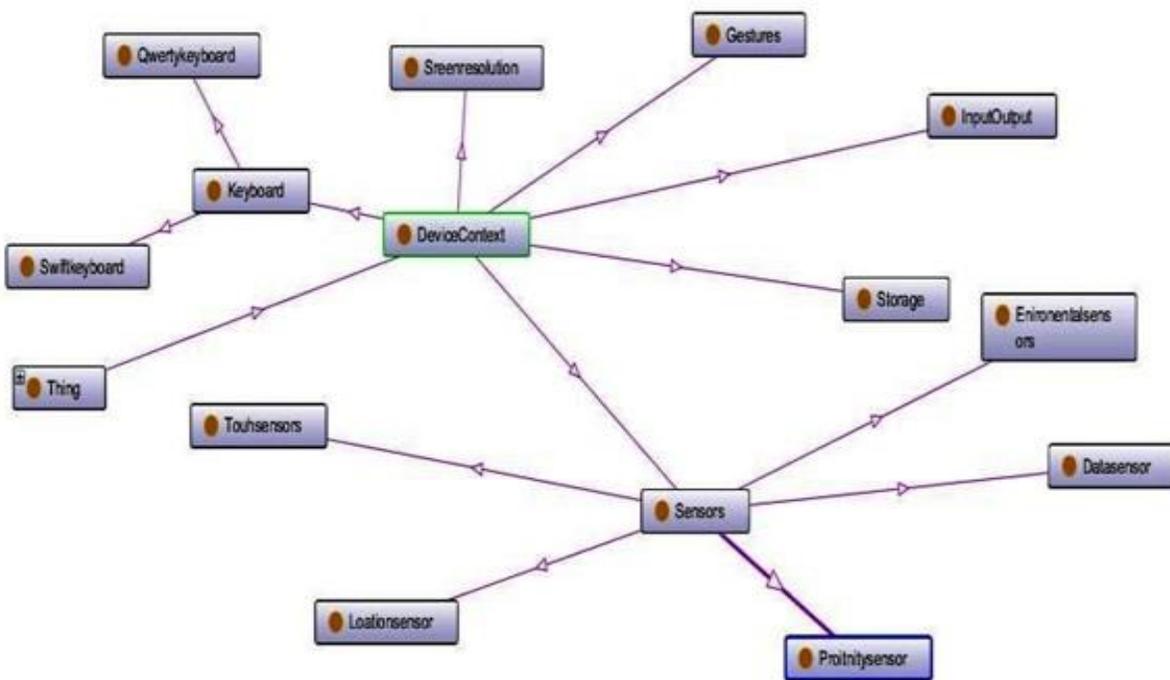


Fig. 4. Device context model.

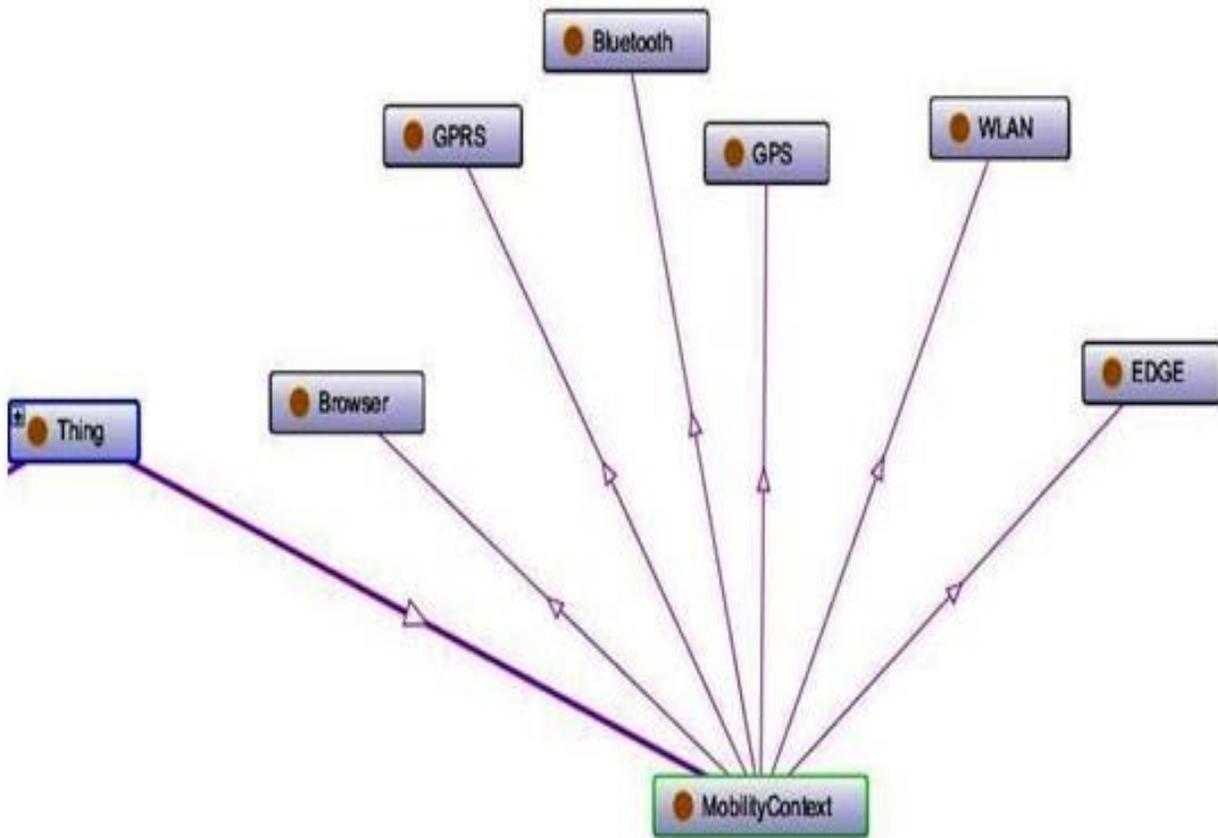


Fig. 5. Mobility context model.

User Context: The classes under this context are as follows:

User Context

- Based on role
 - Category A
 - Category B
 - Category C
 - Category D
 - Category X
 - Category Y
 - Category Z
- Based on preferences
 - Effectiveness
 - Efficiency
 - Satisfaction
 - Memorability
- Based on usefulness

- Perceived ease of use
- Perceived usefulness
- Intention to use
- Trust

These subclasses under user context are modeled to form user context model through OWL DL in protégé 5.0 beta framework. The user context model is shown in Fig. 6 below.

Social Context: The classes under this context are as follows:

Social Context

- Blogs
- Content hosting
- Social networking
- Podcasting
- Wikis

These subclasses under user context are modeled to form social context model through OWL DL in protégé 5.0 beta frame work. The social context model is shown in Fig. 7 below.

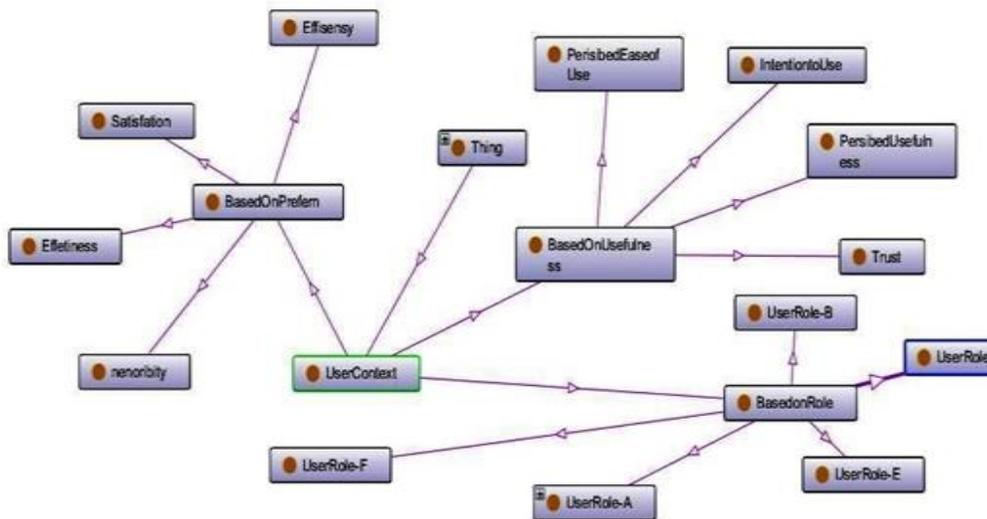


Fig. 6. User context model.

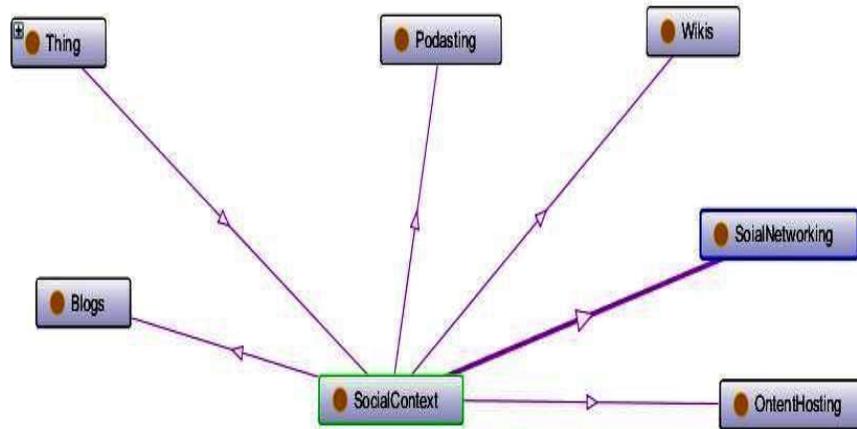


Fig. 7. Social context mode.

VI. STATE OF THE ART

From the empirical study, we have obtained the four contexts such as device context, mobility context, user context and social context under mobile domain. Among these four contexts, device context has a greater impact on building mobile native applications. The requirement specification also specifies these four contexts and their attributes. The requirement analysis provides modeling of these four contexts and their corresponding attributes which are shown in Fig. 5-8. Further these contexts and their attributes have more importance on designing and developing mobile native apps. Here we have taken some activities which are performed in mobile native apps. Further these activities will be drawn from the four contexts elements which will undergo several design phases for developing mobile native apps. These are shown below in Table 3.

The first one deal with doing operations on the keyboard and gestures are the attributes of device context which we

have explained in Section 5.1. These attributes will be taken into consideration for user interface design in designing and developing mobile native apps. The third one imposes the attributes such as WLAN, GPRS and EDGE, etc. which undergo mobility context. These elements are hardcoded into the hardware of the mobile device through establishing connections via adapters and sockets irrespective of any platform. These mobility context elements are configured in the mobile device through protocols and their features are accessed by applications developed for building mobile native applications irrespective of platform. Hence these mobility context attributes will be put in architecture design in building mobile native applications. The fourth activity concerns about installation of any mobile native application which is dependent on Ram size and platform of the device. These attributes are under device context and taken into account for architecture design in mobile native apps.

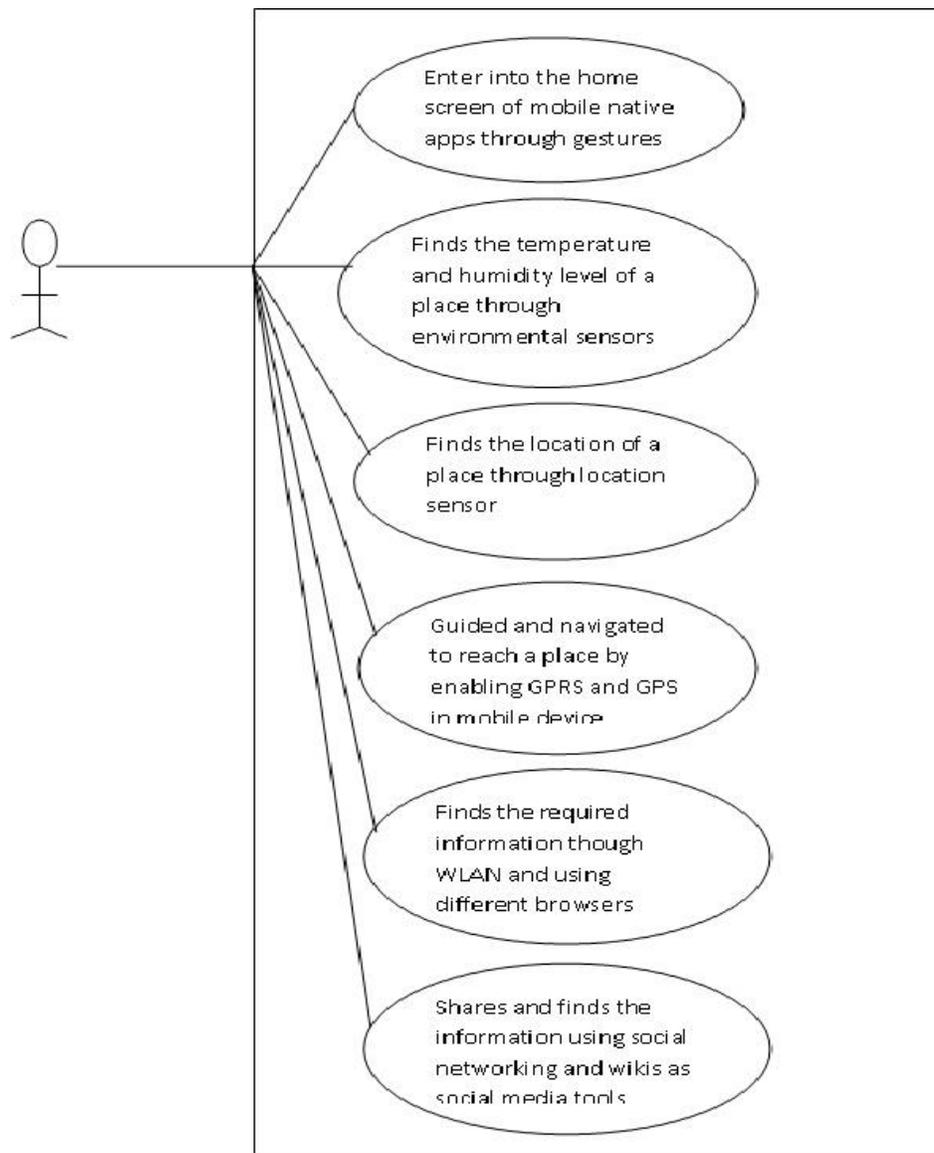


Fig. 8. Use case scenario between the user and mobile native applications.

The fifth one concerns about users based on different role. The based on role attribute undergo user context which is specified in Section 5.1. The content design for mobile native apps will be done based on user's different kind or role.

Similarly the user interface design and navigation design for building mobile native apps will be done based on different users. The conceptual design provides meaningful and consistent information in a semantic manner and it will also be done based on users of different domain. The presentation design deals with presenting views to users of various domain using transition animations. Hence the user context will be considered in content design, user interface design, navigation design, conceptual design and presentation design for designing mobile native apps.

The sixth activity deals with effective information retrieval of users under various domains. This attribute is considered under user context which is specified in Section 5.1. Similarly,

the user context will be considered in content design, user interface design, navigation design, conceptual design and presentation design for designing mobile native apps. The seventh activity deals with sharing of information which is done through social media tool like social networking in mobile native apps. The social networking is the attribute of social context which is discussed in Section 5.1. The personification design is used for achieving customization and personification in native mobile apps, where the mobile native app user should be connected with other users through the social media tools so that mobile native app user can share and find its desired information about any domain. Hence social context is considered in personification design for designing and developing mobile native apps.

The state-of-the-art concludes how the four context elements are used in different design phases for building any mobile native app under generic domain.

TABLE III. MAPPING OF MOBILE CONTEXTS TO DIFFERENT DESIGN PHASES IN MOBILE NATIVE APPS

Activities performed on any mobile native app	Mobile contexts	Design phases of any mobile app to be built
1. Clicking on the app widgets of a mobile native app	Device context	User interface design
2. Opening the menus of a mobile native app	Device context	User interface design
3. Loading of any mobile native app from the play store	Mobility context	Architecture design
4. Installation of any mobile native app on the mobile device	Device context	Architecture design
5. Users of different kind retrieve information from the mobile native app	User context	User interface design, content design, navigation design, conceptual design and presentation design
6. Users of different kind obtain effective information from any mobile native app	User context	User interface design, content design, navigation design, conceptual design and presentation design
7. Information sharing among the mobile native app users	Social context	Personification design

VII. DISCUSSION

We have done an empirical study on contexts specified in various papers (17) of ubiquitous systems, mobile learning apps and pervasive based systems. We have identified contexts and classified the context elements under the contexts of different papers. Further these context elements are classified to the contexts such as device context, mobility context, user context and social context in our proposed model and weight assignment is done to the contexts of our proposed model accordingly which is shown in Table 1. We have obtained the overall value of all the four contexts which is shown in Table 1. We have taken the total overall value as 100 and from this value the % of overall value of device context is 48.67 and % of overall value of mobility context, user context and social context are such as 22.72, 19.71 and 8.87, respectively. Hence device context and its associated efficient features have a greater impact for building mobile native apps. After that mobility context has to be considered for building mobile native apps under any domain.

Here we have validated our result by taking the use case as running example of any generic mobile native application which is shown in Fig. 8.

Based on user's role the specific native mobile app is to be built in a mobile device. In first use case, when a mobile native app user wants to enter into the mobile apps, he/she has to use the keyboard and gestures of a mobile device which are

the context parameters of device context. Hence the first use case uses two device context parameters (2). In second use case, the user can find temperature and humidity level of a place using environmental sensors in mobile native apps subjected to any domain. The environmental sensors are also the context parameters of device context. Therefore this use case provides two device context parameters (2) which is to be considered. In third use case, the mobile native app user also can find the location of a place through location sensors which are built in the mobile device. The location sensor is also a context parameter (1) of device context. Hence the third use case gives again one device context parameter of device context.

In the fourth use case, the users of any domain can be guided and oriented to reach a place through GPRS and GPS which are the context parameters of mobility context. The fourth use case drags two mobility context parameters of mobility context. In the fifth use case, the user specific to any kind, can retrieve information from web and browse through web in mobile native apps using browsers and WLAN. The browser and WLAN are the context parameters of mobility context. Hence this use case gives again two (2) mobility context parameters of mobility context. In the sixth use case, the user subjected to any domain, also can share information in a mobile native app using social media tools. The social media tools are the context parameters of social context. Therefore the sixth use case gives two (2) social context parameters of social context.

Here we have built this use case based on user's role, preferences and usefulness which are considered as three (3) user context parameter of user context. It can be shown from the above example, that the six use cases provide approximately five (5) device context parameters of device context. We have found that device context has % of overall value 48.67 which is validated and proved from above example, the device context have an approx. of five context parameters than other contexts. Again these six use cases drag four (4) mobility context parameters of mobility context which have % of overall value 22.72 determined from empirical study. The six use cases provide three (3) user context parameter and two (2) social context parameters which have the % of overall values 19.71 and 8.87, respectively obtained from the empirical study.

Hence from the four contexts, device context have a great importance when building mobile native apps and secondly mobility context is to taken into account for the same. Further user context and social context is taken into account for developing mobile native apps. Therefore we conclude that the device context has maximum overall value than other contexts under mobile domain. That means device context and its context parameters have more impact while developing mobile native apps.

VIII. CONCLUSION AND FUTURE WORK

In this paper we have taken various activities which are placed in form of questions in Google Forms. Out of 20 numbers of overall selected activities which are specified in Table 2, 9 numbers of activities are mapped to device context and its attributes. Again from 20 numbers of activities, 5

numbers of activities are mapped to user context, 3 numbers of activities are mapped to mobility context and 3 numbers of activities are mapped to social context. Hence it is concluded that out of overall selected activities under mobile domain, the maximum percentage of activities are mapped to device context. From the empirical study it is obtained that the overall weight of device context is more than the other contexts. This is validated from the running example which is shown in Fig. 8 that the use cases are drawn maximum context parameters of the device context. Hence device context and its efficient context parameters or features play a vital role for building mobile native apps. For building mobile native apps under any domain, more emphasis is to be given to mobile device with its efficient numerous features.

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UML based Formal Model of Smart Transformer Power System

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Abstract—Recently many significant improvements have been done in traditionally power system. But still a lot of work is needed in traditional power system to mend many challenges. We propose formal method based on subnet model for smart power system. Formal method is mathematics based technique that is used to develop, specify and verify model in a systematic manner. It involve components i.e., power plant, smart grid, transformer and smart meters. Power plant produces electricity and then distributes it to the smart grid. Smart grid generates electricity to transformers and then transformers transfer electricity to smart meters. Smart transformers and smart meters are deployed inform of subnets that increase the energy efficiency of smart power system. In this paper our main focus is on two components of smart power system that is transformers and smart meters. Graph theory is used for the semi-formal representation of model. In this paper we present system requirements through UML use case diagrams that are used to describe actions of system and then real topology is transferred into model topology in graph theory that is used to represent the structure of system. Mathematical technique and notation based formal method approaches are used for describing and analyzing the system. VDM-SL formal method language is used for formal specification and VDM toolbox is used for the verification and analysis of system.

Keywords—Smart power system; unified model language (UML); formal method; VDM-SL

I. INTRODUCTION

Smart Environment changes the life style of people and improves their behavior. It also changes mental and physical challenges of people in a physical environment. In smart environment everyone has an adequate amount of awareness and information about their different resources like smart system, smart devices, and cloud networks and so on. Today everyplace is going to be smart like smart building, smart House [1], smart city, smart hospital, and smart university as well. For this resolution smart power system is the only basic requirement. Smart city involves infrastructure smart transport, smart hospital, smart market and smart power system [2]. These all components of a smart city are becoming smart that in result making a city smart. The smart building provides better air quality and security, connected to other buildings, provide connection to latest technology, smart grid and global environment [3]. Respectively in smart hospital smart power system plays an essential role in providing

electricity to the hospital requirement. Smart power system or smart energy is the basic need in all smart places. Smart power system is a significant component / infrastructure for the development and establishment of smart city, smart building and any smart place. To address this issue we have focused to design a model on the components of smart power system. Currently energy consumption is a growing problem all over the world. Everyone recognizes that energy is a scarce resource. It is a basic human need. It is noticed that electricity usage has been increased 50% over last 30 years [4]. Therefore, there is need to preserve valuable resources and transfer them to consumer in a better way. The smart power system changes the traditionally power system and it makes the power grid more resourceful, consistent, integrate and secure resilient and sustainable system [5]. Electricity is basic requirement all over the world. The increasing interest on this topic stimulates us to develop a formal method based on subnet model for the components of power system. In this paper our main focus is on two components; smart meter and transformer. Smart grid generates power to transformers and then transformers transmit power to smart meters. In Smart grid microcontroller is attached which monitor all connected transformers and meters. Smart meters can communicate through microcontroller to smart grid and transformers. Transformers transmit power to smart meters through electrical pole. Transformer microcontroller controls and manages transformer capacity and loads limit. It generates notification or alarm when load is exceeding maximum capacity of transformer and send warning message to grid to overcome the load otherwise it will be tripped or burned. Smart meters involve the features like smart payment, automatically and periodically meter reading, microcontroller, automated theft detection and user communication. Monitoring and continuous reading of smart meter automatically leaves no chance behind of stealing because meter reading is record on two locations. It will forecast and determine the demand when demand will increase or decrease. Through microcontroller it communicates with users and provides up-to-date information to users about their electricity on their mobiles through message and call. Smart meter provides the facility of smart payment which mean user can use prepaid units and it automatically send message to customer when less units are left and also notify to recharge their units. Smart meter also control the power of consumer through controlling their units limit. If the consumer cross the

limit it send warning message to consumer that your current load exceeded the limit please check your attached devices. It also determine the peak load time. Through notification it alerts the consumer that at the moment their current unit charges are casting double. In this paper we present our model requirements in UML use case, integration of graph theory to represent model topology and formal method are used as well for the specification of system. In graph theory we represent the model topology and it includes edges, subnets and junctions. To prove the correctness of our model we implement this model in formal way using VDM-SL language. We have analyzed, verified and validate system through VDM-SL tool box. The formal method technique is used to represent system possessions in mathematics. They provide a structure in which developers in methodical manners can specify and develop their system. This paper consists of following sections: Section 2 represents related work, in Section 3 model of system are explained, model is transferred in graph model in Section 4, UML use cases are presented in Section 5, formal specification is given in Section 6 and in Section 7 formal analysis with results and in the last conclusion.

II. RELATED WORK

Papers based on smart meter discuss their issues and challenges. Most of them discuss their issues, consumer and supplier problems, security [6] and privacy issues [7]. We along with these issues and better ways of their solutions addressing and solving the issue of smart payment that is not discussed before in all these papers. Some papers describe smart meter communication technologies to communicate the meter to grid and other smart devices [8] in different papers of smart metering involves smart meter infrastructure ,their privacy and security issues, demand and response and their assessments, monitor and control methods and design smart meters [9], [10]. To address all these issues we attached microcontroller in smart meters that provide feedback to consumer, communication to user, send messages and notification to user which help to control power consumption. Through feedback we can change the long term behaviors of users regarding power consumption [11]. Smart meters are reading monitor continuously and automatically in two locations in smart meters and also in smart grid. Through meter reading it checks continuously meter units when units cross the limits it send warning message to consumer to control power consumption. We also control the load capacity of transformer to control the burning or tripping of transformer. Some of the research papers are using different formal methods like Ada, Z notations and VDM [12, 13] to specify their system. In different papers formal method has been used for different system like traffic management system [14] and hospital management system. In this paper UML (unified modeling language) diagram is used to gather system requirements and to show the user and system interaction [15], [16]. We used graph theory to represent model topology and in addition we used formal specification of system in VDM-SL to prove the correctness of system. In this paper critical component of railway are formalized. For critical component of moving block interconnecting Z notation is used and model topology is represented in graph

theory [17]. Railway tracking is distributed critical system and it risks so high because its failure may cause server injuries, loses of money and loss of human life. For this complex system VDM,Z notation is used by author for this complex system [18]. In this paper railway crossing is analysed which is component of moving block interlocking system. For the safety requirements of train petri net formalism is used for modeling and to verify the correspondence between crossing an (PN)representation reachability graph is used [19]. For the static component of model using graph theory and are then integrated with VDM-SL for the specification to prove the correctness of system it is analyzed by using VDM tool box. Some of other related works based on VDM formal method bring into being in these papers [20]-[22].

III. MODEL FOR SMART TRANSFORMER POWER SYSTEM

Today the life style of people has been changed and everyone wants to live in smart environment or smart places. Everything is going to be smart therefore to develop a smart environment or smart place demand of electricity is also increased. People are using more devices and appliances in their homes and they don't have any information about electricity they are consuming. Electricity is a scarce resource all over the world and it is basic necessity of human life. Therefore it is responsibility of every human to save electricity as much as possible. To address this issue we purposed a model for smart power system in which our main focus is on smart meters and transformers.

Smart meter is an endless user communication module towards too smart grid. It is an important component of our model. Smart meter accurately capture the power consumption of houses and sending meter readings to the smart grid.microcontroller is attached which monitor all operations of smart meter like it monitors the meter reading continuously, check balance, control limit and so on. It provides the communication to consumers in a sense it send messages to consumer about alerts and notification of their electricity consumption. Through microcontroller users alert message when their power consumption of devices is increased on daily routine and it also specify that which devices are ON at this time. It also send message to consumer that unit rate of power will be charged double when peak load is high. This info will help the users to reduce their load and as a result less power will be consumed and in result consumer will pay low billing rate. In smart meters payment will be smart means consumer can use prepaid cards for the payment of power units .It will generate message that few power units are left please recharge. Your smart card meter will be monitored at two locations one is smart meter microcontroller and other location is smart grid microcontroller so no chance of theft remains behind. Smart meter provides two way of communication. It receives the demand of consumer and send it to the supplier and consumption of power is also send to supplier. It receives info from supplier/smart grid and then send it to consumer. Through smart meter consumer will collect all knowledge and information about their appliances and power consumption. Through this they can manage and control their power and save their electricity. Smart meters are attached to transformers and they transmit power through electrical wires to smart meters. Transformers transmitt power

at the define limit which they receive from grid. We control the capacity of transformer by defining their limit. When the power exceed the limit, a notification generate by transformer microcontroller exceed the power of transformer and control the load or shutdown the transformer, otherwise it will be tripped or burned. Electricity will be provided in every area by adding more transformers which are then connected to smart grid.

IV. SUBNET BASED GRAPH MODEL FOR SMART TRANSFORMER POWER SYSTEM

Graphical representation is moreover there via graph theory [23]. In graph model showing system nodes, edges, subnets and junctions. In our system we focus on two main module smart meters and transformers. Smart meters are attached to transformers. One smart meter is attached at only one house. That smart meter will keep all information of power consumption of that house. One transformer will supply power to many smart meters through power lanes so in graph model we represent it in subnets. A subnet consists of transformer and smeter nodes. Smeter nodes through junctions connected to transformers nodes. Transformer supply power to smart meter through lans. One transformer connect to many lans and on lans we define junctions through meters are connect. Through one junction we can access all meters of lan. All subnets connected to smart grid. In transformer module junctions are connected to transformer and all smart meters are not directly connected to edges transformers. Any smmeter can access easily and can get all their information. Smart meters are connected to junctions and junctions are connected to nodes of transformers. Similarly transformers subnets are connected to smart grid.

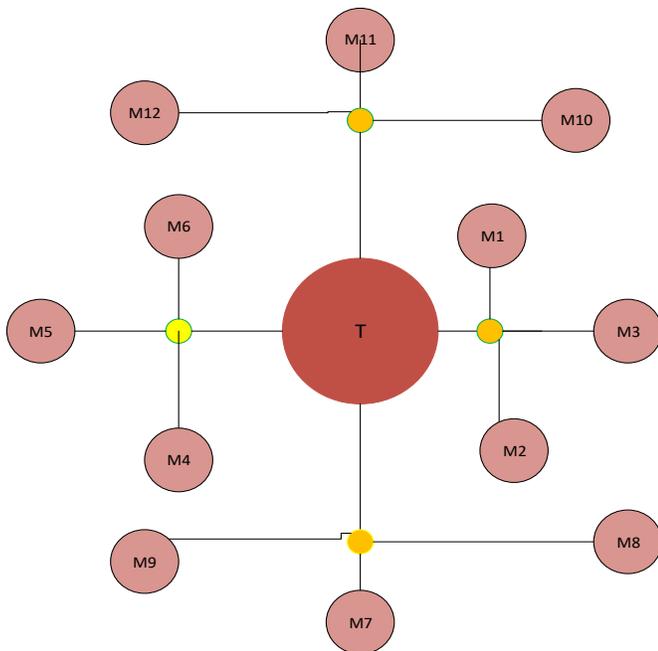


Fig. 1. Subnet based graph diagram of smart power system.

In Fig. 1 M in pink circle are meter nodes which are connected through yellow circle which are junctions attached to T transformer nodes. Many meters are attached to one

transformer through many lanes. Similarly one main lan to derive multiple lanes. Through one lane many smart meters are attached. For multiple lanes we develop it in graph subnets. Through junctions smart meter is attached to transformer after graphical model system is formalized in formal method language VDM-SL to specify the system. Formal methods are the techniques based on basically mathematics. These are used to represent the system properties in a systematic way to prove the system correctly through this we can identify system problems, errors and after that we can develop better system.

V. UML USE CASE MODEL FOR SMART POWER PLANT

Unified Modeling Language is a broadly useful indicative language which is used as a standard approach to visualize a system. A UML consists of sequence of steps and activities to achieve a specific target of system [24]. UML uses case diagram actor and use case are also used. Actor is any system or person and use case is functionality perform by actor. In our system we focused on smart meter and transformer that's why we represent the use case of smart meter and transformer. Smart meter and transformer actor performing the following activities or functions as well.

Fig. 2 is a usecase in which smart meter is an actor and performing following actions. Smart meters used smart payment system. It controls the load limit and microcontroller is attached in it that is used for user communication. It records the automatic and continuous smart meter reading.

In Fig. 3, smart transformer is an actor and performing the following actions. It received power from smart grid and transmit it to smart meters In smart transformer microcontroller is attached that is used to control the transformer capacity.

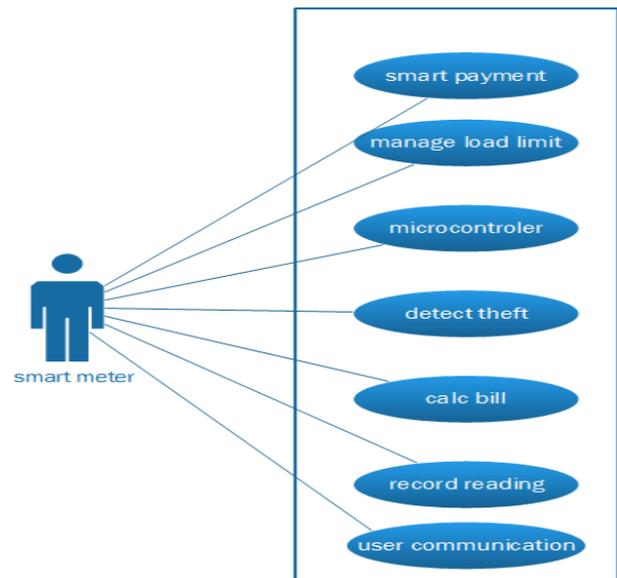


Fig. 2. Use case diagram of smart meter.

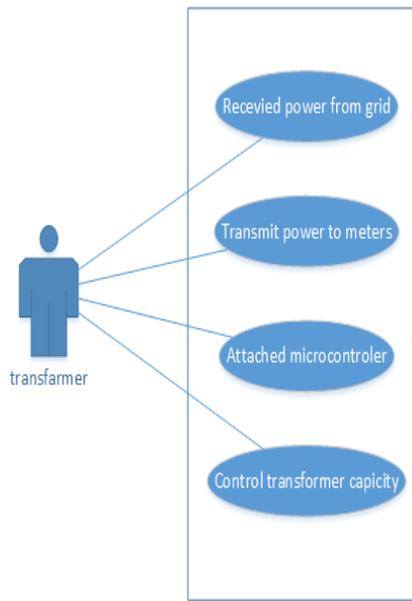


Fig. 3. Use case diagram of transformer.

VI. FORMAL SPECIFICATION OF SYSTEM

For the implementation of system we describe our system in formal specification using VDM-SL language. The functionality of our system is formally modeled by using VDM-SL language. For the verification and validation of our system we use VDM-SL toolbox. Topology of model is demonstrating in the form of graph. Firstly we describe the specification of smart meter. To implement the system we will take different variables and also define its type. ID of every meter is token. MR is denoted as composite object which is meter reading in which three fields are defined as meter reading, message and meter ID. Message type defines as sent or received. Means message can be sent or received. Mobile is denoted as a composite object and it consists of three fields mobile id, message and call. Meter is described as composite object which consists of nine objects. First field meter id and every meter has unique id. Second field is meter units that determine consumed units of consumer. Third field id units rate through which we can calculate the bill, fourth field is defined as a limit, by determining limit value. We can control power of users by sending them notification or alert message that limit is over. Fifth field is payment and in our system smart meter will used smart payment through smart card. Next field is microcontroller that is attached in smart meter.

```

types
ID = token;
Card = int;
MR = int;
MReading :: mr : MR;
Microcontroller :: mid : ID
                mreading : MReading
                message : Message;
Message = <SENT> | <RECEIVED>;
Call = <calling>|<received>;
Mobile :: mo : ID
        message : Message
    
```

```

call : Call;
SMeter :: mtid : ID
        munits : int
        urate : int
        limit : int
        inc : int
        payment : int
        balance : Card
        microc : Microcontroller
        mobile : Mobile

inv mk_SMeter(-, munits, urate, limit, inc, payment, balance,
microc, mobile)==
munits <= limit =>
payment = munits * urate and
munits > limit =>
payment = munits * (urate + inc) and
balance >= 0 and
balance = (balance/4) =>
microc.message = <SENT> and
mobile.message = <RECEIVED>;
    
```

In next step of specification we have described the state of the system. State of system stores the data and invariants that are used further in operations processing.

Invariants: First invariant is that we define the limits of units that consumer can use 1) if meter units is less than limit then meter units will multiply by unit rate and value assign to payment; 2) if meter units are greater than limit then increment will be added in unit rate that will be multiplied to meter units. We specified in our system that we have used smart payment that's why we check the balance. If balance remains less than microcontroller will send the message to users that your balance is not as much of, please recharge your balance. 3) It check balance if it remaining fourth part of balance than it sends the remainder message send to user that please recharge your balance . The main function of system is described in operations. Therefore, we describe some operations of smart meter as following:

operations

first operation of smart meter is simply add a new meter in smart meter set. In pre-condition we check that meter is not already part of meters set and in post condition it will become the part of smart meter set.

```

add_sgrid(g:ID,t: set of Transformer, sm : set of SMeter,mic :
Microcontroller,d : set of nat, gsub : set of GSubnet, ged :
Edges)
ext wr grid:set of SGrid
pre mk_SGrid(g,t,sm,mic,d,gsup,ged)not in set grid
post grid = grid union {mk_SGrid(g,t,sm,mic,d,gsup,ged)};
    
```

Operation: Check Balance

The next operation is to check the balance of Smarter because after checking balance we can decide message is send to user or not. In pre-condition, we check meter is a part of smart meter and in post condition it gives the balance of specific meter.

```
Check_balance(m:SMeter)p:int
ext rd meter:set of SMeter
pre m in set meter
post p = m.balance;
```

In this operation we check the meter units. Meter units check continuously because we have to control power consumption, Through this we get meter units.

```
Check_units(m:SMeter)u:int
ext rd meter:set of SMeter
pre m in set meter
post u = m.munits;
```

Operation: Check Meter Reading

In meter reading operation we check meter reading. Meter reading checking is also important to detect the theft. In pre-condition we check the meter is a part of meter reading meters. In post condition we get reading of a specific meter that we want.

```
check_meterreading(m: MReading)r:int
ext rd mread: set of MReading
pre m in set mread
post r = m.mr;
```

Operation: Control limit

To control the power consumption of user we have to define the limit of units that can they use after crossing their limit microcontroller generate the message to consumer to control their power consumption. In of smart limit operation we check the limit of smart meter.

```
Check_limit(m:SMeter)l:int
ext rd meter:set of SMeter
pre m in set meter
post l = m.limit;
```

Smart Transformer Module

Transformer is another module of our system. Transformer get power from smart grid at a specific capacity and then transmit power to smart meters. So there are many LANs that are attached to transformer and in many LANs there are many smart meters that are attached. Transformer is a composite object with different fields. First field is transformer ID and every transformer has a unique ID. Second field is micro that is attached to every transformer. Third field is transformer edges and subnets are connected to edges. Fourth field is transformer capacity that is used to control the load of transformer.

```
Transformer :: tid : ID
    microc : Microcontroller
    tsubnets : set of TSubnet
    tedges : Edges
    capicity : int
    tunits : int
inv mk_Transformer(tid, -,tsubnets, tedges, -,)=
forall sb in set tsubnets &
exists tj1 in set sb.tjunctions &
exists teg in set tedges &
teg = mk_(tid,tj1.tid);
```

Invariants: (1) Every subnet which belongs to subnets exists in junctions. (2) Edges belong to transformer.

T-junction is composite object which has three fields first is transformer ID and second is transformers and last one is smart meters. Any smart meters are attached to transformer through many Lanes so in graph topology smatter connected to junctions.

```
TJunction :: tid : ID
    transformer : Transformer
    smeter : SMeter;
TSubnet :: smeters : set of SMeter
    tjunctions : set of TJunction
    tedges : Edges
inv mk_TSubnet(smeters, tjunctions, tedges) ==
forall tj1, tj2 in set tjunctions &
exists teg in set tedges &
teg = mk_(tj1.tid, tj2.tid) and
forall sm1,sm2 in set smeters &
not exists teg in set tedges &
teg = mk_(sm1.mtid, sm2.mtid) and
forall tj1 in set tjunctions &
exists sm1 in set smeters &
teg = mk_(sm1.mtid,tj1.tid);
```

Subnet is a composite object type which has three fields. First is a smart meter which is to transform through junctions. Second field is junctions and third is edges.

Invariants: (1) For all junctions exist in edges; (2) all smart meters not exist in edges; and (3) all smart meters exist in junctions.

Values: Values are initialized. Unit limit range define 300 it means if unit increase from 300 then alert message will be sent to consumer. It will help to control power consumption. Similarly transformer capacity load initialize 500. If load is increased to 500 then try to control the load and alert message is send to the user.

```
values
Unitslimit:int =300;
Capicity:int = 500
state smart_grid of
trans:set of Transformer
meter:set of SMeter
miccon:set of Microcontroller
mread: set of MReading
dmeter:set of DMeter
init mk_smart_grid(t,m,mc,mrd,d)== t={ }and m = { } and
mc= { } and mrd = { } and d = { }
end
```

Operations

This is simple operation that is used to get transformer capacity. It is any transformer in set of transformer and we take a variable c in which we get the capacity of transformer t.

```
capacity(t:Transformer)c:int
ext rd trans:set of Transformer
pre t in set trans
post c = t.capicity;
```

This operation is used to control the limit of units. When unit consumed by consumer exceed the limit which we initialized 300 notifications is on and send to customer.

```
control_limit(notification:Notification)
pre true
post if(Unitslimit>300)
then notification=<on>
else notification=<off>;
```

To control the capacity of transformer we set the maximum capacity of transformer is 500. When any transformer cross the limit then notification is ON. In this operation pre-condition is true and in post condition notification will on if capacity greater than 500 and off if it is less then 500.

```
control_transcapacity(notification:Notification)
pre true
post if(Capicity >500)
then notification=<on>
else notification=<off>;
```

This operation is used for theft detection .We take any meter in smart meter and a transformer from where units are supplied. We compare transformer and meter units if both are equal it means not theft and notification is on not detect otherwise notification is on detected.

```
detectTheft(m:SMeter,t:Transformer)notif:Notification
ext rd meter:set of SMeter
rd trans:set of Transformer
pre m in set meter and t in set trans
post if (m.munits)=(t.tunits)
then notif=<not_detect>
else notif=<detect>;
```

VII. FORMAL MODEL ANALYSIS WITH RESULTS

We formally verified two smart power system components.

Smart transformer and smart meter. Formal analyze of our system module by using Vienna Development Method-Specification language (VDM-SL) tool box. To make sure our system integrity we have put different invariants on objects and pre and post conditions on operations. Formally analyze the specification of our module by checking type free and syntax free errors. Sayntax of specification according to VDM-SL language is analyze by syntax checker. Missused values and operators checks typechecker which shows run time errors. Pretty printers evaluated the consistency of specification. To Proof the correctness of our specification of system we put the snapshot of specification in Fig. 4, 5 and 6. Animation, testing and validation is done through interpreter and debugger which increase the correctness of specification.

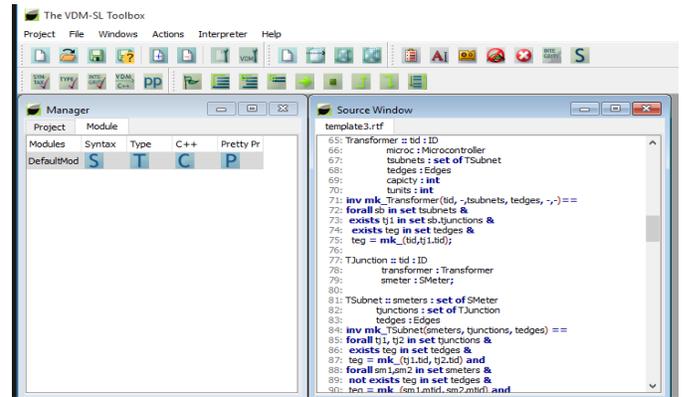


Fig. 4. Snapshot for model analysis of smart meter.

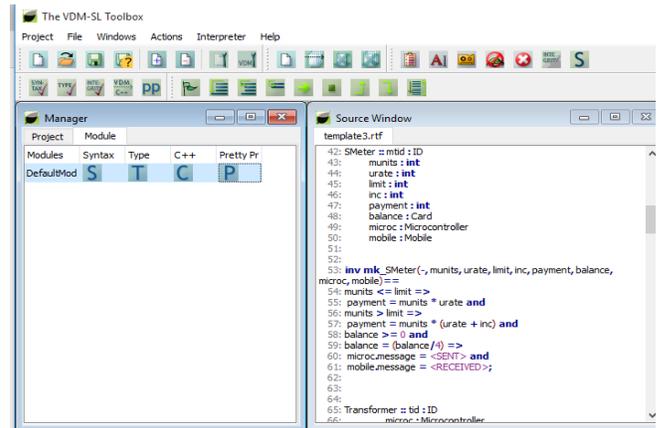


Fig. 5. Formal analysis of transformer module.

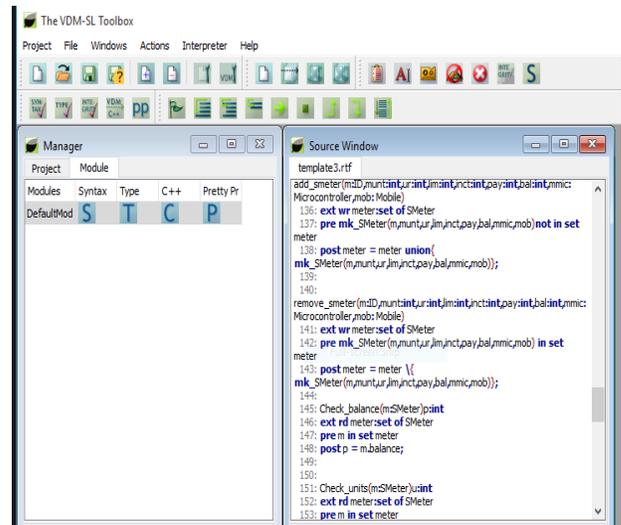


Fig. 6. Formal analysis of operations.

VIII. CONCLUSION

In this paper we present formal method based subnet model for smart power system. We focus on two main components of our system; smart meter and transformer. In smart meter we attached microcontroller that monitors the meter and communicate to users. The smart meter will help to solve the problems of consumer related to control power consumption. Consumers will have to provide all type of information about their power consumption. In another site supplier of electricity continuously measure, control and monitor the electricity. It also provide the communication to supplier. It also solve the issue related to payment to the consumer and also supplier. Because it provide the facility of smart payment. In smart meter microcontroller is also attached which continuously monitor the meter units, meter reading, meter units limit, meter payment and also theft detection. In the occurrence of any issue any problem, it try to solve itself and also send notification/message to supplier and consumer according to situation. Smart meters are attached to transformer through many LANs. Through one LAN many smart meters are attached so therefore we define subnets and junctions at transformers. In transformer subnets we define transformer edges, junctions and smeters. In transformer subnet every junction is belong to transformer edges not every smart meter. Smart meter are connect to transformer junctions .Through this we can easily access to any smart meter that is attached to transformer. We also control the capacity of transformer by defining the capacity of transformer . When load increases the capacity of transformer, the microcontroller attached on transformer will generate the message transformer load is over loaded and control it otherwise it will be triped. So through this we control the burning of transformers. In future, smart power system is required at any smart place like, smart house, smart city, smart hospital, and smart university so it will help to provide on all that places smart power system. Hope in this paper will help to solve many issues of consumer related to control power consumption and suppliers related to monitoring and control. In future this work will help to model the other components of smart power system. This work will contribute to develop other components of smart power system. It is stated that ,in our knowledge their does not exists any real work on modelling of smart transformer power system using formal methods which shows contribution in this area.

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FPGA Prototyping and Design Evaluation of a NoC-Based MPSoC

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Abstract—Chip communication architectures become an important element that is critical to control when designing a complex MultiProcessor System-on-Chip (MPSoC). This led to the emergence of new interconnection architectures, like Network-on-Chip (NoC). NoCs have been proven to be a promising solution to the concerns of MPSoCs in terms of data parallelism. Field-Programmable Gate Arrays (FPGA) has some perceived challenges. Overcoming those challenges with the right prototyping solutions is easy and cost-effective leading to much faster time-to-market. In this paper, we present an FPGA based on rapid prototyping in hardware/software co-design and design evaluation of a mixed HW/SW MPSoC using a NoC. A case study of two-dimensional mesh NoC-based MPSoC architecture is presented with a validation environment. The synthesis and implementation results of the NoC-based MPSoC on a Virtex 5 ML 507 enable a reasonable frequency (151.5 MHz) and a resource usage rate equals to 58% (6,586 out of 11,200 slices used).

Keywords—MultiProcessor System-on-Chip; Network-on-Chip; FPGA Field-Programmable Gate Arrays (FPGA) prototyping; design evaluation

I. INTRODUCTION

Technological advances in recent years on the programmable components, specifically FPGAs, have improved their capacity for integration and the connection between their different logic cells, thus making it possible to implement a complete MPSoC in a single FPGA device. These FPGA-based multiprocessors systems, with hard and soft cores, have become the standard for implementing heterogeneous embedded architectures [1]. They facilitate rapid prototyping and allow building scalable and modular applications. However, massive growth in size and complexity in recent years and future MPSoCs places on-chip interconnect at the system performance center. Traditionally on-chip communication has been conducted via dedicated point-to-point links or a shared media like a bus. Bus-based architectures are simple and completely widespread; use of these approaches do not scale very well when more intellectual property (IP) cores are integrated in a system and will not meet the requirements of the future MPSoCs because of their seriously limited scalability. Also, they quickly become the bottleneck of a system [2]-[4]. By using the interconnection network as the communication infrastructure between cores, Networks-on-Chip (NoCs) are emerging as an efficient and scalable alternative to existing on-chip interconnects which allow systems to be designed modularly. Different NoCs solutions are used in MPSoC platforms and

commercialized by many companies such as SonicsGN [5] developed by Sonics, FlexNoC [6] by Arteris, Æthereal NoC [7] by Philips Research Laboratories and Teraflops Research Chip (also called Polaris) [8, 9] by Intel Corporation's Tera-Scale Computing Research Program. Other NoC-based multi-core system architectures are developed by teams from universities and research institutions such as SoCIN [10], OCCN [11], FAUST [12] and Ninesilica [13].

Some of the above-mentioned proposals and several many-core system designs still use simulation and mathematical analysis for the evaluation of their on-chip interconnects under various network configurations [14], [15]. However, it is important that prototyping must be considered to improve the evaluation accuracy by bringing the design closer to reality.

Unlike conventional hardware prototyping approaches, FPGA-based prototyping of mixed hardware/software MPSoC architecture became an extremely challenging task. It requires specific FPGA expertise hardware/software codesign flow and environments. Moreover, many competences are required such as the mastery of prototyping hardware platform (ML507), the software development flow (tools, drivers, RTOS, etc.) as well as the hardware development flow (specification, synthesis, placement, routing etc.). In addition, different interconnection solutions can be covered between the software and the hardware blocks. Also, the configuration and integration of IP blocks and the use of soft and hard processors were included.

This work focuses on the prototyping of a mixed hardware/software FPGA-based MPSoC using two-dimensional mesh NoC architecture. The basic performances of the investigated MPSoC are to be explored in a fast and efficient hardware-based way. The paper is divided into five sections. Starting with the presentation of a survey on existing FPGA prototyping approaches for MPSoC platforms (section II). Moving to Section III which shows the MPSoC design flow and describes the EDK Tools and Design Flow Integration. Then Section IV that gives the details of the NoC architecture and the Fast Simplex Link (FSL) bus interface as they are the basic elements of the MPSoC platform. Section V shows the FPGA prototyping of a NoC-based MPSoC. Section VI evaluates the hardware simulation and synthesis results. Last but not least, Section VII concludes the paper and highlights future work.

II. RELATED WORKS

MPSoC with NoC are strongly emerging as prime candidates for complex embedded applications. Also, the

interest in NoC prototyping is continuously growing, as many recent processing chips are multi-cores. On the one hand, prototyping such systems is a quite complicated task. In order to allow fast generation of these platforms in the development phase, a full design flow is required. On the other hand, modern FPGAs provide the possibility for fast and low-cost prototyping in HW/SW co-design, representing an efficient response to these needs. With the increase of available reprogrammable logic cells, many works have explored the possibility to implement an entire NoC-based MPSoC on FPGA [16], [17]. In [18], Lukovic et al. presented a framework, based on the Xilinx EDK design flow, for the generation of MPSoCs based on NoCs. This integrated design flow takes as an input a textual description of the system and produces as a final result a configuration bitstream file. In [19], Lokilo et al. proposed an array-based MPSoC architecture, matching requirements of applications where the data can be splitted into several subsets and processed in parallel, as is the case in numerous video processing algorithms. They have physically implemented a 2x2 Xtenxa core system in a Virtex II Pro and tested it in a real time application. Van Langendonck et al. proposed an integrated framework MPSoCDK for rapid prototyping and validating NoC-based MPSoC project targeting FPGA devices [20]. Similarly to this design flow, MPSoCDK aims at speeding up the processes of designing, exploring and prototyping MPSoC projects. It also simplifies the process of designing complex projects through a Graphical User Interface (GUI), providing a hardware and software layer. However, the proposed flow produces pure synthesizable VHDL and does not create project files for tools such as Xilinx XPS or Altera SoPC. In [21], Geng et al. used the FPGA device to prototype the cluster-based MPSoC with 17 processing cores. Moreover, a suite of benchmarks, including several parallel applications with different characteristics of parallelism, workload and communication pattern, are designed and presented. It has been reported that a complete design methodology has been successfully used for the implementation of a NoC-based MPSoC, the NoCRay graphic accelerator. Noting that this design methodology tackles at once the aspects of system level modeling hardware architecture and programming model, the design which is based on 16 processors has been laid out in 90-nm technology after prototyping with FPGA. Post-layout results show very low power, area, and high frequency [22]. Wächter et al. presented an open source platform for MPSoC development named HeMPS Station which derived from the MPSoC HeMPS [23]. In its present state, it includes the platform (NoC, processors, DMA and NI), embedded software (microkernel and applications) and a dedicated Computer-Aided Design (CAD) tool to generate the required binaries and perform debugging. Experiments show the execution of a real application running in HeMPS Station.

The solution proposed in this work is based on a concept similar to [18]. However, its aim is to perform a low cost hardware realization in FPGA taking into account the integration in MPSoC environment. We have realized on a Xilinx Virtex5 FPGA, a system composed of MicroBlazes running without operating system (OS), shared memory blocks, and a NoC as an interconnecting medium among them.

III. DESIGN METHODOLOGY AND FPGA-BASED SYSTEM PROTOTYPING OF MPSOCs

A. MPSoC Design Flow and Verification Approach

The development of complex systems is increasingly involved with specific software and hardware components. The co-design provides solutions for this type of development. It is based on a set of steps that allow as to synthesize a SoC integrating software and hardware components that respect the imposed design constraints (e.g. time and surface). A standard design flow is typically composed by four main steps: specification, partitioning, synthesis and HW/SW verification (see Fig. 1). These steps can be summarized as follows:

1) The system modeling allows describing its functional behavior without taking into account the architecture. At this level, the interest is to obtain relevant results in terms of performance and timing.

2) The SW/HW partitioning is the step following the system modeling. At this level, the architectural details of communication are integrated with the scheduling of all operations.

This step appears to split the system into three major parts:

- A hardware part implemented as a hardware circuits and generally used for performance. This part can be considered as an IP obtained from a library or a hardware accelerator that is made especially for a specific task.
- A software part implemented as an executable program on processor and generally used for features and flexibility. This processor can be a General Purpose Processor (GPP) or a reconfigurable processor (configured according of the application needs).
- A communication interface between these two parts.

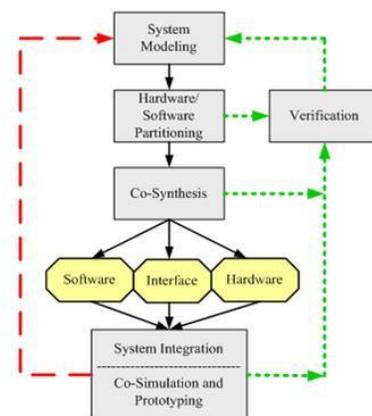


Fig. 1. MPSoC design flow [24].

In fact, these obtained parts must be verified and validated before the synthesis and implementation phases. If the partitions obtained are not satisfied, a feedback is needed to return to the partitioning stage in order to refine the weights that are associated with constraints for each part differently. Then, several simulations will be made to choose the best distribution between the software and the hardware parts.

3) The synthesis step also called implementation. In this step, the Register Transfer Level (RTL) description for the hardware part and the source code for the software part of the system are obtained. Obviously, verification and validation of the functionality of the generated model should be done. At this stage of design, the analysis is concerned with the performance of the architecture at the cycle level and at the bit level through co-simulations.

4) The last step of the design flow consists first of the logical synthesis of the RTL part of the system. Then the logical functions that have been synthesized which will be placed and routed on the chip. This process is accomplished by the use of commercial synthesis tools such as: Simplify [25], Xilinx Synthesis Technology (XST) [26], Leonardo Spectrum [27], etc. The software part of the system will be compiled to generate a hexadecimal image. Finally after obtaining the performance such as area and energy consumption in the logical synthesis, the co-simulation will be established. Once the architecture is validated, various real tests through the FPGA prototyping platform [28] are to be made.

During each step in the design flow of an MPSoC, the verification should be performed by designers. Consequently, it is ensured that the new components or the new implementation details providing a proper functionality. Verification can take up to 70% of the device design time [29], [30]. This step has a major cost in terms of time as well as financial. There are several techniques of verification: formal verification, simulation, co-simulation, emulation, co-emulation and prototyping. In this work the focus is mainly on the prototyping stage.

Prototyping is a solution that reduces the time of design, development, verification and validation of SoCs [31]. Although, FPGA has some perceived challenges, overcoming those challenges with the right prototyping solutions is easy and cost-effective leading to the fastest time-to-market.

The software components made by programs executed through one or more processors. However, the hardware components of the application are made with FPGA programmable blocks. It uses configurable components to implement physical blocks and connections. To achieve this type of prototyping, it is sufficient to just have a description of RTL or gate of all components and reconfigurable prototyping platform.

Several tools and companies have adopted this rapid prototyping in HW/SW co-design approach regarding their simplicity of synthesis and integration of new components. Among these development tools is EDK proposed by Xilinx [32].

B. EDK Tools and Design Flow Integration

Xilinx provides various software which enable to create embedded SoCs, among these softs the ISE and EDK. The ISE tool is used especially to produce hardware IP projects from a Hardware Development Language code (HDL) [33].

However, the EDK tool allows us to establish a direct link between the hardware and the software parts of a system. It includes a system generator for processor and Xilinx Platform Studio (XPS) [34]. Thus, all design flows are grouped in XPS environment [31].

The standard design flow of Xilinx consists of two main steps (Fig. 2): the first one consists of the conception and the synthesis of the design. The second step consists of the design implementation and verification. Moreover, the design of an embedded system typically includes four phases (creation and verification of the hardware and the same for the software platform).

For the EDK tool, the hardware platform is defined by the MHS (Microprocessor Hardware Specification) file. The verification platform allows the user to define the simulation model for each system component (processor and peripherals). If the software application is executable, then it can be used to initialize the memories. The software platform is defined by the MSS (Microprocessor Software Specification) file. The creation and verification of a software application involves several steps: To start with the writing of the code in C, C++ or assembler language that will be executed through the software and the hardware platforms. After that this code is compiled and linked using the GNU tool (other tools can also be used) to generate the executable file in ELF (Executable and Link Format) format. Then, Xilinx Microprocessor Debugger (XMD) and the GNU debugger (GDB) are used to debug the application for the target processor [26].

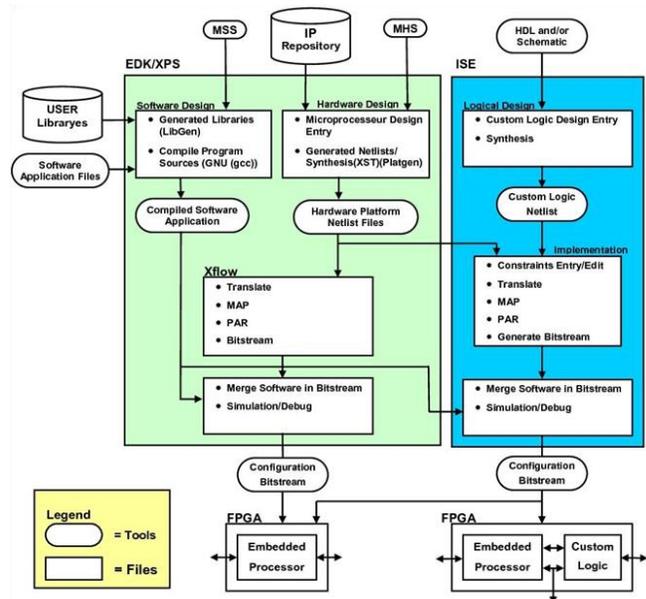


Fig. 2. Detailed design flow XPS/ISE for Xilinx FPGAs [24], [32].

Synthesis and simulation are the two main steps in the Xilinx design flow. The design tasks allow switching from one description to another to arrive at the bitstream configuration file. Indeed, a logical synthesis makes it possible to pass from an RTL description of the architecture to a description at the logical gate level (Netlist). The description of logical elements is optimized according to the speed, area or consumption constraints imposed by the designer. The XST synthesis tool

replaces the generic logical elements with the FPGA. Placement and routing convert the hardware description into a configuration file. It generates a file, which is used to configure the interconnection matrices of the FPGA circuit. At each stage of the design, the CAD enables us to perform simulations in order to validate each step of the implementation: Functional simulation at the RTL level, Post-synthesis simulation at the logic gate level and Post-layout simulation at the physical level.

IV. NOC-BASED MPSOC PLATFORM

The multi-processor platform template is shown in Fig. 3. The architecture platform consists of multiple tiles connected with each other by a NoC. Each tile contains a local memory (M), and a network interface (NI), that is accessed both by the local IP core inside the tile and by the NoC. The IPs are responsible for the computation of the desired functions and may be hardwired or programmable processors. The NoC connects all tiles together via its routers (R) and links (L).

Two different types of tiles are distinguished based on the functionality of the IP inside the tile and the size of the memory (M). The first type, called processing tile, contains an IP as a processor which executes the code of the applications running on the platform. The application code and some of the data structures needed when executing it are stored in the local memory of the tile. The second type called memory tiles contains a part of the memory sub-system that can be accessed from the processing tiles. From the memory's perspective, only the NI and IP processor try to access this memory. In this work, we are interested in the processing tile.

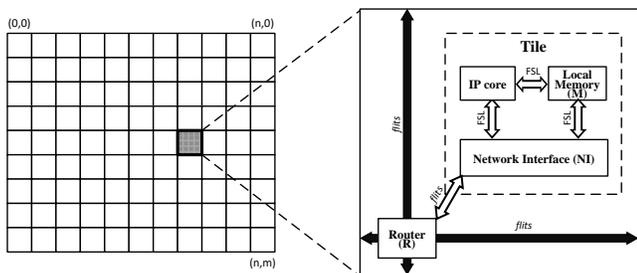


Fig. 3. NoC-based MPSoC architecture overview.

A. NoC Architecture

The on-chip communication structure between the tiles in the platform template should offer unidirectional point-to-point connections between pairs of NIs. The connections must preserve the ordering of the communicated data. To evaluate the MPSoC design, a system interconnection model is needed. The NoC model of Yang et al. [35] has been used.

The architecture platform consists of a set of routers which are connected to each other in an arbitrary topology. Regular topology is a popular NoC architecture due to its predictability and ease of design. The used NoC has a 2D-Mesh topology, where each router is connected with its neighbor and its own NI by bidirectional communication channels [36]. The size of a physical channel is 8 bits. A router has a routing unit, a control block and a number of generic input-output ports. This number depends on the used topology. In this case, there are five communication ports which are indexed as follows: East

(index 0), West (index 1), North (index 2), South (index 3) and Local (index 4). The Local port provides communication between the router and its NI component. The other ports are connected to neighboring routers. In order to avoid deadlock, the XY routing algorithm is used where message or packet will always be routed firstly in X (horizontal) direction, and then into Y (vertical) direction. The serialization and the deserialization steps must be done at the NI interface in order to transfer the data to the heart of IP to the router.

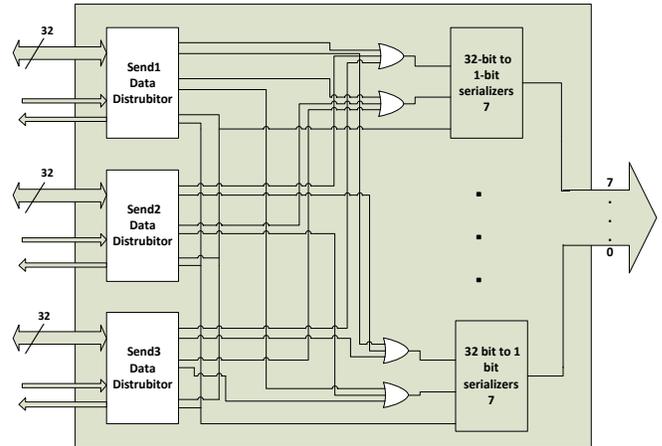


Fig. 4. Block diagram of the NI component.

Fig. 4 shows the NI architecture proposed by the work of [36]. On the one hand, it is connected to the router via eight wires. On the other hand, it is connected to the IP via three communication channels with 32-bit data width for each one. The NI architecture consists of a serializers number from 32-bit to 1-bit. This number depends on the number of wire per port connected to the router (eight wires in this case).

The architecture also consists of three data distributors where each one is connected with an output message queues via a communication channel of 32 bits data width. It is responsible for transmitting data received through this channel to the appropriate serializer. The serializer inputs consist of two OR gates. The first one allows all distributors to forward their data to each serializer. The second and the 1-bit output are handshaking signals between the data distributor and the serializer. The network can operate in normal mode or control mode. The last mode is used to program the routers. The data are used to program the NoC will be transmitted to the control network through the node (0, 0).

B. FSL Bus Interface

Two types of connections are possible to connect a MicroBlaze to the NI: the PLB (Processor Local Bus) or FSL buses [37]. The FSLs are used because they adapt well to the NoC. Indeed, one FSL bus allows fast access (two clock cycles) devices to the MicroBlaze and vice versa (8 FSL connections by MicroBlaze). The FSL bus width is 32 bits and the C-functions were used to read or write data into the FIFO of the bus. So, it is quite simple to create an adapter since it is enough to read or write words in a FIFO with checking their status. Fig. 5 shows the interface of a FSL bus. The IP master of the FSL connection is the MicroBlaze and the IP slave is the NI. Table 1 illustrates an overview of the FSL-related

predefined C-functions available in EDK tools and used in the software applications (swappx).

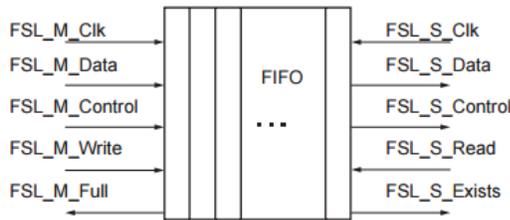


Fig. 5. Block diagram of the FSL bus.

TABLE I. SUMMARY DESCRIPTION OF THE C-FUNCTIONS USED IN SOFTWARE APPLICATIONS

C-Function Name	Description	Parameters	
		Argument	Type
microblaze_bread_datafsl microblaze_bwrite_datafsl	Blocking Data Read and Write to FSL Local Link	DeviceId Data	Xuint Xuint 32
microblaze_nbread_datafsl microblaze_nbwrite_datafsl	Non-blocking Data Read and Write to FSL Local Link	DeviceId Data	Xuint Xuint 32
microblaze_bread_cntfsl microblaze_bwrite_cntfsl	Blocking Control Read and Write to FSL Local Link	DeviceId Data	Xuint Xuint 32
microblaze_nbread_cntfsl microblaze_nbwrite_cntfsl	Non-blocking Control Read and Write to FSL Local Link	DeviceId Data	Xuint Xuint 32

V. 2D-MESH NOC-BASED MPSOC PROTOTYPING ON FPGA

The target system is an MPSoC composed of four MicroBlazes processors interconnected through a NoC mesh 2x2. Fig. 6 shows the system architecture. The four MicroBlazes processors are connected to the NoC via point-to-point links. A laptop connected via Universal Asynchronous Receiver/Transmitter (UART) at MicroBlaze A0; enables debug data to be sent/received in order to verify the NoC functioning.

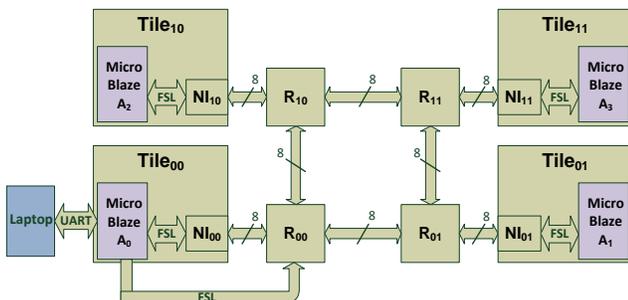


Fig. 6. System architecture of a 2x2 2D-mesh NoC-based MPSoC.

In this work, the Virtex5 FPGA Xilinx XC5VFX70 device is targeted to implement the MPSoC system prototype in order to provide area overhead, power dissipation and operating frequency. The investigated system (see Fig. 7) is composed

mainly of Xilinx MicroBlaze processors, memory blocks and a NoC.

- The MicroBlaze is an embedded soft core provided by Xilinx [38]. Since processing tile was chosen in Section IV, processing nodes includes data and instruction memories connected to the MicroBlaze processor through the dedicated Local Memory Bus (LMB). We connect MicroBlazes to the rest of the system through their interface to the FSL
- Shared memory blocks are implemented using part of the Block RAM (BRAM) available on-chip in Xilinx boards. Memory cores are synchronous and three write mode options were supported: Read-Before-Write, Read-After-Write and No-Read-On-Write. A LMB BRAM controller is associated to the BRAM component in the aim to manage data transfer from and to the adopted bus system.
- NoC is basically composed of two elements: NIs and routers, as described in the previous section.

Fig. 7 shows the block diagram of the entire design of MPSoC based on a NoC 2D-Mesh 2x2. The standard peripherals that are connected to the MicroBlazes through the PLB bus were also presented. The different IPs that make up the MPSoC design prototyped in the Xilinx Virtex 5 target device are summarized in Table 2.

TABLE II. DESCRIPTION OF ALL IPS IMPLEMENTED IN THE MPSOC DESIGN

IPs used in MPSoC	Version	Quantity	Description	
NoC	Router	--	4	K-way router with XY routing algorithm
	NI	--	4	NI component serialize and the de-serialize in order to transfer the data to the heart of IP to the router
Microblaze	8.00.a	4	for each processor is associated a frequency of 100 MHz and a separate software code	
BRAM	1.00.a	4	Local memory blocks, one block for instruction and one for data, 16 KB for each block	
LMB	1.00.a	8	Buses on which must be connected eight local memory controllers	
LMB BRAM controller	2.10.b	8	Four controllers for instructions and data	
PLB	4.6	1	Bus which connects the four processors and other IPs	
FSL	2.11.c	9	Busses that connect the NoC to MicroBlazes processors	
UART Lite RS232	1.01.a	1	To connect the Laptop to MicroBlaze A0, to enable debug data to be sent/received and to verify the NoC functioning.	
MDM	2.00.a	1	For debugging MicroBlaze processor A0	
Clock Generator	4.00.a	1	Takes in common clock requirement and generates architecture-specific clocking circuitry.	
PSRM	3.00.a	1	Reset Module of the system	
JTAG	--	1	To program the FPGA	

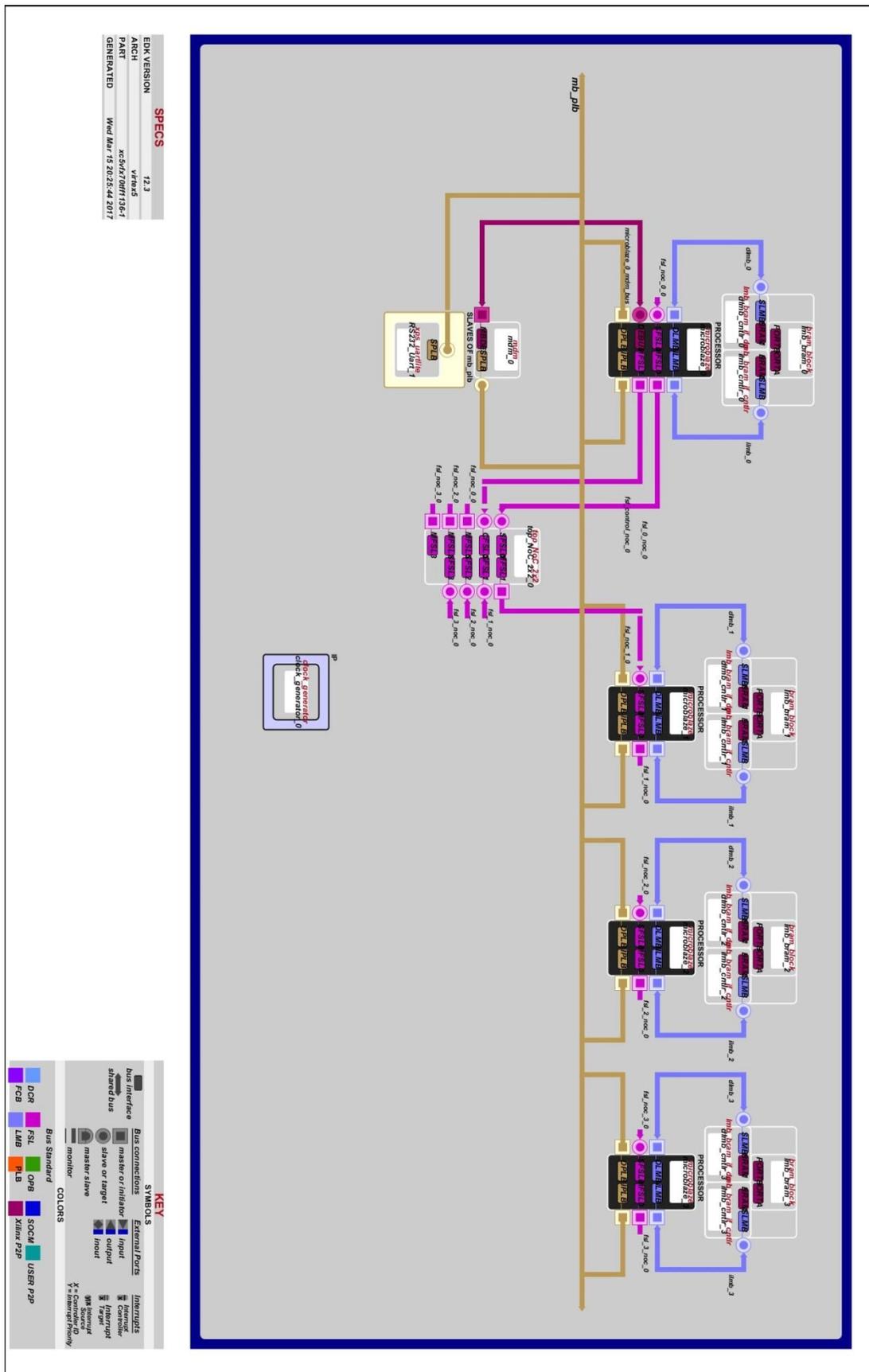


Fig. 7. Blocks Diagram of MPSoC design prototyped in the Xilinx Virtex-5 FPGA.

VI. EVALUATION RESULTS

In this section, simulation and synthesis results are presented to demonstrate the performance of this 2D-NoC-based MPSoC architecture.

A. Environments and Parameters

The Xilinx ISE environment is used for both design and implementation. VHDL behavioral simulations are typically performed with the ModelSim tool. For the MPSoC creation, several criteria are necessary for the choice of the used tools. Among these criteria is the type of the used materials (Xilinx prototyping platform in our case) where each supplier offers these own tools. Another criterion is about the nature and constraints of the MPSoC.

In the running case, the aim is to implement a 2D mesh NoC-based MPSoC at RTL level in a reconfigurable platform FPGA type. As a result, the use of ISE 12.3 tool for the design and implementation of Hardware accelerators, ModelSim for architectural simulation and verification.

Ultimately, EDK is used for the integration of different hardware accelerators into a complete MicroBlaze processor-based system. The necessary parameters used in the hardware accelerators (the 2D-NoC and the NI interface) are shown in Table 3.

TABLE III. CONFIGURATION SETUPS OF HARDWARE ACCELERATORS

IP	NoC		NI	
	Topology	2x2 2D Mesh	Resource allocation	SDM
Router	K-way	Data width	32 bits	
Number of router ports	5	Front-end protocol	FSL	
Routing algorithm	XY	Back-end protocol	Handshaking	
Flow-control Protocol	Handshaking			
Physical link width	8 bits			
Data width	32 bits			

B. Hardware Simulation Results

A test bench file is employed to replace the original IPs modules placed in their corresponding NIs and routers for testing the efficiency of NoC. The test bench module could generate a set of packets. The NoC and NI hardware accelerators are modeled in VHDL language, using the RTL description. Hardware accelerators were simulated with ISE Simulator. This is a very important step to verify the system function and to calculate system performance such as latency and throughput.

Fig. 8 illustrates the packets transmission from the three masters NI00, NI01 and NI10 (sources) to the same slave NI11 (destination).

C. Hardware Synthesis Results

In this section, the synthesis results are presented and discussed. The MPSoC performance will be evaluated in terms of area, power consumption and clock frequency.

The synthesis begins when the system is fully integrated. The make file created in previous phase leads to the execution of HW/SW synthesis tools of the EDK design flow. Hardware flow is run first. After Netlist creation of the target system, Xilinx implementation flow is executed.

Then, the bitstream file is generated and the software flow takes place. This phase consists of three steps: As a first step, software applications (swappx) are added for the four MicroBlazes as cited: swapp0 for MicroBlaze 0, swapp1 for MicroBlaze 1, swapp2 for MicroBlaze 2 and swapp3 for MicroBlaze 3. In this swappx, the C-functions (Table 1) is used in order to send and receive data between the four MicroBlazes. OS is not needed because this system is not oriented neither real-time nor multitasking. The second step consists of the custom libraries generation which is followed by a compilation and linking of source code as a third step. Once both hardware and software flows are executed, the bitstream file is initialized with BRAM data (for initialization of data instruction memories attached to processing units). The final result of the automation engine is a configurable bitstream file which is directly downloaded to the attached Xilinx ML507 Virtex-5-XC5vfx70 platform using the prototyping flow.

The synthesis results of the MPSoC system on Xilinx Virtex 5 target device are summarized in Fig. 9.

The synthesis of the target design enables a moderate operating frequency around 151.5 MHz. The FPGA resource usage rate is about 58% (6,586 out of 11,200 slices used).

The synthesis result of NoC (routers + NIs) is given in Fig. 10. The resource utilization of the NoC is 31% of the device area and the maximum frequency is 264.6 MHz with a critical path delay of 3.386 ns.

It is clearly observed that the maximum frequency of the MPSoC system (152 MHz) is remarkably lower than the IP NoC (265 MHz). Note that the time is inversely proportional to the frequency, the time of the shortest path is higher in the system MPSoC. As a result, the minimal period in this system is higher than the IP NoC.

The resource utilization of the rest of blocks is given in Table 4. The IP that takes low slices is the FSL bus. However, the NI component and MicroBlaze take the higher area cost.

Table 5 illustrates a comparison between this evaluated NoC-based MPSoC design and the design proposed in [18]. The area of this MPSoC design is greater than the area of Homogeneous System presented in [18]. This is due to many reasons. First of all, there is a difference between the composition of the system composed of four MicroBlazes and NoC 2x2, and the other one with three MicroBlazes and NoC 2x1. Second, a five-port router was used while a three-port router was used in [18]. Finally, it is important to note that the NI is reliable and more efficient. Indeed, it gives many services such as the number of used serializers and deserializers. For that, it consumes 863 slices as compared to the NI reported in [18] that consumes 85 slices. Nevertheless, this MPSoC system achieves a higher frequency (151.5 MHz) for an attractive data rate.



Fig. 8. Simulation waveform during packet transmission in 2x2 2D-mesh topology.

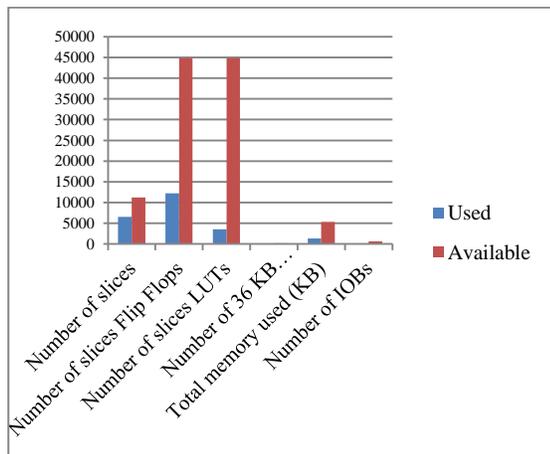


Fig. 9. Synthesis results of MPSoC system based Virtex5-XC5VFX70.

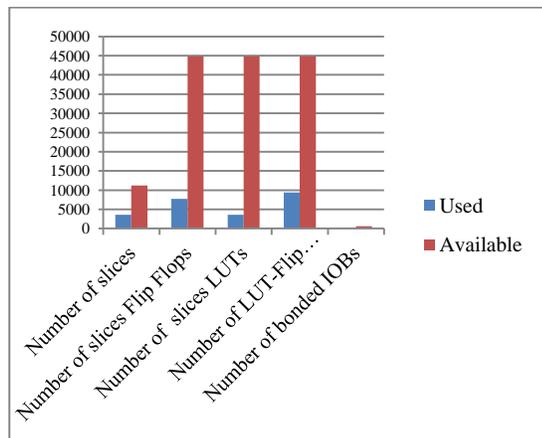


Fig. 10. Synthesis results of NoC-based Virtex5-XC5VFX70.

TABLE IV. SUMMARY TABLE OF AREA COST BY MPSoC SYSTEM COMPONENTS

Component	Area (slices)	Number
Router	78	4
NI	863	4
FSL	22	9
MicroBlaze	1,221	4
MPSoC	6,586	

TABLE V. THE COMPARISON BETWEEN THE EVALUATED MPSoC DESIGN AND OTHER

NoC-based MPSoC	FPGA	Composit-ion of the system	Performance Analysis			
			Area LUTs	Flip Flop	Slice s	Max Frequency (MHz)
Homogenous System of [18]	Xilinx Virtex-II Pro	3 Micro-Blazes and NoC 2x1	5,891	2,510	3,527	--
The evaluated MPSoC design	Xilinx Virtex 5 XC5-VFX70	4 Micro-Blazes and NoC 2x2	9,627	12,216	6,586	151.5

VII. CONCLUSION AND OUTLOOK

In this paper, an FPGA-based rapid prototyping in HW/SW co-design and design evaluation of a mixed HW/SW MPSoC using a network-on-chip (NoC) was described. Xilinx Virtex-5 FPGA installed in ML507 prototyping hardware platform with Xilinx EDK and ISE software was used to perform the prototyping of the system. The system consists of four MicroBlaze processors interconnected through a network-on-chip mesh 2x2. The design evaluation of a NoC-based

MPSoC, that is found, gives a reasonable frequency of about 151.5 MHz and FPGA resource usage rate of 58% corresponding to 6,586 out of 11,200 slices. The OS component Xikernel has not been used and the system, which is developed, was not oriented neither real-time nor multitasking. As a next work, the focus will be on investigating the prototyping multitasking real-time systems on multiprocessor architectures with OS using advanced prototyping platform.

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Investigate the use of Anchor-Text and of Query-Document Similarity Scores to Predict the Performance of Search Engine

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Abstract—Query difficulty prediction aims to estimate, in advance, whether the answers returned by search engines in response to a query are likely to be useful. This paper proposes new predictors based upon the similarity between the query and answer documents, as calculated by the three different models. It examined the use of anchor text-based document surrogates, and how their similarity to queries can be used to estimate query difficulty. It evaluated the performance of the predictors based on 1) the correlation between the average precision (AP), 2) the precision at 10 (P@10) of the full text retrieved results, 3) a similarity score of anchor text, and 4) a similarity score of full-text, using the WT10g data collection of web data. Experimental evaluation of our research shows that five of our proposed predictors demonstrate reliable and consistent performance across a variety of different retrieval models.

Keywords—Data mining; information retrieval; web search; query prediction

I. INTRODUCTION

The need to find useful information is an old problem. With more and more electronic data becoming available, finding information that is relevant becomes more challenging. About 85% of internet users employ search engines as information access tools [1], [2]. The rapid growth of the internet makes it difficult for information retrieval systems to satisfy users information needs. Searching in billions of documents will return hundreds of thousands of potentially useful documents. Due to the impossibility of going through the enormous number of documents to see whether they satisfy an information need, many information retrieval techniques have been introduced. Ranking documents according to their similarity to the information needed is one of the techniques that attempts to overcome the challenge of searching in large information repositories. A number of information retrieval models have been introduced. These models can be classified into set-theoretic, algebraic and probabilistic models. In our research, we used three models. Two of them were classified under probabilistic models and the third under algebraic models. Ranking relevant documents according to their similarity to a user's information need is not the only problem that is facing the information retrieval systems. The quality of returned answers is related to the quality of the submitted query

(request). Poorly performing queries are a significant challenge for information retrieval systems. This issue has been investigated by Information Retrieval (IR) researchers. In particular, query difficulty prediction has been studied since 2003 [3]. It is expected that knowing the performance of a query can help retrieval systems to make a decision, which determines the optimal retrieval strategy, to be used in this situation for obtaining satisfactory results. Thus, studying query difficulty prediction is an interesting problem in its own right.

Knowing the query performance requires the ability of differentiating the queries that perform well from the others that perform poorly. Many predictors have been proposed in order to estimate the difficulty of a query. All these predictors vary in use of resources, to infer the query performance. For example, query model and collection model were used to measure the query clarity by Cronen-Townsend et al. [4]. In our work, we investigate new resources and combinations of approaches. All our investigations are compared to two baseline approaches (MaxIDF and SCS) that were chosen to have good performance in previous papers [5], [6]. We use anchor-text and full-text similarity scores as sources of evidence. The full-text similarity scores for each query are obtained by running each query on the index of document collection (WT10G), where each document returned in the search result list is assigned with a similarity score. Anchor-text is a text that appears on a link and surfers used to click on to reach the destination pointed by this link. It is considered as meaningful element for hyperlink in an HTML page. Eiron and McCurley [7] observed that anchor-texts and queries are very similar. Thus, using anchor-text leads to many advantages, for instance, processing anchor-text is faster than processing the data collection and could be used an evidence of the importance of web page, which many links pointed to it. Furthermore, it exists for pages that could not be indexed by a text search engines such as pages that majority of their contents are images or multimedia files. It is observed by Craswell et al. [8] in Site Finding (a search task where the users is interested in findings a specific named resource) that ranking based on link anchor-text is twice as effective as ranking based on document content. For anchor-text similarity scores for each

query, we ran each query on the index of anchor-text document surrogates. We therefore investigated the use of anchor-text similarity, and whether it can be used to predict query performance. We investigated the use of full-text similarity by running the same topics on the index of the document collection. The third investigation was conducted on one of the document surrogate properties, such the number of anchor-text in each document. We also investigate combinations of approaches. The idea is that in this way, the different strengths of alternative sources of evidence can be combined. We combine the first approach (full-text similarity) with the second approach (anchor-text similarity) in order to see the power of their union of predicting the query performance. Finally, we investigate the combination of each approach (full-text similarity and anchor-text similarity) with the approach MaxIDF. We conduct our experiments using well-known WT10G collection of web documents, and two testbeds from the Text REtrieval Conference (TREC). The results indicate a promising future for query performance prediction, particularly when combining some approaches.

II. RELATED WORK

He and Ounis [6] proposed and evaluated a number of pre-retrieval predictors. They concluded that two of them have strong correlation with average precision. The best two predictors are the `simpli_ed` query clarity score (SCS) and the average inverse collection term frequency (AvICTF). The SCS predictor calculates the Kullbak-Leibler divergence between the collection model and query model. The SCS is calculated by

$$SCS = \sum_Q P_{m1}(\omega|Q) \cdot \log_2 \frac{P_{m1}(\omega|Q)}{P_{coll}(\omega)} \quad (1)$$

Where $P_{m1}(\omega|Q)$ given by qtf/ql , qtf is the numbers of occurrences of a query term in the query and ql is the total number of terms in the query. $P_{coll}(\omega)$: is the collection model, it is given by $tf_{coll}/token_{coll}$, where tf_{coll} is how many times a query term occurs in the collection and $token_{coll}$ is the number of terms in the whole collection. Due to its demonstrated performance, we use SCS as a baseline in our experiments below.

The AvICTF predictor is observed that it has a strong correlation with query performance and it is given by

$$AvICTF = \frac{\log_2 \Pi Q(token_{coll}/tf_{coll})}{ql} \quad (2)$$

Where tf_{coll} is the number of occurrences of a query term in the whole collection $token_{coll}$ is the number of distinct terms in the whole collection, and ql is the query length. The MaxIDF predictor [5] was demonstrated to have a strong correlation with query performance. MaxIDF is calculated by using the largest IDF value of any term in the query. Due to its correlation effectiveness, we use MaxIDF as a second baseline for our experiments. Zhao et al. [9] proposed two new families of pre-retrieval predictors based on the similarity score between query and collection and the variability of distribution of query terms in the collection. The predictors that are based on similarity exploit two common resources of evidence; term frequency (TF) and inverse document frequency (IDF). The first predictor is SCQ that computes the similarity between the query and collection. The second predictor is as result of bias

against long query; they divided the SCQ by the length of the query where the length is calculated by summing the number of query terms that occur in the collection. The third predictor, they suggest that the performance of query can be determined by the query term that has the highest SCQ score. The predictors of the second family hinge on hypothesis that considers standard deviation of term weights as a predictor of an easy or hard query. If the standard deviation of term weights across the collection is high, this would indicate that the term is easy and the system is able to choose the best answer. However, if the standard deviation is low, this indicates that term is hard to be differentiated by system and therefore, the performance could be weak. From this approach, three predictors proposed. The predictor of variability score, normalised variability score and the maximum variability score.

The clarity score is proposed by Cronen-Townsend et al. [4]. They suggest that the quality of query can be estimated by calculating the divergence between query language and a collection of documents and, moreover, query with high clarity score correlates positively with the average precision in variety of TREC test sets. It is observed by Cronen-Townsend et al. [4] that queries that have high clarity scores outperform the ones that have low clarity scores in term of retrieving relevant documents.

The prediction of query difficulty has been studied in intranet search by Macdonald et al. [10] and they found satisfied results to predict the query performance by using the average inverse collection term frequency (AvICTF) and the query scope [6] predictors. The shown prediction results were highly effective when the range of query length was between one to two terms. In their experiments, query performance inversely proportional to query length.

Carmel et al. [11] tried to find the reasons for the problem that makes a query difficult. They attribute the difficulty to three main components of topic: the used expression that describes the information need (request), the relevant document set to topic, and data collection. A strong relationship between these components and the topic difficulty were found. In this work, they found a correlation between the average precision and the distance between the set of retrieved document and the collection as measured by the Jensen-Shannon divergence.

Mothe and Tanguy [12] examined the relationship of 16 different TREC queries linguistic features and the average precision scores. Each feature can be viewed as a clue to a linguistically specific characteristic, morphological, syntactical or semantic. Tow among these features: syntactic links span and polysemy value; had a significant impact on precision scores. Although the correlation was not high, the research demonstrates a promising correlation between some linguistic features and query performance.

Using learning methods to estimate the query difficulty are proposed by Yom-Tov et al. [13]. In this work, the agreement between the top N results of the full query and top N results of each term in that query is taken into account as the basic idea of estimation of query difficulty. The learning methods in this work are based on two features. First, the intersection between

the top N results of full query and the top N results of each query term. Second, the rounded logarithm of the document frequency of each query term. Two estimators used in this research are a histogram and a modified tree-based estimator. The first one is used when the number of sub-queries is large and the second used for short queries. These algorithms were tested on the TREC8 and WT10g collection. The number of topics used with these collections is 200 and 100 respectively. They concluded that the estimators trained on 200 TREC topics were able to predict the precision of untrained 49 (new) topics. Moreover, these estimators can be used to perform selective automatic query expansion for easy queries only. The results in this work showed that quality of query performance is proportional to the query length therefore, some opening questions arise that need to be taken in account, such as how the quality of query performance of short queries can be improved and how the amount of training data can be restricted.

Research was conducted using the query difficulty prediction to perform Metasearch and Federation proposed by Yom-Tov et al. [14]. They argue that the ranked list of documents returned from each search engine or each document collection can be merged by using query difficulty prediction score. The Metasearch technique is, several search engines perform retrieval operation from one document collection while, the Federation technique is, one search engine used to do retrieval from several document collections. The calculation of the query difficulty prediction score in this work is adapted from the approach [13] that proposed a learning algorithm for query difficulty prediction. They used the overlaps between the results of full query and its sub-queries to compute the difficulty prediction. The experimental tools used in this work are Robust Track topics. They used the same document collection for both Metasearch and Federation experiments. In the Federation experiment, they split the collection into four parts while, in the Metasearch experiment, they used available desktop search engines and same collection without splitting. They concluded that using the query difficulty prediction that computed for each dataset (in Federation) or each search engine (in Metasearch) could form a unified ranked list of results.

In the experiments conducted by Yom-Tov et al. [15] focus on query difficulty prediction and the benefits of using query performance prediction in some applications such as:

- *Query expansion (QE)* - It is a method that used to improve the retrieval performance by adding terms to the original query. The terms can be chosen from top retrieved documents that were identified as relevant or they can be selected from thesaurus, a synonym table. QE can improve the performance of some queries, but has been shown to decrease the performance of others. The determination of whether to use QE or not can be decided by knowing the performance of submitted query whether it is easy or hard. Using QE with easy queries improves the system performance, but it is detrimental to hard ones. [16]
- *Modifying search engine parameters* - By using the estimator parameters can be tuned to suitable value

according to the current situation. For example, we can tune the value that assigns to keywords and lexical affinities “pairs of closely related words which contain exactly one of the original query terms” [16]. The lexical affinities usually take the weight 0.25, while keywords take 0.70. These assigned values are an average that can be suitable for difficult and easy topics alike. However, using estimator (by which topic can be determined whether easy or hard) helps system to assign greater weight to lexical affinities when the topic is difficult and lower weight to easy topics.

- *Switching between different parts of topic* - It is observed by Yom-Tov et al. [17] that some topics are not answered very well by using only the short title part while, they are answered very well by using the longer description part. Therefore, they used the estimator to determine which part of the topic should be used in order to optimise the system performance. The title part used for the difficult topics, while the description part used for easy topics.

Many different predictors have been proposed in the literature. We used two well-known predictors, SCS and MaxIDF that have been shown to perform well, as baselines in our experiments.

III. OUR APPROACH

Six post-retrieval predictors of query performance were proposed. Three predictors are based on using a single source of evidence, while the rest are combined predictors, joined together in variant weights. These predictors were investigated using the WT10g collection and anchor-text document surrogates. The proposed predictors are demonstrated as follows:

A. Single Predictors

1) *The similarity of full text predictor* uses the similarity scores between a query and documents in the collection that are returned by a retrieval model. For example, for a particular query, the Okapi BM25 similarity function can be used to calculate a similarity score between that query and each document in the collection. Search results are then ranked by decreasing similarity score.

However, the actual similarity weights can differ markedly between queries: for example, for some queries the top similarity score may be very high, while for others, even the best similarity match may give a relatively lower score. The intuition behind our similarity of full text predictor is therefore that the actual level of the similarity value can provide evidence about how well the query has been able to match with possible answers in the collection. In other words, if the similarity scores are relatively high, then this is evidence for good matches (and therefore we expect this to be an easy query). On the other hand, relatively low similarity scores for even the top matching documents provide evidence that the query is hard.

Since retrieval models generally return a list of documents ordered by decreasing similarity score, the predictor can be based on different numbers of similarity scores. For example,

we could focus on only the top match, or take the mean similarity score of the top 10 matched. In general, we investigate the parameter N which represented the depth of the result list from which we take the average similarity score, as our query difficulty predictor.

We investigate values of N = 1, 10, 50, 100, 500 and 1000. The correlation between each of these variants of the predictor is correlated with average precision (AP) and precision at 10 (P@10) to determine the effectiveness of the prediction.

The similarity of anchor-text predictor, the intuition behind this kind of predictor, is same as the one in the similarity of full-text predictor in addition to the usefulness of anchor-text of giving an accurate description for destination documents. Furthermore, anchor-texts and queries are very similar in terms of many aspects [7]. If the similarity scores of retrieved documents are high, this indicates these documents are pointed by links that their anchor-text may be same as the information need (query). Therefore, submitted topic can be easily answered. Conversely, if the assigned similarity scores are low, this is evidence that the query is relatively more difficult.

We run each query on the index of anchor-text document surrogates in order to obtain the similarity score, and take the mean of top N (1, 10, 50, 100, 500, and 1000) ranked surrogates as the similarity score for each query. After that, we calculate the correlation coefficient between the similarity score of anchor-text and average precision of full-text and precision at 10 retrieved documents of full-text. It is hypothesised that similarity of anchor-text predictor can be used to predict the performance of the search system for that query.

2) *The number of anchor-text predictor, this predictor uses the count of the number of pieces of anchor-text in each document surrogate. We hypothesise that document surrogate that has many pieces of anchor-text, has an important content, because many links point to it. Therefore, we replace the similarity scores of ranked documents returned by search system (runs on index of full-text) with the number of anchor-text that corresponds to each document. The score for each query is calculated by taking the mean of top N (1, 10, 50, 100, 500, and 1000) ranked documents. We calculate the correlation coefficient between the predicted score and average precision of full-text and precision at 10 retrieved documents of full-text.*

B. Combined Predictors

These predictors combine two scores by using a simple linear combination approach to combine two scores. The intuitive idea of combining two approaches is about using variants of resources to predict the query performance. Combining strengths of each individual approach may result in a powerful predictor that outperforms each individual predictor. We calculate the joint score as follows:

$$\text{Combining score} = \alpha \times \text{predictor one} + (1 - \alpha) \times \text{predictor two}$$

$$\text{The alpha value is between } (0,1) = 0.1, 0.2, \dots, 0.9 \quad (3)$$

1) *The similarity of full-text combined with anchor-text, we join the similarity score of full-text with the similarity score of anchor-text in variant weights and take the mean of top N (1, 10, 50, 100, 500, and 1000) ranked documents as the similarity score for each query. We calculate the correlation between the predicted score and average precision of full-text and precision at 10 retrieved documents of full-text. We hypothesise that combining these predictors by specific weight will improve their performance compare to using a single predictor.*

2) *The similarity of full-text combined with MaxIDF, we combine the similarity of full-text combined with MaxIDF (the maximum of inverse document frequency for query terms). We take the mean of top N, and calculate the correlation coefficient between the predicted score and average precision of full-text and precision at 10 retrieved documents of full-text.*

The similarity of anchor-text combined with MaxIDF, we combine the similarity of anchor-text with MaxIDF. We take the mean of top N, and calculate the correlation coefficient same as the above ones.

IV. EXPERIMENTAL SETUP

The study relied on experimental methodology in order to investigate the effectiveness of the adopted approach. In our experiments, we used the facilities (a test set of documents, questions and evaluation software) that are provided by the Text REtrieval Conference (TREC) project in order to evaluate the work. The ultimate goal of TREC is to create the infrastructure necessary for comparable research in information retrieval.

A. Test Collection

The test collections used in the work are WT10g collection and document surrogates (it has same documents in terms of number, name and format, but their contents are consist of anchor-text fragments that point to).

1) *The WT10g (web track 10 gigabytes)*

The WT10g collection is a 10 GB crawl of the World Wide Web from 1997 used to evaluate new proposed algorithms and approaches, and it is widely used in information retrieval experiments. It is a static snapshot of the web and it is a common dataset which used by researchers to conduct their experiments within controlled environment. The features of the collection are:

- Non-English and binary data has been eliminated.
- Elimination of large quantities of duplicate data.
- It supports distributed information retrieval experiments very well.

The key properties of the collection are summarised in TABLE I.

TABLE I. PROPERTIES OF WT10G

Documents	1,692,096
Servers	11,680
Inter-server links	171,740
Documents with out-links	1,295,841
Documents with in-links	1,532,012

2) Document surrogates

To create document surrogates, we harvested all anchor-text from the WT10g collection. Then, all anchor-text fragments that point at a document A, are concatenated together to form a document surrogate, A. Fig. 1 gives an example of a document surrogate.

```
<DOC>
<DOCNO>WTX088-B20-127</DOCNO>
<DOCHDR>http://wings.buffalo.edu/computing/workshops/old/spec-
chars.html
</DOCHDR>
<html>
<body>
  Filename Expansion
  Preventing Filename Expansion
  Other Special Characters
  Wildcards and other shell special characters
</body>
</html>
</DOC>
```

Fig. 1. A document surrogate.

TABLE II. below demonstrates the document surrogates statistics.

TABLE II. STATISTICS OF DOCUMENT SURROGATES

Document surrogates	1,689,111
Document surrogates that contain at least one anchor-text	1,333,787
Document surrogates that don't contain anchor-text(empty)	355,324
Hyperlinks that point to existing documents	11,528,211
Hyperlinks that point to non-existing documents	7,642,241
Valid hyperlinks in WT10g	19,170,452
Identical documents in WT10g	2,985

The Valid hyperlinks in WT10g: These are the hyperlinks that have anchor-text by which a particular document (pointed by a link) can be inquired. For example, the email hyperlinks were not considered as valid links therefore, they were neglected.

Identical documents in WT10g: It is claimed in this collection that identical documents eliminated. That sounds correct in terms of comparing documents URL against crawled documents URLs list. But, “the URL to a particular resource can be represented in many different formats” [18]. One example of identical documents found although, they are considered not be identical as follows:

```
First document: The document number is
<DOCNO>WTX095-B48-113</DOCNO>
The document's URL is http://www.sfbayacm.org:80/
Second document: The document number is
<DOCNO>WTX093-B25-417 </DOCNO>
The document's URL is http://www.sfbayacm.org:80/home.shtml
```

From this example, the URLs do not appear to be identical although they represent one resource. After standardising these

URLs according to the standardisations proposed by Ali [18], the final standardised URL for both document one and two is as follows: <http://www.sfbayacm.org>.

In our research, it is very important to consider these issues because of the need of accuracy of storing the anchor-text into a right document surrogate. If anchor-text not stored into a right document surrogate, this will lead to inaccurate search results. In this research, we standardised all documents URLs and hyperlinks targets (are what the links point to) that occur in these documents as well.

Hyperlinks point to existing documents: the sum of Hyperlinks that are valid and point to existing documents in document collection (WT10g).

Hyperlinks point to non-existing documents: the sum of Hyperlinks that are valid and point to elsewhere. Their targets are not within document collection (WT10g). This number could be propositional to the size of used collection, that is, it could be less when document collection is large and via verse.

B. Topic Set and Relevance Judgments

TREC has produced a series of test collections. Each test collection consists of a set of documents, a set of topics and a corresponding set of relevance judgments (relevant documents for each topic).

The topics used in this research are from web Track:

- TREC-9 ad hoc query set of 50 queries (451-500)
- TREC-10 ad hoc query set of 50 queries (501-550)

Each topic consists of three fields that describe the users' information need: a title, a description and a narrative field. The used field in this work is a title field. The title field was stemmed and stopwords were removed. The stemming algorithm that was used is Porter [19] and the SMART retrieval system stop list used to remove stopwords.

Relevance judgments are a list of answers called 'qrles' accompanied with each query set. These answers were judged by a human. They are used to evaluate the search results returned by a system. We used in this research 'qrles.501-550.trec10.web' and 'qrles.451-500.trec9.web' that belong to TREC-10 and TREC-9, respectively.

C. Evaluation of Prediction

We report results based on three correlation coefficients:

- 1) The Pearson correlation
- 2) Spearman correlation
- 3) Kendall's tau correlation

The higher the value of the correlation, the better predictor is at determining query difficulty. We also report the P-value of the associated statistical hypothesis test for each correlation. When $P < 0:05$, the strength of the correlation is statically significant.

D. Baselines

We take two predictors as a baseline to our proposed predictors. First predictor is Simplified Clarity Score (SCS)

that was proposed by He and Ounis [20]. Second predictor is maximum inverse document frequency (MaxIDF) [5].

E. Retrieval Models

There are many different models used in information retrieval IR. These models differ from one another in terms of used mathematical basis and models properties. In this paper, we use three ranked retrieval models: Okapi MB25 and Unigram language model and Vector Space model. The first two models are based on Probabilistic theorem, and similarity between query and document is computed as probabilities that a document is relevant for a given query. While, the third one represents document and query as vectors, and similarity is represented as a scalar value. Although, these models compute or estimate the Similarity between query and documents (in order to rank documents according to their descending similarity scores), they have different calculation and parameters. Thus, we setup the optimal and recommended values for each model as follows:

1) *Okapi MB25 retrieval function (probabilistic model)*

$K1 = 1:2$

$K3 = 1000$

$B = 0:75$

These values are default and found to be effective in many different collections [21].

2) *Vector Space model (cosine metric)*

3) *There are no parameters that need to be setup.*

Unigram language model using Dirichlet prior smoothing.

Dirichlet prior value = 2000, this found to be optimal prior value [22].

F. The Zettair Search Engine

The Zettair search engine is an open source. It was designed and written by the RMIT university Search Engine Group [23]. It was formally known as Lucy. There are many features of this engine, including:

- Speed and scalability
- Supporting TREC experiments
- Running on many platforms
- Boolean, ranked, and phrase querying
- Easy to make installation and configuration

The version used in this work is 0.9.3, it is considered as a stable tested product.

G. Evaluation Program

The `trec_eval` program made available by TREC [3] is used to evaluate the retrieval results against the relevance judgments that belong to the topics that invoked to the retrieval system. The report that generated by this program gives some statistics for each topic:

- The number of relevant documents in the test collection and relevant document retrieved by the retrieval system.

- Common metrics such as mean average precision (MAP), R-precision, mean reciprocal rank and precision at N retrieved documents.
- Interpolated precision at fixed levels of recall.

V. RESULTS AND DISCUSSION

Variety of predictors were explored, which involved a number of parameter settings. We explore using the mean of top N (1, 10, 50, 100, 500, and 1000) ranked documents as the similarity score for each query in all our approaches. We use variant values of N in order to determine the best value that correlates well against the actual performance average precision and precision at 10 retrieved documents. The results are therefore structured according to the following categories:

- Single predictors

1) The mean of top N of the similarity of full-text scores.

2) The mean of top N of the similarity of anchor-text scores.

3) The mean of top N of the number of anchor-text in each document.

- Combined predictors

In these approaches, the combining computation is defined as:

$$\text{Combining score} = \alpha \times \text{predictor one} + (1 - \alpha) \times \text{predictor two}$$

The alpha value is between (0,1) =

$$0.1, 0.2, \dots, 0.9 \quad (4)$$

1) The mean of top N of the similarity of full-text scores combined with anchor-text scores.

2) The mean of top N of the similarity of full-text scores combined with MaxIDF scores.

3) The mean of top N of the similarity of anchor-text scores combined with MaxIDF scores.

The predictors are evaluated for three retrieval models, as explained in experimental setup section:

1) Okapi MB25 retrieval function (probabilistic model)

2) Vector Space model (cosine metric)

3) Unigram language model, using Dirichlet prior smoothing.

In our experiments, we used TREC 9 as training set in order to determine optimal parameters, while TREC 10 is used as evaluation set to test the optimal setting obtained from training. Two predictors used as baselines, MaxIDF and SCS. To measure the effectiveness of our predictors, we use three correlation coefficients: Pearson (Cor), Kendall (Tau), and Spearman (Rho) between the predicted scores and average precision (AP), and precision at 10 (P@10), on the WT10G collection by using three retrieval models: Okapi, Cosine and Dirichlet.

We first present the results of baseline predictors, and then present the results of our proposed predictors.

H. The Results of Baseline Predictors

Table 3, in the appendices, summarizes the results of correlations of Pearson (Cor), Kendall (Tau), and Spearman (Rho) of the MaxIDF predictor with average precision (AP) and precision at 10 (P@10). The results are given with respect to three retrieval models (Okapi, Cosine and Dirichlet) and the use of two topics: TREC 9 as training set and TREC 10 as evaluation set. The p-value is shown in bold when correlations are statistically significant at the 0.05 level.

The correlations of baseline predictor (MaxIDF) with average precision (AP) are statistically significant on TREC-9 for all correlation coefficients except for the linear correlation (Cor), but on TREC-10 are only statistically significant and showing high important correlation with the performance of the Okapi and Dirichlet retrieval models while, with Cosine model are not significant. However, the most correlations of this predictor with precision at 10 (P@10) are not significant. Although a few numbers of correlations are statistically significant, they cannot achieve the consistency of performance between the training set (TREC-9) and evaluation set (TREC-10). Overall, it can be seen that only correlations (Tau and Cor) with average precision (AP) with two retrieval models (Okapi

and Dirichlet) are statistically and consistently significant with the training set (TREC-9) and evaluation set (TREC-10).

TABLE IV. summarizes the results of correlations of Pearson (Cor), Kendall (Tau), and Spearman (Rho) of the SCS predictor with average precision (AP) and precision at 10 (P@10). The results are given with respect to three retrieval models (Okapi, Cosine and Dirichlet) and the use of two topics: TREC 9 as training set and TREC 10 as evaluation set. The p-value is shown in bold when correlations are statistically significant at the 0.05 level.

The results demonstrate that correlation coefficients of SCS predictor with average precision (AP) are statistically significant and highly effective for TREC-9 with Cosine model and only two of them (Tau, Cor) with Okapi model, while these correlation coefficients are not significant for Dirichlet model. The correlations of this predictor with precision at 10 (P@10) are only significant for Cosine model on TREC-9. There is no consistency between the training set and the evaluation set achieved by this predictor. Overall, the performance of the SCS predictor is less than MaxIDF predictor in terms of consistency and statistical significance for all correlation coefficients across most retrieval models and topics.

TABLE III. PEARSON (COR), KENDALL (TAU), AND SPEARMAN (RHO) CORRELATION BETWEEN MAXIDF PREDICTOR AND AVERAGE PRECISION (AP) AND PRECISION AT 10 (P@10) ON THE WT10G COLLECTION, BY USING THE OKAPI METRIC, COSINE METRIC, AND DIRICHLET METRIC

0	Okapi metric.		Cosine metric.		Dirichlet metric.		Correlation Test
	Coefficient-value	P-value	Coefficient-value	P-value	Coefficient-value	P-value	
AP	TREC 9						
	0.3079	0.0017	0.3036	0.0020	0.2452	0.0123	Tau
	0.4152	0.0027	0.3966	0.0044	0.3399	0.0157	Rho
	-0.1585	0.2716	-0.0894	0.5370	-0.1954	0.1739	Cor
	TREC 10						
	0.1944	0.0465	0.0222	0.8211	0.2522	0.0097	Tau
	0.2835	0.0461	0.0517	0.7213	0.3539	0.0121	Rho
	0.3181	0.0244	0.1981	0.1680	0.4164	0.0026	Cor
	P@10	TREC 9					
0.2090		0.0457	0.2373	0.0391	0.1559	0.1383	Tau
0.2787		0.0500	0.2931	0.0389	0.2022	0.1592	Rho
-0.2284		0.1106	-0.0891	0.5385	-0.2344	0.1014	Cor
TREC 10							
0.0473		0.6468	0.0591	0.6075	0.1114	0.2780	Tau
0.0853		0.5558	0.0681	0.6386	0.1693	0.2398	Rho
0.0496		0.7323	0.1709	0.2355	0.1014	0.4837	Cor

TABLE IV. PEARSON (COR), KENDALL (TAU), AND SPEARMAN (RHO) CORRELATION BETWEEN SCS PREDICTOR AND AVERAGE PRECISION (AP) AND PRECISION AT 10 (P@10) ON THE WT10G COLLECTION, BY USING THE OKAPI METRIC, COSINE METRIC, AND DIRICHLET METRIC

0	Okapi metric.		Cosine metric.		Dirichlet metric.		Correlation Test
	Coefficient-value	P-value	Coefficient-value	P-value	Coefficient-value	P-value	
AP	TREC 9						
	0.2113	0.0308	0.3300	0.0008	0.1812	0.0644	Tau
	0.3187	0.0241	0.4523	0.0010	0.2786	0.0501	Rho
	0.1397	0.3331	0.3960	0.0044	0.1502	0.2977	Cor
	TREC 10						
	0.1323	0.1754	0.1293	0.1885	0.1118	0.2518	Tau
	0.2104	0.1425	0.1908	0.1845	0.1748	0.2238	Rho
	0.2712	0.0568	0.2663	0.0616	0.2389	0.0947	Cor
	P@10	TREC 9					
0.1839		0.0787	0.3120	0.0067	0.1432	0.1733	Tau
0.2393		0.0941	0.3722	0.0078	0.1834	0.2024	Rho
0.1655		0.2508	0.4643	0.0007	0.1490	0.3017	Cor
TREC 10							
-0.0280		0.7860	0.0591	0.6075	-0.0122	0.9055	Tau
-0.0261		0.8574	0.0709	0.6245	-0.0094	0.9482	Rho
-0.0022		0.9877	0.0848	0.5580	0.0150	0.9178	Cor

I. The Results of our Proposed Predictors

1) Single Predictors

This section presents the results of predictors that based on one source of evidence: similarity of full-text; similarity of anchor-text, and the number of anchor-text predictors. The variable parameter that was used in our experiments is the number of top ranked document similarity scores that are averaged. In this research, we used six values to tune this parameter: 1, 10, 50,100,500 and 1000. We choose the optimal parameter that performs very well on training set TREC 9. Then, we test these obtained settings on the evaluation set TREC 10.

TABLE I. 5 shows the results of correlations of Pearson (Cor), Kendall (Tau), and Spearman (Rho) of the similarity of full-text predictor with average precision (AP) and precision at 10 (P@10). The results are given with respect to three retrieval models (Okapi, Cosine and Dirichlet) and the use of two topics: TREC-9 as training set and TREC-10 as evaluation set. The p-value is shown in bold when correlations are statistically significant at the 0.05 level.

The three correlation coefficients of similarity of full-text predictor with average precision (AP) and precision at 10 (P@10) are statistically significant for the probabilistic retrieval models (Okapi and Dirichlet) on the training (TREC-9) and evaluation (TREC-10) sets. It is apparent that no correlation coefficients for Cosine model are significant at all. The optimal parameter values of the mean of top ranked document similarity scores vary for each retrieval model. This predictor is showing promising correlation with Okapi model, when the mean of top 10 ranked document similarity scores, is taken on all query sets. However, with Dirichlet model, the best value is 50. It is noted from the results that similarity of full-text predictor with Dirichlet model gives the highest prediction performance. Overall, comparing this predictor with the baseline ones, it outperforms them and all correlation coefficients with performance of two retrieval models (Okapi and Dirichlet) appear statistically and consistently significant on all topics. Although, some correlation coefficients of baseline predictors show significant performance with Cosine model on training set (TREC-9) only, they are not effective for use with the Cosine model, because of losing the consistency of performance between training and evaluation sets.

The results of TABLE VI. 6 demonstrate the correlation coefficients (Pearson (Cor), Kendall (Tau), and Spearman (Rho)) of the similarity of anchor-text predictor with average precision (AP) and precision at 10 (P@10). The results are given with respect to three retrieval models (Okapi, Cosine and Dirichlet) and the use of two topics: TREC-9 as training set and TREC-10 as evaluation set. The p-value is shown in bold when correlations are statistically significant at the 0.05 level.

The results of three correlations of the anchor-text similarity predictor with average precision (AP) of Okapi model are only statistically significant with coefficients of

Kendall (Tau), and Spearman (Rho) on training set (TREC-9) while, all correlations are not effective for the evaluation set (TREC-10). This predictor performs poorly with the Cosine model. On other hand, it shows consistent performance for TREC-9 and TREC-10 with the Dirichlet model.

The results of correlations with P@10 for the Okapi model appear statistically significant on TREC-9 using Kendall (Tau) and Spearman (Rho) coefficients. It is seen that Kendall (Tau) coefficient keeps the performance consistency on TREC-10. Moreover, correlations with P@10 for Cosine model are not significant. All correlation coefficients for The Dirichlet model performance are statistically significant on TREC-9 although, they lose performance consistency for TREC-10 except for Spearman (Rho) coefficient. The results of the anchor-text predictor show actuated performance across correlation coefficients, retrieval models and topics. This predictor is comparative for the baseline SCS predictor, while less strong than the baseline MaxIDF and the similarity of full-text predictors.

TABLE VII. 7 summarizes the obtained results of correlation coefficients of the anchor-text predictor with average precision (AP) and precision at 10 (P@10). The results are given with respect to three retrieval models (Okapi, Cosine and Dirichlet) and the use of two topics: TREC-9 as training set and TREC-10 as evaluation set. The p-value is shown in bold when correlations are statistically significant at the 0.05 level.

The number of anchor-text predictor shows no significant effect. It is the worst predictor and is not recommended for use.

2) Combined Predictors

This section presents the results of predictors that are based on combining two sources of evidence: similarity of full-text with similarity of anchor-text, similarity of full-text with MaxIDF, similarity of anchor-text with MaxIDF. The variable parameters used in our experiments are based on two parameters: the alpha parameter (determines the weight given to first approach and second approach in the linear combination) and the number of top ranked document similarity scores averaged, after combining. In this work, nine values are used to tune alpha parameter: 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, and six values to tune second parameter: 1, 10, 50,100,500 and 1000. We chose the optimal value of first parameter and second parameter based on training set TREC 9. Then, we test these fixed parameter values on evaluation set TREC 10.

TABLE VIII. 8 demonstrates correlation coefficients of combining similarity of full-text with similarity of anchor-text predictor with average precision (AP) and precision at 10 (P@10). The results are given with respect to three retrieval models (Okapi, Cosine and Dirichlet) and the use of two topics: TREC-9 as training set and TREC-10 as evaluation set. The p-value is shown in bold when correlations are statistically significant at the 0.05 level.

TABLE V. PEARSON (COR), KENDALL (TAU), AND SPEARMAN (RHO) CORRELATION BETWEEN SIMILARITY OF FULL-TEXT PREDICTOR AND AVERAGE PRECISION (AP) AND PRECISION AT 10 (P@10) ON THE WT10G COLLECTION, BY USING THE OKAPI METRIC, COSINE METRIC, AND DIRICHLET METRIC. ASTERISK AND PLUS INDICATE THAT CORRELATION COEFFICIENT OUTPERFORM MAXIDF AND SCS, RESPECTIVELY

	Okapi metric.			Cosine metric.			Dirichlet metric.			Correlation Test
	Mean Of top	Coefficient-value	P-value	Mean Of top	Coefficient-value	P-value	Mean Of top	Coefficient-value	P-value	
AP	TREC 9									
	10	0.3587*+	0.0002	1	0.1028	0.2986	50	0.3731*+	< 0.0001	Tau
	10	0.5131*+	< 0.0001	1	0.1480	0.3049	50	0.5105*+	0.0002	Rho
	10	0.3384*+	0.0163	1	-0.1246	0.3886	50	0.3232*+	0.0220	Cor
	TREC 10									
	10	0.3838*+	< 0.0001	1	-0.1167	0.2373	50	0.4629*+	< 0.0001	Tau
	10	0.5383*+	< 0.0001	1	-0.1683	0.2428	50	0.6374*+	< 0.0001	Rho
	10	0.4392*+	0.0014	1	-0.1691	0.2404	50	0.5770*+	< 0.0001	Cor
	@10	TREC 9								
10		0.2826*+	0.0069	1	0.0702	0.5435	50	0.2575*+	0.0144	Tau
10		0.3877*+	0.0054	1	0.0722	0.6183	50	0.3439*+	0.0145	Rho
10		0.2823*+	0.0470	1	-0.0303	0.8347	50	0.2789*+	0.0498	Cor
TREC 10										
10		0.3258*+	0.0016	1	-0.2027	0.0797	50	0.3063*+	0.0029	Tau
10		0.4490*+	0.0011	1	-0.2491	0.0810	50	0.4166*+	0.0026	Rho
10		0.3448*+	0.0142	1	-0.2054	0.1524	50	0.3214*+	0.0229	Cor

TABLE VI. PEARSON (COR), KENDALL (TAU), AND SPEARMAN (RHO) CORRELATION BETWEEN SIMILARITY OF ANCHOR-TEXT PREDICTOR AND AVERAGE PRECISION (AP) AND PRECISION AT 10 (P@10) ON THE WT10G COLLECTION, BY USING THE OKAPI METRIC, COSINE METRIC, AND DIRICHLET METRIC. ASTERISK AND PLUS INDICATE THAT CORRELATION COEFFICIENT OUTPERFORM MAXIDF AND SCS, RESPECTIVELY

	Okapi metric.			Cosine metric.			Dirichlet metric.			Correlation Test
	Mean Of top	Coefficient-value	P-value	Mean Of top	Coefficient-value	P-value	Mean Of top	Coefficient-value	P-value	
AP	TREC 9									
	1	0.2689 +	0.0061	1	0.1665	0.0962	10	0.3980*+	< 0.0001	Tau
	1	0.4017 +	0.0038	1	0.2604	0.6085	10	0.5608*+	< 0.0001	Rho
	1	0.2214*+	0.1223	1	0.0742	0.6085	10	0.3608*+	0.0020	Cor
	TREC 10									
	1	0.1757 +	0.0721	1	0.1003*	0.3106	10	0.3094*+	0.0020	Tau
	1	0.2505 +	0.0793	1	0.1356*	0.3479	10	0.4307*+	0.0020	Rho
	1	0.2151	0.1336	1	0.0060	0.9670	10	0.3681 +	0.0085	Cor
	@10	TREC 9								
1		0.2900*+	0.0056	1	0.1289	0.2704	10	0.3539*+	0.0008	Tau
1		0.4072*+	0.0033	1	0.1634	0.2552	10	0.4713*+	0.0006	Rho
1		0.2699*+	0.0580	1	0.1640*	0.2552	10	0.3995*+	0.0533	Cor
TREC 10										
1		0.2042*+	0.0480	1	-0.0336	0.7719	10	0.1984*+	0.0533	Tau
1		0.2728*+	0.0552	1	-0.0404	0.7805	10	0.2813*+	0.0478	Rho
1		0.2071*+	0.1490	1	0.0385	0.7905	10	0.2652*+	0.0628	Cor

TABLE VII. PEARSON (COR), KENDALL (TAU), AND SPEARMAN (RHO) CORRELATION BETWEEN THE NUMBER OF ANCHOR-TEXT PREDICTOR AND AVERAGE PRECISION (AP) AND PRECISION AT 10 (P@10) ON THE WT10G COLLECTION, BY USING THE OKAPI METRIC, COSINE METRIC, AND DIRICHLET METRIC. ASTERISK AND PLUS INDICATE THAT CORRELATION COEFFICIENT OUTPERFORM MAXIDF AND SCS, RESPECTIVELY

	Okapi metric.			Cosine metric.			Dirichlet metric.			Correlation Test
	Mean Of top	Coefficient-value	P-value	Mean Of top	Coefficient-value	P-value	Mean Of top	Coefficient-value	P-value	
AP	TREC 9									
	10	0.1748	0.0746	1	0.1047	0.3274	1	-0.2296	0.0199	Tau
	10	0.2590	0.0694	1	0.1396	0.3334	1	-0.3001	0.0343	Rho
	10	-0.0002	0.9987	1	0.0601	0.6786	1	-0.2556	0.0732	Cor
	TREC 10									
	10	0.0614	0.5303	1	-0.0668	0.5172	1	0.0082	0.9333	Tau
	10	0.0861	0.5523	1	-0.0818	0.5725	1	-0.0121	0.9338	Rho
	10	-0.0401	0.7820	1	-0.2191	0.1264	1	0.1570	0.2763	Cor
	@10	TREC 9								
10		0.1519	0.1471	1	0.1121	0.3699	1	-0.1643	0.1206	Tau
10		0.2120	0.1393	1	0.1292	0.3713	1	-0.2137	0.1361	Rho
10		0.1829 +	0.2037	1	0.0372	0.7977	1	-0.1831	0.2031	Cor
TREC 10										
10		0.1167*+	0.2590	1	-0.0016	0.9893	1	0.0341 +	0.7409	Tau
10		0.1595*+	0.2687	1	-0.0099	0.9458	1	0.0576 +	0.6913	Rho
10		0.0182 +	0.9004	1	-0.1368	0.3433	1	-0.0893	0.5373	Cor

TABLE VIII. PEARSON (COR), KENDALL (TAU), AND SPEARMAN (RHO) CORRELATION BETWEEN COMBINING SIMILARITY OF FULL-TEXT WITH SIMILARITY OF ANCHOR-TEXT PREDICTOR AND AVERAGE PRECISION (AP) AND PRECISION AT 10 (P@10) ON THE WT10G COLLECTION, BY USING THE OKAPI METRIC, COSINE METRIC, AND DIRICHLET METRIC. ASTERISK AND PLUS INDICATE THAT CORRELATION COEFFICIENT OUTPERFORM MAXIDF AND SCS, RESPECTIVELY

	Okapi metric – Alpha 0.4			Cosine metric – Alpha 0.1			Dirichlet metric – Alpha 0.1			Correlation Test
	Mean Of top	Coefficient-value	P-value	Mean Of top	Coefficient-value	P-value	Mean Of top	Coefficient-value	P-value	
AP	TREC 9									
	10	0.5225*+	< 0.0001	10	0.2426	0.0138	10	0.5551*+	< 0.0001	Tau
	10	0.6899*+	< 0.0001	10	0.3405	0.0155	10	0.7367*+	< 0.0001	Rho
	10	0.3951*+	0.0045	10	0.1805*	0.2098	10	0.5753*+	< 0.0001	Cor
	TREC 10									
	10	0.3071*+	0.0017	10	0.2166*+	0.0276	10	0.2065 +	0.0343	Tau
	10	0.4173*+	0.0026	10	0.3306*+	0.0190	10	0.2819 +	0.0476	Rho
	10	0.2652	0.0627	10	0.2820*+	0.0472	10	0.2392 +	0.0944	Cor
	@10	TREC 9								
10		0.5159*+	< 0.0001	10	0.1482	0.1977	10	0.4787*+	< 0.0001	Tau
10		0.6588*+	< 0.0001	10	0.1883	0.1902	10	0.6161*+	< 0.0001	Rho
10		0.4550*+	0.0009	10	0.1439*	0.0712	10	0.5634*+	< 0.0001	Cor
TREC 10										
10		0.1664*+	0.1069	10	0.2077*+	0.0712	10	0.0348 +	0.7346	Tau
10		0.3053*+	0.0311	10	0.2531*+	0.0761	10	0.0654 +	0.6518	Rho
10		0.2043*+	0.1547	10	0.2846*+	0.0451	10	0.0153 +	0.9160	Cor

TABLE IX. PEARSON (COR), KENDALL (TAU), AND SPEARMAN (RHO) CORRELATION BETWEEN COMBINING SIMILARITY OF FULL-TEXT WITH MAXIDF PREDICTOR AND AVERAGE PRECISION (AP) AND PRECISION AT 10 (P@10) ON THE WT10G COLLECTION, BY USING THE OKAPI METRIC, COSINE METRIC, AND DIRICHLET METRIC. ASTERISK AND PLUS INDICATE THAT CORRELATION COEFFICIENT OUTPERFORM MAXIDF AND SCS, RESPECTIVELY

	Okapi metric – Alpha 0.5			Cosine metric – Alpha 0.1			Dirichlet metric – Alpha 0.7			Correlation Test
	Mean Of top	Coefficient-value	P-value	Mean Of top	Coefficient-value	P-value	Mean Of top	Coefficient-value	P-value	
AP	TREC 9									
	50	0.3407*+	0.0005	1	0.1304	0.1855	100	0.3747_+	< 0.0001	Tau
	50	0.4808*+	0.0004	1	0.1589	0.2703	100	0.5081_+	0.0002	Rho
	50	0.2667*+	0.0612	1	-0.0646	0.6557	100	0.3030_+	0.0324	Cor
	TREC 10									
	50	0.3838*+	< 0.0001	1	-0.0750	0.4460	100	0.4645_+	< 0.0001	Tau
	50	0.5412*+	< 0.0001	1	-0.1005	0.4876	100	0.6434_+	< 0.0001	Rho
	50	0.4171*+	0.0026	1	-0.1116	0.4405	100	0.5450_+	< 0.0001	Cor
	@10	TREC 9								
50		0.2952*+	0.0048	1	0.1144	0.3198	100	0.2720_+	0.0097	Tau
50		0.4024*+	0.0038	1	0.1347	0.3510	100	0.3536_+	0.0118	Rho
50		0.2750*+	0.0533	1	0.0089	0.9511	100	0.2765_+	0.0519	Cor
TREC 10										
50		0.2820*+	0.0063	1	-0.1471	0.2014	100	0.2959_+	0.0040	Tau
50		0.2820*+	0.0051	1	-0.1794	0.2127	100	0.4105_+	0.0031	Rho
50		0.3033*+	0.0323	1	-0.1687	0.2415	100	0.3144_+	0.0262	Cor

TABLE X. PEARSON (COR), KENDALL (TAU), AND SPEARMAN (RHO) CORRELATION BETWEEN COMBINING SIMILARITY OF ANCHOR-TEXT WITH MAXIDF PREDICTOR AND AVERAGE PRECISION (AP) AND PRECISION AT 10 (P@10) ON THE WT10G COLLECTION, BY USING THE OKAPI METRIC, COSINE METRIC, AND DIRICHLET METRIC. ASTERISK AND PLUS INDICATE THAT CORRELATION COEFFICIENT OUTPERFORM MAXIDF AND SCS, RESPECTIVELY

	Okapi metric – Alpha 0.6			Cosine metric – Alpha 0.1			Dirichlet metric – Alpha 0.8			Correlation Test
	Mean Of top	Coefficient-value	P-value	Mean Of top	Coefficient-value	P-value	Mean Of top	Coefficient-value	P-value	
AP	TREC 9									
	1	0.2672_+	0.0064	1	0.2114	0.0319	10	0.3947_+	< 0.0001	Tau
	1	0.4015_+	0.0039	1	0.3236	0.0219	10	0.5545_+	< 0.0001	Rho
	1	0.2210_+	0.1231	1	0.0038	0.9794	10	0.3593_+	0.0104	Cor
	TREC 10									
	1	0.1748_+	0.0734	1	0.1458_+	0.1382	10	0.3094_+	0.0015	Tau
	1	0.2484_+	0.0820	1	0.2020_+	0.1595	10	0.4307_+	0.0020	Rho
	1	0.2152	0.1335	1	0.0692	0.6331	10	0.3685_+	0.0085	Cor
	@10	TREC 9								
1		0.2900_+	0.0056	1	0.1869	0.1045	10	0.3502_+	0.0009	Tau
1		0.4072_+	0.0033	1	0.2228	0.1199	10	0.4668_+	0.0006	Rho
1		0.2692_+	0.0587	1	0.0806	0.5780	10	0.3976_+	0.0042	Cor
TREC 10										
1		0.2032_+	0.0490	1	0.0925_+	0.4217	10	0.1984_+	0.0533	Tau
1		0.2707_+	0.0572	1	0.1104_+	0.4454	10	0.2813_+	0.0478	Rho
1		0.2071_+	0.1490	1	0.0821	0.5707	10	0.2652_+	0.0627	Cor

With respect to retrieval Okapi model, the results of correlation coefficients with average precision (AP) on training set (TREC-9) are statistically significant and show high performance that outperforms baseline predictors and each individual predictor. On the evaluation set, the performance slows down; although correlation coefficients of Kendall (Tau) and Spearman (Rho) are still statistically significant and outperform baseline and anchor-text predictors. However, with precision at 10 (P@10) on TREC-9 performance is still good as for average precision (AP), but on evaluation set (TREC-10), it loses its consistency with all correlation coefficients except Kendall (Tau). The prediction performance of this predictor with Cosine model is showing interesting results with training and evaluation sets. It is seen that all correlation coefficients except one (Pearson (Cor) on TREC-9) on all topics with average precision (AP) are statistically significant. Although baseline predictors outperform it on TREC-9, they are generally considered less strong than combining similarity of full-text with similarity of anchor-text predictor, because the baseline predictors lose their consistency on evaluation set (TREC-10). As for retrieval Dirichlet model, the three correlation coefficients with AP and P@10 on TREC-9 are statistically significant but the performance of this predictor on evaluation set performs poorly, although some improvement with AP.

Overall, the joint predictor of similarity of full-text with similarity of anchor-text outperforms the baseline, anchor-text and the number of anchor-text predictors, while a strong competition between this predictor and full-text similarity one. This predictor outperforms full-text predictor with respect to retrieval cosine model only and is less strong than combining similarity of full-text with similarity of anchor-text predictor with probabilistic models (Okapi and Dirichlet).

TABLE IX. 9 shows the correlation coefficients of combining similarity of full-text with MaxIDF predictor with average precision (AP) and precision at 10 (P@10). The results are given with respect to three retrieval models (Okapi, Cosine and Dirichlet) and the use of two topics: TREC-9 as training set and TREC-10 as evaluation set. The p-value is shown in bold when correlations are statistically significant at the 0.05 level.

All correlation coefficients are statistically significant with respect to retrieval Okapi model with P@10 and average precision (AP) for all topics except using coefficient of Pearson (Cor) on TREC-9. There is no significance for all correlation coefficients with Cosine model. The performance of this predictor with Dirichlet model is similar to the performance with Okapi model although, for Dirichlet model with P@10, the results of all correlation coefficients are significant. Overall, this predictor is stronger than the baseline and anchor-text predictors, but shows no performance with retrieval Cosine model. It is slightly similar to full-text predictor and it is more consistent with probabilistic models (Okapi and Dirichlet) than the joint predictor of similarity of full-text with similarity of anchor-text, although it performs poorly its failure with the Cosine model.

TABLE X. summarizes the correlation coefficients of combining similarity of anchor-text with MaxIDF predictor

with average precision (AP) and precision at 10 (P@10). The results are given with respect to three retrieval models (Okapi, Cosine and Dirichlet) and the use of two topics: TREC-9 as training set and TREC-10 as evaluation set. The p-value is shown in bold when correlations are statistically significant at the 0.05 level.

The two correlation coefficients (Kendall (Tau), and Spearman (Rho)) of this predictor with the performance of retrieval Okapi model (average precision (AP) and precision at 10 (P@10)) are statistically significant on training set. With the evaluation set, only the coefficient of Kendall (Tau) is significant with precision at 10. With cosine model, this predictor shows no consistent performance between training and evaluation data. Combining similarity of anchor-text with MaxIDF predictor shows a significant correlation with the performance of Dirichlet model with AP on all topics. However, performance consistency between TREC-9 and TREC-10 with P@10 is not achieved. In general, this predictor is stronger than SCS predictor and less strong than others.

Table 11 summarizes the effective use of the predictors for each retrieval model based on the number of significant correlations with average precision (AP) and precision at 10 (P@10). The effectiveness of predictors is determined by the number of times when at least one of correlation coefficients of a predictor with the performance of retrieval model on all training and evaluation sets are consistently and statistically significant. It can be seen that three predictors (Similarity of Full-text, Similarity of Full-text with Similarity of anchor-text and Similarity of Full-text with MaxIDF) with average precision (AP) of Okapi model give a significant performance. While, with precision at 10 (P@10), Similarity of Full-text with Similarity of anchor-text predictor fails to keep its performance. As for Dirichlet retrieval model, all proposed predictors except number of anchor-text predictor perform very well with average precision (AP), while with precision at 10 (P@10), two predictors cannot achieve performance (Similarity of anchor-text and Similarity of Full-text with Similarity of anchor-text). Moreover, all proposed predictors fail to predict the performance of retrieval Cosine model, except Similarity of Full-text with Similarity of anchor-text with average precision (AP).

As is clear from the results, some predictors work well, while others do not. Overall, the similarity of Full-text predictor is the best, the while the similarity of anchor-text predictor does not perform as well in comparison. As is known from full-text search, all of the words in every document can be indexed by the search engine. Therefore, documents have a big chance to be retrieved. For anchor-text, in comparison, the search engine just indexes the anchor-text terms that point to a particular document. As these are generally far fewer terms than are contained in the full text, this lowers the chance of relevant documents to be retrieved. Further, there are 355,324 document surrogates that contain anchor-text (they are empty). Furthermore, it can be seen that the effectiveness of the full-text predictors consistent for both average precision (AP) and precision at 10 (P@10), while the anchor-text predictor is not. This can be attributed to the foregoing reason which emphasizes the importance of indexed content for each document. As we said that anchor-text search has small chance

to retrieve relevant documents because of lack of document surrogates content, and therefore, this chance can be barely found with precision at 10 (P@10). The Number of anchor-text predictor is the worst predictor, and does not perform well on the training set or evaluation set. The speculative reasons that can be stated are two reasons: first, enormous numbers of document surrogates do not contain anchor-text which may be relevant. The second reason is that, while the number of anchor-text items pointing to a document can be an indication of the importance of that document; this does not necessarily mean that the document is actually relevant.

TABLE XI. COMPARISON OF PREDICTOR EFFECTIVENESS FOR EACH RETRIEVAL MODEL WITH AVERAGE PRECISION (AP) AND PRECISION AT 10 (P@10)

Metric	Predictor	Okapi	Dirichlet	Cosine
AP	Similarity of Full-text	3	3	-
	Similarity of anchor-text	-	3	-
	Number of anchor-text	-	-	-
	Similarity of Full-text with Similarity of anchor-text	2	2	2
	Similarity of Full-text with MaxIDF	2	3	-
	Similarity of anchor-text with MaxIDF	-	3	-
P@10	Similarity of Full-text	3	3	-
	Similarity of anchor-text	-	-	-
	Number of anchor-text	-	-	-
	Similarity of Full-text with Similarity of anchor-text	-	-	-
	Similarity of Full-text with MaxIDF	2	2	-
	Similarity of anchor-text with MaxIDF	-	1	-

Where, 1; 2 and 3 are the number of correlation coefficients (Tau, Cor and Rho) that are consistent and statistically significant on all topics (TREC-9 and TREC-10)

VI. CONCLUSIONS AND FUTURE WORK

Query difficulty prediction aims to determine, in advance of showing a set of search results to a user, whether the results are likely to be useful. The ultimate aim, if prediction is successful, is to optimize the performance of search engines. Many predictors have been proposed since the emergence of this technique. Despite intensive research in this area, effective prediction of query difficulty is still an open question for researchers. This study aims to investigate the effectiveness of using full-text and anchor-text similarities to predict the performance of retrieval systems that run on full-text. Six predictors have been proposed in this study, three of which are based on one source of evidence, while the rest are based on combining two sources of evidence. We conducted our experiments on WT10G data collection of web documents, and document surrogates (created by harvesting all anchor-text from the WT10g collection) and used three retrieval models: Okapi BM25 retrieval function; vector space model; unigram language model (using Dirichlet prior smoothing). Three different correlation coefficients (Pearson (Cor), Kendall (Tau), and Spearman (Rho) correlation) were used to evaluate the performance of the techniques, by calculating the correlation

between the predicted performance and the average precision (AP) and precision at 10 (P@10) for each retrieval model. Queries from TREC-9 were used as a training set to determine suitable parameter settings. TREC-10 queries were used as the evaluation set. The performance of the proposed predictors were compared with the performance of two baseline predictors (MaxIDF and SCS) that have been shown to work well in the literature.

The results of some of our proposed predictors demonstrate promising performance and provide a significant correlation between predicted performance and actual performance of retrieval systems, compared with the baseline predictors. These predictors are divided into two classifications: single predictors and combined predictors. The single predictors are similarity of full-text; similarity of anchor-text and the number of anchor-text. The first two predictors outperform the baselines in most correlations, and work well with the Okapi and Dirichlet retrieval models. However, they perform poorly for the Cosine model. As for combined predictors, they are similarity of full-text with similarity of anchor-text, similarity of full-text with MaxIDF, and similarity of anchor-text with MaxIDF. It is apparent from the results of our study that the performance of combined predictors is broadly stronger than baseline and single predictors. It is noted that the performance of each predictor depends on the used retrieval system, correlation coefficient and query set. None can highly perform for all retrieval systems and query sets with all correlation coefficients. Therefore, we recommend that the suitable predictors be chosen for each retrieval model. For Okapi, the best performance overall is given by the Similarity of Full-text, Similarity of Full-text with MaxIDF and Similarity of Full-text with Similarity of anchor-text predictors with average precision (AP), while with precision at 10 (P@10) the first two predictors. For language model (Dirichlet), all proposed predictors work well with AP except the number of anchor-text predictor, while with P@10, similarity of Full-text and similarity of Full-text with MaxIDF predictors work well. For Cosine function, only similarity of Full-text with similarity of anchor-text predictor work well with AP, while none works well with P@10.

In our results, it can be seen that the proposed predictors perform poorly for the Cosine model. In future work, we intend to investigate the issue behind this poor performance. It was seen that using different correlation coefficients leads to different results about the performance of predictors. Therefore, a further methodology of query difficulty prediction is needed to determine appropriate measures for this task. The average count of anchor-text for non-empty document surrogates is 8.6 anchor-texts; while document surrogates that do not contain anchor-text (empty) number 355,324 documents. The small number of anchor-text in each document surrogate and the large number of empty document surrogates can be attributed to the small size of the test collection (WT10G). This is because the empty document surrogates could be pointed to by links, but not in this test collection and non-empty document surrogates could be pointed by more links. Therefore, we plan to carry out follow-up experiments on larger data collections.

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A Survey on the Cryptographic Encryption Algorithms

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Abstract—Security is the major concern when the sensitive information is stored and transferred across the internet where the information is no longer protected by physical boundaries. Cryptography is an essential, effective and efficient component to ensure the secure communication between the different entities by transferring unintelligible information and only the authorized recipient can be able to access the information. The right selection of cryptographic algorithm is important for secure communication that provides more security, accuracy and efficiency. In this paper, we examine the security aspects and processes involved in the design and implementation of most widely used symmetric encryption algorithms such as Data Encryption Standard (DES), Triple Data Encryption Standard (3DES), Blowfish, Advanced Encryption Standard (AES) and Hybrid Cubes Encryption Algorithm (HiSea). Furthermore, this paper evaluated and compared the performance of these encryption algorithms based on encryption and decryption time, throughput, key size, avalanche effect, memory, correlation assessment and entropy. Thus, amongst the existing cryptographic algorithm, we choose a suitable encryption algorithm based on different parameters that are best fit to the user requirements.

Keywords—Cryptography; encryption algorithms; Data Encryption Standard (DES); Triple Data Encryption Standard (3DES); Blowfish; Advanced Encryption Standard (AES); Hybrid Cubes Encryption Algorithm (HiSea)

I. INTRODUCTION

Security plays an important role to store information and transmit it across the undefined networks with secure manner. Hence, the secure communication is the basic requirement of every transaction over networks. Cryptography is an essential component for secure communication and transmission of information through security services like confidentiality, data integrity, access control, authentication and non-repudiation. It provides a way to protect sensitive information by transferring it into unintelligible and only the authorized receiver can be able to access this information by converting into the original text. The process to convert the plaintext into ciphertext with the key is called encryption process and to reverse the process of encryption is called decryption process. The design of cryptographic algorithms is secure and efficient, low cost, require small memory footprint, easy to implement and utilized on multiple platforms. The vast range of applications is developed to secure cryptographic algorithms using different mathematical process. It is quite difficult to develop

fully secure encryption algorithm due to the challenges from cryptanalysts who continuously trying to access any available cryptographic systems [1]-[5]. The right selection of algorithms is important to achieve high-security requirements which protect the cryptographic components to cryptanalysis [6].

Cryptographic systems can be divided into deterministic and probabilistic encryption scheme [7]. Deterministic encryption scheme allows the plaintext is encrypted by using keys that always provide the same ciphertext, but the encryption process is repeated many times. In this scheme, every plaintext has one to one relationship with the keys and ciphertext otherwise it will produce more than one output of particular plaintext during the decryption process. Probabilistic Encryption Scheme shows the plaintext has different ciphertext with the different keys. The probabilistic encryption scheme is significantly secure than the deterministic encryption scheme because it makes difficult for a cryptanalyst to access any sensitive information regarding plaintext that is taken from ciphertext and corresponding key. Furthermore, the cryptographic algorithms can be further divided into two main categories like keyless cryptosystem and key-based cryptosystem as shown in Fig. 1. In the keyless cryptosystem, the relationship between the plaintext and ciphertext having a different version of the message is exclusively depend on the encryption algorithm [8]. The keyless cryptosystem is generally less secure than key-based systems because anyone can gain access to the algorithm will be able to decrypt every message that was encoded using keyless cryptosystem such as Caesar cipher [9]. The key-based cryptosystem can be further categories into symmetric key (secret key) encryption and asymmetric key (public key) encryption based on the type of security keys utilized for the encryption or decryption process [10]-[13]. The detail of the cryptosystems is explained as follows:

A. Symmetric Key Encryption

The symmetric key (secret key) encryption is employed similar key for the encryption and decryption of a message. Encryption and decryption keys are keeping secret and only known by authorized sender and recipient who want to communicate. The allocation of different keys to the different parties increases the overall message security. The strength of the symmetric key encryption is depending on the secrecy of encryption and decryption keys. The symmetric encryption algorithms can be classified into block and stream cipher on

the basis of the grouping of message bits [14], [15]. In a block cipher, a group of messages characters of a fixed size (a block) is encrypted all at once and sent to the receiver. Moreover, the block cipher can be further divided into binary and non-binary block cipher based on the final results of the message, keys and ciphertext. The message bit size for the binary block cipher is 64, 128, 192, and 256 and the non-binary block cipher has not defined the standard that depends on the cipher implementation.

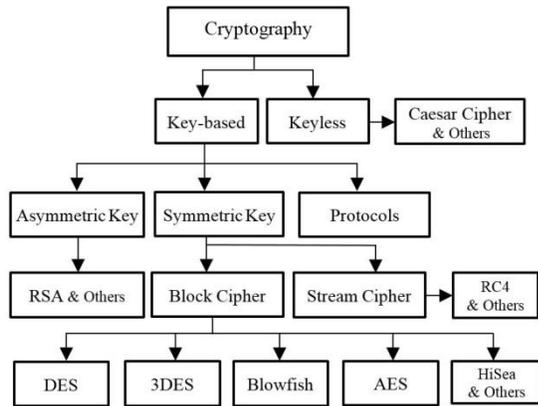


Fig. 1. Overview of the cryptographic encryption algorithms.

Symmetric key block cipher comprises the five main components: plaintext, encryption and decryption algorithm, ciphertext and key schedule algorithm as shown in Fig. 2. There are several symmetric key encryption algorithms such as DES [16], [17], 3DES [9], AES [18], [19], BLOWFISH [20], HiSea [21], RC4 [22], etc. The encryption process in symmetric block cipher converts the plaintext into ciphertext with the secret key that is generated from the key schedule algorithm. Similarly, the ciphertext is transferred to the appropriate recipient is decrypted using decryption process with the same key.

The block size for the stream cipher is one character and it is not more appropriate for software processing due to the key length as long the message [23], [24]. The working of the stream cipher is presented in following steps:

- 1) A single character of plaintext is combined with a single character from key stream to produce the single character of ciphertext.
- 2) The ciphertext character from Step 1 sent to the receiver.
- 3) Step 1 and Step 2 is repeated until the entire message has been sent.

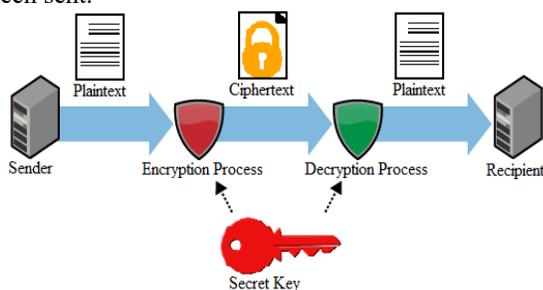


Fig. 2. Components of symmetric block cipher.

B. Asymmetric Key Encryption

The asymmetric key encryption is commonly referred to as public key encryption in which different keys are employed for the encryption and decryption of the message. The encryption key is also said as the public key and can be utilized to encrypt the message with the key. The decryption key is said to as secret or private key and can be used to decrypt the message. The strength of the asymmetric key encryption is utilized with digital signature then it can provide to the users through message authentication detection. The asymmetric encryption algorithm includes RSA [25], Diffie-Hellman algorithm [26], etc. The component of an asymmetric block cipher is shown in Fig. 3.

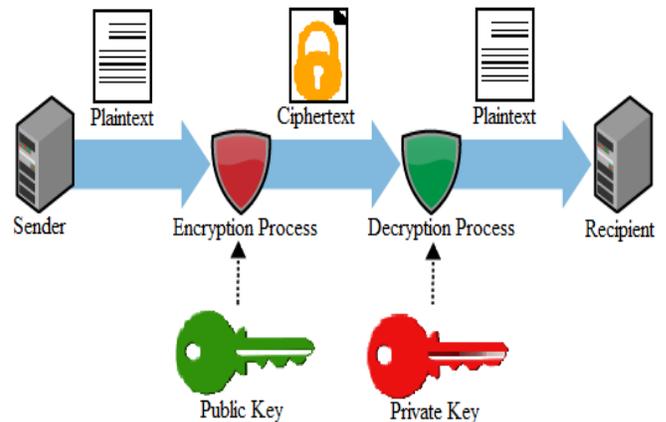


Fig. 3. Components of asymmetric block cipher.

C. Key Schedule Algorithm

Key schedule algorithm is employed to generate secret keys and plays an important role in the development of encryption and decryption key. The insignificant key generation algorithm generates weak keys that are used for encryption process can easily attack using brute force attack because cryptanalyst continuously trying all possible combinations to get original text using this attack [27]-[29]. All cryptographic algorithms follow the consideration of Advanced Encryption Standard (AES) that must support the key lengths include 128 bits, 192 bits and 256 bits [19]. The number of the round for that key length is 10, 12, 14 respectively and the round keys are taken from the cipher key using key schedule algorithm and utilized in the construction of block cipher. For the development of fully secure block cipher, the multiple numbers of rounds ensure the high diffusion and employed invertible transformation.

D. Shannon's Principles for Symmetric Block Cipher

Claude Shannon [30] proposed a set of five criteria for good ciphers is defined as follows:

- 1) In order to cipher a message, the degree of secrecy is required to determine the amount of labor. The value of information tends to decline over time, so additional computation labor is needed to protect the message secrecy for thousands of years that may not be secure in the perspective of information theory.

- 2) Cryptographic keys and encryption algorithms should

be free from complexity. Encryption algorithm should be capable to encrypt any message using any key and the algorithm easy to understand.

3) Implementation of a cipher should be as simpler as possible.

4) Generation of error should be limited.

5) The size and storage required for the ciphertext message should be restricted. Make sure that from where it was executed, the size of the ciphertext should not exceed the size of plaintext under any circumstances.

From the historical perspective, it is interesting to note that these five criteria for good cipher are proposed earlier of the computer age and still they are perfectly valid. Furthermore, the Shannon's introduced the two principles of confusion and diffusion that are very important and closely related the functionality included in the development of secure encryption and decryption algorithms [30], [31]. The principle of confusion refers as the hides and complicating the relationship between the ciphertext and the keys (encryption or decryption key) as much as possible. It will help to prevent from cryptanalyst to predict the secret key using ciphertext. The principle of diffusion refers as the hides and complicating the relationship between the plaintext and ciphertext. It will ensure the small modification in the plaintext effects the unpredictable changes and create avalanche effect to the ciphertext. The relationship between the confusion and diffusion with cipher component is shown in Fig. 4.

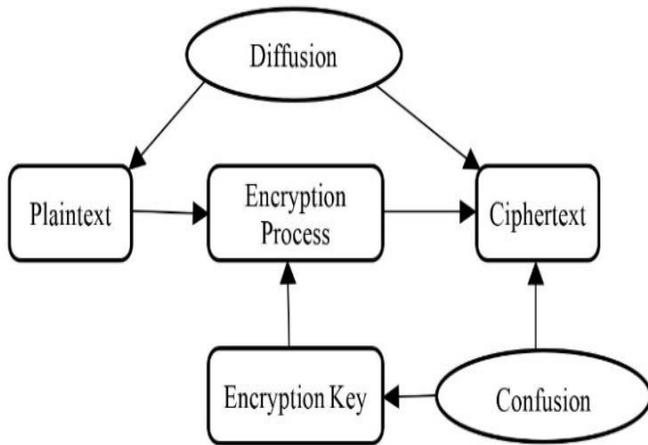


Fig. 4. Relationship between the confusion and diffusion.

E. Evaluation Parameters

To evaluate the efficiency and security, it is required to pass the execution test. Every encryption algorithm has some strength and weaknesses. In order to employ a secure encryption scheme to the applications, we need to evaluate the performance parameters [24], [32]-[35]. In this study, some of the evaluation parameters are discussed.

1) *Encryption time*: The time required to convert the plaintext into the ciphertext is said to be an encryption time. The encryption time is based on the message block size and the key size, and is represented in milliseconds. It has a direct impact on the performance of the encryption algorithm. Every

cryptographic algorithm requires minimum encryption time, in order to make the encryption scheme responsive and fast.

2) *Decryption time*: The time required to recover the plaintext from ciphertext is said to be decryption time. For the purpose of a cryptographic algorithm that is fast and responsive, it is desirable that the decryption time be less similar to the encryption time and it is also measured in milliseconds.

3) *Memory used*: Memory size depends on the implementation of different algorithms. The memory requirement depends on the key size, initialization vectors, and type of operations. It is more desirable that memory size should be small because it impacts on the cost of the system.

4) *Throughput*: For calculating the throughput of an encryption algorithm, divide the total block size (MegaByte) encrypted by the total encryption time. If the throughput value is increased, then the power consumption of the algorithm is decreased.

5) *Avalanche effect*: It determines whether there is any change in the plaintext, then the ciphertext will change significantly. In other words, we can say that it measures the dissimilarity between the plaintext and ciphertext changes. The avalanche effect can be measured using the Hamming distance. If a high degree of diffusion is required, then a high avalanche effect is desirable. It reflects the performance of cryptographic algorithms and can be calculated by dividing the Hamming distance on the file size.

$$\text{Avalanche} = \frac{(\text{Total number of bits} - \text{number of flip bits})}{\text{Total number of bits}} \times 100 \quad (1)$$

6) *Entropy*: The strength of overall implementation of the algorithm is estimated by using a random matrix technique. Entropy is used to measure the randomness and uncertainty in the data. The relationship between the ciphertext and key becomes more complex with high randomness. Encryption algorithms require high randomness in encrypting the plaintext, it results in less or no dependency between the ciphertext and key. This property is referred to as confusion. A high degree of confusion is desirable that makes it difficult for an attacker to guess the entire set of information. To calculate Shannon's entropy test using the following equation:

$$H(X) = - \sum_{i=0}^{n-1} p(x_i) \log_b p(x_i) \quad (2)$$

7) *The number of bits required for encoding optimally*: This evaluation parameter defines the bandwidth required for transmission. An encrypted character or bits encoded with a less number of bits, it will consume less storage and bandwidth. It also impacts on the cost of the system.

This paper explains the overview and performance factors involved during the design of symmetric encryption algorithms such as DES, 3DES, Blowfish, AES and HiSea. The main objectives of this research can be summarized as follows:

- 1) To review the existing encryption algorithms that explore what and how many parameters involved in the development of secure encryption technique.
- 2) To track the trends of research in this field.
- 3) To identify the significances of this area.
- 4) To present the existing performance evaluation in cryptographic schemes and suggest the best encryption scheme based on user requirement.

Firstly, we deeply review and compare the existing symmetric encryption algorithms based on security parameters. The selection of symmetric encryption algorithm instead of asymmetric encryption algorithm because its implementation is very fast, efficient, effective and simple to employ for encryption and decryption process. Furthermore, the AES is symmetric block cipher employed for encryption and decryption of message adopted by the United State of America [36]. Every cryptographic algorithm considered as approval with AES that required to fulfil the validation and execution time's test [19]. Later on, the performance analysis is based on the results of different researchers and addresses the fundamental aspects in the development of encryption algorithm that is based on encryption and decryption time, throughput, key size, avalanche effect, memory, correlation assessment and entropy for the selected cryptographic algorithm. Finally, the best suitable cryptographic algorithm is chosen based on different parameters for further research and future directions are also explored.

The remaining paper is organized as follows: Section II discusses some cryptographic encryption algorithms which include the overview of existing symmetric encryption algorithms. Section III explains the results and analysis of encryption algorithms that are discussed in the previous section. Section IV includes the conclusion and future directions of this research.

II. CRYPTOGRAPHIC ENCRYPTION ALGORITHMS

This section explains the review of existing encryption algorithms that are used to conclude the better encryption scheme based on different parameters.

A. Data Encryption Standard (DES)

DES is the earliest symmetric encryption algorithm developed by IBM in 1972 and adopted in 1977 as Federal Information Processing Standard (FIPS) by the National Bureau of Standard (NBS). The NBS is currently the National Institute of Standards and Technology (NIST) that evaluate and implement the standard encryption algorithm. It includes 64 bits key that contains 56 bits are directly utilized by the algorithm as key bits and are randomly generated. The remaining 8 bits that are not used by algorithm because it is used for the error detection as set to make a parity of each 8-bit byte [17], [37], [38]. DES utilized the one secret key for encryption and decryption process and key length is 56 bits and performs the encryption of message using the 64 bits block size. Similarly, the decryption process on a 64 bits ciphertext by using the same 56 bits key to produce the original 64 bits block of the message is shown in Fig. 5. The DES algorithm processes the 64 bits input with an initial permutation, 16 rounds of the key and the final permutation.

The DES algorithm structure is based on Feistel function that divided the block into two halves. The function (f) based on the four stages such as expansion, key mixing, substitution and permutation. The number of rounds applies for the DES is 16 used for the processing to encrypt the message.

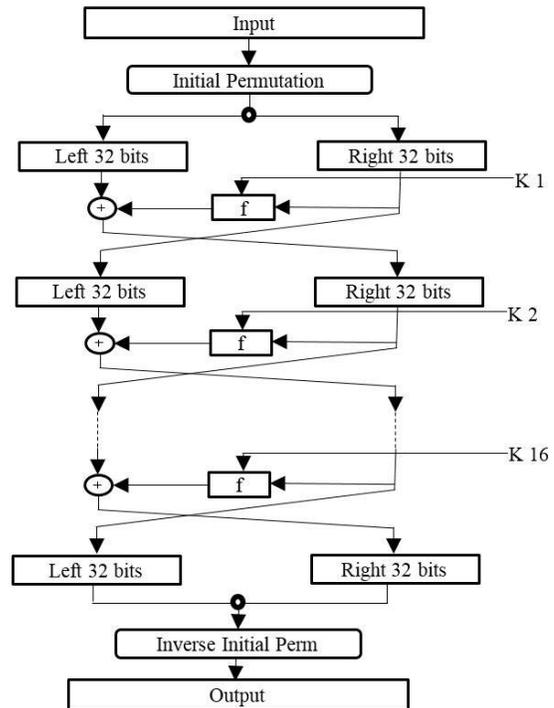


Fig. 5. Data Encryption Standard (DES) Algorithm.

The output after the 16 round consists of 64 bits that are the function of the input message and the key. DES mostly used in the banking industry, commercial and military secret information sharing purpose. Security is the major concern in DES because it uses the 56 bits key (2^{56}) or 7.2×10^{16} keys and cryptanalysts are trying to crack an encrypted message by key exhaustion. Brute force attack is possible through parallel machines of more than 2000 nodes with each node that has capabilities of key search 50 million keys/sec [39]. DES is cracked in 1998 by using Electronic Freedom Foundation constructed device within 22 hours due to the less number of key length and is highly susceptible to the linear cryptanalysis attacks.

B. Triple Data Encryption Standard (3DES)

Triple Data Encryption Standard (3DES) referred as Triple Data Encryption Algorithm (TDEA) that was firstly proposed by IBM in 1998 and standardized in ANSI X9.17 and ISO 8732. 3DES was appeared as the replacement of DES due to the improvement in the key length and applies the DES algorithm to the three times in each data block. The 56 bits key length of DES algorithm was generally adequate earlier when the algorithm designed but as the computation power increases then the brute force attack is feasible. On the other hand, 3DES provides a very simple method by the increment of key length instead of design a complete block cipher and it protects against the brute force attack. A brute force attack continuously trying every possibility of accessing keys until

the original message is obtained. Table 1 demonstrated four key sizes that show how long it required for the various key spaces [9], [40]. The DES employed the 56 bits key size and 3DES utilized the 168 bits key size.

The key length for the 3DES is 112 bits and 168 bits, the number of rounds 48 and the block size is 64 bits [41]. The purpose of this algorithm is to increase the security with longer key length, so it is challenging for the cryptanalyst to predict the pattern and attacks become rapidly impractical. The Key size, Number of keys, Time required at 1 Decryption/ μ s and Time required at 10^6 Decryption/ μ s is represented as Ks, Nk, Tr1D, Tr10⁶D respectively.

TABLE I AVERAGE TIME REQUIRED FOR EXHAUSTIVE KEY SEARCH

Ks	Nk	Tr1D	Tr10 ⁶ D
32-bits	$2^{32} = 4.3 \times 10^9$	$2^{31} \mu s = 35.8$ minutes	2.15 millisecond
56-bits	$2^{56} = 7.2 \times 10^{16}$	$2^{55} \mu s = 1142$ years	10.01 hours
128-bits	$2^{128} = 3.4 \times 10^{38}$	$2^{127} \mu s = 5.4 \times 10^{24}$ years	5.4×10^{18} years
168-bits	$2^{168} = 3.7 \times 10^{50}$	$2^{167} \mu s = 5.9 \times 10^{36}$ years	5.9×10^{30} years
26 characters (permu)	$26! = 4 \times 10^{26}$	$2 \times 10^{26} \mu s = 6.4 \times 10^{12}$ years	6.4×10^6 years

The main advantage of the 3DES algorithm is three times secure having key size 2^{168} (use keys as a combination or each level with different keys size) as compared to DES algorithm having key size 2^{56} , that's why 3DES algorithm is preferred as compared to the DES algorithm. Moreover, it provides adequate security to the information but the problem with that it consumes more time in encryption process as compare to DES. The encryption algorithm of 3DES is presented as follows:

$$C = \text{Encrypt}_{K_3}(\text{Decrypt}_{K_2}(\text{Encrypt}_{K_1}(P))) \quad (3)$$

and decryption algorithm of 3DES is given as follows:

$$P = \text{Decrypt}_{K_3}(\text{Encrypt}_{K_2}(\text{Decrypt}_{K_1}(C))) \quad (4)$$

Where C represented the ciphertext, P represented the plaintext and K1, K2, K3 represent the keys.

The overview and attraction of 3DES over next few years can be defined in two ways [9]. Firstly, it overcomes the vulnerability of brute force attack of the DES by using 168 bits key size. Secondly, the encryption algorithm of 3DES is similar as in DES due to that more analysis than another algorithm over long time period. Moreover, this algorithm didn't find any effective cryptanalysis attack rather than brute force. If we analyze in term of security, then 3DES appears as a suitable choice for the standard encryption algorithm in future decades. The major drawback of the 3DES algorithm is that it is slow in software because DES was designed in 1972 in hardware implementation with no efficient software. 3DES algorithm has three more times more rounds, that's why it is correspondingly slow. The second drawback of DES and 3DES is that it uses 64 bits block size and for the demand of more security and efficiency, the large block size is desirable.

C. Advanced Encryption Standard (AES)

The NIST announced a call for the candidates of a cipher to implement a new encryption standard in 1997 because of the need for high security and efficiency, it's time to replace the existing DES and 3DES encryption algorithm with new AES. All candidates of ciphers submitted its proposal by 1998 and finalized in 2000. Finally, Rijndael was selected as the AES out of 15 candidates. Rijndael is developed by Vincent Rijmen and Joan Daemen in 2001. US government is employed AES to protect sensitive information and implemented across the world for data encryption purpose in form of software and hardware. AES appears as the recent generation block cipher and significantly increases in the block size up to 128 bits with the key sizes 128 bits, 192 bits and 256 bits. The number of rounds set with respective key size is the 10, 12, 14 for the 128 bits, 192 bits, 256 bits, respectively [9], [42], [43]. The number of AES parameters based on the key length mentioned in Table 2. The parameters Key size, Block size, Number of rounds, Round key size, and expanded key size are represented as Ks, Bs, Nr, Rks, Eks, respectively.

AES was designed with the following characteristics:

- Compactness of code and speed on the large range of platforms.
- Simple design.
- Protection against all known attacks.

The data blocks are used as the array of bytes and represented in a matrix that is referred as the state array which changed in every step of encryption and decryption process. Each round follows some steps during encryption process to complete each round until 'n'. After the final step, the state array is transferred into output matrix [18], [19], [44]. The steps for each round consist of four layers i.e. substitute byte, shift rows, mix column and add round key is shown in Fig. 6. In the first layer, S-box of order 8 is applied to each byte. For the linear mixing, the second and third layers are used. In these layers, the columns are mixed, and rows of the array are shifted. The subkey bytes are XORed with every byte of the array in the fourth layer. The round operation is done iteratively that is based on the key size. The decryption process has also the similar operation and same sequences of transformations as with the encryption, but it employed in the reverse order. The transformation is an inv-substitute byte, inv-shift rows, inv-mix columns and adds round key that assigns the key schedule form as identical for encryption and decryption process. All operation of AES can be combined into XOR operation and a lookup table, so the implementation can be very efficient and fast.

TABLE II ADVANCED ENCRYPTION STANDARD PARAMETERS

Ks (words/bytes/bits)	Bs (words/bytes/bits)	Nr	Rks (words/bytes/bits)	Eks (words/bytes)
4/16/128	4/16/128	10	4/16/128	44/176
6/24/192	4/16/128	12	4/16/128	52/208
8/32/256	4/16/128	14	4/16/128	60/240

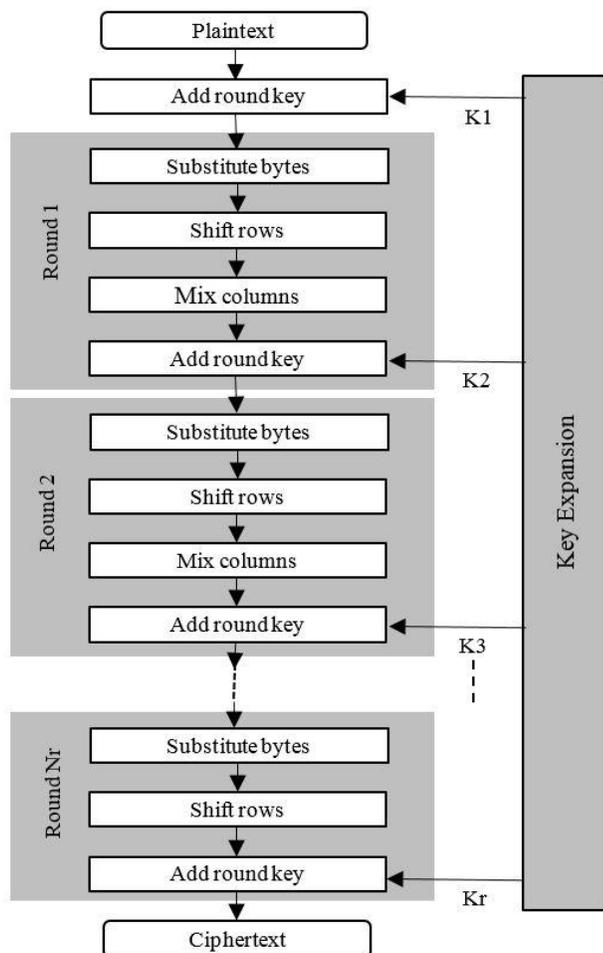


Fig. 6. Advanced Encryption Standard (AES) Algorithm.

D. Blowfish

Blowfish is symmetric block cipher based on the Feistel function that is effectively used for encryption and decryption process. It was introduced by one of most leading cryptologists Bruce Schneier in 1993. Most of the encryption algorithms are not available for the public and most of them are protected by patent. Blowfish is fast, license free, unpatented, freely available and alternative for existing encryption algorithms. It uses the key length range up to 32-448 and 64 bits block. Blowfish algorithm employed 16 rounds for the encryption process. Blowfish is a Feistel structure that consists of 16 rounds shown in Fig. 7. This algorithm considerably analyzed and with the instance of time, it gains popularity as a robust block cipher [38]. Like the other ciphers, this algorithm also effectively used in VLSI hardware and can be optimized in software application [16], [45]. The input as a plaintext is 64 bits data E.

Divide the data E into two halves of 32 bits: EL, ER

For $i = 1$ to 16:

$$EL = EL \text{ XOR } EP_i$$

$$ER = F_n(EL) \text{ XOR } ER$$

Swap EL and ER

Next i

Swap EL and ER (Undo the last swap.)

$$ER = ER \text{ XOR } EP_{17}$$

$$EL = EL \text{ XOR } EP_{18}$$

Recombine EL and ER

Function F_n is represented as follows:

Divide EL into four 8 bits quarters: w, x, y, and z

$$F_n(EL) = ((S_1, w + S_2, x \text{ mod } 2^{32}) \text{ XOR } S_3, y) + S_4, z \text{ mod } 2^{32}.$$

The decryption process of Blowfish algorithm is similar as encryption process, except that $EP_1, EP_2, \dots, EP_{18}$ are employed in the reverse order. Blowfish primarily utilized four S-boxes instead of the one S-box to prevent similarity between the different bytes when the input is equal to the 32 bits input to the function F_n is bitwise permutation with other input of 32 bits [46]. This algorithm used one S-box in each process, so four different outputs are generated a non-trivial permutation of each output. The design of four S-box seems more secure, faster and easy to program. The function that joins the output of four S-boxes is fast that would be XOR the four output values with mix addition of $\text{mod } 2^{32}$. The repetition of addition in each round and all XOR operations end with an addition because the final result is combined with XOR to the RE.

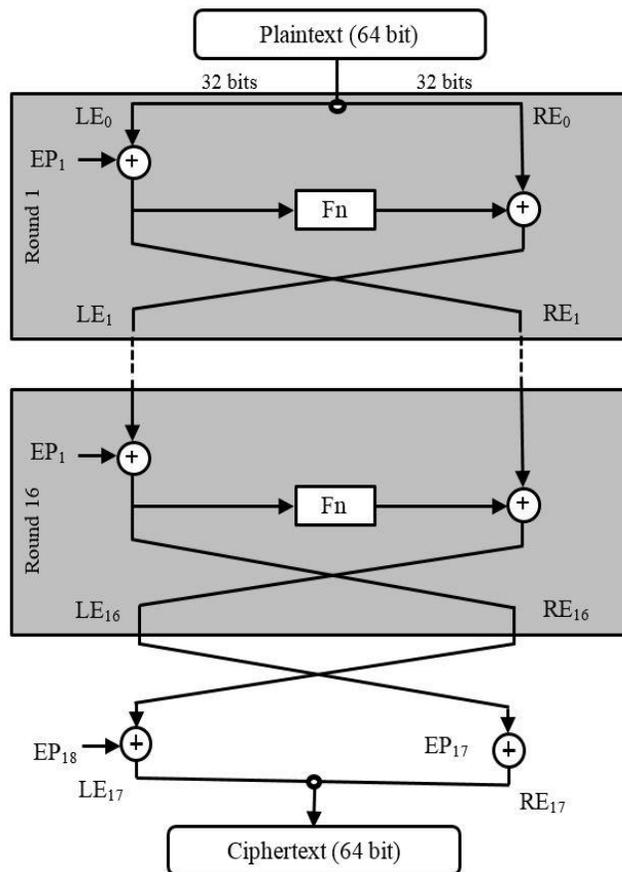


Fig. 7. Blowfish Encryption Algorithm.

Blowfish algorithm needed more processing time because it depends on the key size. The subkey generation process increases the complexity that protects from brute force attack and provides better security than existing encryption techniques. Moreover, the use of a large number of weak keys will damage the reliability of Blowfish [39]. It also utilized 64 bits block, but the larger block size is more desirable.

E. Hybrid Cubes Encryption Algorithm (HiSea)

Hybrid Cube Encryption Algorithm (HiSea) is the symmetric non-binary block cipher because the encryption and decryption key, plaintext, ciphertext and internal operation in the encryption or decryption process that is based on the integer numbers. HiSea encryption algorithm is developed by Sapiee Jamel in 2011. The plaintext size for the encryption process is the decimal ASCII characters of 64 bytes. Hybrid Cube (HC) is generated based on the inner matrix multiplication of the layers between the two Magic Cubes (MC) [47]. HC of order 4x4 matrix $H_{i,j}$, $i \in \{1, 2, 879\}$ and $j \in \{1, 2, 3, 4\}$ is defined as follows:

$$H_{i,j} = MC_{i,j} \times MC_{i+1,j} \quad (5)$$

where the $MC_{i,j}$ is a j^{th} layer of i^{th} magic cubes.

Let us consider the HC 1 is generated through the inner matrix multiplication of MC 1 layer with $\{x=1, 2, 3, 4\}$ coordinates and MC 2 layer having coordinates $\{x=1, 2, 3, 4\}$. Similarly, HC 2 is generated with the inner matrix multiplication of MC 2 and 3, and so on. A new cube structure HC is generated by using the layers of MC where the layer entries lie between the set of integers $\{1, 2, 3, \dots, 4096\}$. All possible combination of HC layer entries can be utilized to increase complexity in the design of encryption and decryption algorithms [48], [49]. The overall design of the HiSea in which the plaintext, keys and ciphertext in encryption process are formatted into order 4 matrix is shown in Fig. 8. The encryption algorithm used the following steps:

1) The plaintext is format as 64 characters into 64 Extended ASCII codes and four matrices of Plaintext is represented as P1-P4. The intermediate result (P1') for P1 is used in the encrypting process of P2. The intermediate result (P2') for P2 is used in the encrypting process of P3. This process is repeated for P4. The major reason for integrating this method to ensure any change made in P1 will reflect into another ciphertext. The process of diffusion is performing on the initial stage to increase complexity in the ciphertext.

2) P1 is mixed with Initial Matrix (IM), P2, P3 and P4 that generate the temporary ciphertext called P1'. P1' is then added with the session Key 1 (K1). The Function MixRow and MixCol are used to create diffusion in Ciphertext 1 (C1).

3) P2 is mixed with P1' to produce P2'. This plaintext is then added with session Key 2 (K2). The results derive through MixRow and MixCol that create diffusion in Ciphertext 2 (C2).

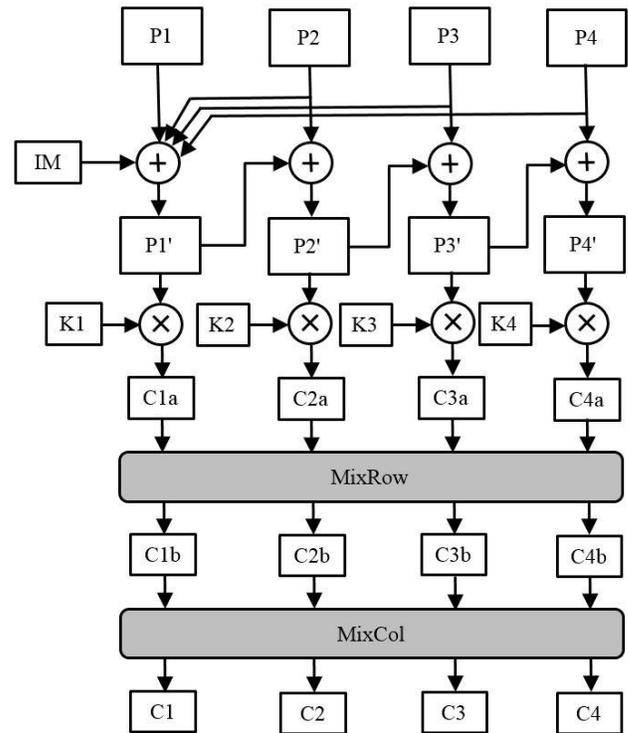


Fig. 8. Hybrid Cube Encryption Algorithm (HiSea).

4) Repeat step 3 with P3 and P4 to generate Ciphertext 3 (C3) and Ciphertext 4 (C4)

HiSea is computationally secure and has a large key space $10^{153.6}$ keys that make the brute force attack difficult or time-consuming [21], [27]. Furthermore, the comparison of different encryption algorithm is presented in Table 3.

III. RESULTS AND DISCUSSION

This section explains the performance analysis based on the results of different researchers and addresses the security aspects in the development of encryption algorithm based on the evaluation parameters. Moreover, there is a number of studies that assembling up-to-date development and improvement in this field. Some researchers have a major focus on surveying about the cryptographic algorithms and their performance evaluation. Generally, the performance of the block cipher depends on the block size and key length. The large block size will make the algorithm faster because a large portion of data will be encrypted in the single execution cycle. Similarly, the small block of data required more execution cycle that increase the overall execution time. On the other hand, the large key size will affect the algorithm performance because all key bits are involved in algorithm execution that makes the slower performance. However, the large key length brings the algorithm more security and provides more protection against cryptanalyst. Moreover, the importance of performance evaluation is to determine the software and hardware related best configuration setting, allowing the assessment that which one algorithm setting is more efficiently and effectively solve the problem.

TABLE III COMPARATIVE ANALYSIS OF SYMMETRIC ENCRYPTION ALGORITHM

Algorithms/Parameters	DES	3DES	AES	Blowfish	HiSea
Published	1977	1998	2001	1993	2011
Developed by	IBM	IBM	Vincent Rijmen, Joan Daeman	Bruce Schneier	Sapiee Jamel
Algorithm Structure	Feistel	Feistel	Substitution- Permutation	Feistel	Substitution- Permutation
Block cipher	Binary	Binary	Binary	Binary	Non-Binary
Key Length	56 bits	112 bits, 168 bits	128 bits, 192 bits and 256	32 – 448 bits	1 – 4096 set of integers
Flexibility or Modification	No	YES, Extended from 56 to 168 bits	YES, 256 key size is multiple of 64	YES, 64-448 key size in multiple of 32	No
Number of Rounds	16	48	10, 12, 14	16	4
Block size	64 bits	64 bits	128 bits	64 bits	64 characters
Throughput	Lower than AES	Lower than DES	Lower than Blowfish	High	Lower than AES
Level of Security	Adequate security	Adequate security	Excellent security	Excellent security	Highly secure
Encryption Speed	slow	Very slow	Fast	Fast	Moderate
Effectiveness	Slow in both software and hardware	Slow in software	Effective in both software and hardware	Efficient in software	Efficient in software
Attacks	Brute force attack	Brute force attack, Known plaintext, Chosen plaintext	Side channel attack	Dictionary attack	Not yet

A performance comparison of symmetric encryption algorithms based on the execution time using Electronic Codebook (ECB) and Cipher Feedback (CFB) modes was considered [38]. They used different data size in bytes (20527, 36002, 45911, 59862, 69646, 137325, 158959, 166364, 191383 and 232398) for both modes and apply test on DES, 3DES, AES and Blowfish. Firstly, they execute the test using ECB mode on Pentium II having 266 MHz and Pentium 4 having 2.4 GHz machine, respectively. The average execution time (in seconds) of both machines and the comparison of the average execution time is given in Table 4 and Fig. 9.

TABLE IV AVERAGE EXECUTION TIME OF ENCRYPTION ALGORITHM IN ECB MODE

Algorithms/Machine	DES	3DES	AES	Blowfish
Pentium 2	134	383	228	108
Pentium 4	14	42	21	11

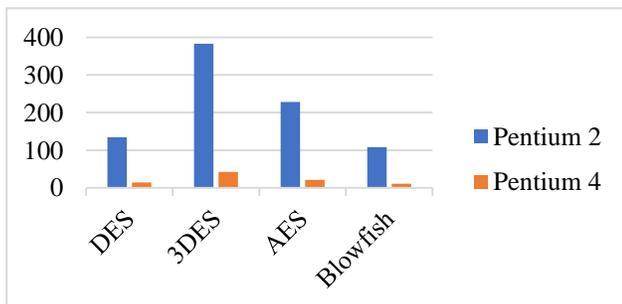


Fig. 9. Average execution time of algorithms in ECB mode.

It shows that the execution time in the encryption process of Blowfish is faster than the rest of the techniques but 3DES appear to be the slow in term of execution time using ECB mode. Moreover, the same data size is applied to find the execution time (seconds) in CFB mode shown in Table 5 and comparison of the results in Fig. 10.

TABLE V AVERAGE EXECUTION TIME OF ENCRYPTION ALGORITHM IN CFB MODE

Algorithms/Machine	DES	3DES	AES	Blowfish
Pentium 2	1015	2909	3551	812
Pentium 4	106	328	328	86

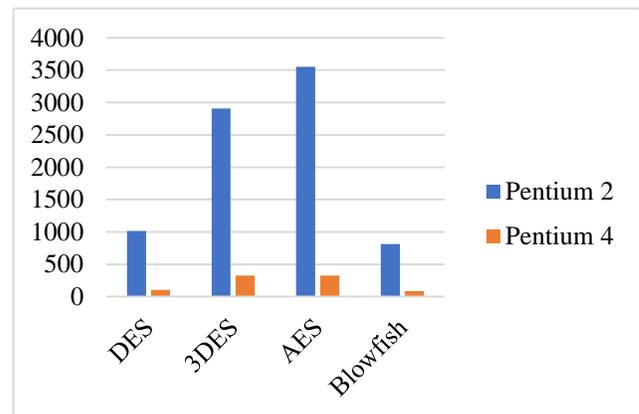


Fig. 10. Average execution time of algorithms in CFB mode.

The average execution time in encryption time shows that the Blowfish is faster than the other encryption technique using the CFB mode. Also, it is noted that the 3DES takes more encryption time as compare to DES due to the triple key size. Meanwhile, the performance evaluation of symmetric encryption algorithms that are based on different blocks size, key size, data types, encryption/decryption time and power consumption is explained [50], [51]. This paper evaluates the encryption algorithms such as DES, 3DES, AES and Blowfish and calculates the throughput by changing the block size. They used different block size in Kbytes (49, 59, 100, 247, 321, 694, 899, 963, 5345.28 and 7710.336) for the encryption and decryption algorithms. The execution is done on laptop IV and CPU 2.4 GHz. The throughput value of encryption and decryption process is shown in Table 6 and Fig. 11.

TABLE VI THROUGHPUT OF ENCRYPTION AND DECRYPTION ALGORITHM

Algorithm/Process	DES	3DES	AES	Blowfish
Encryption	4.01	3.45	4.174	25.892
Decryption	6.347	5.665	6.452	18.72

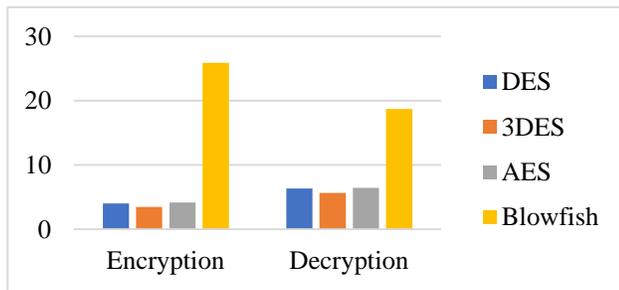


Fig. 11. Throughput of encryption and decryption algorithms (Megabyte/Sec).

The experimental result shows that the throughput value of Blowfish is better in encryption and decryption process than the other algorithms. The basic terminology is that the throughput value increases, then the power consumption will be decreased. We found that the AES performance is better than DES and 3DES. Moreover, the performance evaluation of DES and Blowfish is based on execution speed using different memory sizes and explain the relationship between the function memory size and run speed [16]. In this paper, performance is estimated on PC Pentium (R) 4, 3.00 GHz and run program 109 times to encrypt plaintext of 256 characters. The memory size is from 96M to 992M as illustrated in Table 7 and Fig. 12.

TABLE VII COMPARE THE RUN TIME (μS) BETWEEN DES AND BLOWFISH

Memory size/Algorithm	96	224	352	480	608	736	992
DES	1.1528	0.8370	0.8330	0.8463	0.8350	0.8440	0.8445
Blowfish	0.1503	0.1373	0.1234	0.1234	0.1250	0.1245	0.1245

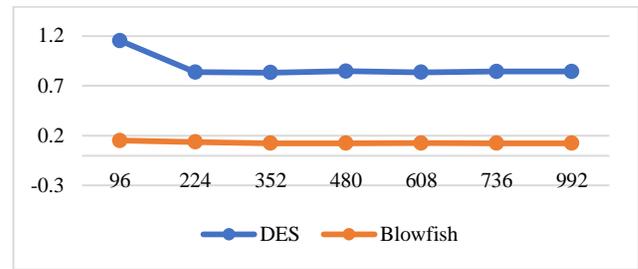


Fig. 12. Execution speed of DES and Blowfish.

The results demonstrate that the blowfish execution speed is faster than DES, but it consumes more memory to initialize the Subkey and S-box than the DES.

Meanwhile, the performance evaluation of the DES and AES is based on the parameters such as memory, simulation time and avalanche effect on Pentium dual-core T4300, 2.0 GHz with RAM 2GB [1]. The analysis of DES and AES based on different parameters is shown in Table 8 and Fig. 13.

AES shows significantly high avalanche effect than DES by changing the one bit in plaintext keep the constant key and variation of bits from 83 to 81. Also, it shows AES required less memory and execution time. So, AES is a better choice where the less memory is required. Meanwhile, the performance evaluation of DES and AES is based on the encryption time by using Intel Pentium processor 2.34 GHz and 1GB RAM [11]. Different size of files is used to evaluate the performance as demonstrated in Table 9.

The results show that the encryption time of AES is less than DES. So, it means that AES performance is much better than the DES as shown in Fig. 14.

TABLE VIII COMPARISON OF DES AND AES BASED ON AVALANCHE EFFECT, REQUIRED MEMORY AND EXECUTION TIME

Algorithm	Variation of 1 bit in plaintext having constant key	Variation of 1 bit in key having constant plaintext	Required memory	Execution Time
DES	43	41	43.3	0.32
AES	83	81	10.2	0.0304

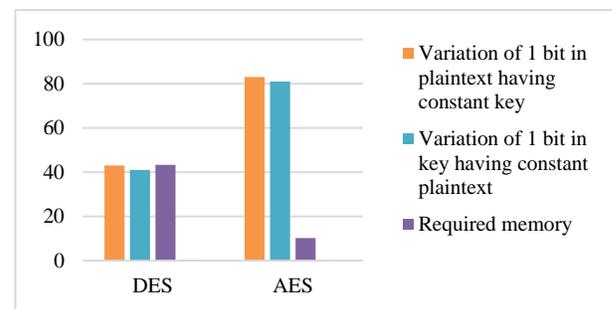


Fig. 13. Execution speed of DES and Blowfish.

TABLE IX PERFORMANCE EVALUATION BASED ON ENCRYPTION TIME

File Size (KB)	32	126	200	246	280
DES	0.27	0.83	1.19	1.44	1.67
AES	0.15	0.46	0.72	0.95	1.12

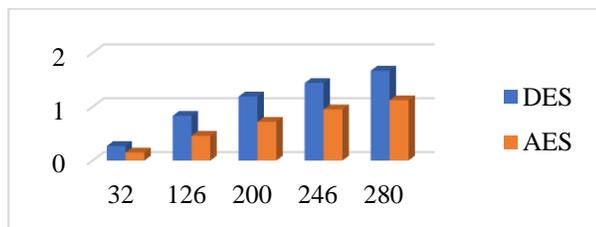


Fig. 14. Performance evaluation based on encryption time.

The evaluation of HiSea encryption algorithm is based on randomness between ciphertext and key, and the correlation between the message and ciphertext [48]. The simulation was performed on HP 2530, core 2 duo, 2.13 GHz and RAM 2GB. The Ciphertext (C1-C4), Session Key (SK), Initial Matrix (IM) and Correlation Assessment is illustrated in Table 10.

TABLE X ENTROPY AND CORRELATION ASSESSMENT FOR HiSEA

IM	SK	C1	C2	C3	C4	CA
0.8199	0.8632	0.9999	0.9998	0.9998	0.9995	0.0440

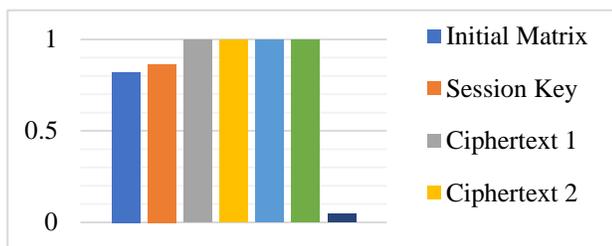


Fig. 15. Entropy (IM, SK, C1-C4) and correlation test.

The entropy results show that the keys generated through hybrid cubes are 0.8632 or 86.32% random and the initial matrix that is used to add plaintext 1 during the encryption process is 81.99% random demonstrated in Fig. 15. The keys used to generate a ciphertext are more than 99% random which means that ciphertext (C1-C4) blocks are almost random and hide the relationship between the key and ciphertext. The value of correlation test on HiSea is 0.0440 which means that there is no correlation exists between the message and ciphertext pairs. Furthermore, the performance analysis of AES (128, 192, and 256), DES, 3DES and Blowfish are based on the average response time with different data size of 1MB, 3MB, 7MB and 10MB using the laptop 2.4 GHz is shown in Table 11.

TABLE XI PERFORMANCE EVALUATION BASED ON AVERAGE RESPONSE TIME

File Size (MB)	DES	3DES	Blowfish	AES 128	AES 192	AES 256
1	0.14	0.39	0.08	0.12	0.14	0.15
3	0.38	1.08	0.22	0.33	0.37	0.43
7	0.99	2.71	0.51	0.79	0.91	1.03
10	1.34	3.63	0.71	1.10	1.25	1.41

The results demonstrate that the Blowfish takes less time to encrypt the specified file size than other encryption algorithms as shown in Fig. 16. AES-128 and AES-192 show

good response time than DES and 3DES but AES-256 takes more time than DES to encrypt the file sizes [52]. 3DES shows more response time to encrypt the file and provide less performance than the other encryption algorithms.

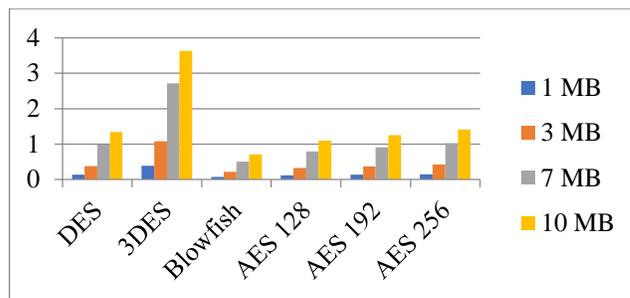


Fig. 16. Evaluation based on average response time.

In the end, overall results of encryption algorithms are presented based on the different evaluation parameters shown in Table 12. All cryptographic algorithms are depending on the block size, key and number of rounds. Generally, the algorithms must consider the security requirements such as computational resources availability, the application's requirements, and the distribution of secure key. In order to apply appropriate encryption algorithm for the applications, we must have knowledge about the strength, weakness, and performance based on different parameters. Blowfish is appeared as fast encryption scheme in terms of execution time, throughput and runtime that is better than DES, 3DES, AES and HiSea. An analysis based on brute force and correlation assessment shows that the HiSea encryption and decryption key are suitable in the development of secure non-binary block cipher. AES algorithm has excellent avalanche effect and high in execution time and performed better as compare to DES, 3DES. The problem with the AES algorithm is that it requires a significant amount of resources and power. The 3DES show the low performance in the following parameters because it uses 64 bits block size and 168 bits keys that have no more modification from DES only the three-time the key size, but it effects on throughput, encryption and decryption time. Also, DES and 3DES software are not more efficient. The demand for more efficiency and security is that it required the large block size and key size, smallest the memory and resources are desirable.

IV. CONCLUSION AND FUTURE WORK

A comprehensive review based on the cryptographic algorithm for the security of data has been performed in this paper. The detailed summary of a symmetric block ciphers such as DES, 3DES, AES, Blowfish and HiSea along with different design methodologies have been presented. The demonstration of results and discussion about these algorithms are mainly focused on evaluation parameter like encryption and decryption time, memory, avalanche effect, throughput, correlation assessment and entropy because these parameters show a more security, confidentiality, integrity, and reliability for secure communication. Based on the performance evaluation, the results of Blowfish, AES and HiSea provide more security based on the resources availability. Blowfish is the best option in those applications where the memory and

encryption/decryption time is the major factor and it is efficient in software. However, AES can be evaluated based on the avalanche effect that shows excellent performance and HiSea show good performance in term of entropy and correlation assessment. So, we conclude that the AES and HiSea can be employed in those applications where integrity and confidentiality is the highest priority.

HiSea provides great strengthened to the encryption algorithm because the entropy of encryption keys is 99%

random. However, based on the comparison between the symmetric block ciphers, the Blowfish is a best suitable candidate for security and it has the potential for further development due to a significant advantage in memory, encryption and decryption time, throughput and efficient encryption design. Based on the above study, this research analyzes that there is a need to develop the hybrid encryption algorithm which combines different encryption algorithms based on all suitable parameters that are used to enhance the overall security of the encryption techniques.

TABLE XII PERFORMANCE EVALUATION BASED ON DIFFERENT PARAMETERS

Algorithm	Evaluation Parameters	Nadeem et al. (2005)	Elminaam et al. (2008, 2009)	Nie et al. (2009)	Jamel et al. (2011)	Mandal et al. (2012)	Silva et al. (2016)	Faiqa et al. (2017)
DES	Encryption time	**				*	**	*
	Throughput		**					
	Run time test			*				
	Memory			***		*		
	Avalanche effect					*		
3DES	Encryption time	*					*	
	Throughput		*					
AES	Encryption time	***				****	***	****
	Throughput		***					
	Avalanche effect					****		
	Memory					***		
Blowfish	Encryption time	****					****	
	Throughput		****					
	Run time test			****				
	Memory space			**				
HiSea	Entropy				****			
	Correlation assessment				****			

* = Low; ** = Medium; *** = High; **** = Excellent

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University ERP Preparation Analysis: A PPU Case Study

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Abstract—The Enterprise Resources Planning (ERP) systems are one of the most frequently used systems by business organizations. Recently, the university sectors began using the ERP system in order to increase the quality of their academic and administrative services. However, the implementation of ERP is complicated, risky, and no factor can guarantee a successful system. Previous studies were primarily concerned with Critical Success Factors (CSFs) in business organizations and organizational success factors. This produced plenty of information about these topics. However, the university environment and structure is different, which encourages us to study its specific technical critical success factors. In this paper, Palestine Polytechnic University (PPU) will be our case study. Our attention is concentrated on technical success factors at PPU. Firstly, the paper focused on the technical problems which current systems in the PPU suffered from, in order to extract the particular CSFs which are needed to implement ERP systems. Secondly, the paper focused on the most technical critical factors that ensure successful implementation of the ERP project. Thirdly, a study of the degree to which PPU's technical staff uses software engineering practices during the development process has been conducted by focusing on phases activities. Our main aim is to get a pool of parameters related to a successful preparation of universities' ERP systems.

Keywords—Enterprise Resources Planning (ERP); University ERP; software engineering practices software engineering phases activities; critical success factor; technical success factors; ERP implementation; successful ERP

I. INTRODUCTION

Enterprise resource planning (ERP) systems, also named integrated information solutions, or integrated application packages, give us the ability to control all the main functions of a business by using integrated information architecture. The main goal of implementing ERP systems is to connect all units of the business and all organization functions into a unified or integrated computer system that meets the needs and satisfies the users of the entire organization [1]. (ERP) is information system software that aims to integrate all business processes and functions in a central database. This boosts the management of business resources (finance, production, human resource, materials, etc.) in an effective, efficient, and productive way [2]-[5]. Moreover, the universities ERP system is defined as “an information technology solution that integrates and automates recruitment, admissions, financial aid, student records, and most academic and administrative services” [6]. University administrative services include

human resources, billing, accounting, and payroll. On one hand, academic services include deployment, admission, registration, and all aspects of student records [7]. On the other hand, university ERP systems that are implemented for academic purposes provide all administrative and academic functions. Universities have made important investments in ERP implementation in order to improve their business operations planning.

The usage of ERP is not new; it started in the 1960s as accounting software named Inventory Control (IC), in the 1970s it was developed into Material Requirements Planning (MRP) which developed into planning and control of the production cycle. After that, in the 1980s, MRP was advanced in Manufacturing Resource Planning (MRP II) which used to increase the efficiency of manufacturing by technology integrations for information. Then, MRP II extended to ERP systems [5], [8], [9]. Table 1 depicts the evolution of ERP systems.

TABLE I. ERP EVOLUTION [5]

Year	Chronology
2009	ERP Cloud
2000s	Extend ERP
1990s	ERP
1980s	MRP II
1970s	MRP
1960s	IC



There is no single critical factor that can guarantee the success of the ERP system. ERP requires a mix of critical factors to achieve the desired outcomes. From an ERP point of view, CSFs are the important areas that organizations should focus on in order to achieve successful performance [10]-[12]. Previous studies identified plenty of critical factors which had an impact on ERP implementation. These factors guided, influenced, and helped achieve desired goals. Nonetheless, 60% to 80% of ERP systems failed to meet expected results in the university environment [13]. On the other hand, it will be a way towards failure, when an organization misunderstands of how the software is implemented, and how efficiency and system functionality are to be maintained [14]. In addition to

that, ERP system implementation practices will be full of devastating implementation stories. Implementation processes had never been on time, budget, and achieving goals [15]. So researchers define software engineering as “an engineering discipline that is concerned with all aspects of software production” [16]. This paper focuses on the university’s situation during preparation for ERP system implementation. In addition, we will concentrate on technical success factors’ that influence building ERP at PPU and also the critical success factors that generally conform to gain a successful university ERP in broader context. More specifically, we studied to which degree software engineering practices are used during the software development life cycle process at PPU. The results of the study can be used as guidelines to support the structure that must be followed during the implementation of university ERP systems.

II. UNIVERSITIES’ ERP CRITICAL SUCCESS FACTORS

Critical Success Factors (CSFs) are among the important issues that ERP literature focuses on. Approaches and issues of CSFs by case studies were studied, developed, proposed, identified, and analyzed. CSFs are defined as a set of activities which need constant attention in order to plan and implement an ERP system [11]. Despite the differences that exist between organizations’ environments, the main categories of technical CSFs discussed in this paper are a concern of almost all universities. In [17] they identified the CSFs in a case study of higher education, and organized factors into categories: organizational, technical, vendor, individual, cultural, social, political and national. Hence, this paper focused on technological aspects. These CSFs include [17]:

- 1) Complexity
- 2) Network reliability
- 3) Flexibility and efficiency of use
- 4) System’s response time to users’ requests
- 5) Data quality, analysis, and conversion
- 6) Minimum customization
- 7) User friendliness, help, and documentation
- 8) Visibility of the system’s status
- 9) Robustness and error prevention
- 10) Software development, testing and troubleshooting

III. UNIVERSITY SITUATION ANALYSIS-PPU CASE STUDY

We conducted our experiment using qualitative analysis, which entails studying the current phenomenon as real. We saw that qualitative analysis through the form of questionnaires was the best way to conduct this research. Also, we used some quantitative analysis to collect some of the factors to get more specificity to the PPU.

The qualitative method affirms our understanding of situations and allows us to analyze them critically without any bias from information based on previous experiences of the research [18]. Such methodologies are good when the subjects have previous research done in the same area with the same

exploratory frame. Quantitative methodology is quite different from qualitative methodology because it affirms and strongly depends on testing and verification. Also, it focuses on facts and hypothesis testing, and is generalizable to the population [18].

A. Study Methodology

This research was conducted by using three questionnaires in total. The first two aimed to study CSFs; one specifically focused on the technical problems which current systems in the PPU suffered from, in order to extract the particular CSFs which are needed to implement ERP systems. The other simply focused on the most technical critical factors that ensure successful implementation of the ERP project. These were extracted from the previous literature and the first questionnaire. The third questionnaire studied the degree to which the technical people utilized standard software engineering practices and activities during the PPU’s systems’ implementation. After completing the questionnaires, verifying their validity, and measuring their reliability, we printed and distributed them amongst the sample of the study. The completed questionnaires were statistically analyzed and recommendations were extracted.

1) Population

The population studied was technical people at PPU, who are responsible for developing system inside the university.

2) Sample

Consists of (11) technical people who have a significant effect on the development process. Table 2 shows the demographic information about the sample.

3) Validation of questionnaires

The validity of the questionnaires was verified by presenting it to a group of experienced professors at PPU. They made a number of observations and notes on some of the paragraphs and questions that were taken into account when directing the study in its present form.

4) Study reliability

To verify the reliability of the study, the internal consistency coefficient was extracted in order to measure the degree to which software engineering practices were utilized during the systems’ implementation process at PPU. The Cronbach’s Alpha was 94.7%

5) Statistical processing

After collecting the data, we reviewed it in order to prepare and did the required statistical processing. Statistical analysis of the data was done by extracting figures, percentages, mean, standard deviations, and t-test using SPSS.

6) Scales

- Questionnaire number one and three uses 5 levels Likert scale as: (1=extremely disagree, 2=disagree, 3=undecided, 4=agree, 5=extremely agree).
- Questionnaire number two uses 5 level Likert scale as: (1=extremely not critical, 2=not critical, 3=undecided, 4=critical, 5=extremely critical) in order to study the criticality and importance of factors.

TABLE II. DEMOGRAPHIC INFORMATION

<i>Parameters</i>	<i>Levels of Parameters</i>	<i>Number</i>	<i>Percentage %</i>
<i>Gender</i>	Female	2	18.2
	Male	9	81.8
<i>Position</i>	Managerial Employee	4	36.4
	Technical Employee	7	63.6
<i>Experiment Field</i>	Programmer	5	45.5
	Software Engineering	2	18.2
	Computer Engineering	2	18.2
	Other	2	18.2
<i>Certification Level</i>	Diploma	1	9.1
	Bachelor	5	45.5
	Master	4	36.4
	PhD	1	9.1
<i>Academic University Specialization</i>	Information Technology	5	45.5
	Computer Science	3	27.3
	Network	1	9.1
	Informatics	2	18.2
<i>Experience Years</i>	6 years	1	9.1
	8 years	1	9.1
	9 years	1	9.1
	10 years	1	9.1
	12 years	1	9.1
	14 years	1	9.1
	16 years	1	9.1
	25 years	2	18.2
	31 years	1	9.1
	33 years	1	9.1

B. PPU Case Analysis Results

1) First: PPU current technical situation analysis.

The aim of this survey is to study the technical problems where current systems at PPU suffer from. These problems are extracted from literature reviews according to the success factors that affect the university's environment and form the internal reports. Each problem is translated into one success factor. Our objective is to specifically investigate the possible ERP factors in this university. The objective of an open question is to indicate additional factors that must be taken into consideration during the implementation of a new system.

The questionnaire includes 18 questions aimed at studying different technical problems of current systems, and how much of the staff actually adheres to the details and concepts associated with the development process.

The subjects of the questions were: complexity, network reliability, flexibility, efficiency, system's response time to users' requests, data quality, analysis, and conversion mechanisms, minimum customization, user friendliness, help menu and documentation, visibility of the system's status, robustness and error prevention, software development, software testing and troubleshooting [17]. In addition to internal documentation, additional factors are added: data redundancy, process workflow, and System alerts.

To answer the previous question, the mean and the standard deviation of the study questions were extracted as shown in Table 3.

According to results shown in Table 4, the factors which were less than 3 must be taken into consideration. They are: menu and documentation, processes workflows, system alert, and data redundancy.

TABLE III. MEANS AND STANDARD DEVIATION OF FIRST STUDY QUESTION

<i>Question</i>	<i>Success Factor</i>	<i>Mean</i>	<i>Std. Deviation</i>
The current systems have no redundant data	Data redundancy	4.2727	.64667
Help manuals, and documentations are always provided to user in the current systems	Menu and documentation	3.7273	1.10371
Processes' workflows in the university are managed correctly	Processes workflows	3.6364	.92442
The current systems are designed to provide useful and needed alerts	System alerts	3.0909	1.04447
The use of the current system is efficient.	System efficiency	2.9091	.83121
The current system was designed to be less complex structures	System complexity	2.8182	.98165
One of the current systems' characteristics is prevention errors	Error prevention	2.7273	1.00905
The current system interfaces are designed to be user friendly	User friendliness	2.64	1.120
One of the current systems' characteristics is robustness	System Robustness	2.6364	1.12006
The current system was designed to be flexible.	System flexibility	2.5455	.68755
The current systems have an easy data conversion mechanism	Conversion mechanisms	2.4545	1.12815
The current system responses to user's requests quickly	System's response time to users' requests	2.4545	.93420
The current system's status is an aspect is always you concern to be visible to user	Visibility of the system's status	2.3636	1.12006
The current systems are highly customized with business processes	Minimum customization	2.3636	.92442
The current systems are tested	Software testing and troubleshooting	2.0909	.83121
The network in the current system is reliable.	Network reliability	2.0000	.63246
Frequent development and testing are activities that current systems reveal.	Software development and testing	1.9091	.53936
A good data quality is a feature that took under consideration when provided to the current systems' implementation	Data quality	1.8182	.98165

Consequently, the factor of process workflows is converted to the Business Process Reengineering (BPR): because there must be a change of some of the work processes to optimize the implementation of ERP systems [6]. The factor of data redundancy was merged with system integration because it will be eliminated when the integration is achieved, so it is converted to system integration. Also, the system alert merged with system integration because the needed alerts will be provided and automated easily when integration is successfully accomplished. In the "undecided answers" pool, we noticed that there was a problem of technical people not being able to choose answers regarding their systems' aspects, specifically the systems that they themselves are working on. Consequently, we decided to cover the factors which earned a high rate of undecided (>2.5). They were: System efficiency, System complexity, Error prevention, User friendliness, and System robustness.

Moreover, the questionnaire also included open questions that sought additional factors that the staff thought must be considered as technical aspects of the systems at PPU. The results were:

- 1) Security.
- 2) IT infrastructure.
- 3) Business process reengineering.
- 4) Applying software engineering standards.
- 5) Database administrator.
- 6) Using unified theme of technology.
- 7) System integration.
- 8) Training.

Hence, according to Table 4, the literature review, internal documents, and response of the interviewees to the questionnaire and interview, we found that the critical success factors which we should be concerned with when studying the implementation of new ERP systems in PPU are:

- 1) Complexity.
- 2) Efficiency.
- 3) Data analysis.
- 4) Help menu.
- 5) Documentation.
- 6) Robustness and error prevention.
- 7) Security.
- 8) IT infrastructure.
- 9) Business process reengineering.
- 10)Applying software engineering standards.
- 11)Database administrator.
- 12)Using unified theme of technology.
- 13)System integration.
- 14)Training.

2) *Second*: Technical CSFs for PPU case.

The aim of the second questionnaire was to study the question of “which critical factors were the best at ensuring the technical successful ERP project implementation”. These factors were extracted from the first questionnaire and literature review as explained in the previous section. Table 4 was created which includes the results of the mean and the standard deviation for each technical factor.

TABLE IV. MEAN & STANDARD DEVIATION OF CRITICAL SUCCESS FACTORS FROM TECHNICAL PERSPECTIVE IN PPU

	<i>Factor</i>	<i>Mean</i>	<i>Std. Deviation</i>
1.	Security	4.9091	.30151
2.	System integration.	4.6364	.50452
3.	Data analysis	4.6364	.50452
4.	Database administrator	4.4545	.52223
5.	Efficiency of use	4.4545	.52223
6.	Complexity	4.4545	.52223
7.	Robustness and error prevention	4.3636	.50452
8.	Business process reengineering	4.1818	.87386
9.	IT infrastructure	4.1818	.40452
10.	Training	4.0909	.30151
11.	Applying software engineering standards	3.9091	.94388
12.	Documentation	3.7273	1.10371
13.	Using unified theme of technology	3.6364	.67420
14.	Help menu	3.5455	.82020

Table 6 shows that the dominant answers were between “agree and extremely agree”. In order to verify which critical success factors at PPU were more critical and effective, the sample t-test method was used, where the null hypothesis H0 is $\mu < 3$ and the alternative hypothesis H1 is $\mu \geq 3$. Following t is the used statistic test [6]:

$$t = \frac{\bar{x}-3}{s/\sqrt{n}} \tag{1}$$

The results of questionnaire are shown in Table 5.

Therefore, according to the questionnaire results which were shown in Table 5; the 14 critical and effective CSFs of ERP implementation in PPU, arranged from more critical to less critical, which are:

- 1) Security.
- 2) Training.
- 3) Data analysis.
- 4) System integration.
- 5) IT infrastructure.
- 6) Database administrator.
- 7) Complexity.
- 8) Efficiency of use.
- 9) Robustness and error prevention.
- 10)Business process reengineering.
- 11)Applying software engineering standards.
- 12)Using unified theme of technology.
- 13)Help menu.
- 14)Documentation

TABLE V. THE T-TEST

<i>Factors</i>	<i>Test Value = 3</i>	
	<i>t-test</i>	<i>p-value</i>
Security	21.000	.000
Training.	12.000	.000
Data analysis	10.757	.000
System integration.	10.757	.000
IT infrastructure	9.690	.000
Database administrator	9.238	.000
Complexity	9.238	.000
Efficiency of use	9.238	.000
Robustness and error prevention	8.964	.000
Business process reengineering	4.485	.001
Applying software engineering standards	3.194	.010
Using unified theme of technology	3.130	.011
Help menu	2.206	.052
Documentation	2.185	.054

3) *Third*: PPU current software engineering situation analysis.

The aim of this questionnaire is to study the degree of software engineering activities which are utilized during systems process implementation at PPU. All theoretical information is extracted from [16].

a) Software Specification or Requirements Engineering

Requirements engineering activity is the process that is responsible for developing and extracting software requirements. The specifications are designed to communicate the system needs of the users with system developers.

In our research, we studied main sub-activities that must be done during this phase. These include:

- 1) Feasibility study.
- 2) Perform elicitation and specification of requirements.
- 3) Making a scenarios and prototype constructions.
- 4) Constructing system models.

The percentage PPU technical staff utilizing this stage was 41.9%. Results of mean and standard deviation for sub-activities that were included in the phase of software specification are represented in Table 6. The results are listed in order from the most to the least applied. Looking at the data, the feasibility study is the activity that is most applied. Here, according to [16] elicitation requirements will keep us away from facing problem and errors in the next stages.

TABLE VI. SOFTWARE SPECIFICATION PHASE RESULTS

<i>Software specification activities</i>	<i>Mean</i>	<i>Std. Deviation</i>
Feasibility study	3.5000	1.26930
Constructing system models	2.7273	1.00905
Making scenarios and prototype constructions	2.7273	1.00905
Perform elicitation and specification of requirements	2.4545	.82020

b) Software Design

The next stage that our research deals with is software design, in which design face describes the structure of the system intended for implementation, indicates data models which will be used, and determine interfaces between components, etc. In our research, we studied the main sub-activities that must be carried out during this stage. They include:

- 1) Applying an architectural design.
- 2) Applying an interface design.
- 3) Applying a component design.
- 4) Applying a database design.

The percentage of PPU technical staff utilizing this stage was 40.9%. The results of mean and standard deviation for sub-activities that are included in this phase can be found in Table 7. The results are listed in order from the most to the least applied. Looking at the data, the architectural design is the activity that is most frequently applied.

TABLE VII. SOFTWARE DESIGN PHASE RESULTS

<i>Software design activities</i>	<i>Mean</i>	<i>Std. Deviation</i>
Applying an architectural design.	3.0909	1.30035
Applying an interface design.	3.0000	1.18322
Applying a component design.	2.9091	1.22103
Applying a database design.	2.0909	.94388

c) Software development

The software development stage is responsible for converting system requirements and specifications into an executable system during the process of software development. In our research, we studied main sub-activities that must be carried out during this stage. They include:

- 1) PPU project developers' team members.
- 2) PPU technical team members who are well skilled
- 3) Availability of technology tools which support the capabilities and productivity.
- 4) Making system documentations.
- 5) Conversion plan.

The percentage of PPU technical staff utilizing this stage was 45.5%. The results of mean and standard deviation for sub-activities included in this phase can be found in Table 8. According to results, we see that "Availability of technology tools which support the capabilities and productivity" is too low which indicates that the staff needs more resources besides the skills which must be developed.

TABLE VIII. SOFTWARE DEVELOPMENT PHASE RESULTS

<i>Software development activities</i>	<i>Mean</i>	<i>Std. Deviation</i>
A high turnover rate of the project developers' team members	3.4545	1.21356
Making system documentations	3.3636	1.12006
Having a conversion plan	2.8182	.98165
PPU technical team members are well skilled	2.3636	.67420
Availability of technology tools	2.2727	.46710

d) Verification and Validation

Software validation is the process of verifying that the system complies with its specifications and it meets the real needs of system users. In our research, we studied the main sub-activities that must be carried out during this stage:

- 1) Test plan
- 2) Development testing
- 3) System testing
- 4) Acceptance testing

The percentage of PPU technical staff utilizing this stage was 45.5%. The results of mean and standard deviation for

sub-activities that are included in this phase are shown in Table 9. The results are listed in order from the most to the least applied. Looking at the data, creating a test plan is the most applied activity.

TABLE IX. VERIFICATION AND VALIDATION PHASE RESULTS

<i>Verification and Validation activities</i>	<i>Mean</i>	<i>Std. Deviation</i>
We always have a test plan	2.8182	.98165
We always do development testing	2.8182	.98165
We always do acceptance testing	2.5455	.82020
We always do a system testing	2.4545	.93420

e) Project management

All systems should be developed using a clear development process. The university must plan the development process and have clear and complete ideas about what will be developed and what is the outcome of the development process and when it will be completed. Accordingly, we decided to focus on the project management as a stage. In our research, we studied the main sub-activities that must be done during this stage which include:

- 1) Determine project's activities by milestones
- 2) Frequently sending the project progress reports to the manager by employees
- 3) Setting project schedules (e.g. activity chart, bar chart)
- 4) Creating project risk management plan

The percentage of PPU technical staff utilizing this stage was 40.9%. The results of mean and standard deviation for sub-activities included in this phase can be found in Table 10.

TABLE X. PROJECT MANAGEMENT PHASE RESULTS

<i>Project management activities</i>	<i>Mean</i>	<i>Std. Deviation</i>
Setting project schedules (e.g. activity chart, bar chart).	3.4545	1.03573
Creating a project risk management plan.	3.2727	1.19087
Determine project's activities by milestones.	2.8182	.98165
Frequently sending the project progress reports to the manager by employees.	2.6364	.92442

As summary, Table 11 represents the fundamental software engineering activities for any software development process which are done by PPU staff. They are listed in descending order from most to least applied. We concluded that the most applying activity is project management, then software development, after that software specification, then software design. At the table shows that verification and validation activity to be the least applied.

TABLE XI. TOTAL RESULTS

	<i>Mean</i>	<i>Std. Deviation</i>
Project management.	3.0455	.82778
Software development.	2.8545	.57335
Software specification.	2.8182	.88099
Software design.	2.7727	1.05744
Verification and validation.	2.6591	.76053

IV. CONCLUSIONS

Enterprise Resource Planning (ERP) or integrated information solutions provide a controlling ability to all main business functions of organizations and companies using integrated information architecture. Thus, universities exploit ERP system to take its advantages and to improve the information systems they possess. In this paper, we took Palestine Polytechnic University (PPU) as a case study in order to help preparation of ERP implementation, and to improve the information system at PPU. The current situation is fragmented and non-integrated system, in addition to different data identification and redundancy.

This paper focused on the university's situation during the preparation of ERP system implementation. In addition, the study concentrated on technical success factors' influenced on and important to PPU case. The critical success factors that generally conform to gain a successful ERP system are also mentioned. More specifically, we studied the degree that software engineering practices are used during the software development life cycle process at PPU. The results of the study were used to support the structure that must be followed during the implementation process. The final list of technical CSFs of PPU includes:

- 1) Security
- 2) Training.
- 3) Data analysis.
- 4) System integration.
- 5) IT infrastructure.
- 6) Database administrator.
- 7) Complexity.
- 8) Efficiency of use.
- 9) Robustness and error prevention.
- 10) Business process reengineering.

In the case of software engineering practices, we found that the most applying activity is project management, then software development, after that software specification, then software design. At the end we find verification and validation activity is the least applied.

A potential future work is to empirically use these results to improve a PPU's ERP framework in order to prepare and plan to implement an efficient ERP system.

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Improved QoS for Multimedia Transmission using Buffer Management in Wireless Sensor Network

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Abstract—Wireless Sensor Network (WSN) diverts the attention of the research community as it is easy to deploy, self-maintained and does not require predefine infrastructure. These networks are commonly used to broadcast multimedia data from source to destination. However, this kind of data transmission has some challenges, i.e. power and bandwidth limitation with small delay. Art of work mainly focus on optimization either by the shortest route or to minimize the delay by increasing the bandwidth. However, Buffer management is the main constraint to cause delay and loss of packets. In this paper, an approach is presented to manage the buffer and increase the packet delivery ratio (PDR) and reduce delay by assigning the priorities to Intra-coded (I) frame, predictive – coded (P) frame and bidirectional-coded (B) frames dynamically. This approach is very much effective to control the loss of packets in WSN. The presented approach is validated by using Network Simulator 2.

Keywords—Packet delivery ratio (PDR); multimedia; buffer; priority; delay

I. INTRODUCTION

In the past decade, Internet is most commonly used from education to entertainment. The broadband wireless sensor network (WSN) as well as cellular networks collectively with improved computing power have exposed the entry for an innovative type of utilization to be formed, i.e. audio, video multimedia real time applications. So multimedia transmission needs conventional examines that result in faithful appliances such as surveillance and video conferencing. The Wireless networks give an area to expand these requirements mostly in WSNs to enhance the multimedia communication on these networks. Hence is the necessity of the time to exploit the complete possibilities of such networks, also to understand the reimbursement of multimedia. WSN initiate further challenges for enhanced Quality of Service (QoS), as resource availabilities are less that is channel capacity, buffer capacity and power at every intermediate node. Therefore QoS is viable during a multimedia data transmission session. To present an adequate quality of service in multimedia data transmission appliances, delay and order of packets is the key issue that necessitates to be tackled. i.e., uninterrupted multimedia data packet transmission must run from sender to receiver, and delay, if exist, must be optimized with all the broadcast links. This must be attainable to calculate flow of data packets from every sender in a reasonable approach. As Multimedia data packets are liberal to loss upon certain time limit. So if a few packets get corrupted, multimedia data packets can still be acknowledged. Packet loss mainly occurs in WSNs due to (i)

Route failure, (ii) communication errors and (iii) jamming at nodes which behaves as routers. The loss of data is mainly because of obstruction in the network, transmission errors and failure of the route. The failure of Packets can also happen if the order of data packets depraved due to communication failure. This type of failure can be controlled up to maximum value by the use of Error coding techniques to protect the order of the packet. Failure of the route can be restricted by different techniques like arrangement of the route decision in advance, if failure occurs, or by proper hand off. In real time application, multimedia transmissions usually want QoS guarantees that is huge bandwidth, rigorous delay bound and comparatively error-free multimedia excellence. Multimedia transmission over WSN becomes a demanding because of its dynamic nature as a result the channel is having changeable bandwidths and arbitrary loss of packets. Almost all the existing approaches try to optimize the channel capacity and delay using shortest path algorithm and constant priority approach, very less approaches have been presented that can optimize the buffer, as buffer management is a challenging task in WSN. The time-changing behavior of wireless communication channels and resource allocation made wireless strategy difficult. In this paper an approach called Improved QoS for Multimedia Transmission using Buffer Management is proposed to control the loss of data packets by assigning the dynamic priority to the different data frame packets (i.e. Intra coded (I), Predictive coded (P) and Bi directional coded (B) frames) in the router buffer. This not only minimizes delay but also improves the packet delivery ratio (PDR). The presented approach increases the quality of service (QoS) by assigning the priorities dynamically as per the laxative time of a packet.

The organization of this paper is as follow. Section II presents related work. In Section III we propose our approach, in Section IV we are presenting the simulation results and discussion and conclusion is given in Section V.

II. RELATED WORK

In wireless broadcasting networks, numerous studies have been elucidated for approved Quality of Service on interruption and fairness such as [1] and [2]. But in WSNs number of issues and challenges happened, such as mobility of nodes, available resources and coordination among the nodes. Jacobson [3] presented an approach called TCP algorithm and the presented approach was improved, recognized as Reno TCP approach [4]. Brakmo et al. [5] presented another approach identified as Vegas TCP enhanced packet delivery

ratio than Reno TCP. Both the approaches are the basic descriptions of the Transmitted Control Protocol. However, these approaches cannot achieve QoS in the WSNs with more delay bandwidth product. Both the two approaches are based on the size of the window, such that if congestion happens, it may reduce and if no jam occurs it may boost the window size. The type of system used in these approaches is recognized as Additive Increase Multiplicative Decrease (AIMD). This approach is traditional not planned for huge size of the window to recuperate subsequent to a retreat; the transmission capacity is also not effectively exploited [6]. Numerous options are being recommended to a present TCP within eminent rate networks i.e. [7]-[13]. Even if these approaches have definite advantages more than standard TCP, but, they do not considerably achieve enhanced with respect to standard TCP.

Avrachenkov and Antipolis [14] proposed an efficient method for buffer dimension (Router buffer). But, this method communicates toward a linear permutation of the regular transmitting speed and delay in the line. This approach fails to compute packet loss and usage of the link. Wei et al. [15] presented an approach to control packet loss in networks in which speed is high also the authors showed the problems occurred in the present TCP approach. Sarker and Johansson [16] got optimum results to estimate the packet loss and delay using a system called LTE (Long Term Evolution). However this approach may not be optimum in multimedia transmission, as this approach takes more time to check behavior of the path within the network. Bauer et al. [17] verified that the expansion of these networks results in the growth of ECN. But on the other side, the proposed approach has no consequence (or slightest consequence) on storing the data packets within the buffer the, particularly while the window size is increased [e.g. 18]. Gettys and Gettys [19] proposed the difficulties in buffering management, i.e. a definite approach is used in the data gram switching networks mainly in PSCN. The difficulties associated with this approach are that the overload of data packets reveals in discontinuation and jitter. Jarvinen et al. [20] addressed RED (Random Early Deduction) technique in which the authors proved that it has not more benefits as it is too moderate to tackle rapid change because of slow start TCP, particularly while the data traffic is inadequate. Each and every one of above methods changes the buffer size either by incrementing or decrementing the window size. From the best of my awareness, no approach has given precise calculation of packets lost that is very essential for data transmission (i.e. Multimedia transmission). As the multimedia transmission is allowed to tolerate only up to definite time limit, after this limit care has to take.

Jingyuan Wang et al. [21] presented an approach to manage the packet loss known as TCP-FIT depends on AIMD technique. However the presented approach did not get the accurate window size as desired value.

Ossama Habachi et al. [22] addressed a technique called MOS (Mean Opinion Score). In presented technique, the authors understood that the source node knows the complete information about the data traffic and the current environment of the wireless network. However this approach fails in WSN

because of mobility of nodes. Chen et al. [23] presented an approach called CARM (congestion aware routing protocol) to enhance the QoS by controlling the data packets. In this particular protocol, data rate has been used in metric system to avoid disparity. This method fails to give optimum response, when the routes are less from sender to receiver is or if the anchoring node is not available which acts as a router. Parminder Kaur et al. [24] addressed a efficient packet loss control technique. In this approach the authors tried to manage the packet loss by altering the dimensions of the given network, mobility of nodes and power. But this approach may not be optimum when the mobility of node is more and it consumed more energy because of continuous broadcasting of data packets from sender to receiver.

Ksentini et al. [25] addressed an approach using cross layer optimization technique to maintain QoS for video data coding within 802.11e network. However, the proposed model is static so cannot be used to optimize multimedia data transmission. Shin et al. [26] proposed an approach called MPEG-4 algorithm, through a lonely multimedia data packet flow. This method defines three different categories of frames for video transmission represented by *intra coded I*, *Predictive coded P* and *Bidirectional coded B frames* to streamline the compression. In this approach every data frame have given unique type of priority according to the dependency of frame. However this approach fails for multimedia data transmission because it assigns static priorities all the time. Raji and Mohan Kumar [27] proposed a technique that enhances the QoS for multimedia data transmission. However, the presented technique does not guaranteed, when data packets are not acknowledged positively in the destination side.

Lee et al. [28] presented a dynamic algorithm to improve the QoS for multimedia data transmission. However this approach didn't examine the packet time limit of *Predictive coded frame P* and *bidirectional coded frames B*, if *Intra coded data frame packets* are still present within the buffer. Which results loss of *Predictive coded data packets* and reduces the QoS .Because of immense priority of *intra coded data packets*, so *predictive coded data frame packets* are not permitted to move early while their laxative time is over (expiry time of a packet). The presented approach also takes care of each and every acknowledgement which increases delay.

Ding et al. [29] presented an approach to increase QoS based on energy of the node in wireless sensor networks. Li et al. [30] proposed a model to optimize the loss in wireless sensor networks by using cross layer technique. This approach optimizing the loss by allocating the channel based on resource accessibility. However this approach may not be useful, when the routes are less and packet transmission is more from transmitter to receiver.

The presented approach controls the lost packets by assigning priorities to *intra coded*, *predictive coded* and *bidirectional coded data packets* dynamically and also takes care of expiry time of all types of data packets which increases PDR and decreases the delay of packet transmission from sender to receiver.

III. PROPOSED APPROACH

In the proposed approach a control technique is used to streamline the data packets and the source rate control mechanism is employed to reduce the problems associated with the multimedia data over the WSC (wireless sensor channels).

Here the optimization of buffer management in WSN is done by giving the priorities to multimedia data packets. Fig. 1 represents the network buffer.

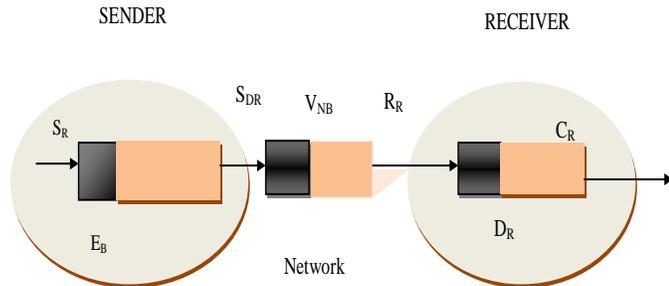


Fig. 1. Network model of buffer.

Where,

E_B - Encoder Buffer; S_R - Source Rate; S_{DR} - Sender Rate,

V_{NB} - Virtual network buffer, R_R - Receiver Rate; D_R - Decoder buffer; C_R - is the consuming rate.

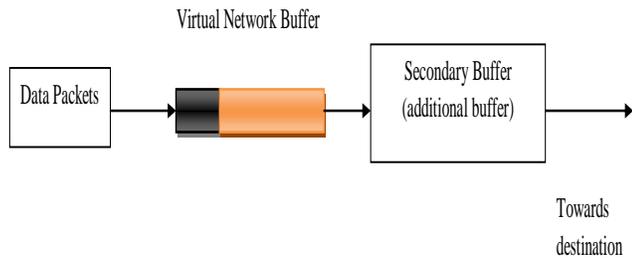


Fig. 2. Buffer management block diagram.

Fig. 2 represents the block diagram of the buffer management in which the data packets are transmitting towards destination via the secondary buffer and the virtual buffer (i.e. primary buffer). Here the secondary buffer is used only to find the status of the loss, and accordingly assign the priorities to the multimedia data packets to increase the QoS. Fig. 3 represents a proposed mapping method called *Priority based Scheduling Mapping method* PBSMM. The presented approach dynamically allotted the priority to the different multimedia packets on the bases of the threshold time limit of a packet, particularly called the *laxity time* of a packet. In the presented method, the secondary (additional) buffer is split into four separate buffers called *I-Coded Packets*, *P-Coded packets*, *B- Coded packets* and *Direct Access Based (DAB)* packets. The initial three i.e. I, P, B buffers are used to compress only video information. However the additional buffer i.e. DABS is used to transfer the multimedia data packets towards the subsequent anchoring node/destination

node directly, whose acknowledgements are not received correctly within the given amount of time. The data packets may not be received correctly at the subsequent intermediate node or end node either by jamming or due to noise in communication. In the scheduler mechanism first priority is specified to *I* coded packets, then to *P* coded and finally given to *B* coded data packets. Because *I* coded packet loss have more consequence on multimedia transmission. Conversely, if *B* coded packet is lost, it affects itself only. At this juncture, the buffer *DAB* will resolve the issue of packets whose acknowledgements are not received properly or not reached the end node (destination) prior to the packet expiry time.

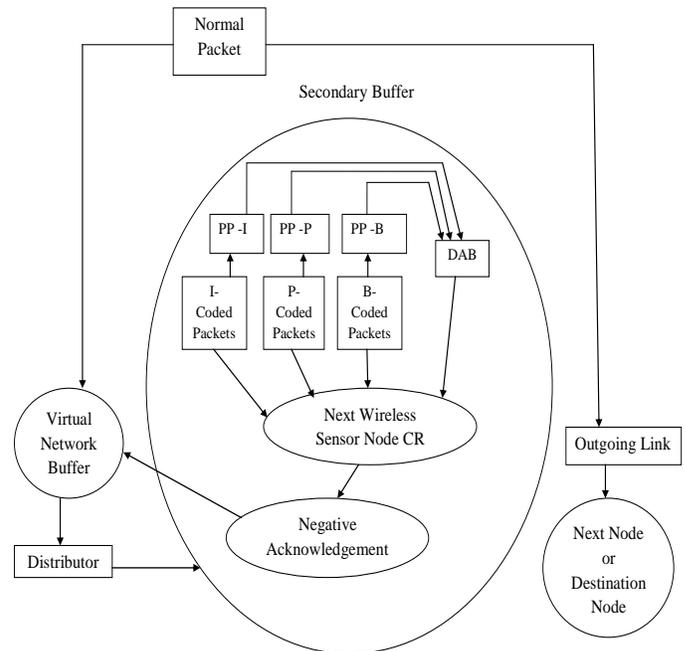


Fig. 3. Priority based scheduling mapping method.

In this approach, a service is being introduced to move the packets ahead called *Packet Forwarding Service (PFS)*, so an extra field is inserted in the packet header. An extra field of six bytes space is provided as a part of header to accumulate the hop count and the laxity time. The laxity time can be represented as:

$$\text{Laxity time} = \text{time limit} - \text{present time}$$

Where time limit is the time, up to which packet is alive and present time is the time taken by the packet to reach anchor/destination node. Thus, packets whose expiry time is more than the laxity time is directly transfer to the *DAB* by the use of a switching technique from which they can move directly towards the next node or destination node. So, the packet loss and delay are minimized. The packets which are directly going to *DAB* are marked as Priority Packets (PP-I, PP-P and PP-B). The PPs are those data packets whose entry time is more than the threshold time limit and waste the bandwidth. So to save the bandwidth and delay, a separate threshold time limit is defined for every type of data packet. The *DAB* is used to access the packets which are not received properly by the next sensor node or end node within the allotted time (refer Fig. 4). It transmits intra coded data

packets I and checks the *time Limit* of Intra coded I frame packets i.e. T_{LI} . If the time limit does not exceed T_{LI} , it will forward the packets constantly towards next sensor node or end node via intra coded buffer I. Let the *Time* of a packet (t_p) is equivalent to the time limit of a data packet (time limit for voice data packet is 150 ms and for video it is 400 ms Reddy et al. [31]). Subsequently the data packet is precisely given to the *DAB*, in which it will access accurately to the next node. Likewise, if the time limit of *predictive coded P* and *bidirectional coded B* packets are T_{LP} and T_{LB} correspondingly and let this time limit exceeds, then the data packets of these frames will also accessed directly to DAB and can arrive at the end node without any further delay. The DAB buffer is again split into three additional buffers represented as DAB_I , DAB_P and DAB_B to take the packets priority wise which are not being received properly, initially it will consider the intra coded packets through DAB_I , next it will access data packets of predictive coded packets through DAB_P and lastly bidirectional coded via DAB_B .

Fig. 4 represents the flow diagram of PBSMM for successful multimedia type of data transmission. The packets coming from input sensor nodes are directly stored in the buffer as indicated by the scheduler mechanism.

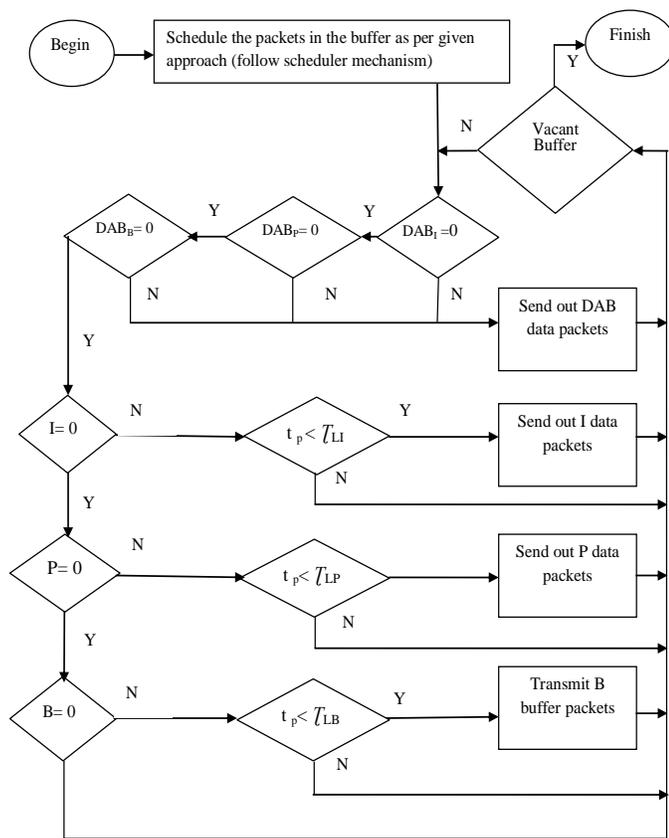


Fig. 4. Flow diagram of PBSMM for multimedia communication.

Whenever DAB is unfilled, it checks intra coded data packets and also it checks the time limit of intra coded data packet. If the time of the packet is not more than the time limit of a packet, subsequently intra coded data packets are accessed to the intra-coded buffer for communication. Similarly, predictive & bidirectional coded data packets are

accessed via their particular buffers for communication. If the time of the data packet is equal to time limit of the packet, subsequently the data packets of these frames are accessed to DAB directly for communication.

The presented method is different from Lee approach [28], with respect to the below mentioned facts.

- Secondary buffer is connected with all the Wireless Sensor nodes to assign the priority to data packets dynamically.
- Considering only acknowledgements of data packets which are either acknowledged wrongly or damaged because of noise or due to other network effect.
- One extra buffer (i.e. DAB) is placed beside Intra coded I frame packets, predictive coded P frame packets and bidirectional coded B packet buffers which gives more interest to the time limit of a packet. This also takes care of the data packets that are not received properly before the time limit of a packet.

A brief mathematical modeling is presented to calculate the packet time limit, for this purpose an assumption is made that the transmission of packets between two nodes follow duplex system of communication.

For realistic transmission between end users a router must exist prior to establish a connection among any sensor node via an intermediate node. So jamming may take place at any intermediate node if more packets are entering to the node in association with the leaving ability of the given node. With no loss of generalization, we are using the below mentioned facts.

1) The buffer capability of the router is ' μR ' data packets and data packets arriving from input nodes follows average value equal to ' γ ' packets/sec. The output capacity of the router buffer is ' δ ' packets/sec. such that $\gamma \leq \delta$.

2) The secondary (additional) buffer is recommended immediately after the virtual buffer. The additional secondary buffer splits in four associate buffers namely Intra coded, Predictive coded, Bidirectional coded and Direct Access Buffer (DAB) with capacities μI , μB , μP and μDAB correspondingly.

3) The number of regular packets/second transfer to Intra coded, Predictive coded and Bidirectional coded to the subsequent sensor node is δI , δP and δB correspondingly, and also the subsequent proceeding time is T_I , T_P and T_B correspondingly.

4) In case of non-reception of Ack. (packets not received), the time requisite to transfer once again data packets via 'DAB' buffer is τ_{DAB} , such that $\tau_{DAB} \leq (t_p + \frac{RTT}{2})$, $RTT \rightarrow$ round trip time and t_p is the time to live of a data packet, ' τ_{DAB} ' \rightarrow sum of entity time of lost data packets.

5) Let on an average the number of packets lost from Intra, Predictive and Bidirectional coded buffer be ϕI , ϕP and ϕB correspondingly.

The data packets, arriving from buffer is identical to the summation of every data packet in the entity buffers in the secondary buffer i.e.

$$\mu_R = \mu_I + \mu_P + \mu_B \quad (1)$$

μ_R ' also can be given as

$$\mu_R = \delta \times \tau \quad (2)$$

Where ' δ ' \rightarrow data rate, and ' τ ' is the time to process the packets from intermediate buffer to secondary buffer. Also

$$\mu_R = \mu_{RI} + \mu_{RP} + \mu_{RB} \quad (3)$$

where μ_{RI} , μ_{RP} and μ_{RB} are the output data rates of Intra coded, Predictive coded and Bidirectional coded buffers correspondingly (when $\mu_{RDAB} = 0$ i.e. empty 'DAB' buffer, so ' δ_{DAB} ' is zero). The buffer capability is equivalent to rate into time, so ' μ_R ' can also be given as:

$$\mu_R = \delta_I T_I + \delta_P T_P + \delta_B T_B \quad (4)$$

Let the data packets are lost because of delay or due to some other cause with a mean rate of δ_Q and time T_Q . Thus, the total packets lost in all buffers can be represented as ' μ_{RDAB} ' and can be shown as:

$$\mu_{RDAB} = \delta_{DABI} T_{DABI} + \delta_{DABP} T_{DABP} + \delta_{DABB} T_{DABB} \quad (5)$$

Where β_{DABI} , β_{DABP} and β_{DABB} are the data rates of packets lost from Intra, Predictive and Bidirectional buffers correspondingly, T_{DABI} , T_{DABP} and T_{DABB} are the handing out time of lost packets of Intra, Predictive and Bidirectional correspondingly from secondary buffer to next sensor node.

Also ' μ_{RDAB} ' can also be given as:

$$\mu_{RDAB} = \phi_I + \phi_P + \phi_B \quad (6)$$

Where ' μ_{RDAB} ' is the sum of all packets lost that flows via 'DAB' buffer to the subsequent sensor node or end node. The data packets coming from Intra, Predictive and Bidirectional packets will loss if,

$$\frac{\mu_{RI}}{\delta_I} > T_I$$

$$\frac{\mu_{RP}}{\delta_P} > T_P$$

$$\frac{\mu_{RB}}{\delta_B} > T_B$$

Or else, the data packets coming from these buffers received effectively at the subsequent sensor node or end node. The replica of the lost data packet be able to accept effectively via 'DAB' buffer, if,

$$T_{DABI} < \left(T_I + \frac{RTT}{2} \right)$$

$$T_{DABP} < \left(T_P + \frac{RTT}{2} \right)$$

$$T_{DABB} < \left(T_B + \frac{RTT}{2} \right)$$

Since the buffer takes data packets through any sub buffer (i.e. intra, predictive & bidirectional), when the packet time fulfills the condition $t_p < T_L$.

IV. SIMULATION RESULTS AND DISCUSSION

In this section, the outcome of the presented approach is compared with the results of Lee and Raji methods. The results are validated by NS-2. Fig. 5 shows the deviation of packet delivery ratio (PDR) against the simulation time of end user pairs.

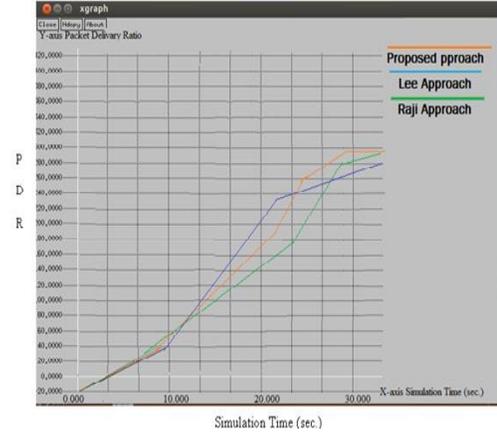


Fig. 5. Variation of PDR Vs Simulation Time.

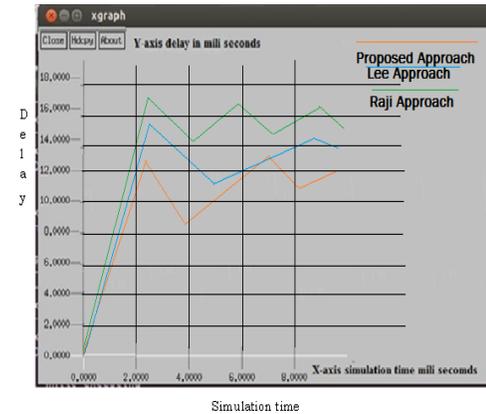


Fig. 6. Variation of Delay Vs Simulation Time.

From the figure it has been observed that if the source and destination nodes are far from each other (i.e. multiple hops), as the time increases, the PDR also increases. The, presented approach generates higher values than Lee approach and Raji approach. Fig. 5 shows that initially the PDR of Lee and Raji model is enhanced when contrast to my model because of sustaining a routing table that shows an original overhead. However, after elapse of time, the planned method has very much higher PDR, once routing table is maintained, the planned method saves maximum 'Intra', 'Predictive' and 'Bidirectional' data packets that are lost in Lee and Raji approach. Fig. 6 represents the deviation of delay versus simulation time in proposed approach and existing approaches.

From Fig. 6 it is observed that the delay in presented approach is less when compared with the existing approaches.

As the number of hops increase, the sensing time of existing approaches will increase and take extra time to sense and transfer the data packets into the channel with more delay.

Table 1 represents the simulation atmosphere and the different framework values calculated.

TABLE I. SIMULATION PARAMETERS

Parameters	Values
Simulation Time	60 seconds
Number of nodes	1 to 60
silence Time	40 sec.
Medium Accesses Control type	802.11
Network Area	1000m x 1000m
Transmission capacity	4Mbps
Data Traffic	Audio, Video
Area of Network	1000m x 1000m
Simulation Speed	3,7,9,12,14 m/sec
Pause Time	60 sec.
Size of the Packet	512 bytes

V. CONCLUSION

Multimedia data transmission with enhanced QoS can be acquired by manipulating a suitable control strategy for smooth flow of multimedia data packets at the router for a multi-hop link. In this approach the QoS of multimedia data applications in WSNs is enhanced to control the packet loss by exploiting the uniqueness of the multimedia data frame and the packet priorities. Disparate the Raji and Lee approach, the presented approach authenticates the data transmission of all type of multimedia data packets (i.e. Intra, Predictive, and Bidirectional packets) with no increment in the delay. The offered method also maintains the sequence of data packets as per the given time plan of data packets, hence the presented approach is very efficient for multimedia data applications in multi-hop WSNs.

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A Comparative Study of Stereovision Algorithms

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Abstract—Stereo vision has been and continues to be one of the most researched domains of computer vision, having many applications, among them, allowing the depth extraction of a scene. This paper provides a comparative study of stereo vision and matching algorithms, used to solve the correspondence problem. The study of matching algorithms was followed by experiments on the Middlebury benchmarks. The tests focused on a comparison of 6 stereovision methods. In order to assess the performance, RMS and some statistics related were computed. In order to emphasize the advantages of each stereo algorithm considered, two-frame methods have been employed, both local and global. The experiments conducted have shown that the best results are obtained by Graph Cuts. Unfortunately, this has a higher computational cost. If high quality is not an issue in applications, local methods provide reasonable results within a much lower time-frame and offer the possibility of parallel implementations.

Keywords—Stereo vision; disparity; correspondence; comparative study; middlebury benchmark

I. INTRODUCTION

Stereovision is an area of computer vision focusing on the extraction of 3D information from digital images. The most researched aspect of this field is stereo matching: given two or more images as input, matching pixels have to be found across all images so that their 2D positions can be converted into 3D depths, producing as result a 3D estimation of the scene. As many other breakthrough ideas in computer science, stereovision is strongly related to a biological concept, namely stereopsis, which is the impression of depth that is perceived when a scene is viewed by someone with both eyes and normal binocular vision [1]. By aid of stereoscopic vision, we can perceive the surroundings in relation with our bodies and detect objects that are moving towards or away from us. While the entire process seems an easy task for us and other biological systems, the same does not apply to computer systems. Finding the correspondences across images is a challenging task. The earliest stereo matching algorithms were developed in the field of photogrammetry for automatically constructing topographic elevation maps from overlapping aerial images [2].

Stereo matching has been one of the most studied topics, starting with the work of D. Marr and T. Poggio [3] which focuses on human stereopsis. Lane and Thacker's study on stereo matching [4] presents a dozen algorithms from 1973 up to 1992, but no comparison between them was made. Another important study is the one done by Scharstein and Szeliski [5], in which they have compared several algorithms and their performance based on different metrics.

Stereo vision has a wide range of applications nowadays, especially domains in which realistic object models are needed. Depending on how important the processing time is, these applications can be classified into two categories: static scene description and dynamic scene description. For the first category, accuracy is of higher importance compared to the processing time. Usually, image pairs are acquired by means of a special device and reconstructed afterwards for cartography, crime scene reconstruction, car crashes scene reconstruction, 3D models for architecture. In dynamic scene description real-time processing of the data is critical. Of course, a certain level of accuracy must be fulfilled. Possible applications are obstacle (e.g. pedestrians) avoidance, autonomous navigation in which an internal map is continuously updated, height estimation, etc.

This paper aims to review different stereo methods available and compare several stereo matching algorithms across sets of images. Section 2 describes the fundamental of stereo correspondence that makes possible the depth estimation, and discuss some of the stereo methods available nowadays, classifying them into local, global and semi-global algorithms, while Section 3 analyses in more detail some referenced algorithms considered for experiments. The results are discussed in Section 4.

II. A CLASSIFICATION OF STEREOVISION ALGORITHMS

This section reviews some of the stereo correspondence algorithms that have been proposed over the last decades. These can be classified depending on multiple criteria such as the method which assign disparities to pixels, occlusion handling, color usage, matching cost computation etc.

A. Local Methods

Local methods assign disparities depending on the information provided by the neighboring pixels, usually fast and yield good results. One broad category of local methods is represented by the block matching algorithms, which try to find a correspondence for a point in the reference image by comparing a small region surrounding it with small regions in the target image. This region is reduced to a single line, called the epipolar line. Block matching algorithms are used not only in stereo vision, but also in visual tracking and video compression.

Among the first techniques which appeared is box filtering. This involves replacing each pixel of an image with the average in a box and it is an efficient general purpose tool for image processing. In [6] a procedure for mean calculation has been proposed. The advantage of box filtering is the speed, cumulating the sum of pixel values along rows and columns.

This way, the sum of a rectangle is computed in a linear time, independent of its size.

Another algorithm that achieves high speed and reasonable quality is the one proposed by Mühlmann et al. [7]. It makes use of rectified images and can be used by other, more sophisticated, algorithms that need an initial guess at the disparity map. In order to eliminate false matches it makes use of the left-right consistency check and uniqueness validation.

A new block matching algorithm has been proposed in [8] and even though the focus of this paper was on video compression, the algorithm can be applied also to stereo vision. This is based on a winner-update strategy which uses a lower bound list of the matching error to determine the temporary winner.

Efficient usage of color information can improve results, therefore, some of the best stereo correspondence algorithms use color segmentation techniques. One of the most popular color segmentation algorithms has been proposed in [9], based on the mean-shift algorithm which dates back to 1975, but extended on computer vision only later on. The algorithm proposed in [10] is one of the top performing algorithms in the Middlebury classification [11] and it makes use of this segmentation technique. This is based on inter-regional cooperative optimization. The algorithm uses regions as matching primitives. More exactly, they use color statistics of the regions and constraints on smoothness and occlusion between adjacent regions. A similar algorithm, that is currently one place above the before mentioned [10], is the algorithm proposed by Klaus et al. in [12]. Firstly, homogenous regions are extracted from the reference image, also with the method [9]. Secondly, local windows-based matching is applied using a self-adapting dissimilarity measure that combines SAD and a gradient based measure. Using the reliable correspondences, a set of disparity planes are derived.

Yoon K.J. and Kweon [13] have proposed a new window-based method that uses varying support weights of the pixels. These are adjusted in a given support-window depending on the color similarity and geometric proximity to the reference pixel in order to reduce the image ambiguity (repetitive textures, image noise) and to obtain good results also in homogeneous regions. The algorithm in [14] is a local stereo correspondence algorithm which employs segmentation cue and which has two main steps: initial matching and disparity estimation. The initial matching is performed with the contrast context histogram descriptor and two-pass cost aggregation with segmentation-based adaptive support weight. The disparity estimation has two sub-steps: narrow occlusion handling and multi-directional weighted least-squares fitting for large occlusion areas.

A novel similarity measure called DSM (Distinctive Similarity Measure) was introduced in [15] to resolve the point ambiguity problem, based on the idea that the distinctiveness is the appropriate criterion for feature selection under point ambiguity. DSM is based on the distinctiveness of image points and the dissimilarity between them, both of which are closely related to the local appearances of points. The first one is related to the probability of a mismatch and the second one to the probability of a good match.

Another class of local algorithms is represented by the gradient-based methods, also known as optical flow. In this case, the matching costs are insensitive to bias and camera noise. These methods determine the disparities between two images by formulating a differential equation relating motion and image brightness. In order to do this, the assumption is made that the image brightness of a point in the scene is constant between the two views [16].

One of the earliest methods for optical flow estimation is the one developed by Kanade and Lucas [17]. This solves the flow equations for all the pixels in the neighborhood using the least squares criterion. However it cannot provide flow information inside regions that are uniform. This method can be used in many applications of image registration, including stereo vision. More similar information can be found in [18].

A newer algorithm from the same class is the one proposed by Zhou and Boulanger [19]. This is based on relative gradients in order to eliminate the radiometric variance. Most stereo matching methods assume that the object surface is Lambertian, meaning that the color for every point in the scene will be constant in the views captured by two separate cameras. However, to most real-world objects this does not apply, reflecting light that is view dependent. The algorithm is able to deal with both view dependent and independent colors and both color and gray scale images.

Block matching and gradient-based methods are sensitive to depth discontinuities, since the region of support near a discontinuity contains points from more than one depth. These methods are also sensitive to regions of uniform texture [16]. Another class of algorithms that aims to overcome these drawbacks is represented by the feature-matching algorithms, which limit the support region to reliable features in the image. Because they produce sparse output and the demand nowadays seeks dense output, this class of algorithms is not given as much attention as in the past. An early review of such algorithms can be found in [20], proving how popular these were. Feature-matching algorithms can be divided into two subclasses: hierarchical and segmentation-based.

One example of a hierarchical feature-matching algorithm is the one in [21] which groups lines into complex structures. This method exploits four types of features: lines, vertices, edges and surfaces. As mentioned before, another approach is to first segment the images and only afterwards to match the segmented regions. Most of the existing algorithms assume that all the surfaces are parallel to the image plane, which is not actually the case. The algorithm proposed in [22] tries to solve the correspondence problem in the presence of slanted surfaces by alternating two steps: segmenting the image into non-overlapping regions, each corresponding to a different surface, and finding the affine parameters of the displacement function of each region.

B. Global Methods

Local methods are sensitive due to occlusions and uniform texture. On the other hand, global methods exploit nonlocal constraints in order to achieve more accurate results. However, accuracy comes with a trade-off, an increased computational complexity.

One of the most common global correspondence methods is based on dynamic programming. This is a fair-trade-off between the quality of the matches and the complexity of computations, which is decreased by decomposing the optimization problems into smaller and simpler sub problems. The disadvantage of DP is the possibility that local errors may be propagated along a scan line, corrupting also good matches [16]. One of the earliest algorithms which make use of dynamic programming is the one proposed by Ohta and Kanade [23]. This needs a pair of rectified images, this way, finding corresponding points can be done within the same scan lines in the left and right image, also known as the intrascan line search.

An alternative to the traditional search for global matching can be found in [24]. The authors propose a new representation of image scan lines, called intrinsic curves. An intrinsic curve is a path that a set of local image descriptors trace as an image scan line is traversed from left to right. These descriptors are defined by applying operators such as edge and/or corner operators. Another approach is to apply the DP technique to a tree structure instead of individual scan lines [25]. Because in the case of traditional DP algorithms the disparity estimates at a pixel depend only on the disparity estimates of pixels on the same scan line, but is completely independent of the disparity estimates on the other scan lines, these are not truly global optimization methods as the author states. The advantages of this approach are the following: firstly, since a tree structure is connected, the estimate of a disparity at one pixel depends on the disparity estimates at all the other pixels, making it a truly global algorithm and, secondly, a tree contains much more edges of the original grid than the collection of scan lines. Although the results obtained are in the middle range according to the classification in [11], the implementation is suitable for real-time applications.

As mentioned before, traditional approaches that use DP do not implement both horizontal and vertical continuity constraints. Methods like the one in [25] try to improve this aspect while maintaining a more than reasonable computational cost. Still, these do not fully exploit the two constraints. A solution would be to use 2D global optimization techniques like graph cuts, simulated annealing, belief propagation and others.

Graph-cut, also known as min-cut, is an algorithm that finds a globally optimal segmentation solution. Having a graph that can be partitioned into two disjoint sets by simply removing edges connecting the two sub-graphs we can compute the degree of dissimilarity between the two sub-graphs as the total weight of the edges that have been removed. One of the most cited works is the one in [26]. The authors propose an expansion move and swap algorithms that can simultaneously modify labels of large pixel sets.

The algorithm in [27] uses the graph cuts method in conjunction with color segmentation. The authors use the mean-shift algorithm to decompose the image into homogenous regions, based on the fact that large disparity discontinuities only occur on the boundaries of homogenous segments. Afterwards, the disparity plane estimation takes place. Finally, the graph-cut technique is applied to

approximate the optimal solution of the energy function. The graph-nodes represent here the homogenous segments, and not the pixels as in most of the approaches.

Another approach is to use belief propagation. Sun et al. [28] formulate the stereo matching problem as a Markov network and solve it using Bayesian BP (Belief Propagation). According to the authors, the Bayesian approach, which tries to solve the stereo correspondence problem by finding a best guess, has many advantages. It can encode several prior constraints such as spatial smoothness, uniqueness and the ordering constraint and it can handle the uncertainties. Also, Bayesian methods model discontinuities and occlusions. Bayesian methods can be classified into two categories, depending on the computational model: DP-based and MRF-based (Markov Random Fields). In this paper, three MRF are used, modeling the spatial interaction with the aid of a smooth field for depth/disparity, a line process for depth discontinuity and a binary process for occlusion. Belief propagation is used to obtain the maximum a posteriori model in order to enhance the stereo results obtained.

Nonlinear diffusion is another class of global methods. One of the main problems in the stereo correspondence problem is finding the optimal window sizes for comparing the image blocks. If the window is too small, a wrong match might be found. On the other hand, if the region is too big, it can no longer be matched entirely because of problems such as occlusion and foreshortening. The paper in [29] does not use fixed-sized windows, but introduces some novel algorithms which find the best support region based on iteratively diffusing support at different disparity hypotheses and which are an alternative to the adaptive windows. One of these algorithms is the membrane algorithm. This sums the neighboring matching costs iteratively and uses an additional term to prevent the support region from growing indefinitely. When a local stopping condition is used, the authors have seen that the algorithm behaves similar to the adaptive window algorithms. Another algorithm proposed is derived from the Bayesian model of stereo matching and results in a nonlinear diffusion process, having an increased performance compared to the standard diffusion.

Beside the above mentioned global methods many other ideas exist [30]. For example, there is a class of methods that do not seek explicit correspondences, used mainly when reconstructing a 3D object from different views of the scene. These model the scene using different objective functions. Furthermore, some algorithms make use of wavelets. Based on the continuous wavelet transform, such a method extracts the redundant information and uses it for the matching process.

C. Semi-Global Methods

Local methods try to find optimal disparities for small image regions which can lead to discontinuities between different regions in the image. On the other hand, global methods try to optimize all the disparities at once, which can offer better results, but at higher computational costs. More recently, a third class of algorithms has been developed, namely the semi-global class, which tries to incorporate the advantage of both groups.

The first semi-global algorithm has been developed by Hirschmüller [31] and used since then in real-time stereo vision and intelligent vehicles applications. In this implementation, mutual information was used as matching cost, because it is insensitive to radiometric differences and models very well image noise. Radiometric differences occur because of the different camera characteristics (vignette effect, different exposure time etc.) and different scene properties (non-lambertian reflection, changes in the light source etc.). Using mutual information, the global radiometric difference is modeled in a joint histogram of corresponding intensities. The matching is done pixel-wise based on the mutual information and approximation of a global smoothness constraint. Beside the good results delivered fast, this approach has the advantage of occlusion detection and sub-pixel accuracy in determining the disparities. Post-processing is possible afterwards in order to clean up the disparity image.

Another algorithm that aims to preserve depth discontinuities and to give good results in low-textured regions is the one in [14]. The authors have proposed three solutions for improving the sub-pixel accuracy. Firstly, they show the benefits of evaluating the disparity space at fractional level. Secondly, they introduce a new constraint, called the gravitational constraint. This assumes that the disparity levels are sorted in the vertical direction and it helps global algorithms to reduce the false matches. Finally, they propose a new algorithm that enforces smoothness at a sub-pixel level.

A more recent approach and an optimization to the original algorithm are proposed in [32]. The original algorithm favors regions of constant disparities because of the two penalties applied by the objective function. This way, a large amount of errors is caused. In order to obtain better results, the authors propose an extension to the algorithm's parameterization, by using individual penalties, depending on the path orientations and on intensity gradients. Furthermore, because the results obtained from one path can be better than the ones obtained by another path with a different orientation, they have introduced weights for each path orientation. Last but not least, the authors extend the original adaptation of penalty depending on the intensity gradient to a more general approach. Due to the high number of parameters, they need to be automatically tuned in order to find the best configuration.

III. THE ALGORITHMS CONSIDERED IN OUR STUDY

This section describes in detail several stereo vision algorithms with the aid of which the correspondence problem is solved. The comparative results obtained by them on the Middlebury benchmark are discussed in the next section.

A. The Problem of Finding Pixel Correspondence

With regard to software implementations, there are two main categories of algorithms that solve the correspondence problem: those that produce sparse output, and the ones that produce dense output. The first category is also known as the feature-based algorithms and they find correspondences by matching sparse sets of image features like edges, corners, line or curve segments, all of which are robust against change of perspective. These methods are inspired from human vision studies and have been very popular at the beginnings of stereo

vision, having the great advantage of being feasible for implementation on the hardware available at that time. Investigating only a small subset of pixels, such algorithms are very fast. Moreover, the accuracy is very good, limiting the results to matches with very high certainty. This happens for example in applications where the illumination can vary significantly and edges are the only stable features. The main disadvantage is the sparse output which cannot be always of use in applications. However, sparse 3D reconstructions can be later interpolated.

Even if we gain computational time and accuracy, a lot of time is invested in finding a feature extractor that performs well. One of the most successful and applied methods is using the SIFT (Scale Invariant Feature Transform) detector proposed in [33]. This algorithm extracts interesting points of an object in order to provide a feature description of the object during a training phase and uses them afterwards when recognizing the object in a new image, by comparing each feature from the new image to the features stored in the database based on the Euclidian distance of their feature vectors. Location, scale and orientation are a few of the descriptors that are used for finding the best match.

In order to overcome the disadvantage of the feature-based methods, dense correspondence algorithms have appeared, especially because nowadays computational resources are no longer a big issue. Many contemporary applications such as image-based rendering and modeling demand such a dense output and this approach is more challenging than the previous one, having to solve the correspondence problem in case of image sensor noise, perspective distortions, textureless regions, repetitive structures and textures, reflections, occlusions, photometric variations [34].

In [5], a taxonomy has been proposed for the dense stereo correspondence algorithms. According to the authors, a large set of existing algorithms can be easily constructed from a set of building blocks, steps that all these algorithms perform, as in Fig. 1. Matching cost computation is the first step in extracting the disparity map and it quantifies the similarity between pixels in the reference and target images. In general, the more similar the pixels are, the lower is the value of the matching cost.

The simplest method relies on pixel color information, for example, SSD (Sum of Squared Differences) [35] and SAD (Sum of Absolute Differences) [36]. These techniques are used also when matching objects from consecutive frames in video processing, but under the names of MSE (Mean Squared Error) and MAD (Mean Absolute Difference).

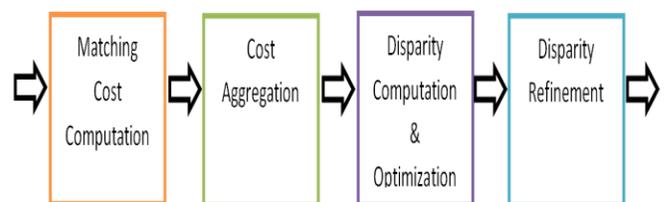


Fig. 1. Disparity map extraction flow.

In both cases, for every pixel in the reference image we search for a match on the epipolar line in the target image. Usually, only a maximum disparity is allowed so the search occurs in a defined window. For every possible pair, a cost is computed using (1) in case of SSD and (2) in case of SAD.

$$f(x, y, d) = \sum (I_L(x, y) - I_R(x, y - d))^2 \quad (1)$$

$$f(x, y, d) = \sum |I_L(x, y) - I_R(x, y - d)| \quad (2)$$

Some local algorithms combine matching cost computation and aggregation and use a matching cost that is based on a support region. NCC (Normalized Cross-Correlation) (equation 3) is such an algorithm and behaves similar to SSD, but is more complex, involving more mathematic operations. Due to the fact that in many image-processing applications the brightness of the image can vary due to lightning and exposure, the image must be firstly normalized.

$$f(x, y, d) = \frac{\sum I_L(x, y)I_R(x, y - d)}{\sqrt{\sum I_L^2(x, y)\sum I_R^2(x, y - d)}} \quad (3)$$

After computing the cost for each pixel, one way to choose the best corresponding pixel would be to choose the pixel for which the cost has the smallest value, approach also known as WTA (Winner Takes All). However, the resulting disparity map is very noisy. An alternative would be to compare small patches of pixels, instead of individual pixels.

As mentioned before, in order to overcome the bad result produced by comparing single pixels, a matching window around the pixel of interest is used instead. Increasing the window size reduces the noise effect in the disparity map.

However, this also results in increasing the computational time and choosing the correct window size is just another problem to address. Among the techniques used are SAD and SSD, which are applied also to single pixels, but the difference is that $f(x, y, d)$ is computed now over an area and summed afterwards. Very similar is STAD (Sum of Truncated Absolute Differences), defined by (4), where T is the disparity threshold.

$$f(x, y, d) = \sum \min\{|I_L(x, y) - I_R(x, y - d)|, T\} \quad (4)$$

It can be seen from Fig. 2 that matching cost aggregation has produced better results, but they are still far from being optimal because there exist some problems with fixed windows. Firstly, such a method assumes that the depth is constant within the window. Usually this is not the case due to depth discontinuities and slanted/non-planar surfaces. Secondly, many images contain repetitive textures or uniform areas. In these cases, there are many "weak" minima of the matching cost. Last but not least, sometimes the window is larger than the structure. Even so, because its simplicity, fast execution time and low memory requirements, SAD followed by a WTA approach is often chosen in implementations. It can be run real-time on standard processors (SIMD) and hardware implementations like FPGA, consuming a limited amount of power.

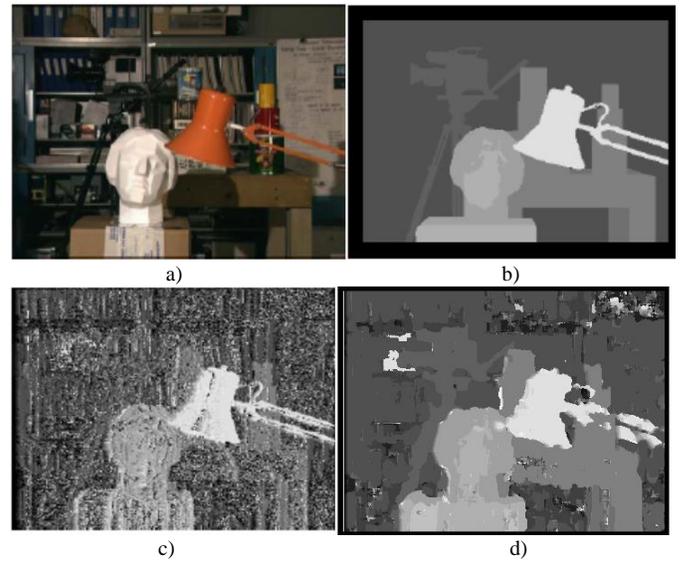


Fig. 2. Single pixel vs. matching window. a) left camera image; b) optimal result; c) single pixel comparison; d) matching window.

The next step tries to find the best disparity assignment and we can distinguish two main classes of methods: local and global ones.

In local methods, the most important steps are matching cost computation and cost aggregation. Choosing the disparity is a trivial task, namely finding the one associated with the minimum cost. As mentioned before, this is WTA optimization applied to each pixel. The disadvantage of these methods is that a uniqueness match is not enforced both directions: the reference image has a single match in the target image, but pixels in the target image can correspond to multiple pixels in the reference image.

On the other hand, in global methods the focus is put on this step. Sometimes, the cost aggregation step is skipped. In many methods, the aim is finding a disparity function that minimizes a global energy. Usually, the global energy function has two terms like in (5).

$$E(d) = E_{data}(d) + E_{smooth}(d) \quad (5)$$

The first term measures how well the disparity function d agrees with the input image pair in terms of overall matching cost [5]. The cost functions used can be pixel-based or, more effective, support aggregation strategies. The second term encodes assumptions (of continuity) of the scene made by the algorithm. Large disparity variations are penalized and are allowed only at depth borders. Finding the best assignment that minimizes the energy function is an NP-hard problem. In order to make this computationally possible, often only differences between neighboring pixels' disparities are computed.

A different class of global optimization algorithms is based on dynamic programming, which can find the global minimum for independent scan lines in polynomial time [5]. Complex problems are solved by breaking them down into sub-problems, each of which is solved only once. This technique has the advantage of enforcing the ordering constraint (e.g. the pixels must be in same order both in reference and target image) and

being accurate at depth borders and uniform regions. DP algorithms find the optimal disparity solution for a scan line in two steps: forward pass and backward pass. The forward pass, the minimum sum of aggregation, matching cost and smoothness penalty for each disparity candidate pixel along the scan line is searched. At each iteration, the winner is then summed with the first term of (5), resulting in an aggregation cost. In the backward pass, the optimal disparity map scan line solution is obtained iteratively backwards.

Cooperative algorithms are another class of optimization algorithms and are among the earliest methods proposed [37]. They perform local computations, but use nonlinear operations that result in an overall behavior similar to global optimization algorithms [5]. In some implementations it is possible to state the global function to be minimized. The authors have formulated two assumptions on which the algorithm is based: uniqueness, allowing only one match along each view direction, and continuity, meaning that neighboring matches should have similar disparity values. These constraints define a complicated error-measure which is minimized through cooperative network dynamics [6].

The last step from the stereo matching workflow is the disparity refinement, which is an optional one, used for improving the matching quality. In this pass, outliers produced by the previous steps, are identified and corrected. Also, because the disparity maps are usually computed at pixel level, more accurate disparity assignments (computed at sub-pixel level) would be desirable.

B. Shiftable Window SSD

Shiftable window SSD is a classic stereo vision algorithm which belongs to the area-based correlation category. It follows four steps, in which each area-based algorithm is divided: matching cost computation, cost aggregation, disparity computation and the optional disparity refinement.

The basic idea is matching the intensity values within windows between the stereo image pair. The algorithm needs as input a pair of rectified images. For every pixel in the reference image, a correspondent in the target image is computed by comparing a square window centered on this pixel against windows of the same size centered at points on the corresponding scan line (epipolar line) in the target image. The number of candidate points in the second image is given by the maximum disparity value, which typically lies between 10 and 20. SSD is used as a measure of dissimilarity between the windows. The point for which the surrounding window has yielded the minimum sum of squared intensity values will be chosen as the best match and the offset between its location and the location of the reference point will be stored as the disparity at that location [38].

As mentioned in the previous sections, the main issue in window-based methods is choosing the optimal window size. If the value is too small, wrong matches are likely to occur due to noise and ambiguities. However, the object shape will be preserved. On the other hand, if the window is too large, it will reduce the number of wrong matches, but at the same time it will blur the object boundaries. In Fig. 3, the results have been obtained by using various window sizes.

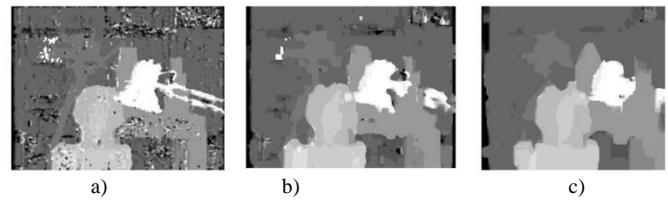


Fig. 3. Disparity maps obtained by applying shiftable window SSD [39]. a) window size = 3; b) window size = 11; c) window Size = 25.

The shiftable window algorithm can be implemented with other matching costs, for example SAD or NCC instead of the presented SSD. The SSD method has a higher computational cost compared to SAD, involving numerous multiplication operations.

C. Dynamic Programming

Dynamic programming is a technique that is used not only in the stereo correspondence problem, but also in fields very different with regard to computer vision, such as mathematics, economics and bioinformatics. The basic idea is to decompose a problem into a set of sub problems, such that, given a solution to the sub problems, the solution to the original problem can be quickly computed and the sub problems can be solved recursively in terms of each other. Because the solution to a sub problem is used later on, multiple times, we need to store the solutions in order to avoid recomputing them.

DP can be thought of as a method for filling in a table. At each position a value is found, corresponding to a sub problem we need to solve. DP algorithm iterates over the table entries and computes for each location a value that is based on the previously seen entries. The relationship between the current entry and the previous ones is usually given in a simple, recursive manner, but at times can be more complex. Generally, it provides better results than the area-based methods and it is even faster than these.

In the stereo correspondence problem, DP helps to find a path through the image which provides the best match. For each pair of corresponding scan lines, a cost matrix of all pair wise matching costs is built. The goal is to find the minimizing path through this matrix. Fig. 4 depicts how such a matrix looks like.

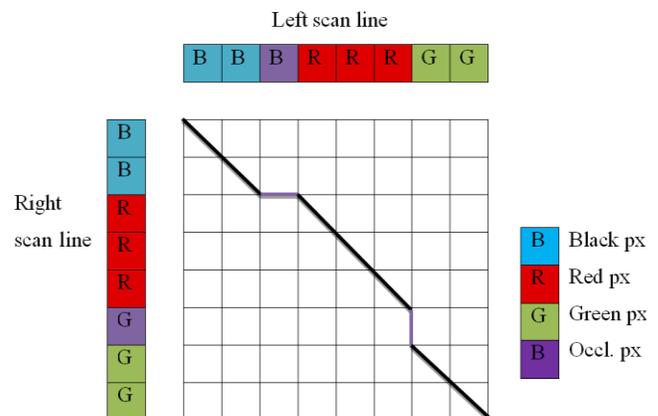


Fig. 4. Stereo matching using DP.

Let's assume that we have two scan lines, with black, red and green pixels which need to be matched. Also, we have 1 left occluded pixel and 1 right occluded pixel. Any path starting from the top left of the matrix and ending at the bottom right of the matrix represents a specific correspondence of pixels in the left scan line to pixels in the right scan line. In this example, the best possible path assumes that the first 2 pixels correspond and then there is a left occlusion. The next 3 pixels correspond again, followed by a right occlusion and another match of 2 pixels.

We can observe that at each location there are 3 possible directions:

- diagonal: match
- right: left occlusion
- down: right occlusion

Usually, when searching for a match, only a limited range of disparities is considered which will lead to fewer paths. A path is constituted by a succession of values on the matrix. The value of an arbitrary point in the matrix represents the value of getting there. As seen in (6), for a point $P(x, y)$, if we have a match, we will pay no penalty, but add a matching cost to the previous, precomputed value for the previous point, $P(x-1, y-1)$, from which we arrived by following the diagonal direction. This is the case for the first 2 pixels in Fig. 4, for example. On the other hand, in case of no match, we will pay an additional cost, the occlusion cost, which will add up to the precomputed values for the previous points, depending on the type of occlusions: $P(x-1, y)$ in case of left occlusion and $P(x, y-1)$ in case of right occlusion.

$$P(x, y) = \min \begin{cases} \text{match cost } P(x, y) + P(x-1, y-1) \\ \text{occlusioncost} + P(x-1, y) \\ \text{occlusioncost} + P(x, y-1) \end{cases} \quad (6)$$

In the end, we will obtain the correspondence cost. This is the first part of a DP algorithm. However, once found the best cost, we need to reconstruct the optimal path using backtracking, which is the second part of the algorithm. The disadvantage of DP is that local errors might be propagated.

Optionally interpolation can be used. Such a method is Birchfield-Tomasi interpolation [22], which computes for every pixel the minimum and maximum values in the two half-intervals before and after it. These values are further used when computing the matching cost (SAD, SSD etc.).

D. Scan Line Optimization

Scan line optimization (SO) is like DP, a global optimization technique which optimizes one scan line at a time. However, unlike DP, SO is an asymmetric method and does not make use of constraints such as ordering and visibility constraints. What is more, there is no penalty cost for occlusions. At each point, a disparity value is assigned so that the overall cost along the scan line is minimized. This way, a global minimum on each scan-line is obtained, but no inter-scan line consistency, resulting in a horizontal streaking effect in the resulting disparity map.

SO is very similar to another global technique, Graph Cuts, which is presented in the next section. The difference is that vertical smoothness is not taken into consideration. However, it does use the horizontal smoothness terms, without which the algorithm would be just WTA optimization.

The first step of this algorithm is computing the DSI. This means that for every pixel in every scan line a cost is computed for a maximum number of disparities, ranging from 0 (the case in which the corresponding pixels have the same location) to disparity max (the maximum possible offset of two corresponding pixels). The cost is computed in this version of the algorithm using SAD, but any other matching cost could be used. The aggregation step is skipped. Afterwards, for each point, the best disparity is chosen using, in this case, the scan line optimization technique.

E. Simulated Annealing

Simulated annealing (SA) is a global method which performs standard moves, meaning that only one pixel changes at a time. This is why in many stereo vision implementations it is shown to be the slowest optimization techniques. Such a disadvantage is solved by the algorithm presented in the next section, which changes a whole group of pixels in one move. However, SA is still used occasionally, especially in highly connected and highly non-submodular graphs.

SA is a random search function that effectively approximates the global optimum solution. This is inspired by the process in metallurgy in which a metal alloy is heated to a very high temperature. The atoms are left at this temperature long enough to reach thermal equilibrium. Afterwards, the metal is gradually cooled on a very specific and gradual schedule. As they cool, the atoms settle into an optimal crystalline structure. This process improves the cold-working properties of the metal.

One main characteristic of this algorithm is the iterative improvement, which means that it goes through a several number cycles, each of them trying to improve the current solution. It uses local random search, instead of sampling through the entire sample space. Also, SA is an algorithm that explores the solution space, especially early in the search, but as the search progresses, coming closer to the global optimum; it becomes greedy, accepting only improvements of the solution.

SA starts at a high temperature so that a large part of the state space is explored randomly, and cools gradually the temperature to find a suitable local minimum. There are several variants of this algorithm. For example, in the Metropolis variant, downhill steps are always taken, and uphill steps are only sometimes (randomly) taken in order to avoid being stuck in a local minima. Another variant is the Gibbs sampler. Instead of choosing the lowest energy for the variable being updated, it chooses among several possible states: either a new, random state (disparity), either one of the possible disparities at a given pixel is chosen. As mentioned above, the algorithm starts at a high temperature and then this is gradually decreased. The algorithm is terminated when a maximum number of iteration is reached.

F. Graph-Cut Optimization

The graph-cut algorithm (GC) belongs to the global class and it is one of the best algorithms available. It produces very accurate results and, therefore, it is a very popular one. However, this happens at an increased computational cost. As in the case of other global techniques, we are interested in minimizing an energy function. In the case of GC, we have a label set, namely the disparities and a set of pixels. The goal of the algorithm is to find a labeling f which minimizes some energy. Min-cut/max-flow algorithms which come from combinatorial optimization have been proven to minimize such energy functions in computer vision. Stereo matching and image segmentation are such applications.

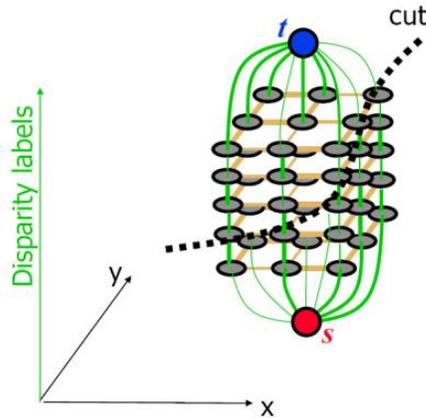


Fig. 5. S-T graph cut [40].

A graph is a model that looks like a network and is built from a number of nodes and a number of edges that connects them. A graph is called a directed graph if the edges have a direction associated with them. Very often, each of these oriented edges are associated a cost so that choosing one path or the other results in different costs. Sometimes, a graph contains a number of additional special nodes, called terminals. For this algorithm, graphs with two terminals are considered, the source s and the sink t . With respect to the stereo vision application of graph theory, the terminal nodes correspond to the disparities that will be assigned to pixels. There are two types of edges in the graph: n -links and t -links. The first category is used to connect neighboring pixels, representing the neighborhood system in the image. The cost associated to these represents the penalty for the pixel discontinuity. The second category connects pixels with the terminals, labels (more exactly, disparities). In this case, the cost of such links corresponds to the penalty for assigning a certain label to a pixel.

In a two terminal graph, a cut is a partitioning of the graph nodes into two disjoint subsets, S and T , such that the source s is in S and the sink t is in T [41]. This is also called s - t graph cut and can be 2D or 3D, as illustrated in Fig. 5. A cut has an associated cost, the sum of the edges that are eliminated when partitioning the graph into two sub-graphs.

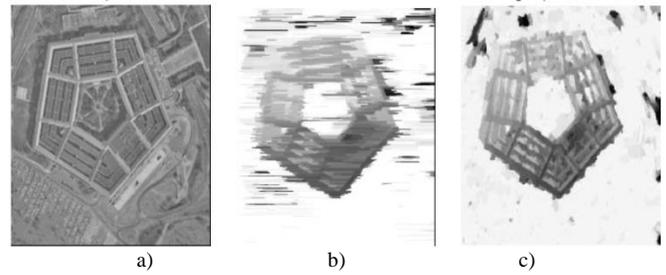


Fig. 6. SO vs. GC. a) original image; b) SO result; c) GC result [42].

One fundamental problem in combinatorial optimization is the minimum s/t cut, sometimes also called the maximum flow problem, because of their equivalence. We can think of it in the following way: maximum flow is the maximum “amount of water” that can be sent from the source to the sink by interpreting graph edges as directed “pipes” with capacities equal to edge weights [41]. The goal is to delete enough edges so that each pixel is connected to exactly one label node, while finding the global minimum of energy function. As mentioned above, the cost for a cut has two terms, the image consistency (horizontal edges) and the spatial consistency (vertical edges) like in (7). Because of these two costs, the streaking effect from SO is no longer visible, as shown in Fig. 6.

$$E(d) = \sum |I(p) - I(p + d_p)| + \sum w_{pq} |d_p - d_q| \quad (7)$$

The authors of [42] have developed two new algorithms for energy optimization, which uses graph-cuts iteratively. These generate a labeling representing the global minimum of energy with respect to two types of moves: α -expansion and α - β -swap. Through such moves a large number of pixels change their labels to α or β simultaneously. The main purpose of these algorithms is to compute swaps or expansions until convergence.

G. Bayesian Diffusion

In the previous sections the main focus of the algorithms lied in the optimization step. However, in this section we will focus on the aggregation step. In [29] the authors have presented a Bayesian model with non-Gaussian statistics to handle gross errors and discontinuities in the surface.

The Bayesian model presented consists of two parts. Firstly, there is a prior model which uses MRF to encode preferences for smooth surfaces. Such a model uses the Gibbs distribution in (8), where d is the vector of all disparities and Z_p is a normalizing factor.

$$p_p(d) = \frac{1}{Z_p} \exp(-E_p(d)) \quad (8)$$

$$E_p(d) = \sum_{c \in C} E_c(d) \quad (9)$$

Secondly, is the measurement model, which is based on the intensity differences between the left and right images.

IV. EXPERIMENTAL RESULTS

This section presents the data sets used for experiments, with the main characteristics, as well as the quality metrics used to assess the performance of the algorithms tested. Furthermore, a series of experiments are described, comparing different matching cost techniques, from both the quality and time-related performance point of view. Also, an overall comparison of the algorithms presented in the previous section is described.

A. Data Set

The experiments presented below are run on four image sets, also known as the 2001 stereo data sets [5]. Two of the data sets, *Sawtooth* and *Venus*, are directly acquired by the authors of the paper mentioned. They each consist of a sequence of 9 images, taken at equally-spaced intervals by a camera mounted on a horizontal translation stage, along with a ground truth disparity map. The original images are sampled down to a resolution which is four times less and cropped in order to normalize the motion of the background objects to only a few pixels by frame. The content is made up of piecewise planar objects such as posters or paintings, some with cut-out edges. The other two sets are *Tsukuba*, from the University of Tsukuba, and *Map*, whose ground-truth disparity map has been computed the same way as for the first two sets.

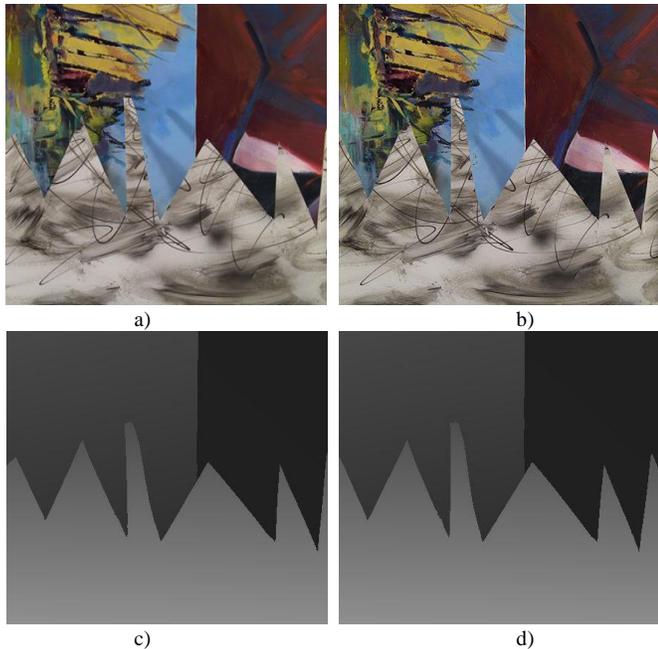


Fig. 7. Sawtooth data set. a) image 2 and b) image 6; c) ground-truth disparity maps for image 2 and d) image 6.

Finding a proper data set on which the correspondence algorithms can be tested is a difficult challenge. On one hand, there are the synthetic images which have been largely used, but because they often contain scenes that are not very complex, made up of simple geometric objects and textures, they do not produce very relevant results. On the other hand, images obtained from real cameras are difficult to convert into working sets because of issues such as aliasing, misalignment, lens aberrations, gain and bias, etc. but they model the real-

world better. However, such images contaminated with noise are too difficult to be solved. For each of the images, a border of 10 pixels is excluded to avoid the border effect. For the *Tsukuba* image data set, this border is 18 pixels because no ground-truth disparity values are provided.

The *Sawtooth* data set contains both grayscale and color textures with sloping walls. It contains 9 images (numbered from 0 to 8) and 2 ground-truth disparity maps for images 2 and 6, scaled by a factor of 8 (Fig. 7). This means that for a value of 80 in the ground-truth disparity map for image 2, the corresponding pixel in image 6 is 10 pixels to the left. The images for which no ground-truth disparity map is given are only used in case the prediction error is measured. Image size: height 380, width 434 and disparity: minimum 3.875, maximum 17.875.

The *Venus* data set contains color textures. It is actually a superposition of several sloping planes: newspaper, painting, illustration. Just like the *Sawtooth* data set, it is made up of 9 images and 2 ground-truth disparity maps, for images 2 and 6 (Fig. 8). Image size: height 383, width 434 and disparity: minimum 3, maximum 19.75.

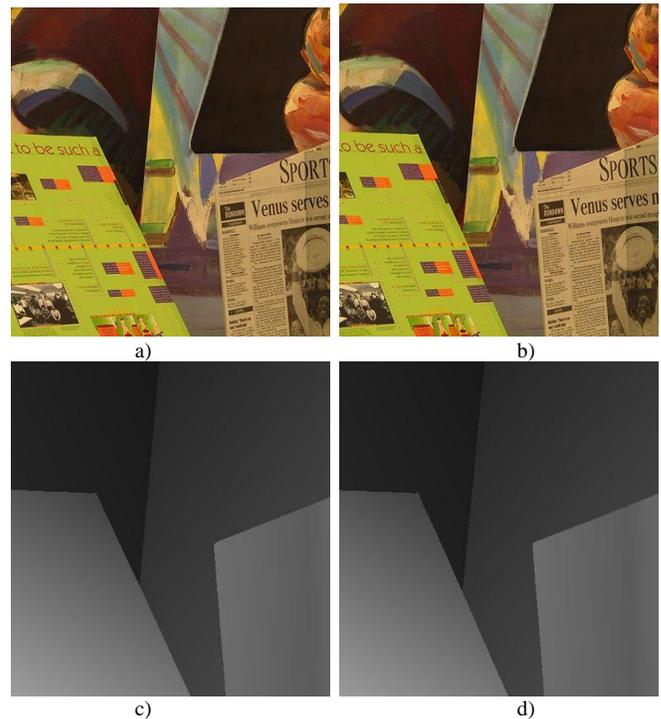


Fig. 8. Venus data set; a) image 2 and b) image 6; c) ground-truth disparity maps for image 2 and d) image 6.

The *Map* data set contains grayscale images, representing a map on top of other maps, with different textures (Fig. 9). It contains non-repetitive textures and very small occlusions, which means that all algorithms will perform well on this data set. Unlike the previous stereo sets, it contains only 2 images and 2 ground-truth disparity maps. Image size: height 216, width 284 and disparity: minimum 4.375, maximum 28.125.

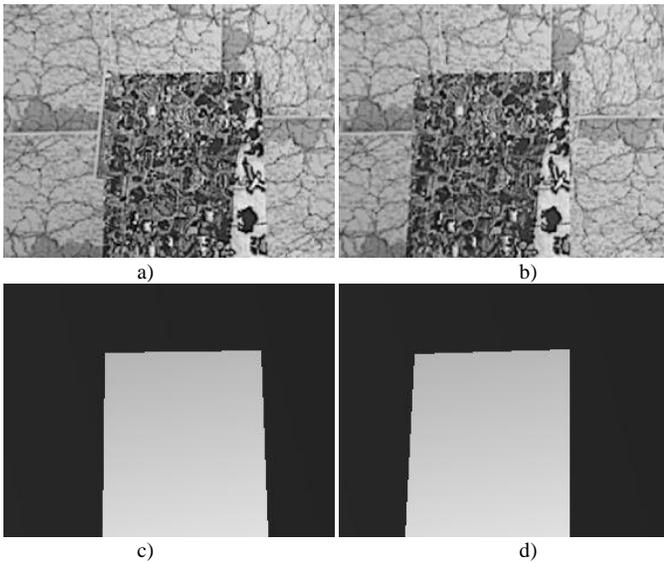


Fig. 9. Map data set; a) image 0 and b) image 1; c) ground-truth disparity maps for image 0 and d) image 1.

The *Tsukuba* data set contains images that represent a real scene (Fig. 10). It is made up of several distinct colored layers, one on top of the other. Almost all algorithms have problems in finding the lamps' arms because they try to provide smooth disparities. It contains 5 images and 1 ground truth disparity map. Image size: height 288, width 384 and disparity: minimum 0, maximum 14.

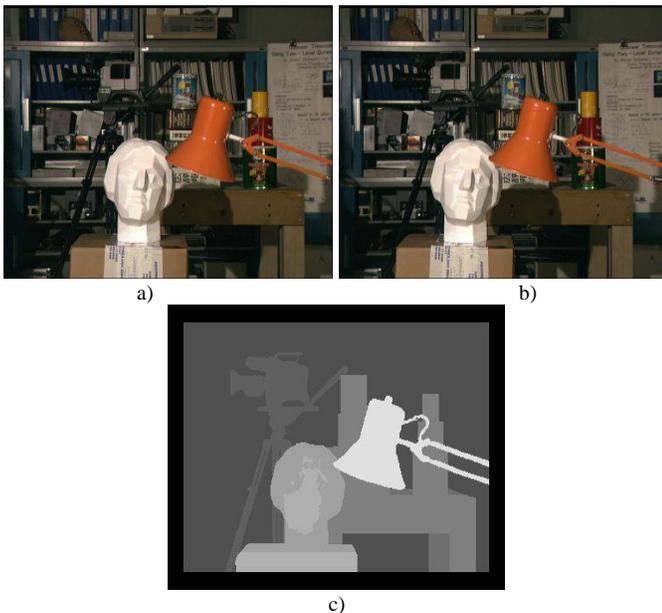


Fig. 10. Tsukuba data set; a) image 4 and b) image 5; c) ground-truth disparity map.

B. Quality Metrics

In order to assess the performance of the stereo correspondence algorithms we need some quality metrics. There exist two approaches in this direction. Firstly, some statistics can be computed based on the results obtained and the ground truth disparity map that already exists in the data set.

The second approach is to assess the quality of the algorithm by using the entire image set and the resulted disparity map in order to predict the appearance of other views. This can be done by either forward wrapping the reference image by the computed disparity map to a different view, or by inverse wrapping a new view by the computed disparity map to generate a stabilized image and compare it against the reference image [5].

For a more clear and quantitative image of the algorithms the first approach will be used. These statistics can compute the RMS (root mean square) or several percentages of pixels that are labeled with bad disparities. The RMS is a statistical measure widely used for comparing obtained results against some ground data. In our case, it is measured in disparity units between the obtained disparity map and the ground-truth disparity map existing in the data set. This is computed with (10), where N represents the total number of pixels, $d_C(x, y)$ represents the computed disparity for the pixel at location (x, y) and $d_T(x, y)$ the ground-truth disparity.

$$RMS = \frac{1}{N} \sum_{(x,y)} |d_C(x, y) - d_T(x, y)|^2 \quad (10)$$

In addition to RMS, the percentage of bad-matching pixels can be computed using (11), where T denotes a threshold, the acceptable disparity error for counting the bad-matching pixels.

$$B = \frac{1}{N} \sum_{(x,y)} (|d_C(x, y) - d_T(x, y)| > T) \quad (11)$$

Depending on the regions investigated we can segment the image in three regions. Firstly, there are the textureless regions, where the difference in intensity gradient is below a certain threshold. Secondly, occluded regions are the ones which exist only in the reference image. Depth discontinuity regions are the ones that contain pixels with a significant difference in the neighboring disparities. Computing such percentages of bad-matching pixels gives us a more relevant image of the overall performance of an algorithm. For example, according to [5], a stereo correspondence algorithm is said to perform reasonably well if the percentage of non-occluded bad-matching pixels is less than 10%. Because of the 10% poorly matched image region, the RMS is contaminated by the large disparity errors, even if the 90% rest of the image can have no errors at all. RMS measure is to be used when the bad pixel percentage is very low.

In order to assess the performance of the algorithms at least two stereo images and a corresponding ground-truth disparity map are needed by the program. The quality metrics to be computed have been described above, but in the following experiments only some of the regions will be considered: textureless, depth-discontinuity, non-occluded. Also, an overall performance was referred. Besides the percentage of bad pixels, the RMS was also displayed graphically.

C. Results for Matching Costs

This experiment aims to assess the performance of matching costs using a local algorithm which actually translates to the traditional SSD/SAD algorithm presented above, but with a fixed square window of 9 pixels.



Fig. 11. Experiment 1 workflow.

Fig. 11 shows the blocks of a stereo-correspondence algorithm with regard to this experiment. The images are not preprocessed beforehand. The matching costs tested are SAD and SSD by themselves or in combination with the previously presented Birchfield-Tomasi interpolation. Also, for each of the matching costs truncation has been applied with values 1, 2, 5, 10, 20 and 50. This plays a role in the step in which the matching costs are computed. The minimum between the computed difference and the truncation value is chosen to be stored in the cost matrix. It is to be noted that if SSD is used, the truncation value is squared.

Three specific categories of metrics have been taken in consideration for this experiment: the non-occluded pixels, the

textureless pixels and the pixels that are near depth-discontinuities. An overall percentage of bad pixels were also computed. The experiment has been run on all four data sets presented in the previous section and the results are presented in Fig. 12. Besides the percentage of bad pixels, also the RMS measure is graphically displayed for all regions in Fig. 13.

As an overall conclusion we can state that there is very little difference between the performance of SSD and SAD matching costs. Generally, SAD tends to have better results for larger truncation values (e.g. 50, 20) and SSD for lower truncation values (e.g. 5, 10). Truncation values such as 1 and 2 should not be taken into account here, because the errors are very large in these cases. Good results are obtained for values greater than 5 and less than 50, usually around the value of 20. The greatest impact of truncation is definitely on the regions with depth-discontinuities, which contain pixels that correspond to the background and pixels that correspond to the foreground. Truncating the matching cost helps to limit the influence of bad matches.

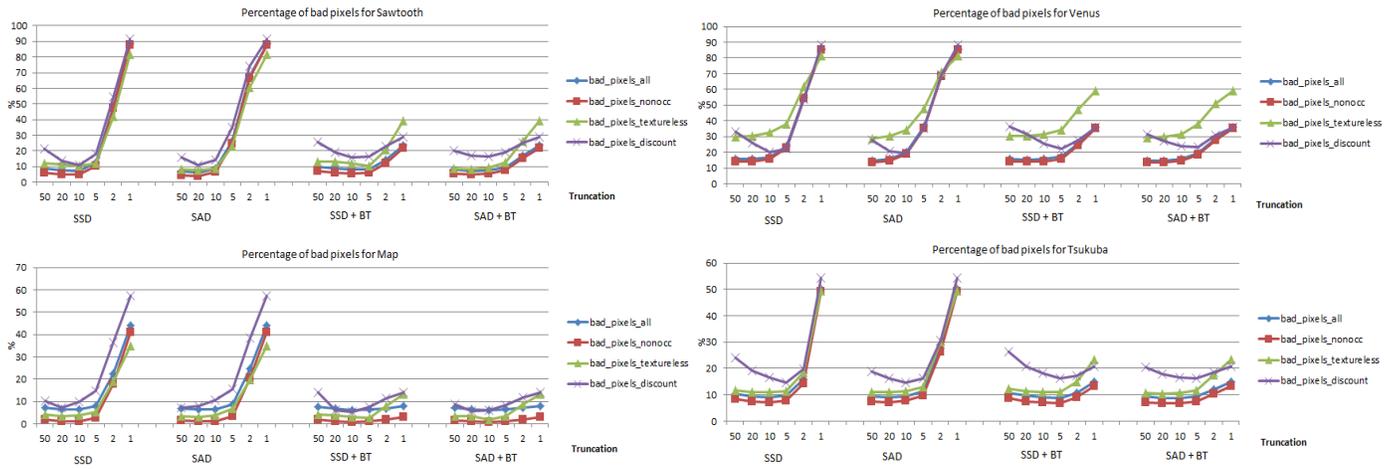


Fig. 12. Bad-matching pixel percentage for experiment 1.

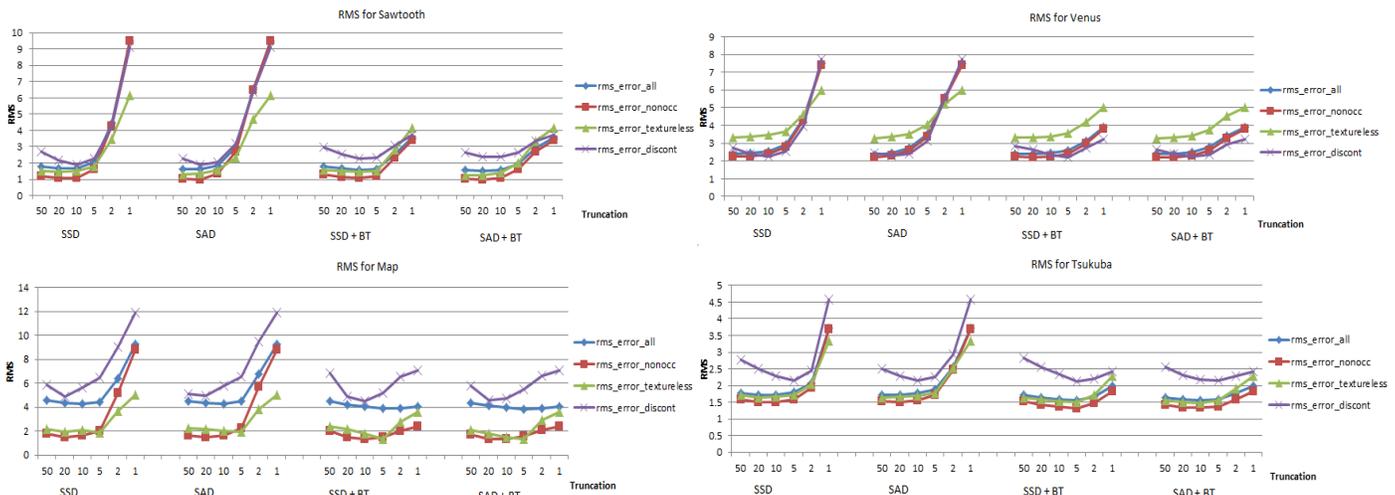


Fig. 13. RMS results for experiment 1.

Birchfield and Tomasi's interpolation improves the results for small truncation values, but does not improve them in case of large truncation values. On the contrary, in the latter case it tends to raise the errors for truncation values such as 20 and 50. This happens across all stereo image pairs. It can be seen that the RMS obtained by the matching costs follows the same trend as in the case of bad-matching pixel percentages.

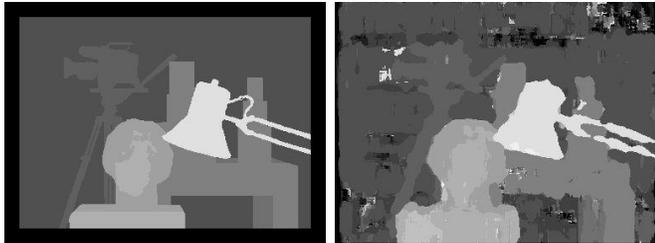


Fig. 14. Ground-truth vs. obtained disparity map for *Tsukuba* data set.

In Fig. 14, the ground-truth and the best disparity map for *Tsukuba* data set are displayed. These were obtained with SAD and Birchfield-Tomasi matching cost, with a truncation value of 10.

D. Results for Shiftable Windows

This experiment aims to assess the performance of shiftable windows and is very similar to experiment 1 (Fig. 15). In fact, it does the same operations as in experiment 1, but uses a 9x9 min-filter, which is equivalent with the shiftable windows aggregation. SAD/SSD matching costs are combined with Birchfield-Tomasi interpolation and truncation values.

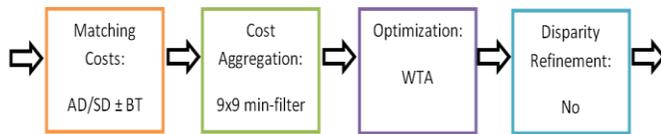


Fig. 15. Experiment 2 workflow.

This experiment has been run on all four data sets and the same statistics as the ones computed for experiment 1 are presented in Fig. 16 and 17. Trying all $n \times n$ shifted windows around a pixel is equivalent to applying a box-filter and a min-filter of the same size and it is not expensive from the computational point of view [5].

Just like in experiment 1, there is little difference between the AD and SD matching costs. What is interesting to observe is that for all experiments, the larger the truncation value, the smaller the error. Using no truncation at all yields the best results. The most obvious decrease in the error along with increasing the truncation value can be seen for the pixels that are near depth-discontinuities. This is very helpful, because we have already seen that choosing the best truncation value is a difficult task, depending very much on the data set. Instead, shiftable windows (box filter and min-filter aggregation) can be used for very good results, avoiding outliers. Birchfield-Tomasi interpolation is helpful in reducing very large errors, which occur for low truncation values, but does not bring any significant improvement for reasonable errors, which are obtained for larger truncation values.

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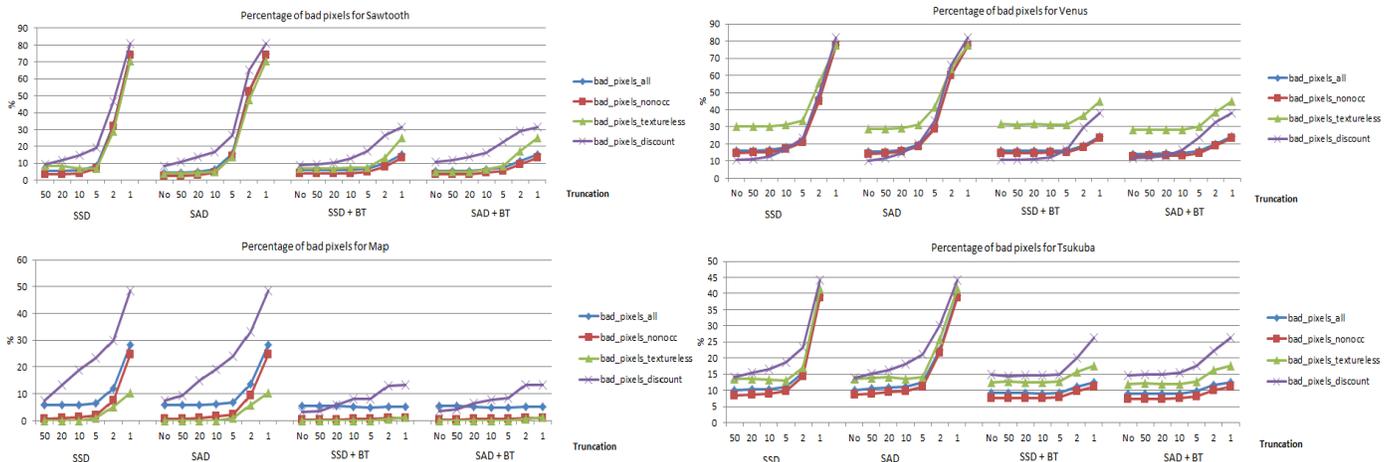


Fig. 16. Bad-matching pixel percentage for experiment 2.

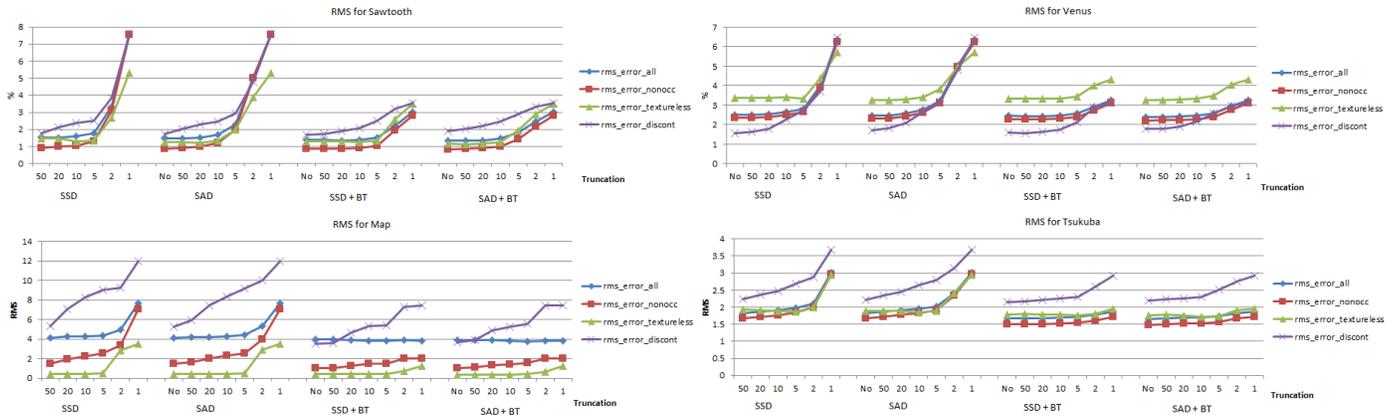


Fig. 17. RMS for experiment 2.

In Fig. 18, the best resulting *Tsukuba* disparity map was displayed, along with the ground-truth disparity map. The lowest percentage of bad-matching pixels on this data set was obtained for SAD with BT, with no truncation: 7.176 %. The best percentage on this data set in experiment 1 was 6.8003 %.

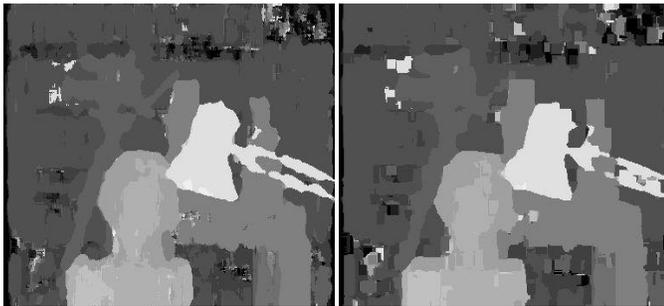


Fig. 18. Experiment 1 vs. experiment 2 results on *Tsukuba* data set.

E. Results for Aggregation Methods

Unlike the previous experiments, experiment 3 focuses on the aggregation step (Fig. 19). Three methods are used: square windows, shiftable windows and diffusion. For the square windows, the algorithm is in fact SAD. Several window sizes are used, starting from 3 x 3 and ending with 29 x 29. The shiftable windows algorithm is reproduced by using a box filter

followed by a min-filter. Several window sizes are also used here, just like for the square windows. Last but not least, regular diffusion is tested. In this case, we no longer need a window size. The algorithm is controlled by the number of iterations, which ranges from 10 to 150, but which has the same meaning, controlling the extent of the aggregation.

Regarding the other steps, AD is used for computing the matching costs. The aggregation is followed again by a WTA optimization and no disparity refinement is done. The images were not preprocessed.

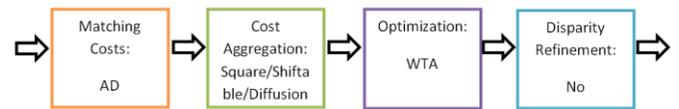


Fig. 19. Experiment 3 workflow.

Regular diffusion is an alternative to using fixed windows, easier than the Bayesian model which is controlled by much more parameters. This technique aggregates support with only a weighted support function, for example a Gaussian. Four neighbors of the pixel are used when computing the energy and lambda, which controls the speed of the diffusion. In this experiment, lambda was chosen 0.15. According to [29], to ensure convergence, lambda needs to be < 0.25.

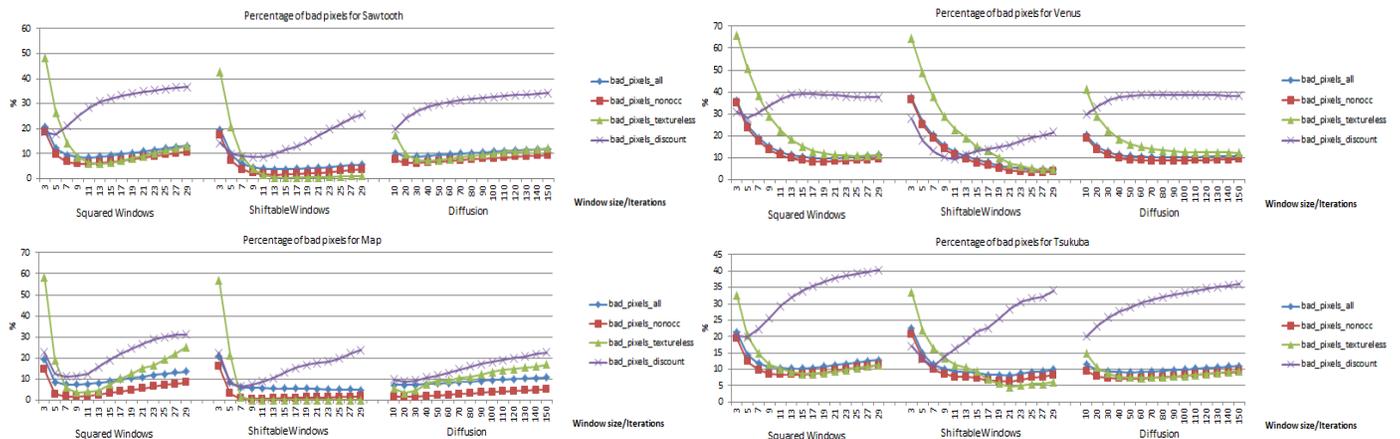


Fig. 20. Bad-matching pixel percentage for experiment 3.

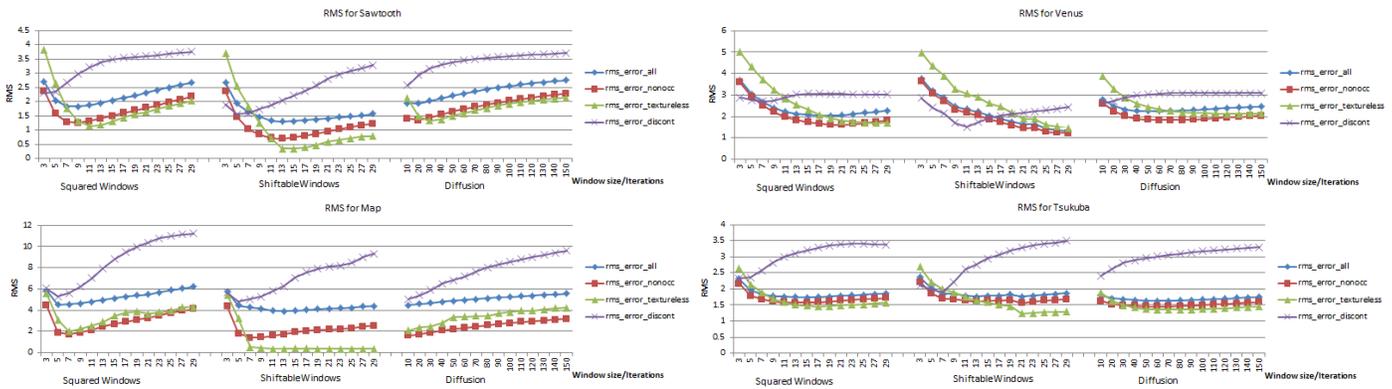


Fig. 21. RMS for experiment 3.

In Fig. 20 and 21, the results of this experiment were displayed. The most interesting observation is that the curves shows opposite trends for the textureless pixels and the ones located near depth-discontinuities. The larger the window sizes for aggregation, the smaller errors in the textureless areas. On the contrary, in the depth-discontinuities regions, the errors increase with the size of the aggregation extent.

This is the fundamental drawback of local algorithms: choosing the window size proves to be a difficult task, depending on the image sets and the regions they contain. The local methods assume that all pixels in one window share the same characteristics, namely disparities. However, often, especially in highly textured images, such windows contain mixed pixels. Some belong to the background and some belong to the foreground. The aggregated cost of such a window can only take one direction and this is done depending on how much horizontal texture exists in the regions near a depth-discontinuity. This problem is also known as fattening effect, which characterizes the local methods. This means that the center of a window inherits the disparity of the pixels with a stronger texture. In case of strong depth-discontinuities, this is called foreground fattening effect. The fattening effect, as stated by its name, makes the objects in the blocks look larger (fatter) than in reality. This is not very obvious in 2D, but becomes very noticeable in 3D depth reconstruction, creating unrealistic models.

In Fig. 22, it can be observed the ground-truth disparity map and the obtained disparity map with the squared windows and shiftable windows methods, having window size 29. The squared windows technique makes the foreground object visibly larger than in reality, while the shiftable windows technique recovers the original proportions pretty well.

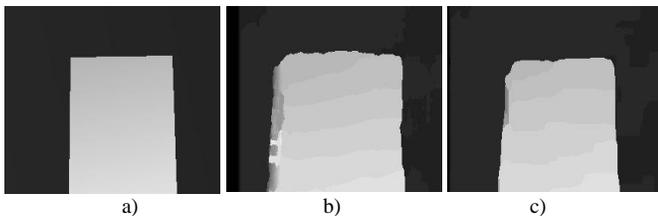


Fig. 22. Fattening effect on *Map* data set. a) ground-truth; b) square windows; c) shiftable windows disparity maps.

If we look at the graphics we can see that the shiftable windows algorithm yields the best results from all the three techniques, especially in the case of depth-discontinuity regions. Shiftable windows method is the simplest variation of the adaptive window techniques, which try to eliminate the fattening effect. This is followed by the diffusion model. Although it is the simplest method from the three, the square windows has the poorest results and choosing the right window size has even more impact than in the case of the shiftable windows.

F. Optimization Methods

Experiment 4 focuses on the next step of a stereo correspondence algorithm, the optimization (Fig. 23). Four methods are compared: dynamic programming, scanline optimization, graph cuts and simulated annealing. For the dynamic programming, three variants have been tested, depending on the occlusion cost: 20, 50 or 80. The experiment aims to assess the effect of the smoothness parameter on the four techniques above mentioned. Therefore, the smoothness parameter ranges from 5 to 1000. Also, for SA a number of 500 iterations have been chosen. The images are not preprocessed beforehand. As matching cost, AD is used. No aggregation and no disparity refinement are used.



Fig. 23. Experiment 4 workflow.

The experiment has been run on all data sets and the findings are displayed graphically in Fig. 24 and 25. It can be seen that among the four techniques tested, GC clearly yields the best results in a consistent manner. Unfortunately, among these methods, GC and SA are much slower. The best results are seen especially in textureless and depth-discontinuities regions. The other three techniques do not display large differences in performance. Sometimes SO is slightly better, like in the case of *Map* and *Tsukuba* data sets, but, as it will be seen in the next experiment, will cause a streaking effect in the disparity maps obtained, because it ignores the vertical smoothness term. DP with an occlusion cost of 20 has the smallest errors.

Comparing the results of different smoothness parameters, it is interesting to see that errors are not monotonically growing or decreasing, especially in the case of SO and GC. For very small smoothness values, the errors are large and the same happens also for very large values. Therefore, choosing the right value has a great impact on the results. These are also

influenced by the data set. For example, in the case of an image with very few objects, such as *Map*, the optimal value is quite high, around 500. On the other hand, in images with many objects located at different depths, the best results are obtained for small smoothness values, between 20 and 200.

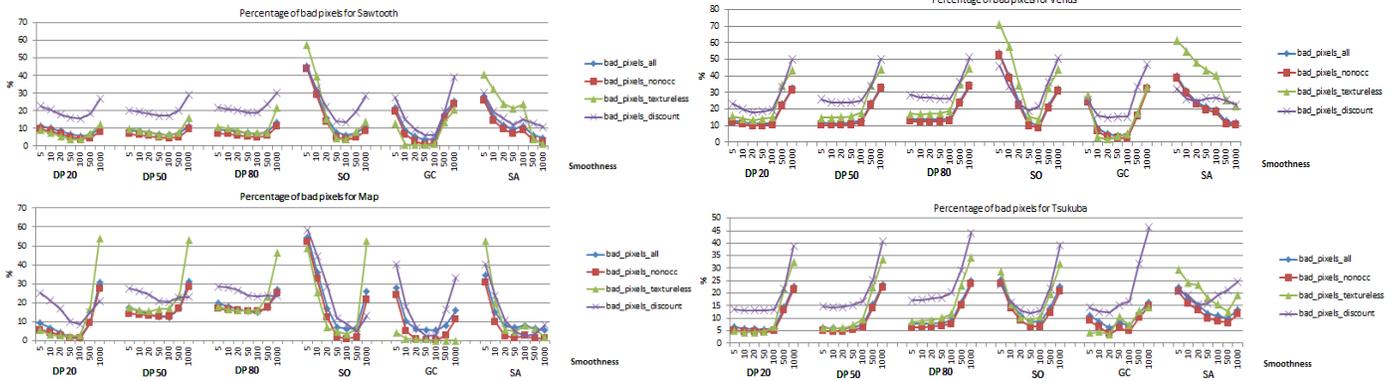


Fig. 24. Bad-matching pixel percentage for experiment 4.

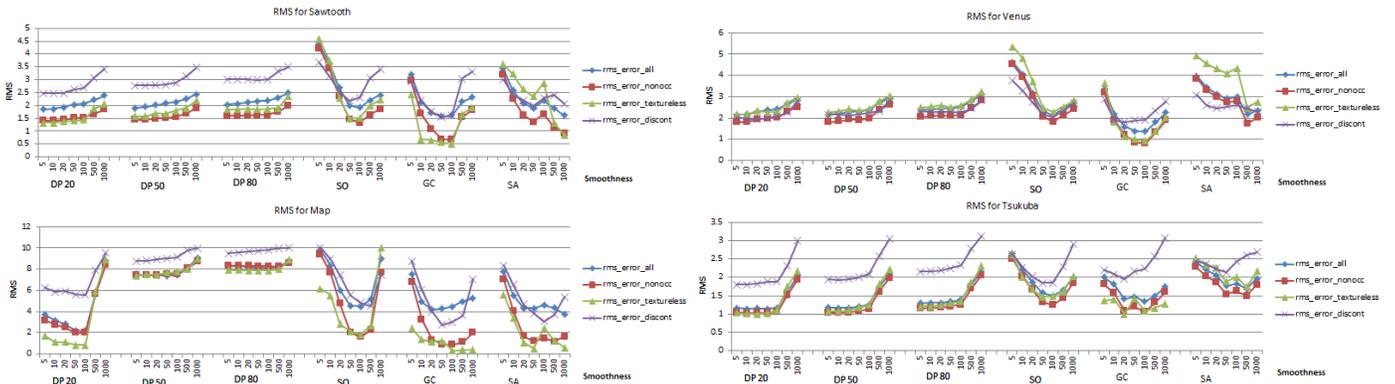


Fig. 25. RMS results for experiment 4.

G. Overall Comparison

We have compared the performance of the 6 algorithms described above, among them one being a local algorithm and the other five, global algorithms. For each, the parameters used in the tests are listed in Table 1.

Table 2 displays the results obtained by these algorithms with the parameters above applied to each image. Of course, these results would have been better if they would have been fine-tuned for each set of images, but a general configuration should be found. From all of the metrics discussed, the percentage and ranking of non-occluded bad-matching pixels is listed.

From Table 2 and from the results of the above subsections, it can be seen that the best overall performance is obtained by global optimization algorithms. In particular, the best method is definitely GC, on which there is large focus nowadays. SA solves the same optimization problem, but generally does not yield very good results. The execution time for SA is way higher than the one for GC, so the latter algorithm is preferred.

The diffusion-based method, Bayesian diffusion, performs well, following GC. In the case of *Map* image data set, it even outperforms this method. This happens because these images contain more noise than the others, which leads to bad results in case of algorithms that depend very much on internal parameter settings. On the other hand, in case of *Tsukuba*, which is a more complex data set, with many objects at different depths, the Bayes diffusion algorithm has poor results.

SSD, which is the only local algorithm in the experiment, yields reasonable results, especially if we are to think at the complexity of the algorithm and execution times, which make it a good choice if the results do not need to be of very high accuracy. As do all algorithms, it does not perform well in regions with depth-discontinuities.

Lastly, but not least, the scanline algorithms DP and SO perform less well, having the poorest results of them all, with the exception of *Tsukuba* image set, where they recover the shape of the objects pretty well, and the lack of inter-scanline consistency raise the percentages of bad-matching pixels.

TABLE I. PARAMETERS FOR THE 6 ALGORITHMS TESTED

	SSD	DP	SO	GC	SA	Bayes
Matching cost	SD	AD	AD	AD	AD	AD
Match function	No	No	No	No	No	No
Truncation	No	Yes	Yes	Yes	Yes	No
Birchfield-Tomasi						
Aggregation						
Window size	21	-	-	-	-	-
Min filter window size	21	-	-	-	-	-
No. of iteration steps	1	-	-	-	-	1000
mu parameter for Bayesian diffusion	-	-	-	-	-	0.5
sigma parameter for Bayesian diffusion	-	-	-	-	-	0.4
epsilon parameter for Bayesian diffusion	-	-	-	-	-	0.01
scale for Bayesian diffusion	-	-	-	-	-	0.01
Optimization						
Optimization function	WT A	DP	SO	GC	SA	Bayes
Smoothness	-	20	50	20	20	-
Occlusion cost	-	20	-	-	-	-
Start temperature	-	-	-	-	50	-
Maximum number of optimization iterations	-	-	-	-	100 0	-
Threshold for intensity gradient	-	8	8	8	-	-
Smoothness penalty if gradient is too small	-	4	2	2	-	-

TABLE II. RANKING AND PERCENTAGE OF BAD-MATCHING PIXELS FOR THE 6 ALGORITHMS TESTED

	Sawtooth	Venus	Map	Tsukuba
SSD	(3) 2.2051	(2) 3.7441	(4) 0.6638	(3) 5.3337
DP	(5) 4.3094	(5) 8.8257	(5) 0.7748	(2) 4.5472
SO	(6) 4.4275	(4) 7.7776	(6) 1.1016	(4) 6.0406
GC	(1) 1.4049	(1) 1.8324	(2) 0.3103	(1) 1.9184
SA	(4) 3.5237	(6) 9.1775	(3) 0.5878	(6) 7.6125
Bayes	(2) 1.4533	(3) 4.0044	(1) 0.1973	(5) 6.4924

V. CONCLUSIONS

In this paper, the domain of stereo vision, one of the most studied fields of computer vision of the last decades, has been explored. The hardest part of stereo vision is finding the right match for every point in the image, also known as the stereo correspondence problem and solved by the stereo matching algorithms. The building blocks of every such algorithm have been presented: matching cost computation, cost aggregation, disparity computation and optimization and disparity refinement. Additional preprocessing and postprocessing can also be done. The focus in this paper was put mainly on the first three building blocks, as disparity refinement is rather optional. The results obtained by the algorithms are more than often sufficient for applications such as tracking or robot navigation.

During the years, many techniques have been proposed, some novel or refinements of existing ones. A literature overview has been presented for both local and global algorithms and also for the newly introduced semi-global category, presenting techniques from the most basic ones, such as SAD/SSD, up to the state-of-the-art in the domain, GC.

As mentioned before, most of the existing algorithms can be split in several building blocks. In order to obtain the best performance, each of these components should be optimized. The first experiments have tried to display different techniques for each individual step, showing how choosing parameters influences the results. Unfortunately, sometimes there are so many parameters, that it is hard to find the optimal combination. Furthermore, the image data sets are comprised of different textures, occluded/non-occluded regions, different color information, all of which make a general optimal configuration very hard to find. Some algorithms perform better than the others depending on the input information.

The literature probably contains a great number of algorithms variations, such as a full comparison of stereo matching algorithms would have been practically impossible. Instead, a few diverse algorithms have been presented, focusing on their core ideas. A number of experiments have been conducted, comparing them from the quality point of view (RMS and statistics on bad-matching pixels). If we do not want a very accurate disparity map in our application, the local methods such as the SSD algorithm should be sufficient. If, on the other hand, quality is very important, GC is one of the best techniques nowadays. What more, it has been shown that SA, which solves almost the same optimization problem as GC, has the highest computational costs and the results are in many cases far from the best. Of course, its performance depends very much on the internal parameters such as the start temperature and number of iterations. However, increasing the number of iterations will also increase the computational time, so the focus should be moved rather to GC methods.

The quality of matching could be studied not only by computing the RMS and statistics on bad-matching pixels, but also the prediction error. Another idea would be to find a solution to adapt parameters of algorithms to the content of the images automatically. As we have seen, a small smoothness value is needed when the image is complex, containing many objects, but a larger value can be used of the image is not so complex. Because GC has obtained good results, this method can be further studied for improvements, along with other state of the art techniques such as tree filtering, for example. Last but not least, besides the two-frame approach, the area of multi-view stereo can be investigated. Using multiple images will reduce the matching ambiguity, leading to quality improvements.

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A Systematic Report on Issue and Challenges during Requirement Elicitation

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Abstract—We say that researchers made a lot of contribution in requirement engineering by introducing many helpful tools and efficient methods for Requirement Engineering (RE) but simultaneously this field demands more research to overcome the ongoing consequences and provide their solutions. Some hot challenges in RE can be faced while explaining system limits, understandability issue between groups influenced by the advancement of the system. Because of these challenges we have poor requirements and abortion of the system or this can lead us inefficient and disappointing results of system. So, that RE is decomposed to sub-phases: Elicitation, Analysis, Specification, validation. This paper also proposes the problem classification in requirements elicitation. If the requirements are elicited properly, we can upgrade the requirement elicitation process. As requirement elicitation is the most important area of requirement engineering, we have tried to find out and describe those problems and difficulties in requirement gathering.

Keywords—Problems and difficulties in requirement gathering; process of eliciting requirements; requirement gathering

I. INTRODUCTION

Requirement elicitation is the first phase of requirement engineering and it is the most significant phase of development of software life cycle. This includes: elicitation, analysis, documentation and validation (see Fig. 1). More specifically, Requirement Engineering is a process that analyzes the stakeholder and its needs, reason and importance of the systems to be developed [1]. Gathered requirements and their related errors are often neglected for coming stages of developing software that increases the effort and cost. This shows that this must be paid more attention to reduce the effort and cost of the project.

It is evident from the literature that the failure or success of software system developed is quality requirements' dependent [2]. Requirements' quality is affected; the way requirements are elicited. By elicitation we understand the gathering of user desires and intercommunicating those needs to systems experts [3]. This phase is important phase of RE that is followed by three other steps: specification and analysis, validation and integration of requirements. The

contribution of this process is to mention the systems' limits and communication properties of software system. It is very important to welcome stakeholders for information gathering to expose the viewpoints [3]. There are numerous complexities in attaining elicitation goal.

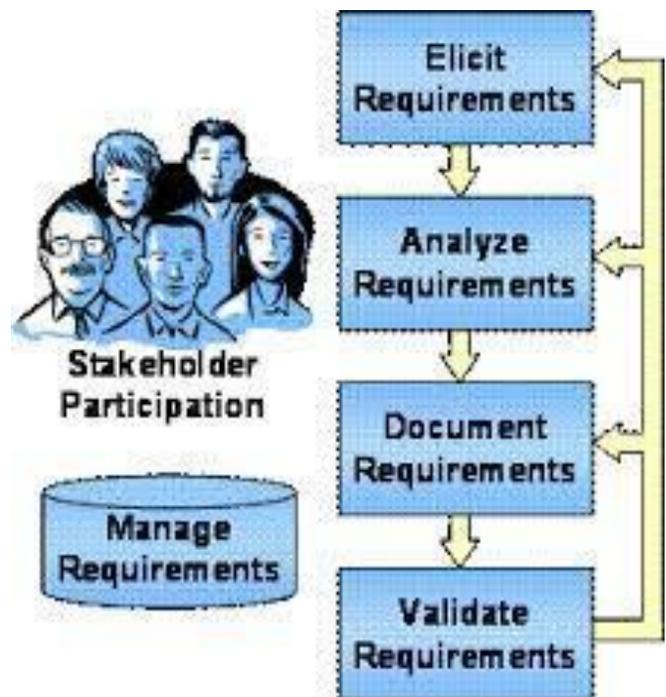


Fig. 1. Requirements management.

II. PROCESS OF REQUIREMENT ELICITATION

A. The Application Domain

It is very worthy to know about the area of application. It is important to examine the environment where systems will take place. This supplies key knowledge about: functionality and resources limitation, domain knowledge [4].

B. Sorting based on Requirements

Requirements are gathered from different resources and existed in different formats. Subjects and users are helpful in providing the information about the user requirements and issues [5], [6]. The documentation of business process and current system includes: manual, reports and forms that can be helpful for gathering information about that organization and its existing environment, the requirements for coming up new systems and their importance and supporting rationale.

C. Analyzing, Identifying and Documenting Gathered Requirements of Stakeholders

In requirement elicitation, we need to identify and analyze all the related stakeholders, all those stakeholders who have knowledge of the systems and who are influenced by the system. Clients are prominent stakeholders of the system and other parties like partners, investors are also considered as stakeholders.

D. Gathering Key Data of User Desires

Here it is very important to clear the scope of the system. This also addresses some problems like domain area of knowledge, abilities of stakeholder and limitations of computer resources [6]. Every stakeholder writes her/his needs for the proposed system. This decreases the unpredictability; when expectations are prone to change as reality of process enhancement becomes clear.

E. Organize Interview for Different Stakeholders

Interviews can be structured or unstructured and it may also be based on information gathered from user. The focus of interview is to refine and detail the opportunity and needs explained in description of users to know the keywords [6].

F. Selection of Set of Methods or an Elicitation Method

It is well known and accepted that single elicitation technique cannot be suitable for all projects. This selection of technique depends on project environment and depends on analyst choice.

G. Fitting Requirements to Application Domain

Specifying requirements to a specific domain is of more interest. This solves the issues related to domain that helps the remaining steps of development. Such challenges can be solved by hiring knowledge and experts of application area.

H. Prototyping

Here, analyst must have right set of requirements. Such requirements will be tested by designing a prototype. This helps in testing completeness and efficiency of requirements. This is an easy method to verify elicited requirement from the user.

I. Validation of Prototype

Each system is tested before it is put into practice. This should also be tested for its accuracy, unambiguity, quality and practicality. This helps expert to have complete understanding of user and depth of the system.

J. Complete Analysis

This is the last phase of process, where it is checked that everything is done exactly as user desires. After completing above phases developer starts developing system (see Fig. 2).

III. PROBLEM CLASSIFICATION

Analysis of the paper produced a long database of problems that are named as leading to poor requirements elicitation. Such list is prepared by those who summarized the paper of Requirement Engineering and writers who enlighten with their judgment for existing causes of requirement elicitation and generate solutions to those mentioned causes. It is obvious from the sources and concluded problems that RE is a difficult and complex task. IV. Meta-analysis of the paper of requirement engineering is done by many authors which include Lyytinen, Berente and Hansen (2009), Juristo and Dieste (2011), Browne and Appan (2012), Harris (2006), Zave (1997), Moreno, Juristo, Hickey, Dieste, Davis (2006), Davis and Hickey (2004), Reichental (2006), Elam and Marakas (1998), Pan (2005), Davidson (1996), Finkelstein (1994), Chin, Lim, Beath, Majchrzak (2005), Coulin and Zowghi (2005), browne and pitts (2007) and in less formal way by Zahedi (2003) and Vitharana, Jain.

Problems which are identified in Requirement elicitation can be summarized in nine groups:

- Human language is as not appropriate for technical solution.
- Human aspects of Requirement elicitation that prevent the casual oral communication between client and consultant.
- When project proceeds, the elicited requirements change.
- Client himself is not known which requirement is the need for the organization or not. So, he sometimes asks for requirement which an organization does not need.
- Client is not clear what requirements does his business need.
- Sometimes the client is not agreeing to help you in the project.
- Requirement elicitation process fails if proper elicitation technique is not followed.
- Usually symptoms are reported instead of real problems.
- Requirement elicitation is not deterministic.

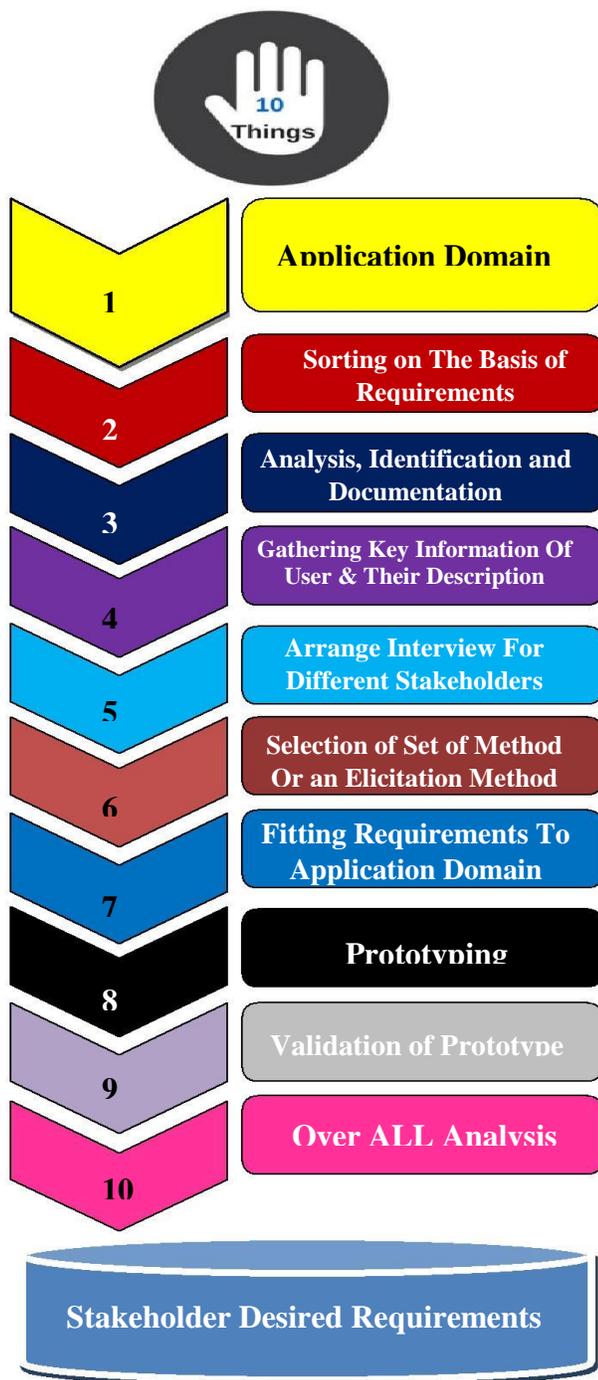


Fig. 2. Process of Requirement Elicitation.

IV. CHALLENGES AND ISSUES IN ELICITATION

A. Conventional Methods

These methods support intercommunication between group of people and known as “deliver the idea”, premeditated the clearance or requirements of doubts can be called

conversational methods that include focus group, brainstorming, workshops and interviews. Interviews used for many different fields are often successful. People who conduct such interviews have sound knowledge of that domain [5], [7], [8]. Most issues explained by practitioners and experts about conventional methods are:

- Conversation between the stockholder and interviewer are quite difficult.
- Questionnaires, questions are enquired from stakeholders; they do not know what terms or terminology is recurring in other sessions on same subject. Such vocabularies give different understanding for diverse people in dissimilar environments.
- Survey, interviewers ask questions but do not get answer as per their requirements.
- Result of such technique with displeased response, so; gathering requirements stage is not proceeded.
- Concepts and classification that is related to one society which can be impermeable to people of other society.

B. Shared Methods

One method of gathering requirements is not sufficient to develop requirement of system. Elicitation methods are most important in some circumstances and environments [9], [10]. It is good then combining individual technique, analysis and observation, into single methods for the development of requirements [8]. So, logically we have other ways to coordinate and communicate to have complete knowledge of desired product [11], [12].

Some major issues listed by practitioner and experts are:

- Joint technique is, stakeholders will not be able to communicate the root information [5]. Facilitators also group the information to stakeholders but there are less chances that stockholder share the information in the meeting.
- According to [5] Stakeholders have different position in the firm, requirement engineers will have difficulty while sharing their idea, if ideas are not widespread.
- Finally, in the last, it will be an issue for non-technical stakeholders to find out the implementation of technical findings. So, this technique seems patronage; that is why it is possible; condition must be well known through empirical observation.

C. Contextual Technique

This technique is also known as observational technique. This provides platform to develop strong thoughtful concept. There are some requirements which are easy to understand but not easy to verbalize. Which are also known “implicit requirements”. This is not helpful in gathering requirements because this makes verbal communication. Major focus is to gather data of background pattern, working methods, stakeholders, flow and related domain information of routine

job to interpret the data to improve in detail, the knowledge of gathered requirements and appropriate sys design.

Some problems that are explained by practitioners and expert in contextual method are:

- Most important issue is the sensitivity, time limitation and such methods do not support the way of doing [11]. If there is limited time for requirements elicitation, then there come to be faced some important problems within contextual technique.
- Observation does need awareness and sensitivity for the environment because it's easy for observer to get knowledge from enrich picture about work, but usually it's not easy to investigate and specify opinions. So, there should be some responsible person, an observation performer but in his absence schedule of project may be affected, which generates problems in this stage [5]. These Observation techniques are followed in abstract development.

D. Cognitive Methods

This is used for knowledge gathering. In observational methods or communication technique, gathering requirements is directly from people verbal idea and their activities. In this method information is never straightforwardly explained; Method deals with user spokesperson level in most natural way.

Some problems mentioned by practitioner or experts as follows:

- Such techniques are very effective when you have proper documentation and expert knowledge. E.g. laddering is used to explanation and elaboration of scientific or subjective terms [5].
- According to [5] Experts are trying to order their information about application area to elicit requirement, repertory grid and card sorting provides different methods to gather attributes that are not easily expressed by experts. This reveals that it's not easy for different domain experts to converse features of this method.

E. Inventive Methods

This is also called model driven prototyping based technique. This is also grouped as evolutionary and rapid prototyping, that's the graphical representation of "how the system will look" [1]. Generally, user is expected to draw the characteristics by help of pen or pencil on the paper and shares it with engineers. Sometimes graphics based software tool is used for this purpose. Some important problems described by practitioners and experts are:

- The method is used for user interface and indicates prototyping technique used for elicitation of requirements for medium and small projects than huge projects.

V. CONCLUSION AND FUTURE WORK

This research paper gives general idea of requirements gathering process. In addition to that (talking about above sentence), paper also presents complete explanation of different requirement elicitation techniques that are used by Requirement Engineering experts. This paper also depicts challenges and issues in elicitation of requirements. These issues are seen in requirement elicitation and have shown several times a key reason of system failure. This paper describes the problem classifications in the context of requirement elicitation. There are many other requirements gathering methods which are helpful for one or more issues. For future; researchers should come forward with new approaches/ideas to overcome the issues and come with validated results. It is proved that the root causes that arise out of most challenges are due to human error in this practice. Using techniques of Artificial Intelligence, we may be able to limit such issues and may AI bring some profitable result; so, the Researchers can see how AI technique will be useful for requirement elicitation. This may help practitioner for bringing quality software in the market with minimum effort and cost.

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Resilient Framework for Distributed Computation Offloading: Overview, Challenges and Issues

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Abstract—Gradually, mobile and smart computing devices are becoming pervasive and prevalent in society and also increasingly being used to undertake the daily tasks and business activities of individuals and organizations worldwide as compared to their desktop counterparts. But these mobile and smart computing devices are resource constrained and sometimes lack the needed computational capacities; thus, memory, energy, storage, and processor to run the plethora of resource intensive applications available for mobile users. There is a lot of benefit of offloading resource demanding applications and intensive computations from mobile devices to other systems with higher resource capacities in the cloud. Mobile cloud computing is a form of cloud computing that seeks to enhance the capacity and capabilities of mobile and smart computing devices by enabling mobile devices to offload some computational tasks to the cloud for processing which otherwise would have been a challenge. The study setup an experiment to investigate computation offloading for mobile devices. The study also presented an energy model for computation offloading. It was observed during the experiment that by offloading intensive applications from mobile and smart computing devices to other systems with higher resource capacities, a great amount of resource efficiency is achieved.

Keywords—Cloud computing; mobile cloud computing; computation offloading; distributed computation offloading

I. INTRODUCTION

There is an ever growing proliferation and widespread use of mobile and smart computing devices and applications worldwide to perform various kinds of work related activities. Devices such as smartphones, tablets, and e-book readers enable users to connect to the internet instantly, giving them access to a vast amount of information and enabling them to perform their daily activities and tasks using productivity applications on their mobile devices [15], [16], [23]. Despite the growing trends in mobile and smart computing technologies, these mobile devices still lack the needed computational resources to execute and run resource demanding applications and intensive computations [5], [24].

Mobile cloud computing is a variant of cloud computing which addresses the challenges faced by mobile and smart computing devices in running resource intensive applications [5], [23], [27]. Mobile cloud computing seeks to enhance the capacity and capabilities of mobile and smart computing devices in order to execute the many resource demanding applications available for mobile users [12], [20], [25]. Mobile Cloud Computing is an emerging type of cloud computing that provides resource efficiencies among mobile devices. Mobile cloud also enhances the capabilities of mobile devices to execute the plethora of resource demanding applications available for mobile users [3], [12]. Mobile cloud computing is a computing paradigm in which computationally intensive and resource demanding mobile applications such as 3D graphics, face recognition, voice recognition, games, videos, malware protection and data manipulation are transferred to other systems with higher resource capacities for efficient processing in the cloud [4], [6], [10]. The goal of mobile cloud computing is to enable mobile and smart computing devices to run and execute the plethora of resource hungry mobile applications which greatly consumes processing power, energy and battery life of mobile devices by offloading computations to surrogates in the cloud [19], [26]. Mobile cloud computing also boost the computational power of mobile and smart computing devices to enable them execute the plethora of resource hungry mobile applications which greatly consumes processing power, energy and battery life of mobile devices by offloading computations to surrogates in the cloud [11], [24], [25], [28]. From Fig. 1, mobile and smart computing devices can access computer applications, platforms and infrastructure via cloud systems.

A. Problem Statement

The computational power and capacity of mobile and smart computing devices have increased over the years. This has allowed mobile and smart computing devices to run resource demanding applications [1], [16], [27]. In spite of the increase in computational capacity such as processor, memory, storage, display and battery life; mobile and smart computing devices are still very much limited regarding the kind of applications that they can run and execute [9], [17], [18]. Also the open nature of mobile applications market has encouraged the

development of applications by millions of enthusiasts over the world. Unfortunately many of these applications are resource intensive and put a lot of strain on the mobile device [12], [13], [16], [18]. In many instances the mobile and smart computing devices are unable to run these applications. This is making mobile and smart computing devices unattractive to users in terms of applications that these systems can run and execute [2], [15], [20]. The limitations in computational power, battery life, memory, storage capacities and other resources has led to a emergence of several techniques to enable mobile devices process and execute the many rich and resource demanding applications available for mobile and smart computing devices [9], [14], [19], [27].

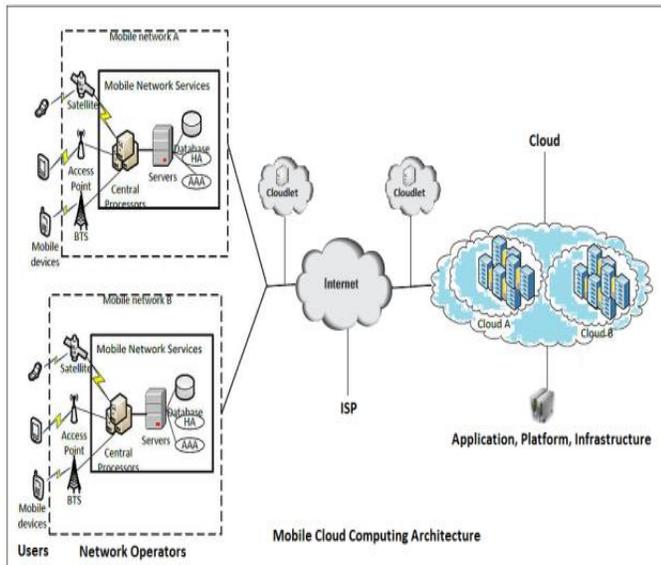


Fig. 1. Mobile Cloud Architecture [22].

II. RELATED WORK

Mobile computational offloading is an aspect of mobile cloud computing that focuses on transferring computations from native applications running on resource limited mobile devices to other powerful systems such as cloud servers for processing and execution [5], [10], [13], [18], [26]. Increasingly, computation offloading is seen as a growing cloud based service for mobile and smart computing devices [9], [12], [20], [24]. Computation offloading is sending very intensive and resource demanding and complex computations to resourceful servers with higher computational capacities for efficient and effective execution and processing which would otherwise be impossible for mobile and smart computing devices to execute locally [16], [18], [27], [30]. Also computation offloading algorithms determine which tasks should be performed locally and which should be performed remotely in order to provide efficient use of resources thus saving battery life and processing power of mobile and smart computing devices [1], [17], [18].

Previous works have identified different mechanisms to solve the seamless execution of offloaded computational tasks from resource limited mobile devices to other systems with higher computational power and resources in the cloud. Most of these research devised a variety of approaches to implement

energy saving, time saving and both energy and time saving strategies in computation offloading for mobile cloud computing [28], [10], [22], [7]. Some of these researches have proposed sending computationally intensive tasks to nearby mobile devices with higher computational resources [28], [10].

Others have identified elastic computation offloading methods in which resource intensive applications are partitioned into user interaction activities and computational activities and some parts of the computational activities are sent to surrogates or remote servers for efficient and timely processing while the mobile devices process the other parts locally [7], [18], [24]. Some other works have also proposed the complete cloning, mirroring or imaging of a mobile device system together with its operating system and applications and sending the mirrored or cloned image to a clone cloud server located at a remote place for processing and the results sent back to the mobile devices [10]. Also some other works have suggested context-aware computation offloading schemes which enables mobile and smart computing devices to learn about their environment and state before making offloading decisions [22].

Furthermore, other research works [8] have studied a game-based approach to computation offloading in which mobile devices learn about the current state of surrogates before deciding to send computational tasks to these remote servers depending on their resource availability. Satyanarayanan et al. [27] and Chun & Maniatis [9] have proposed the encapsulation of a mobile device software stack including operating environment and applications into a virtual machine image and offloading it to a more powerful system in the cloud for execution. Also Giurgiu et al. [13] proposed consumption graphs to decide which part of the computation should run locally and which part should be executed remotely. Klovachev and Klamka [18] have also proposed a mobile augmented cloud services (MACS) middleware to enable the execution of elastic mobile applications in the cloud. Wolski et al. [29] presented a framework for computation offloading decisions in which schedulers determine when to move parts of a computation to more resourceful systems for execution in the cloud. Chen [7] have also suggested a decentralized computation offloading game in which resource constrained mobile devices wait and learn about the state of surrogates before offloading computational tasks depending on their resource availability. Also Orsini et al. [21] have proposed a context-aware mechanism for computation offloading in which mobile devices decide when and how to offload based on their state and resource capacities. Moreover, Cuervo et al. [6] presented a fine grained energy aware computation offloading mechanism dubbed MAUI. MAUI decides at runtime which part of computational tasks should be performed remotely to achieve energy savings based on the mobile devices connectivity constraints. Kemp et al. [17] also presented Cuckoo, a computation offloading framework that simplifies the development of mobile applications and provides a dynamic runtime system that determines which part of the computation should be offloaded to the cloud and which part should be locally executed to save battery life. Also Cong et al. [8] presented a computation offloading as a service (COSMOS) to provide leverage for all mobile device requests

and reduce monetary cost to the cloud provider. Deng et al. [10] also proposed a computation offloading scheme for service workflow in which similar service components are managed during computation offloading. Some studies have provided alternative means of computation offloading but lack the fundamental models to evaluate energy consumed during the computational offloading process. Hence there is still much work to be done in order to find a good resource efficient computational offloading scheme for mobile and smart computing devices which have variable resource capacities and computational power [6], [11], [24], [30].

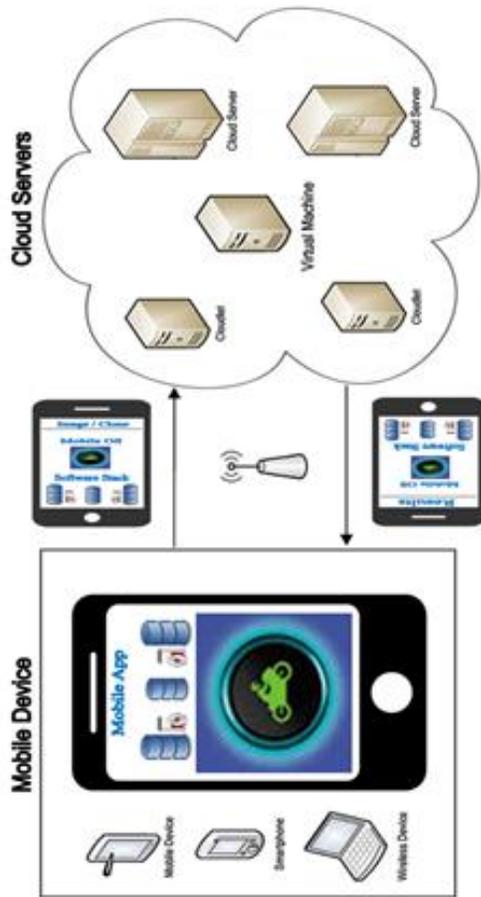


Fig. 2. Traditional Computation Offloading Scheme.

A. Traditional Computation Offloading

Fig. 2 shows the traditional computation offloading framework. The traditional computation offloading scheme allows mobile devices to examine the computational task to be executed to determine whether it can execute the task using its local resources or it cannot [5], [6], [11], [12], [15], [16], [18]. The resource manager determines the available resource capacity of the mobile device. Based on the available resource capacity of mobile devices, a decision is made whether or not to execute the computational task locally or to partition it and send the intensive part to a remote server in the cloud for processing. Then the partitioner divides the computational task or mobile application to be executed into user interaction and intensive tasks. The user interaction task is then assigned to the

local execution manager to execute locally while the computationally intensive tasks are sent to the offload manager. The offload manager then transfers the intensive tasks to other powerful server systems with higher and scalable resource capacities in the cloud. The result of the computation in the cloud is sent back to the mobile device. The main setback of the traditional computation offloading approach is the limited available servers to offload computational tasks. The intensive part of the computation is offloaded to a server in the cloud for processing. This leads to an increase in the computational tasks load of the cloud server. Depending on the nature and volume of the resource intensive computation to be executed, this might bring additional burdens to the chosen server in the cloud.

III. PROPOSED DISTRIBUTIVE COMPUTATION OFFLOADING FRAMEWORK

The distributive computation offloading framework in Fig. 3 seeks to overcome the challenges inherent in traditional computation offloading schemes for mobile cloud computing. The distributive offloading scheme seeks to provide a resource savings by enabling both resource poor mobile devices running intensive mobile applications to save a great amount of time and energy during computations of intensive mobile applications and also reducing the burden on servers in the cloud during the processing of computational tasks. This distributive approach to computation offloading helps to reduce the overwhelming burden of intensive, complex and huge computations on servers in the cloud by dividing and sharing tasks among cloud servers based on their resource capacities, availability and computational capabilities. The resource intensive and complex tasks is divided and shared among servers in the cloud with available computational resources to compute the tasks and the results returned back to the mobile devices instead of one server processing the entire computationally intensive and complex task as in the case of traditional computation offloading schemes. The distributive approach further reduces the workload and burden on resource poor mobile devices which have to process locally parts of the resource intensive mobile applications that is sent to the cloud for processing. As a result, the mobile device will have less workload and tasks to process than would have been in traditional computation offloading schemes.

The distributive framework enables resource savings for both mobile devices and cloud server systems in mobile cloud computing. It provides the smallest amount of time and energy needed to execute tasks per cloud server in mobile cloud computing. Therefore the distributive offloading scheme delivers the best resource savings in mobile cloud computing than traditional computation offloading schemes. In order to minimize the cost of computation in terms of energy and time and also to achieve optimum energy and time savings for both mobile devices and cloud servers, the distributive computation offloading framework divides the computationally intensive tasks among different servers in the cloud with available resources that can execute these tasks and reduce the total workload on the cloud servers thereby achieving greater energy and time savings. Since the computationally intensive task is divided among available servers with resources capable of computing the tasks, then each cloud server assigned a task can

execute it within the shortest possible time and return the results back to the mobile device. Thus each cloud server assigned part of the computationally intensive task to execute then utilizes a small amount of energy compared to the amount of energy that would have been used if the entire computationally intensive task was executed on one single cloud server. The distributive computation offloading scheme enables computationally intensive tasks to be divided and shared among servers in the cloud with enough resource capacities to compute these tasks. This allows resource limited mobile devices to separate user interaction tasks from computationally intensive tasks that must be sent to the cloud for efficient and effective processing and execution.

The resource manager determines the resource capacity of the mobile device and which tasks it can process locally depending on its available resources thus; processor power, memory, storage and energy or battery capacity. The partitioner then divides the resource intensive mobile applications into less computation intensive tasks or user interaction activities and computationally intensive activities. The local execution manager is responsible for processing the less computation intensive or user interaction tasks on the mobile device locally. The offload manager sends the computationally intensive parts to the middleware software which acts as an interface between the mobile device and cloud servers.

The cloud resource manager determines the resource capacity and availability of surrogates and servers in the cloud and chooses M available cloud servers. Based on these resource availability decisions and computationally intensive task, a number of N surrogates and servers are selected in the cloud to execute the computationally intensive mobile applications. The computationally intensive task is divided into N parts by the partitioner depending on the number of cloud servers that have been selected to execute the tasks.

The cloud offload manager then transfers the allocated tasks to each server in the cloud up to the Nth server system depending on the number of resource available cloud server systems. The load balancer also ensures that tasks are assigned to different cloud servers based on their resource capacities and that no server in the cloud is over burdened with too much tasks to execute. It also helps to adjust the load capacity between various server systems in the cloud.

The network manager monitors and ensures a reliable connection between remote cloud servers and mobile devices. In case of any network connection failures, the network manager notifies the load balancer, resource manager and cloud offload manager to reassign the task to another server system in the cloud with available resources to execute the task.

The remote execution manager monitors and controls all tasks under processing in the cloud and helps to send results of the processed tasks back to the mobile device. The distributive computation offloading scheme thus offers an efficient and better approach to computation offloading that greatly saves energy and time for both mobile devices and remote servers in the cloud. It pursues an optimum approach to energy and time

savings for both mobile devices and remote servers in the cloud.

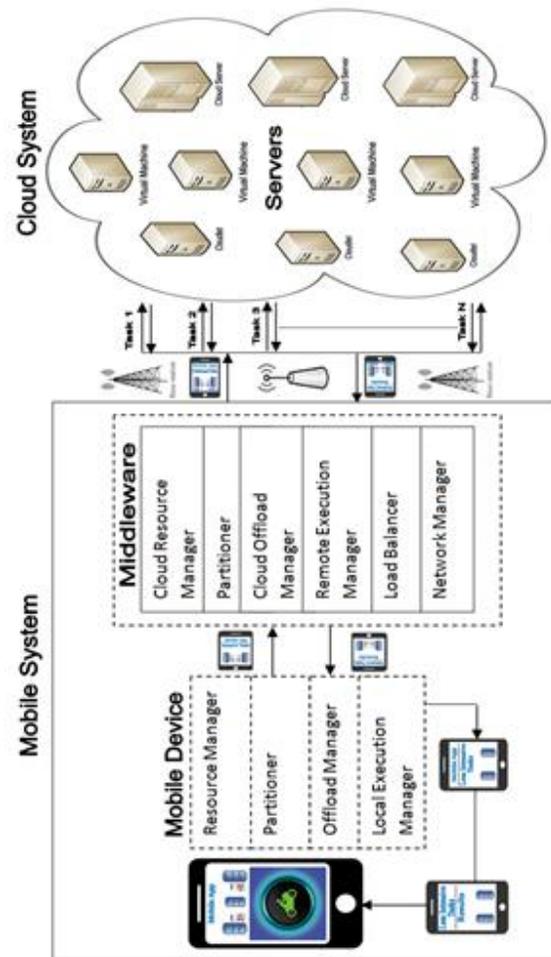


Fig. 3. Distributed computation offloading framework.

A. Algorithm for Distributive Computation Offloading

1. Start:
2. Initialize mobile device
3. Run mobile application
4. If mobile application is not intensive
5. Run application locally
6. Else if mobile application is intensive
7. Determine resource capacity of mobile device
8. If mobile device is capable
9. Run application locally
10. Else if mobile device is not capable
11. If wireless access is not available
12. Force local execution or end application

13. Else if wireless access is available
14. Partition application into user interaction and computationally intensive tasks
15. Send user interaction to mobile device for computation
16. Send computationally intensive tasks to middleware
17. Partition computationally intensive tasks into n selected cloud servers.
18. Send partitioned tasks to n selected cloud servers for computation
19. Return results to mobile device
20. End

As stated in the algorithm, without being switched on and without any computational activities, the computation offloading process cannot be followed by the mobile device. Therefore the mobile device has to be switched on and initialized. The initialization involves loading of the operative system and other essential component systems on the mobile device. After the initialization, the mobile application to be executed is run by the mobile device. If the mobile application is not intensive, then it is executed locally else if the mobile application is intensive, depending on the resource availability of the mobile device and also if wireless connectivity is available on the mobile device, the mobile application is divided into less intensive and intensive parts. Then the less intensive user interaction part is executed locally by the mobile device while the computationally intensive part is divided among available cloud servers and sent to them for remote execution and the results is sent back to the mobile device.

B. Flowchart of Distributive Computation Offloading Framework

The flowchart shows the rudimentary procedures of task execution in a distributive computation offloading framework. The distributive process is made possible due to the elastic nature of mobile applications which enables mobile applications to be partitioned into smaller chunks of executable tasks. Similarly intensive computations to be performed by mobile devices can be partitioned into smaller chunks of tasks. Mobile applications and computations can be partitioned during development (compile time) or execution (runtime).

From the flowchart in Fig. 4, the mobile device is switched on and its operative system initialized together with other system components. If the mobile device is not powered on, then the computation offloading process is cannot start. If the mobile device is powered on, then the mobile application to be executed is run by the mobile device. If the mobile device detects that the mobile application is not intensive, the mobile device will then execute the mobile application locally using its own resources. But if it the mobile device detects that the mobile application is intensive or it cannot execute the

computational task, it will determine its resource availability. If the mobile device can strain execute the computational task or mobile application, depending on the situation, it might attempt to execute it if it is still efficient in the worst case. Otherwise if there is a wireless connectivity capability on the mobile device, then the computational task or application is divided into intensive and less intensive tasks. The less intensive tasks is then sent to the mobile device for processing locally while the computationally intensive parts is then divided and sent to available servers in the cloud for remote execution and the results of the remote processing is sent back to the mobile device.

C. Mathematical Model of Distributive Computation Offloading

The study presented a mathematical model for distributive computation offloading. In addition, a model for calculating the energy and time cost of distributive computation offloading is presented.

1) Distributive Computation Offloading Decisions

Let MA denote mobile application

Let MD denote the mobile device

Let S denote cloud servers

Let m be the number of available cloud servers

Let n be the number of selected cloud servers

Let S_i denote a particular selected cloud server i

where $i = 1$ to n

Let the intensive part of the mobile application (MA) be partitioned into n parts and let MA_i denote intensive mobile application part i

where $i = 1$ to n

Also

Let MA_u denote the user interaction part of mobile application (MA)

Then we can assign the partitioned computation intensive tasks to available servers in the cloud for execution as follows;

MA_1 assign to S_1

MA_2 assign to S_2

MA_3 assign to S_3

MA_n assign to S_n

where $i = 1$ to n

Also we can assign the user interaction activities to mobile device for processing locally as follows;

MA_u assign to MD

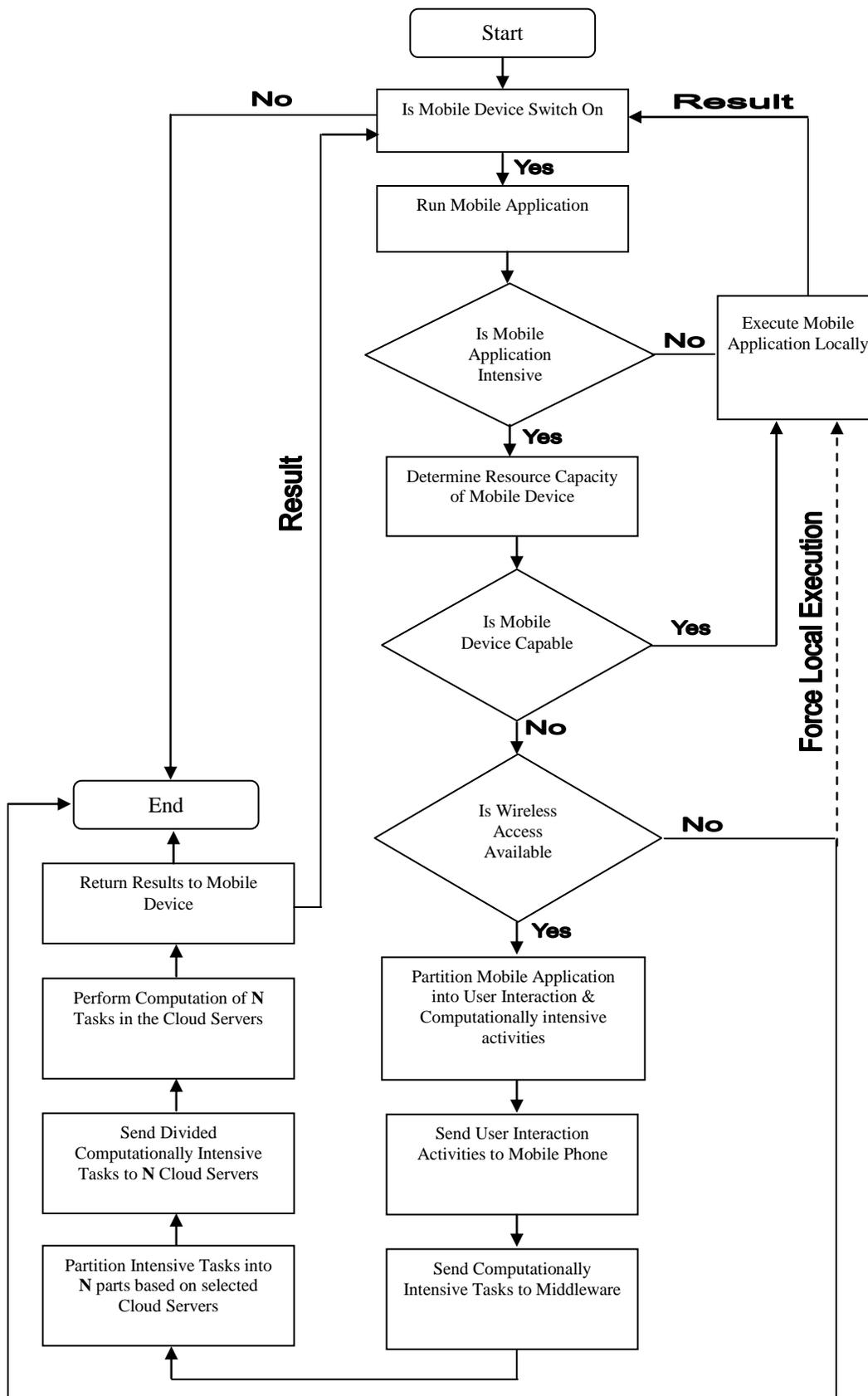


Fig. 4. Flowchart of distributive computation offloading framework.

2) *Energy Cost of Computation*

Let EC denote energy consumption

Let ECC denote energy cost of computation

Let MAC denote intensive parts of mobile application in the cloud

Let MAL denote intensive parts of mobile application locally executed on mobile device

Let EC_{MAC} denote energy consumption of intensive mobile applications in the cloud

Let EC_{MAL} denote energy consumption of less intensive mobile application locally executed

Let ETT_{MAi} be the energy used to transmit intensive mobile application i to the cloud

Let ETE_{MAi} be the energy used to execute the intensive mobile application i in the cloud

Let ETR_{MAi} be the energy spent to receive the results of executing mobile application i in the cloud

Then

$$EC_{MA1} = ETT_{MA1} + ETE_{MA1} + ETR_{MA1}$$

Likewise

$$EC_{MA2} = ETT_{MA2} + ETE_{MA2} + ETR_{MA2}$$

Thus

$$EC_{MA_n} = ETT_{MA_n} + ETE_{MA_n} + ETR_{MA_n}$$

$$EC_{MAC} = EC_{MA1} + EC_{MA2} + EC_{MA3} + \dots + EC_{MA_n} \quad (1)$$

where $i = 1$ to n

Now

$$EC_{MAL} = EC_{MAu}$$

Hence

$$EC_{MAL} = EC_{MAu} = ETE_{MAu} \quad (2)$$

Then the total energy cost of computation is given by Energy Cost of Computation (ECCMA) where

$$ECC_{MA} = EC_{MAC} + EC_{MAL} \quad (3)$$

$$ECC_{MA} = EC_{MA1} + EC_{MA2} + EC_{MA3} + \dots + EC_{MA_n} + EC_{MAu} \quad (4)$$

Therefore

$$ECC_{MA} = \sum_{i=1}^n EC_{MAi} + EC_{MAu} \quad (5)$$

3) *Time Cost of Computation*

Let TC denote time consumption

Let TCC denote time cost of computation

Let MAC denote intensive parts of mobile application in the cloud

Let MAL denote intensive parts of mobile application locally executed on mobile device

Let TC_{MAC} denote time consumption of intensive mobile applications in the cloud

Let TC_{MAL} denote time consumption of less intensive mobile application locally executed

Let TTT_{MAi} be the time to transmit intensive mobile application i to the cloud

Let TTE_{MAi} be the time to execute the intensive mobile application i in the cloud

Let TTR_{MAi} be the time spent to receive the results of computing mobile application i in the cloud

Then

$$TC_{MA1} = TTT_{MA1} + TTE_{MA1} + TTR_{MA1}$$

Likewise

$$TC_{MA2} = TTT_{MA2} + TTE_{MA2} + TTR_{MA2}$$

Thus

$$TC_{MA_n} = TTT_{MA_n} + TTE_{MA_n} + TTR_{MA_n}$$

$$TC_{MAC} = TC_{MA1} + TC_{MA2} + TC_{MA3} + \dots + TC_{MA_n} \quad (1)$$

where $i = 1$ to n

Now

$$TC_{MAL} = TC_{MAu}$$

Hence

$$TC_{MAL} = TC_{MAu} = TTE_{MAu} \quad (2)$$

Then the total time cost of computation is given by Time Cost of Computation (TCC_{MA})

$$TCC_{MA} = TC_{MAC} + TC_{MAL} \quad (3)$$

$$TCC_{MA} = TC_{MA1} + TC_{MA2} + TC_{MA3} + \dots + TC_{MA_n} + TC_{MAu} \quad (4)$$

Therefore

$$TCC_{MA} = \sum_{i=1}^n TC_{MAi} + TC_{MAu} \quad (5)$$

D. *Computation Offloading Challenges*

According to Suradkar & Bharati (2016), there are key challenges and technical issues affecting computation offloading have been identified. Some of these challenges include;

Latency: Mobile devices experience frequent intermittent delays whiles communicating with other devices on the network. This impedes the overall performance of the network thus affecting the throughput of mobile devices.

Bandwidth: Also lack of robust network technologies and inadequate access to networks with high speed, reliability and availability is a hindrance to computation offloading.

Mobility management: Mobile devices are nomadic in nature and this sometimes makes the management of these ubiquitous devices very difficult.

Context-processing: Mobile devices have limited context-aware capabilities this hinders them from processing location and context based computations.

Energy constraint: Mobile devices have limited battery life which hinders them from processing huge computational tasks that might require a lot of energy.

Security and privacy: Mobile devices lack the needed resource capacities to enable them execute some security and encryption algorithms thus exposing them to frequent attacks and hacks.

Operative Environment: Due to limitations in resources, mobile operative systems lacks the needed security and critical features that can properly safeguard it.

Heterogeneity: Diversity in access technologies such as GSM, WiMax, WiFi, WLAN, Bluetooth and their inherent challenges also hinder effective computation offloading.

IV. METHODOLOGY

The study setup an energy test bed using a De Lorenzo DL3155AL power supply and De Lorenzo DL10060 power meter and two digital meters connected in parallel to the power supply and in series to the mobile device respectively. The test bed was used to measure the energy consumed during the processing of tasks by the mobile device client. Fig. 5 shows the experimental setup and energy test bed for the study.

The study also developed a mobile application for performing intensive computations and processing of large volumes of data files in comma separated values (CSV) format.

The study used a Samsung Galaxy Mega phone and a laptop which acts as a server to process and migrate very large volumes of data files in comma separated values (CSV) format into a database which was developed for the mobile phone and laptop systems to help collate, process and transfer huge volumes of data in a flat file format for further computations.

Different sizes of huge data files from thousands of records less than 1MB up to about ten million (10,000,000) records approximately 500MB in size were passed to the application to process and the results were logged for both mobile phone and laptop systems. The study experimented on five scenarios involving; very low computation, low computation, moderate computation, high computation and very high computation. The very low computation involved data of size between 1000 to 5000 records, the low computation involved data of size between 10000 to 50000 records, the moderate computation involved data of size between 100000 to 500000 records, the high computation involved data of size between 600000 to 1,000,000 records and the very high computation involved data of size between 2,000,000 to 10,000,000 records. The study also tried to determine the time taken to execute various computational tasks during the experiment.

The results of the demonstration were exported into Microsoft Excel for analysis and plotting some useful graphs to help the study discussions. It was observed during the experiment that by offloading intensive applications from mobile and smart computing devices to other systems with higher resource capacities, a great amount of resource efficiency is achieved.



(a)





(b)

Fig. 5. Energy emulation test bed.

V. RESULTS

A. Results Presentation

Below are the results of the study experiment:

Very Low Computation

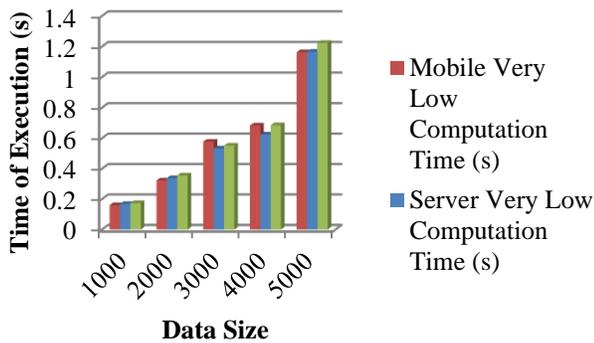


Fig. 6. Very low computation.

Low Computation

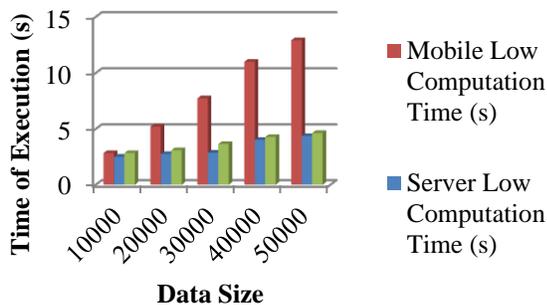


Fig. 7. Low computation.

Moderate Computation

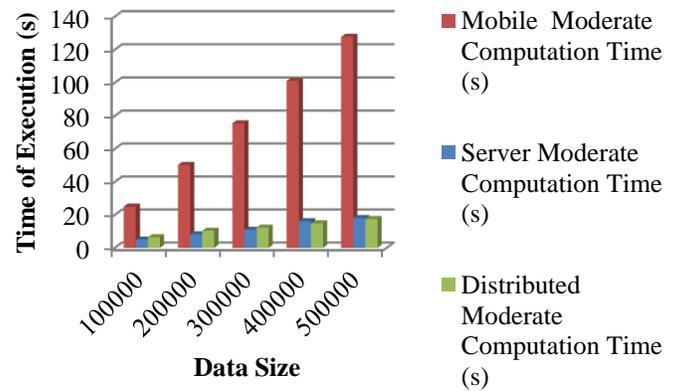


Fig. 8. Moderate computation.

High Computation

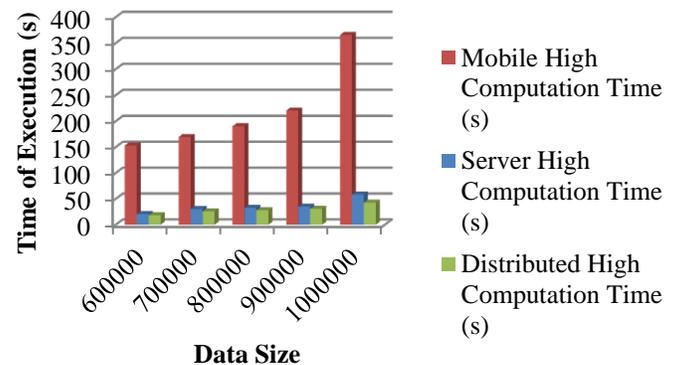


Fig. 9. High computation.

Very High Computation

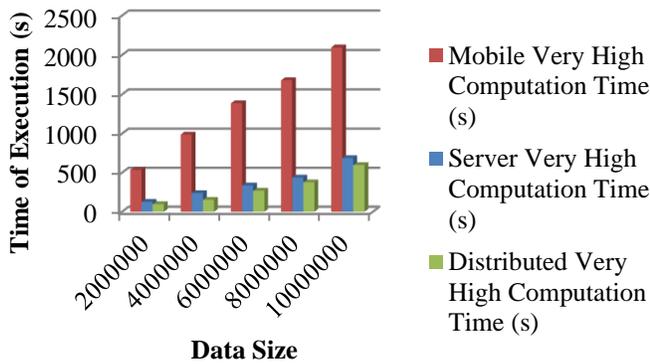


Fig. 10. Very high computation.

Mobile Energy Consumption

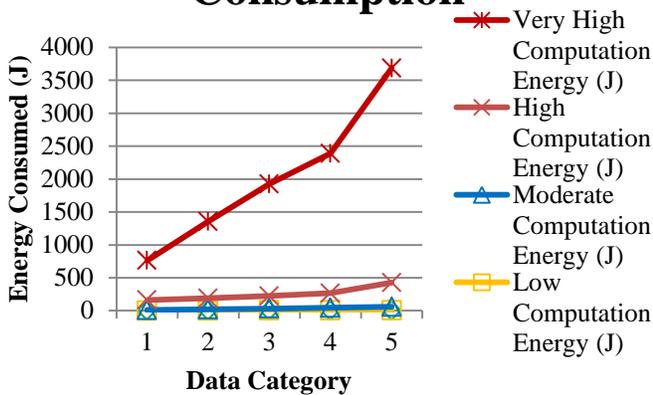


Fig. 11. Mobile energy consumed.

B. Results Discussion

The result from Fig. 6 depicts the case of very low computation. This shows that the time of execution for the mobile, server, distributed computations is almost indifferent. This is largely due to the fact that mobile devices are capable of executing some very low computations hence there is no need to offload such less intensive tasks to other systems with higher resource capacities.

Also the result from Fig. 7 shows the case of low computation. As the size of data increases, the time taken to execute the task by the mobile device also increases proportionally. Also the time taken to execute the task by the server and distributed also increases minimally. It is sometimes beneficial to run and execute low computation tasks on mobile devices than to offload to other systems with higher capacities. Some mobile devices are capable of running and executing low computational tasks faster and efficiently and hence there is no need to offload some low computational tasks.

Additionally, the result from Fig. 8 describes the case of moderate computation. As the size of data increases, the time taken to execute the task by the mobile device increases astronomically at a higher rate compared to the computational tasks hence the need to offload these tasks for efficient execution by other systems with higher resource capacity. As the task to be performed increases, the amount of time needed to perform the computation also increases with respect to the computational task. The server and distributed system has more computational resources thus memory, storage and processor power and are able to execute tasks faster and efficiently than the mobile device. It can be observed that with moderate computational tasks, the server and distributed systems performance is better than that of the mobile device. The time taken to execute tasks by the mobile device client is much higher compared to that of the server systems. In the case of moderately high computations, it is sometimes beneficial and efficient to offload some computational tasks to other systems with higher capacities than enable resource constrained mobile devices to execute the tasks.

Furthermore, the result from Fig. 9 illustrates the case of high computation. Again as the size of computational task increases, the time of execution by the mobile device also increases astronomically due to the limited capacity of mobile device hence the need to offload these computational tasks to other systems with higher resource capacities. Hence given any huge or intensive computational tasks, the server and distributed systems are able to execute computational tasks within the shortest possible time using a small amount of time compared to the mobile device. It can be observed that, for intensive computational tasks, it is more efficient to offload to other systems with higher resource capacities than to use resource poor mobile devices.

Lastly, the result from Fig. 10 illustrates the case of very high computation. As can be seen with very high computational tasks, mobile devices are very inefficient at processing these tasks thereby wasting a lot of time and energy. It was observed that, for very huge and intensive computations it is very inefficient to use resource poor mobile devices to execute these tasks. Therefore there is the need to offload very huge, intensive and complex computational tasks from mobile devices to other systems with higher resource capacities for efficient and effective processing.

In addition, Fig. 11 shows the energy consumption of the mobile device during the very low computation, low computation, moderate computation, high computation and very high computation experiments. It can be observed that, the amount of energy needed to execute a task increases with respect to the size of data and computational task to be executed. In the very low computation, low computation and moderate computation experiments; the amount of energy needed to execute a task increases proportionally with respect to the computational task to execute. Also in high computation and very high computation experiment, a large amount of energy is needed by the mobile device to execute intensive and resource demanding tasks. As the size of data and computation increases, a lot of energy is needed to execute these resource demanding and intensive tasks hence the need to offload intensive computations for efficient processing.

VI. CONCLUSION

Generally, mobile devices are resource limited and handicapped [13], [20], [23], [30]. During the study, it was observed from the experiments that, most mobile devices are unable to run and execute highly intensive computational tasks. Computation offloading is a key benefit of mobile cloud computing which focuses on transferring very intensive computations from resource limited mobile devices to other powerful systems such as cloud servers for efficient and timely processing and execution [8], [12], [24], [26].

It was discovered during the research experiment that, offloading or transferring intensive computations from mobile devices to other systems with higher resource capacities in the cloud is far more efficient than processing of these intensive applications locally on mobile and smart computing devices. A great amount of time and energy resource is saved when resource demanding applications are transferred to cloud servers for execution.

Also the mathematical model presented during the study provides a means of evaluating the time and energy consumed during computation offloading in mobile cloud computing. It provides a way of assessing how much time or energy is supposedly used during the computational offloading process by resource limited mobile devices.

Computation offloading provides a high degree of time and energy resource savings and optimizations than local processing of tasks on resource poor mobile devices [10], [11], [16], [17]. Moreover, it was observed that a great amount of resources such as time and energy is saved when intensive mobile applications and computations are transferred from mobile phones to other systems with higher resource capacities in the cloud [7], [9], [19], [28].

The study recommends a secured computation offloading scheme to safeguard computational tasks and computations being transferred and executed on third party systems in the cloud. Also it recommends a further research into network related issues to enable a smooth transfer and execution of computational tasks in the cloud.

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Fuzzy Logic Tsukamoto for SARIMA

On Automation of Bandwidth Allocation

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Abstract—The wireless network is used in different fields to enhance information transfer between remote areas. In the education area, it can support knowledge transfer among academic member including lecturers, students, and staffs. In order to achieve this purpose, the wireless network is supposed to be well managed to accommodate all users. Department of Electrical Engineering and Information Technology UGM sets wireless network for its daily campus activity manually and monitor data traffic at a time then share it to the user. Thus, it makes bandwidth sharing becomes less effective. This study, build a dynamic bandwidth allocation management system which automatically determines bandwidth allocation based on the prediction of future bandwidth using by implementing Seasonal Autoregressive Integrated Moving Average (SARIMA) with the addition of outlier detection since the result more accurate. Moreover, the determination of fixed bandwidth allocation was done using Fuzzy Logic with Tsukamoto Inference Method. The results demonstrate that bandwidth allocations can be classified into 3 fuzzy classes from quantitative forecasting results. Furthermore, manual and automatic bandwidth allocation was compared. The result on manual allocation MAPE was 70,76% with average false positive value 56 MB, compared to dynamic allocation using Fuzzy Logic and SARIMA which has MAPE 38,9% and average false positive value around 13,84 MB. In conclusion, the dynamic allocation was more effective in bandwidth allocation than manual allocation.

Keywords—Bandwidth allocation management; dynamic allocation; fuzzy logic; Tsukamoto inference method; SARIMA

I. INTRODUCTION

Computer network becomes the important aspect in data communication. Thousands of user are using the network to transfer information to the remote area. The wireless network is common of computer network technology that is widely used in many different institutions to achieve different activity, including educational institution [1]. Therefore, network bandwidth in campus is supposed to be managed to meet user needs.

Bandwidth is channel capacity or the maximum throughput of a physical or logical communication path in a digital communication system [2]. The higher bandwidth consumption

needs a good management. Bandwidth management is a way to achieve optimum usage with limited available bandwidth [1].

Universitas Gadjah Mada (UGM) as an educational institution is also implementing Wireless Local Area Network (LAN) or Wi-Fi on their campus. This Wi-Fi is installed at all faculties in UGM. Every UGM staffs and students are provided with their own username and password to connect to the internet through the Wi-Fi. The number of users who connects to access point tends to rise. Thus, it is necessary to manage bandwidth efficiently.

The earlier study, especially in Electrical Engineering and Information Technology presented that bandwidth usage had a seasonal pattern. Seasonal Autoregressive and Moving Average (SARIMA) was applied to predict bandwidth usage. The results showed that bandwidth traffic tends to rise on Tuesday and get down on Sunday. Traffic fluctuations indicate the weekly bandwidth allocation should be changed [3].

Indra Hidayatulloh et al, added Exponential Generalized Autoregressive Conditional Heteroscedasticity (EGARCH) to reduce heteroscedasticity effect on bandwidth prediction using SARIMA. SARIMA- EGARCH increased prediction accuracy around 19,15% compared to stand alone SARIMA. Unfortunately, the auto-correlation effect happened during prediction on time series bandwidth data [4].

One of the methods of bandwidth management is by using system scheduling[5]. Mikrotik outerOS™, that is applied at UGM Hotspot, is a network router based on Linux. Mikrotik is also supported by Windows application (WinBox) to ease its router adjustment. Some scheduling methods are implemented at Mikrotik RouterOS, for example, Simple Queue, Per Connection Queue (PCQ) and Hierarchical Token Bucket (HTB). Simple Queue is used to restrict the number of data for specific addresses or subnet [5]. It is the simplest scheduling since the limitation of maximum upload and download is implemented refer to IP address client. PCQ method can divide bandwidth automatically from the active users. Additionally, this method also has disadvantages, whereas may result in bandwidth leakage or unfair division [6]. HTB method implements link sharing so that the residual bandwidth in a class node can be distributed into another class. It uses Token

Bucket Filter (TBF) as an estimator in the determination of bandwidth allocation. It is more adaptive since TBF provides bandwidth in rate. In HTB method, the admin needs to define the maximum rate in every class node. Unfortunately, it is still doing manually based on admin intuition. Therefore, the bandwidth management is less efficient and less adaptive.

Refer to the problem, there is important to develop an adaptive model for bandwidth management. A model must be able to provide the values of maximum rate automatically. The forecasting results could not be used directly for system input because it has a decimal data type with wide class boundaries that will be hard for a network administrator to manage these quantitative values. Moreover, forecasting results still have more error potential if the data applied directly rather than using a specific range. These data have to be converted into classification form to determine the maximum rate allocation. Fuzzy Logic was implemented to achieve this goal.

Some studies on bandwidth management have investigated. A previous work [7] has explored rate control strategies for real-time multimedia variable bit rate (VBR) services. It was implemented in IEEE 802.16 broadband wireless networks. This study managed bandwidth allocation on max-min fairness queue scheduling using a time constraint condition. Liu, et al [8] has predicted network traffic by using chaos theory and Support Vector Machine (SVM). This research used campus data including wired and wireless. The forecast values could be used to manage the bandwidth. A proposed scheme dynamically reserves and allocates bandwidth based neural network has been studied by Song et al. [9]. It was applied to different types of calls. Lee et al [10] has implemented round-robin schedule to allocate bandwidth. Prediction of Available Bandwidth Estimation with Mobility Management in Ad Hoc Networks has been undertaken by Belbachir et al. [11]. Hierarchical game theory models were also implemented for bandwidth management [12]. While Maestrelli et al. [13] proposed quantization model for bandwidth adjustment.

The aim of this research was to develop a Fuzzy Logic Tsukamoto in order to support bandwidth allocation decision automation system called BIOMA (Bandwidth Automation Management). Fuzzy Logic Tsukamoto uses monotone membership function with Center Average Deffuzzyfier method. By this defuzzification method, Tsukamoto selects mean from the range given. Meanwhile, Mamdani method selects Minimum or Maximum Value. If the minimum is selected, it might affect bandwidth allocation doesn't meet the network requirement. In the other side, if the maximum is selected, it might cause bandwidth being extravagant. The other method, Sugeno Method, gives consequences value as crisp values using some linear calculation. So this method doesn't meet the system requirement like Fuzzy Logic Tsukamoto.

The remainder of the paper is structured as follows. Section 2 illustrates data input. Section 3 presents the methodology. Section 4 describes experimental results. Finally, Section 5 presents the conclusion of the study.

II. DATA INPUT

Forecasting results of bandwidth usage were used as input data [2]. It was used real downstream dataset (Mbps). Data was collected from monitoring Universitas Gadjah Mada (UGM) portal at <http://mon.ugm.ac.id/cacti/weathermap>. This study collected time series data for the 20 week period from 09 September 2013 to 27 January 2014. The original data is plotted as presented in Fig. 1. Bandwidth usages were predicted by using SARIMA method with outlier detection.

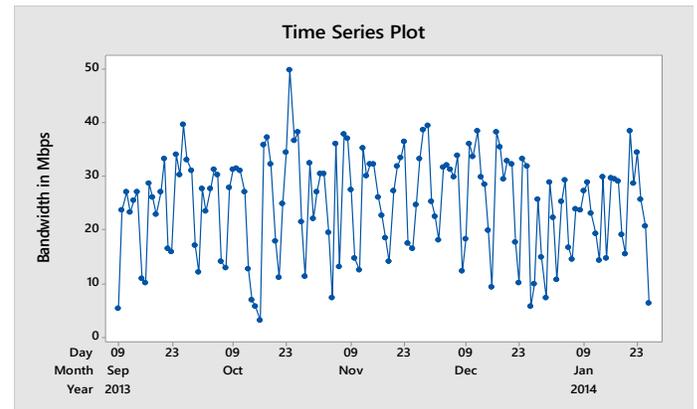


Fig. 1. Bandwidth usage original dataset.

Refer to previous research [2], the most appropriate SARIMA model was $(0,1,1)(0,1,1)7C$ from various traces. The observation found that some outliers in data collection influenced forecast accuracy. This problem was solved by including outliers detection to the model. Missing value analysis was done by using mean substitution operation to handle outliers. The approach could reduce forecasting error (MAPE) into 14.49%.

From computation, the parameter results were $MA(1) = 0.9519$ and $SMA(7) = 0.9246$ and constant = 0.010686. The estimated parameters were included to form the final model that expressed as backshift model shown in equation (1).

The forecasting results are shown in Table 1 is a month prediction of bandwidth usage in the Department of Electrical Engineering and Information Technology, UGM.

TABLE I. FORECASTING RESULT

Day	Week 1	Week 2	Week 3	Week 4
Monday	9.794235	8.960937	8.037514	7.023966
Tuesday	26.93602	26.08984	25.15355	24.12712
Wednesday	23.88494	23.02589	22.07672	21.03742
Thursday	27.52276	26.65084	25.68879	24.63662
Friday	27.81239	26.9276	25.95267	24.88762
Saturday	25.52054	24.62286	23.63506	22.55714
Sunday	12.64095	11.7304	10.72973	9.63893

III. METHODOLOGY

In order to build adaptive and dynamic bandwidth management, it is necessary to build a system that can model bandwidth needs and give maximum value rate automatically. To do this, SARIMA method was used to predict bandwidth needs and Fuzzy Logic method was used to allocate bandwidth dynamically.

A. SARIMA Model Transformation

The SARIMA model for this research is model (1) which transformed into regular equation form in order to be used as system model.

The model used in the research as follows.

$$z_t = 0.010686 - (1 - 0.9519B - 0.9246B^7 - 0.8801B^8)\alpha_t \quad (1)$$

with,

- z_t = prediction value
- B = Backshift operator for MA1
- B^7 = Backshift operator for MA7 (seasonal lag L)
- B^8 = Backshift operator for MA8 (seasonal lag L)
- α_t = forecasting residual.

z_t could be written as follows in order to facilitate computation.

$$z_t = \delta - \theta_1\alpha_{t-1} - \theta_{1,7}\alpha_{t-7} + \alpha_t \quad (2)$$

with,

- z_t = Prediction value
- δ = constant atmodel
- θ_1 = Coefficient of MA1
- $\theta_{1,7}$ = coefficient of MA1,7 (seasonal lag L)
- α_t = forecasting residual data number t

Based on Four Stationarity Transformation formula by Box [14] the z_t value for SARIMA with the first order of regular and seasonal differencing is as follows.

$$z_t = y_t^* - y_{t-1}^* - y_{t-L}^* + y_{t-L-1}^* \quad (3)$$

with,

- z_t = forecasted time series value
- y_t^* = time series value at t
- y_{t-1}^* = time series value at t-1

y_{t-L}^* = time series value at t-L

y_{t-L-1}^* = time series value at t-L-1

Subsequently, based on the same book [14] a model that has an MA time series character, in both seasonal and regular part, will require one or more multiplicative terms to be combined on the model. Therefore, final model of z_t as follows.

$$z_t = \delta - \theta_1\alpha_{t-1} - \theta_{1,7}\alpha_{t-7} - \theta_1\theta_{1,7}\alpha_{t-8} + \alpha_t \quad (4)$$

with,

- z_t = Prediction value
- δ = constant atmodel
- θ_1 = Coefficient of MA1
- $\theta_{1,7}$ = coefficient of MA1,7 (seasonal lag L)
- α_t = forecasting residual data number t

By combining the formulas (4-2) and (4-3) the value of the predicted value y_t^* can be determined as follows.

$$y_t^* = y_{t-1}^* + y_{t-7}^* + y_{t-8}^* - \theta_1\alpha_{t-1} - \theta_{1,7}\alpha_{t-7} + \theta_1\theta_{1,7}\alpha_{t-8} + \alpha_t + \delta \quad (5)$$

B. Fuzzy Logic Method

There is some approach that can be implemented to bandwidth allocation. One of them is a heuristic model. Fuzzy Inference System (FIS) is a heuristic model that widely used [6]. This study implemented Fuzzy Logic Tsukamoto. This method was represented by a fuzzy set with a monotonical membership function. The monotonical reasoning was used when two Fuzzy areas are related with the following implication:

$$IF x \text{ is } A \text{ THEN } y \text{ is } B \text{ or transfer function} \quad (6)$$

$$y = f((x, A), B)$$

The implication function extends monotonical reasoning into:

$$If (x_1 \text{ is } A_1). (x_2 \text{ is } A_2). \square \dots \square. (x_n \text{ is } A_n) \\ THEN y \text{ is } B \text{ with } \square \text{ is Operator} \quad (7)$$

For example, there are two input variable Var-1(x) and Var-2(x), and output variable Var-3(z). Var-1 is divided into two sets: A_1 and A_2 . Var-2 is divided into set B_1 and B_2 . Whilst, Var-3 is divided into sets: C_1 and C_2 , whereas C_1 and C_2 are supposed to be monoton. Therefore, two rules are used:

$$[R_1] IF (x \text{ is } A_1) AND (y \text{ is } B_2) THEN (Z \text{ is } C_1)$$

$$[R_2] IF (x \text{ is } A_2) AND (y \text{ is } B_1) THEN (Z \text{ is } C_2)$$

The first step is finding membership function for each fuzzy set in its rule. Sets of A_1 , B_2 , and C_1 are driven from fuzzy rule $[R_1]$ and sets A_2 , B_1 , and C_2 come from fuzzy rule $[R_2]$. Fuzzy rule R_1 and R_2 may be represented in determining crisp values Z .

Furthermore, the inferred output for each rule is defined as a crisp value induced by the rule's firing strength (α -predicate).

The final output result is taken from the weighted average of the output of each rule [15]. Fig. 2 illustrates steps of Tsukamoto method.

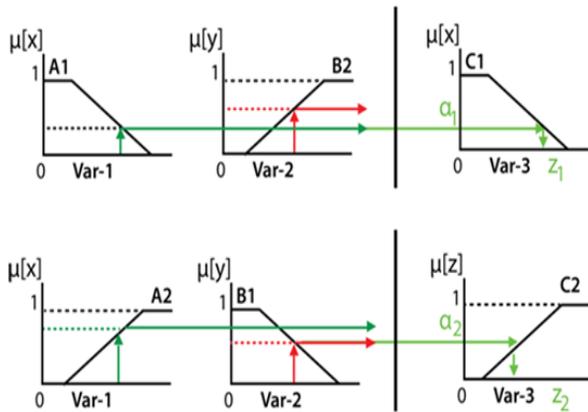


Fig. 2. Tsukamoto Step[15].

IV. EXPERIMENTAL RESULT

This following section is discussing the result of Tsukamoto steps in order to manage bandwidth allocation on available dataset.

A. Construction of Membership Function

This step is focus on the developing a fuzzy set. There were 2 variables for modeling, “Usage” is for input variable and “Allocation” is for output variable. The Usage has 3 fuzzy sets, they are Small, Medium, and Large. “Usage” is real type variable with its own domain:

Small, domain = [0.00 15.00]

Medium, domain = [12.50 27.50]

Large, domain = [25.00 35.00]

Membership function in this study is represented as triangle curve in Fig. 3.

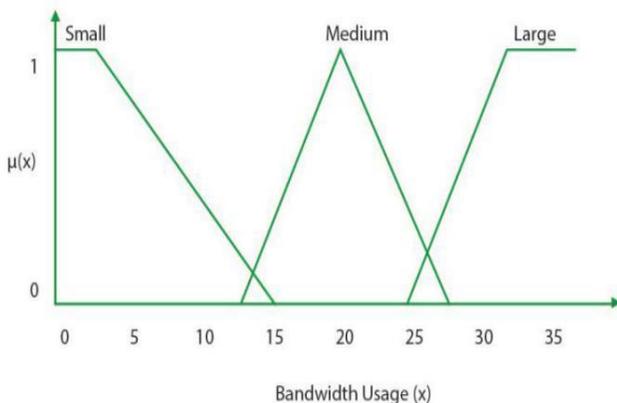


Fig. 3. Triangle curve of data.

Membership function for each set has been calculated as the following:

$$\mu_{SMALL}(x) = \begin{cases} 1, & x \leq 5.00 \\ \frac{15.00-x}{10}, & 5.00 \leq x \leq 15.00 \\ 0, & x \geq 15.00 \end{cases} \quad (8)$$

$$\mu_{MEDIUM}(x) = \begin{cases} 0, & x \leq 12.50 \text{ or } x \geq 27.50 \\ \frac{x-20.00}{7.50}, & 12.50 \leq x \leq 20.00 \\ \frac{27.50-x}{7.50}, & 20.00 \leq x \leq 27.50 \end{cases} \quad (9)$$

$$\mu_{LARGE}(x) = \begin{cases} 0, & x \leq 25.00 \\ \frac{x-25.00}{10}, & 25.00 \leq x \leq 35.00 \\ 1, & x \geq 35.00 \end{cases} \quad (10)$$

Furthermore, “Allocation” variable was determined as crisp values. This output has 3 sets: SMALL, MEDIUM, and LARGE.

Small, domain = [15.00]

Medium, domain = [27.5]

Large, domain = [35.00]

These values were refer to the highest average from bandwidth allocation in 20 last week.

B. Identify the Headings Rule Formation

Rules are one of FIS requirement [16]. The calculation includes Usage as input variable and Allocation as output variable. It yields the following rule format:

$$[R_i] \text{ IF } X_i \text{ is } A_i \alpha_i \text{ AND } X_n \text{ is } A_n \text{ THEN Allocation is } B_i \quad (11)$$

where:

R_i : fuzzy rule-i (i=1..m).

X_i : weight values of Usage-i

A_i : fuzzy set of Himpunan weight values of Usage-i

α_i : operator

n : number of data

B_i : fuzzy set for allocation variable

C. Weight Calculation and Determination of Bandwidth Allocation

The previous rules were used to determine each data weight. Values of predicate α were found from rule composition (α_i). The predicates are associated differently with the operator.

In AND operator, predicate value of “ α is A_1 AND X_2 is A_2 ” is given as:

$$\alpha_i = \mu_{A_1 \cap A_2} = \text{Min}(\mu_{A_1}(x_1), \mu_{A_2}(x_2)) \quad (12)$$

$$\alpha_i = \mu_{A_1 \cap A_2} = \text{Max}(\mu_{A_1}(x_1), \mu_{A_2}(x_2)) \quad (13)$$

One consequent values are obtained, y values can be calculated as:

$$y = \frac{\sum_{i=1}^m \alpha_i y_i}{\sum_{i=1}^m \alpha_i} \quad (14)$$

D. Allocation Calculation

The calculation was started with the determination of membership weight. Membership weight for each data was calculated based on 2 domain, with each domain consists of Small, Medium, and Large. The result is presented in Table 2.

TABLE II. WEIGHT RESULTS

x	SMALL	AVERAGE	LARGE
9.7942	0.5206	0	0
26.9360	0	0	0.1936
23.8849	0	0.2230	0
27.5228	0	0	0.2523
27.8124	0	0	0.2812
25.5205	0	0	0.0521
12.6409	0.2359	0	0
8.9609	0.6039	0	0
26.0898	0	0	0.1090
23.0259	0	0.3948	0
26.6508	0	0	0.1651
26.9276	0	0	0.1928
24.6229	0	0.0754	0
11.7304	0.3270	0	0
8.0375	0.6962	0	0
25.1535	0	0	0.0154
22.0767	0	0.5847	0
25.6888	0	0	0.0689
25.9527	0	0	0.0953
23.6351	0	0.2730	0
10.7297	0.4270	0	0
7.0240	0.7976	0	0
24.1271	0	0.1746	0
21.0374	0	0.7925	0
24.6366	0	0.0727	0
24.8876	0	0.0225	0
22.5571	0	0.4886	0
9.6389	0.5361	0	0

Where, x are time series from SARIMA forecasting results.

Next step was determining y values that represented as allocation values for each time series by using formula (14). The calculation results are shown in Table 3.

TABLE III. RESULTS OF BANDWIDTH ALLOCATION

Day	Week-1	Week-2	Week-3	Week-4
Monday	15	15	15	15
Tuesday	35	27	27	27
Wednesday	27	25	27	27
Thursday	35	35	27	27
Friday	35	35	27	27
Saturday	27	27	27	27
Sunday	15	15	15	15

V. BIOMA SYSTEM IMPLEMENTATION

Bioma system has been implemented with a user friendly interface design using Bootstrap. Fig. 4 shows the interface of dashboard page that contains history of bandwidth allocation and bandwidth prediction the next few days.

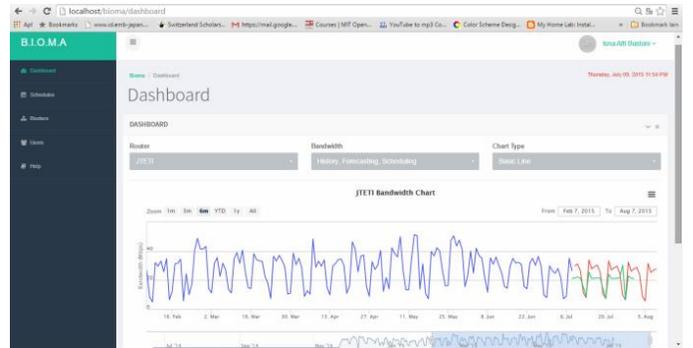


Fig. 4. Dashboard.

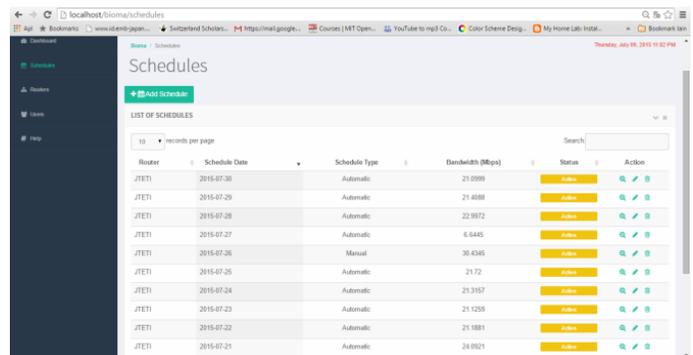


Fig. 5. Schedules.

Fig. 5 as follows is the interface of schedules page that used to set bandwidth allocation on specific date.

Bioma system tested by comparing MAPE between manual/ static and dynamic allocation using Bioma. The test results are shown in Table 4 below:

TABLE IV. RESULTS OF BANDWIDTH ALLOCATION

Method	MAPE	Avg. False Positif Value (MB)	Avg. False Negatif Value (MB)
Manual/Static	70,77 %	56,61	0
Dynamic (Bioma)	38,90 %	13,84	0

VI. CONCLUSION

Fuzzy Tsukamoto method has been demonstrated its capability in the bandwidth allocation automation at UGM-Hotspot by using forecasting traffic usage data as an input for Fuzzy Logic. The fuzzy approach was able to convert the quantitative values of forecasting results into classification form. Bioma system as dynamic bandwidth allocation system had MAPE amounted to 38.90 %, smaller than the MAPE of manually calculating bandwidth allocation of 70.77%. Besides showing the error, MAPE in this case also shows the huge excess bandwidth allocation or the rest of the unused bandwidth. Thus it can be said that the bandwidth allocation by the Bioma system is more efficient than manually allocation by an administrator under normal conditions.

However, False positive happened in both manual and dynamic allocation. This false positive result indicates remaining unused allocation became wasteful. Therefore, further research is needed to be able to automatically transfer the remaining allocation of unused bandwidth so it can be utilized better. In the future research, we should consider other variables such as the number of users, the role of users and the autocorrelation effect in the bandwidth data since bandwidth data are fluctuating.

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Figural a Flexibility Test for Improving Creative Thinking in an Arabic Learning Environment

A Saudi Arabia-Based Case Study

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Abstract—The capability of graduates to be flexible in the face of rapidly altering situations is an increasingly crucial requirement that teachers should be conscious of, given that persistent development and technological progress are characteristic of contemporary life. Proficiency for learning and cognitive abilities are two areas in which learners need to acquire knowledge. Cognitive spatial ability has various dynamics, the assessment of which can be undertaken through numerous techniques. The major objectives of this paper are to develop a web-based system for measuring adult cognitive ability within an Arabic learning environment, in addition to enhancing their creative thinking and learning capabilities through utilising the kit of factor referenced cognitive tests, devised by Ekstrom et al. (1976). The web-based system will focus on the figural flexibility test (Toothpicks test - planning patterns – storage test). Each test has its own objective with regard to assisting with the measurement of people’s creative ability in different ways, as a means of enhancing creative thinking and learning. Prior to constructing the figural flexibility test system, we are going to distribute a questionnaire in order to assess and examine certain crucial aspects, to inform the construction of our system. The questionnaires were distributed to university students in the Faculty of Computing and Information Technology (FCIT), in addition to random distribution via email and social media, namely, Facebook, Twitter and WhatsApp. Over 500 questionnaires were distributed with 400 responses received. The objective was to assess the new system’s feasibility, as well as to design a system that meets the user’s requirements. As a result of the questionnaire, 77% of people were found to believe that creating a web-based system can assist students with developing their creative thinking and learning abilities.

Keywords—Creative thinking; kit of factor referenced cognitive tests; students; toothpicks; planning patterns; storage test; cognitive abilities

I. INTRODUCTION

Some of the primary definitions of relevance to this paper include:

Cognitive training: As Coutinho [4] explained, memory, attention and problem-solving skills and various other cognitive functioning capabilities are reviewed and practice

through engagement in such training.

Working memory: This term refers to a brain system that offers impermanent data banking and handling, permitting complicated cognitive tasks such as language comprehension, learning and reasoning to be completed [1].

Cognitive abilities: These govern a spectrum of tasks from the most basic to the incredibly complicated, based on the capabilities of the brain. As opposed to being concerned with information itself, it is the means through which one focuses, tackles challenges, recalls and learns which cognitive ability is relevant to. Even the task of holding a phone conversation requires various abilities: conversing appropriately with the other individual and interpreting their voice manner necessitates social abilities; comprehension of language and discussion requires language ability, holding the telephone draws on motor abilities; responding to a call necessitates choice making, while hearing the initial call requires perception. Mental functions or cognitive abilities are founded on particular neuronal networks. For example, memory skills draw largely on temporal lobe and frontal lobe areas, the latter of which is behind the forehead [11].

According to the particularly pertinent aspects that the psychology specialist identifies in relation to reasoning ability, an array of questions in relation to cognitive ability can be applied in psychometric analysis. Mechanical, spatial, abstract, verbal and numerical questions can be classified as part of psychometric assessments. Psychometric assessments may be narrowly focused on a particular classification of questions, while different assessments will be broader. As Psychometric [6], [13], [14] explained, data that is conveyed in words and the ability to comprehend it will be the sole focus of a verbal reasoning ability assessment.

Language, calculation, problem resolution, visual-spatial awareness, concentration, memory and various other abilities can be quantified and analysed as thinking or cognitive skills, through cognitive ability assessments. Drawing on Michelon [10], [11], Table 1 outlines the major brain activities associated with thought, while certain puzzles and tests to train and hone one’s cognitive skills are also identified.

TABLE I. COGNITIVE ABILITIES AND THE BRAIN'S FUNCTIONS

Cognitive Ability/Brain Function	Skills involved
Perception	Recognition and interpretation of sensory stimuli, for example smell, touch and hearing. Brain puzzles: <ul style="list-style-type: none"> ○ Is this a circle? ○ Catch the number
Attention	The ability to sustain concentration on a particular object, action or thought. The ability to manage peting demands within our environment. Brain puzzles: <ul style="list-style-type: none"> ○ Count the letters ○ Spot the differences ○ Awareness test
Memory	Short-term/ working memory (limited storage). Long-term memory (unlimited storage).
Motor skills	The ability to mobilise our muscles and bodies. The ability to manipulate objects. Brain puzzles: <ul style="list-style-type: none"> ○ Tap your right hand on the table. Consecutively, make a circular movement with your left hand, in the motion of cleaning the table. ○ Switch hands
Language	Skills permitting us to translate sounds into words, thus generating verbal output. Brain puzzles: <ul style="list-style-type: none"> ○ Words associations ○ What is the word?
Visual and Spatial Processing	The ability to process incoming visual stimuli. The ability to comprehend spatial relationships between objects. The ability to visualize images and scenarios. Brain puzzles: <ul style="list-style-type: none"> ○ Build the box ○ Which piece is missing?

This paper's major objectives are to develop a web-based system for measuring adult cognitive ability, while also seeking to enhance their abilities for creative thinking and learning proficiency, by focusing on the figural flexibility test (Toothpicks Test - Planning Patterns – Storage test).

II. KIT OF FACTOR REFERENCED COGNITIVE TESTS

The kit of factor referenced cognitive tests is unique among multiple aptitude measures, due to it being intended solely for research, while also being based on an amalgamation of factor analysis and information processing theory. This version of the kit comprises of two to three measures, each consisting of 23 basic cognitive factors covering dimensions including reasoning, verbal ability, spatial ability, memory and fluency (see Table 2). The kit is supported on a large body of research stretching back to the 1940s, thus strengthening its reliability and validity [5].

TABLE II. MARKER ASSESSMENTS FOR 23 APTITUDE FACTORS

Closure, Flexibility of 1. Hidden figures assessment 2. Hidden patterns assessment 3. Copying assessment	Memory, Visual 1. Shape memory assessment 2. Building memory 3. Map memory
Closure, speed of 1. Gestalt completion assessment 2. Concealed words assessment 3. Snowy pictures	Number 1. Addition assessment 2. Division assessment 3. Subtraction & Multiplication assessment 4. Addition & subtraction correction
Closure, verbal 1. Scrambled words 2. Hidden words 3. Incomplete words	Perceptual speed 1. Finding A's assessment 2. Number comparison assessment 3. Identical pictures assessment
Fluency, associational 1. Controlled associations assessment 2. Opposites assessment 3. Figures of speech	Reasoning, general 1. Arithmetic aptitude assessment 2. Mathematics aptitude assessment 3. Necessary arithmetic operations assessment
Fluency, expressional 1. Making sentences 2. Arranging words 3. Rewriting	Reasoning, logical 1. Nonsense syllogisms assessment 2. Diagramming relationship 3. Inference assessment 4. Deciphering languages
Fluency, figural 1. Ornamentation assessment 2. Elaboration assessment 3. Symbols assessment	Spatial orientation 1. Card rotations assessment 2. Cube comparisons assessment
Fluency, ideational 1. Topics assessment 2. Theme assessment 3. Thing categories assessment	Spatial scanning 1. Maze tracing speed assessment 2. Choosing a path 3. Map planning assessment
Fluency, word 1. Word endings assessment 2. Word beginnings assessment 3. Word beginnings and endings assessment	Verbal comprehension 1. Vocabulary assessment 1 2. Vocabulary assessment 2 3. Extended range Vocabulary assessment 4. Advanced Vocabulary assessment 1 5. Advanced Vocabulary assessment 2
Induction 1. Letter sets assessment 2. Locations assessment 3. Figure classification	Visualization 1. From board assessment 2. Paper folding assessment 3. Surface development assessment
Integrative processes 1. Calendar assessment 2. Following directions	Flexibility, figural 1. Toothpicks assessment 2. Planning patterns 3. Storage assessment
Memory, associative 1. Picture-Number assessment 2. Object-Number assessment 3. First & last names assessment	Flexibility of use 1. Combining objects 2. Substitute uses 3. Making groups 4. Different uses
Memory span 1. Auditory number span assessment 2. Visual number span assessment 3. Auditory letter span assessment	

For factor analytic research, a tool permitting analysts to assess particular aptitude variables is provided by the cognitive assessments based around a set of 72 factors. The ability to contrast particular variables in a valid manner, with understanding simplified, is the objective of such an assessment. Nevertheless, across various kinds of investigation, the process of identification of comparable factors across studies may be made more objective, through incorporating marker tests for factors that may be anticipated to appear or for factors that a researcher wishes to isolate from other domains of interest [5].

A. Figural Flexibility Test

The figural flexibility assessment provides the ability to alter the set order, generating new and alternative solutions to figural problems. In the 1963 edition of this kit and through the work done in Guilford's laboratory, this factor was called figural adaptive flexibility. Cattell [3] refers to it as adaptive flexibility, because the existence of this factor has been demonstrated only with flexibility material, while there appear to be other types of flexibility restricted to non-figural material, therefore the new term was selected.

Both Royce [16] and Cattell [3] have stated that figural adaptive flexibility can be amalgamated with several other abilities to produce a second-order visualisation factor. Carroll [2] proposed that figural adaptive flexibility necessitates the equivalent process, imaging a figure in relation to a surrounding visual representation field, similar to flexibility of closure; however, it also entails a search for relevant hypotheses in long-term memory and the performance of serial operations. In accordance with Ekstrom et al. [5], [8], the figural flexibility test for measuring cognitive spatial ability can be outlined as follows:

1) Toothpicks Test

In this assessment, the individual will be asked to produce outlines of different squares using toothpicks. The participant will be shown a pattern of squares and then be asked to alter it by removing some of the toothpicks. Subsequently, they can show which toothpicks should be removed by drawing a short line on them. Consider the example below (see Fig. 1):



Fig. 1. Toothpicks test example.

2) Planning Pattern Testing

In this assessment, the participant is asked to plan how certain figures may be arranged onto a group of dots. The respondent will be asked to consider as many different ways that they possibly can to arrange the figures. Consider the example below, where three possible solutions to the problem are illustrated on the right (see Fig. 2).

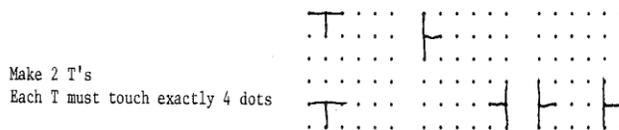


Fig. 2. Planning pattern test example.

3) Storage Test

In this assessment, the participant will be asked to plan objects that may be stored within a given space. The respondent will be asked to consider as many different ways as possible for the objects to be arranged in this space.

How many different ways may 4 boxes, as displayed in Fig. 3 on the left below, be stored in the container shown on the right? The numbers on the sides of the boxes and the dotted lines are to assist the viewer in comparing the sizes.



Fig. 3. Storage test example.

III. LITERATURE REVIEW

For the purpose of this research, it is essential for a brief background and historical account to be provided concerning some theories relating to cognitive tests in adulthood, as a means of enhancing creative thinking and learning abilities.

A. Virginia State University, Department of Technology

A 3-dimensional rotation test was utilised in this research, which sought to assess engineering students' cognitive spatial ability, who were based at Virginia State University at the time. Such tests are regularly adopted to assess engineering students' cognitive spatial abilities, for example Vandenberg and Kuse's [18] mental rotation test, or Guay's [9] Purdue spatial visualisation assessment.

Nevertheless, as N.E. Study [12] explained, science, technology, engineering and mathematics (STEM) subject assignments, issue resolution, engineering planning and a host of other aspects' effective undertaking, often rely upon myriad spatial ability skills to formulate the mental models that are required, thus learners' capacity to mentally orientate objects in three dimensions are just one requisite skill.

B. The Relationship between Rigidity-Flexibility and Cognitive Abilities in Adulthood

Adult cognitive abilities and rigidity-flexibility's physical correlation is the focus of this research investigation. The justification for this is that as one enters later life from their earlier adulthood, variations in cognitive decline across people may be explicated on the basis of rigidity-flexibility, it having been posited as a character variable of significant importance. In accordance with Schaie et al. [17], 1,628 individuals aged between 22-95 years comprised the research sample.

Rigidity-flexibility is a personality dimension that has been repeatedly associated with the ability to estimate cognitive decline during advanced maturity. Nevertheless, the multidimensional character of the factor of rigidity-flexibility is also acknowledged. Three rigidity-flexibility dimensions were investigated by Schaie et al. [17] in relation to cross-generation and age alteration variations. Certain rigidity-flexibility aspects were characterised by greater rigidity. Additionally, the researchers determined that younger subjects were advantaged by beneficial cohort impacts.

C. Playing an Action Video Game Reduces Gender Differences in Spatial Cognition

Mental rotation ability- a spatial cognition procedure of a higher order- as well as spatial focus, are both characterised by a discrepancy of ability between genders, however the research has indicated that this discrepancy may be virtually eradicated through participation in the video game. Females were found to be advantaged to a greater degree than males with regard to cognitive rotation and spatial focus ability, skills that increased considerably following participation in the action computer game of just 10 hours. No enhancement in capability was seen for the control participants who were using the non-action game. As Feng et al. [7] proposed, the process of encouraging both females and males to enter engineering science and mathematics careers may be informed by the outcomes of this research, due to the crucial role of refined spatial capabilities.

IV. METHODOLOGY

The overall methodology for this research comprise of several stages:

Stage 1: Reviewing the existing literature and previous work concerned with the design of cognitive spatial ability, in order to improve creative thinking.

Stage 2: Interview

An interview was conducted with a Psychological Counsellor from the Brain Training and Psychological Counselling Office, who possesses expertise in the field of cognitive spatial ability assessments and special needs (learning difficulties) in particular.

Stage 3: Questionnaires:

The questionnaires were distributed among university students in the FCIT, in addition to random distribution via email and social media, namely Facebook, Twitter and WhatsApp. Over 500 questionnaires were distributed, with 400 responses obtained. The objective was to assess the feasibility of the original system, in addition to designing a system reflecting the users' requirements.

Stage 4: Implementation

Installation, configuration, running, testing and the introduction of essential alterations to original software and hardware, as a means of ensuring efficient running of the system, can be encapsulated in the procedures of implementation.

During this stage, all of the planned activities were implemented. The implementation process continues until the production system is operating in accordance with the defined requirements [15]. Furthermore, this phase will incorporate the tools utilised to build our system, including the hardware, software, programming languages and system walkthrough. Drawing on the discussion with certain psychology specialists, the implementation of this process was reliant upon their perspective of how the test would be practically implemented, in addition to how the website would provide instructive information supporting users and simplifying their requirements. Therefore, we focused our effort on being as helpful as possible, for example making the website contents as simple and straightforward to use as possible.

V. RESULTS AND DATA ANALYSIS

The questionnaire results are presented in Table 3. 400 participants responded, characterised by different ages and educational levels.

TABLE III. PARTICIPANTS' RESPONSES TO THE QUESTIONNAIRE

QUESTIONS	Answer		
	YES	NO	Sort of
1) Do you know how to use a computer?	56.5 %	5.4 %	38.1%
2) Do you know how to use the Internet?	76.2 %	5.4%	18.4%
3) Do you have any understanding of creative thinking?	21.8%	39%	39.2%
4) Have you taken a test to measure your creative thinking before?	37.8%	62.2%	
5) Do you support the idea of creating a website to measure creative thinking?	85.8%	3.7%	10.5%
6) Do you think that this test will help students to develop their creative thinking?	77%	2.5%	20.5%
7) Do you support the idea of measuring creative thinking for each student when they join the university or school, in order to increase and improve the student's academic level?	72%	8%	20%
8) Do you prefer the implementation of this idea to be via a website or mobile application?	Mobile	Website	
	52%	48%	
9) Which language do you prefer for the website?	Arabic	English	Arabic & English
	20%	3%	77%

VI. DESIGN AND IMPLEMENTATION OF WEB-BASED SYSTEMS

The web-based system is connected to an external database, which we have established using the WAMP Server. We used MYSQL as a means of creating the database, while we utilised HTML, CSS, and Java script programs in order to design and develop the website. Furthermore, we adopted Notepad++ to write the PHP codes, which work as a mediator between the database and the website in the process of sending

and receiving instructions. Additionally, we utilised Photoshop to design the logo.

A. Web-based System Design

The home of the web-based system is presented in Fig. 4. The home page displays the major menu that comprises of certain features, such as 'Home', 'About us', 'Cognitive test', 'Quick games', 'Help', 'Feedback' and 'Contact us'. Moreover, an introduction to the test is provided, alongside some movable pictures.

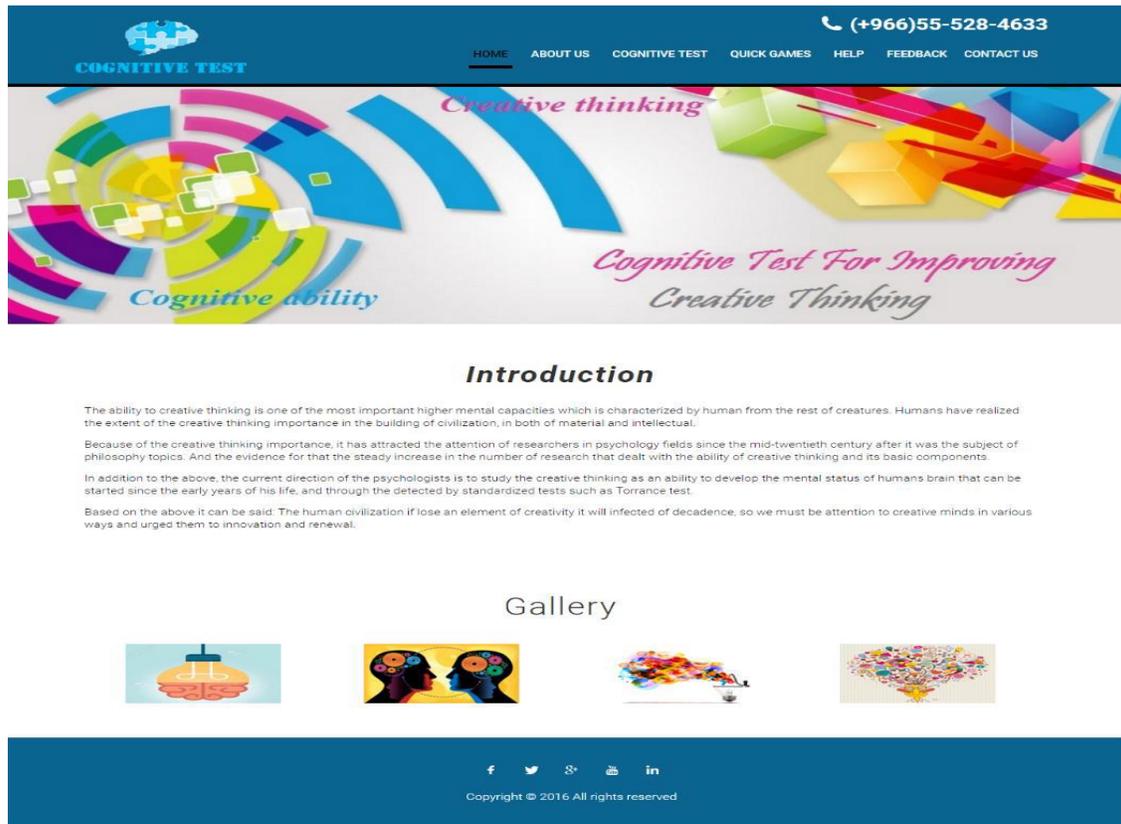


Fig. 4. Home page.

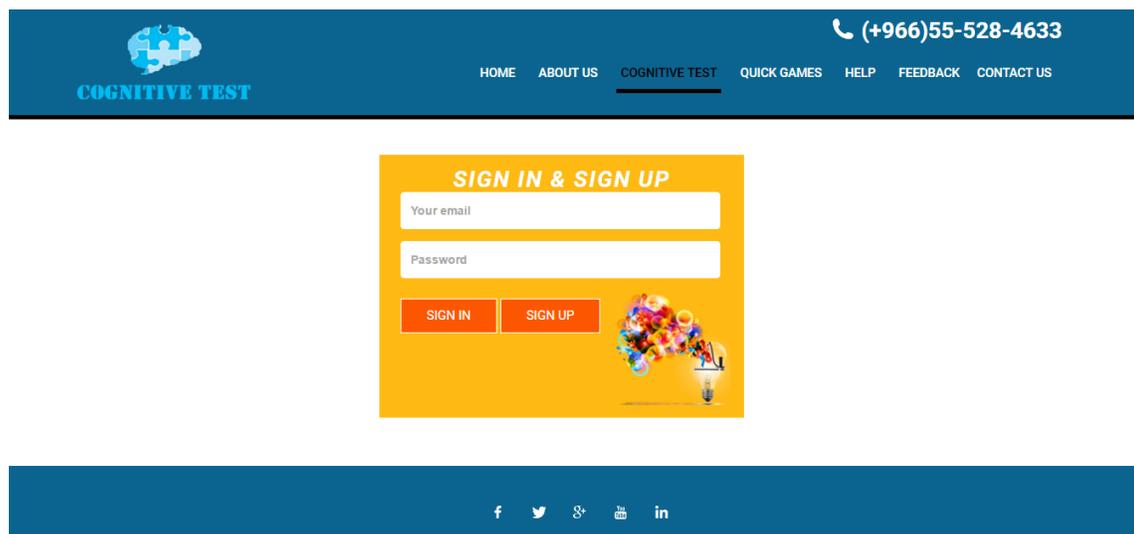


Fig. 5. Cognitive test page.

The site is divided into three main areas: the top area, the content area and the bottom area.

The top area: This displays the main menu and the banner.

The content area: This displays the website content, namely the text, pictures, forms and the test.

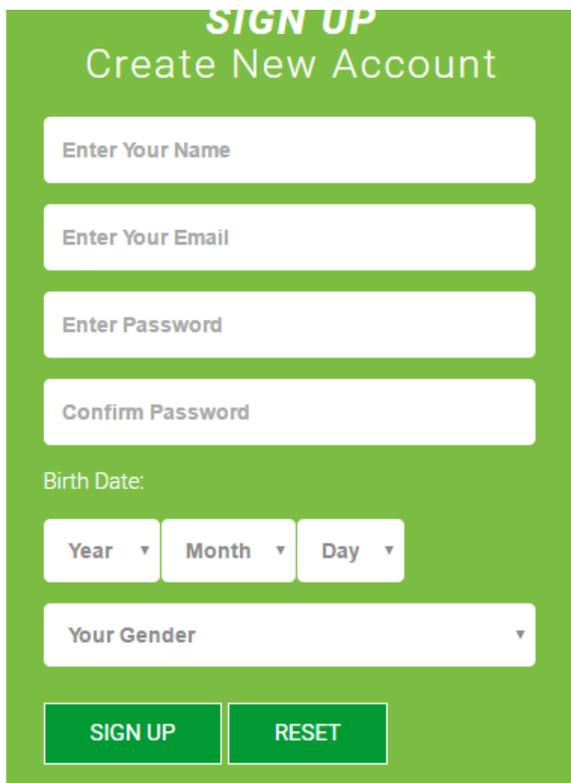
The bottom area: This contains the copyright regarding the website, alongside the social media links.

1) Cognitive test

This page provides a brief description and definition of cognitive ability, while also displaying the test logo and the sign-in form, as illustrated by Fig. 5.

2) Sign up

On this page, the web-based system visitor can fill in the registration form, creating a new account that permits entry to the system where they are able to take the test, as presented in Fig. 6.



The sign up page features a green background with white text. At the top, it says "SIGN UP Create New Account". Below this are four input fields: "Enter Your Name", "Enter Your Email", "Enter Password", and "Confirm Password". Underneath these is a "Birth Date:" section with three dropdown menus for "Year", "Month", and "Day". Below that is a "Your Gender" dropdown menu. At the bottom, there are two buttons: "SIGN UP" and "RESET".

Fig. 6. Sign up page.

3) Toothpicks Test

When the user wishes to initiate the test, they can select either the English version or the Arabic version. Once they have chosen the version of the test that they want, it will begin (see Fig. 7 and 8).



Fig. 7. Test page.

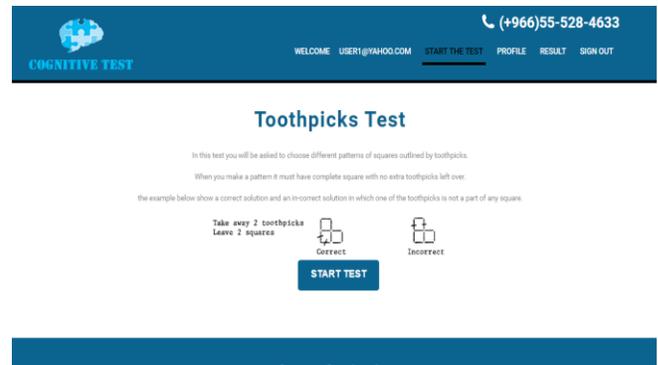


Fig. 8. Toothpicks test.

4) Result

As illustrated in Fig. 9, this page displays the user's last result, enabling them to review it in any point.



Fig. 9. Results page.

VII. CONCLUSION

This paper handles a crucial subject, which is an assessment of the ability to engage in creative thinking in relation to various psychological components. Ultimately, the interaction and overlap between these components enhances the ability for creative thinking, which is one of the most crucial higher cognitive abilities that humans possess, providing them with such capabilities as sensitivity to problems, fluency, flexibility, originality, details or enlargement. The major objective of this paper is to create a Web-based system measuring adults' cognitive ability, which enables them to enhance their ability for creative thinking. Furthermore a Web-based system was devised that provided

certain advices and guidance, based on the information provided by certain psychology specialists.

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Development of Self-Learning Program for the Bending Process of Quartz Glass

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Abstract—Quartz glass is a high-performance glass material with its high heat and chemical resistance, wide optical transparency ranging from ultraviolet light to infrared light, and the high formativeness as a glass material. Because it has high morphological stability due to its heat resistance and low thermal expansion, it is widely used as material for specialized research and development or high-precision components. There are several techniques to process quartz glass material, and an important process among them is the fire processing. The fire processing requires technology to heat and mold glass material in high temperature, and high-quality processing is done by the manual works of experts. In this study, we focused on bending work, which is the process that demands particularly high skill among the fire processing. We developed a self-learning program for beginners to improve their skill in short time by using the bending know-hows of the experts that were clarified through process analysis, product evaluation and an interview with the expert, and examined its effectiveness. As a result, a consistent educational effect was observed in the bending skill improvement of the beginner in a short period of time.

Keywords—Quartz glass; self-learning; bending; experts; beginner; process analysis; text analysis

I. INTRODUCTION

At the bending process, a technician holds the both ends of a quartz glass tube with his both hands while heating it with the flame of a burner with rotating the tube with his fingers. He bends the heated and softened tube to a predetermined angle, and this entire process is conducted manually. Fig. 1 shows the technician's posture during this process and the positions of the quartz glass tube and the burner. Bending work is an indispensable technique to produce a tube-shaped components for stably transporting fluids such as special chemicals and gases. Because of its heat resistance and small thermal expansion characteristics, high precision work is required when processing quartz glass products. Especially in case of bending a tube, smooth curve and inner surface are required as let the

flow of chemical or gas transferred smoothly without disturbance, in addition to the dimensional accuracy. Only an expert who possesses high degree of skill can achieve such a high-quality bending work. However, the know-how required for improving beginners' bending technique is equivalent to the tacit knowledge that experts possess. And these tacit knowledge has not been converted into explicit knowledge that can be understood by beginners. Thus, when beginners start learning bending work, they repeat trial and error, therefore the learning period naturally becomes prolonged. For instance, in the example of a Japanese quartz glass product manufacturing company, it requires more than 20 years to for technicians to reach the same skill level as experts. And even among these experts, there are only a small number of technicians who are capable to produce a high-quality bending work. Therefore, if shortening of learning period is achieved, it is expected to have a significant effect on human resources development.

It is easy to use for technical learning in the current technology environment. We can use self-analysis by the video to help engineers learn to notice [1]. In the Kounin's study, the effect of self-analysis using video in teacher education programs has been reported [2]. In Nakahira's study, it is reported that technology improvement is effective by taking and viewing its own video [3].

Especially small business companies in Japan are required to make effective use of limited human resources and time. There are many requests for self-learning programs such as e-learning, and examples of learning programs using video have been reported [4].

Efforts on self-learning using e-learning in the field of nursing skills [5] suggested that viewing and exercising video influences student motivation and self-evaluation ability. In addition, the work of Downey, it has been reported that it was possible to see himself from a different point of view by looking at their own video [6].

In addition, it is suggested that the effectiveness of feeding back to the educators about the level of comprehension of the subjects of education [7]. However, in the case of teaching beginners directly from experts, grasping the problems and understanding levels of beginners is left to the individual's sense, so it is difficult to objectively evaluate them. Moreover, when experts pass on tacit knowledge, "recipients acquire their own interpretations and tips in accordance with their own system and give repeat accuracy" [8] due to lack of languageization of know-how and Ambiguity in expression. As a result, beginners take a long time to improve technology.

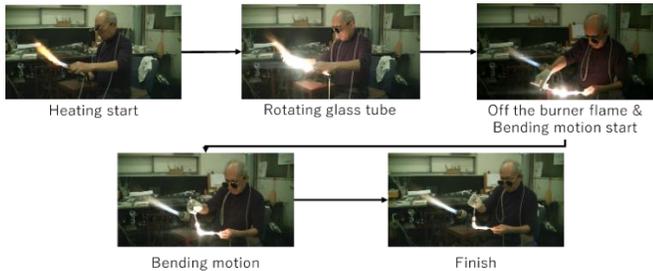


Fig. 1. Technician's posture during bending process and the positions of the quartz glass tube and the burner.

In this study, in order to analyze his know-how in bending work, an interview with an expert was conducted using a video that documented his process. In the field of fire processing of quartz glass, the number of previous study examples are very limited. Though there is one example, the study of Umemura et al., that analyzed the motion of the work to machine a glass tube while rotating it by fingers [9], there has no study on the process sequence of experts and the know-how that exists in that process regarding the fire processing of quartz glass. As a result of process analysis [10] and product evaluation conducted by Suda et al., it is clarified that the products made by the expert possess significant characteristics [11]. In this study, we engaged with the identification of the know-how of an expert through an interview with the expert using a video. Moreover, we developed a self-learning program for beginners based on the know-how obtained from the expert, and examined its effect on beginners.

In order to improve the bending skill of a beginner in a short period of time, it is considered necessary for beginners to notice the difference in skill between experts and beginners. In recent years, a skill improvement program that uses virtual reality (VR) is being examined. Takahashi et al. reports that: "Using the direct advantage of VR, it becomes possible to construct a system to numerically measure how closely the movement of a learner followed the example, displays it in real time and supplies feedback. This system enables to produce a training system and use it as an indicator to make sure the achievement of training level. This has an advantage, especially for beginners, of copying correct forms. Also in this case, it is desirable to develop a VR educational tool that listens to experienced trainers, learns from trainers a series of basic movements from the beginning to the final stage of movements, measures movements of beginners and gives feedbacks" [12]. Thus, also in bending work, the beginner comparatively examines the movements of the expert and himself by watching video, which provides him an opportunity

to notice the difference in movements and to follow the expert's movement for improving his skill. Moreover, by adding the expert's information to the self-learning program, such as the intention of the expert and the effect of each step that are difficult for beginners to understand only by watching a video, it is expected to contribute to the skill improvement in the short time by acquiring the expert's know-how through this program.

In this study, we developed a new self-learning program and verified its effect, which is not direct teaching by experts on quartz glass fire processing. First, we interviewed an expert using process videos and process analysis, and worked on elucidating important expert know-how in bending processing. Next, I developed a self-learning program using video viewing and added expert know-how gained by interview. And we conducted experiments for a beginner. In order to measure the effect that the program brings to a beginner, it was evaluated compared to a non-expert who did not experience this program. We report on its learning effect.

II. EXPERIMENTAL METHOD

A. Identification of the Know-How of the Expert by Interview

We identified the know-how the expert uses at each step through an interview while watching a video of his bending work. The selected expert has 55 years of experience in bending work. In the previous study by Suda et al. clarified that bending work consists of two steps, namely a heating step and a bending step [2]. In the interview with the expert using the bending process video. The process is consisted of the following three steps: 1) the heating step; 2) transition from the heating step to the bending step; and 3) the bending step.

B. Self-Learning Program

In this program, we showed the beginner of two videos every time when he engaged in the bending process, one is the video recording his work movement during the bending process and the other is the example video of the expert. Moreover, the beginner answered a writing-type questionnaire on bending process after watching the videos, and then conducted the bending process. The questions in the questionnaire were thus: 1) "what were some of the specific differences in your processing work compared to the expert's?" 2) "what do you think are the points that the expert place emphasis on?"; and 3) "what do you think needs improvement in your work?" From the first to the fourth time when conducting the bending process, the know-how of the expert was not disclosed to the beginner, but from the fifth time to the eighth time, a diagram showing the know-how was disclosed to the beginner during the bending process. Fig. 2 shows the flow of the program. In this program, beginners try only video information from the first time to the fourth time. The aim is to improve the comprehension of know-how by disclosing know-how of experts after beginners thought about themselves by trial and error. In addition, to update every time the beginner video in this program. It is possible for beginners themselves to learn while confirming growth. Furthermore, in this program, it is also one of the features that educators or managers can visualize progress and changes on beginners' thinking aspects by describing comments each time.

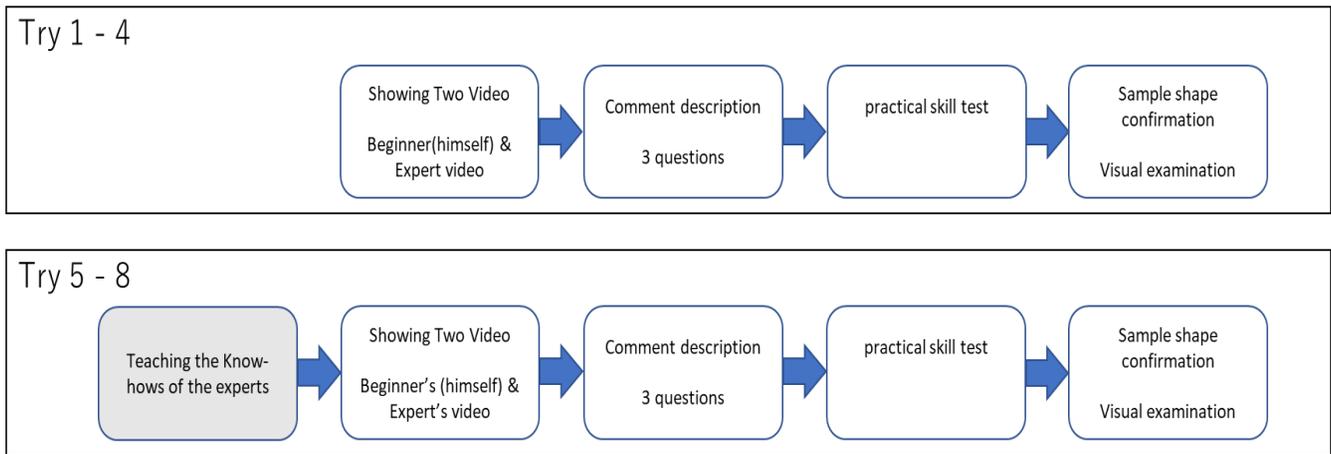


Fig. 2. Self-learning program of bending process.

C. Process Analysis

We assigned an expert (55 years of experience), a non-expert (5 years of experience) and a beginner (half year of experience) as test subjects. Their bending works were recorded as digital videos, and time measurement of each step was conducted using these footages. The work of the expert and the non-expert were measured for three times each, and that of the beginner was measured for eight times in total using the self-learning program.

D. Product Evaluation

We assigned an expert (55 years of experience), a non-expert (5 years of experience) and a beginner (half year of experience) as test subjects, asked them to conduct the bending work for comparing the external appearances of the bent parts on their finished products. Moreover, the outer diameter of the bent tube was measured by a digital vernier caliper, to examine the changes before and after bending process. The works of the expert and the non-expert were measured for three times each, and that of the beginner was measured for eight times in total using the self-learning program.

E. Text Analysis of Writing-Type Questionnaire

Counting the word numbers and the word classes included in the answers to the questionnaire written by the beginner for the self-learning program, we examined how his answer changed through eight times trials. For the text analysis, “KH Coder” which is a freeware for statistically analyzing text-type (sentences-type) data.

III. RESULT

A. Interview with the Expert

As the result of the interview, the following know-hows were identified: 1) in the heating process, the expert set the heating range first, and then heat the part to be bent based on the curvature angle; 2) during the transition from heating to bending step, as the important point to be focused on during the heating, the expert checked the contraction status on the tube first, especially at the boundary between the heated area and non-heated area, then moved to bending work; 3) during the bending work, the expert conducted the bending motion at the angle that is easy to visually observe the expansion of the

tube. Fig. 3 shows the whole process, and the timings where each know-how is employed.

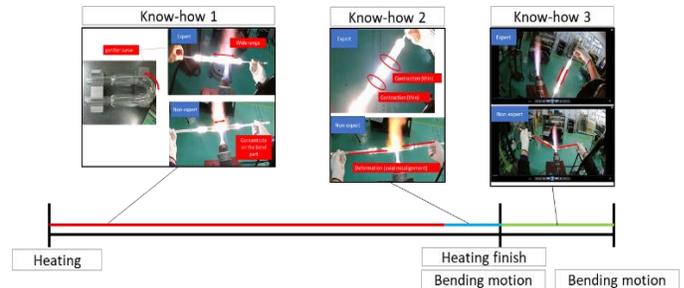


Fig. 3. The whole process and timings of the each know-hows.

B. Process Analysis

Fig. 4 shows the work time ratio between the heating step and the bending step. As can be seen from the video of the process, it was clarified that the ratio of bending work increased in the work of the non-expert compared to the expert or the beginner. Fig. 5 shows the transition in the total processing time of the beginner. In the first to the fourth time conducted before the beginner was informed of the know-how, the total processing time tended to increase. However, from the fifth and the subsequent trials after the know-how education, the processing time of the beginner tended to decrease.

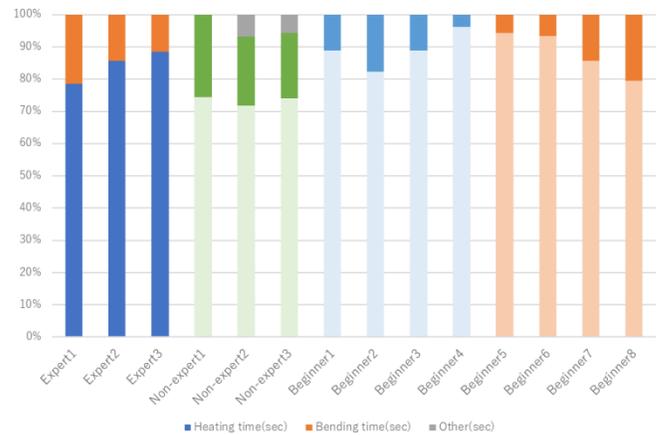


Fig. 4. Process time of heating & bending step.

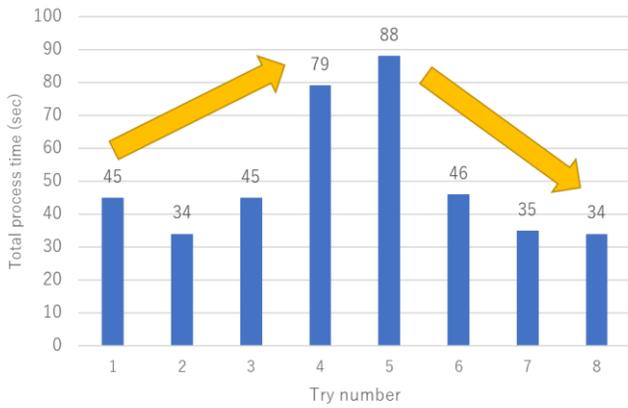


Fig. 5. The transition in the total processing time of the beginner.

C. Product Evaluation

Fig. 6 shows the picture of the bent part of each sample. Compared to the expert, the inside of the bent part done by the non-expert displayed a pleat-shaped deformation. The similar deformation can be seen in the products done by the beginner before the know-how education, but it cannot be seen in the samples produced by the beginner after the know-how education. Additionally, Fig. 7 shows the changes in the outer diameter of the bent parts. Though the beginner displayed a larger outer diameter change compared to the work done by the expert throughout the program, the change significantly decreased by the eighth time. Fig. 8 shows the correlation between the processing time and the outer diameter change. The non-expert, who did not take part in the self-learning program, showed a little change in the outer diameters, but his process time tends to increase. While the beginner, who took part in the self-learning program, displayed a tendency to shorten the processing time, even though there were large changes in the outer diameters by his seventh trial. But he finally approached to the result of the expert at the eighth trial.

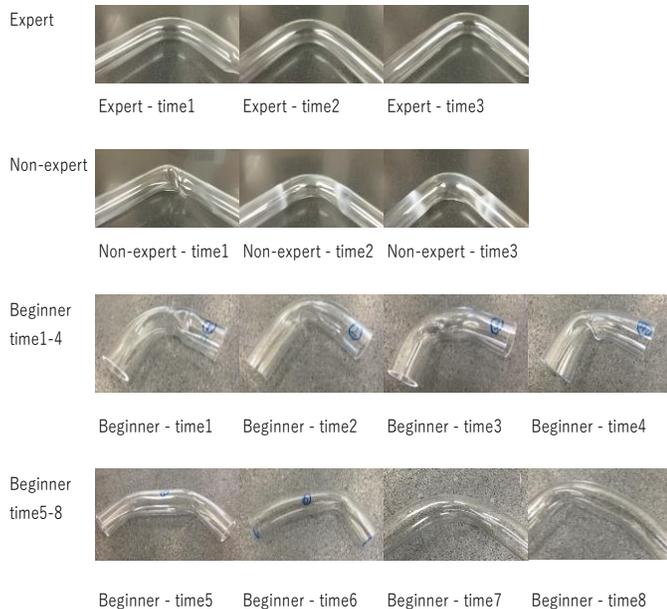


Fig. 6. The sample shapes of bent part.

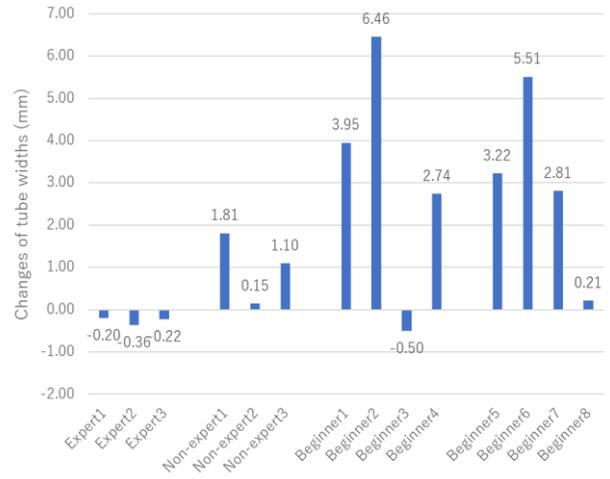


Fig. 7. The changes about the outer diameter of bent part.

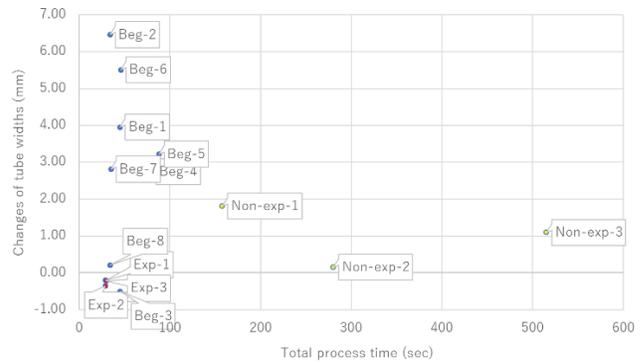


Fig. 8. The correlation between the processing time and the outer diameter change.

D. Text Analysis of Writing-Type Questionnaire

The text analysis of the questionnaire filled by the beginner during the self-learning program was conducted. The research result counting the total word number and the number of adjectives is shown in Fig. 9. The adjectives tended to increase from the fifth time through to the eighth time. Moreover, as can be seen in Fig. 10, words related to heating and to the glass joint called “ponte” were seen for the first time from the fifth to eighth trials, after the introduction of the know-how.

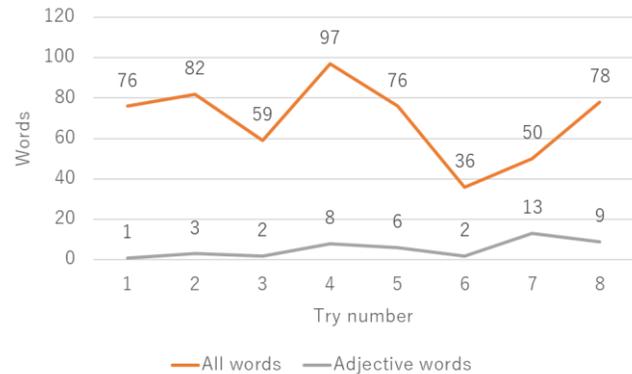


Fig. 9. The result counting the total word number and the number of adjectives.

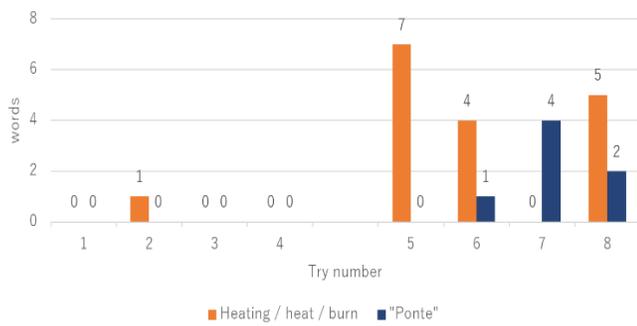


Fig. 10. Comparison of words related to heating and "Ponte".

IV. DISCUSSION

As a result of comparing the beginner who underwent the self-learning program and the non-expert who has five years of experience, a clear difference in the total processing time required for the bending work was observed. It is considered that through comparatively watching and learning from the video of this learning program, the beginner noticed that the expert formed a bent part only by one bending motion, while he noticed his motions differed from the expert through the video. However, in the early stage of the experiment, the beginner merely mimicked the movement of the expert from the video and there was absolutely no improvement in the quality of the bent parts. On the other hand, because the non-expert knew the difficulty of the bending technique that the expert employs, to complete the bending work through only one bending movement. Therefore the non-expert employed a method where he gradually bended the angle. Therefore, the forming of the bent part was better compared to that of the beginner done in the early stage, but it was inferior in the productivity due to the significant increase in the processing time.

Until the fourth time, the quality of the bent part by the beginner did not improve and it was almost entirely stagnated. During this time, there was no significant change in the comments the beginner wrote on the questionnaire and therefore it can be inferred that he could not find a solution or suitable method. The effect of being informed about the know-how of the expert at the fifth time did not appear immediately. It can be inferred that, even though the beginner knows the expert's know-how, he does not have sufficient skill to convert it to the actual work movement. In the comments the beginner wrote after the fifth time, he started to mention of the heating power of the burner, the condition of the fire and the handle part for holding the glass tube called ponte. These words are related to the skill in rotating glass tubes and the skill in heating the tubes while rotating them. Therefore, these statements suggest the sign of the beginner becoming aware of the limit of his skill while trying to achieve high-quality bending work through trial and error. The quality of the product the beginner produced at the eighth time can be considered as the state he achieved through his own skill based on the know-how of the expert. It is thought that non-expert imitates only appearance features of expert. On the other hand, the meanings of the motions are clarified by hearing on expert's know-how, and beginner who learned it has a clear the

problems and it seems that learning effect which cannot be obtained by simple imitation of experts comes out.

It is possible for viewers to get noticed by using video, and furthermore, it was shown that quality could be improved by adding expert's know-how information in this program. In addition, it is possible to get of know-how of experts by interviewing using process analysis even if the expert cannot realize his know-how. The expert's know-how is difficult to realize in the conventional method of directing experts to beginners, but this self-learning program is considered effective in that know-how is accumulated in companies and its effect can be verified.

V. CONCLUSION

In the bending work of quartz glass, we discovered our newly developed self-learning program has the potential in contributing to improve the productivity and the quality of the bending work by beginners. In the past training of the processing skill, only the video of the expert was shown to the beginners and the skill improvement after that was left to the personal effort of each beginner. In this program, the differences in movement were made easier to recognize through the comparison of the movements of beginners themselves and the movement of the expert in video. Hence a potential for passing on the short-time processing that is characteristic to the work of the expert was detected. Moreover, by asking the beginner to write down comments after each production trial, it was made it possible to visualize the thinking of the beginner toward skill improvement, and therefore, aside from the problem recognition of the beginner, enabled the educator and the supervisor to grasp the situation and provide an appropriate support. Such a self-learning program has no previous example in the training of the fire processing of quartz glass, and it is possible to develop it toward other fire processing techniques in future through this study. One can speculate on the possibilities of developing a learning program with function to synchronize the videos of the expert and the test subject in order to heighten the visual effect or with function to automatically feedback the differences from the videos. This study demonstrated the basic effect. This program is expected to be applied in future to the entirely different areas where there exist experts and beginners, such as sports or medical sites.

VI. FUTURE WORK

It is necessary to investigate the tendency when the number of subjects is increased. However, since there are very few beginners engaged in quartz glass processing, we plan to verify the effect of this program when non-experts with some experience years are taken as subjects.

In addition, it is necessary to add expert knowhow information to enhance the effectiveness of this program. There is a possibility that the glass temperature just before the expert's bending motion is higher than the beginner's. We are planning to shoot thermography video under processing. We think that learning effects of subjects can be further enhanced by subjects watching the difference in processing temperature on video.

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A Remote Sensor Network using Android Things and Cloud Computing for the Food Reserve Agency in Zambia

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Abstract—In order to introduce modern warehousing, improve upon the storage of grain and grain marketing business processes for the Food Reserve Agency in Zambia, a prototype of a remote sensor network was developed and built as a proof of concept for a much wider deployment using cloud computing and the internet of things concept. It was determined that a wireless sensor network would aid the Food Reserve Agency in analytics, timely action and real-time reporting from all its food depots spread-out throughout Zambia. Google's Android Things Platform was used in order to achieve the objectives. Advantages of Android Things over traditional platforms that have been used to develop wireless sensor networks were looked into and presented in this paper.

Keywords—Internet of things; android things; wireless sensor network (WSN); remote sensor network; Food Reserve Agency (FRA); grain marketing; modern warehousing; cloud computing

I. INTRODUCTION

Since its establishment Zambia's Food Reserve Agency (FRA) has been a key in ensuring food security for the nation. In times of severe drought, even neighbouring countries such as South Africa and Zimbabwe have procured their staple food requirement, maize, from the Food Reserve Agency. Grain marketing is a key activity of the Food Reserve Agency. The major output of the agency though still remains in ensuring that the nation at large has enough food stored up for the future. The agency has also been key in ensuring that the commodity price for especially maize is regulated so as not to burden the citizens of Zambia with overwhelming costs [1]. This key organization has been managed by the same processes and procedures since its inception in 1995.

The agency generates a lot of data and information regarding Zambia's strategic food reserves that is a key for national planning. However, the organization has been facing a lot of challenges in managing this information due to lack of automation. In 2013, the Department of Computer Science at the University of Zambia started collaborating with the agency in an effort to resolve some of the key problems through computerization of some key business processes. The outcome of this collaboration is the current research jointly funded by the National Research Foundation (NRF) of South Africa and National Science and Technological Council (NSTC) in Zambia that will be used to automate the key business

processes of Zambia's Food Reserve Agency in order to improve on its operations. The study is jointly being carried by University of Zambia in collaboration with Tshwane University of Technology in South Africa.

The agency, despite being a very important structure in Zambia has lagged behind in the adoption of ICT's. Reports are manually generated which may result in errors and delays, warehouses are not monitored in real time and specialized personnel are required in order to assess the environment at both satellite and main depots where grain is stored. The activities at the Food Reserve Agency are mostly seasonal and hence are managed with just the minimal workforce until the next season. This entails that food storage locations and supply depots have less contact hours with individuals experienced in monitoring the environment at which stock is stored. As an example, it has been clear through preliminary interviews at two of the agency's depot in the capital city Lusaka that 24 hour monitoring of the environment and farmer produce at both the central and remote warehouses is not available. A very good example is when the central warehouses are fumigated and no individual is allowed into the warehouses under any circumstances due to the toxic nature of the chemicals that are used. Further, the 2011 Auditor General's report [2] lists the following problems as concerns FRA:

- 1) Weaknesses in grain management.
- 2) Excess purchase of crops.
- 3) Excess stock losses attributed to spillages, pilferage.
- 4) Warehouse Management – Poor Stacking making hard to take stock.
- 5) Poor State of Storage Facilities – Silos.

The 2011 audit report of the Food Reserve Agency was used because there were no subsequent audits carried out. The reasons of which might be conjecture. However, interviews and physical visits corroborate the 2011 auditor general's report findings.

The problems highlighted present huge losses to both government and risk in terms of food security for the nation at large. It is presented in this paper that all the highlighted problems can be addressed using automation and ICT's [3]. It has been shown in research that the use of ICT's introduces

efficiency and accountability in agriculture [4]. For the purpose of this research, only FRA will be targeted but the solutions presented can be applied to all institutions that deal with warehousing and food storage as well. Against this background, this paper will attempt to address the challenges.

- 1) Collecting of real time environment data from FRA warehouses.
- 2) Storing the data indefinitely.
- 3) Ensuring that the stored data is well backed up.
- 4) Generating real time environment reports.

The challenges highlighted above are addressed by a low cost and easily mass-produced remote sensor network. It is believed that the government of Zambia through the Food Reserve Agency will be able to begin to better manage the grain marketing business through the use of the platform that we have developed. Cloud computing, digital sensors and an open platform are used in order to develop a generic platform that is easily scaled and applied to various environments.

II. LITERATURE REVIEW

Remote sensor networks have traditionally relied on four components, a sensor to collect the data, an aggregator to centralize the collection of data, an uplink network to relay the data and a server to which the data is to be sent, the wireless sensor network can be further broken down into two main components, the remote sensor network and the uplink. In this chapter, each of the main components that make up the implementation of the wireless sensor network using Android Things are discussed

A. Remote Sensor Network

The remote sensor network is that part of the network that is composed of the sensors which have energy sources and some kind of personal area network used for localized communication. The network may also comprise a collaboration algorithm which may determine its work mode. The three main work modes that enable collaboration in a wireless sensor network are a star network, a mesh network or a ring network. The remote sensors basically sense, process and send the data either individually or through aggregator. Each of them is indicated below;

B. Cloud Computing

With the spread of broadband internet across the globe, more emphasis has been placed on how to effectively and efficiently utilize and allocate all the available computing, processing and storage capacity available globally. A reduction in latency and increased throughput has made it possible for remote computers to be managed and applications run as though they were physically local. Resource sharing has enabled concepts such as Software as a Service, Platform as a Service and Database as a Service where the end user does not need to worry about the technical requirements of systems,

software and the technical specifications of the database but just focuses on service usage [5]. Cloud computing has made it possible for emerging companies to rollout their services at a much faster pace as the cost of datacentres is slowly becoming a non-factor with cloud based solutions such as Data Centre as a Service (DCaaS).

Cloud computing has brought about novel ideas where a computer is no longer viewed as a standalone entity but can span multiple hardware platforms and multiple geographical locations. A very good example was the so called first world computer Ethereum. The Ethereum platform relies on individual machines spread-out throughout the globe to run a client application with distributed consensus and a distributed ledger. This makes it possible for an application to be installed on the world computer and be able to run even if there was a global disaster of immense proportions. The application is able to run with just one computer that downloaded the entire Blockchain. The Blockchain is a public ledger of all transactions that ever occurred on a distributed network and is termed by many as a disruptive form of technology equivalent to the advent of the internet in the early 1990's. Blockchain technology is perhaps the de facto example of what is entailed by cloud computing as it is a classical implementation of device as a service (DaaS) and software as a service (SaaS) and Ledger as a service (LaaS).

C. Android Things

The most popular standard for the implementation of internet of things prototypes and solutions has been to use the Raspberry Pi and Arduino with various sensors. One would then have to attach GSM, WiFi or some other wireless protocol shield in order to achieve remote connection to either a distributed or a centralized server, there has been several attempts at creating sensor networks that use a mobile device for obvious reasons of taking advantage of the use of a mobile phone and that is to send and receive data [6]. Android Things aims to bridge that gap by leveraging already existing hardware platforms and development environments by installing an operating system on those capable hardware devices. That operating system called Android Things is built with an internet of things architecture at its core and therefore supports native functions and routines that make implementing a prototype or developing a solution a very easy thing to achieve. There is no requirement to write code for multiple devices such as one that serves as a master and supporting slave nodes. All nodes including sensors are controlled from one operating system. Because Android Things is a fork of the popular Android operating system that is used in various devices around the world today, its API does not differ from that of the mobile application development and every sensor is an object level abstraction in the system. The compact nature of this solution means the development and deployment time is significantly cut down. Android Things is naturally the choice for use on the proposed remote sensor network. Fig. 1 below lists the Google Android Framework and API which is also the Android Things Framework and API.

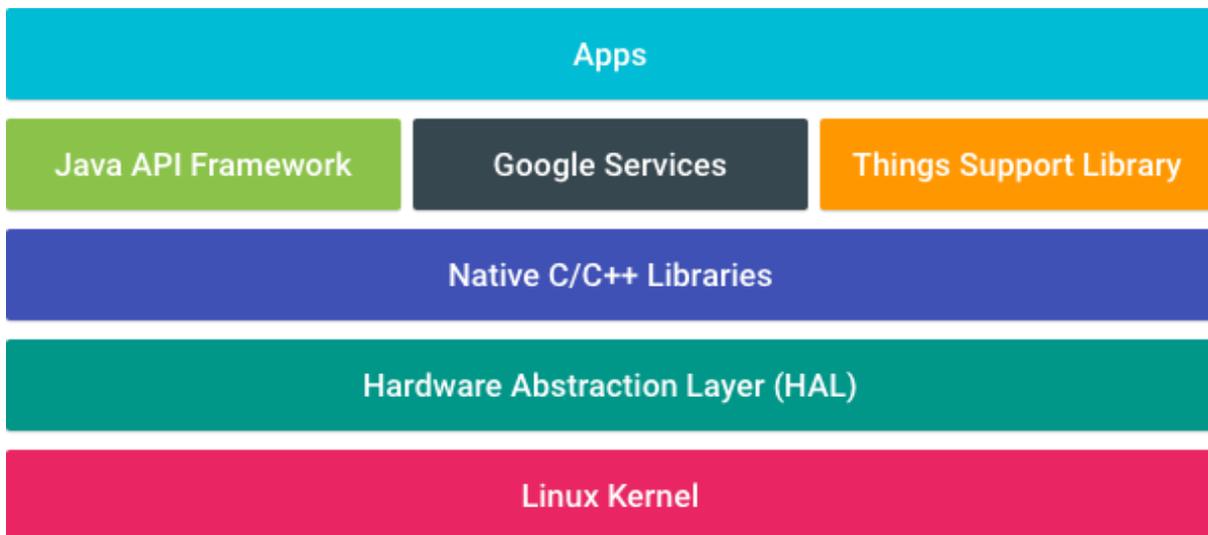


Fig. 1. Android things framework and API.

As of early 2017, about 4 devices from different manufacturers around the world support the Android Things operating system. Some of the devices include the Intel Edison, Intel Joule and the Raspberry Pi 3. While there are similarities in the framework and API to that of Google's Android, the development methods differ slightly. The Google API for Android is extended by Android Things which adds additional API's used to enable the integration of hardware devices that are not normally found on mobile phones and tablets such as smoke detectors. It is also important to note that the Android Things OS does not come with any app installed. The first app to be deployed on the platform is the app that starts-up as soon as the device is booted. This solves one major issue which is the use of system resources in remote sensor networks. It is important to make the remote sensors as lean as possible in order to conserve battery life and processing ability.

D. Mobile Queuing Telephony and Telemetry (MQTT)

MQTT stands for Message Queuing Telemetry Transport. The protocol is specifically designed for internet of things devices with low bandwidth requirements. It is a lightweight publish/subscribe protocol over TCP/IP with a level of quality of service defined and was originally created by IBM and Arcom [7]. The later company became part of Eurotech. It has since become an ISO standard with filing ISO/IEC 20922:2016. It is ideal for mobile applications because of its small size, low power usage, minimized data packets, and efficient distribution of information to one or many receivers. A specific implementation of MQTT for sensor networks is called MQTT-SN (Message Queuing Telemetry Transport for Sensor Networks).

By its nature, the Internet of Things relies on a messaging broker to relay information between various devices. The MQTT protocol is standardized by ISO under the filing ISO/IEC 20922:2016[8]. MQTT is a variation of Zigbee [9] which we discuss below.

E. Mosquitto Broker

In the typical architecture of an internet of things project,

there is the Thing which is a device connected to the internet that can be sensor or an actuator which performs an action and there is also the broker which can be a centralized or cloud based system that publishes messages to what are called topics. Each of the Things in an internet of things setup subscribes to a topic and each topic can cover a specific need or requirement such as a topic to control lights at the end of the day in a specified geographic region. The broker can publish a message to switch on lights in a specific geographic area and any switch that can be viewed as a thing that is subscribed to the switch topic will flip the switch to on. The Mosquitto Broker is an open source broker that is used in internet of things applications and was the selection for the model. The Mosquitto broker implements the mobile queuing telephony and telemetry protocol version 3.1 as of this writing. Version 3.1.1 of the broker was specifically designed with internet of things applications in mind as it implements a light weight publish/subscribe methodology.

F. Raspberry Pi and Arduino

The Raspberry Pi is a very tiny computer that is popularly used in prototype development for educational purposes. It has the standard computer architecture of read only memory (ROM), read and write memory (RAM), processor and bus. It is possible to extend the functionality of the Raspberry Pi with peripherals as it supports most of the common input interfaces from the general purpose input/output to the USB and peripheral input/output interfaces.

The Arduino is a very simple programmable open source electronic device that can interpret the Arduino Programming Language code which is similar to the Python programming language. The Arduino can also be programmed to do basic things such as read both digital and binary inputs to its circuit board. The Arduino differs from the Raspberry Pi in that it is a basic microcontroller while the Raspberry Pi is a full-fledged scaled down computer. Programs written in the Arduino Programming Language tend to be basic and loop. They are also functional in nature.

G. Zigbee

Zigbee is a low power wireless protocol operating at layer 2 of the OSI protocol stack using the IEEE 802.15.4 standard [10, p. 15]. Zigbee is primarily used in the local area network of a remote sensor network. Because of its usually limited reach as concerns the wireless signal, it is further classified into a set of wireless personal area networks (WPAN). The protocol can be used to send small payloads between a sensor and its controller. Because of its design focusing on low computational complexity, it is ideal in the deployment of sensor networks communications requirements. Zigbee will be a very important part of the proposed implementation as concerned with the one of the primary goals of achieving a power efficient implementation. Zigbee is not a standardized protocol but has reached maturity in industry. Zigbee devices can be setup and configured in three distinct modes, coordinators, routers and end devices. There can only be one coordinator in a Zigbee network and this will usually be connected to a device that has access to the backhauling network. Router devices as the name suggests, aim to forward packets or frames to the targeted device while end devices are passive and only send/receive data within the cloud setup. Zigbee data can be converted to a different protocol by the use of a Zigbee gateway which is part of the standard architecture. This protocol conversion is important in remote sensor network scenarios when sending wireless sensor network aggregated data to a remote server over a different wide area network that operates on a completely different protocol stack. A Zigbee network can be set up in multiple types of topologies namely the star, tree, mesh and clustered tree topology.

H. Products and Platforms

With respect to sensor networks, a product is defined as a tool that is used in order to build the sensor network. Various products may be used in order to achieve the goal ranging from hardware products to software products. Each of these products may have a different method of operation or rely on different software and hardware in order to get them working. For example, a wireless sensor network may be composed of a Raspberry Pi, an Arduino, a mosquito server and some communication network. Below it is defined which of these products are platforms. The broad definition of a platform is that it serves multiple groups or products or users and facilitates interactions between them. The users may be human, machines or software and each of them may be distinct, requiring individual functionality but at the same time may require exchange of data. With that broad definition, the hardware, software and other components used in a sensor network are listed and it is defined as to whether they are platforms or products by asking the following questions:

- 1) Does it serve multiple users or customers?
- 2) Does it facilitate interaction between users?

Each of the above questions is discussed below in order to show the context in which the questions were applied to determine whether an item is a product of a platform. Let us consider a practical example such as AirBnB [11]. On the question of whether it serves multiple users, the answer is yes

because it is a platform at which anybody that does not own it or does not need to know its technical workings may use its services. It also facilitates the interaction between multiple users because it brings together buyers and sellers who can then interact by exchanging goods or services for money. While looking at the current popular model used in building sensor networks, the most common devices and applications were listed in Table 1 below and those two important questions above were applied to each of them. The questions were also applied to the selected environment, Android Things. The conclusions are indicated below:

TABLE I. PRODUCTS OR PLATFORMS

Determine whether component is a product or a platform	Major components of our wireless sensor network			
	<i>Mosquito Broker</i>	<i>Raspberry Pi</i>	<i>Arduino</i>	<i>Android Things</i>
Does it serve multiple users	Y	Y	N	Y
Does it facilitate interaction between users	Y	Y	N	Y

Android things is our selected software for the development of the Food Reserve Agency's remote sensor network because it is a platform and the following benefits will be realized if a platform is used as opposed to a product or multiple products.

1) Reduced technical overhead

Platforms offer reduced technical overhead because they form a base layer that facilitates interaction between several parties without the unnecessary technical complexity such as the need for specific programming languages and development environments for each component within a system. An example for the sensor network is that one programming language may be used to communicate with all peripherals and the aggregator.

2) Scalability

Platforms can easily scale to support new features by simply designing them to be modular such as the case is in most operating systems. This way, new peripherals, sensors and devices could easily be supported by third parties because the platform by its definition serves the needs of multiple users hence it is assumed that for it to be a true platform, it must support extensibility and scalability third parties through access to the platform specific application programming interface.

III. METHODOLOGY

A baseline study was carried out in order to map out the FRA business processes and also to see whether business process reengineering could be applied and the processes automated. The baseline study was also used in order to identify whether FRA would benefit from the inclusion of ICT's in the daily business activities and what perceived benefit these would have on the organization as a whole and on the grain marketing business in Zambia.

A. Baseline Study

A baseline study was carried out between November 2015 and June 2017. Self-administered forms, interviews and observations were used in order to understand the FRA business processes. FRA also provided with the Microsoft Excel forms that were used for data capture purposes. A mix methods research methodology was employed in trying to map out the FRA business processes. A descriptive approach was also employed in order to affirm the finding from the mixed method that was initially used. It was necessary to use the two approaches because it became evident that while there were systems in place governing the daily operations of FRA, there was no documented standard and existing processes were bound to change at short notice with no log as to what necessitated the changes. The descriptive approach provided us with a broad overview of the individual business processes and how those map to each other in order to achieve the final goal of grain marketing.

B. Illustrative System Modelling

The remote sensor network was illustratively modelled in a modular approach. This was done so as to avoid restrictions on the kind and type of modules to be used. The bus connectivity of each module was not defined and was left open to interpretation.

C. Functional Prototyping

In order to prove the practical implementation of the remote sensor network using android things, two prototypes were developed. An iterative development approach was used. The first prototype transformed into the second prototype. This method was only useful to the author in order to assess practicality of the overall project as there was little contact with the technical team at FRA. It is suggested that for a third prototype, an agile development method be adopted so as to have constant input from the end user during the development life cycle.

IV. RESULTS

The baseline study was carried out and this presented the challenges faced by FRA in the current manual systems employed in grain marketing and grain storage. The baseline study determined that FRA had challenges such as manual report generation, no connectivity to remote warehouses, inability to track stock on demand, theft, spoilage of stock due to lack of environmental monitoring. The business processes for the Food Reserve Agency were also mapped out and details are presented in a paper by Cynthia Muyunda [12] and Jackson Phiri [12] who were also participating in this research. As the business process mapping and business process reengineering was already completed, those will not be focused on much in this paper. However it was recognized that further efficiencies could be employed by using an agile approach with further input from the FRA staff.

There were challenges faced in collecting the empirical data that it was hoped would ascertain whether the Food Reserve Agency would require ICT's in order to better manage the grain marketing business. Over 150 questionnaires were prepared but a poor response rate of only 41%. It was therefore decided to substantiate the data with purposive visits to the

agency's management offices and warehouses. Interviews were conducted with key staff and further insight was used to create a detailed description of the business processes which were mapped and can be seen in a paper by Cynthia Muyunda and Jackson Phiri [12]. For the purpose of this paper, we focused on creating a solution for all locations that are used to store grain before it is further transported to other locations or permanently stored until sold.

In trying to develop a low cost remote sensor network solution relying on cloud computing, the requirements and components for such a network were determined and these were sensors, aggregators, an uplink and downlink network and a cloud based storage service. The most usual method of creating a sensor network would be to connect a series of sensors to a personal area network and an aggregator that has a GSM shield. This GSM shield may support the common mobile network technologies such as GSM, 3G, LTE and most recently 5G. The GSM shield is connected to the aggregator and an operating system is used in order to communicate with the shield and upload data to a remote server. The cloud based service earlier referred to for the purposes of the prototype was a broker that is used to gather all the information from the remote sensors, the most popular open source broker being the Mosquito server. Popular devices that are used for the aggregators are the Raspberry Pi or some other device with acceptable computational power and computer architecture as there would have to be some sort of operating system installed on the aggregator. The common setup was looked at and analyzed as to know whether a low cost solution based on the common architecture could be built and whether it could be improved upon. The conclusion was that since the Android operating system supported native sensors, it could be used along with its high level API calls as the operating system of choice for the remote sensor networks aggregator. The advantages were found to be as follows:

- It already supports native mobile functionality.
- It supports native calls to supported and unsupported sensors with custom drivers.
- It can be stripped down to its most basic requirements for the sensor network.
- It works well on mobile phones hence has low power requirements.
- A device could be fabricated by removing unnecessary features such as the screen, speakers, mic, etc. in order to remain with the basic operating system functionality.
- The prototype could make use of the USB port in order to interface with devices that required serial communication.

Fig. 2 shows a very early iteration in which it was attempted to connect sensors to the mini USB port of an Android device. Here an Arduino was used as an aggregator for the sensors and the Android device as the processor and communications network interface. The sensors in the figure include a temperature/humidity sensor and a motion detector. Location sensors on the Android device were made use of in order to provide localized data.



Fig. 2. Android device with temperature, humidity and motion sensor connected via USB on-the go cable (OTG).

While still trying to develop the remote sensor network, Google announced in December 2016 that they would be releasing an operating system called Android Things that would support several common hardware platforms which are commonly used in sensor networks. This meant that our research took a turn from using Android to using Android Things. There were obvious advantages such as:

- The Android Things platform was specifically built for the internet of things:
 - Low cost
 - Low power
 - Native support for the Google Cloud Platform.
- Support for several types of commonly used sensors and the ability for a developer to create custom drivers.
- Native support for mobility functions such as GSM, 3G, LTE and WiFi.
- Support for popular prototyping devices such as the Raspberry Pi 3.

For the purposes of the development, a Raspberry Pi 3 with the following sensors and support peripherals were used:

- Temperature and humidity sensor(BME280 I squared C or Serial Peripheral Interface).

- Motion sensor(Pyroelectric (“Passive”) Infrared Sensor)
- Wearable GPS sensor
- Zigbee transceivers
- WiFi access point for communication with the Mosquitto broker.

A free version of Amazon Web service AWS was used and the Mosquitto Broker was installed on it in order to collect the sensor data. Fig. 4 below is a model of our remote sensor network setup. Fig. 3 below is our model for the remote sensor network. We have only been able to implement a network with temperature, humidity and location information as a proof of concept. With our modularized design, one could add all manner of sensors and even actuators.

For the purpose of future deployment of the entire system, we developed a model for a platform and we have previously discussed the advantage of a platform in that it can be used not only by the intended user but by any other users. Our model may be utilised as a service using the Zambian government’s national data centres for storing and processing the sensor network data. Fig. 4 shows our system model. The sensor network was previously depicted in Fig. 3. Cloud computing is proposed in our model for reasons previously discussed. The Food Reserve Agency in Zambia can leverage already existing data centres and indeed the national data centre which aims to make computing resources universally accessible to all government agencies and organizations. Our model is a layered architecture where each layer may be composed of different product types with standard application programming interfaces native to the selected product. A user may for example decide to use any manner of distributed operating system in existence or yet to be implemented. A user may also decide to use any other message broker besides our prototype selection, the Mosquitto broker. This design gives true independence as to the flavor of the products selected for deployment onto the standardized platform.

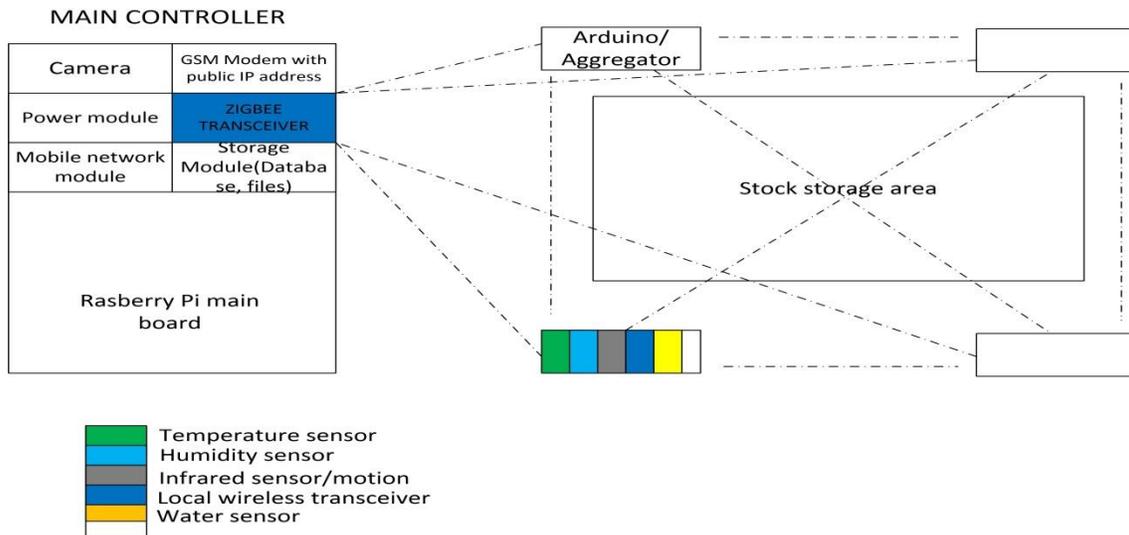


Fig. 3. Remote sensor network model.

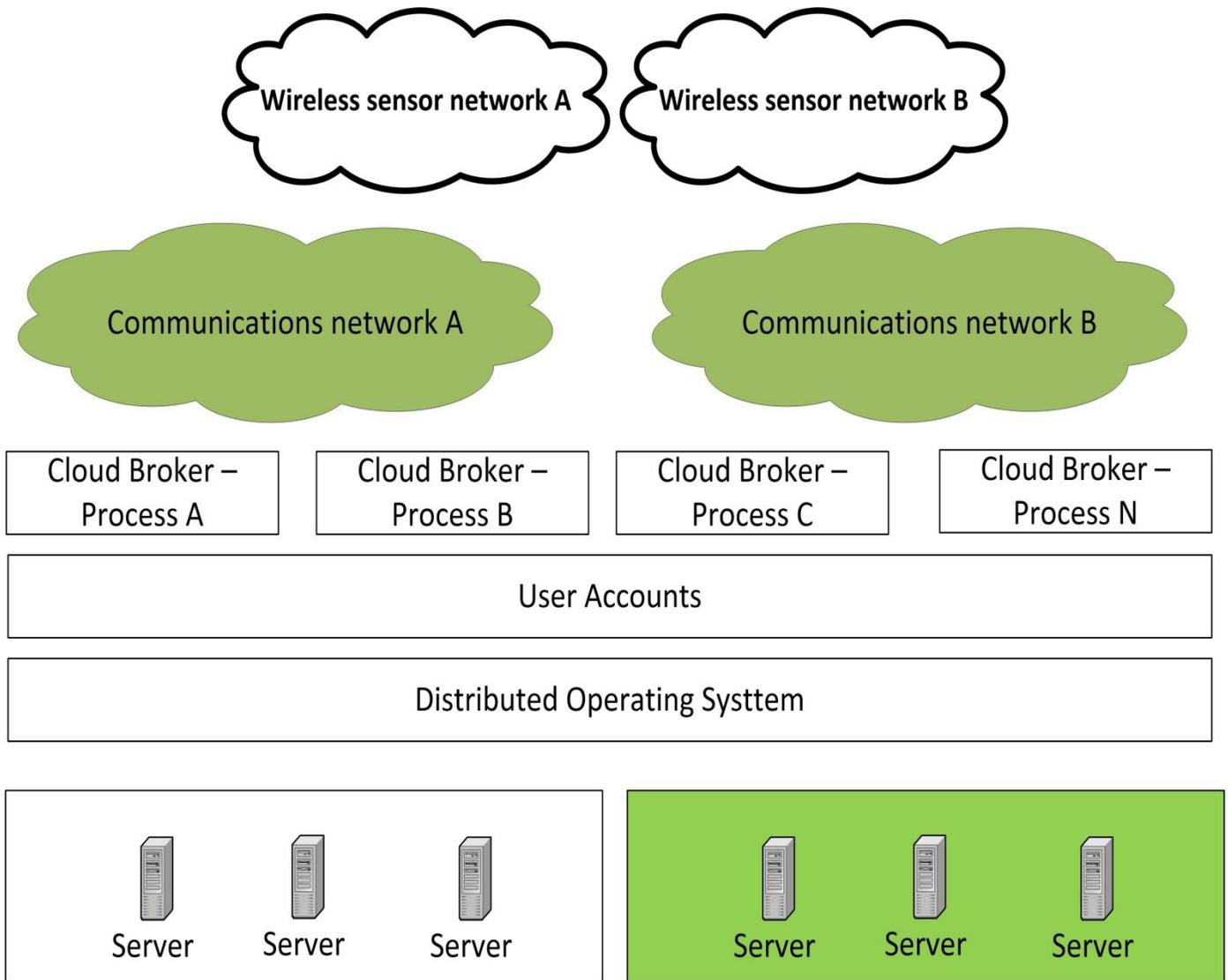


Fig. 4. FRA universal remote sensor network architecture.

V. DISCUSSION

A. Limitations of the Study

The study used what may be seen as an impractical implementation for a real world use case as it is unlikely that a government agency may decide to use services hosted by third parties on the internet such as the Amazon Web Services. Access to the government owned data centre would have provided the best prototyping implementation but the proof of concept stands to consolidate the practicality of the solution.

A proper cost analysis of the sensor network solution in mass production was not carried out. This is important in order to determine the financial implications of a mass rollout to all Food Reserve Agency depots.

B. Summary

We decided to use the Google Cloud Platform because it offers a data centre as a service. There has been a lot of research done that suggests that outsourcing of the data centre can save an organization or indeed a government a lot of

money. We also came to the conclusion that a government and its institutions may consider the use of Blockchain technology for the purpose of data storage and maintenance of ledgers. We have previously presented a conference paper to that effect “unpublished” [13]. While the Google Cloud Platform was used for the prototype, we have not assessed the financial implications of its usage in an actual mass rollout of the sensor network and we believe that because the government of Zambia has an active data centre, the issue of data storage and data processing for the model sensor network can be addressed with the current facilities. This it is suggested may be taken up as additional research work.

VI. CONCLUSION

The choice to use Google’s Android Things platform for the development of a remote sensor network is mainly due to the fact that Google has created a platform with advantages that we believe are essential towards the further development and standardization of remote sensor network architecture at both the hardware and software level. The change that we expect to

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follow is equivalent to that change that followed the smart phone ecosystem following the introduction of the Android operating system which is essentially a software platform and several third parties were able to leverage Android and communicate with other parties through a standardized development environment.

It is believed that the Android Things platform will continue to develop and evolve especially since it is open source and this will in turn lead to industry self-standardizing sensor interfaces and API for seamless development and deployment. Our developed proof of concept follows the platforms model and can easily be extended by third parties.

As for how to solve the storage of data that is generated from multiple sensors and multiple warehouses, it is believed that cloud based storage holds the key. For the prototype Google Cloud Platform was used. However, cost implications may prevent the government of Zambia from utilizing that platform. It is recommended that the national data centre of Zambia is leveraged for data storage and data processing. Since redundancy and resilience are a key factor in national data storage and indeed for the Food Reserve Agency's everyday work, it is further recommend that Blockchain technology is explored as the standard for the backend storage and data processing.

A universal model for a simple and possibly low cost remote sensor network that may be implemented by the Food Reserve Agency in Zambia was developed and through literature, it is evident that modern warehousing relying on components such as sensors provide better grain storage, management, transparency of operations and hence lead to cost effective grain marketing which leads to better national food security [13].

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Implementation of an Image Processing Algorithm on a Platform DSP Tms320c6416

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Abstract—In the context of emerging technologies, Cloud Computing (CC) was introduced as a new paradigm to host and deliver Information Technology Services. Cloud computing is a new model for delivering resources. However, there are many critical problems appeared with cloud computing, such as data privacy, security, and reliability, etc. But security is the most important between these problems. Biometric identification is a reliable and one of the easiest ways to recognize a person using extractable characteristics. In addition, a biometric application requires a fast and powerful processing systems, hence the increased use of embedded systems in biometric applications especially in image processing. Embedded systems have a wide variety and the choice of a well-designed processor is one of the most important factors that directly affect the overall performance of the system. This study highlights the performance of the Texas Instrument DSP for processing a biometric fingerprint recognition system.

Keywords—Fingerprint; biometrics; images processing; embedded systems; DSP

I. INTRODUCTION

Security is a natural human need that continues to increase as applications requiring access control are developed. In recent times, a large number of users have used Internet communication for managing different multimedia data such as health-care, e-business, social networking, intelligent transport systems. [1]

In the context of emerging technologies, Cloud Computing (CC) was introduced as a new paradigm to host and deliver Information Technology Services. In such an environment, privacy and security issues are critical areas that still require to be deeply explored. [2]

With the cloud computing technology, variety of devices are used such as PCs, laptops, smart phones, and PDAs to enable users access programs, storage, and application. Cloud computing can be viewed as a collection of services, which can be presented as a layered cloud computing architecture [3], [4].

The attack of unauthorized users to access the cloud services is the dangerous threat to authorized user as well as to the computing environment. To prevent such environment there are various techniques designed some of them are biometric and some are non-biometric [5].

The techniques of authentication can be divided into three categories: what we possess (ID card, smart card, magnetic

badge), what we know (password, PIN code) [6], [7] and what we are (this is biometric identification).

Although a growing number of work is done in studying searchable encryption, most of them can only support exact keyword search. [8]

When customer issues a query on the protected multimedia files, it is quite likely for him to specify a keyword that is a synonym of the present keyword in the encryption phase, which may cause erroneous authentication [9].

To provide secured authentication biometric authentication technique is used by author. The fingerprint image is considered as a biometric input. The mobile phone camera is used as a biometric sensor to capture fingerprint image. If the captured image match with the image stored in the database then authentication is provided to user [5].

Biometrics is the mathematical analysis of the biological characteristics of a person in order to determine his identity irrefutably. Contrary to what we know or what we possess, biometrics is based on what we are and thus avoids duplication, theft, forgetting or loss.

The characteristics used must be universal (i.e. common to all individuals), unique (to be able to differentiate two individuals) and permanent (i.e. time-invariant for each individual).

The biometric identification techniques are various: we can analyze the shape of the hand [10], the design of the iris [11], the voice, the vascularization of the retina and the shape of the face [12]. Likewise, the dynamic recognition of the signature [13], analyzed in real time (speed, pressure on the pen, etc.), but the most used technique is the fingerprint. The use of the fingerprint accounts for more than one third of the market for biometric processes. It is clearly the preferred solution for companies working in this field. The strength of this process is that the use of the fingerprint is generally easier to accept by the community and is one of the most effective and least expensive techniques.

The use of embedded biometric systems is interesting in view of the multitude of fields of application of biometric recognition which require a mobile system or a system which does not take a large place or which will be used as a biometric recognition terminal hence the importance of the use of embedded systems for data processing [14].

Among these applications, we note:

- Control of access to companies and management of staff schedules. This application is very widespread and in great demand in the market.
- The biometric passport which contains an electronic chip embedded in the passport which contains an image of the signature of the owner of this passport [15].
- The BIOCard is a smart card that allows the storage of the 10 fingerprints of the wearer. The comparison time is less than 1 second [16].

Biometric embedded systems use several technologies to give acceptable reliability and execution times. The main technology used is the DSP (Digital Signal Processor). Indeed, DSPs are processors specific to signal processing in particular images. They are characterized by an important power of mathematical calculations.^{1*}

In this article we study the performance of a DSP TMS320C6416 (Texas Instruments) by implementing a fingerprint recognition algorithm on a DSK TMS320C6416 hardware platform.

II. RELATED WORKS

Since security is a need that keeps increasing, several works have been developed; some of them present an integration between two areas in full evolution: biometrics and cloud Computing, we note for example the authors of [17] who presented the most important standards and recommendations for cloud biometrics and capitalize on the challenges the most important ones encountered during development work on biometric services. The authors [18] cited various security problems, different authentication algorithms and the most recognized security attacks in cloud computing. On the other hand in [19] authors presented and adoptable different cryptographic algorithms to improve the security of the cloud by noting the main problems encountered [3].

In [20], the authors proposed a new remote authentication protocol for network services based on the concept of sharing secrets. Three phases are illustrated in the proposed protocol, namely the initialization phase, the registration phase and the authentication phase. In [21], “a secure and blind biometric authentication protocol is proposed that addresses privacy concerns, model protection, and user trust issues”. In [22], the authors proposed a work plan that eliminates concerns about data privacy using encryption algorithms to improve cloud security from the different perspectives of cloud clients [3]. On the other hand the authors of [23] have proposed a pattern of fingerprint identification based on the cloud and preserving privacy, based on a matrix operation. In their work, the user's fingerprint data is sent to the data server. Then, the database owner encrypts all fingerprint data and outsources the database to the cloud. In the identification phase, candidate fingerprint data is first sent to the database owner for encryption. Upon receipt of the encrypted fingerprint data, the cloud performs raster operations to determine the best match

in the database. Matrix-based encryption is much faster than existing asymmetric biometric identification schemes based on encryption. The security property of this system, however, has been reviewed and found to be unsafe [24]. Therefore, the authors of [24] have proposed a security-based matrix-based biometric identification scheme called CloudBI [24]. First, they show that the database and identification requests are publicly disclosed because of the lack of randomness in encryption. Then they build a new construction for biometric identification preserving privacy. The attack model in their schema, however, does not cover opponents who are able to arbitrarily enter selected data into the database [25].

Other work has been focused on the biometric domain regardless of the type of application it will be used, and since the fingerprint is the most widely used recognition tool in biometrics, there are some examples of work representing different types of fingerprint recognition algorithms.

The authors of [26] proposed a privacy-preserving fingerprint authentication scheme based on asymmetric homomorphic encryption. In the identification phase, their schema produces all the corresponding results for a specific threshold instead of the best match between the candidate fingerprint data and that of the database. However, due to the adoption of asymmetric encryption, the identification time is considerably longer than that of the biometric identification scheme based on the matrix operation [23]. To overcome the weakness of previous privacy-preserving biometric identification schemes, the authors of [27] proposed a more efficient protocol that exploited an enhanced Euclidean distance process to increase the speed of the identification phase. Nevertheless, the method has shown a serious flaw in that users take the lead of the identification system, resulting in huge computing and communication costs on the users' side [25].

In the course of this present work we will use an algorithm that we have elaborated and validated previously since we are concentrating this time on the implementation step: a demonstration of the properties of the biometric recognition with respect to the processor and the platforms hardware which is a necessary and important passage to be able to validate practically its algorithm.

III. BIOMETRIC FINGERPRINT RECOGNITION

In order to be able to compare two fingerprints we must extract the useful information in each image: this is what is called *minutiae*.

For this purpose, a well-dedicated image processing must be carried out starting from a gray-level image until obtaining the signature vector containing the necessary and sufficient information for the authentication of the two different fingerprints.

There are several fingerprint recognition algorithms based on various image processing techniques, some algorithms such as HMFA (Histogram-Partitioning, Median-Filtering Fingerprint Recognition Algorithm) are based on Gaussian filters to minimize noise existing on the image to be processed [28]; other studies have focused on improving the comparison phase to ensure rapid authentication [29].

¹ <http://www.futura-sciences.com/tech/definitions/technologie-dsp-1839/>

The fingerprint recognition algorithm that is used to validate this study is based on the improvement of the general aspect of the captured image by performing a well-defined pre-treatment consisting of five phases as shown in Fig. 1.

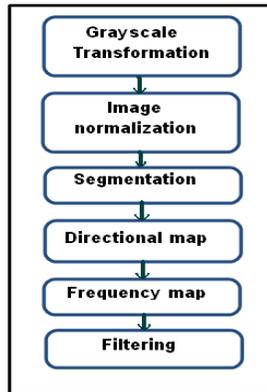


Fig. 1. Pre-processing steps.

The input of the algorithm is an RGB (Color Image) image, after the gray transformation the image becomes smaller because each pixel will be represented on 8 bits (from 0 to 255 gray levels) instead of 24 bits for the color image (RGB).

Normalization is used to standardize intensity values in an image by adjusting the range of gray levels. The structure of the image does not change and the variation of gray levels is standardized. Then the segmentation eliminates the edges of the image as well as areas too noisy.

The directional map makes it possible to specify the local direction of the constituent elements for each pixel (or pixel block) while the frequency map consists of estimating the local frequency of the elements of each pixel. Finally, we use a Gabor filter which consists on modifying the value of the pixels of an image, generally to improve its appearance.

After the preprocessing steps we can then proceed to the minutiae extraction procedure and that is, in turn, composed of five steps (Fig. 2), a minutiae extraction procedure making it possible to minimize the useful information for the comparative phase while keeping all system performances (Fig. 2).

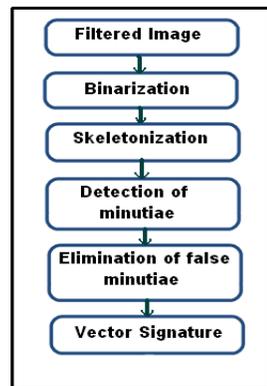


Fig. 2. Extracting signature steps.

The filtered image (which is in 256 levels of gray) is transformed into a binary image where the black pixels correspond to the streaks and the white pixels to the valleys.

Skeletonization involves reducing the thickness of the streaks to a point equal to one pixel while maintaining the connectivity of the streaks. The minutiae are extracted by examining the local neighborhood of each pixel in the image of the fingerprint using connectivity of 8 neighbors. Then a procedure for extracting false minutiae will make it possible to have at the end the true minutiae which will serve to define the vector characteristic of the fingerprint. The signature vector is a file containing information useful for the comparison of the two signatures.

IV. HARDWARE PLATFORM DSK TMS320C6416

DSK TMS320C6416 is a development platform for low cost applications and designed to quickly develop high performance applications. It is based on a DSP (Digital Signal Processor) of the Texas Instruments TMS320C64x family [30].

The C6416 DSK allows as to download and step through code quickly and uses Real Time Data Exchange (RTDX™) for improved Host and Target communications. The DSK utilities include Flash burn to program flash, Update Advisor to download tools, utilities and software and a power on self-test and diagnostic utility to ensure the DSK is operating correctly [31].

TMS320C6416 platform uses a USB connection which will later be transformed into a JTAG interface. The DSK features the C6416 DSP, a 600-MHz device delivering up to 4800 MIPS and designed to meet the needs of high-performing, memory-intensive applications, such as networking, video, imaging and most multi-channel systems. Other hardware features of the C6416 DSK board (Fig. 3) include:

- Embedded JTAG support via USB
- A high-quality 24-bit stereo codec
- Four 3.5-mm audio jacks for microphone, line in, speaker and line out
- 512 Kwords of Flash and 16 MB of SDRAM
- An expansion port connector for plug-in modules
- An on-board standard IEEE JTAG interface
- A +5-V universal power supply

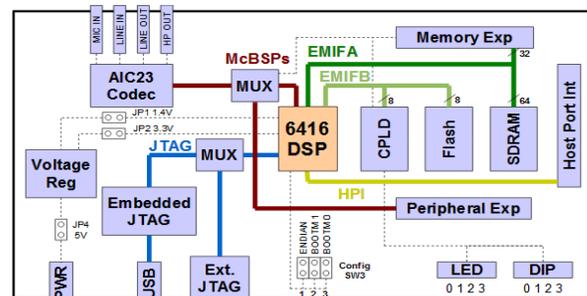


Fig. 3. Block diagram TMS320C6416 DSK.

A. Platform Architecture:

The main component, the DSP, is linked to the various peripherals surrounding it by different types of interfaces. The memory circuits are connected through an EMIF (External Memory Interface) interface. The device expansion port and audio codec are linked via a Multichannel Buffered Serial Port (MCBSP) interface. There is also an expansion port to establish a Host Port Interface (HPI).

The various interfaces are internal peripherals to the DSP. There are also 8 configuration switches to select the operating mode of the platform.

B. Platform Components

The DSP TMS320C6416 represents the core of the system. It is a member of the Texas Instruments (TI) fixed-point DSP family of CSPs that perform well. Indeed, the C6416 is designed according to the architecture *VelociTI.2™*, invented by TI, which is based on the architecture VLIW (Very Long Instruction Word).

With clock rates at 500 and 600 MHz, the C6412 DSP enables as to increase system performance while reducing overall system cost through its combination of low-price point, high-frequency performance, integrated peripherals, large on-chip memory and more channels per processor. The new C6416 DSK (part number TMDSDSK6416) provides an easy-to-use, cost-effective development tool, allowing designers to evaluate the C6412 DSP in their high-performance design [32]. Fig. 4 shows a synoptic diagram of the internal architecture of the DSP chip.

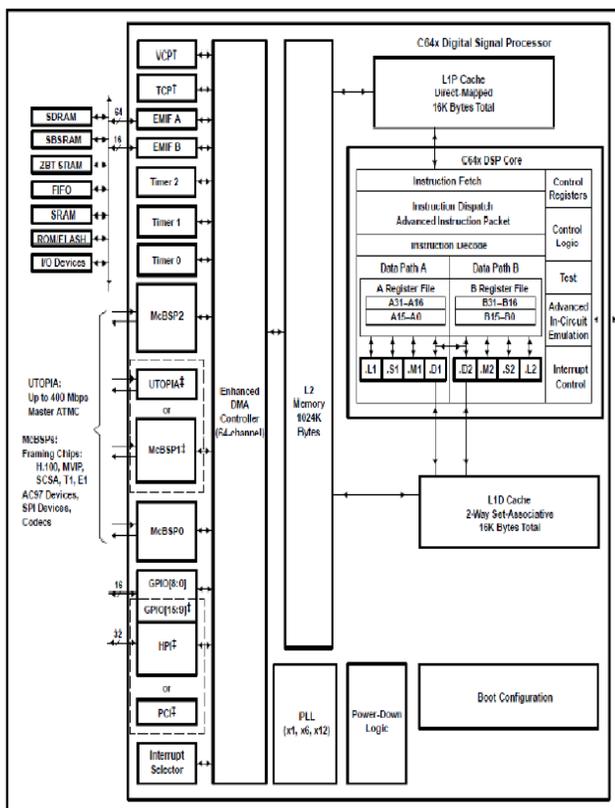


Fig. 4. Internal architecture of the DSP.

1) DSP Core:

The core of the DSP is based on the Very Large Instruction Word (VLIW) architecture, which provides eight 32-bit instructions for every clock stroke, and with a maximum frequency of 1 GHz (generated by an internal PLL). Can therefore reach 8000 MIPS (Million of Instructions Per Second).

VLIW offers the advantages of superscalar implementations without the overhead expense of instruction scheduling hardware since all instructions are scheduled at compile time.

The instructions are grouped into 256-bit packets. There are two types of packages: “fetch” packages and “execute” packages. The first type has a fixed size of 256 bits, the packets are searched from the program memory, while the second type varies in size. It contains the instructions that will be executed in parallel, linked together by a bit to 1 in the LSB (Low Significant Bit) of each instruction, the instructions are said to be chained. The presence of a 0 in the LSB of an instruction will cut the string and place the following instructions efficiently in another packet, one deduces that within an execute package the instructions are linked by 1 at the level Of the LSB.

A “fetch” packet can contain one or more “execute” packets (Fig. 5):

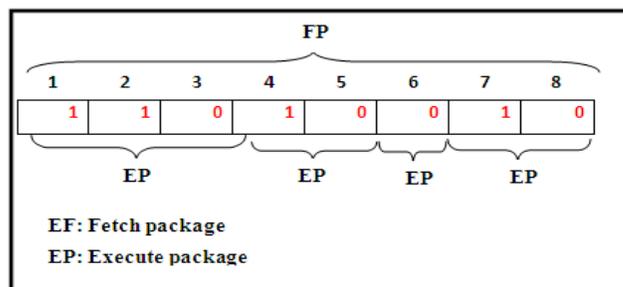


Fig. 5. Fetch package and execute package.

The DSP core contains a three-stage pipeline: “fetch”, “decode” and “execute” (Fig. 5). An execution cycle begins with the “fetch” or the search of the instruction packet from the program memory. Then, in the “decode” stage, the dispatch (DP) or the “fetch” packet is divided into “execute” packets, and for each instruction the appropriate functional unit is assigned. Each instruction is then decoded (DC). The following “fetch” packet is searched only when the “execute” packets are sent to the decoder. The implementation phase is divided into five phases. The first phase is used by any type of instruction for reading the operands (E1). The second phase is used to send addresses and data (E2). Subsequently, the data memory (E3) is accessed to be sent to the CPU (E5). Finally, the results are written in the registers (E5). These registers are 32 bits in number and 64 are divided into two parts to have two data paths A and B.

2) The Internal Memory:

The internal memory, of size 1Mo, is an important advantage of this DSP. It is a fast on-chip memory, performance approaching the cache memories.

3) Cache Memories:

The C64x uses a two-level cache-based architecture and has a powerful and diverse set of peripherals. The Level 1 program cache (L1P) is a 128-Kbit direct mapped cache and the Level 1 data cache (L1D) is a 128-Kbit 2-way set-associative cache. The Level 2 memory/cache (L2) consists of an 8-Mbit memory space that is shared between program and data space. L2 memory can be configured as mapped memory or combinations of cache (up to 256K bytes) and mapped memory.

4) External memories:

The 6416DSK platform has two types of external memory:

- **Synchronous DRAM:** The DSK uses a pair of industry standard 64 megabit SDRAMs in CE0 of EMIFA. The two devices are used in parallel to create a 64-bit wide interface. Total available memory is 16 megabytes. The DSK uses an EMIFA clock of 100MHz. The integrated SDRAM controller is started by configuring the EMIF in software. When using the SDRAM, we note that one row of the memory array must be refreshed at least every 15.6 microseconds to maintain the integrity of its contents.
- **The DSK uses a 512Kbyte external Flash as a boot option.** It is connected to CE1 of EMIFB with an 8-bit interface. Flash is a type of memory which does not lose its contents when the power is turned off. When read it looks like a simple asynchronous read-only memory (ROM). Flash can be erased in large blocks commonly referred to as sectors or pages. Once a block has been erased each word can be programmed once through a special command sequence. After than the entire block must be erased again to change the contents. The Flash requires 70ns for both reads and writes. The general settings used with the DSK use 8 cycles for both read and write strobes (80ns) to leave a little extra margin.

5) Improved DMA (EDMA):

A DMA (Direct Memory Access) is a component that allows the transfer of data blocks without the intervention of the processor; it only gives the transfer order and the addresses of the source and destination.

The EDMA (Enhanced DMA), is a peripheral that can be set up to copy data from one place to another without the CPU's intervention. The EDMA can be setup to copy data or program from a source (external/internal memory, or a serial port) to a destination (e.g. internal memory). After this transfer completes, the EDMA can "autoinitialize" itself and perform the same transfer again. It can also be reprogrammed.

6) Other components:

We can also note the following components:

- **Interface with EMIF external memories:** this is an interface between the DSP and the external memories. It is programmable and can be initialized, modified configuration, etc.

- **The Timers:** The DSP has 3 general-purpose 32-bit timers used to count events, generate pulses and interrupts, and send timing events to EDMA
- **The ports McBSP, HPI and PCI:** The Multichannel Buffered Serial Port (MCBSP) serial port operates in full-duplex mode, meaning that data can be sent and received at the same time. The number of transmission channels can be up to 128 channels. The Host Port Interface (HPI) port is a parallel port that allows a host processor (such as a PC) to directly access the memory space of the DSP CPU. The PCI (Peripheral Component Interconnect) port allows connection of the DSP with a PCI host via a "PCI master / slave bus" integrated interface.
- **Embedded coprocessors VCP (Viterbi Decoder Coprocessor) and TCP (Turbo Decoder Coprocessor):** they are designed for channel encoding / decoding. They are used to decode the AMR (Adaptive Multi Rate) channels with different rhythms and constraints. The communication between these coprocessors and the CPU is done through the EDMA.

C. Software Libraries

These libraries feature a highlight of the C6416DSK platform. They are made up of APIs (Application Programming Interface) or pre-written functions in C language (sometimes in assembler). These make it easier to handle most of the components that make up the platform.

We notice:

- The CSL library (a set of functions and macros in C language)
- The BSL library (Board Support Libraries) is intended for handling a few card devices such as flash memory, LEDs, SWITCH and audio codec.

V. IMPLEMENTATION OF THE ALGORITHM

The properties of the development platform TMS320C6416 DSK will be exploited to implement the algorithm.

A. Development Environment: Code Composer Studio

Code Composer Studio is an integrated development environment (IDE) that supports TI's Microcontroller and Embedded Processors portfolio. Code Composer Studio comprises a suite of tools used to develop and debug embedded applications (Fig. 6). It includes an optimizing C/C++ compiler, source code editor, project build environment, debugger, profiler, and many other features. The intuitive IDE provides a single user interface taking you through each step of the application development flow. Familiar tools and interfaces allow users to get started faster than ever before. Code Composer Studio combines the advantages of the Eclipse software framework with advanced embedded debug capabilities from TI resulting in a compelling feature-rich development environment for embedded developers [33].

Code Composer Studio includes the following components:

- TMS320C6000 code generation tools
- Code Composer Studio IDE (Integrated Development Environment)
- DSP / BIOS
- RTDX and Hardware Emulation

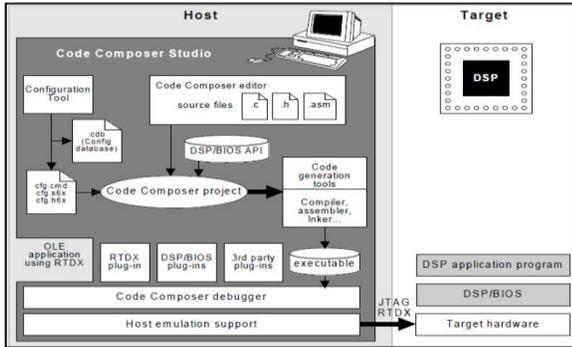


Fig. 6. Code composer studio components.

A Code Composer Studio project (Fig. 7) brings together the source files (C or assembly language), configuration files, and APIs (Application Programming Interface) from DSP / BIOS to switch to code generation tools and the compiler. These provide an executable file to load it into the target platform. Through the debugger and the RTDX tool, we can check the code line by line and view the results on the host PC without affecting the operation of the application.

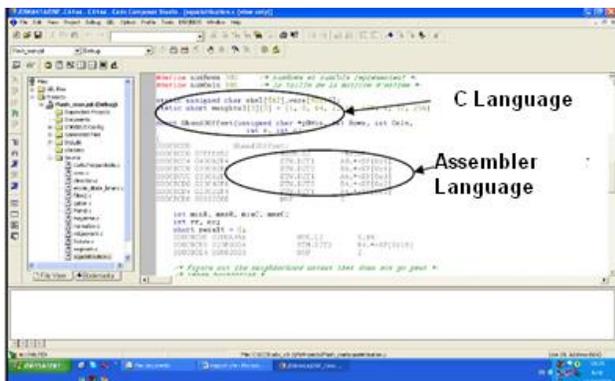


Fig. 7. Code Composer Studio project.

B. Writing to FLASH Memory

To test the functions implemented on the platform, we need test images.

Since we do not have a sensor connected to the evaluation board, we had the idea to save some images in Flash memory. For this, we took advantage of the Flash Burn tool. This allows you to specify the location in the Flash memory where you want to write the data. However, this tool only writes specific file formats (.hex, .dat, or .txt). The type of .dat files has been chosen (Fig. 8), which contains the values of the pixels of the images already transformed into gray levels in order to gain memory size.

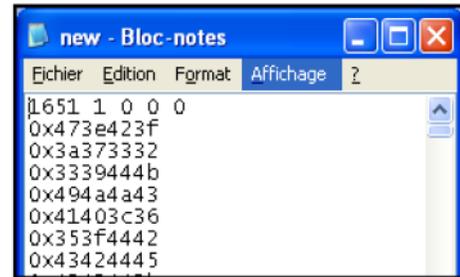


Fig. 8. Format of DAT files.

DAT files, in general, do not have a specific shape. They are raw, header-free data files. However, for this case, this type of file must have a well-defined header so that it can be read by the Flash Burn tool (Fig. 5). This header must begin with a magic number “1651”, then the format of the data (1 for hexadecimal, 2 for integers and 3 for real). Finally, the useful part can be written according to the format used. In this project, the hexadecimal format was used. During reading, the tool used reads in 4 bytes, that is to say 4 pixels at a time by storing them as they are in the memory.

Let’s take the example of Fig. 5. The number 0x473e423f contains the value of 4 pixels in hexadecimal of respective values 0x47, 0x3E, 0x42 and 0x3F.

C. Memory Allocation

Unlike the PC that has only one RAM, this platform contains two types of memory (internal and external RAM) with separate physical address ranges. On a PC, the memory management is done by the operating system, programmer C simply typing the commands of static allocation of variables (type variable_name or type table [] for the allocation of a vector) or dynamic (Malloc, calloc, realloc ...) and the operating system takes the responsibility of allocating memory areas for each variable.

For this development platform, you can use these memory allocation instructions, but you must add a command file (.cmd) and include it in the project. This file must fix the different memory sections. This operation is complex, and if you want to modify the project, you must also modify the partitioning memory.

A very practical solution is to use the Texas Instruments DSP / BIOS real-time kernel that is well suited to the architecture of the DSP used.

DSP/BIOS™ kernel is a scalable real-time multi-tasking kernel, designed specifically for the TMS320C6000™, TMS320C55x™, and TMS320C28x™ DSP platforms. Together with its associated networking, microprocessor-DSP communications, and driver modules, DSP/BIOS kernel provides a solid foundation for even the most sophisticated DSP applications. DSP/BIOS kernel is also one of the world’s mostly widely used real-time operating systems.

The advantage of this kernel is that it provides standardized APIs across C6000™, C55x™ and C28x™ DSP platforms to support rapid application migration and is also optimized to run on the DSP cores (Fig. 9).

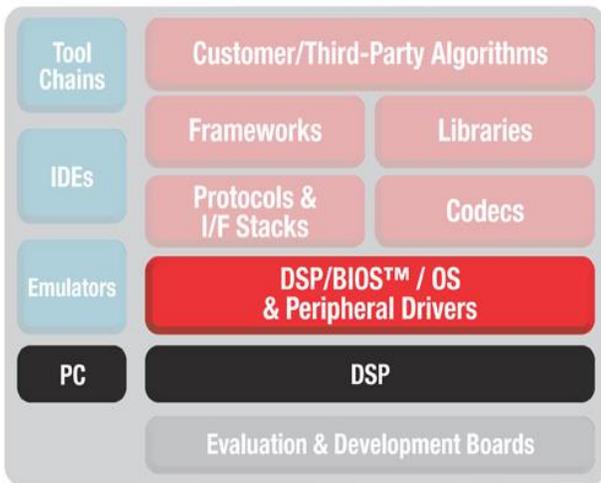


Fig. 9. DSP BIOS kernel.

DSP/BIOS kernel is available both standalone and as an integral part of the Code Composer Studio™ Interactive Development Environment (IDE) and includes graphical Kernel Object Viewer and Real-Time Analysis tools specifically focused on debugging and tuning multitasking applications.

D. Memory Access Problem

An image processing application requires a large data size. Now the fast internal memory cannot contain all the data, so one must then use the external memory which is of sufficient size. Similarly, for this type of applications, there are also a large number of accesses to the external memory. However, with a CPU that can operate up to a frequency of 1 GHz and an external memory of 125 MHz, the large difference is noticeable, in this case the CPU remains in seven waiting cycles at each memory access.

Therefore, to process on a 300 × 300 or 90 000 pixel image, a number of 7 × 90 000 = 630 000 lost clock cycles is lost, which gives 630 μsec that represents a great loss and degrades performance considerably.

1) Use of the EDMA

A first idea is the use of EDMA (Enhanced Direct Memory Access) since it does not require the intervention of the CPU only to launch the transfer that takes place in the background.

We know that the internal memory is a fast memory. It was therefore thought to use the EDMA to bring the data to be used from the external memory to the internal memory, to process them and then to return those to their original place while using fixed size memory areas as a kind of buffer.

Example of using the EDMA: How do we setup the six EDMA parameters registers to transfer 4 byte-wide elements from loc_8 to myDest? (Fig. 10)

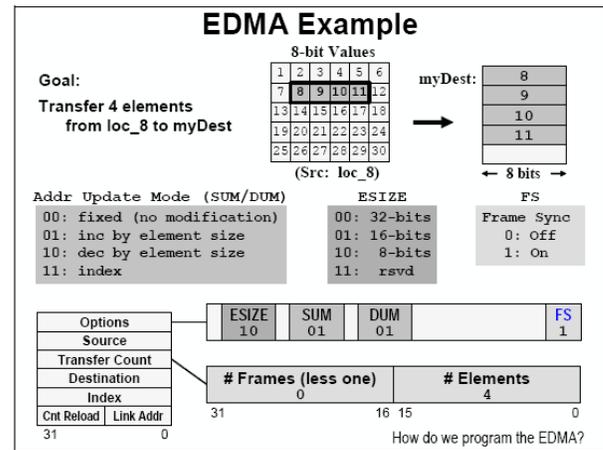


Fig. 10. EDMA example.

- Looking at the EDMA parameters we register at a time
- ESIZE should be self-explanatory based on our previous definitions.
- SUM and DUM fields indicate how the source and destination addresses are to be modified between elements and writes.
- Frame Sync (FS) indicates how much data should be moved whenever the EDMA is triggered to run.
- Source should have the source address of loc_8.
- Transfer counter will have the value 4. Actually it is 0x00000004.

It has been found that this solution is presents some problems such as the management of the order of transfer of the vectors (it is only possible to make one transfer at a time) and if there is a processing which requires a size of Which is greater than the size of the internal memory, then it is necessary to use the SDRAM memory. Moreover, on the performance side, we did not notice a big change concerning the execution time.

We then thought about the activation of the second cache level.

2) Using the cache memory

Why using the cache?

In order to understand why the C6000 family of DSP uses cache, let's consider a common problem. Take, for example, event where a lot of people want to get to one place at the same time (Sporting event, symphony...etc.) so how we can handle parking? We can only have so many parking spots close to the event (Fig. 11). Since there are only so many of them, they demand a high price. They offer close, fast access to the event, but they are expensive and limited. (This is the case of the fast internal memory of the DSP). The other option is the parking garage. It has plenty of spaces and it's not very expensive, but it is a ten minute walk and so you be late (this is the case of the external memory of the DSP).

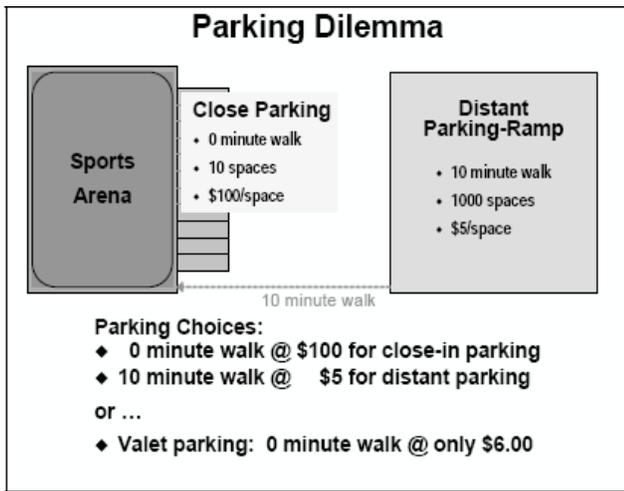


Fig. 11. Example without using cache.

So what is the solution? We must have a valet service which gives the same access as the close parking for just a little more cost than the parking garage. So we can be on time without spending a lot of money: this is the case of cache memory in the DSP.

Cache is the valet service of DSPs. Memory that is close to the processor and fast can only be so big. We can attach plenty of external memory but it is slower. Cache helps solve this problem by keeping what we need close to the processor (Fig. 12). It makes the close parking spaces look like the big parking garage around the corner.

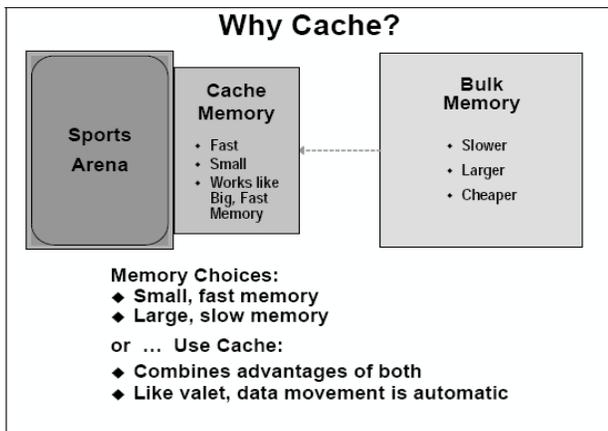


Fig. 12. Example with cache.

One of the often overlooked advantages of cache is that it is automatic. Data that is represented by the CPU is moved automatically from slower memories to faster memories where it can be accessed quickly.

The cache feature of the C6000 allows us to store code automatically in large off-chip memories, while executing code loops from fast on-chip memory (Fig. 13). That is, the cache moves burden of memory management from the designer to the cache controller which is built into the device.

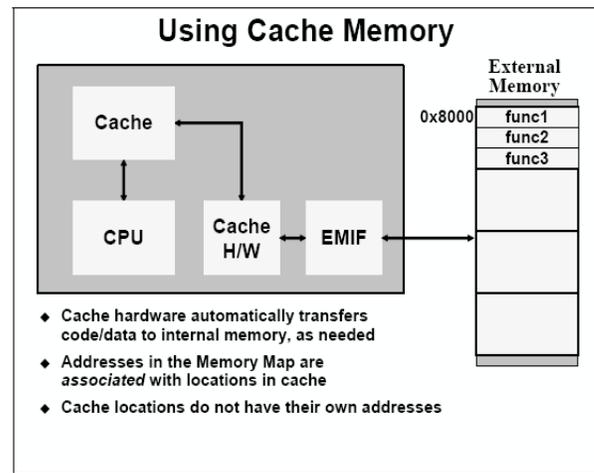


Fig. 13. Using cache memory for C6000 DSP.

Notice that cache, unlike the normal memory, does not have an address. The instructions that are stored in cache are associated with addresses in the memory map.²

Application to the Hardware Platform

The hardware platform used makes good use of this concept. It has two caches level L1: one data (L1D) and one program (L1P). A portion of the internal RAM can be configured as an L2 cache memory (Fig. 14).

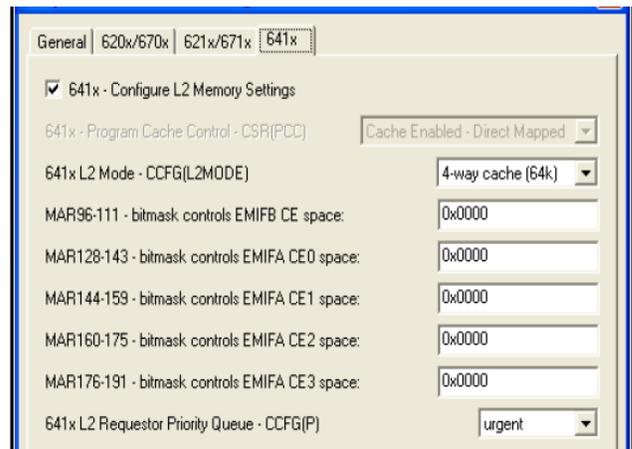


Fig. 14. Configuring the L2 level of cache.

Activation of the L2 cache level can be done through the DSP / BIOS configuration interface. This architecture will be very interesting in this project, because the image processing requires a lot of loops and access to the external memory, and especially for the convolution operation.

VI. RESULT AND DISCUSSION

In order to evaluate performance, we note the execution times of the different pre-processing (Table 1) and minutiae extraction (Table 2) functions.

² https://e2e.ti.com/cfs-file/_key/communityserver-discussions-components-files/115/iw6000_5F00_workshop.pdf

TABLE I. PRE-PROCESSING RUN TIMES

Function	Estimated execution time
Standardization & Segmentation	54.12 ms
Directional Map	314.22 ms
Frequency map	89.71 ms
Gabor Filtering	1215.8 ms

TABLE II. EXECUTION TIMES FOR BIOMETRIC DATA EXTRACTION FUNCTIONS

Function	Estimated execution time
Binarization	0.47 ms
Skeletonization	62.7 ms
Detection of Minutiae	0.98 ms
Elimination of false minutiae	0.72 ms
Comparing Two Signatures	804.06 ms

The total execution time will be the sum of the different times obtained. The total time is equal to **2.54278 s.**

Interpretation:

We note that the function that took most of the execution time is the Gabor filtering. Indeed, the operation of this filter rests on a large number of convolutions of blocks of larger or smaller sizes. This explains the value obtained. We can also, to better highlight the results obtained, make a comparison with other processor, note for example the work [35] where the authors have carried out an implementation on an FPGA of the two interesting steps of the fingerprint recognition algorithm which are the binarization and the skeletonization (thinning), the following table represents a comparison of the results of implementation (Table 3):

TABLE III. COMPARAISON BETWEEN FPGA AND DSP

Platform	Binarization	Skeletonization
Matlab	14.762 ms	80.40 ms
FPGA	1.489 ms	7.673 ms
DSP	0.47 ms	62.7 ms

We note that the processor used have good performance compared to the FPGA since it is a dedicated processor for signal processing so it is the most suitable for this type of treatment.

VII. CONCLUSION

The use of fingerprinting is nowadays one of the most reliable technologies on the market to authenticate an individual. This technology is simple to use and quick to implement.

On the other hand, the increased evolution of the embedded systems allows the improvement of the execution time and the reliability of the system.

The image processing, since it presents a significant number of morphological operations and mathematical iterations, requires a dedicated processor.

The platform used, despite having limited memory resources, remains adequate for this type of processing and gives good performance compared to an ordinary computer.

To be able to solve the problem of memory access and at the same time improve DSP processing advantages, our future work will be focused on the study of mixed platforms integrating several types of processors, we can so implement the parts of the algorithms differently (one part on FPGA and another part on DSP for example).

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Efficient Node Monitoring Mechanism in WSN using Contikimac Protocol

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Abstract—Wireless Sensor Network is monitored with ContikiMAC Cooja flavor to diagnose the energy utilization ratio by nodes and the fault detection process in distributed approach; adopted the Low power Listening (LPL) mechanism with ContikiMAC to prolong the network's lifetime. LPL locate the root cause of communication issue, get rid of the interruption problems, and get back normal communication state. The LPL mechanism reduces the energy utilization in centralized and distribute approaches. Even more, the distributed approach is best suited for network monitoring when energy utilization is main objective in the presence of LPL. It is also important how soon the faulty node can be detected. In this case, latency has vital contributions in monitoring mechanism and latency is achieved by developing the efficient faulty node detection methodology.

Keywords—Wireless sensor networks; low power listening; ContikiMAC; Cooja

I. INTRODUCTION

At large scale the human centered appliances are advanced by the remote sensing technology. In-order to provide the accurate judgment, at specific places where human presence is not possible WSN provides the diversity in communication. In Various situations, & scenarios the WSN are deployed whether for indoor & outdoor usage, low and high span of environmental vigilance, the health monitoring.

Usually indoor appliances are deployed on small area. Target is to measure the sensing variables and transmit to the sink, a device received the data packets provided by nodes from different locations and sink act as a gateways for providing the access to the Internet and might add some functionalities such as data caching [1]. WSN always have a variety of limited resources like communication bandwidth, memory, reckoning capability & energy etc. The major task is to provide the communication link which is said to be as the "Not a every bodys' cup of tea". Due to environmental effect and the quality factor of the sensors it is essential to maintain the sensor network efficiently to work properly. Nodes and links' status is required to be probed regularly and the critical

faults should be detected within a bounded time period to provide appropriate countermeasures and prevent unexpected consequences due to network dysfunctions [2]. For this purpose various type of node information e.g. residual energy and packet transmission succession rate, are required to evaluate the network health. In-order to keep a close eye on network performance, the network frequency probing and the parameter monitoring is the important point. By utilizing existing information leads to the fault occurrences without generating extra packets is also crucial in monitoring environment.

The work is going on to design the intelligent network routing protocol for WSN. Routing provides the best suited pathway to carry the data and much expertise are required to accrue the best routing phenomenon that prolongs the network life. WSN is categorized according to its applications and requirements; hence protocol choice depends on demand of the application. Medium Access Control (MAC) protocol has great role in data routing, as it maintain the structure of routing table that grant access to different sensor nodes to use the channel and medium [3]. The choice of exact and proper MAC protocol is not easy in some cases because every application have different scenarios and models. MAC is responsible to render the best medium capacity and get rid of collision. In real world deployment, energy efficient MAC protocols lead to a great difference in forms of nodes power utilization. Energy efficient MAC protocols were introduced to WSNs area with the aim to decrease the waste of node's energy in idle listening state which increase the network's lifetime and this mechanism is known as sleep wake system [4]. In some books it is also referred as Duty Cycling mechanisms and commonly classified as synchronous and asynchronous schemes.

Several MAC duty cycle protocols have been proposed during the last decade to address specific WSNs requirements and constraints such as a low energy consumption linked to battery operated nodes one of them is a Radio Duty Cycle (RDC) MAC protocol which try to reduce the energy consumption by allowing a node to keep its radio-transceiver

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off most of the time [5]. This allow a node to avoid to keep the radio on unnecessarily i.e. when not involved in any transmission Idle listening is used to solve such problem in which RDC MAC forces node to switch its transceiver between short active(listen) periods and long inactive (sleep) periods. Similar to it around the neighbors, packet transmission is listened by using the periodical wake ups in ContikiMAC protocols as it behaves as radio duty cycling protocol. It works in such a way that If at the time of wake up interval, received the packet transmission, the receiver remain in active state and if the packet is received it send the acknowledgement [6].

In order to send the packet, sender sends packet time after time till it receives the acknowledgment by the receiver that sent a broadcast, is not the form of output in link layer ACK. Rather, sender sends packet, time after time all along full active wake up period, that every neighbour accepted it [7]. Fig. 1 below shows the connection mechanism of ContikiMAC protocol.

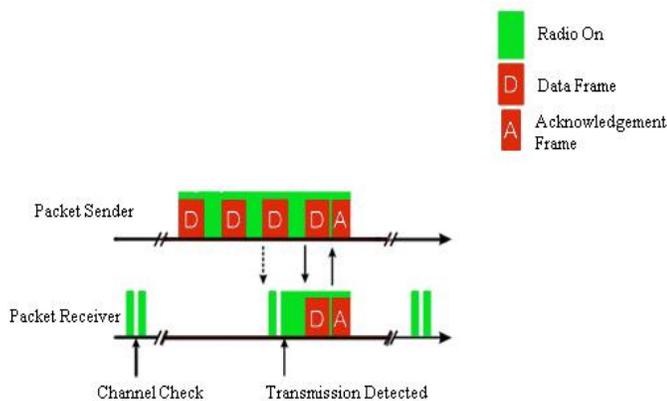


Fig. 1. ContikiMAC operation mechanism.

The power efficacious wake up system of ContikiMAC demands the smooth timing among the transmission. The node's sleep-wake mechanism is carried out by the two well know techniques the Low Power Listening (LPL) and Low Power Probing (LPP) used for asynchronous process. To understand the WSN monitoring mechanism, consider the bunch of various activities launched by the sensor nodes to look after the actions of their next door friends' node, known as monitored nodes [8]. The target is to just odd man out the unusual activities in network regarding the nodes' behavior, as if there is any non-cooperative node; also, the availability of battery timing, sensing board issue, adjustability of sensor nodes and the wireless communication link quality including high collision rates, jamming attacks, etc. All these challenges are based on WSNs' characteristics. The monitoring targets are the intended and non-harmonious node.

To propose the WSN monitoring mechanism a framework is suggested to pattern the MAC protocol. The idea is rest on a heartbeat mechanism to detect node failures in both centralized and distributed scheme. The LPL is used to represent energy efficient MAC protocols instead of the higher overhead, difficult to implement synchronous methods. They took the help from ContikiMAC protocol based on the LPL

mechanism. The suggested mechanism focuses on energy utilization & the detection factors.

The remaining sections are arranged as, Section II possessed the related work, and implementation is given in Section III, while Section IV is highlighted with performance judgment. Finally, Sections V and VI possessed the conclusion and future work, respectively.

II. RELATED WORK

Node behaves, as the self-organizing pillars of the WSNs. The task of monitoring is accomplished by the mutual cooperation of the nodes in WSN. Layered clustering of network structure is used when the size of network is broader [8]. Basically network fault monitoring system of WSN is composed on four layers as given below:

1. Application development layer
2. Data manager layer
3. Network layer
4. Fundamental layer

Starting from bottom the foundation layer is considered as core of the sensor node, containing the hardware & software of every sensor like perception gear, memory & embedded processor, communication gears, embedded O.S and specially designed database architecture. This layer is responsible of detecting sensing nodes, capturing of objects data and send it to relevant instance. The 2nd network layer, the core layer of the network, conceive sensor node and data capture technique, provides communication among diversity of sensing broader collaborative tasks. It supports the hand shaking mechanism in the network & provides the pace for resources like hardware & software. Core of the data management and processing of sensor is performed by the 3rd layer as Data Manager Layer. Keep records of sensory data; manage the storage structure, retrieval of data, analysis and mining, query support. The last top and upper most layers provides the support for software development tools as its name depict the application development layer so it supports to rest of the layer to provide the development environment for different applications of WSN [9].

In classical, network monitoring system is divided into two approaches, first one is the centralized, where sink node of the WSN receives the node information of all aspects, the centralized decision making system closely decided whether fault is reported or not, hence this approach determine the root-cause of faults using a decision tree. Although it is much better mechanism but it has some drawbacks like in the case of getting heavy amount of data. Second approach is distributed, where sink do not receive information from all nodes but nodes by themselves have responsibility to monitor the system in order to achieve more energy efficiency [10].

It is a major hardline for WSN to make sure the smooth & low tariff communication link between node to node with balanced data delivery. The uneven load distribution disturb the network lifetime across the network. Nodes located near to the sink suffer with high energy deficiency rather than the nodes away from the sink. Network may goes down for undefined period due to the unavailability of the communication link with sink. The network demands the

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unbroken connectivity and small delay may be accepted. For long periods the nodes can't be sleep time to time and they must be alive for unaltered functionality. All this can be achieved by the unique MAC protocols that save the nodes energy and fixed the workload for each node in the network. One of the best approaches to reduce the node energy consumption by scheduling the node's radio state on and off is the Duty Cycling mechanism [11].

The goal is to make nodes operate in low duty cycles, spending most of their time sleeping and waking up only when engaging in packet transmissions, to diminish energy waste in idle listening and overhearing conditions. Up to 50% unnecessary power consumption can be reduce by turning off the nodes' radio, during the off duty interval of the nodes. There are two approaches of MAC duty cycling mechanism, the synchronous & asynchronous. The sleep and wake up time schedule of the nodes are created by the Synchronous approach while transmitter initiated & receiver initiated are the further division of the Asynchronous approach [12]. The regular transmission packets with short preamble data packets themselves are sent by the node in transmitter initiated approach, in expectation any of them collide with listening time of the destination node. While frequent packets requests are sent by the node in receiver initiated approach with acknowledgment to notify the neighboring nodes regarding expedition of node to gain the packets. The complexity of global time synchronization can be reduced by employing the schemes which nodes only agree on a local common clock within neighbors and use asynchronous methods as inter-cluster communication [13]. In asynchronous approach, among nodes, the communication is carried out due to Low Power Listening Protocol (LPL), to such a degree vanish the overhead for time synchronization. In designing of energy efficient MAC protocol, the attributes of the LPL are greatly explored because LPL possessed the common mechanism. Time to time node in LPL look for receive checks and if it do not detect any channel activity it put off its radio. During channel busy period, node remains in active state to accept the packets. This technique is highly susceptible to false wakeups, especially in noisy environment, Noise may causes to triggered the false wakeup and node do not receive any incoming packet but due to the false triggered it may receive unusual duplicate unreal packets [14].

The ContikiMAC protocol improves sleep wake mechanisms, nodes used by ContikiMAC, periodically wake up to sense radio activity on the channel using Clear Channel Assessment (CCA) mechanism. Unicast transmission is done by having the sender keep transmitting the same packet until it receives an ACK from the intended receiver. The maximum time of repeating transmission is the full wake-up interval which has been proven that the packet reception is guaranteed if the sender sends packets throughout this interval. In the case of broadcast transmission, there is no ACK mechanism, thus the sender must send packets continuously for the full wake-up interval [15]. The ContikiMAC fast sleep optimization scenario is given in Fig. 2. Before the time t_i , if silence period do not detected, receiving node turn towards sleep mode, and if such silence interval is longer than t_i , then receiving node remain to a sound sleep, the receiving node travel back to

sleep mode if no packet is received after the silence interval, though radio activity is alive [16].

According to the author in [17], the energy level is checked by each node itself and forwards the message to central object if the state change is occurred. On the other side the author [18] developed a tool to detect the fault. The scheme Based on sink that utilized the message spreading technique to choose the event related data & present states of the network.

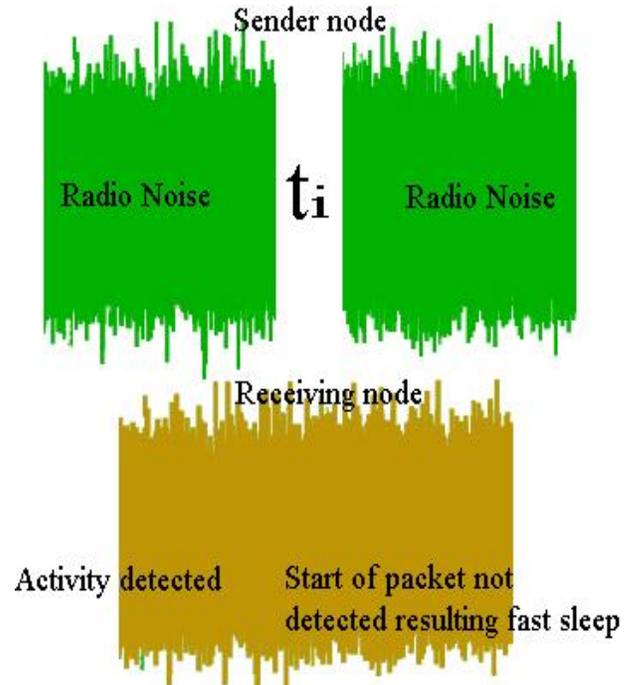


Fig. 2. ContikiMAC's duty cycling process.

According to the distributed approach, it is decided locally to detect the fault, for that only few messages are enough to transmit towards central object. While another author in [19] worked on two phase self-monitoring mechanism (TP) which highlights the node self-health monitoring system by this individual node can monitor its own health and the neighbors node health too, upon the state report it explore the local fault detection mechanism.

III. IMPLEMENTATION

Taking the help from Contiki OS, possessed the LPL based medium access control mechanism. In-order to monitor the network performance proceeds to judge the results of network monitoring with and without LPL implementation. Centralized and distributed approaches are considered to check the impact of LPL on the performance of the network. The system is composed of heartbeat messages mechanism which is a general and well known network monitoring approach, as node periodically sends packets to its monitoring node which could be the powerful sink or any node in the network. Every node sends the heartbeat messages to the sink after every second in the centralized monitoring scheme. Packet collision is avoided by adding the small amount of delay time before transmitting the message. The process is explained in below Fig. 3.

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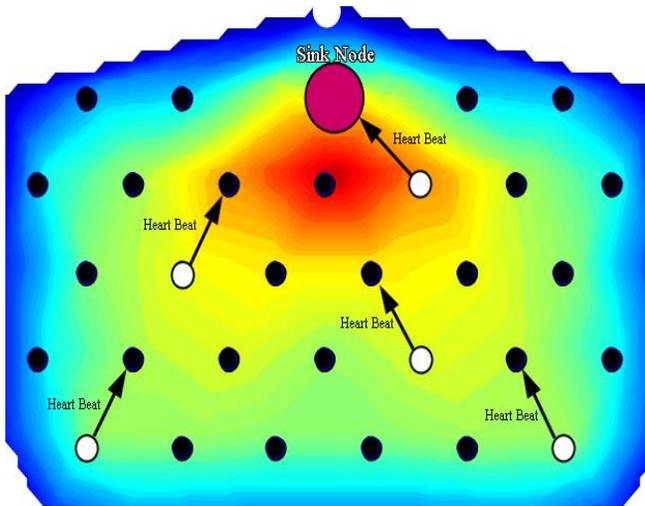


Fig. 3. Heartbeat message mechanism in centralized approach.

As sink receive the heartbeat signal & send the acknowledgment signal to the sending node, resulting the sending node shall be referred as active node and its monitoring session shall be started. If the time difference between nodes current time and nodes recent timestamp is greater than the monitoring interval then node shall be considered as in idle state. Hence sink shall monitor all nodes and share the status with monitoring administrator.

While in distributed approach the case is change, any node can take the responsibility of monitoring, not the all node. Every node just broadcast to its neighboring one. It is just like a tree fashion the credentials of monitoring node is embedded in the message by which the child node to be known. When a monitoring node starts monitoring a new node, it will transmit a message to inform the sink. The sink assumes that all nodes are currently active unless there is a report of node's inactive status as illustrated in below Fig. 4. While rest of the process is as it is like in centralized approach.

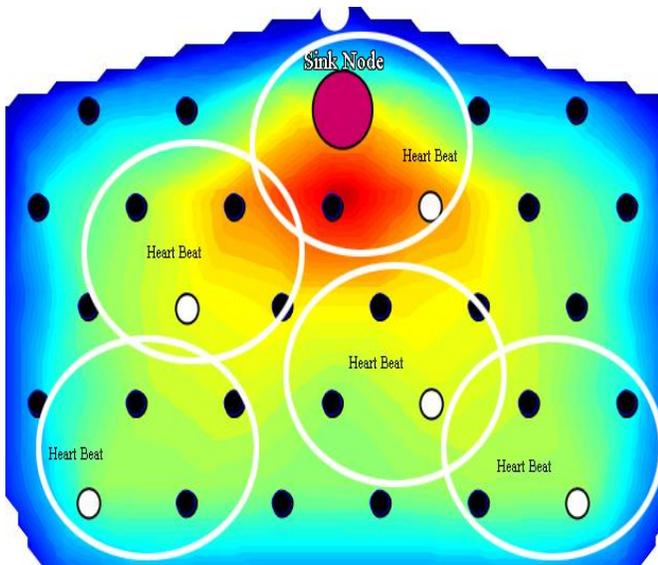


Fig. 4. Heartbeat message mechanism in distributed approach.

Considered the parent node as sink or monitoring node, the whole phenomenon is managed by routing algorithm but if the parent is going to be change the previous monitoring node will automatically stop the monitoring process after receiving a heartbeat containing a different node address from its child node in order to prevent false alarms.

IV. PERFORMANCE JUDGMENT

The network performance has been evaluated on Contiki's Cooja simulation. Contiki is a Linux, Ubuntu based O.S for the Internet of Things.

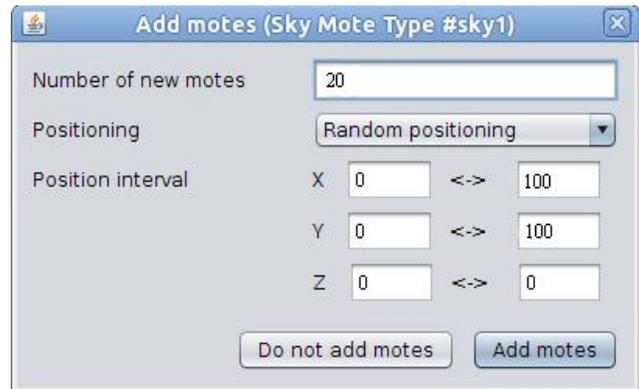


Fig. 5. Addition of number of nodes in Contiki Cooja.

It works as virtual machine that is bound with VMWare player, whereas Cooja is a Contiki Java based discrete event simulator. The sensor nodes are represented by the Motes. It is used to inspect the network behavior, very fast and support the longer networks.

The simulation began by entering the parameters values. Added the 20 number of nodes including the sink in the form of motes in Cooja is shown in Fig. 5 above. The random positioning has been chosen whereas position intervals are set as 100 for x and y while z coordinate is 0. While in Fig. 6 the number of nodes are flowed out in random position.

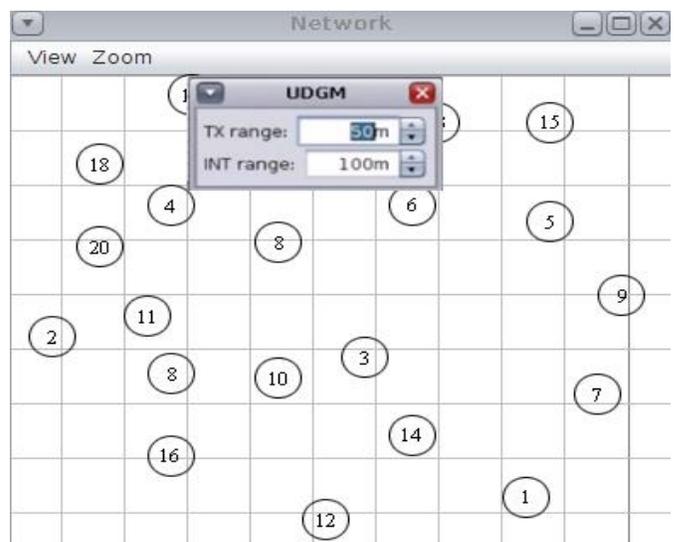


Fig. 6. Nodes distribution in random fashion.

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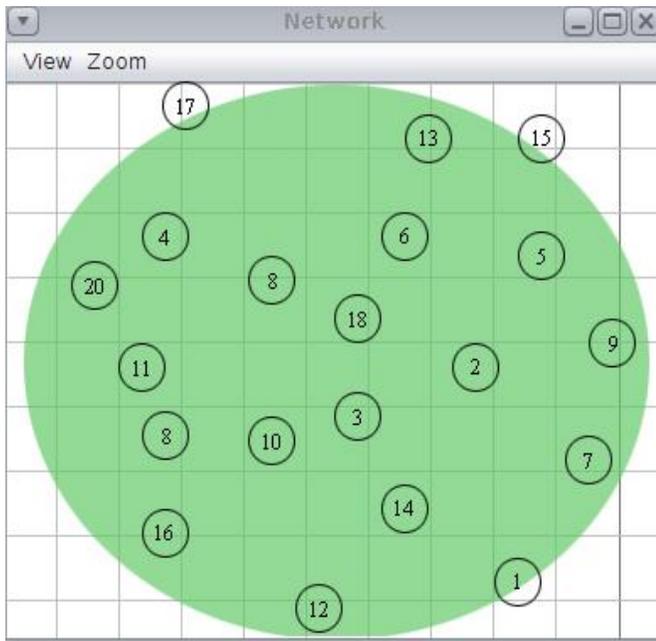
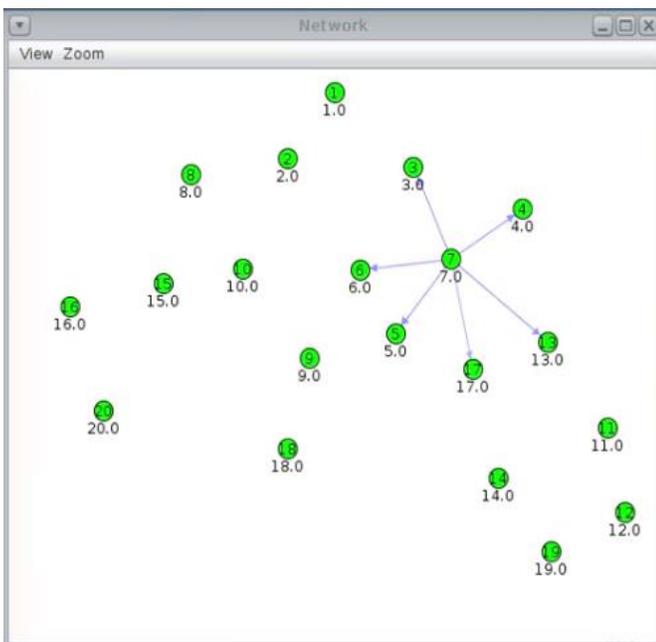


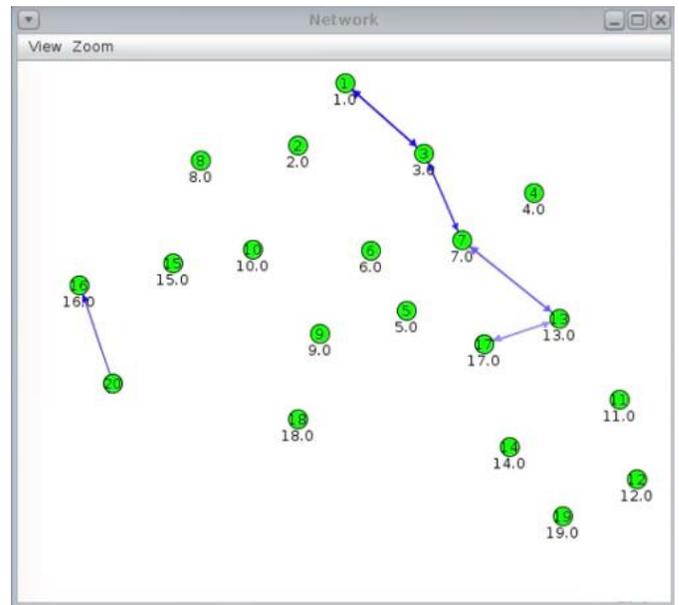
Fig. 7. Nodes in radio range.

Transmission range is entered as 50 meter while Interference is 100 meter. More the Heartbeat time is fixed at 10 second while monitoring time range is 35 seconds. It is to be make sure the all the nodes should be in radio range and it can be verified as by clicking on view menu and radio Environment and just click on any node it will show the range boundaries in green color or just change the Transmission Range (TX) and Interference Range to adjust the nodes, illustrated in Fig. 7.

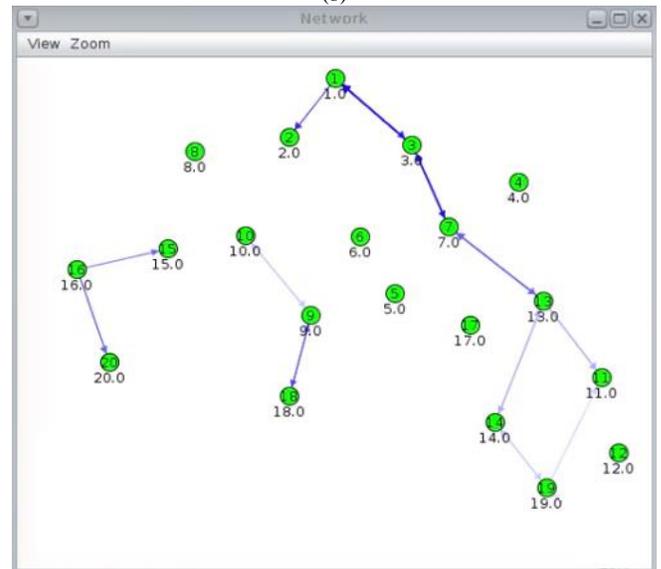
Now by starting the simulation it will begin to broadcast the messages among the nodes as shown in Fig. 8 (a)-(c).



(a)



(b)



(c)

Fig. 8. (a)-(c) Node begun to broadcast message.

Every node is following its path towards sink. Each node chose the nearest node with the smallest number of hops to the sink as its parent node. If there is fault in any node, the rerouting process shall be activated [20]. The comparison of two different results are carried out between ContikiMAC, having LPL mechanism & IEEE802.15.4 or VoidMAC in the absence of LPL.

The point of monitoring in simulation is to monitor the average power consumption of each node and the detection of fault accuracy. The monitoring observation is focused on fault detection & the generation of unreal alarm ratio. If the greater number of fault detection reported it means that overall monitoring process is working fine. In addition the unreal false detection ratio should be lower or minimized as it just indicates the sensitivity of the network & the unreal status of

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the nodes. Secondly the lesser power usage is also highlighted because it will prolong the network life time.

A. Energy Utilization

It is calculated by taking the ratio of CPU beats in every state of sensor node among the fixed given interval. This job is done by the Energest module of contiki. The sensor nodes consist of Transmission (TX), Receiving (RX), CPU Idle and Sleep or Lower Power (LPM) mode. The states of the node are monitored by these parameters. It is observed that in LPM mode the node utilize less amount of energy as compare to other, so overall energy utilization is shown in Table 1, from where it is certified that nodes in LPM state is much better than the nodes in CPU idle state due to the less consumption of energy.

TABLE I. NODE ENERGY UTILIZATION STATES

Node states	Energy Utilization
Transmission (Radio TX)	17.7 mA
Receiving (Radio RX)	20 mA
CPU Idle	1.8 mA
Low Power Mode (LPM)	0.0545 mA

Fig. 9 shows the energy consumption by the nodes. It is the depiction of network monitoring in the presence of ContikiMAC and VoideMAC, it shows evidently that having LPL process it works fine and but during idle state node losses some energy so there is a slight difference in power consumption if avoided the LPL in both centralized and distributed approach.

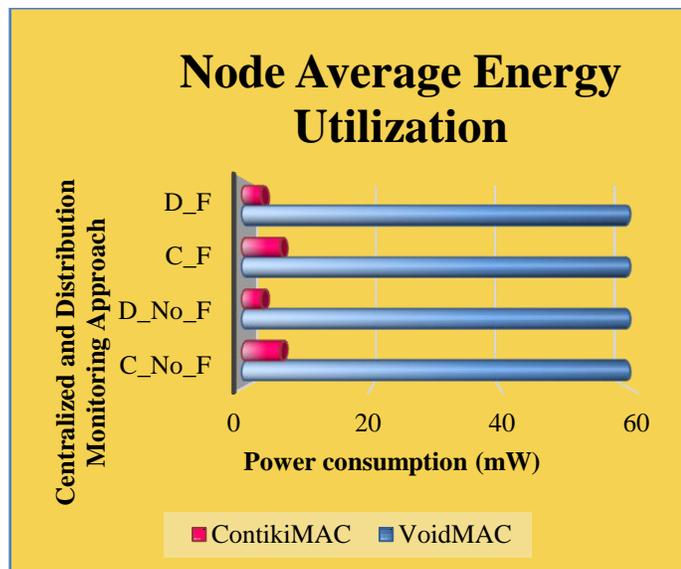


Fig. 9. Power consumption by the nodes in both approaches.

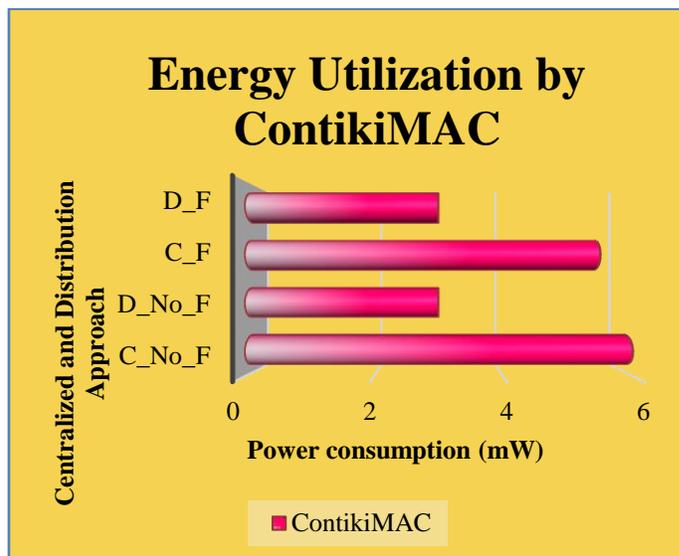


Fig. 10. Power consumption by ContikiMAC.

In contrast to centralized approach, in distribute approach the ContikiMAC utilize only half of the power, thus this approach is more suited than the centralized as appears in Fig. 10 above.

ContikiMAC proves the principle of low-power listening but with better power efficiency. The lower the duty cycle, the longer the nodes batteries, as the most important contribution to the ContikiMAC's reduction in duty cycle is the fast sleep optimization at the heart of the wake up procedure. The negligible energy is consumed when the node sleeps while most energy is consumed during listening (LISTEN), transmitting (TX) or receiving (RX) states.

B. Determination of Adhesion

It is the process of accurate network activity detection and requires some network related credentials like current State of the Network, denoted by SN, the real Time of the detection represented by t, now if time beat is 1 for node n in the network it means the node is alive and possessed the passage up to sink. The status of the sink is denoted by $R_{n,t}$, if the $R_{n,t}$ is 1 it automatically indicates that node is active in current time hence it may be dead in 0 time.

In-order to detect the fault accurately, the idea of fault detection and false alarm ratio is proposed. Fault detection is analyzed as the ratio of the time duration where fault is identified in the mean time of the total fault appears. The detection of fault appears, if the value of $SN_{n,t}$ and $R_{n,t}$ are to be 0, whereas the false alarm ratio can be described as the ratio of the total time having dead node reported and false alarm is obtained when $SN_{n,t}$ becomes 1 whereas $R_{n,t}$ remain equal to 0. Fig. 11 shows the absolute scenario.

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States of the Network Node

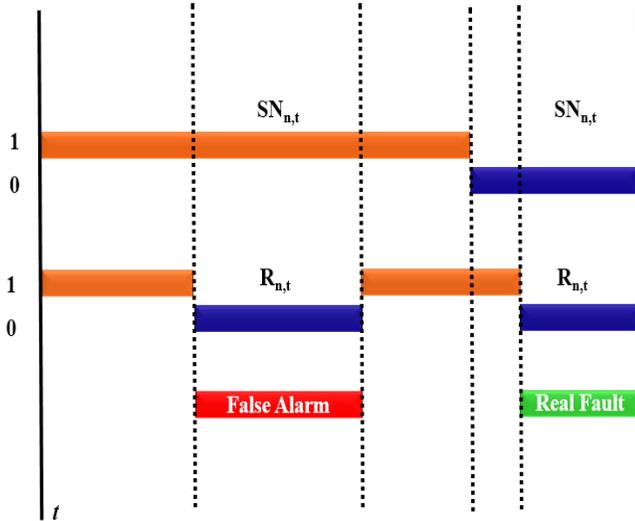


Fig. 11. Generation of real Fault detection and false alarm ratio.

It is important to see how sooner, the fault in the node can be detected by the network, is a major challenge and it can be resolve by determine the latency in the network. For this the Direction Algorithm is developed to determine the faulty node in network. The message packet is broadcasted around the neighbor node by the sink node to odd out the faulty node. The receiving nodes send the ACK packet to the sink. Consider parameters

$$V = \{v_1, v_2, v_3, \dots, v_n\}$$

V represent the number of nodes while S is the Sink node. The contents of broadcast message are given in Table 2 below. Each message possessed the Probelist with all node related information, stored in a table, its initial value is set as α , as sender node received the acknowledgment by the receiving node, updates their table regarding L-node value and decide whether to decision by itself regarding further forwarding of data packet or not. The process continues until it finds the dead node, as the acknowledgment packet will not receive in the predefined time τ and the broadcast message shall be paused. Overlapping is reduced by the random decision among the Probepath.

The defected nodes are exposed by attending the series of Algorithm 1.

TABLE II. BROADCAST MESSAGE INFORMATION

Message Packet	Description
B-Id	Broadcast packet Identification
S-id	Sender node Identification
R-id	Receiving node identification
L-Node	Live node available
T-Interval	Real time to broadcast the message

Algorithm 1: Detection Process of Faulty Node

```

Initialized Prob_List = {  $\alpha$  } where  $V_i \in V$  // Broadcast the message by sink node
Select neighbor node  $v_j$  by SelectNode ( $m1, s$ );
Sink broadcast message to  $v_j$  // Process start the receiving node
FIRST: if ( $v_j$  Alive) then
    Update Prob_List;
    Send ACK;
    If node_value > 0 //check weather node is live here node value is 1
        Update LiveNode;
        Select neighbor node through SelectNode ( $m1, v_j$ );
        Proceed message;
        goto step FIRST;
    else message pause;
else If (ACK NotBack) then // wait for given time  $\tau$ 
    Send neighbor Not_Alive;
    
```

In Fig. 12, it is shown that how fast the latency works against different number of nodes available in a network. It can be observe that latency increases as number of node increases but at some point due to environmental factors it slow down and again get adjusted. While in Fig. 13, the probability of faulty node is illustrated and it is shown that how fast the latency detects targeted faulty nodes. The Latency shall increase if failure probability ratio is lower, resulting lesser chance to detect the faulty node path. Aftermath greater latency is observed against lower probability of sick nodes.

More, by adopting the VoidMAC it shows the false alarm ratio approaches to zero as depicted in Fig. 14.

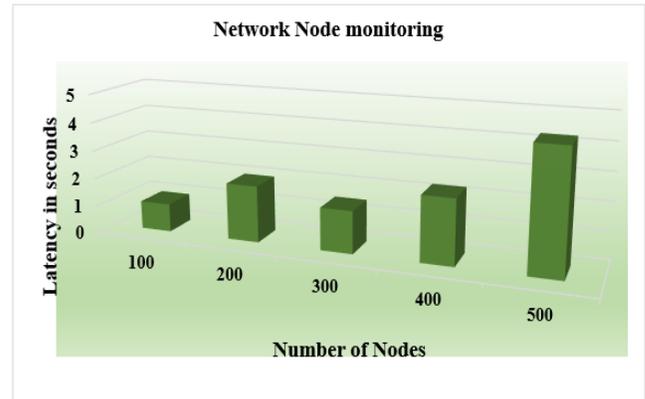


Fig. 12. Latency observation in monitoring session.

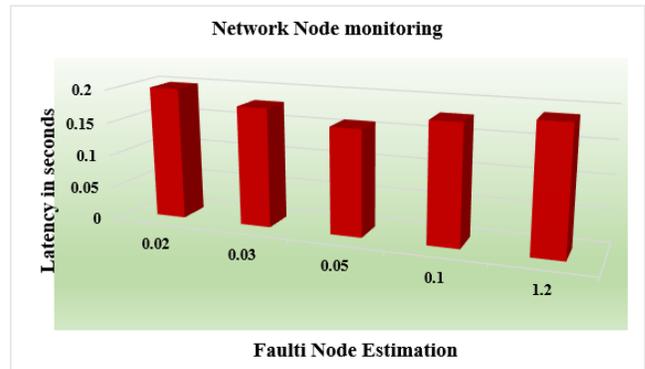


Fig. 13. Latency observation in monitoring session.

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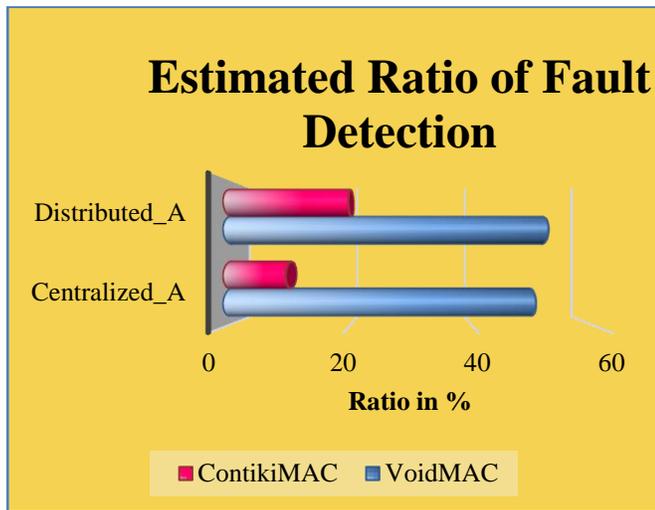


Fig. 14. Latency observation in network monitoring session.

From all results it is observed that by adopting the LPL in centralized and distributed approaches node utilized the much lesser energy, as in LPL sleep mode do not utilized higher energy as compare to idle state. Lower power consumption rate of the network monitoring process will cause less impact on WSNs applications and prolong the lifetime of the network. On the other hand there are some drawbacks of LPL as it generates much duplicate packets for faulty node probing. The large number of packet transmissions generated by the LPL mechanism denotes higher chances of packet collisions, resulting in more losses of packets.

V. CONCLUSION

The node faults are estimated by Probe based algorithm, the node make decision by own about the failure state. The Probepath is associated with sink and node failure information is disseminated towards the neighboring nodes. It is observed that the average power consumption of the network by adopting LPL mechanism is tremendously lower, thus it prolong the network's lifetime. Distributed approach is best suited with LPL for best performance in terms of low power utilization.

VI. FUTURE WORK

It is suggested to develop efficient node detection method which should warn the node failure time before its life end. It is also suggested to investigate the causes of node failure in real time scenario. Duplicate packet transmission consumes much energy, urge to develop the intelligent packet transmission methodology to avoid such situation.

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Relaxed Random Search for Solving K-Satisfiability and its Information Theoretic Interpretation

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Abstract—The problem of finding satisfying assignments for conjunctive normal formula with K literals in each clause, known as K -SAT, has attracted many attentions in the previous three decades. Since it is known as NP-Complete Problem, its effective solution (finding solution within polynomial time) would be of great interest due to its relation with the most well-known open problem in computer science (P=NP Conjecture). Different strategies have been developed to solve this problem but in all of them the complexity is preserved in NP class. In this paper, by considering the recent approach of applying statistical physic methods for analyzing the phase transition in the complexity of algorithms used for solving K -SAT, we try to compute the complexity of using randomized algorithm for finding the solution of K -SAT in more relaxed regions. It is shown how the probability of literal flipping process can change the complexity of algorithm substantially. An information theoretic interpretation of this reduction in time complexity will be argued.

Keywords—Constraint satisfaction problem; K -SAT; threshold phenomena; randomized algorithm; entropy; NP-completeness

I. INTRODUCTION

In computer science, there is an important family of problems known as Constraint Satisfaction problem. In this family we are looking for the values of variables which satisfy the set of constraints simultaneously. Although many of these constraints deals with non-Boolean variables, but they can be reduced to the well-known form of satisfying a canonical form of logical formula called Conjunctive Normal Form (CNF). When each clause in CNF has K literals, this problem is called K -Satisfiability problem or K -SAT.

This problem covers a wide range of different theoretical and applied problems. Scheduling time table problem [1], Planning in Artificial Intelligence [2], validating software models [3], routing field programmable gate arrays [4] and synthesizing consistent network configurations [5] are recognized among these problems.

Furthermore, an important problem of designing digital circuits and their verifications can be reformulated easily into the satisfying of K -SAT formula [6]-[8].

The theoretical reason behind this wide range of application for K -SAT problem was discovered by Stephen Cook [9]. He proved the NP-Complete nature of the K -SAT problem. It means all of NP problems can be reduced to the version of K -SAT problem by using an efficient procedure with polynomial time complexity [10]. Therefore it is not hard

to imagine that how much the effective strategy for solving K -SAT would be advantageous, both from theoretical and practical perspectives.

This paper has been organized into four sections. After this primary introduction about K -SAT, different strategies which have been designed to solve k -SAT are reviewed in Section 2. Section 3 focuses on randomized algorithm, in which it is tried to improve the time complexity of algorithm by relaxing the conditions imposed on random walking in the solution space inspired by the recent studies about the typical time complexity of K -SAT problem [11]. Finally in Section 4, concluding remarks and future works will be discussed.

II. RELATED WORKS

Classically constraint satisfaction problems are solved by systematic search algorithms. For K -SAT problem, this approach is followed in the DPLL algorithm [12], [13].

In this algorithm after choosing a value for any unassigned variable, the formula is simplified by considering the propagation of chosen value in the formula. Since the constraints are represented in conjunctive normal form, two main equivalence rules in propositional logic about disjunctive phrases are used to deduce the consequences of any variable assignment (1) & (2).

$$expression \vee True \equiv True \quad (1)$$

$$expression \wedge False \equiv False \quad (2)$$

For any K -SAT formula on n Boolean variables, 2^n assignments are possible. This exponentially large state space can be pruned by considering the structural properties of the CNF formula. Sometimes it is better to start the process of assigning value to variables from highly constrained variables and sometimes it is better to start with more relaxed variables.

In the case of applying DPLL algorithm, the process of assignment is started with unit-clause (single literal clause). These unite clauses provide a suitable way to reduce the size of state space by imposing a strict type of restriction on the value of literals in the unite-clauses.

The best scenario happens when deducing the consequences of any unite-clause assignment provide an opportunity for forming another unite-clause. Consider the following formula:

$$\varphi(x_1, x_2, \dots, x_n) = (\overline{x_1}) \wedge (x_1 \vee x_2) \wedge (\overline{x_2} \vee x_5) \wedge \dots \quad (3)$$

Certainly for satisfying φ , x_1 must be assigned 0, considering this value for x_1 , the second clause is transformed into a unit clause x_2 . Therefore x_2 must be assigned 1 or true. Again considering this value for x_2 the third clause is transformed into unit clause x_5 and the process is continued by choosing proper values for the variables of formula. This condition provides a clear guide for choosing the values for variables without any doubt and reduces the time complexity of the problem.

Unfortunately this consecutive formation of unite clauses happens rarely and cannot be used as a general technique. As a matter of fact the consecutive emergence of unit clauses in the process of deducing the consequences of the variable assignment reduces the branching factor of the search tree.

Studies have shown the considerable amount of reduction in the time complexity of solving K-SAT, whenever one can find a way to represent the formula in the way that imposes maximum restriction for variable assignment. Sometimes this type of forced assignment leading to the pruned search tree is called implication. The best example of this type of forced assignment can be observed in Horn theory [14].

It must be mentioned that in the case of unsatisfiable formula, reaching to conflict as soon as possible (in polynomial time) is realized as a sign of an effective search strategy. A conflict can be detected in the formula if at some point there is a clause in the formula with all of its literals evaluating to zero. The clause with this condition is called conflicting clause. A conflict in the formula happens as the result of earlier improper assignments.

Different strategies have been developed to escape from conflicts. Backtracking to the earlier assignments and change them in the controlled way, is the common them of all these strategies [11]. DPLL has experienced many significant improvements over the years based on these backtracking techniques. Conflict Driven Learning and Non-Chronological Backtracking are among the best improvements which have enhanced the power of DPLL algorithm in a considerable way [15], [16]. These improvements are based on the simple strategy of learning as much as possible from any conflict and its source in order to avoid it in the subsequent assignments.

Modern algorithms for solving SAT problem, gets the benefit of an improved type of unit clause rule, called two-literal watching and also improved technique in branching and variable assignment by considering the variables presented in recently conflicting clauses [17]. Sometimes it is justifiable to apply random restart technique due to the complications associated with Conflict Driven Learning techniques and correlations among different clauses [18].

There is an interpretation of K-SAT which puts it in the category of discrete optimization problems. In this perspective, we are looking to maximize the number of satisfied clauses. This maximum can reach to the total number of clauses in which satisfaction happens. Therefore it is possible to use discrete optimization techniques like Simulated Annealing [19], Tabu Search [20], Neural Network [21] and Genetic Algorithms [22] to solve it.

Realization of K-SAT as an optimization problem refreshes our mind about the general difficulties of finding the maximum of the objective function. The intractable nature of the problem exhibits itself as the difficulties of bypassing the exponential number of local maximums or local minimums in its objective function [23]. Considering the K-SAT as an optimization problem, one can use stochastic local search algorithms to bypass the pathological difficulties of finding the global maximum of its objective function.

Stochastic local search algorithms were used for the first time by Minton et al. [24] for solving constraint satisfaction problem and for MAX-SAT problem by Hansen and Janmard [25]. Particularly for K-SAT, stochastic local search was used by Gu [26] and Selman et al. [27]. Selman et al. introduced GSAT algorithm which was more effective than DPLL variants used in those days and their approach sparked considerable interest in Artificial Intelligence Community.

In spite of all efforts, up to now, we don't have a polynomial time algorithm for solving K-SAT. On the other side there is a belief supported by many practical experiments which asserts that exponential time complexity occurs for a limited sub-space of K-SAT instances [28]. After the seminal work of Cheesman et al. [29], today we know that hard instances for K-SAT reside at the threshold of satisfiable to unsatisfiable phase, which occurs at specific value of $\frac{m}{n}$ known as α_s (here m is the number of clauses or constraints and n is the number of variables in the K-SAT formula). Theoretical investigations about the source and nature of this phase transition in the K-SAT problem have revolutionized our understanding from this problem and its state space geometry. Recently threshold conjecture has been proved analytically for some specific conditions [30].

The effectiveness of applying statistical physic methods for analyzing the source of phase transition in the K-SAT problem, has provided us a very detailed picture of solution space upon which many other thresholds of transition have been recognized. In addition to α_s (Satisfiable to Unsatisfiable threshold), an algorithmic threshold α_A is defined in such a way that all known algorithms running in polynomial time fail to find solution for $\alpha > \alpha_A$. Generally it is known that $\alpha_A < \alpha_s$ [31].

Therefore the previous satisfiable phase is partitioned into different regions in the light of new detailed picture of the solution space. Generally as α is increased the clusters of solutions in the solution space shrink and the connectivity among them is lost [32]. Let w and z be two distinct solutions in the set of all satisfying assignments for a specific K-SAT instance. A step [33] is defined as the number of variables which must be inverted in w to produce some w' that is also in a solution space. A path from w to z is defined as a sequence of steps starting with w and ending with z .

Intuitively we expect that increasing $\alpha = \frac{m}{n}$ decreases the number of solutions up to reaching to the unsatisfiability region but this phase transition is accompanied with other micro-transitions especially in the solution space of the problem.

For example bellow α_S for $\alpha \ll \alpha_S$, we observe connectivity in solution space. This connectivity exhibits itself as the existence of path between any two arbitrarily chosen solutions w and z . This connectivity is transformed at some specific value, called $\alpha_d < \alpha_S$ in which the solutions are partitioned into different clusters. Therefore at this value α_d , the condition can be described technically by the following equation[33].

$$S = \cup_{i=1}^p S_i \text{ such that } \forall m, l \in \{1, \dots, p\}: S_m \cap S_l = \emptyset \ \& \ \nexists \text{ path from } w \text{ to } z \text{ if } w \in S_m \text{ and } z \in S_l \text{ and } m \neq l(4)$$

Further increment of α changes the size and the number of clusters into exponentially large number (in the problem size n) where two solutions belonging to different clusters, have a large hamming distance that scales with problem size [34].

There are several other phase transitions which can be defined for the topological transformation of the solutions in the state space [33], [35]. For example one can also identify α_C in which a condensation takes place such that for any $\alpha > \alpha_C$, the majority of solutions belong to sub-exponential number of clusters. Generally we have: $\alpha_A < \alpha_d < \alpha_S$ [36], [37].

In this paper by considering this picture of solution space, it is tried to improve randomized algorithm presented by Schoning [38] in 1999 and reduce its time complexity.

III. RANDOMIZED ALGORITHM AND ITS ANALYSIS

When the structure of K-CNF formula cannot provide an insight for pruning the solution space, nothing can do better than random search [23]. Theoretically the maximum amount of information can be extracted by this strategy from state space of the problem. The first successful randomized local search was introduced by Schoning [38]. His method has been based on random walking in the space of possible assignments starting from random truth assignment and flipping the suitable literals until the formula gets satisfied.

Taking into account different thresholds mentioned in the previous section, we expect to find a solution in polynomial time when $\alpha < \alpha_A$. The situation would be harder for α near α_d and after it due to the clusterization. Because of the interaction between different clauses, up to now, no one has given an analytic model which makes us able to count the number of unsatisfied clauses during the process of random walking in the solution space. Therefore the performance of Schoning's algorithm is analyzed by focusing on the hamming distance between current assignments namely B and one particular satisfying assignment called A^* . Let's look at the Schoning's algorithm [38].

This algorithm starts at a uniformly random truth assignment B . If B satisfies the formula, it would be returned. Otherwise the algorithm repeatedly chooses a clause c from unsatisfied clauses, then chooses a variable x uniformly from c 's literals and flipping it until the formula is satisfied or the algorithm runs out of time.

As a matter of fact, starting from random initial assignment B , the algorithm tries to reduce the hamming

distance between current assignment and satisfying assignment by random flipping of variables in unsatisfied clauses. Obviously $Hamming - distance(B, A^*)$ would be less than n (the number of variables in the formula) and greater or equal to zero.

$$0 \leq Hamming - distance(B, A^*) \leq n \quad (5)$$

Reaching to the zero hamming distance means the satisfying assignment has been found. Let's define $P(d)$ as the probability of reaching to the zero. We know that:

$$P(0) = 1 \ \& \ \lim_{d \rightarrow \infty} P(d) = 0 \quad (6)$$

As a matter of fact we are looking for the evolution of $P(d)$ during the execution of randomized algorithm. Considering the algorithm, it is not hard to realize that flipping the variable chosen uniformly from the unsatisfied clause is responsible for the evolution of $P(d)$. Let c be the chosen clause from unsatisfied clauses with assumption that the formula is satisfied finally at threshold of α_S , one can expect that A^* agrees with c on at least one of its variables. Therefore flipping one variable would lead to reducing the hamming distance and moving toward A^* (satisfying assignment) with probability $\frac{1}{K}$. Consequently the hamming distance is increased due to this flipping with probability $(1 - \frac{1}{K})$. Now we have enough information to write the governing equation of $P(d)$ at the vicinity of α_S .

$$P(d) = \frac{1}{K} P(d - 1) + \frac{K-1}{K} P(d + 1) \quad (7)$$

Equation (7) reflects the evolution of $P(d)$ when we are dealing with highly constrained problem near α_S . For more relaxed type of problem in which α is around α_A , the agreement of A^* with c equals to l , where $l > 1$, due to the connectivity in the solution space among the satisfying assignments. Therefore, (7) can be transformed for covering more relaxed problems into (8).

$$P(d) = \frac{l}{K} P(d - 1) + \frac{K-l}{K} P(d + 1), \ k - l > 1 \ \text{and} \ l > 1(8)$$

The boundary conditions ($P(0) = 1 \ \& \ \lim_{d \rightarrow \infty} P(d) = 0$) are still valid for relaxed type of problem. Solving (8) will give us the answer:

$$P(d, l) = \left(\frac{K-l}{l}\right)^{-d} \quad (9)$$

Equation (9) shows that the success of finding the satisfying assignment is completely controlled by the hamming distance of randomly chosen initial assignment with the satisfying assignment A^* and also by the probability of having suitable flipping of variables. In order to calculate the $P_{Success}$ (the probability of finding the satisfying assignment by algorithm), it is enough to divide the 2^n possible assignments into partitions with the same hamming distance to the desired satisfying assignment and compute the average of $P(d)$ over d .

$$Prob(Hamming - distance(B, A^*) = d) = 2^{-n} \binom{n}{d} \quad (10)$$

Therefore for computing $P_{Success}$ by applying the generalized type of Schoning's algorithm in which the random

walker reduces the hamming distance to the desired satisfying assignment with probability $\frac{l}{K}$ and increases it with probability $\frac{K-l}{K}$, we have the following equation:

$$P_{Success}(l) = \sum_{d=0}^n 2^{-n} \binom{n}{d} P(d, l) = \sum_{d=0}^n 2^{-n} \binom{n}{d} \left(\frac{l}{K-l}\right)^d 1^{n-d} = 2^{-n} \left(\frac{l}{K-l} + 1\right)^n = 2^{-n} \left(\frac{K}{K-l}\right)^n = \left(\frac{2(K-l)}{K}\right)^{-n} \quad (11)$$

By applying amplification technique in order to get rid of emergent error associated with randomized algorithm [39], the time complexity of applying this algorithm for solving K-SAT problem is $T(n) = poly(n) \left(\frac{2(K-l)}{K}\right)^n$. For computing this time complexity, it has been assumed that Schoning's algorithm needs polynomial time complexity.

Therefore boosting technique applied for reducing the error of randomized algorithm is the source of emerging exponential time complexity of the resulted algorithm. In the next section we argue how the parameter l , taking part in the probability of reducing hamming distance, can change our usual expectation from the complexity of this method.

IV. CONCLUSION AND FUTURE WORK

In this paper we analyzed the consequences of applying Schoning's randomized search method [38] for values of $\alpha \ll \alpha_S$. Usually the performance of algorithms is analyzed in worst case, in which the maximum time complexity can be observed.

For K-SAT, as it has been shown by Cheeseman et al. [29], the worst instances happen at the onset of α_S in which one can expect that each clause is satisfied by a proper value of just one of its variables. In this highly constrained region, we have $l=1$ and the time complexity of algorithm is $\left(\frac{2(K-1)}{K}\right)^n Poly(n)$. By applying an information theoretic method [40] to calculate the entropy of the random walk in this case (where $P(\Delta d = +1) = \frac{K-1}{K}$ & $P(\Delta d = -1) = \frac{1}{K}$) we reach to (12).

$$H[P_{Worst}] = \frac{1}{K} \log_2 K + \frac{K-1}{K} \log_2 \frac{K}{K-1} \quad (12)$$

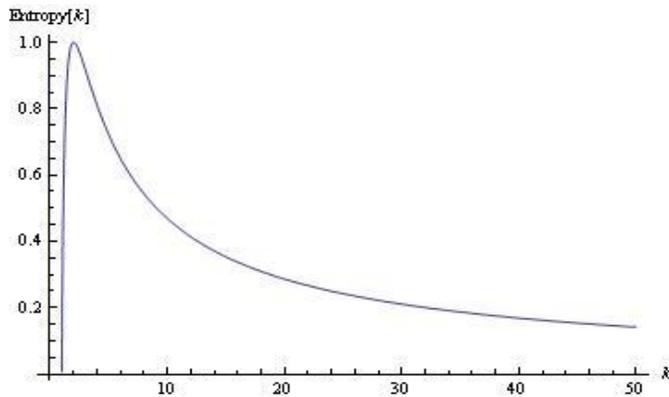


Fig. 1. The Entropy of random walking in the state space at the vicinity of α_S .

Fig. 1 shows the entropy function of K-SAT problem at the threshold of α_S in which satisfaction comes in highly constrained manner. Remember that for $\alpha > \alpha_S$ the K-SAT would be unsatisfiable.

A deeper look at Fig. 1 shows that maximum value of entropy function for k-SAT occurs at $k=2$. We know that k-SAT is solvable in polynomial time for $k=2$. It means that, the exponential size of solution space is pruned maximally when the amount of information gained from random walk in solution space becomes maximum at $k=2$.

In Fig. 2, the entropy function of random walking in the solution space of more relaxed situation in which $P(\Delta d = +1) = \frac{K-l}{K}$ & $P(\Delta d = -1) = \frac{l}{K}$ where $l > 1$, has been depicted. As it can be observed, for larger value of l , which is seen in more relaxed problem ($\alpha \approx \alpha_A$), the maximum value of function is shifted toward larger values of k .

It has been known for several years that random walking in the solution space is the best strategy in the lack of any guide for pruning the large state spaces [23]. The result of this paper approves this hypothesis. When the entropy of random walk is maximized the problem can be solved effectively in polynomial time due to the vanishing of exponential part of time complexity. Obviously $T(n) = poly(n) \left(\frac{2(K-l)}{K}\right)^n$ is transformed to $poly(n)$ at $l = K/2$, in which maximum entropy of random walk is happened and deviation from this maximum entropy of random walk would be accompanied by the emergence of exponential time complexity.

Although l is known to be larger than 1 for $\alpha \ll \alpha_S$, It is an open question to find a strict mathematical bound for it. This trend of study will improve our understanding in the future.

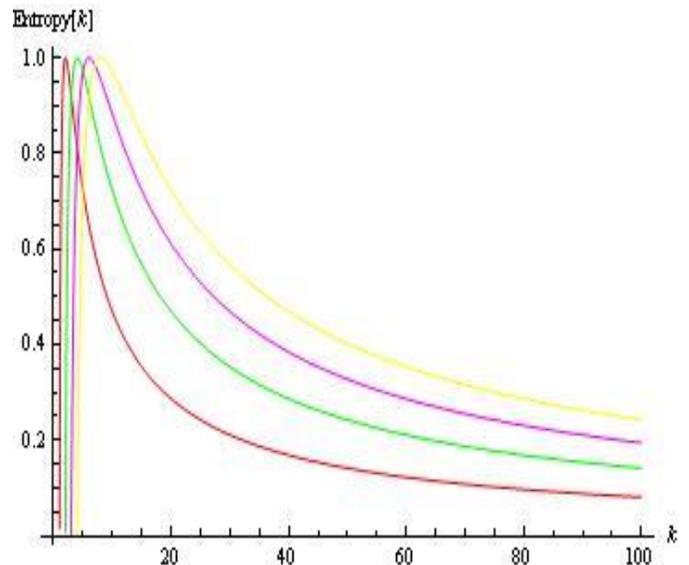


Fig. 2. The entropy of random walk for different values of l . $l = 1$ with red line, $l = 2$ with green line, $l = 3$ with magenta line and $l = 4$ with yellow line.

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A Review of State-of-the-Art on Wireless Body Area Networks

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Abstract—During the last few years, Wireless Body Area Networks (WBANs) have emerged into many application domains, such as medicine, sport, entertainments, military, and monitoring. This emerging networking technology can be used for e-health monitoring. In this paper, we review the literature and investigate the challenges in the development architecture of WBANs. Then, we classified the challenges of WBANs that need to be addressed for their development. Moreover, we investigate the various diseases and healthcare systems and current state-of-the-art of applications and mainly focus on the remote monitoring for elderly and chronically diseases patients. Finally, relevant research issues and future development are discussed.

Keywords—Wireless body area networks; review; challenges; applications; architecture; radio technologies; telemedicine

I. INTRODUCTION

As time goes on, communication technologies have started the gap toward a pervasive world. Because of, MP3 players and mobile phones are portable devices; people normally carry these devices around their bodies. In 1995, Zimmerman examined how these electronic devices operate near or inside the human body. He used the term PAN, personal wireless network as a communication channel for communication within the body. Later, around 2001, PAN term has been changed to encompass communications and implantable use of devices around or inside the body to the physical network BAN [1]. Body sensor networks are called, BSN. The Physical wireless network is a mono-purpose wireless sensor network that combines different wireless networks and devices to able remote monitoring. BAN devices may be embedded in the body or may be mounted on the body or in a fixed position on the wearable technology or may be placed in mobile devices that people can carry in different situations, in clothing, pocket, hand or different bags [2]. Gateway devices are used to connect wearable devices to the Internet through the human body. As a result, medical professionals can use online patient data from the patient's own Internet access [3].

One of the WBANs applications is the medical environment in which the situation of a large number of patients should be controlled permanently or in real-time. To create WBANs, several tiny wireless sensors are in strategic areas in or around the patient's body. Currently, wireless monitoring of physiological signals is one of the basic needs

to deploy complete WSNs in health systems. The main purpose of the WABNs is to provide biological feedback information and consistently control the body's health parameters such as body temperature, blood glucose, heart rate, body movement, electrocardiogram (ECG), electroencephalogram (EEG), electromyography (EMG), galvanic skin response (GSR), photoplethysmography (PPG), and arterial blood pressure and heart with a simple and efficient way. Because of health care costs are increasing and the world population ageing, human health monitoring is one of the important issues [4], [5].

The rest of the paper is structured around the following sections: different architecture of WBANs and characteristics of communication and the position of WBANs presented in Section 2. In Section 3, medical and non-medical application and different device of WBANs are evaluated. Design challenges and requirements and open issue are discussed in Section 4. Communication standard and radio technologies present in Section 5. Telemedicine and diverse disease that monitor by WBANs are discussed in Section 6. Finally, conclusion and future direction are provided in the last section.

II. WBANs ARCHITECTURE

WBANs were classified with intelligent nodes based on implementing within the body as follows: In the body or implantable sensors - these nodes implanted in the patient's body, inside the body tissue or underneath the skin. On the body or wearable sensors - these nodes placed the surface of the patient body or two centimeters away from it [6]. Placed it around the body or surface sensors - these nodes are external of the body rather than five meters away from a patient's body [7].

These nodes are continually monitoring patient vital information and usually utilize wireless communication to join a master node. The first, master node accumulates data from all the other nodes in the network and then directs the information to the medical devices. According to the received data and patient's specifications, the medical team can do proper medical practice. Moreover, this system can provide records of vital sign of the patient. In general, these sensors measured the precise parameter of the patient and the actor sensor action based on the information gained from sensors.

In another classification, the sensors in each WBANs are divided into two categories based on the kind of signal measurements [7]. The first type is gathering with variable signal continuous which needs to real-time signal processing such as, electrocardiograms graph [8] sensors and accelerometer [9]. The second type is a collection of discrete variable time signal that they are not immediately for instance, Pressure sensors [10], and respiratory tract sensor [11]. In Table 1, the summary of the general characteristics of WBANs is provided [2].

These nodes can have diverse topologies including the star, mesh, and tree topologies. Nevertheless, the most standard topology is the star in which node in the center of the star being placed at a location and the other nodes are connected to a central master node. Based on the application, sometimes various nodes connect to a central master node to merge the process and transfer information. Some of the parts of the human body movements are pondering the relative to each other and this process should be considered until deploying nodes in the body. In Fig. 1 explains an example of nodes based on the human body. Nodes to transmit sound and images must be cautiously established with attention to sensitive nerve in the head. In addition, the sensitivity of the SAR (Specific Absorption Rate) eye should be regarded. The nodes located in the torso and head towards each other will not move very much. Nevertheless, the nodes located in boundaries for example legs, arms, torso and head may move toward each other more [12].

In Table 2 is explained possible communication between nodes in the body [13]. These nodes have very low processing power and are able to produce energy for the whole body in the body and on the body. Nevertheless, these nodes in close proximity to or inside the human body and thus position SAR can be a slightly larger, if all power is available for a small volume of data. Thus, localization of SAR in the body must be at least [14].

Another architecture for WBANs in medical and non-medical application are designed. According to demand, it can be used in the emergency event or normal traffic. Upon demand to attain special information, traffic is started by master node and is the maximum goal for diagnostic recommendations. These are divided in two interconnected (in case of operation) and discrete (when information is required from time to time). Emergency traffic management is started by starting node when more than a predefined threshold exists and must be replaced in less than a second. This kind of traffic is not created at regular intervals and is quite unpredictable [14].

Normal traffic data is requested in a normal condition with no critical time for events. This consists of the general health of patients and their treatments for many diseases; for example, gastrointestinal, neurological disorders, cancer, rehabilitation, disability, heart diseases and more. Normal data are gathered, and the master node does the processing. Depending on the application requirements, the master node may include a raiser radio circuit to transfer of critical life emergency and an additional circuit to connect multiple physical layers. More master nodes are connected to critical

telemedicine and medical server for the appropriate recommendations [15].

TABLE I. GENERAL CHARACTERISTICS OF WBANs

Attribute	Value
Network size	Max 100 devices
Network density	2-4 Nets/m ²
Network Setup time	<1 Sec/device
Power consumption	<1 m W/Mbps
Startup time	<100 ns
Latency (end to end)	10 ms
Distance	2 meter stander 5meter special case

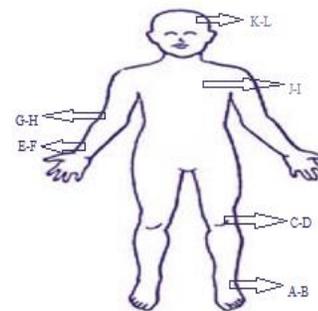


Fig. 1. Description node links on the body.

TABLE II. DISTRIBUTED WBANs ON BODY

Link	Description
A-B	Through the ankle
C-D	Through the thigh
E-F	Through the hand
G-H	Through the wrist
I-J	Torso, front to back
K-L	Left ear to right ear

WBANs in many ways are similar to the wireless network, but the differences between the two can be seen. Scalability in WBANs limited in the human body, but in WSN can monitor the environment in the wide area covered. Node density also is numerous in WBANs while in WSNs is few and limits. Security and privacy level and authentication of a node and real-time communication among most important issue in WBANs while in WSNs no attention to support them. Usually in the WBANs nodes perform multi-tasks, but in WSNs is purpose single.

In addition, data rate, mobility, network topology, node size between two networks is diverse result in different architect to design and implementation. Most importantly, energy source and high reliability and low delay are very critical for WBANs because data mostly consist of medical information and can be as a life threat for patients [16], [17]. Thus, WBANs have several advantages rather than WSNs such as flexibility, effectiveness and cost-effective. Table 3

shows the differences between wireless body area networks and wireless sensor networks.

TABLE III. DIFFERENCES BETWEEN WIRELESS BODY AREA NETWORKS AND WIRELESS SENSOR NETWORKS

Issues	Wireless Body Area Network	Wireless Sensor Network
Node Size	Small is essential	Small is preferred, but not important
Scale	Human body (centimeters/ m)	Monitored Environment (meters/ km)
Node Tasks	Node performs multiple tasks	Node performs a special task
Network Topology	More variable because of body movement	Very likely to be fixed or static
Node Number	Fewer, limited in space	Many redundant nodes for wide area coverage
Energy-Scavenging Source	Most likely motion and thermal	Most likely solar and wind power
Node Lifetime	Several years/months, smaller battery capacity	Several years/months
Node Replacement	Replacement of implanted nodes difficult	easily
Power Demand	Likely to be lower, energy supply more difficult	Likely to be large, energy supply easier
Wireless Technology	IEEE 802.15.6	Bluetooth, ZigBee, GPRS, WLAN
Result Accuracy	Through node accuracy and robustness	Through node redundancy
Security Level	High	Low
Biocompatibility	A must for implants and some external sensors	Not a consideration in most applications

III. APPLICATION AND DIFFERENT TYPE OF DEVICES

The human body sensor network has a lot of potential for a variety of applications including remote medical diagnosis, interactive games and military applications. Table 4 lists some of the applications of the sensor in the body and on the body. Applications inside the body include the supervision and program changes for regulating heart rate and substantial heart implant in the body, the limb movement, and restoration of bladder function control. Medical applications in the body sensors include monitoring of ECG, blood pressure, temperature, and respiration. On-body sensors communicate between a getaway device and sensors. In addition, the body of non-medical applications includes monitoring of forgotten things, creating social networks and assesses soldier's battle. Some of the human body sensor network applications are discussed below [13], [15].

According to the type of application, data rate information and ranging from transferring data are different. Data can also be sent in similarly stream and the higher rates posted during the explosion. The reliability of the data transmission for the guarantee of the correct data is received from health-care professionals in term of bit error rate (BER) for the number of

lost packets [17]; for medical devices, the reliability is based on the speed of the data. Low data rate can be a high BER (10^{-4}) while devices with higher data rates require a lower BER (10^{-10}) can be gained [16]. Energy consumption is critical issue in the design for improving the lifetime of battery WBANs. Energy is used for sensing, communication, and processing data. Usually, the available energy for nodes is limited. Energy consumption based on utilities, shape, and position and the rate of transfer data is different. Generally, providing Qos in management of medical applications, especially in healthcare application is important [16].

Additional demands have increased fast exponential cost of health care and medical interventions for innovative solutions for remote health monitoring as a body sensor network [12]. The result in WBANs extends a wide area in medical application.

In medical application for healthcare is prevention, diagnosis, treatment of diseases and other physical and mental of people activities. Also, for animal healthcare with different sensors such as accelerometer, GPS, Bluetooth, temperature, humidity, wind sensor monitoring for realizing the disease, for example, respiratory, gastrointestinal, metabolic [18], [19] that prevent of these disease could be helpful for massive financial losses in the animal agriculture industry. Medical application has many classifications for monitoring general healthcare, disability assistance, infant healthcare, pregnant women, elderly monitoring. In neonatal monitor the smart jacket or wrist band with wearable sensors and smart textile. In [20] author has suggested design of continuing vital health monitoring. There are different sensors, such as ECG with conductive textiles and phototherapy with skin sensors and temperature sensor, pulse rate sensors.

Also, the system consists of special hardware, namely, microphone to record voice, memory and processors for analyzing information and Bluetooth for transferring information. In [21] the author suggested a wrist band for the baby named Kims. Wrist sensor monitors vital parameters of infant and processing information for early detection of infectious diseases and treatments. Wristband consist of various types of sensors for the instance microphone for record audio signals and then with processing signal recognize health sings for example cry, sneeze, vomit and cough. Then processing with coding scheme and compare with original signs for awareness of disease to beginning the treatment.

In non-medical application can be classified in entertainment such as interactive games, dance lessons, microphones, shopping and cameras and advanced computer and so on [22], [23] and training the sports for instance golf, football, and cricket where athletes sensors connected to the body and move them to record and review their training and monitoring and self-assessment and better adjustment to professional athletes plan and rehabilitation and motion capture [24]. Smartphone and wearable watches are being connected to BANs for gaining physiological parameters, for example heart rate, acceleration, gait length by distance measurement, pace, burned calories and elapsed time.

Military and security applications consisting of the camera, biometric sensors, GPS are supported by body sensor

networks, particularly for the control and monitor the battlefield where the sensors are located with soldiers, move to track, monitor their health, and detect the existence of toxic substances in the air and that life-treating people [13]. Sleep disorders are the significant issue in daily lives. Thus, sleep monitoring attracted many researchers in these years. Moreover, it is widely used in varied medical application and implant sensors, for example cardiovascular diseases, diabetes, cancer and remote control sensors such as telemedicine system, patient monitoring. New BANs applications suggested in [25] for example, identify frostbites, assist blind swimmers that support the special disease. Fig. 3 summarizes categories of WBANs application.

A taxonomy of the device represents for monitoring patients as follow: Node wireless sensor is a device that collects and responses to physical stimuli and makes the process on data report data for wireless sensor. This device includes hardware components, such as sensors, processing unit, a processor, memory and a transmitter or receiver [26]. A Wireless Driving node is a device that the data received from the sensor or through user interaction works. The sensor actuator components consist of hardware drivers (medical hardware, for instance a drug-delivery system) a processing unit, processor, memory and a receiver or transmitter [2].

Wireless personal devices (PD) is a device that all information gained by the sensors and actuators to gather user information through an external gate driver or a page Show - LEDS on it. The components of this device consist of a processing unit, processor, memory and a transmitter and receiver [16]. This device is called Body Control Unit (BCU), body gateway or sink. In some design, a Personal Digital Assistant (PDA) or smart phone is used [27]. Many diver's kinds of sensors and actuators are used in WBANs. The significant target of all these devices can be found in health applications. The number of nodes in WBANs depends on the abilities and the nature of the network. Usually, the number of nodes is in the range of 20-50 [28], [29]. There are challenging issues in the design and implementation of WBANs. Following are mentioned some of the issues.

IV. WBANs DESIGN CHALLENGES AND OPEN ISSUE

In this section, we present the main challenges of WBANs. There are numerous challenges such as reliability, security, size, latency, privacy, availability, capacity constraints, confidentiality, data speed, bandwidth, mobility, the quality of service requirements, transmission range, and so on [30]. Proficient communication is as ease of deployment and scalable, reliable (in data measurement, data communication, data analysis), user-friendliness, fast, fault-tolerant, low power of data communications [31], [32].

So that gain operational efficiencies, body wireless network implementations must ponder that significant issues depend on the proper coverage area in most of the human body. Small coverage area causes to body temperature and change location, and movement of nodes. So, the implementation of the network is vital aspect [33]. Moreover, exist major challenges between BANs and applications. For example, increased attenuation for communicating application, data rate, power consumption, trade-off between

processing and communication, storage energy harvesting. In summary, we classified power efficient mechanism for BANs applications in scheduled contention, lower power listening, and TDMA based mechanisms.

Some challenging issues exist in the Wearable Health Monitoring System (WHMS) for example, battery technologies and energy scavenging, sensor miniaturization and efficiency design, security and validation of information, standardization and cooperation between different communication levels.

The most critical limitation is the energy source for gathering, processing, and transfer data for extending the lifetime of the network. Hence, to widespread the lifespan of the network, particular implanted nodes is necessary. Therefore, especially focused should be given to network lifetime when selecting or implementing communication protocols for WBANs such as routing and so on [34]. In this regard, routing algorithms are designed respect to energy challenge that can be classified into ten categories including: Thermal-Aware, Cluster and Tree-Based, Medium Access Control, Cross-Layer, Opportunistic, Restriction of Location and Number of Relays, Mobility-Aware, Link-Aware, QoS-Aware, Hybrid protocol. The classification of the body area network application is shown in Fig. 2 [35].

The patient needs to be capable of moving easily. For instance, motions of the hands, walking, sleeping, running, twisting, up to and down stairs, etc. this category named "Mobility-aware" [36], [37]. Protocols that investigate the location and placement and relay of nodes are the category of "location restriction and number of relays" [38], [39]. This category uses multi-hop for data transferring, that cause reduces energy consume. Also, determine location case to increasing packet delivery rate and reduce packet drops.

Some protocols deal with the link status between the transmitter and the receiver for exchange information, including packet delivery ratio, HELLO message and signal strength. This category named "Link-aware" [40], [41]. Any protocol in this category that considers the link status for direct impact on various factors, include energy consumption, delay, reliability. Another category is links between the source and destination with cluster and tree for data transmission is "cluster and tree based" protocols [42]. This category is efficient in improving WBANs by using tree-based methods for allocating nodes and also gathering data, that cause reduce energy consumption. Next classification composed of multiple layers, containing network layer and transport layer, to improve WBANs. In other words, improve the efficiency and interaction between the protocols and two or more layers of the protocol stack.

This category named "Cross-layer" [43]. Also, another category related to the communication channel is "opportunistic" protocols [43]. This category discusses on how sensor nodes achievement of the communication channel. "Medium Access Control" is another category that focuses on energy consumption and cost. According to access the communication channel MAC protocols have been divided into two subcategories of scheduled and random protocols [44], [45].

The movements of the body may effect on topology networking capabilities, communications, or signal reception. However, the most significant restriction of energy is its source in which the body sensor network node is equipped with a small battery. The Sensors node in WBANs perform different activities, such as sensing, processing, analyzing which radiation absorption and heating effects on the human body; also because, if excessive heat will damage body tissues. So, mechanisms need to be supplied to impede the temperature rise in the nodes; for example, limited or traffic controls algorithms. This class named "thermal-aware" [46], [47]. For instance, the Thermal Aware Routing Algorithm (TARA) that routes data away from high temperature areas [47]. Packets are receding from the heated zone and rerouted via alternate paths. The disadvantage of TARA is from low network lifetime and low reliability into account and high ratio of dropped packets. The development and smarter of TARA is Least Total Route Temperature (LTRT) [48] that the node temperatures are modified on to graph weighs and minimum temperate routes are acquired. But LTRT suffers that a node needs to know the temperature of all nodes in the network.

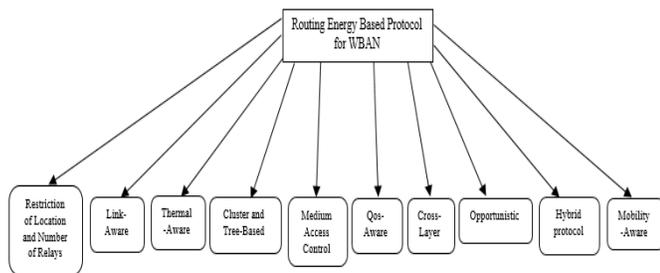


Fig. 2. Classification of routing protocols in body area networks with respect to energy

Energy efficiency requirements in MAC protocols have been evaluated in [49]. The method is proposed [50] to reduce power consumption by data aggregation mechanism. The energy-efficient and reliable protocol has been proposed in [51]. The protocol for patient monitoring has been presented in [52] that investigated location and position. Relay nodes placement schemes for minimizing energy consumption proposed in [53]. All of these protocols are the category of "Qos-Aware".

The last category is mixture of other categories called "Hybrid protocol". The protocol can be the mixture of two or more category for instance, link status and MAC. Fig. 2 shows classification of routing protocols in WBANs based on the consumed energy. Table 5 summarizes the examples of routing protocols with respect to energy in WBANs.

Cloud computing is a new method that able to sorting, processing, delivering, securing, analyzing, and distributing data streams [58] that relay on signal characteristics and the rate of data production and the sensing parameters. The algorithm processing can provide additional information for monitoring, emotion detection, activity recognition, skin prevention. Cloud computing in WBANs has some challenges such as, data management (collected and store data in a specific time and space and locations), data processing, data analysis (modeling and analysis tools for different applications), communication interface between the cloud and BAN resources, and stream data management for collecting and cleaning and aggregating and transferring and storing data. Also, aggregation and real-time processing of large scale data information.

Scalability is other challenges of WBANs communications [59]. Moreover, flexible system should be able to handling and configure it self-automatically. Therefore, self-organization and self-maintenance and self-management should be supported. Providing quality of service is another issue that related to the WBANs, where service is the appropriate service depends on their application and the nature of transport sensitive data [60]. For instance, when the WBANs implemented to monitor and support the patient's health care status, the information must be transfer real-time. Delays in the transfer of significant or critical alarms may be disastrous [61]-[63].

Another significant factor of WBANs applications is security of information. For instance, data confidentiality (transmit information private and encryption the information), data authenticity (verify the data is being sent from the trust center and not a false adversary), data integrity (verify when data is transmitted in an insecure) and data freshness (guarantees data in transmission). The security and the privacy of the collected personal medical data for protection should be encrypted to protect the patient privacy.

WBANs nodes should ensure integrity, high accuracy, confidentiality, and authenticity of data downloaded [64]-[66]. A privacy enhanced authentication scheme for the medical information system is proposed in [67], however, in [68] by Kumari et al. proposed scheme for verifying the attack, online password guessing attack and imitation attack. The digital signature is investigating in [69] to ensure the security of information that can ensure confidentiality of information. False alarms or Adding false data may lead to misleading results on patient safety. Result in a life threatening for the patient. Thus, security in WBANs should be established in various layers and levels for instance the physical layer and the network layer. Nonetheless, security upstairs may increase the energy consumption and influence the network lifetime [70], [71].

TABLE IV. APPLICATION AND USAGE OF WBANS

Application Type	Sensor Node	Type of sensor	Bandwidth (Hz)	Accuracy (bits)	Data Rate	Duty Cycle % per time	Power Consumption	QoS	Privacy
In-Body Application	Glucose sensor	Strip-base	0-50	16	Few Kbps	< 1%	Extremely low	Yes	High
	Pacemaker	accelerometer	0-500	12	Few Kbps	< 1%	low	Yes	High
	Endoscope Capsule	a pill and contains a tiny camera	--	--	> 2 Mbps	< 50%	low	Yes	Medium
On-Body Medical Application	ECG	Skin/chest electrodes	100-1000	12	3 Kbps	< 10%	Low	Yes	High
	EMG	Skin electrodes	0-10000	16	320Kbps	--	--	--	--
	Temperature	Temperature probe or skin patch	0-1	8	120bps	--	--	--	--
	SpO2	Pulse Oximeter	--	--	32 Kbps	< 1%	low	Yes	High
	Blood Pressure	Arm cuff based monitor	0-1	8	< 10 bps	< 1%	High	Yes	Medium
On-Body Non-Medical Application	Music for Headsets	sound	--	--	1.4 Mbps	High	Relatively High	Yes	Low
	Forgotten Things Monitor	monitor	--	--	256 Kbps	Medium	Low	No	Low
	Social Networking	Mixed sensor	--	--	<200 Kbps	< 1%	Low	No	High

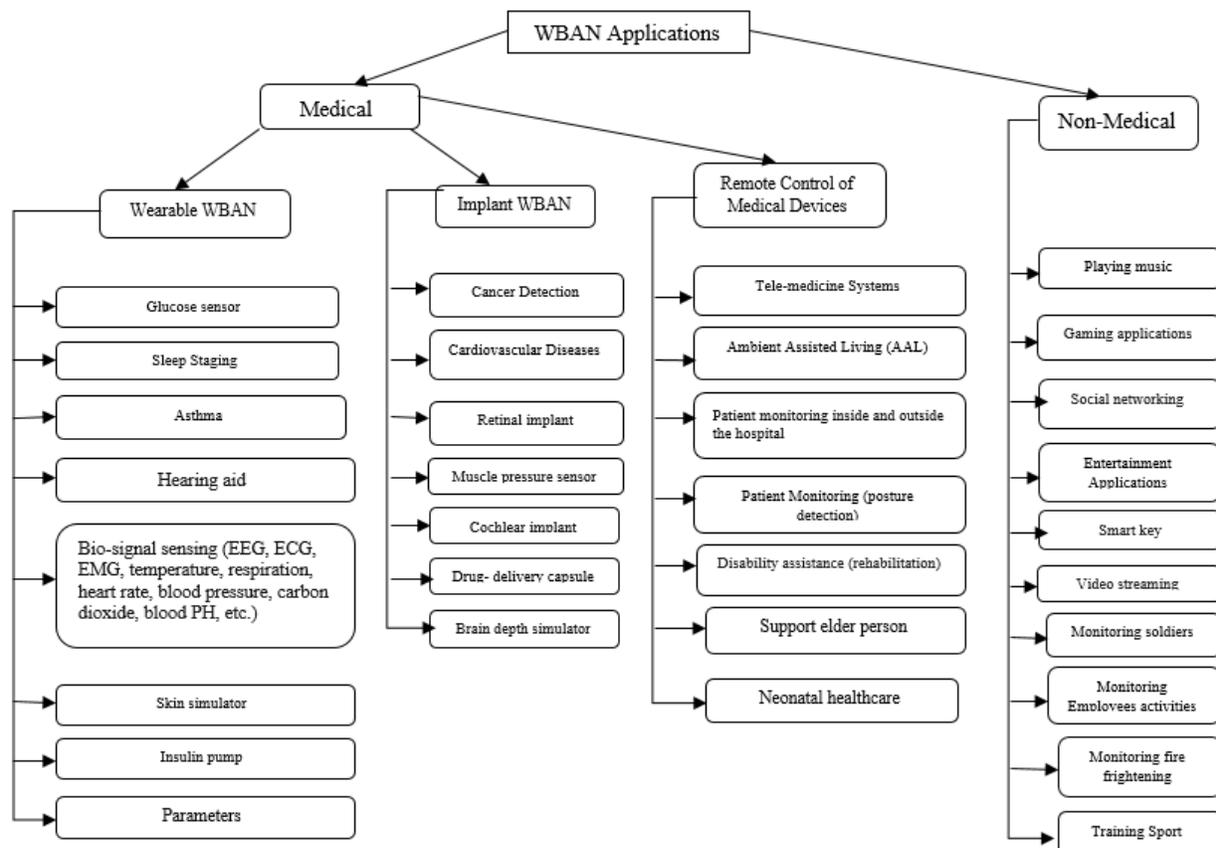


Fig. 3. Application for WBANS.

TABLE V. SUMMARIZE THE EXAMPLES OF ROUTING PROTOCOLS WITH RESPECT TO ENERGY IN WBANS

Type of protocols	Protocol	Author	Date[] Ref []	Advantage	Disadvantage	+Simulator	Energy Consumption	Goal
Mobility-Aware								
	IM-SIMPLE	Javaid, N., et al.	2014 [36]	stability period: Good network lifetime: Good throughput: Good energy consumption: Good Throughput Good Stability: Good Life Time: Intermediate	packet drop: high	-	Good	Reducing energy consumption
	EERS	Liang, L., Ge, et al.	2014 [37]	network lifetime: Very Good energy consumption: Low delay: Low	Overhead: high	Lab Room	Low	Achieving higher reliability and energy efficiency
Restriction and number of relay								
	REEC	Sandhu MM, et al.	[38] 2014	stability period: Good network lifetime: Good throughput: Good Residual energy: Good	—	--	Good	Reliable energy-efficient critical data routing
	EAWD	Elias J	[54] 2014	energy consumed: Low does not need to install additional relays	—	3D electrom	Low	increase the network lifetime
	Braem, et al.	Braem B, et al.	[39] 2007	network lifetime: Good	There is not the possibility of the continuous use of relays, so the cooperation technique has been proposed instead.	--	Good	Energy efficiency of communication despite path loss
Link-Aware								
	IM-Simple	Javaid, N., et al.	[36] 2014	stability period: Good network lifetime: Good throughput: Good energy consumption: Good	packet drop: high	---	Good	Reducing energy consumption
	AMR	Ortiz AM, et al.	[55] 2012	network lifetime: Good, packet delivery rate: increased data loss: decreased residual energy: high	Requires additional packet switching between nodes	---		Adaptive multi-hop tree-based routing; improving network performance
	EERS	Liang, L., Ge, et al.	[56] 2014	network lifetime: high energy consumption: low delay: low	overhead : high	Lab room		Achieving Higher reliability and energy efficiency
	CO-LAEEBA	Ahmed, S., et al.	[41] 2015	stability period: Very Good network lifetime: Very Good throughput: Very Good residual energy: Good path loss: Good	--	---		Providing a link-aware and energy-efficient protocol
Thermal-Aware								
	IA-MAC	Ahmad A, et al.	2014 [46]	energy consumption: Low Cost: Low network lifetime: Good packet loss rate: low Packet delivery ratio: Intermediate Number of packet drops: Good	packet transmission: low cycle count: low	--	Good	Improving medium access control; achieving adaptive sleep/wakeup mechanism
	LTRT	Takahashi D, et al.	[48] 2007	temperature rise: Low Delay: Low	Packet delivery rate: High	Java	Low	Reducing the temperature rise

				average hop count: low				of the implanted sensor nodes in the human body
	TSHR	Ahourai F, et al.	[57] 2009	temperature rise: Low Delay: Intermediate packet drop: zero network lifetime: long	packet delivery: high	C++	Low	Efficient thermal-aware routing
	TARA	Tang Q, Tummala N, et al.	[47] 2005	Temperature rise: High Temperature: balance	packet delay: high network lifetime: short	Matlab	Low	Avoiding hotspots during packet transmission
Cross-Layer								
	COMR	Abbasi UF, et al.	[43] 2014	network lifetime: Good delay: Good energy consumption: Good	packet delivery ratio: decrease	Omnet++	Good	Improving reliability by a cross-layer opportunistic method
Cluster and Tree-Based								
	RTT	Chebbu H, et al.	[42] 2012	Reliability: high	a large number of relays	Channel sounder	Good	Reliable data transfer
Medium Access Control								
	BODY MAC	Fang G, et al.	[44] 2009	bandwidth allocation: Good delay: decreases power consumption: Good	--	OPEN-ZB TOOLSET	Good	Presenting a MAC protocol for energy efficiency
	MED MAC	Timmons NF, et al.	[45] 2009	power efficiency: Good overhead: no synchronization	---	OPNET	Good	Presenting a medical MAC protocol for energy-efficient and adaptable channel access
Opportunistic								
	COMR	Abbasi UF, et al.	[43] 2014	network lifetime: Good delay: Good energy consumption: Good	packet delivery ratio: decrease	Omnet++	Good	Improving reliability by a cross-layer opportunistic method

V. RADIO TECHNOLOGIES OF WBANS

The general standard used in Body Wireless Communication is IEEE 802.15.1 (Bluetooth) and 802.15.4 (Zigbee), a primitively section of the 802.15 operate in a wireless personal area network (WPAN). Bluetooth is a short-range communication system that replaces the cables for electronic devices. Two categories of basic rate (BR) configuration consist of Enhanced Data Rate (EDR), and Low Energy (LE). Then, proposed Zigbee for a special case of sensor networks that extensively adopted to perform WBANS.

IEEE Standard Association recommendation the IEEE 802.15 task groups 6 for low power devices and operated on, in or around the human body for different applications in WBANS. Generally, the characteristics of the physical layer are classified in RF communication (Radio Frequency), movement of the body, None-RF communication [72]. This layer is responsible for archiving some tasks such as, active and reactive of the radio transceiver. The choice of this layer depends on usage and aspect of the application, on medical or non-medical, implantable sensor, wearable sensor, surrounding sensors. Monitoring critical signs, for example heart rate, body position, blood pressure, and oxygen saturation are now performed through small sensors [73].

These lightweight and intelligent devices are able to measure physical events, processing and wireless transmission. Wireless sensor particles are placed intra-body or implanted on the body and extend or extra-body of the smallest in a short distance of wireless networks surround the human body is done by using an RF transmission technology [74].

In late 2011, the standard of wireless network protocols was approved. The standard has explained three physical layers, Ultra Wideband (UWB), Narrow band (NB), Human-Body Communication (HBC) [75]. All of them extract to the conclusion that propagate physical layer operations based on radio frequency, whereas human body communication based on non-radio frequency. Numerous researchers have been scrutinizing inside the human body by narrowband radio signals and ultra wide band in the path lose [72].

Multiple frequency bands use monitoring operation of the physical narrowband with 402-405 MHz frequency in implantable devices. Three various bands of frequency (863-956 MHz) are for coverage wearable applications, and from 2360 to 2400 MHz they are for medical applications. Moreover, UWB PHY operates at higher frequency regions, particularly the low (3-5 GHz) and high (6-10 GHz) bands with a channel bandwidth of 499.2 MHz [76]. HBC is

classified in two-body communications channel (BCC) or internal body communications (IBC) [77]. IBC can reuse frequency in the following desirable features, security, and energy [78]. Since NB is lower frequencies, so numerous numbers of healthcare applications are matched.

Table 6 summarizes the characteristics of the body communication channel and internal body communications [72], [79]. HBC has some advantages such as, intrinsic security, saving, energy consumption compared to UWB. Molecular communication use molecules as messages transferred between a sender and a receiver by using nanotechnology for Nano medicine application and alternative of ultrasonic communications [80].

Generally, IBC communication within the body can be categories into two sets based on how the electrical signals are transmitted, Capacitive coupling (electrical field) and the galvanic pair (waveguide) [74]. In both kinds of the sender and receiver, two pairs of electrodes are needed. In the coupling capacitor, only one of the electrodes of the deliver and the receiver is connected to the body, while the other electrode (ground electrode) is floating. In the galvanic pair method, both the sender and the receiver electrode are connected to the human body [78].

Capacitive theory with communication within the body by coupling capacitor engender is attached from human body to the around environment. The signal is created between transmitter and receiver channel by creating a loop through the surrounding. The transmitter signal electrode genders the electric field in the human body. The electrical signal is controlled by an electrical potential and acts as a conductor with the earth and return path in the body [79]. On the other hand, a galvanic couple of pairs of alternating current is achieved in the human body, which is controlled by the AC current in the body as a deliberation line [77]. Using various electrical signals between the electrodes of the transmitter in the galvanic coupling with communications inside the body, main release of the two signal transmitter electrode and a weak signal in the receiver occurs by two electrodes [74]. Generally, ion content in the human body carries information by galvanic coupling method. Table 7 summarizes the capacitive coupling method and compares galvanic coupling [72].

TABLE VI. COMPARISON BETWEEN IBC AND RF

	IBC	RF (NB, UWB)
Communication Medium	Human Body	Air
Frequency Band	Centered at 21 MHz ($f_{BW} = 5.25$ MHz)	Different bands (402 M-10 GHz)
Data Rate	less than 2 Mb/s	less than 13Mb/s
Transmission Range	less than 2 m	10 m
Signal Attenuation	Low	High(Body Shadowing)
On-Body Antenna	No	Yes
Energy Efficiency	High	Low

TABLE VII. COMPARE BETWEEN TWO METHODS OF COMMUNICATION IN WBANS

Galvanic Coupling	Capacitive Coupling
Quality of signal influenced by dielectrics of human tissue.	Quality of signal influenced by the environment around the body.
Lower transmission data rate.	Higher transmission data rate.
Must be connect with body tissue .	Dose not require connect with the human body tissue.
Location base, exact distance and orientation along the body.	Interference the surrounding devices
Modeled by a waveguide.	Modeled by a perfect conductor.
Ground is not require as a refrence.	Ground is require as a refrence.
Domain of signal is the body tissue.	Domain of signal is the environment.

VI. PATIENT MONITORING AND TELEMEDICINE SYSTEMS

Monitoring human activity with WBANS classification is: Remote monitoring (elderly, baby, staff, etc.), security (soldiers), training (sport), emergency situation (rescue, firefighters), safety (elderly, personal safety, etc.) [25].

The recent innovation in telecommunications and information technology provide clinical health care system at a distance. This system improves health care quality and helps the barriers of distance, special in rural communities that they are inaccessible. Developments in the mobile application, to health care system professionals in various locations, permit the patient to share information and discuss issues of helping them to be used in the same place. A telemedicine system through mobile technology can significantly reduce the overall cost and it can save time [81]. The incidence of disease such as kidney problems, Alzheimer's disease, Parkinson disease, anxiety disorder, and infant death syndrome, assistance to the disable people can be reduced by providing health care [82].

Disable people, for example paraplegic diseases used for monitoring the position of the legs and nerves and simulate the positioned of the muscles. BANs for disability people classified in way finding for blind persons, monitoring elderly people, activity monitoring, posture detection, rehabilitation. This kind of device can direct involvement for disabling the person, such as electric wheelchair or control the function invention, for instance fall detection system. In [83] suggested the architecture for fall and accident detection that consist of a gyroscope and accelerometer and a magnetometer that placed on the hip and the user's leg and on the upper torso. The result depicts that this system can investigate and reduce the fall detection and accident in 85/6%.

In chronic diseases that usually take more than three months. The diseases kill 17 million people a year, which can be reduced or prevented by a strategy of suitable health care system. Common chronic diseases exist, for example, asthma cancer, diabetes, and viral diseases such as hepatitis C. In the following, some of the disease can support and monitor, the vital sign of patients are explained.

Diabetes includes a metabolic disease in which blood glucose in the long term is more than one level. Diabetes is resulting not enough insulin production in the pancreas. In the early stages of diabetes, people may have no symptoms. Many people are identified random in a test or during screening. Increasing blood sugar, diabetes symptoms become apparent. Frequent urination, Polydipsia, overeating, weight loss, despite increased appetite; fatigue and blurred vision are common early symptoms of diabetes. Many patients diagnosed with diabetes or have diabetes for several years. Worldwide, more than 246 million people endure from diabetes [13]. A number that is expected to reach 438 million in 2030 to about 7.8 percent of the population accounts for young people. Conclusion monitoring and proper dosage reduce the risk of fainting. By using WBANs to automatic, monitoring diabetes, as soon as high or low level of glucose, a signal can be transferred to the system and alter the patient for doing proper actions.

Cardio Vascular Disease (CVD) is the leading death in the world and includes almost 30% of all deaths globally. Based on the World Health Organization, 17.5 million people worldwide each year die from heart attack or stroke [12]. Most of these deaths could be avoided with suitable medical health care. This is an instance to show the need for constant monitoring of wireless networks and their usefulness in the body.

Numerous of people suffer diabetes or cardiovascular diseases, and percent of population aged 60 years and elderly population will grow in the future that is predicted to prompt to 1200 million people in year 2025. These disease rapid epidemics show many potential customers and the absence of the medical center and staff and nursing homes for older people are observed. WBANs continuously monitor the vital physiological parameters of the body [84]. Therefore, there is no need the patient stays in hospital for a long time and do not spend lots of money for health care. For instance, the place of a wireless sensor network used to monitor a patient's medical body is explained in Fig. 4 [16].

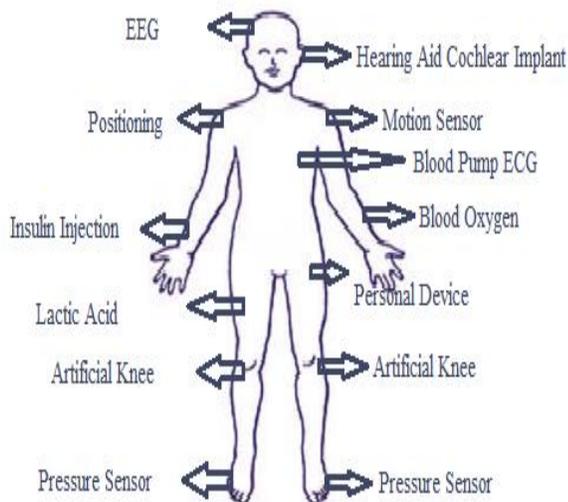


Fig. 4. Example of patients monitoring in WBANs

Different sensors installed on clothes that connect with the body or even under the human skin of a person to measure temperature, control the blood pressure, heart rate, ECG, EEG, respiration rate, SPO2 and after measuring the device; the patient can get medications from the system [16]. Accelerometer sensors are used to monitor and distinguish body posture that placed on some strategically location on the human body. The WBANs has a critical role in real-time monitoring of healthcare. Any wearable sensors monitor a special physiological sign. These drugs can be predetermined and is delivered by an external source or instant after the sensor notice a problem [85].

Cancer is one of the biggest ventures to human life. A series of partial sensors that are able to monitor cancer cells in the human body sensor integrated network and this allows doctors to detect tumors without biopsy. It is estimated that by the National Center for Health Statistics, 2020 with an increase of 50 percent, cancer deaths reach to 15 million.

The epileptic is seizures due to abnormal activity of nerve cells in the brain cortex. Brain imaging and blood tests may diagnose the disease. Epilepsy often confirmed by electroencephalogram (EEG) and imaging. Electroencephalogram (EEG) can help show brain activity increased risk of seizures. In the diagnosis of epilepsy, EEG may help distinguish the kind of seizure or already syndrome. Diagnostic imaging by CT scan and MRI after a febrile convulsion to detect structural problems in and around the brain is recommended [86].

WBANs can also be used to prepare assistance to people who are not acting well. To illustrate, paraplegic patients can be equipped with sensors to determine the position of the legs, or the sensor is connected to the nerve and creates to restore the ability to move. An additional example is the help for the vision. The artificial retina includes a matrix of miniature sensors, which can be implanted in the human eye. Artificial retina chips deliver electrical pulses to the brain and nervous system. The input can be gained locally by light sensor or by an external camera in a pair of sensitive glasses. Therefore, help patients that limited or no eye to see [87].

Body sensor networks for monitoring patients with asthma and allergy factors in the air and provide feedback in real-time to help a doctor [13]. Location-based system was designed, which diagnosed oversees environmental factors and allergy diagnosis in patients [88]. Approximately 300 million people in worldwide suffer from asthma and 250000 people death every year death.

There are other survey studies in the literature [30], [89], [90]. This overview currently explains thousands of opportunities where wireless sensor networks are suitable for body. The significant characteristic of all these programs is that the wireless sensor network is used to improve the quality of the user's life.

VII. CONCLUSION

The accelerating health care cost and high demand for medical services call for innovative solutions to ensure fast and cost-effective medical monitoring cause for evolution in health care systems. Becoming mature, enough in wireless

communication radio technologies led to emerge WBANs. This network consists of miniature electronics and low-power sensors that attached or implanted on body for transferring information of monitoring patient health in all-day and anywhere. With the current technological evolution, these networks have various usages in different scope not only in medicine, but also in entertainment, fight, travel, industry, game, sport and so on. Thus, recently researchers focused on issues related to improve communication and applications.

We believe that, using WBANs can cause patient no longer stays in the hospital and attains easier communication with doctors and gain online medical consultation and save time and cost for care. These technologies can regard the next step in improving personal health care systems. In soon, wearable BANs could be used for virtual social interactions: all data can be swapped through BANs when meeting each other or share in social networks. This information can gather processing and management by ad-hoc mobile sensors and different applications in events and analysis information for preventing disasters and prevention medical emergency.

In this survey, we have reviewed the current research on WBANs. In order to find and investigate the most relevant research articles in this area. First, we present some fundamental mechanism and concept in WBANs and review challenges and numerous WBANs applications. Then, we highlighted to need to be addressed to make WBANs for a wide range of applications for researchers and developers.

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Performances Analysis of a SCADA Architecture for Industrial Processes

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Abstract—SCADA (Supervisory Control And Data Acquisition) systems are used to monitor and control various industrial processes, and have been continuously developed in order to incorporate the new technologies from software development and field busses areas. The middleware communication has the most relevant role in the development of such complex distributed systems as SCADA systems. These systems are very complex and must be reliable and predictable. Furthermore, their performance capabilities are very important. This paper presents a performance analysis of a SCADA system developed for Windows platform, including Windows Compact Embedded. The analysis is focused on the performance difference between computing systems based on Windows desktop and Windows CE operating systems. The utilization of the Windows CE is useful on the application with real-time requirements that cannot be achieved by the Windows desktop. Testing the application and analyzing the results led to the validation of the proposed SCADA system.

Keywords—SCADA systems; middleware; data acquisition; data stream; distributed systems

I. INTRODUCTION

In the last decade, the SCADA systems that are found anywhere have been developing exponentially by including the new efficient and reliable technologies from the IT&C field. The SCADA applications are complex systems that acquired data from one or more local and remote processes. Furthermore, a SCADA system can control these processes by sending commands to the actuators depending on the type of process [1]. This system has the advantages of increases efficiency and profits and lowers costs.

A human operator can use this distributed system to remote monitor and control of the industrial processes, by using the HMI (Human Machine Interface) [2] provided by the SCADA system. This interface allows the handling of data related to that application (data acquired from the processes and the commands sent to the processes).

The most common areas of applicability for SCADA systems are the following: telecommunication systems [3], [4], power distribution systems [5], energy transmission systems [6], oil industry [7], gas and natural gas extraction, ore extraction systems, storage systems [8], irrigation systems [9], water distribution systems [10], sewerage systems, parameters measuring equipment for fluids, hydroelectric systems [11], monitoring systems for a production line or an entire company

[12], monitoring systems for a building or a building complex, etc.

In this paper, it is analyzed a proposed new architecture of a SCADA system. The analysis focuses on the performance achieved with different data volumes and different operating systems.

Furthermore, this paper is organized as follows: Section II presents the most important specifications launched for the industrial field and the main manufacturers for the SCADA applications; Section III describes the architecture of the SCADA system; Section IV focuses on several considerations regarding the implementation; Section V highlights the experimental results obtained, whereas Section VI finalized with conclusions.

II. RELATED WORK

Over the years, a wide variety of applications have been developed to achieve the data exchange between two devices or between a device and a software application using the client-server or peer-to-peer paradigm (M2M – Machine to Machine and D2D – Device to Device). These include: COM / DCOM (Component Object Model/Distributed Component Object Model) -based classic applications, applications based on the .NET platform, CORBA (Common Object Request Broker Architecture) - based applications, Web Services applications, Adaptive Communication Environment (ACE) applications, or applications based on other technologies.

In turn, the applications using the specifications launched by the OPC Foundation have a unified view [13]. These specifications are the following: OPC (Object Linking and Embedding for Process Control) Data Access, OPC Alarm and Events, OPC Historical Data Access, OPC Unified Architecture, OPC .NET (previously called OPC eXpress Interface - XI) [14]. Depending on the type of architecture they use, these specifications have been divided into: OPC classic – based on DCOM (it includes: OPC Data Access, OPC Alarm and Events, OPC Historical Data Access), OPC Unified Architecture and OPC .NET [15].

Due to this unified vision, the OPC specifications have become widely known and used by most of the production systems as the following: MES (Manufacturing Execution System) systems, HMI/SCADA systems and ERP (Enterprise Resource Planning) systems.

Currently, SCADA applications used in industry are being produced by many manufacturers, such as the following: Siemens, ABB, Emerson, Rockwell Software, Schneider Electric, Matrikon, B-Scada, Iconics, Intellution, Indusoft, Mitsubishi Electric, Yokogawa Electric, Honeywell, WonderWare, Omron, Citect, GE/Fanuc, USDATA, National Instruments, and Think & Do. However, each of the application developed by the manufacturers mentioned above, is targeted for certain issues and for some devices.

III. ARCHITECTURE OF THE PROPOSED SCADA SYSTEM

In order to implement a monitoring and control system of some industrial processes, the main functions that a SCADA application must consider are the following:

1) *Data acquisition* – It refers generally to acquiring data from a process, either as inputs or outputs, or even data that change during the process.

2) *Communication/Data transfer over the network* – It is related to the “transport” of data towards the Master station and vice versa (from the Master station towards the process). An important role is played by the communication network that must be well developed, flexible and easy to remodel.

3) *Data presentation* - It can be seen by the human user through a graphic interface located on the Master server. It presents an overview of the monitored process, it alerts the human operator if certain limits are exceeded, it processes the data collected from the process, it details the information at the command of the user, and keeps record of all the logs.

4) *System Control* - Represents the manual or automated configuration of the system, depending on the parameters and events that have been generated. This function can only be performed with the help of the human operator (the user), and the communication environment between the operator and the system is represented precisely by the interface of the SCADA system. This interface displays real-time process data, and the system is controlled by entering commands or messages for the process.

All these four important functions of a control and monitoring system intertwine at the most important level that is **middleware** level. In fact, this is where the **data exchange** is performed.

Starting from the proposed architecture presented by the Gaitan et al. in [16] the system is an industrial process to monitoring and control, designed and developed to meet the requirements of a complex system called the Metropolitan Heterogeneous System for Monitoring Utility-Specific Data (SMEDU).

The architecture of this system is presented in Fig. 1 and contains two software modules, namely: the client module and the server module; the middleware bus connects the two modules [17], [18].

The client module is an executable software module, called MCIP (Monitoring and Control of Industrial Processes) [19], after the role it has to fulfill within the proposed SCADA system. This is in fact a standard communication interface through which the user (the manager of an enterprise or a

production line) can create and organize all the objects needed in the managed industrial process. The MCIP application presents two working modes:

- The first is the working mode, enabling the implementation and modification of the project. This working mode is performed when the application is unplugged from the servers. Basically, in the editing mode, the user can add as many graphic objects as he needs in the process, connecting them to the real devices to be monitored. Also, he can set certain features, and has the possibility to change or delete objects. The types of objects used are: graphic objects for displaying texts or images, template objects, control objects and middleware interfacing objects, through which the human operator can access the values in the process.
- The second working mode is the execution mode. In this case, the application executes what has been designed in the editing mode.

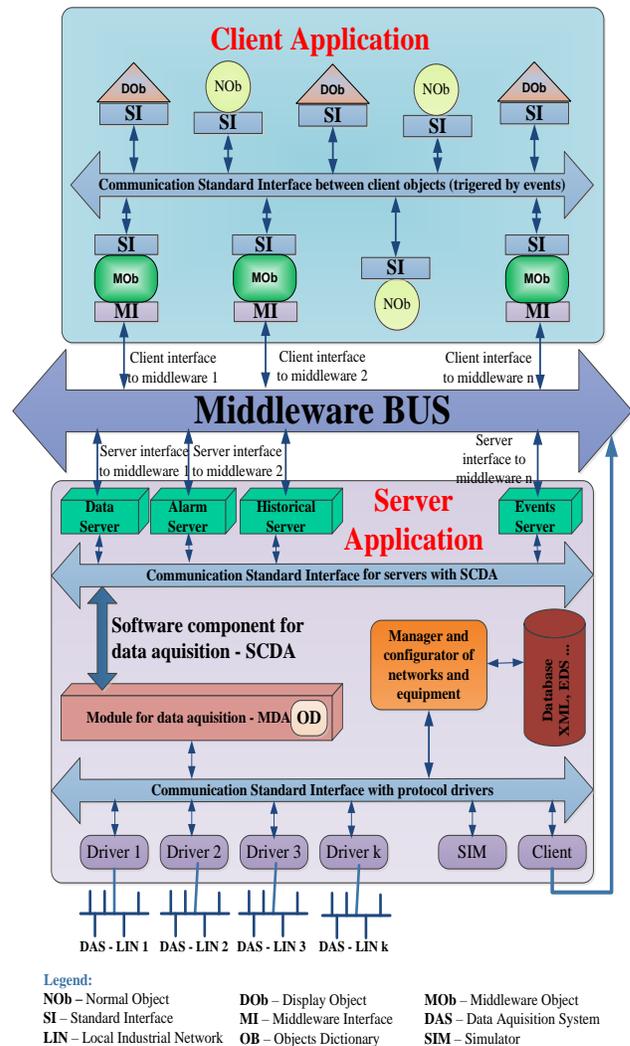


Fig. 1. Architecture for real-time heterogeneous distributed systems oriented SCADA applications [16].

The middleware bus is a software bus connecting the client mode to the server mode. Here, we can find some middleware technologies from the ones mentioned above, namely: COM/DCOM, CORBA, .NET technology, Web Services, but also others. These technologies must ensure the client-server communication in all possible cases.

The server module is also an executable software module that brings together, through standard communication interface, a variety of servers with the data acquisition software component, the object dictionary, the network manager, the database and the device drivers.

Within the server module, there may be several types of servers that use different specifications, but also serve a wide range of activities. For example, the most common types of servers are: data access servers, alarms and events servers and history servers.

The data dictionary, which can be found at the level of the data acquisition software, is nothing more than a hierarchical organization of the process data. Its most important feature is the uniformity of the data presentation, namely, it remains the same for any type of server used.

The server application also includes a standard interface for connecting to the database, as well as to the network manager.

IV. THE IMPLEMENTATION OF THE PROPOSED SYSTEM

As mentioned in the previous sections, the proposed system has been designed according to the client-server model and contains two software modules, namely: the MCIP client and the gpDAServer [19] data server.

Each of these has been designed so that in the end it could be easily installed and used by any device in the industry. Therefore, in the end, the two software modules will be executable.

The server module was developed in C++, and the MCIP client was developed as an application in C # (using the .NET platform).

When implementing both modules, the following aspects have been considered:

- A middleware object can connect to a single server placed on the same computer as the client application or any other computer in the network that supports the same middleware technology. If we are dealing with different computers, we have two possible cases: the two devices are in a LAN (local connection) or the two devices are connected to the Internet (this time, the connection is remote).
- The data provided by a server can be retrieved by as many middleware objects need that data.
- A server can connect to as many local industrial networks as possible.
- At the level of the data dictionary, the most important thing is the uniformity of the data presentation. In other words, all servers must have the same data and in the same mode.

V. EXPERIMENTAL RESULTS

In order to validate the proposed system, a total of four tests have been performed on two similar star architectures. The differences between the two test architectures are the type of system used (real time or not) and the implementation mode for each individual case.

The first architecture consists of 7 test stations and a Master station (8 PCs with Windows XP/7/8/10 operating systems) connected in a TRENDnet TEG224WS+ switch, with a 100Mbps Ethernet interface. This test architecture is presented in Fig. 2.

The second test architecture consists of 6 embedded eBox 2300 SX systems, 1 embedded PDX 089T system with Windows CE real-time operating system, a Master desktop PC (the same as in the first test architecture) and a Super Stack II Baseline 10/100 Switch. This test architecture is presented in Fig. 3.

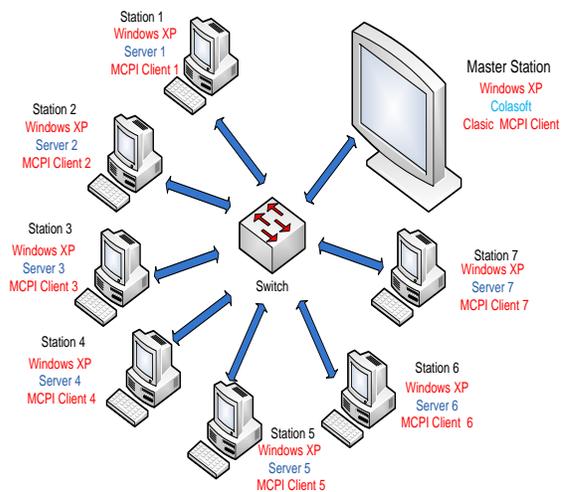


Fig. 2. Test architecture 1 [19].

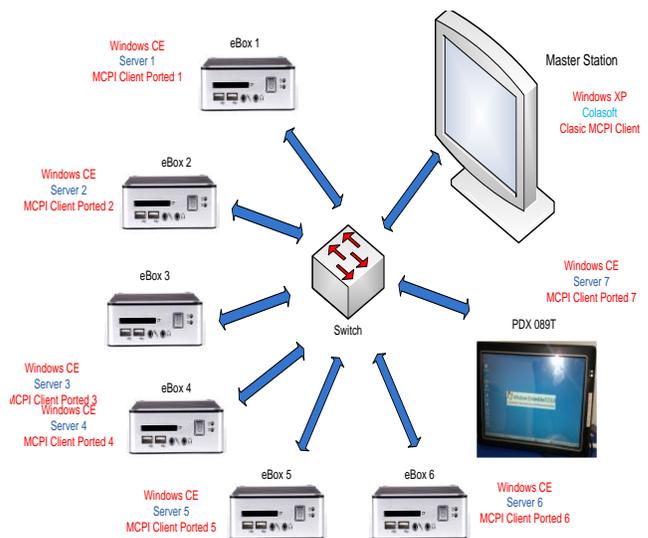


Fig. 3. Test architecture 2 [19].

In both cases, the Master station was used to monitor the flow of data sent to the local network. That is why the Colasoft Capsa Enterprise software (software developed for analyzing data flow) was installed on the Master station. It allows the interception and analysis of Ethernet frames in terms of transmission speed.

A MCIP client application and a server application have been installed on each of the other 7 systems (either the 7 PCs in the case of Test Architecture 1, or the 7 embedded eBOX or PDX embedded systems in the case of Test Architecture 2). These were launched in execution, and a process and the objects required for test have been added to each MCIP application. In this way, the client application has connected to the server through a OPC middleware object, thus managing to read or even write data. Through this object, it was possible to set an update rate required for reading and writing data.

In terms of transmission rates, the test range was of 100ms (0.1seconds) to 1000ms (1 second). Also, for each OPC object, the data transfer speed for 1 item, 5 items, 10 items and 15 items has been tested.

Fig. 4 shows the chart of experimental results obtained by testing the Test Architecture 1 at different refresh rates and for a different number of items in a group.

Similarly, tests have been performed for Test Architecture 2 and the experimental results are shown in Fig. 5.

In order to facilitate the analysis and interpretation of data obtained from the experimental tests, a comparison has been performed between the data resulted from the tests performed on the two operating systems (Windows XP and Windows Embedded CE), using identical parameters.

The analysis of the experimental results chart in Fig. 3 shows a tendency to decrease the data transfer speed once with the increase of the update rate.

The analysis of the experimental results chart in Fig. 4 also shows a tendency to decrease the data transfer speed once with the increase of the update rate.

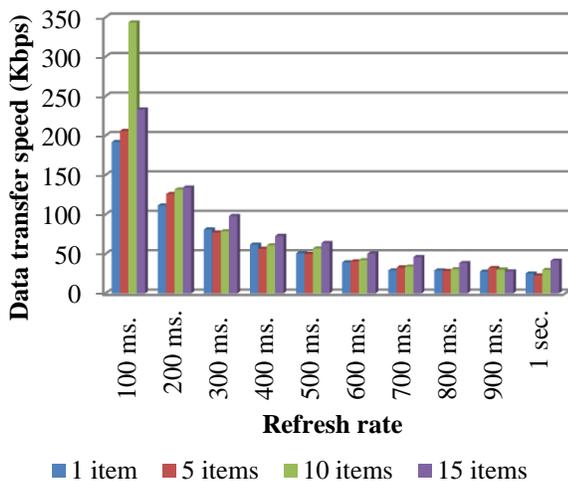


Fig. 4. Results diagram for test architecture 1.

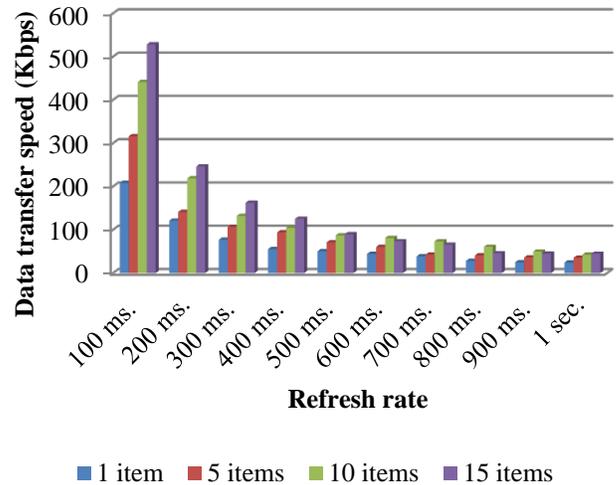


Fig. 5. Result diagram for test architecture 2.

Also, there is a minor difference between the data transfer speed of the two tested operating systems. This difference may be due to the fact that the server, at a certain point, might not perform exactly the update rate, because the CPU is overloaded. The update rate is performed on the server, because it calls a callback function in the MCIP client application.

Another explanation might be the implementation mode of the TCP/IP stack for the Windows Compact Embedded (CE) operating system. It can also be noticed that, at high update rates, the data transfer speeds in the case of Windows CE tests are close to the values obtained for Windows XP.

In conclusion, following the tests carried out on the two architectures and the analysis of the experimental results, the proposed model and solutions have been validated.

VI. CONCLUSIONS

The need to have more and more efficient and reliable systems led to the rapid development of SCADA systems. However, there is not yet an architecture pattern that can be used by all types of SCADA systems and that can meet all requirements.

The system proposed in this article attempts to satisfy these needs. This is why it has been designed to be easy to use and improvable by adding new components or features that might completely change the context.

This paper presented the performance analysis of a SCADA application that is executed on a computing device based on Windows desktop and Windows CE operating systems. We can conclude that the Windows CE can be used at the application with real-time requirements, which cannot be achieved by the computing systems based on Windows desktop.

As future work, we intend to develop the proposed system to approach other technologies. We also want to port the server application on a real-time system (Linux RTAI or Windows Compact Embedded).

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Performances Comparison of IEEE 802.15.6 and IEEE 802.15.4

Optimization and Exploitation in Healthcare and Medical Applications

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Abstract—In this paper, we simulate the energy consumption, throughput and reliability for both, Zigbee IEEE 802.15.4 Mac protocol and BAN IEEE 802.15.6 exploited in medical applications using Guaranteed Time Slot (GTS) and polling mechanisms by CASTALIA software. Then, we compare and analyze the simulation results. These results show that the originality of this work focuses on giving decisive factors to choose the appropriate MAC protocol in a medical context depending on the energy consumption, number of used nodes, and sensors data rates.

Keywords—Guaranteed Time Slot (GTS); polling; WBAN; IEEE 802.15.6; IEEE 802.15.4; energy consumption

I. INTRODUCTION

Continuous Monitoring of patient's vital signs by Wireless Sensor network WSN can help in the diagnosis and can also monitor the patient's history in everyday life activities so as to provide accurate diagnosis simulation results compare.

Doctors can check the complete details of patients from a remote location and can then recommend a suitable medication. The main purpose of this technology is to presents reduce the load at hospitals and provide efficient healthcare facility remotely.

Recently, WBANs are becoming more and more studied and developed by research organizations. In 2003 IEEE has standardized IEEE 802.15.4 for industrial applications, but with the increasing of WBAN demand, this protocol was adopted as the main solution in several WBAN projects [1]. Then Bluetooth Low Energy, have been proposed as likely candidates to lead the development and extended deployment of WBANs, but his small network scalability was a handicap. In 2012 the IEEE 802.15 Task Group 6 (BAN) [2] standardized the IEEE 802.15.6 communication standard optimized for low power devices and operation on, in or around the human body to provide a variety of applications including medical, personal entertainment and others [3].

In the literature, we notice that a big importance is given to WBAN and especially the comparison between IEEE 802.15.6 and old WBAN protocols, starting with the authors in [4] that provide a comprehensive survey on Wireless Body Area Network. Others in [5] attracted a review paper on the recent advances in MAC protocols for WBANs. In [6] authors presents the specifications and characteristics of medium

access protocols for WBAN. Based on this comparison many researches were done to improve WBAN performances especially in terms of physical layer and energy consumption [7].

However, all these papers compare WBANs protocols in a high sense without taking into consideration neither the application field, nor the sensors constraints. In this paper our contribution aims to compare the IEEE 802.15.4 and IEEE 802.15.6 from a medical point of view taking into consideration the practical medical sensors data rate. For this purpose, this paper is presented into three sections: Section 1 introduces an overview of IEEE 802.15.4/6 MAC layers specifications; in Section 2 we investigate the power and throughput compromise between the two protocols access mechanisms namely Guaranteed Time Slot (GTS) and polling; in Section 3 we present our simulation results to compare between the two protocols under the same simulation conditions, then the paper gives some proposals how to improve WBANs efficiency in the medical field.

II. AN OVERVIEW OF THE IEEE 802.15.4 AND IEEE 802.15.6 MEDIUM ACCESS CONTROL SUB-LAYER

A. IEEE 802.15.6 MAC Specifications

IEEE 802.15.6 is the standard developed by the IEEE 802.15 task group 6 (BAN) to face several wireless technologies challenges especially ultra-lower power constraint, lower device complexity, higher transfer data rate, shorter range communication and security [2]. The last draft of this standard was published in 2012 and specified the three IEEE 802.15.6 physical layers such as the Narrowband (NB), Ultra wideband (UWB), and Human Body Communications (HBC) layers. It defines also the MAC layer specifications that facilitate the control operation of the entire system. The Nodes that communicate are organized into logical sets controlled by a collective hub. The hubs are responsible for coordinating channel access by establishing one of the following three access modes: Beacon mode with beacon period superframe boundaries, Non-beacon mode with superframe boundaries, Non-beacon mode without superframe boundaries using polling access method which is the most important advantage of the standard. Polling process begins with the nodes getting connected to the hub. The hub sends a polling packet to the node that is being polled. The node that receives the polling

packet transmits data packets stored in its buffer. When the transmission of data is over, the polled node sends a poll finish packet to the hub [8]. The hub on receiving the packet starts polling the next consecutive node in the cycle and the process is repeated. If no packets are present in a node's buffer, the hub switches the poll to the next node immediately. Polling is, in fact, in between TDMA and CSMA/CA [9]. The base station retains total control over the channel, but the frame content is no more fixed, allowing variable size packets to be sent. The base station sends a specific packet (a poll packet) to trigger the transmission by the node. The latter just waits to receive a poll packet, and upon reception sends what it has to transmit. Polling can be implemented as a connection oriented service (very much like TDMA, but with higher flexibility in packet size) or connection less-service (asynchronous). Fig. 1 well-describes the polling process.

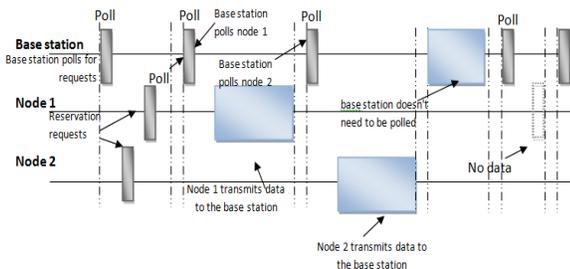


Fig. 1. IEEE 802.15.6 polling process.

B. IEEE 802.15.4 MAC Specifications

IEEE 802.15.4 [10] defines the physical layer (PHY) and MAC sublayer specifications for Low Rate WPAN (wireless personal area network) devices. The standard is defined for devices with short-range operation and low energy consumption. The IEEE 802.15.4 LR-WPAN uses two types of channel access mechanism, depending on the network configuration:

- Nonbeacon-enabled PANs use an unslotted CSMA-CA channel access mechanism.
- Beacon-enabled PANs use a slotted CSMA-CA channel access mechanism using The Guaranteed Time Slot (GTS) mechanism. GTS allows devices to access the medium without contention for nodes requiring guaranteed bandwidth, based on special superframe structure.

As shown in Fig. 2, the superframe is defined between two beacon frames and has an active period and an inactive period [11]. The active portion of the superframe structure is composed of three parts, the Beacon, the Contention Access Period (CAP) and the Contention Free Period (CFP):

- ✓ Beacon (BCN). The beacon frame is transmitted at the start of slot 0. It contains the information on the addressing fields, the superframe specification, the GTS fields; the pending address fields and other PAN related data.
- ✓ Contention Access Period (CAP). The CAP starts immediately after the beacon frame and ends before the beginning of the CFP, if it exists. All transmissions

during the CAP are made using the Slotted CSMA/CA mechanism. However, the acknowledgement frames and any data that immediately follows the acknowledgement of a data request command are transmitted without contention.

- ✓ Contention Free Period (CFP). The CFP starts immediately after the end of the CAP and must complete before the start of the next beacon or the end of the superframe. Transmissions are contention-free since they use guaranteed time slots (GTS) that must be previously allocated by the Zigbee Coordinator.

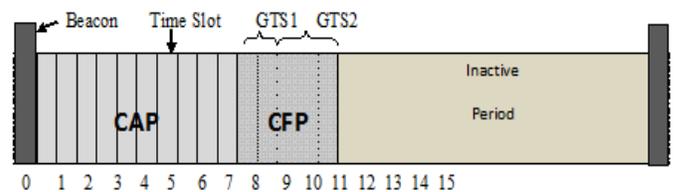


Fig. 2. IEEE 802.15.4 MAC superframe structure.

III. POOLING AND GTS: POWER AND THROUGHPUT COMPROMISE

With IEEE 802.15.6 polling mechanism, sensors sleep most of their lifetime. They wake up only to transmit Data. As soon as transmission is finished, they sleep again. The node getting uptime is determined by the coordinator [8]. The hub sends a poll packet to a node according to the poll schedule stored in the hub. Ideally, a node need to wake up just at the moment it should receive the poll packet from the hub. If the node wakes up earlier, it will have to stay awake to receive the poll packet from the hub causing unwanted energy losses. If the node wakes up after the poll packet is sent by the hub, the poll packet will be lost and the polling mechanism fails. The hub has to ensure that the node receives the poll packet. The coordinator therefore sets a sleeping time for each node after the transmission of the packets. The node should sleep for the time specified by the hub after which it wakes up at the right moment to receive the poll packet. However, because of clock synchronization problems, and due to variations in times for which packets are transmitted, the sensor may wake up before or after the stipulated time for sending the poll packet by the hub [12]. All this explains why the polling mechanism is less efficient in terms of energy consumption.

IEEE 802.15.4 standard allows for dedicated bandwidth allocation to devices through GTS mechanism. The Contention Free Period (CFP) of the superframe consists of GTS slots which the devices can use for contention free data transmission. The devices request for GTS allocation through GTS request command by specifying the number of slots needed and direction of GTS transmission (from or to the coordinator). The GTS slots are allocated in every superframe so they consume a significant bandwidth of the superframe duration. Therefore, inefficient allocation of GTS can lead to significant loss of bandwidth and degradation of the overall system performance. According to the IEEE 802.15.4 standard, the size of a GTS slot is the same as a CAP slot (i.e. 1 GTS slot = 1 CAP slot = Superframe Duration (SD) / 16). The

maximum bandwidth available by GTS should also be higher than the packet arrival rate of a device for data transmission to be complete. However, the packet transmission duration during GTS is much lower than the available bandwidth and thus a significant amount of bandwidth is wasted for every slot allocated in every superframe [13]. Thus, the GTS Mechanism is less efficient in terms of throughput.

IV. SIMULATIONS AND RESULTS ANALYSIS

In this section, and based on Castalia simulator and OMNET++ [14], we proceed to analyze the performance of protocols ZigBeeMAC IEEE 802.15.4 and IEEE 802.15.6 (BaselineMAC).

A. Sensors Data Rates

Table 1 details data rates required for some known sensors used in medical and health care applications [15].

TABLE I. DATA RATES OF SOME MEDICAL AND HEALTHCARE SENSORS

Health information	Data rate
ECG	36 kbps
EEG	98 kbps
Pulse rate	2.4 kbps
Respiratory rate	1.0 kbps
Blood pressure	1.92 kbps
Heart rate	1.92 kbps

B. Simulation Parameters

Simulations are realized by CASTALIA-3.3 software based on Zigbee/IEEE 802.15.4 and BAN BaseLine IEEE 802.15.6 MAC protocols, the parameters used for these simulations are shown in Table 2.

TABLE II. SIMULATION PARAMETERS

Number of Nodes	6
Radio Output Power	-15dBm
Sensors data rates	{20kbps to 260kbps for 802.15.4} {20kbps to 1Mbps for 802.15.6}
Frequency band	ISM 2.4GHz

C. IEEE 802.15.4 Simulations and Results Analysis

1) Throughput and reliability

During 50 s, which is the time set at the code for the simulation, we vary parameters of the MACs related to random access (CSMA/CA) and guaranteed access (GTson) and the nodes data rates. If the communication is ideal we would achieve 12500 packets when the data rate is 250 kbps, as the packet size is 1kbit [14]. However, in fact, we just receive 1600 packets according to Fig. 3.

In Fig. 3, the y-axis is the average packets received per node (only node 0 receives packets but it receives them from multiple nodes, this is what the "per node" means). The x-axis represents the data rate of nodes. We notice that the number of received packets is low for high data rates (>40 kbps) compared to the number of sent ones, and in the best case

(GTson, noTemporal) the maximum of received packets don't exceed 1600 packets.

For the same mode (GTson, noTemporal), the graph shows that the number of received packets is saturated for rates over 40 kbps which conforms to theoretical suppositions. That is because every node uses $(250\text{kbps}/5) = 50$ kbps assuming that the maximum Zigbee PAN data rate is 250kbps [10]. So as to show explicitly the dependence of the saturation data rate to the number of nodes, we vary the number of nodes from 2 up to 32 using the mode (GTson, noTemporal), which is the best simulation scenario; therefore, we illustrate results in Fig. 4.

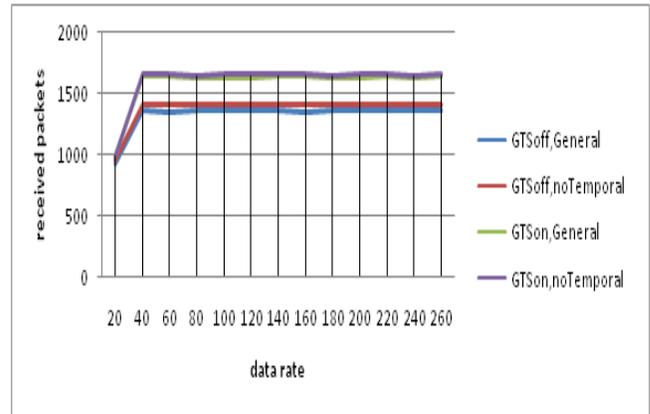


Fig. 3. Packets received per node 0 in function of sensors data rates.

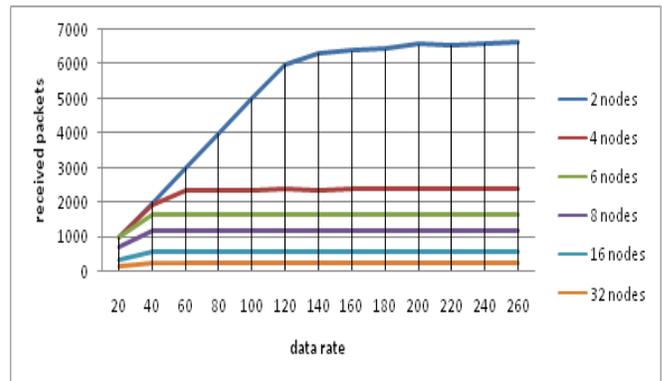


Fig. 4. IEEE 802.15.6 received packets per node 0 in function of sensors data rates for various numbers of nodes.

Fig. 4 is a plot between the number of nodes and throughput for various data rates. This plot shows that the more the number of nodes in the PAN (star topology) increases, the more the throughput of sensors decreases.

This curve gives also an idea about "Saturation Throughput" defined as the limit reached by the system throughput when the offered system load increases [16]. We observe that throughput linearly increases with the load to a certain point and achieves a constant saturation throughput. This is an important observation that contradicts the assumption used in the literature for the analytical modeling of the IEEE 802.15.4 MAC protocol. We demonstrate this fact in the table hereunder.

TABLE III. COMPARISON BETWEEN SIMULATION AND THEORETICAL SATURATION DATA RATE IN FUNCTION OF NODES NUMBER

Number of nodes (without node 0)	Saturation Throughput(packets)	Saturation data rate(kbps)	Theoretical nodes uplink data rate(kbps)
1	6500	240	250
3	2400	60	83.3
5	1600	40	50
7	1175	40	35.7
15	540	40	16.6
31	250	40	8

The results in Table 3, significantly means that nodes cannot reach their maximum data rate due to the saturation throughput. Moreover, they also show that we cannot exceed 6 nodes (including node 0) in a coordinated 802.15.4 PAN otherwise we reach the saturation data rate of 40 kbps.

We translate these results into reliability, which is the number of received packets divided by the number of transmitted ones.

According to Fig. 5, we observe that reliability is less than 80% for cases over 6 nodes, and taking into consideration that accepted value of reliability should be over 80% [17], we conclude that a coordinated Zigbee 802.15.4 PAN (star topology) can't be scalable over 6 nodes. We also observe that the best case of reliability (2 nodes), the data rate couldn't exceed 160 kbps.

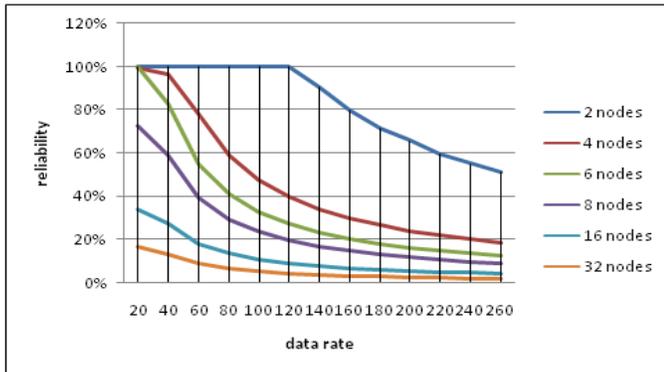


Fig. 5. IEEE 802.15.4 received packets per node 0 in function of sensors data rates for various numbers of nodes.

2) Energy consumption

To define the main operating parameters of a radio, Castalia follows a specific format. Castalia defines 2 radios: CC1000 and CC2420, they define the real radios of the same name by Texas Instruments. To evaluate simulation performance, we used CC2420 radio.

Fig. 6 illustrates the energy consumption histogram. We notice that when the GTS is active, the energy doesn't exceed 0.09 j. However, when GTS is OFF, the consumption is higher and can reach 0.11 j. These results are conforming to the theoretical supposition, because with the inactive period in the superframe, all sensors radios are in sleep mode, which saves an important amount of energy [18]. As a result, the applied mechanism conserves an important amount of energy and consequently increases the node life time.

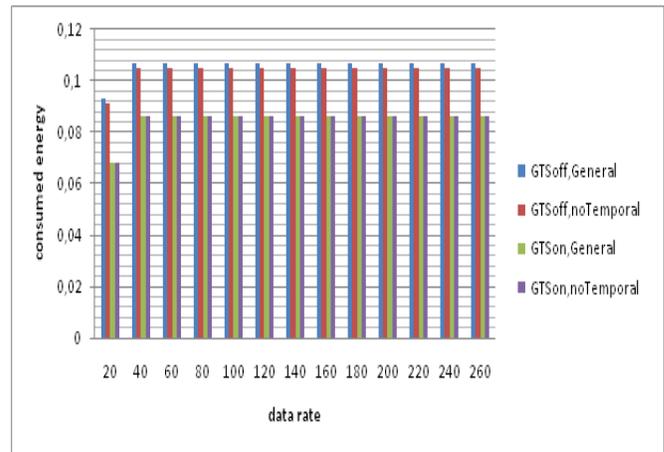


Fig. 6. IEEE 802.15.4 energy consumption (J) in function of nodes data rates.

Based on these results above, we conclude that GTSon mode is better than GTSoff mode when it comes to throughput and reliability. In terms of energy consumption, GTSon saves up to 20% of the supposed energy to be consumed. Thus, the results respond to the economic energy consumption criteria of Zigbee.

D. IEEE 802.15.6 Simulations and Results Analysis

1) Throughput and reliability

In this section we keep the same conditions of the first simulation, we change the Zigbee Mac protocol by BaselineMAC IEEE 802.15.6 protocol and we vary parameters of the MACs related to scheduled access, random access and improvised access (polling) mechanisms. We also choose data rates interval to attend 1Mbps (theoretical IEEE 802.15.6 data rate).

From Fig. 7, we notice that the optimal case is obtained when polling is activated without channel time variations. Particularly for data rates over 40kbps, and in the best case (pollingON, noTemporal) the maximum of received packets reached 6300 packets.

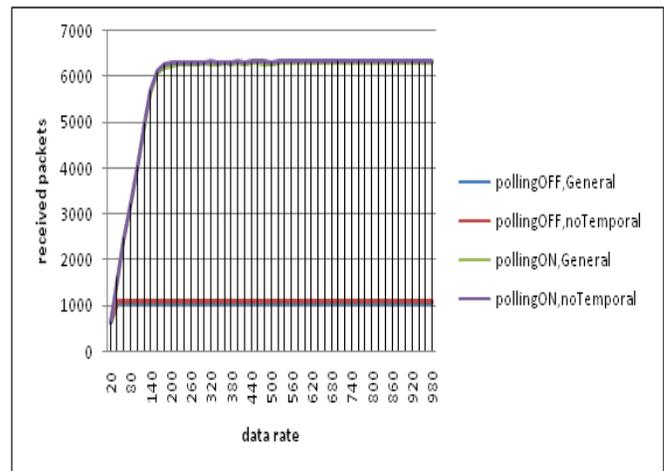


Fig. 7. IEEE 802.15.6 packets received per node 0 in function of sensors data rates.

As shown in Fig. 7, the number of received packets is saturated for rates over than 170 kbps, which conform to theoretical suppositions. That is because every node uses $(1024\text{kbps}/5) = 204$ kbps, assuming that the maximum WBAN area data rate is 1024kbps when the modulation DQPSK is used [15]. As done for GTS in the first simulation, and in the purpose of clarifying the number of nodes impact on the saturation data rate we have varied the number of nodes from 2 up to 32 using the mode (pollingON, noTemporal), which is considered the best simulation scenario.

Fig. 8 gives an idea about "Saturation Throughput». We observe that throughput linearly increases with the load to a certain point and achieves a constant saturation throughput. We also notice that the more the number of nodes in the PAN (star topology) increases, the more the saturation data rate decreases. Unlike GTS where the saturation data rate blocks at 40 kbps for more than 6 nodes, pollingON saturation data rate is relatively dependent on the number of nodes. Table 4 resumes the results shown in Fig. 8.

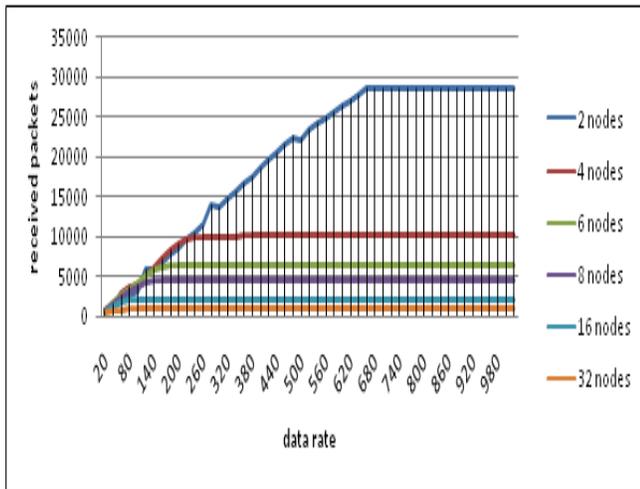


Fig. 8. IEEE 802.15.6 received packets per node 0 in function of sensors data rates for various numbers of nodes.

TABLE IV. COMPARISON BETWEEN SIMULATION AND THEORETICAL SATURATION DATA RATE IN FUNCTION OF NUMBER OF NODES

Number of nodes (without node 0)	Saturation Throughput (packets)	Saturation data rate(kbps)	Theoretical nodes uplink data rate(kbps)
1	28500	660	1024
3	10200	280	341
5	6300	180	204
7	4500	140	146
15	2100	80	68.2
31	790	40	33

As done in the first simulation and to evaluate IEEE 802.15.6 scalability, we translate throughput results into reliability and we obtain results in Fig. 9.

We notice that reliability is optimal when we use 6 (including node 0) or less than 6 nodes already recommended by authors in reference [15]. We also observe that the best case of reliability (2 nodes) data rate shouldn't exceed 720kbps.

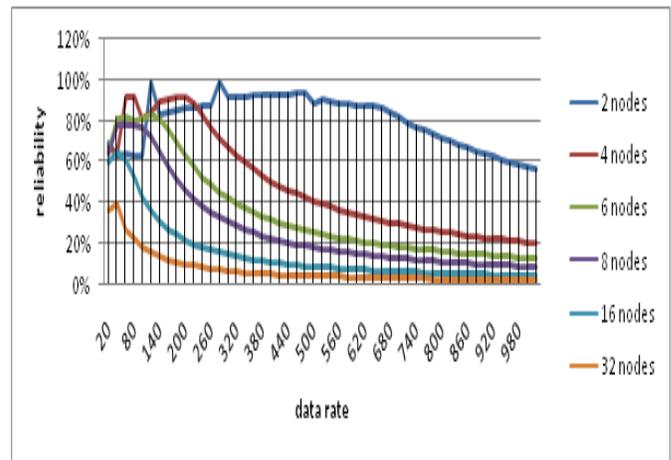


Fig. 9. Coordinated 802.15.6 reliability in function of sensors data rates for various numbers of nodes.

2) Energy consumption

From Fig. 10, we remark that when the polling is active the consumed energy achieves 0.29 joule for data rates higher than 40kbps. However, for data rates fewer than 40 kbps, the consumption is lower and doesn't exceed 0.16 j. That is, because the polling process bases on nodes synchronization, if the node wakes up earlier, it will have to stay awake to receive the poll packet from the hub causing unwanted energy loss [12]. If the node wakes up after the poll packet is sent by the hub, the poll packet will be lost and the polling mechanism fails.

Based on results, and as far as throughput and reliability are concerned, we conclude that pollingON mode is better than pollingOFF mode. In terms of energy consumption, in one hand, pollingON mode is more exigent and 45% of battery saved energy will be consumed only to activate this mode, on the other hand, pollingOFF mode is energy saving, but its low reliability is the major disadvantage as it deprives it from the overuse in WBANs.

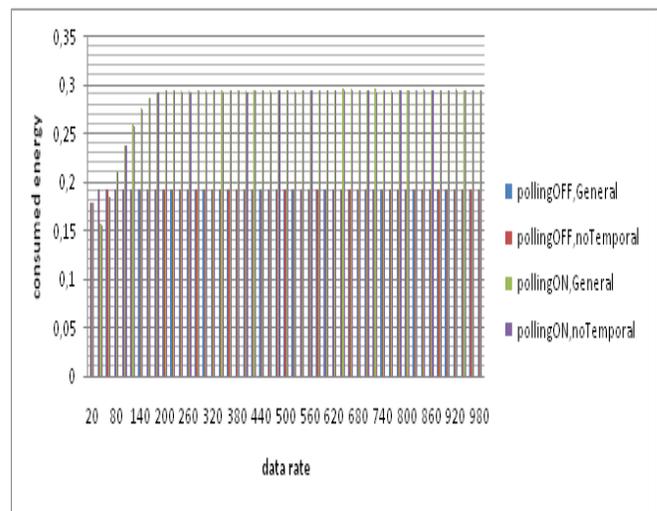


Fig. 10. IEEE 802.15.6 Energy consumption (J) in function of nodes data rates.

E. GTS and Polling Comparison and Discussion

Given that IEEE 802.15.4 (GTSon,noTemporal) and IEEE 802.15.6 (pollingON,noTemporal) are the best scenarios the simulations above, in this section of this paper we compare their results and performances.

Fig. 11 shows that in terms of throughput, the polling offers better results than GTS and especially for high data rate (>40kbps). Thus, the use of GTS is more beneficial if data rates are fewer than 40 kbps.

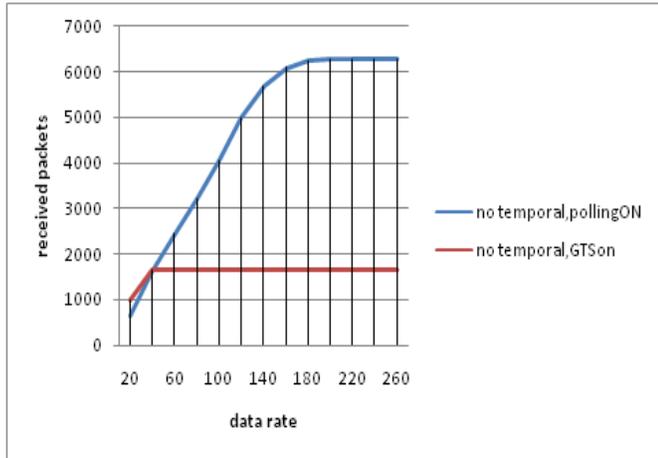


Fig. 11. IEEE 802.15.6 vs. IEEE 802.15.4 received packets performance.

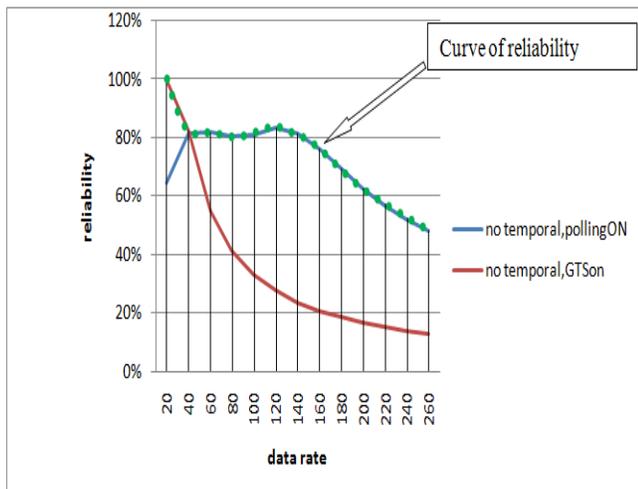


Fig. 12. IEEE 802.15.6 vs. IEEE 802.15.4 reliability performance.

In Fig. 12 and In terms of reliability, we can observe the complementarity of the two protocols. The graph shows that up to 40 kbps GTS gives more than 80% of reliability, and from 40 kbps to 150 kbps polling takes over and the reliability is around 80%. Consequently, the painted area in the graph is the new curve of reliability obtained when we use GTS for sensors data rates less than 40 kbps and polling for sensors data rates between 40kbps and 150 kbps.

In terms of energy consumption, Fig. 13 shows that GTS consume less energy than polling saving up to 72% of supposed energy to be consumed, especially for data rates less than 40kbps.

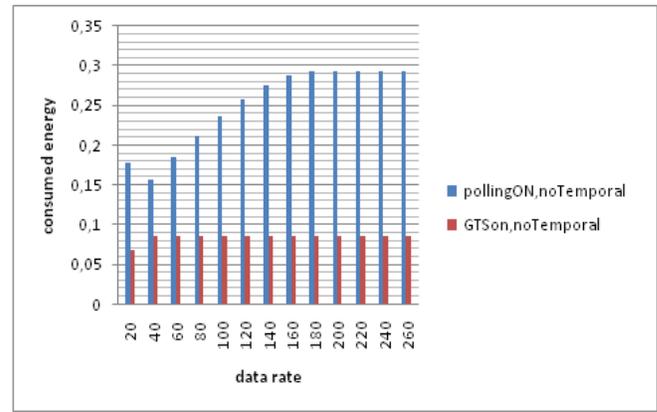


Fig. 13. IEEE 802.15.6 vs. IEEE 802.15.4 energy consumption performance.

We conclude that as far as medical exploitation is concerned, the use of IEEE 802.15.4 is more beneficial for sensors with minimum data rate requirement (less than 40 kb/s) like temperature and glucose sensors, profiting from its important reliability for low data rates, and increasing our sensor lifetime by saving up to 72% of required energy as resumed in Table 5.

TABLE V. GTS AND POLLING ENERGY CONSUMPTION COMPARISON

	Min. energy	Max. energy
GTS	0.06	0.08
polling	0.16	0.29
Gain	62%	72%

For sensors enquiring high data rates like ECG and Endoscopy the use of BAN IEEE 802.15.6 is more beneficial profiting from its reliability for high data rate (>40 kbps) even though the constraint of energy consumption still exit.

V. CONCLUSION

In this paper we presented an overview of WBANs IEEE 802.15.4 and IEEE 802.15.6 performances especially on the MAC Layer. Then we compared their communication modes and access mechanisms namely GTS and Polling. Thereafter we analyzed their performances in terms of throughput, reliability and energy consumption using OMNET++ with Castalia simulator. Based on the simulation results we synthesize that:

- In terms of throughput and reliability, GTSon mode gives better results than GTSoff mode. In terms of energy consumption, GTSon mode is energy saving and the gain is 20% of the supposed energy to be consumed.
- In terms of throughput and reliability, IEEE 802.15.6 pollingON mode gives better results than pollingOFF mode. However, In terms of energy consumption, on one hand, pollingON mode is more demanding and 45% of battery saved energy will be consumed only to activate this mode, on the other hand, pollingOFF mode is energy saving, but it's of limited use because of its low reliability.

- In regard of medical exploitation, the use of Zigbee technology is more beneficial for sensors with minimum rate requirement (less than 40 kb/s) profiting from its important reliability for low data rates, and increasing our sensor lifetime by saving up to 72% of required energy. For sensors requiring high data rates (>40kbps) the use of BAN 802.15.6 is more beneficial profiting from its reliability for high rate.

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Model Study and Fault Detection for the Railway System

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Abstract—The wheel-rail-sleepers system is simulated as a series of moving point loads on an Euler–Bernoulli beam resting on a visco-elastic half space. This paper concentrates on the rail-sleepers interaction system (railway system) and the fault detection. The main objective is to mathematically develop and implement a dynamic model of a railway system then the diagnosis of system defects using a Luenberger observer (LO). The simulation results are based on a physical description, mathematical equations and simulations with MATLAB simulation program.

Keywords—Dynamic model; the wheel-rail-sleepers system; interaction system; Euler–Bernoulli; Luenberger observer (LO); fault detection

I. INTRODUCTION

Because of the importance of the safety and the great rail-sleepers interaction effect on it, in the last few years there has been a growing interest in the diagnosis of the railway system and the rail-sleepers interaction induced by moving high-speed trains. The early detection and isolation are very important to avoid costly breakdowns and improve equipment reliability as reported in [1] and [2]. In the past decades, various analytical, semi-analytical and numerical methods with different accuracies have been attracted much attention from research teams to investigate the rail vibrations then the diagnosis of this system and isolation of the defect [23], [24], [25] and [26]. The finite elements method [29] is a very effective method for the railway model calculates. This paper is focused on this method for the model calculation.

There are essentially two opposing attitudes for diagnosis system [22] and [27]. First one is corrective maintenance or diagnosis after the failure, second one is the preventive maintenance [28] or diagnosis before the failure. While the second attitude seems more attractive, it's not systematically applied on industrial process. In practice, these two approaches still coexist. Previous studies indicate that the good maintenance is to implement the most appropriate technique for each device, sub-assembly or each element. The maintenance type choice is based on the knowledge available on the installation and objectives.

To diagnose and isolate the fault of the railway system, it must first calculate its dynamic model [30] and [31]. The

model considers the rail and the sleepers as a whole system and couples the vertical interaction with the lateral interaction. To calculate the railway model it must consider the wheel-rail interaction. The vertical contact forces between wheels and rails are described by Hertzian nonlinear elastic contact theory and the tangential wheel-rail forces are decided by the creep theory. Generally, there are three main classes of dynamic interactions between rails and sleepers: vertical, lateral and torsional. Vertical rail-sleepers interactions are responsible for damage and service life of the system [3] demonstrated that. Lateral and torsional interactions usually influence the safety against derailment of train and wear of wheels and rails. In fact, the vertical and lateral rail-sleepers interactions can't be separated from each other.

So this work is a mathematical calculation of the railway model, then the isolation of default with Luenberger Observer (LO) [21].

Section II describes the real system in which this work is applied. Section III analyzes the system model where the dynamic model of the system is calculated. Section IV the different variation cases of the system where there is the global model study of the railway system. Section V concentrates for the fault detection where there is study of observer type used in this work. Choice of Luenberger observer for the diagnosis and fault isolation, calculation of parameters and experimental results are presented in Section VI; Section VII concludes the paper.

II. SYSTEM DESCRIPTION

The system is a train rail. The rail treated as a rigid model in which it is supported on two double-axles with the primary and the secondary suspension systems. The primary suspensions, connecting the wheels, are represented by ordinary Kelvin elements. The secondary suspensions, connecting the sleepers, are also modeled as ordinary Kelvin elements.

The wheels and sleepers are coupled through the suspension elements. The rail and sleepers each undergo lateral displacement and vertical, but only vertical displacement is considered in the four wheels. More knowledge about this system presented in [4]-[6].

The dynamic model of railway system can be presented in the form of equations of motions vertical, lateral and torsional [7].

III. MATHEMATIC MODEL

There are several experiments in order to verify the validity of the infinite element method [8]-[15].

The research in this work started by these equations that describe the motion of the rail is as follows:

- Vertical Motion:

$$EI_y \frac{d^4 Z_r(x,t)}{dx^4} + m_r \frac{d^2 Z_r(x,t)}{dt^2} = -\sum_{i=1}^N F_{vi}(t)\delta(x-x_i) + \sum_{j=1}^4 G_{vj}(t)\delta(x-x_g) \quad (1)$$

- Lateral Motion:

$$EI_z \frac{d^4 Y_r(x,t)}{dx^4} + m_r \frac{d^2 Y_r(x,t)}{dt^2} = -\sum_{i=1}^N F_{Li}(t)\delta(x-x_i) + \sum_{j=1}^4 G_{Lj}(t)\delta(x-x_g) \quad (2)$$

- Torsional Motion:

$$\rho I_0 \frac{d^2 \phi_r(x,t)}{dt^2} - GK \frac{d^2 \phi_r(x,t)}{dx^2} = -\sum_{i=1}^N M_{Fi}(t)\delta(x-x_i) + \sum_{j=1}^4 M_{Gj}(t)\delta(x-x_g) \quad (3)$$

Where $Z_r(x,t)$, $Y_r(x,t)$ and $\phi_r(x,t)$ are respectively the vertical, lateral and torsional displacements of the rail, EI_y and EI_z are the rail bending stiffness to the y-axis and to the z-axis respectively, m_r the rail mass per unit length, ρ the rail density, I_0 the torsional inertia of rail, GK the rail torsional stiffness and $\delta(x)$ the Dirac delta function.

Equation (4) represents the vertical and lateral dynamic forces of the i-th rail/sleeper point.

$$\begin{cases} F_{vi}(t) = K_{pv}(Z_r(x_i,t) - Z_{si}(t) - a\phi_{si}(t)) + C_{pv}(\dot{Z}_r(x_i,t) - \dot{Z}_{si}(t) - a\dot{\phi}_{si}(t)) \\ F_{Li}(t) = K_{ph}(Y_r(x_i,t) - Y_{si}(t) - a\phi_{si}(t)) + C_{ph}(\dot{Y}_r(x_i,t) - \dot{Y}_{si}(t) - a\dot{\phi}_{si}(t)) \end{cases} \quad (4)$$

Where, $Z_{si}(t)$, $Y_{si}(t)$ and $\phi_{si}(t)$ Vertical, lateral and torsional displacements of the i-th sleepers They can be assumed to be zero, K_{pv} and K_{ph} are the vertical and lateral stiffness between the rail and the sleepers and C_{pv} and C_{ph} are the vertical and lateral rail/sleeper damping.

The dynamic of wheel/rail forces can be written as (5), where $G_{vj}(t)$ vertical forces and $G_{Lj}(t)$ lateral forces.

$$\begin{cases} G_{vj}(t) = P_j(t) - P_0 \\ G_{Lj}(t) = Q_j(t) \end{cases} \quad (5)$$

$P_j(t)$ and $Q_j(t)$ are the j-th wheel/rail forces and P_0 the static wheel load.

Equation (6) defines the moments of forces acting on the rail due to fastening system and due to wheel / rail forces.

$$\begin{cases} M_{fi}(t) = K_{\psi}\phi_r(x_i,t) \\ M_{gi}(t) = G_{Lj}(t)e_1 - G_{vj}(t)e_2 \end{cases} \quad (6)$$

Where, K_{ψ} the torsional stiffness of the fastening system, e_1 and e_2 are the arms of the lateral and vertical wheel/rail forces to the torsional center of the rail.

To facilitate the solution of motion differential equations of the rail, the following railway mode shape functions are assumed:

$$Z_k(x) = \sqrt{\frac{2}{m_r l}} \sin\left(\frac{k\pi x}{l}\right) \quad (7)$$

- Vertical Vibration

$$Y_k(x) = \sqrt{\frac{2}{m_r l}} \sin\left(\frac{k\pi x}{l}\right) \quad (8)$$

- Lateral Vibration

$$\phi_k(x) = \sqrt{\frac{2}{\rho I_0 l}} \sin\left(\frac{k\pi x}{l}\right) \quad (9)$$

- Torsional Vibration

Where l is the length of the rail and k is the mode number.

Thus, the characteristic variables of (1), (2) and (3) can be expressed as:

$$Z_r(x,t) = \sum_{k=1}^K Z_k(x)q_{zk}(t) \quad (10)$$

$$Y_r(x,t) = \sum_{k=1}^K Y_k(x)q_{yk}(t) \quad (11)$$

$$\phi_r(x,t) = \sum_{k=1}^K \phi_k(x)q_{tk}(t) \quad (12)$$

$q_{zk}(t)$, $q_{yk}(t)$ and $q_{tk}(t)$ are the k-th mode time coordinate and K is the total number of modes considered.

Then the second order ordinary differential equations simplified in terms of the time coordinates (1), (2) and (3) can be computed by the following equation:

- Vertical Motion

$$\ddot{q}_{zk}(t) + \frac{EI_y}{m_r} \left(\frac{k\pi}{l}\right)^4 q_{zk}(t) = -\sum_{i=1}^N F_{vi}(t)Z_k(x_i) + \sum_{j=1}^4 G_{vj}(t)Z_k(x_{gj}) \quad (13)$$

$K = 1, 2, \dots, k$

- Lateral Motion

$$\ddot{q}_{yk}(t) + \frac{EI_z}{m_r} \left(\frac{k\pi}{l} \right)^4 q_{yk}(t) = - \sum_{i=1}^N F_{Li}(t) Y_k(x_i) + \sum_{j=1}^4 G_{Lj}(t) Y_k(x_{gj})$$

$$K = 1, 2, \dots, k \quad (14)$$

- Torsional Motion

$$\ddot{q}_{tk}(t) + \frac{GK}{\rho I_0} \left(\frac{k\pi}{l} \right)^4 q_{tk}(t) = - \sum_{i=1}^N M_{fi}(t) \phi_k(x_i) + \sum_{j=1}^4 M_{gj}(t) \phi_k(x_{gj})$$

$$K = 1, 2, \dots, k \quad (15)$$

If K fixed by the value 1 and with a small change of the variables the vertical, lateral and torsional vibration system of the rail could be mathematically written as:

- Vertical movement equation

$$M_z \ddot{q}_{z1}(t) + C_z \dot{q}_{z1}(t) + K_z q_{z1}(t) + C_{zy} \ddot{q}_{t1}(t) + K_{zy} q_{t1}(t) = P_z(t) \quad (16)$$

Where

$$M_z = 1, C_z = \sum_{i=1}^N C_{pv} \left((Z_1(x_i) - Z_1(x_{si})) Z_1(x_i) \right)$$

$$C_{zy} = -a C_{pv} \sum_{i=1}^N (\phi_1(x_{si}) Z_1(x_i))$$

$$K_z = \sum_{i=1}^N \left(K_{pv} (Z_1(x_i) - Z_1(x_{si})) Z_1(x_i) \right) + \frac{EI_y}{m_r} \left(\frac{k\pi}{l} \right)^4,$$

$$K_{zy} = -a K_{pv} \sum_{i=1}^N (\phi_1(x_{si}) q_{t1}(t) Z_1(x_i))$$

$$\text{and } P_z(t) = \sum_{j=1}^4 (P_j(t) - P_0) Z_1(x_{gj})$$

- Lateral movement equation

$$M_y \ddot{q}_{y1}(t) + C_y \dot{q}_{y1}(t) + K_y q_{y1}(t) = P_y(t) \quad (17)$$

$$\text{Where } M_y = 1, C_y = C_{ph} \sum_{i=1}^N (Y_1(x_i) - Y_1(x_{si})) Y_1(x_i) \quad ,$$

$$K_y = \frac{EI_z}{m_r} \left(\frac{k\pi}{l} \right)^4 + K_{ph} \sum_{i=1}^N ((Y_1(x_i) - Y_1(x_{si})) Y_1(x_i)) \quad \text{and}$$

$$P_y(t) = \sum_{j=1}^4 G_{Lj}(t) Y_1(x_{gj})$$

- Torsional movement equation

$$M_t \ddot{q}_{t1}(t) + C_t \dot{q}_{t1}(t) + K_t q_{t1}(t) = P_t(t) \quad (18)$$

$$\text{Where } M_t = 1, C_t = 0, K_t = \frac{GK}{\rho I_0} \left(\frac{\pi}{l} \right)^2 + \sum_{i=1}^N K_{\psi} \phi_1^2(x_i) \quad \text{and}$$

$$P_t(t) = \sum_{j=1}^4 (G_{Lj}(t) e_1 - G_{vj}(t) e_2) \phi_1(x_{gj})$$

In order to consistent with rail vertical, lateral and torsional vibration matrix differential equation, the rail vibration system is mathematically written as (19).

$$M \ddot{q}_1(t) + C \dot{q}_1(t) + K q_1(t) = P(t) \quad (19)$$

Where M, C and K represent mass matrix, damping matrix and stiffness matrix of the rail vertical, lateral and torsional vibration system respectively $q_1(t)$, $\dot{q}_1(t)$ and $\ddot{q}_1(t)$ are rail displacement vector, velocity vector and acceleration vector, respectively, and P is the load vector [10].

$$M = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, C = \begin{bmatrix} C_z & 0 & C_{zy} \\ 0 & C_y & 0 \\ 0 & 0 & C_t \end{bmatrix}, K = \begin{bmatrix} K_z & 0 & K_{zy} \\ 0 & K_y & 0 \\ 0 & 0 & K_t \end{bmatrix},$$

$$\ddot{q}_1(t) = \begin{bmatrix} \ddot{q}_{z1}(t) \\ \ddot{q}_{y1}(t) \\ \ddot{q}_{t1}(t) \end{bmatrix}, \dot{q}_1(t) = \begin{bmatrix} \dot{q}_{z1}(t) \\ \dot{q}_{y1}(t) \\ \dot{q}_{t1}(t) \end{bmatrix}, q_1(t) = \begin{bmatrix} q_{z1}(t) \\ q_{y1}(t) \\ q_{t1}(t) \end{bmatrix} \text{ and } P(t) = \begin{bmatrix} P_z(t) \\ P_y(t) \\ P_t(t) \end{bmatrix}$$

IV. THE DIFFERENT VARIATION CASES OF THE SYSTEM

After the mathematical calculation of railway dynamic model, this part focuses on this dynamic model study, where there is the study of each equation of motion and the presentation of different variation cases.

A. Vertical Motion Equation

This system is a SIMO system (Single Input Multi Output) with two outputs $q_{z1}(t)$ and $q_{t1}(t)$.

$$M_z \ddot{q}_{z1}(t) + C_z \dot{q}_{z1}(t) + K_z q_{z1}(t) + C_{zy} \ddot{q}_{t1}(t) + K_{zy} q_{t1}(t) = P_z(t)$$

$$\text{We propose: } C_z = \frac{C}{M}, K_z = \frac{K}{M}, C_{zy} = \frac{C_1}{M}, K_{zy} = \frac{K_1}{M} \text{ and } P_z = \frac{F}{M}$$

C, C1 are respectively the damping constant of the first and second subsystem, K, K1 are the displacement constant of the first and second subsystem, respectively and F is the result force.

With the superposition method, this system can be divided on two SISO subsystems with $q_{z1}(t)$ and $q_{t1}(t)$ output. This method is presented in the following calculation of this paper.

The output $q_{t1}(t)$ supposed null then the first subsystem like:

$$\ddot{q}_{z1}(t) + C_z \dot{q}_{z1}(t) + K_z q_{z1}(t) = P_z(t) \quad (20)$$

Now the second output $q_{z1}(t)$ supposed null then the second subsystem like:

$$C_{zy} \ddot{q}_{t1}(t) + K_{zy} q_{t1}(t) = P_z(t) \quad (21)$$

The final solution of this system is the sum of two outputs $q_{z1}(t)$ and $q_{t1}(t)$ since both subsystems are parallel.

First subsystem (20) is a damped oscillating system with output $q_{z1}(t)$.

We can take:

$$\begin{cases} 2\varepsilon_z \omega_z = C_z \\ \omega_z^2 = K_z \end{cases} \quad (22)$$

ε_z the damping coefficient and ω_z the natural frequency of the system.

Where
$$H_a(p) = \frac{1}{2\varepsilon_z \omega_z p + \omega_z^2 p + p^2} \quad (23)$$

If $\varepsilon_z = 0$ the system unamortized and $C_z = 0$.

So
$$\sum_{i=1}^N C_{pv} \left(\sin\left(\frac{\pi x_i}{l}\right) - \sin\left(\frac{\pi x_{si}}{l}\right) \right) \sin\left(\frac{\pi x_i}{l}\right) = 0 \quad (24)$$

The solution of this system is

$$\{C_{pv} = 0 \text{ or } x_i = nl \text{ or } x_i = x_{si}; n \in N\}$$

Else if $\varepsilon_z \neq 0$ the system is a damped oscillating system.

So the study of this part is like the following.

$$\begin{aligned} 2\varepsilon_z \omega_z p + \omega_z^2 p + p^2 &= 0 \\ \Delta_z &= 4\omega_z^2 (\varepsilon_z^2 - 1) \end{aligned}$$

There are three cases to solve this system.

First case if $\varepsilon_z > 1$ then $\Delta_z < 0$ (a periodic regime).

Second case if $\varepsilon_z \in]0, 1[$ then $\Delta_z > 0$ (pseudo periodic regime).

Third case if $\varepsilon_z = 1$ then $\Delta_z = 0$ (Critic regime).

First, the periodic regime study, $\varepsilon_z > 1$.

$$F_z = C_{pv}^2 A^2 - 4 K_{pv} D - 4 \frac{EI_y}{mr} \left(\frac{\pi}{\rho} \right)^4 > 0$$

$$A = \sum_{i=1}^N (Z_1(x_i) - Z_1(x_{si})) Z_1(x_i)$$

Then the solution of this equation is

$$A_z \in]-\infty, A_1[\cup]A_2, +\infty[.$$

Where A_1 and A_2 are the two roots of this equation.

The solution is written as

$$\sum_{i=1}^N \left(\sin\left(\frac{\pi x_i}{l}\right) - \sin\left(\frac{\pi x_{si}}{l}\right) \right) \sin\left(\frac{\pi x_i}{l}\right) \in]-\infty, \frac{A_1 m_r l}{2} \cup \left] \frac{A_2 m_r l}{2}, +\infty[\quad (25)$$

Second, the critic regime study. $\varepsilon_z = 1$ and $F_z = 0$.

The solution in this case is written as

$$\sum_{i=1}^N \left(\sin\left(\frac{\pi x_i}{l}\right) - \sin\left(\frac{\pi x_{si}}{l}\right) \right) \sin\left(\frac{\pi x_i}{l}\right) = \left\{ \frac{A_1 m_r l}{2}, \frac{A_2 m_r l}{2} \right\} \quad (26)$$

Third, the pseudo periodic regime study. $\varepsilon_z \in]0, 1[$.

In this case the solution is written as

$$\sum_{i=1}^N \left(\sin\left(\frac{\pi x_i}{l}\right) - \sin\left(\frac{\pi x_{si}}{l}\right) \right) \sin\left(\frac{\pi x_i}{l}\right) \in]0, \frac{A_2 m_r l}{2} \quad (27)$$

If there is no wagon on the rail: $X_{gi} = 0$ and $P_z = 0$. So $q_{z1}(t) = 0$ then it's the case where $t < 0$.

$$\begin{aligned} \text{then } \sum_{i=1}^N \left(\sin\left(\frac{\pi x_i}{l}\right) - \sin\left(\frac{\pi x_{si}}{l}\right) \right) \sin\left(\frac{\pi x_i}{l}\right) &= \sum_{i=1}^N \left(\sin\left(\frac{\pi x_i}{l}\right) \right)^2 \\ \text{Now if there are no sleepers: } X_{si} &= 0 \text{ and } \sin\left(\frac{\pi x_{si}}{l}\right) = 0 \end{aligned}$$

Finally the general solution of the system is:

$$\begin{cases} \text{a periodic regime: } \sum_{i=1}^N \left(\sin\left(\frac{\pi x_i}{l}\right) \right)^2 \in]-\infty, \frac{A_1 m_r l}{2} \cup \left] \frac{A_2 m_r l}{2}, +\infty[\\ \text{Critic regime: } \sum_{i=1}^N \left(\sin\left(\frac{\pi x_i}{l}\right) \right)^2 = \left\{ \frac{A_1 m_r l}{2}, \frac{A_2 m_r l}{2} \right\} \\ \text{Pseudo periodic regime: } \sum_{i=1}^N \left(\sin\left(\frac{\pi x_i}{l}\right) \right)^2 \in]0, \frac{A_2 m_r l}{2} \end{cases}$$

Second subsystem is a system with uniform motion (constant speed system) so it can be written as a first order system with an output q_{t1} (t).

We can take:

$$\begin{cases} C_{zy} = \frac{\tau}{k} \\ K_{zy} = \frac{1}{k} \end{cases} \quad (28)$$

Where τ is the time constant and k is the static gain. The equation (21) can be written like (29) and the transfer function of this system is written like (30).

$$\frac{\tau}{k} \dot{q}_{t1}(t) + \frac{1}{k} q_{t1}(t) = P_{zr}(t) \quad (29)$$

$$H_b = \frac{q_{t1}(p)}{P_{zr}(p)} = \frac{k}{p\tau + 1} \quad (30)$$

The general transfer function vertical motion equation is the sum of (23) and (30):

$$H_z(p) = H_a(p) + H_b(p) \quad (31)$$

B. Lateral Motion Equation

Apply the same principle of the calculation in the previous part for the vertical motion equation but in this case a SISO (Simple Input Simple Output) system.

$$M_y \ddot{q}_{y1}(t) + C_y \dot{q}_{y1}(t) + K_y q_{y1}(t) = P_y(t)$$

The general solutions of the system are:

$$\left\{ \begin{array}{l} \text{a periodic regime:} \\ \text{Critic regime:} \\ \text{Pseudo periodique regime:} \end{array} \right. \sum_{i=1}^N \left(\sin \left(\frac{\pi x_i}{l} \right) \right)^2 \in \left] -\infty, \frac{B_1 m_i l}{2} \cup \left[\frac{B_2 m_i l}{2}, +\infty \right[$$

$$\sum_{i=1}^N \left(\sin \left(\frac{\pi x_i}{l} \right) \right)^2 = \left\{ \frac{B_1 m_i l}{2}, \frac{B_2 m_i l}{2} \right\}$$

$$\sum_{i=1}^N \left(\sin \left(\frac{\pi x_i}{l} \right) \right)^2 \in \left] 0, \frac{B_2 m_i l}{2} \right[$$

C. Torsional Motion Equation

In this part also select the same principle as the previous ones. This subsystem is a SISO system.

$$M_t \ddot{q}_{t1}(t) + C_t \dot{q}_{t1}(t) + K_t q_{t1}(t) = P_t(t)$$

Or $C_t=0$ so $\varepsilon_i = 0$ always, in this case the general system is unamortized.

This part presented the detailed study of general system which is divided into three essential parts: the lateral, vertical and torsional motion equations. There is a resolution for each part of nonlinear system based on accurate mathematical calculation in different regimes.

V. FAULT DETECTION

After the system study this section focuses on the quantitative diagnosis which contains many mandatory steps to have good results. The error detection this step should make it possible to decide whether the system is in a state of normal running or not, defect location step where the fault elements defined and the decision making step where the incorrect operation of the system being found so the decision how to keep the desired performance of the system under surveillance. The diagnosis can be generated using different methods, a few methods have studied and shown in [16]-[20].

This work deals with one of the finest methods for generating residuals it's the Luenberger Observer (LO) [21]. To prove the efficiency and accuracy of this method, analysis was performed and a result was presented on the following of this paper.

Suppose the linear system affected by a sensor fault, an actuator fault and a measurement noise following:

$$\begin{cases} \dot{x}(t) = Ax(t) + Bu(t) + F_x f(t) + D_x d(t) \\ y(t) = Cx(t) + F_y f(t) \end{cases} \quad (32)$$

A dynamic observer of this model given by:

$$\begin{cases} \dot{\hat{x}}(t) = A\hat{x}(t) + Bu(t) + L(y - \hat{y}) \\ \hat{y}(t) = C\hat{x}(t) \end{cases} \quad (33)$$

Where, L is the Observer gain.

The error is: $e_x(t) = x(t) - \hat{x}(t) \Leftrightarrow \dot{e}_x(t) = \dot{x}(t) - \dot{\hat{x}}(t)$

$$\begin{aligned} \dot{e}_x(t) &= Ax(t) + Bu(t) + F_x f(t) + D_x d(t) - A\hat{x}(t) - Bu(t) - L(y(t) - \hat{y}(t)) \\ &= Ax(t) + Bu(t) + F_x f(t) + D_x d(t) - A\hat{x}(t) - Bu(t) - L(y(t) - C\hat{x}(t)) \\ &= Ax(t) - A\hat{x}(t) - L(y(t) - C\hat{x}(t)) + F_x f(t) + D_x d(t) \\ &= Ax(t) - LCx(t) - LF_y f(t) + F_x f(t) + D_x d(t) - A\hat{x}(t) + LC\hat{x}(t) \\ &= (A - LC)(x(t) - \hat{x}(t)) - LF_y f(t) + F_x f(t) + D_x d(t) \\ &= (A - LC)e_x(t) + (F_x - LF_y) f(t) + D_x d(t) \end{aligned}$$

$$\dot{e}_x(t) = (A - LC)e_x(t) + (F_x - LF_y) f(t) + D_x d(t)$$

In the absence of default ($f(t) = 0$) and neglecting the effect of the unknown inputs ($d(t) = 0$), the estimation error becomes $\dot{e}_x(t) = (A - LC)e_x(t)$. The objective is $\lim_{t \rightarrow +\infty} e_x(t) = 0$, this is the case by calculating L.

The dynamic of the state estimation is the residue of the system:

$$r(t) = y(t) - \hat{y}(t) = C\tilde{x}(t)$$

As followed from Fig. 1 shown below, the principle of the generation of residues based on the observer.

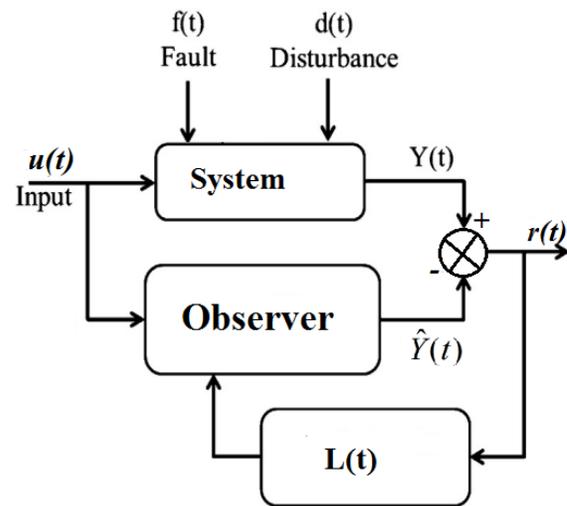


Fig. 1. The principle of the generation of residues based on the observer.

The knowledge that the system contains a defect or not the residue value must be determined, the general conditions of residue presented in (34).

$$\begin{cases} r(t) \neq 0 & \text{if the default } f(t) \neq 0 \\ r(t) = 0 & \text{if the default } f(t) = 0 \end{cases} \quad (34)$$

VI. APPLICATIONS AND SIMULATIONS

A. The Global Model

This part presented the model and study simulations based on the MATLAB program.

Fig. 2 shows the three global outputs of the railway system model, vertical, lateral and torsional displacement.

The first output is the vertical movement; it is a damped system as Fig. 2(a) shows. It is amortized signal with maximum value in the begin movement equal 120 mm, with damping value $C=0.0713$ and stiffness value $K=1.1891$.

The second output is the lateral movement it's a damped system also as Fig. 2(b) shows, but it is more frequency than the first. It is amortized signal with maximum value in the begin movement equal 10 mm, with damping value $C= 0.6454$ and stiffness value $K= 25.8164$.

The third output is the torsional movement, it is unamortized system as Fig. 2(c) shows, but more frequency than the other outputs. It's unamortized signal with maximum value of movement equal 100 mm, with damping value $C= 0$ and stiffness value $K= 173.7861$.

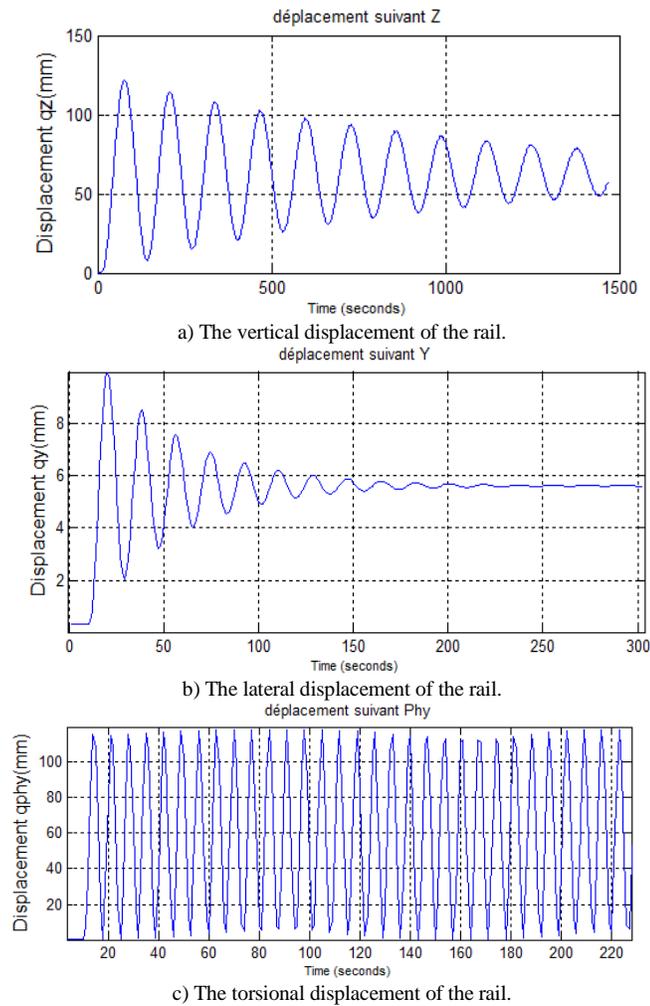


Fig. 2. The railway model system.

B. The Model Study

Some examples of numerical results in a few positions on the rail are studied such cases are depicted in the following figures:

- First case is the initial position of the system ($X=0$).

Damping coefficients are $\varepsilon_z = 0$, $\varepsilon_y = 0$ and $\varepsilon_t = 0$. The natural frequency are $W_z = 0.0043$, $W_y = 0.0047$ and $W_t = 0.2602$.

The Transfer function H_z (vertical movement), H_y (Lateral movement) and H_t (Torsional movement) respectively like these:

$$H_z(p) = \frac{1}{p^2 + 1.83310^{-5}}, H_y(p) = \frac{1}{p^2 + 2.210^{-5}}$$

$$\text{and } H_t(p) = \frac{1}{p^2 + 0.067}$$

Fig. 3 illustrates the transfer functions of three motions directions. Like the simulations present they are unamortized then the system is in a Critic regime.

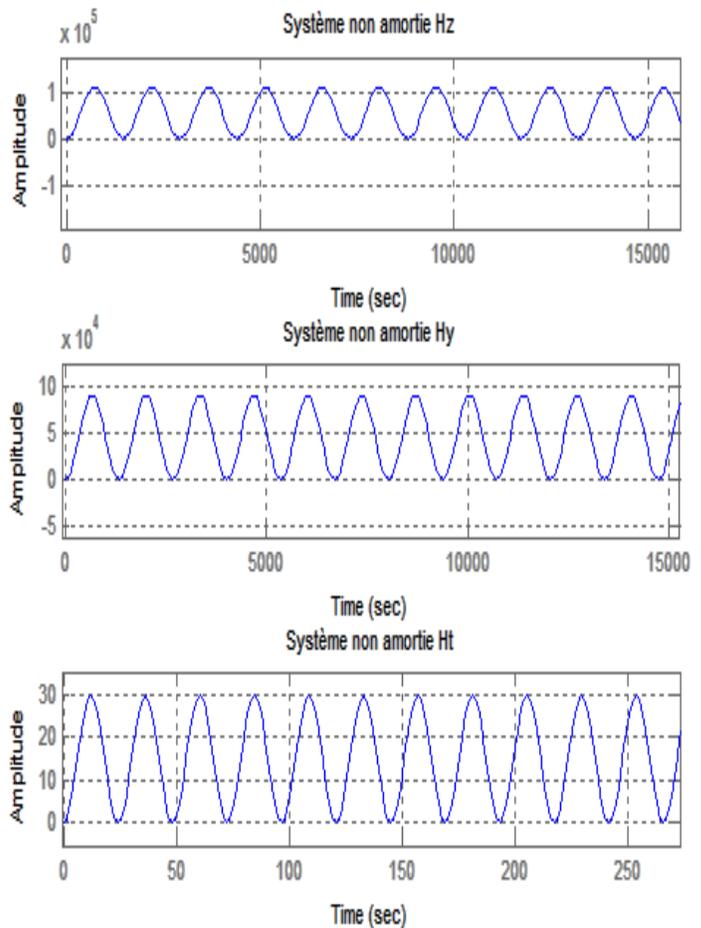


Fig. 3. Transfer function of the system in the first case.

- Second case is the seventh position for the system ($X = 7$).

Damping coefficients are $\varepsilon_z = 0.539$ and $\varepsilon_y = 0.305$. The natural frequency are $W_z = 1.295$, $W_y = 0.915$. The Transfer function H_z and H_y , respectively like these:

$$H_z(p) = H_a(p) + H_b(p) \quad \text{where} \quad \begin{cases} H_a(p) = \frac{1}{p^2 + 1.398p + 1.678} \\ H_b(p) = \frac{1}{0.833p + 1.678} \end{cases}$$

$$H_y(p) = \frac{1}{p^2 + 0.559p + 0.838}$$

The simulation of these transfer functions illustrated in Fig. 4. Like these simulations present they are in a pseudo periodic regime then the system is amortized.

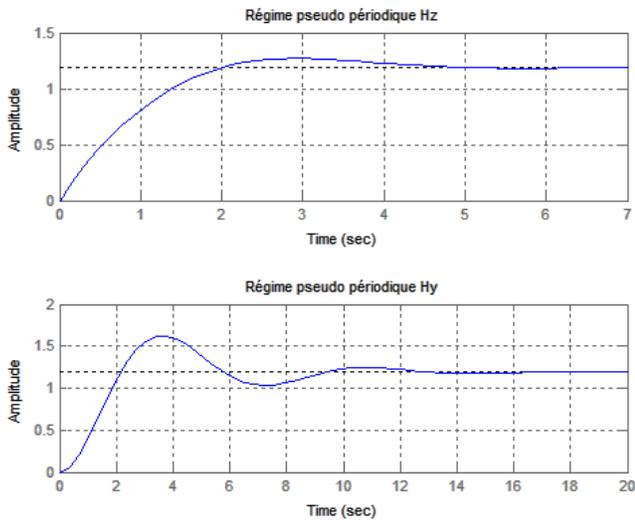


Fig. 4. Transfer function of the system in the second case.

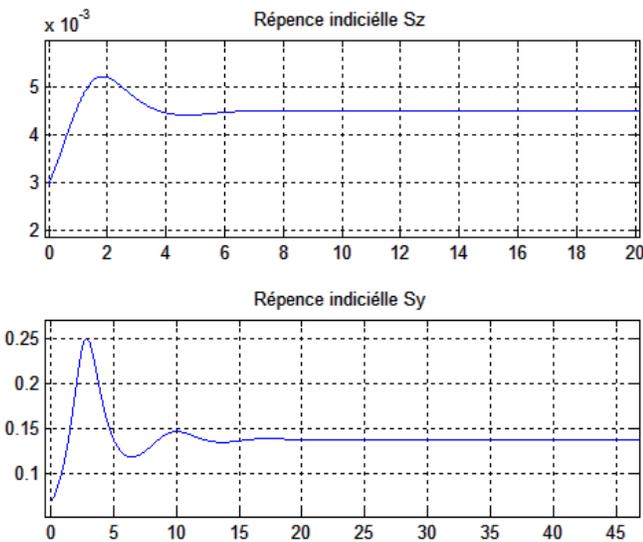


Fig. 5. The Step response of the system (Sz and Sy) in the second case.

The step response of this system with step unit function input is presented in Fig. 5.

- Third case is the final position for the system (X=30).

Damping coefficients in this case are $\varepsilon_y = 2.2045$ and $\varepsilon_z = 3.8971$. The natural frequency are $W_z = 9.3531$, $W_y = 6.6136$.

The Transfer function Hz and Hy:

$$H_z(p) = H_a(p) + H_b(p) \quad \text{where} \quad \begin{cases} H_a(p) = \frac{1}{p^2 + 72.9p + 87.48} \\ H_b(p) = \frac{1}{0.83p + 87.48} \end{cases}$$

$$H_y(p) = \frac{1}{p^2 + 29.16p + 43.74}$$

The simulations of these transfer functions are given in Fig. 6. From this figure it can be see that the global system become a first order system and the simulation are in a periodic regime.

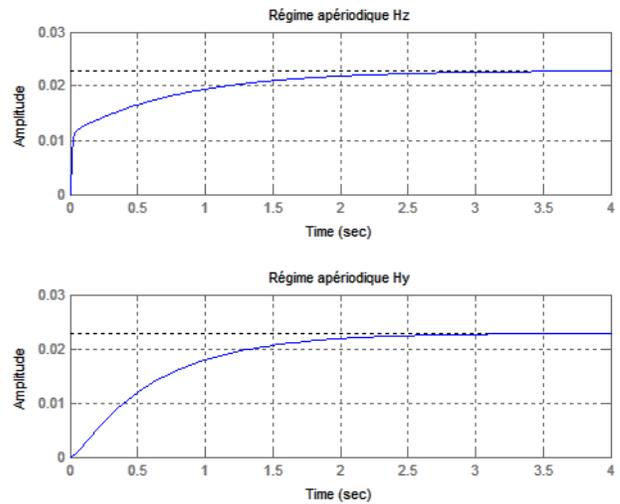


Fig. 6. Transfer function of the system in the third case.

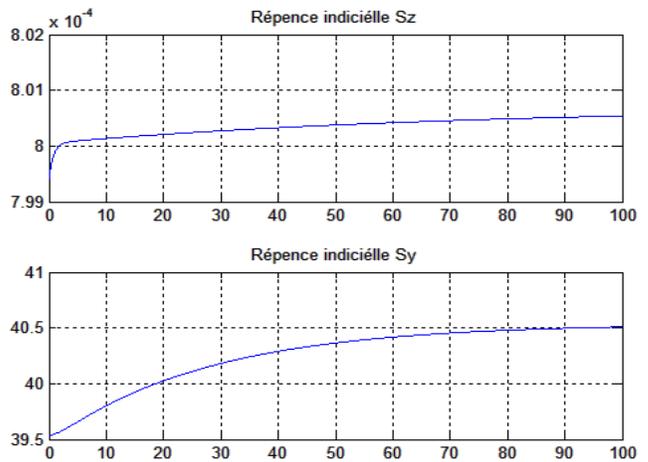


Fig. 7. The step response of the system (Sz,St) in the third case.

With the input of the system is step unit function, the step response being found in Fig. 7.

C. The Fault Detection

To calculate and isolate the system fault, first it must calculate the global system model which is done in the following. First there is a model calculation then an application for the LO, the numerical results are presented and the simulations are done.

The general model (19) demonstrate that the railway system have three defaults, one default on each side of vibration $f(t)$. The simulation in this paper with no disturbance ($d(t) = 0$).

To complete this work it must linearize the system to apply the luenberger observer. So after the linearization, the railway system described by the following state representation:

$$\begin{cases} \begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \\ \dot{x}_4 \\ \dot{x}_5 \\ \dot{x}_6 \end{bmatrix} = A \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{bmatrix} + Bu(t) \\ \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = C \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{bmatrix} + F_y f(t) \end{cases}$$

Matrices of the state are:

$$A = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ -K_z & -C_z & 0 & 0 & -K_{zy} & -C_{zy} \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & -K_y & -C_y & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & -K_r & 0 \end{bmatrix}, B = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$C = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}, F_y = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, f(t) = \begin{bmatrix} f_1(t) \\ f_2(t) \\ f_3(t) \end{bmatrix}$$

$$\text{and } u(t) = \begin{bmatrix} u_1(t) \\ u_2(t) \\ u_3(t) \end{bmatrix}$$

In the case $N=20$ the numerical values are founded as follow:

$$K_z = 0.4951, C_z = 0.0297, K_{zy} = 0.6940, C_{zy} = 0.0416, \\ K_y = 25.8164, C_y = 0.6454, K_r = 173.7861.$$

The state representation of system in the expanded form:

$$\begin{cases} \begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \\ \dot{x}_4 \\ \dot{x}_5 \\ \dot{x}_6 \end{bmatrix} = A_1 \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{bmatrix} + B_1 U(t) \\ \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = C_1 \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{bmatrix} + D_1 U(t) \end{cases}$$

$$A_1 = A, B_1 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix}, C_1 = C,$$

$$D_1 = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \text{ and } U = \begin{bmatrix} u_1(t) \\ u_2(t) \\ u_3(t) \\ f_1(t) \\ f_2(t) \\ f_3(t) \end{bmatrix}$$

The actual structure of the LO is:

$$\begin{cases} \begin{bmatrix} \dot{\hat{x}}_1 \\ \dot{\hat{x}}_2 \\ \dot{\hat{x}}_3 \\ \dot{\hat{x}}_4 \\ \dot{\hat{x}}_5 \\ \dot{\hat{x}}_6 \end{bmatrix} = A_{ob} \begin{bmatrix} \hat{x}_1 \\ \hat{x}_2 \\ \hat{x}_3 \\ \hat{x}_4 \\ \hat{x}_5 \\ \hat{x}_6 \end{bmatrix} + B_{ob} U(t) \\ \begin{bmatrix} \hat{y}_1 \\ \hat{y}_2 \\ \hat{y}_3 \end{bmatrix} = C_{ob} \begin{bmatrix} \hat{x}_1 \\ \hat{x}_2 \\ \hat{x}_3 \\ \hat{x}_4 \\ \hat{x}_5 \\ \hat{x}_6 \end{bmatrix} \end{cases}$$

$$A_{ob} = A - LC, B_{ob} = [B \ L] \text{ and } C_{ob} = C$$

The eigenvalues of A_{ob} are $\lambda_1 = -5, \lambda_2 = -9, \lambda_3 = -6, \lambda_4 = -5, \lambda_5 = -2$ and $\lambda_6 = -10$. These eigenvalues gives the gain Matrix L.

$$L = \begin{bmatrix} 11.6844 & -1.4550 & -1.0819 \\ 19.7897 & -4.1470 & -9.1942 \\ -1.2283 & 6.9358 & -0.7012 \\ -2.4554 & -22.2438 & -2.7048 \\ -1.2962 & -0.8920 & 13.7047 \\ -9.2933 & -4.3545 & -130.8955 \end{bmatrix}$$

Therefore the numerical values of the state matrices for LO are:

$$A_{ob} = \begin{bmatrix} -11.6844 & 1 & 1.4550 & 0 & 1.0819 & 0 \\ -20.2848 & -0.0297 & 4.1470 & 0 & 8.5002 & -0.0416 \\ 1.2283 & 0 & -6.9358 & 1 & 0.7012 & 0 \\ 2.4554 & 0 & -3.5725 & -0.6454 & 2.7048 & 0 \\ 1.2962 & 0 & 0.8920 & 0 & -13.7047 & 1 \\ 9.2933 & 0 & 4.3545 & 0 & -42.8907 & 0 \end{bmatrix}$$

$$B_{ob} = \begin{bmatrix} 0 & 0 & 0 & 11.6844 & -1.4550 & -1.0819 \\ 1 & 0 & 0 & 19.7897 & -4.1470 & -9.1942 \\ 0 & 0 & 0 & -1.2283 & 6.9358 & -0.7012 \\ 0 & 1 & 0 & -2.4554 & -22.2438 & -2.7048 \\ 0 & 0 & 0 & -1.2962 & -0.8920 & 13.7047 \\ 0 & 0 & 1 & -9.2933 & -4.3545 & -130.8955 \end{bmatrix}$$

$$C_{ob} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}$$

The system provides three outputs $q_z(t), q_y(t)$ and $q_t(t)$ are respectively the vertical, lateral and torsional displacement of rail because the vibration. The simulation of the real and estimate outputs of the railway system then the simulation of the residual of each default in the following of the paper finally the conclusion of fault detection part.

In the simulation, the default value, $f(t) = \begin{bmatrix} 0.5 \\ -0.6 \\ 0.1 \end{bmatrix}$.

Fig. 8 defines the real and estimate vertical displacements of rail they are respectively Y1r and Y1es.

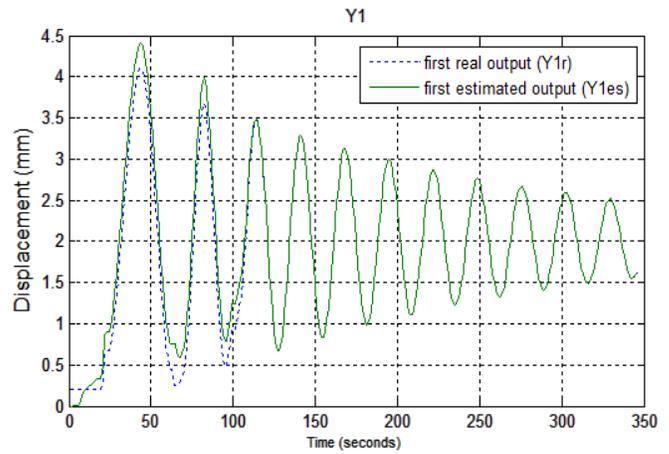


Fig. 8. Real and estimated outputs.

Fig. 9 indicates the real and estimate lateral displacements of rail they are respectively Y2r and Y2es.

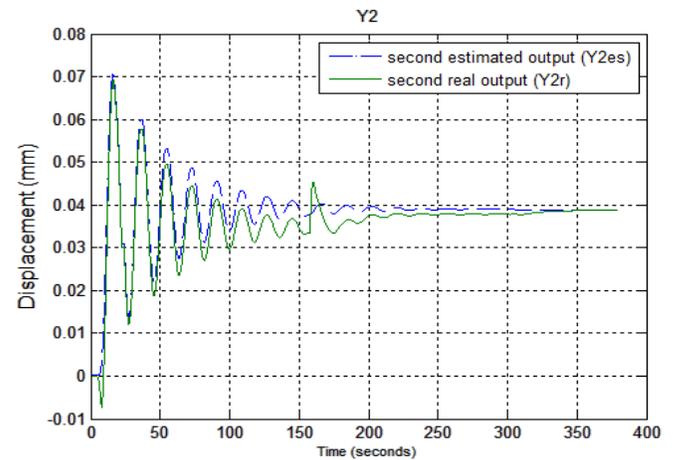


Fig. 9. Real and estimate second outputs.

Fig. 10 depicts the real and estimate torsional displacements of rail they are respectively Y3r and Y3es.

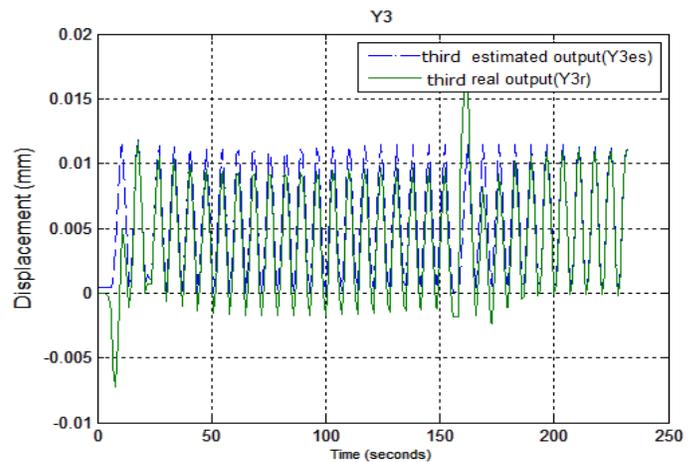


Fig. 10. Real and estimate third outputs.

This fault case of $f(t)$ gives a residue value to each output of the railway system, these values are described in the simulations of the following figures.

The fault on the first output in this case where:

$$f_1(t) = \begin{cases} 0.5 & \text{if } t=500s \\ 0 & \text{elsewhere} \end{cases}$$

This case is shown in Fig. 11 where the result of the residue r1 is sensitive to the fault.

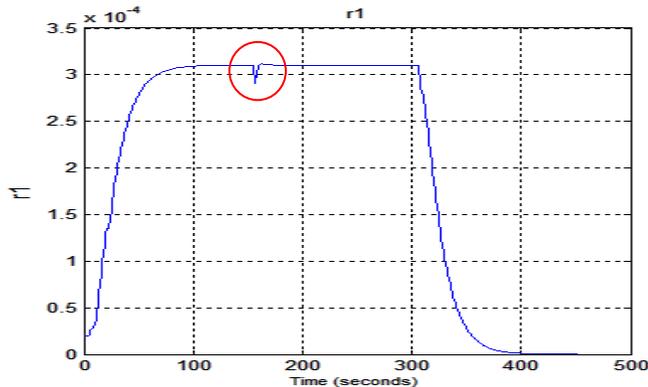


Fig. 11. The residue r1 with default $f_1(t)$.

Now the simulation for the effect of the second value $f_2(t)$ on the residue r2 of second output found is shown in Fig. 12.

$$f_2(t) = \begin{cases} -0.6 & t = \{10s \text{ and } 301s\} \\ 0 & \text{elsewhere} \end{cases}$$

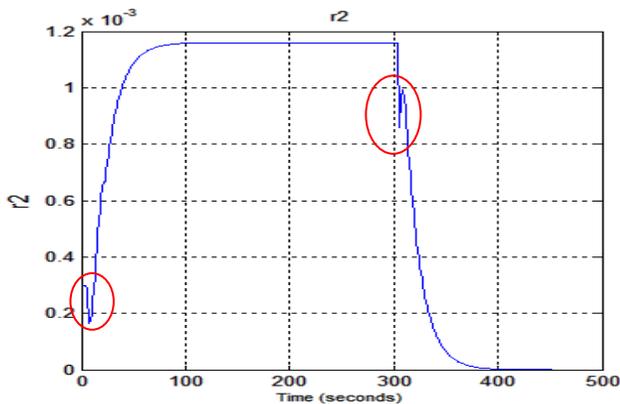


Fig. 12. Residual r2 with default $f_2(t)$.

Finally, the case of the effect of the third default on third residue r3 of the third output is:

$$f_3(t) = \begin{cases} 0.1 & t=57s \\ 0 & \text{elsewhere} \end{cases}$$

With this value of default, Fig. 13 shows the result of the residual r3 is sensitive to the fault $f_3(t)$.

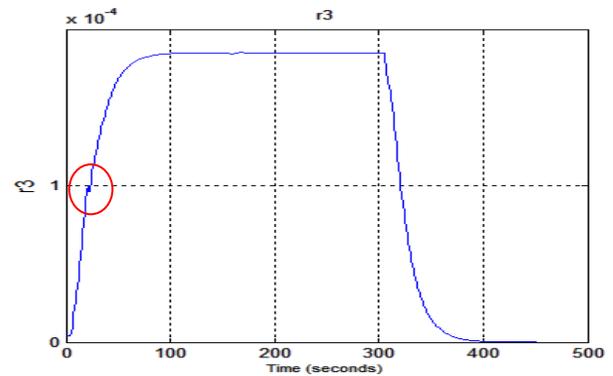


Fig. 13. Residual r3 with fault $f_3(t)$.

VII. CONCLUSION

Based on the results, it can be concluded that the research into the detection and isolation the default of a railway system has been very successful. A complete model for simulating dynamic interactions between rail and wheels has been presented. An explicit integration algorithm has been employed to numerically solve the equations of motion of the system. After linearization, is studied the linear system and numerical results presented in this work. With the model of railway system we made an embedded system for the robust prediction and diagnosis that can guarantee the security of railway system. A Luenberger Observer (LO) used to generate residuals for detection of faults of a MIMO system.

The future research will concentrate on detection of default based on nonlinear local observer for the railway system and prediction for this default. The future work based on the Local exponential Observer and will apply the results of Sundarapandian research on this type of observer [32], [33].

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NHCA: Developing New Hybrid Cryptography Algorithm for Cloud Computing Environment

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Abstract—The amount of transmitted data through the internet become larger and larger every day. The need of an encryption algorithm that guarantee transmitting data speedily and in a secure manner become a must. The aim of the research is to encrypt and decrypt data efficiently and effectively protect the transmitted data. This research paper presents a model for encrypting transmitted cloud data. This model uses the following encryption algorithms RSA, Triple DES, RC4, and Krishna to generate a new encryption algorithm that encrypt and decrypt transmitted data. The algorithm will help cloud agencies and users to secure their transmitted data and prevent it from being stolen.

Keywords—Hybrid cryptography algorithms; symmetric encryption algorithms; asymmetric encryption algorithms

I. INTRODUCTION

Nowadays the amount of currently stored data on the internet become large, cloud suffers from securing their own data when it transmitted through the internet. Users only think about how to save their own sensitive data from being stolen and when they use encryption algorithms like RSA encryption algorithm or Triple DES encryption algorithm the time become longer to encrypt or decrypt the transmitted data.

RSA is an encryption algorithm used to encrypt and decrypt data, RSA is asymmetric cryptographic algorithm and this is mean that agencies must use two different keys to encrypt the data, one of them is a public key and other is private key. RSA is a relatively slow encryption algorithm [1].

Triple DES is asymmetric block cipher algorithm created from the Data Encryption Standard (DES) by using it three times to each data block. Triple DES key sizes 168, 112 or 56 bits with three options. First one all three keys are independent, second option key one and key two are independent, and key three = key one, and finally third option all three keys are identical. But Triple DES is slow encryption algorithm [2].

Although of the advantage of high security offered by these encryption algorithms it still takes a long time to encrypt data. There are other encryption algorithms that can perform the same process with a high speed, but it suffers from ability of being easily hacked.

Krishna is an encryption algorithm which uses public random bits key merged with a secret key. This key is shared between sender and receiver to encrypt and decrypt data [3].

The Advanced Encryption Standard (AES) is the inheritor of DES as standard symmetric encryption algorithm. This algorithm was developed to solve the small size key on DES encryption algorithm. AES is faster and stronger than DES [4], [5].

Rivest Cipher 4 (RC4) is a symmetric stream cipher algorithm requiring a secure exchange of a shared key. RC4 encryption process is about 10 times faster than DES [6].

The proposed hybrid cryptography algorithm aims to build an efficient and secure encryption algorithm based on merging the encryption algorithms to make hybrid encryption algorithm that can encrypt and decrypt data efficiently and in a secure manner.

In this paper we present a hybrid cryptography algorithm that efficiently encrypts the transmitted data through the cloud. The hybrid cryptography algorithm presents a variety of different encrypting algorithms that allow the user to choose the encrypting method which is suitable with his own type of data.

The proposed hybrid cryptography algorithm studies the time and throughput for a set of encryption algorithms. More than one combination was made to implement hybrid encryption algorithms. User will have different varieties to encrypt and decrypt his own data with any of the hybrid algorithms based on the time consumed by this algorithm to encrypt the data and the level of security provided by this algorithm. Also, the proposed hybrid cryptography algorithm shows the points of strength and weakness of making hybrid encryption algorithms.

The remainder of the paper is organized into five sections: In section 2, presents an overview for the previous works related to our research. In section 3, the materials and methods of the proposed system is described. In section 4, results and discussions are produced, before drawing conclusions and future work in section 5 and 6.

II. RELATED WORK

Jiehong et al., [7] provided evaluation of three of the common encryption algorithms: AES, Blowfish, and GOST. A comparison has been conducted for those encryption algorithms at different sizes of data blocks. They presented results of comparison among selected cryptography algorithms. The Blowfish shows better performance independently on plain-text size. They conclude that the weak part of Blowfish algorithm is a key expansion process; it could

take even more time to expand the key than perform encryption or decryption if plain-text size is small. Also, they mention that GOST algorithm key expansion takes almost same time as for Blowfish, and both encryption and decryption for GOST algorithm costs almost same time. Lastly, they conclude that decryption is the longest operation for AES algorithm.

Bhandari et al., [8] mentioned that the most challenging issue today in cloud servers is to ensure data security and privacy of the users. They presented HE-RSA or hybrid encryption RSA along with Advanced Encryption Standard or AES to ensure efficiency, consistency and trustworthiness in cloud servers. They aimed to use various cryptography concepts during communication along with its application in cloud computing and to enhance the security of cipher text or encrypted data in cloud servers along with minimizing the consumption of time, cost and memory size during encryption and decryption. They observed that the difference between the running time of the original RSA and Improved Algorithm using Hybrid Encryption-RSA and AES is increasing drastically as the exponent size is increasing.

Jakimoski et al. [9] analyzed and evaluated the most important security techniques for data protection that are already accepted from the cloud computing providers. They classified them in four sections according to the security mechanisms that they provide: authentication, confidentiality, access control and authorization. They conclude that if all recommended measures are taken into account providing authentication, confidentiality, access control and authorization, then the cloud computing can be trusted in data protection. They focused on the security issues that should be taken into account in depth in order to have proper data security in the cloud. They recommended important security measures relating to data protection in the cloud that must be taken into account.

Waleed et al., [10] focused on improving the security of the cloud and user's privacy. They emphasized on the security deficiencies and the subsequent repercussions regarding the commonly ignored area of private cloud users' information privacy. They proved that UEC can be a valuable point for cloud database researchers, designers, and the cloud platform vendors. By proving that there is a balance between the duties of the unrestricted cloud administrators and providing only the important identified information based on administrator, they achieved that the UEC ensures security and privacy in cloud computing.

Alotaibi et al., [11] examined the factors contributing to the adoption of SaaS. They drew upon prior research to develop a revised model based on the UTAUT. The proposed model offers a comprehensive explanation for SaaS adoption behavior, by modeling QoS as a primary antecedent of BI, due to its role in online services. Furthermore, education was incorporated into the model as a moderating factor to fit the context of SaaS adoption in developing countries. The revised model was empirically examined using empirical data collected by means of an online questionnaire.

D S Abd Elminaam et al., [12] presents a performance evaluation for six of the most common block Symmetric

encryption algorithms the selected algorithms are AES, DES, 3DES, RC6, Blowfish and RC2. The results show that Blowfish has better performance than other common encryption algorithms used, followed by RC6.

Many other researchers who are recognized in literature such as [13]-[17] reviewed a comparative analysis of encryption algorithms like AES, DES and RSA for data communication by using encryption time; memory usages output byte and battery power. They also studied the evaluation of performance of selected symmetric key algorithms. In [18]-[21] authors studied the security threats and maintain in mobile ad hoc networks. They also studied the main attack types and several security techniques that help the MANETs to protect from internal or external attacks and aspects of intrusion detection.

III. MATERIALS AND METHODS

The proposed hybrid cryptography algorithm developed to secure the data and information which is transmitted through the cloud. The aim of the hybrid cryptography algorithm is to efficiently encrypt and secure the transmitted data. Fig. 1 shows the structure of the implemented hybrid cryptography algorithm.

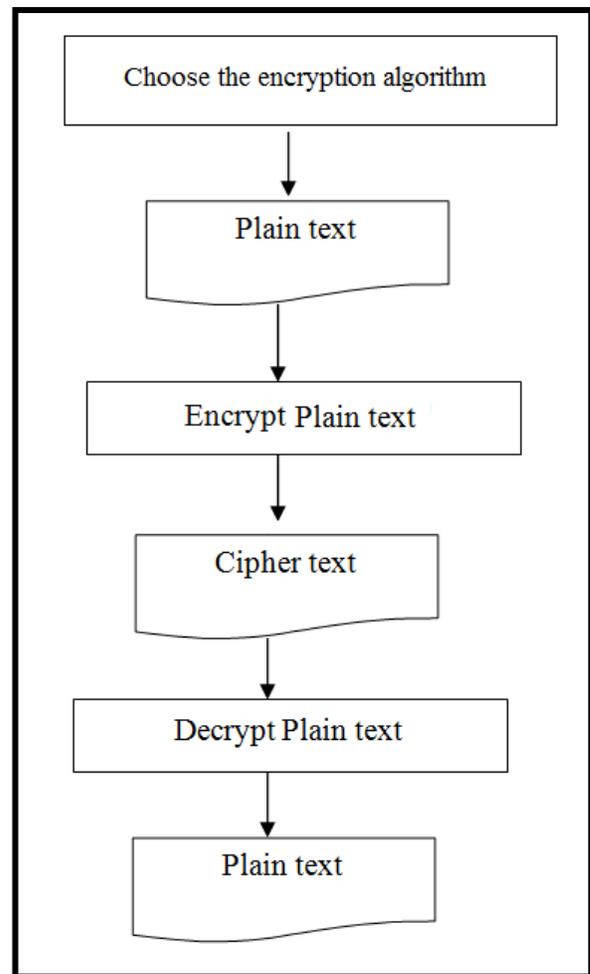


Fig. 1. System structure.

The proposed hybrid cryptography algorithm offer set of encryption algorithms:

- 1) Hybrid encryption algorithm using Krishna and Triple DES algorithms.
- 2) Hybrid encryption algorithm using Krishna and AES algorithms.
- 3) Hybrid encryption algorithm using Krishna and Blowfish algorithms.
- 4) Hybrid encryption algorithm using RSA and Triple DES algorithms.
- 5) Hybrid encryption algorithm Krishna and AES and Blowfish algorithms.

The aim of the proposed hybrid cryptography algorithm is to determine the most fast and secure encryption algorithm of the previous presented encryption algorithms. It also allows the user to choose the encryption algorithm which is more suitable for the type of his own data. Also, the hybrid cryptography algorithm implements several encryption algorithms and allow the user to use them to encrypt his own data these algorithms are:

- 1) AES
- 2) Blowfish

In Krishna algorithm, several steps have to be done to encrypt and decrypt the text. To encrypt the text the algorithm will work as follow:

- 1) In the Text, each letter is treated as a digit in base 26
- 2) A block of n letters is considered as a vector of n dimensions.
- 3) Multiply the vector by a $n \times n$ matrix (Key).
- 4) Get the modulo 26 of the resulted matrix.

In order to decrypt, we turn the cipher text back into a vector, then simply multiply by the inverse matrix of the key matrix.

Fig. 2 shows how the system encrypts the data using the Krishna encryption algorithm and Triple DES encryption algorithm.

Fig. 3 shows how the system encrypts the data using the Krishna encryption algorithm and AES encryption algorithm.

Fig. 4 shows how the system encrypts the data using the Krishna encryption algorithm and Blowfish encryption algorithm.

Fig. 5 shows how the system encrypts the data using the RSA encryption algorithm and Triple DES encryption algorithm.

Fig. 6 shows how the system encrypts the data using the Krishna encryption algorithm, AES encryption algorithm and Blowfish encryption algorithm. In this algorithm the system divides the plain text in to two parts. The first part was encrypted and decrypted using Krishna encryption algorithm and AES encryption algorithm. The second part was encrypted and decrypted using Krishna encryption algorithm and Blowfish encryption algorithm.

The proposed hybrid cryptography algorithm calculates the time and throughput for each of the pervious encryption algorithms.111

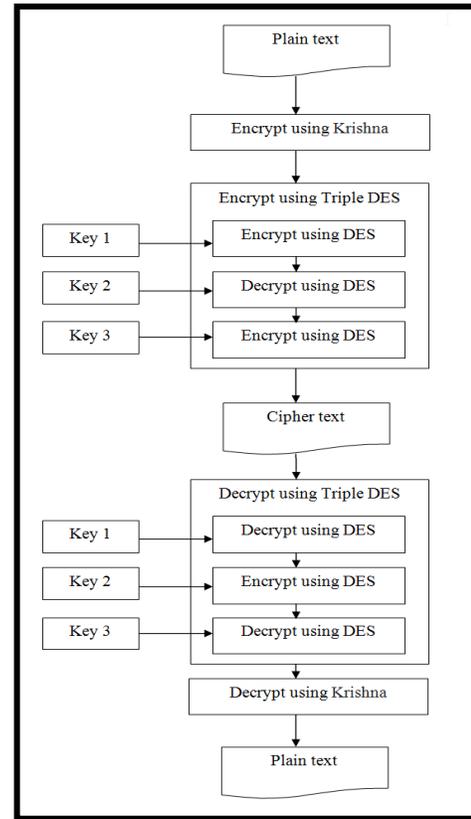


Fig. 2. Hybrid encryption algorithm using Krishna and Triple DES algorithms.

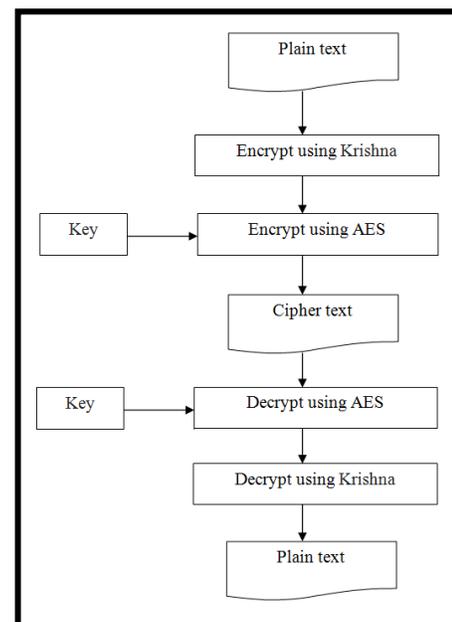


Fig. 3. Hybrid encryption algorithm using Krishna and AES algorithms.

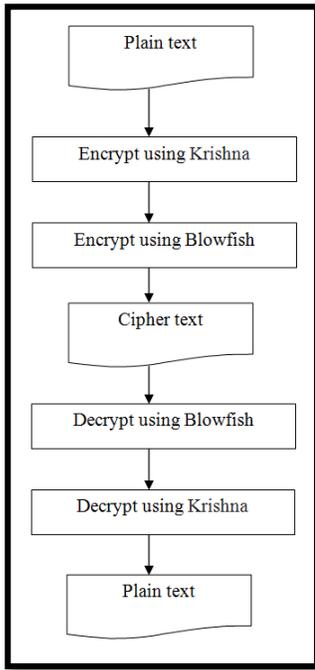


Fig. 4. Hybrid encryption algorithm using Krishna and Blowfish algorithms.

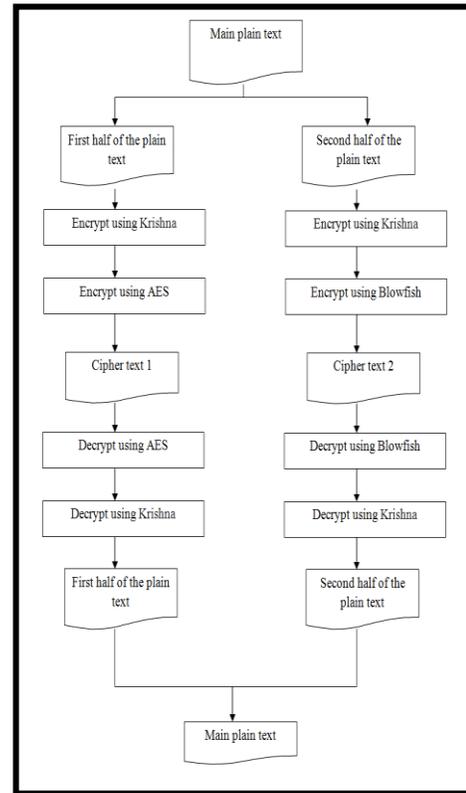


Fig. 6. Hybrid encryption algorithm Krishna, AES and Blowfish algorithms.

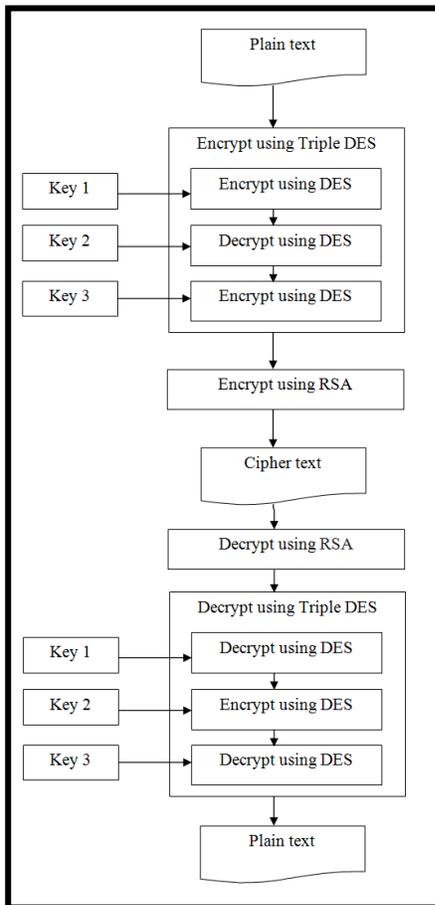


Fig. 5. Hybrid encryption algorithm using RSA and Triple DES algorithms.

IV. RESULTS AND DISCUSSION

Extensive experiments are performed to study the efficiency of the implemented hybrid cryptography algorithm encrypt and decrypt data in a minimum time. The hybrid cryptography algorithm was tested on different file sizes. The system runs 50 times for each file size to calculate the average time for each encryption algorithm. Table 1 show the time consumed in encrypting data using the eight algorithms.

As shown in Table 1, the proposed hybrid cryptography algorithm allows the user to encrypt his data with hybrid encryption algorithms that uses two strong encryption algorithms without taking large time in encrypting data. For example, encrypting a file with 1 MB using Blowfish algorithm takes 11.99 seconds and at the same time encrypting the same file using Blowfish and Krishna takes 9,28 seconds. This is because at the second algorithm the plain text was encrypted using Krishna algorithm at the first then the cipher text was re-encrypted using Blowfish algorithm and because that Krishna minimize the size of the plain text in on word the size of the cipher text sent to Blowfish will be small and the algorithm will take minimum time to encrypt it. Table 2 and Fig. 8 illustrate the throughput of the algorithms. Throughput was calculated by dividing the size of the file in bytes over the consumed time in seconds. The throughput was calculated using the following equation:

$$\text{Throughput} = \frac{\text{File size}}{\text{Encryption time}} \quad (1)$$

TABLE I. THE TIME CONSUMED IN ENCRYPTING DATA FOR EACH ALGORITHM

File size \ Algorithm	250 KB	500 KB	750 KB	1 MB	1.25 MB	1.5 MB	1.75 MB	2 MB	2.25 MB	2.5 MB	2.75 MB	3 MB	3.25 MB	3.5 MB	3.75 MB	4 MB
Triple DES & Krishna	0.7	0.8	2.2	3.1	4.3	5.7	6.4	7.1	9	10.9	12.3	13.4	14.7	15.3	16.6	18.1
AES & Krishna	.6	1.1	1.7	3.4	4.2	7.1	8.5	12.3	16.8	18.9	20.5	23.7	25.2	29.6	33.1	36.3
Blowfish & Krishna	2.3	4.9	6.4	9.2	12.3	13.6	15.5	18.6	20.1	23.2	27.8	29.6	32.9	36.7	40.7	42.5
Triple DES & RSA	2.7	4.5	6.8	8.5	11.3	15.5	19.4	20.8	23.7	25.8	27.4	31.6	33.4	34.4	38.3	42.1
AES & Blowfish & Krishna	2.8	4.0	4.3	6.9	8.9	10.4	13.1	15.9	17	19.4	22.1	24.9	27.6	30.3	32.8	34.7
AES	0.6	1.2	1.8	2.4	3.3	4.2	5.8	6.9	7.3	8.7	9.9	11.5	13.6	15.9	18.1	20.6
Blowfish	2.4	5.1	8.4	11.9	14.2	17.9	21.4	24.3	26.2	29.5	31.8	35.7	39.1	42.4	46.2	48.9

TABLE II. THE THROUGHPUT FOR EACH ALGORITHM

File size \ Algorithm	250 kb	500 kb	750 kb	1MB
Triple DES & Krishna	328947.36	595238.09	337837.83	327156.54
AES & Krishna	412903.23	435744.68	432919.95	300193.52
Blowfish & Krishna	110678.77	103038.84	11864.66	112968.75
Triple DES & RSA	90252.70	109649.12	112275.44	120046.89
AES & Blowfish & Krishna	89074.46	126482.21	175824.17	150484.50

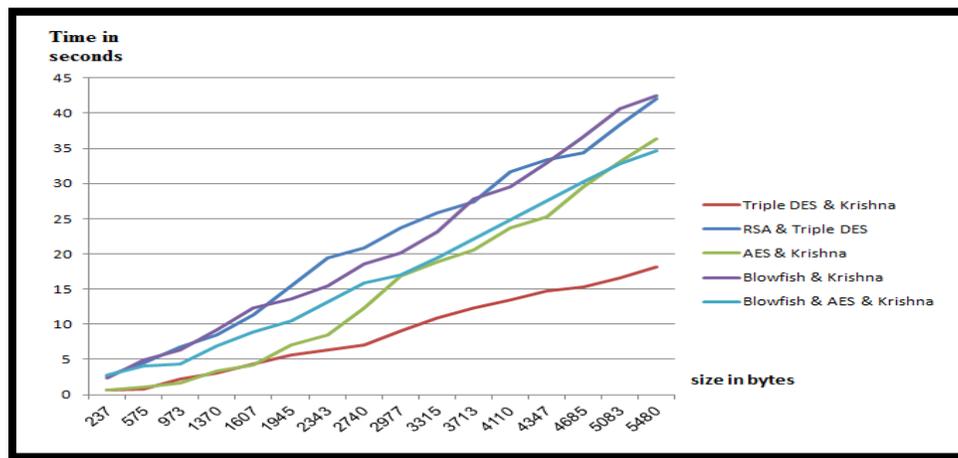


Fig. 7. The time consumed in encrypting data for each algorithm.

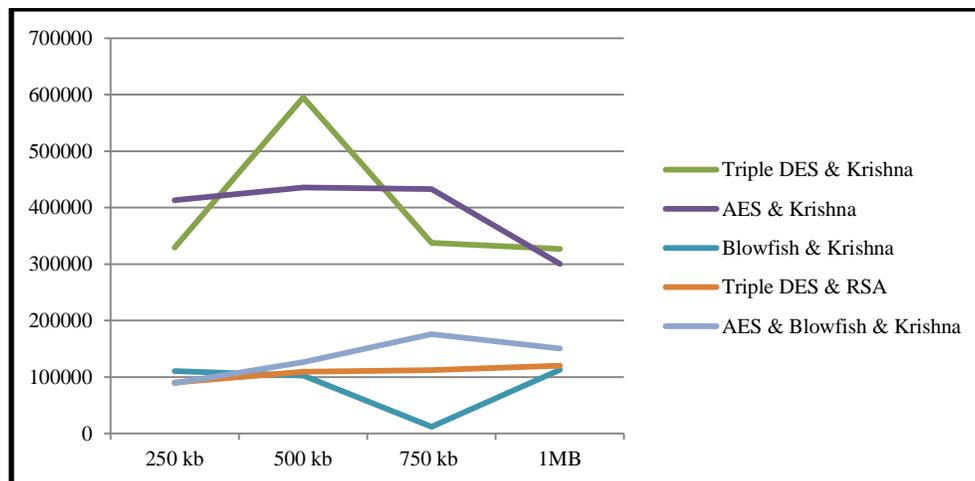


Fig. 8. The throughput for each algorithm.

The result show that the hybrid encryption algorithm (Triple DES & Krishna) takes the lowest time to encrypt the data comparing with other algorithms as shown in Table 1 and Fig. 7.

Jiehong et al., [1] provided evaluation of three of the common encryption algorithms: AES, Blowfish, and GOST. A comparison has been conducted for those encryption algorithms at different sizes of data blocks. Also, Bhandari [2] presented HE-RSA or hybrid encryption RSA along with Advanced Encryption Standard or AES to ensure efficiency, consistency and trustworthiness in cloud servers. His goal was to use various cryptography concepts during communication along with its application in cloud computing and to enhance the security of cipher text or encrypted data in cloud servers along with minimizing the consumption of time, cost and memory size during encryption and decryption. Our implemented hybrid cryptography algorithm (Triple DES & Krishna) shows a better result than the results presented in [1], [2].

To use the hybrid cryptography algorithm the user, choose the algorithm he wants to encrypt his own data with as shown in Fig. 9. The user will choose the algorithm and press “use” to begin the encryption process.

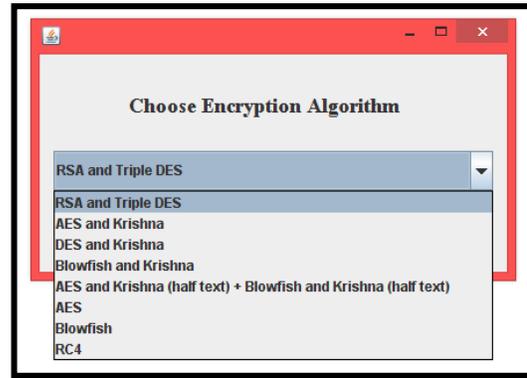


Fig. 9. Selecting the encryption algorithm.

The user determines the place of the file as shown in Fig. 10 then he will enter the keys of the algorithm and press encrypt. As shown in Fig. 11 the hybrid cryptography algorithm retrieves the time consumed in encrypting the data on the selected file. The same steps will be made in the decrypting process but the selected file will be the encrypted file resulted from the encryption process; Fig. 12 and 13 illustrate the decryption process.

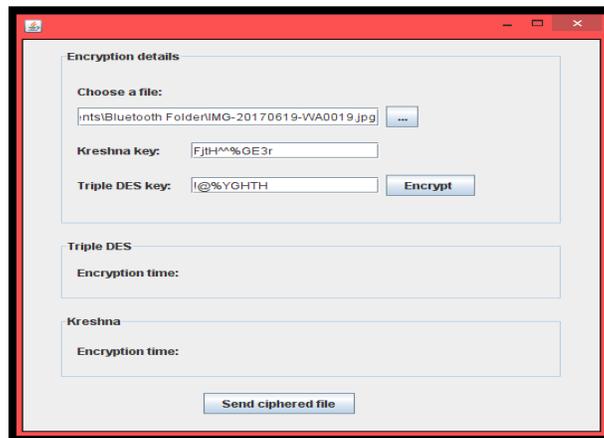


Fig. 10. Selecting the file to be encrypted.

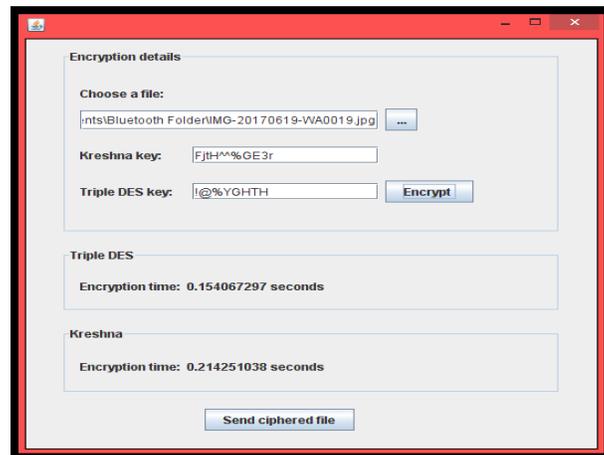


Fig. 11. Retrieves the time consumed in encrypting the data.

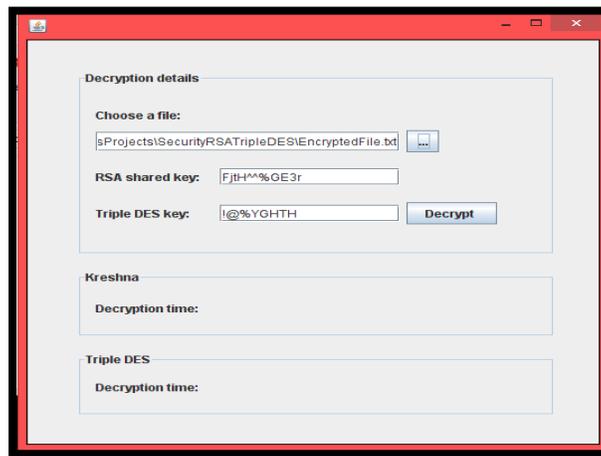


Fig. 12. Selecting the file to be decrypted.

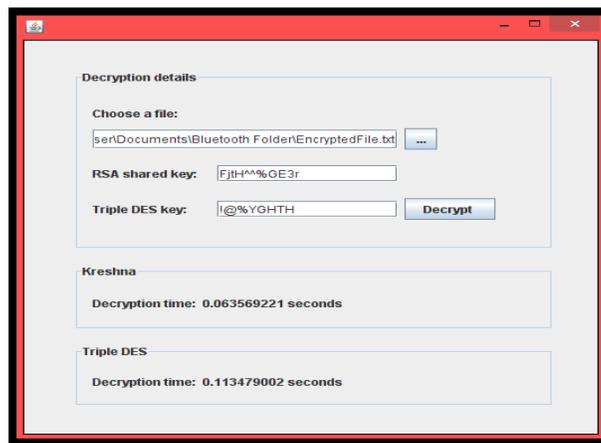


Fig. 13. Retrieves the time consumed in decrypting the data.

V. CONCLUSION AND FUTURE WORK

In this paper, we present a hybrid cryptography algorithm that efficiently encrypts the transmitted data through the cloud. Firstly our hybrid cryptography algorithm presents a variety of different encrypting algorithms that allow the user to choose the encrypting method which is suitable with his own type of data. Secondly, the hybrid cryptography algorithm improves the performance of the encryption algorithms since it encrypts the data in a minimum time and in a secure way. Thirdly, the proposed hybrid cryptography algorithm allows the users to send and receive data in a secure way without facing the problem of attacking data. Fourthly, the encryption times for encrypting a file with a size 1 MB using difference hybrid algorithms come in the following ascending order: using Triple DES & Krishna hybrid algorithm takes 3.13 seconds, using AES & Krishna hybrid algorithm takes 3.493 seconds, using Triple DES & RSA hybrid algorithm takes 8.53 seconds and using Blowfish and Krishna hybrid algorithm takes 9,28 seconds. Fifthly, the proposed hybrid cryptography algorithm prove that merging the three encrypting algorithms AES, Blowfish and Krishna to have AES & Blowfish & Krishna hybrid algorithm increases the security level and also saves the encryption time, so we

can encrypt a file with a size 1 MB using AES & Blowfish & Krishna hybrid algorithm in 6.968 seconds. Sixthly, after calculating the throughput for all hybrid algorithms on a file with a size 1 MB, the Triple DES & Krishna hybrid algorithm shows the largest value for the throughput and on the other side the Blowfish & Krishna hybrid algorithm shows the lowest value for the throughput. Lastly, the proposed hybrid cryptography algorithm proves that using hybrid algorithms increase the level of securing the encrypted transmitted data and also minimize the time taken to encrypt it. As a future work, new hybrid algorithms will be constructed from different existence algorithms to improve the encryption process and compare it with the results of our current work.

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Recognizing Rainfall Pattern for Pakistan using Computational Intelligence

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Abstract—Over the world, rainfall patterns and seasons are shifting in new directions due to global warming. In the case of Pakistan, unusual rainfall events may outcome with droughts, floods and other natural disasters along with disturbance of economy, so the scientific understating of rainfall patterns will be very helpful to water management and for the economy. In this paper, we have attempted to recognize rainfall patterns over selected regions of the Pakistan. All the time series data of metrological stations are taken from the PMD (Pakistan Meteorological Department). Using PCA (Principal Component Analysis), monthly metrological observations of all the stations in Punjab have been analyzed which covers the area of 205,344 km² and includes monsoon-dominated regions. To tackle the problem of inter-annual variations, trend detection, and seasonality, rainfall data of Lahore, the Pakistan is taken that covers the period of 1976-2006. To obtain results, MASH (Moving Average over Shifting Horizon), PCA (Principal Component Analysis) along with other supporting techniques like bi-plots, the Pair-wise correlation has been applied. The results of this study successfully show seasonal patterns, variations and hidden information in complex precipitation data structure.

Keywords—Rainfall patterns; trend detection; time-series analysis; principal component analysis; box-plot; moving average over shifting horizon; inter-annual variability

I. INTRODUCTION

In the previous two decades, the topic of weather change has appeared strongly over global in perspective to its expected inferences on the atmosphere. Extreme weather events and disturbed patterns of rainfall outcomes with the uncertain behavior of the seasonal phenomenon in many areas over the world due to global warming [17] that affects water resources and agriculture directly [14]. These deviations in the seasonal patterns are noteworthy in their consequences. In case of Pakistan, economy and human life significantly depend upon the seasonal behaviors [6]. Moreover, national task force on climate change (2010) reports many droughts, floods, earthquakes, natural disasters and heavy rainfall events in this country [4]. Recognition of rainfall shapes has gained importance and interest during last decades to identify changes in the seasonal phenomenon [13]. Principal Component Analysis (PCA) is a well-known technique of multi-dimensional scaling having valuable properties such as expository analysis and computational simplicity [8]. Moreover, this is especially helpful to recognize unknown nature of component patterns [15]. It retains maximum

information by the linear transformation that converts high dimensional variables into low dimensional space i.e. dimension reduction [19] where new coordinates known as principal components. PCA is a standard analysis technique and used in many fields to clarify total variance in the dataset [9].

MASH (Moving Average over Shifting Horizon) is an innovative technique to identify patterns in time-series data by visualizing the variabilities via graphical representation based on EDA (Exploratory data analysis) [1]. Graphical representation of time-series dataset can be helpful in interpreting, identifying the patterns [7] and associations among data [16]. In general, MASH aims to determine sequential variation in a seasonal pattern based on metrological observations over time. Rainfall data can be monthly, daily, yearly. In our case, statistic measurement is the mean, but one can be used others like median as well. Results of MASH make possible and easier to investigate about seasonal patterns along with trends that can be detected by visual inspection [1]. This paper is arranged as follows: This part contains the importance of rainfall and a short introduction of methods used in this study. The following section includes the picture of the study area. The material and methods part incorporate the techniques that are used to reveal patterns in rainfall of selected areas, while the section of results & discussion shows the major findings of this study. In the last SECTION, the conclusions of the research are presented in Software testing.

II. STUDY AREA

The Pakistan is positioned at 23°, 37° north latitudes, and 61°, 76° east longitude having a large variety in a seasonal and spatial variation of the weather. Coastal areas of the country are located along with the Arabian Sea and have little rainfall and extreme warm seasons and; its western areas are waterless and very hot cover with deserts. The northern areas have heavy rainfall and very low temperature. Moreover, the East-South areas have very low rainfall and remain very hot in the monsoon [18]. To analyze the behavior's and patterns of rainfall in the Punjab Pakistan, five years' monthly precipitation observations of different stations have been taken which covers the period of 2005-2010. All the metrological stations that are selected for the study have their own significance due to their geographical location. Selected stations are listed in Table 1.

TABLE I. METROLOGICAL STATIONS

Station	Latitude (°N)	Longitude (°E)	Elevation (a.m.sl)
Islamabad	33.71	73.06	622
Lahore	31.54	74.22	214
Jhelum	32.93	73.73	287
Sialkot	32.31	74.32	255
Jhang	31.16	72.19	159
Sargodha	32.03	72.40	187
Multan	30.12	71.26	121.95
Mianwali	32.58554	71.5436	210
Khanpur	28.39	70.41	88.41
Faisalabad	31.26	73.08	185.6
Bahawalpur	29.2	71.49	110
Muree	33.9	73.39	2291
Bahawalngar	29.2	73.51	161.05

III. LITERATURE REVIEW

Ellouze et al. [5] made an investigation to recognize patterns of rainfall along with temporal and spatial variability in precipitation dataset for the area of southern Tunisia. Rainfall data was covering the period of 1930 to 2000. To discover governing variables related to their variability and the nature of precipitation distribution, they applied Principal Component Analysis (PCA) on metrological observations recorded in 12 stations. They found first three PCs (principal components) that were significant to explain the total variance of 90%. Rainfall variability was exposed to be dependent on the seasonal situation. Annual precipitation was significant over the area of south-eastern. [11]. This study was conducted by applying PCA (Principal Component Analysis) with the aim of identifying daily precipitation pattern over a period of twenty years i.e. 1994 to 2013 using records from eighty-nine (89) metrological stations located throughout the country of Malaysia. Six principal components were retained by using principal component analysis with the whole variance of 53.43 percent. The 1st and the 2nd component incorporated the areas that were showing attributes of south-west and north-east monsoon seasons respectively. The 4th principal component was covering the northern areas of the peninsular Malaysia along with two extreme points in precipitation amount occurred per year. They analyze the difference between regions in 3rd, 5th, and 6th principal components. At the end of the study, they suggest that PCA is a suitable technique to reduce the dimension in complexity dataset.

Alkan et al. [2] determine the precipitation patterns of monthly rainfall data of Turkey by computing PCA (Principal Component Analysis) biplot. To extract patterns of seasonal rainfall, they use rainfall data which was covering the period of 1970-2010 recorded from 81 metrological stations. Principal component analysis bi-plot was applied to inspect the

relationship multidimensional variations between the metrological variables. The conclusion of this research revealed that bi-plots and PCA can be helpful graphical techniques to monitor rainfall [2].

Anghileri et al. [1] proposed and applied an approach named MASH (Moving Average over Shifting Horizon) based on EDA (Exploratory Data Analysis), which reveals the patterns of rainfall by computing daily precipitation observations for the time period of 1974-2010. They find out the inter-annual variability and seasonality. The results of this study were showing many important trends in considered time horizon. The results obtained by MASH were successfully visualized to observe seasonal behavior and to detect precipitation trends via visual examination.

IV. MATERIAL AND METHODS

Principle component analysis (PCA) is a statistical procedure and commonly used in various modern data processing fields [10]. The general algorithm for performing a principal component analysis is below.

- Consider the total data-set having d-dimensional observations and ignore the data labels.
- For the whole dataset, compute the means for each dimension i.e. (Calculate the mean vector of d-dimensional)
- Compute the covariance matrix of the whole dataset.
- Calculate the eigenvectors and corresponding eigenvalues.
- The computed eigenvectors are now orthogonal and can be used to project the actual data into the new coordinate system. The projection of actual data by a matrix of eigenvectors reveals the PCs (principal components) Y. [3].

Moreover, this calculation can be done by the equation i.e. $y=WT \times x$. (where x is a d×1-dimensional vector representing one sample, and y is the transformed k×1-dimensional sample in the new subspace.)

We have applied Moving Average over Shifting Horizon (MASH) technique to explore rainfall patterns while handling the subject of inter-annual variability and seasonality in rainfall data. The objective of this technique is to evaluate changes in the seasonal pattern. In this method, seasonal patterns are represented through 12 values of the average monthly flow over the year. While averaging, rainfall data over successive months in the same year and over same months in successive years will consider. On the other hand, the horizon of successive years is increasingly shifted-ahead to take into account any pattern to develop. Thus, MASH is a matrix and is shown below

$$\text{MASH} = \begin{pmatrix} \mu_{1,1} & \mu_{1,2} & \mu_{1,3} & \dots & \mu_{1,Nh} \\ \mu_{2,1} & \mu_{2,2} & \mu_{2,3} & \dots & \mu_{2,Nh} \\ \mu_{3,1} & \mu_{3,2} & \mu_{3,3} & \dots & \mu_{3,Nh} \\ \dots & \dots & \dots & \dots & \dots \\ \mu_{12,1} & \mu_{12,2} & \mu_{12,3} & \dots & \mu_{12,Nh} \end{pmatrix}$$

Columns in above MASH matrix are the mean of seasonal flow patterns that are calculated over dissimilar horizons (Nh). More accurately $\mu_{t,h}$ denotes the average monthly flow on the time of t-th i.e. month of the year in horizon (h-th) and calculated as in equation below

$$\mu_{t,h} = \text{mean}_{y \in [h, h+Y-1]} \left[\text{mean}_{d \in [t-w, t+w]} x_{d,y} \right]$$

In this equation, $x_{d,y}$ denotes the inflow over specific d-th month of y-th year with respect to time series. Y is equal to total length of years of the shifting horizon, $1+2w$ is a scalar figure of months. Nh is actually total number of horizons and associated with Y i.e. $(Nh = N_y - Y + 1)$ where N_y is total number of years in actual time-series data.

V. RESULTS AND DISCUSSION

Box-plotting or whisker-plotting is a commonly used statistical approach that provides graphic representation of distribution and patterns placed in quantitative data [12].

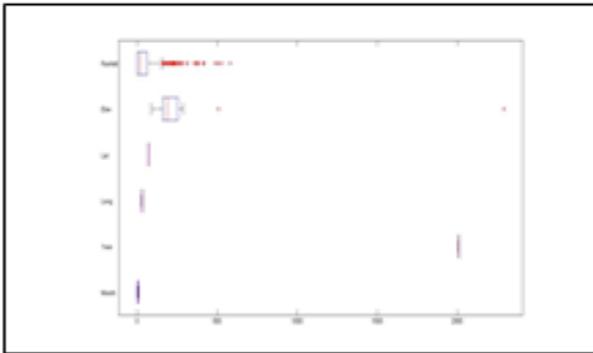


Fig. 1. Boxplot to analyze the distribution of rainfall data of the Punjab.

In the above Fig. 1, can see from a red dotted area that there is more variability in the variables of the Rainfall along with elevation than in other variables.

Before computing principle components of rainfall dataset, the pair-wise correlation between pairs of all variables has been checked and it was as high as 1 and 0.95. This shows the high correlation among some variables. However, PCA develops new independent variables which are the linear combination of actual variables.

PCA computes the rainfall dataset variables into scores known as component scores that are orthogonal (can be plotted on 2D graph).

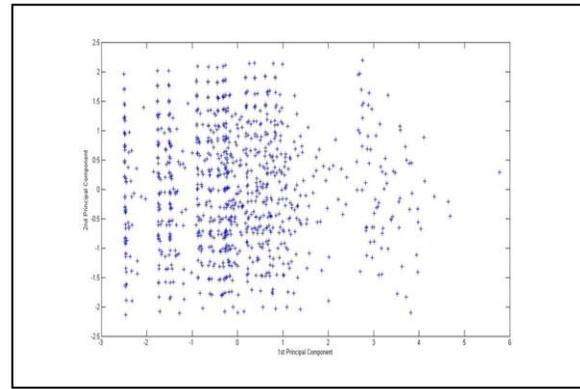


Fig. 2. Plot of the first two columns of scores generated.

Principle component analysis actually computes the all component scores to have mean zero. Above Fig. 2, plot shows the centred and scaled precipitation data plotted onto the initial two PC's i.e. PC1 and PC2.

Below is a vector that contains the values of variance in percentage by corresponding six PC's.

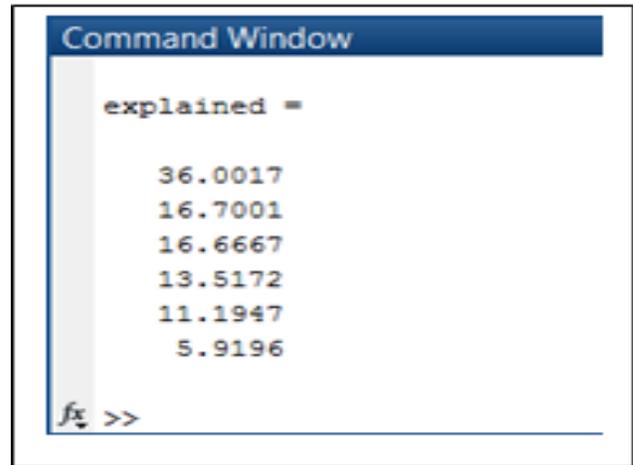


Fig. 3. Observed variance in first six PC's.

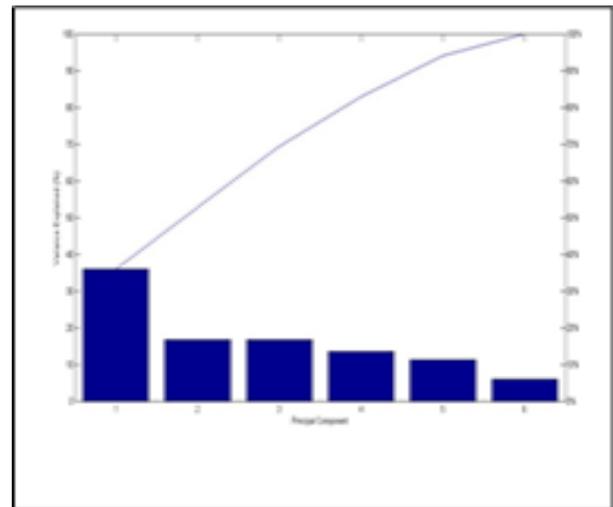


Fig. 4. Variance in PC1 to PC6.

The above Fig. 3 shows variance (in percentage) with respect to PC1, PC2, PC3, PC4, PC5 and PC6. From this one can analyze that how much variance in the dataset is explained by which PC (as a bar) and how much variance is explained by the first 6 PCs. In Fig. 4, plot shows the six components that explain 100% of the total variance. The only clear break in the amount of variance accounted for by each component is between the first and second components. However, the first component by itself explains less than 40% of the variance. We can see that the first three principal components explain roughly two-thirds of the total variability in the standardized ratings, so that might be a reasonable way to reduce the dimensions. By removing the PCs that contribute little to the variance, we project the entire Data-set to a lower dimensional space but retain most of the information. So, we will take the PC1 and PC2 to visualize results. Hoteling's T2 is the last output that PCA gives and systematic approach to get most extreme points in the dataset. When we compute this value, it gives us index number of data that was locating the extreme point in rainfall dataset and from this, we observe that the rainfall values for Muree are the furthest from the average Punjab stations. All six variables are represented in Fig. 5 by a vector, and the direction and length of the vector indicate how each variable contributes to the two principal components in the plot. For the figure below, the first principal component, on the horizontal axis, has positive coefficients for all variables except Year (because year falls in negative side and have less effectiveness/variance and can be deduced in the PC1 to reduce dimensions). That is why the five vectors are directed into the right half of the plot. The major coefficients in the first principal component are the Longitude, elevation, and latitude having most positive effectiveness respectively. The second principal component has positive coefficients for rainfall to show his importance (positive effectiveness). Month variable has less positive variance and is difficult to see as it lies on the x-axis so we draw it in next 3D (Fig 6).

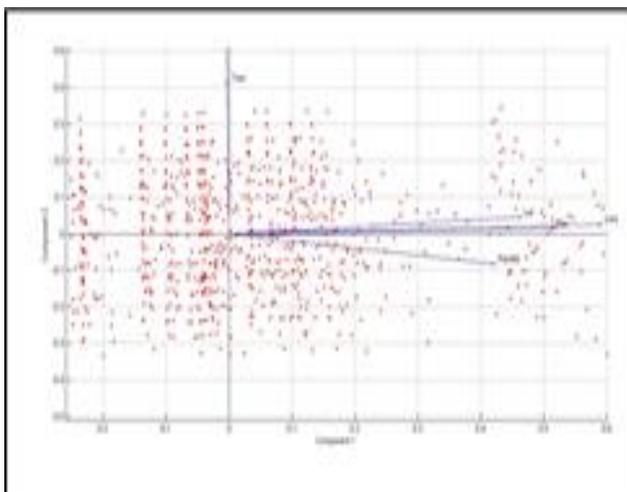


Fig. 5. 2D representation of PC1 vs. PC2.

This indicates that the first component distinguishes among metrological stations that have high values for the first set of variables and low for the second, and stations that have the opposite.

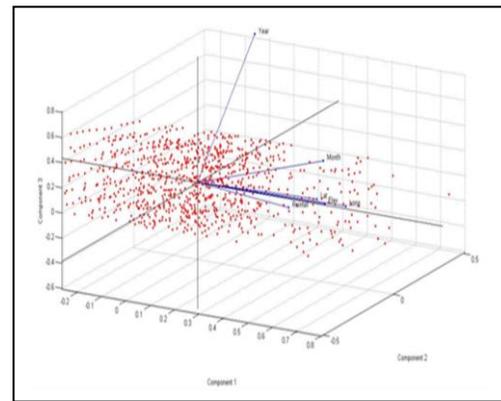


Fig. 6. 3D representation of PC1, PC2 and PC3.

The MASH technique has two numbers of tuning parameters used for averaging i.e. a number of months along with years. As other smoothing methods, there is also no general rule to fix these parameters.

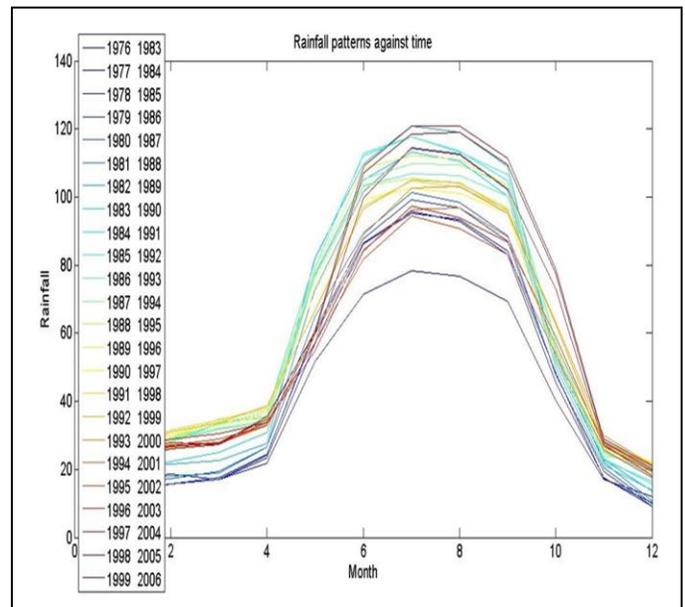


Fig. 7. Graphical representation of plotted MASH of the historical monthly inflows.

Above Fig. 7 provides a graphical illustration of a MASH of monthly inflows at the values of $w = 2$ months, $Y = 7$ years over the time horizon of 1976-2006. The first line in the color bar is actually the moving average calculated over the specific horizon of 1976-1983 and the second line represents the moving average computed over the period of 1977-1984, etc. Since the actual time-series of our monthly rainfall data covers a period of $N_y = 30$ years i.e. from 1976 to 2006 but the MASH is made of $N_h = 24$ flow monthly seasonal patterns due to the selected value of shifting horizon. In above figure, latest horizons are plotted through red-colored lines and older horizons are plotted through blue colored lines. In addition, above figure shows the rainfall phenomenon over 12 months along with variations in seasonal rainfall among different time horizons.

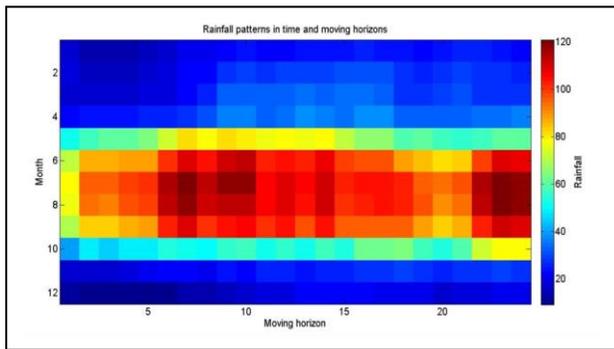


Fig. 8. Visual Inspection of MASH: Rainfall patterns of hydrological seasons.

The above Fig. 8 gives an informative and very concise representation of rainfall patterns along with variations during distinct hydrological seasons. The cool dry season has enlarged to 3rd month i.e. March, Monsoon season having red colored area starting from 6th and ending at 9th month comes with disturbed patterns and unusually heavy rainfall events. Moreover, one can also inspect the different seasons of the selected region i.e. Lahore, the Pakistan. These results were obtained using $w = 2$ which filter out the variation between months and $Y = 7$ which filter out the variability year to year.

VI. CONCLUSION

The study identifies the spatial and temporal characteristics of possible physical significance.

In this study, rainfall patterns along with seasonality and inter-annual variability's over selected regions of the Pakistan have been successfully extracted from time series data using PCA (Principle component analysis) and MASH (Moving average over shifting horizon). PCA has been put into work for the extraction of rainfall patterns in the Punjab, Pakistan. Using PCA, variability in the monthly rainfall of Jhelum, Sialkot, Jhang, Sargodha, Multan, Lahore, Mianwali, Khanpur, Islamabad, Faisalabad, Bahawalpur, Muree, and Bahawalnagar was examined. The supporting technique of PCA i.e. box-plot reveals that variability in the variables of the Rainfall and elevation was more than in other variables. Pair-wise correlation between pairs of all variables has been checked and it was as high as 1 and 0.95. Rainfall values for Muree were the furthest from the average Punjab stations. Six principal components were computed to check the Variance and first two PC's was considered to obtain results as they were explaining two-thirds of the total variability. The first eight principal component patterns explain for 96.70% of the total variance. The first principal component was showing positive coefficients for all variables except Year. The analysis of Lahore, Pakistan reveals some significant trends of rainfall with disturbed patterns and heavy rainfall events in a monsoon for the period of 1976-2006: Moreover, different seasons of the selected region have been projected. The results of this investigation suggest that PCA and MASH can be very useful techniques to inspect metrological data as well as for rainwater management.

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Analysis and Formal Model of RFID-Based Patient Registration System

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Abstract—Patient Registration System (PRS) is an important part of hospital environment. Therefore, semiformal model of Patient Registration System that registers the patients by assigning Radio Frequency Identification (RFID) card or bracelet is presented in this paper. The existing Patient Registration Systems do not properly work due to ambiguities and semiformal modeling techniques. However, that is why we will propose formal modeling for PRS using Vienna Development Method (VDM-SL). Firstly, we develop the Unified Modeling Language (UML) based semiformal model of PRS because UML is used for better understanding of the system architecture. Formal methods are used to ensure accuracy and robustness of the system. Therefore, we transform the UML based model into formal model by writing formal specification of the system to improve accuracy and efficiency of PRS. In this way, development time, testing and maintenance cost in building RFID based PRS software is reduced to a great extent.

Keywords—Patient registration system; Radio Frequency Identification (RFID); bracelet; formal method; semiformal modeling; verification

I. INTRODUCTION

The patient registration systems handle the complex situations. Therefore, a good patient registration system is very important for the development of healthcare system. The principal commitment for the patient registration system is to improve the quality of healthcare system. Mostly the existing patient registration systems (PRS) just provide basic functionalities and do not assign RFID card or RFID bracelet to the patients at registration time. RFID is used for remotely storing and retrieving records. An integrated structure is provided to build an RFID card system by inserting smart tags in medical cards and medical bracelets to store medical information [1]. In this paper RFID bracelets or cards are used to track patients. Assigning RFID tag to patients improves the patient safety, prevention and depletion in medical errors.

We use Unified Modeling Language (UML) for semiformal modeling of PRS. UML describes a system in detail. Although UML provides deeper understanding of the system but it does not provide assurance about the correctness of the system. The specification of software system is a major issue in software engineering. There are always conflicts which cause errors in

the upcoming stages of software development. Formal methods are good techniques for verifying and removing ambiguities. By using formal methods, we can identify the system in better way. Therefore, this paper presents formal modal of RFID base PCS. Formal methods are used in the very beginning level of the software development, so that the errors in later levels are eliminated. Formal methods are procedures used to model complex systems as mathematical entities. Formal strategies are used to transform the complex structures into mathematical models thereby making it possible to validate in more careful way than conventional testing strategies [2].

This RFID based PRS is based on the electronic storage of the patient records. The purpose of the system is to give access through internet to authorized users in the system. The patient information which is stored and put in the PRS system must also be correct. To improve the quality of patient registration system in terms of accuracy, robustness and reliability, we model the requirements of PRS in VDM-SL by removing all the errors. Currently we concentrated on registration of the patients in our model by inserting RFID tag into RFID bracelet or card and give it to the patient at registration time. Remaining sections are as follows.

II. LITERATURE REVIEW

RFID based healthcare system and patient registration system has been studied by researchers in different backgrounds. RFID based conceptual system for smart hospital which provides safe and secure patient management system is described in [3]. The proposed system in [4] uses RFID tags for reliable access, allows efficient positioning and identification of patients who are unfit to communicate. In [5] an RFID based smart suite is implemented to create a healthcare monitoring system for monitoring patients in real-time and it uses Android-based Smartphone for sending patient alarm messages to healthcare workers for improving daily emergency healthcare operations. The proposed system in [6] introduces electronic healthcare smart card (eHC) for patients and a counterpart health professional card (HPC) for doctors and paramedical staff. In [7], authors recommend a smart hospital that uses RFID identification technology to improve the patients' care, optimize the actions, reduce the operating costs, help avoiding serious mistakes and reduce costly thefts.

In [8], authors describe a hospital laboratory workflow, present the system modeling which deals with security matters related to information stored in the smart cards and use Bracelets for identification with RFID placed on the arm of hospitalized patients and also uses RFID tags stuck to containers containing patient's collected samples for the correct identification of the patient who gave away the samples. The system in [9] introduces a reliable health monitoring system designed for monitoring patients through wireless technology. It processes the large number of biomedical signals through wireless body area network and mobile technology. The system in [10] presents a new dynamic ID based lightweight RFID authentication protocol, which is designed to increase patient safety.

In [11], authors give emphasis on cost-effective applications of formal techniques in verification and validation by automatic test generation of conceptual model. The authors in [12] explain the formal specification and verification of two microprocessor based cryptographic devices that control access to a network of workstations, and a message authentication device. A Logical architecture of the Forest Fire Detection is presented in [13] which helps to generate algorithm and it is then converted into an equivalent formal model using Vienna Development Method-Specification language (VDM-SL). In [14], author presents a formal axiomatic model for ubiquitous healthcare systems which defines the formal specification requirements for healthcare systems including functional and security related requirements. In [15], authors evaluate the potential languages that can be used to formally show the extracted health insurance portability and accountability act privacy policies.

The proposed system in [16] applies and discusses the formal methods in the area of medical guidelines and protocols. In [17], authors adopt a first-order theorem proving method (Event-B) to model wireless body sensor network (WBSN) and verify security requirements of privacy at different level of abstraction for WBSN. In [18], the proposed system presents some cases of specifications for an e-Health system using Z to remove those errors which remain during the early phase of requirements collection. The developed system in [19] presents testing and verification of healthcare system by simulation based methods, formal methods and semi-formal methods which identify several open issues and challenges in healthcare environment.

III. PROBLEM STATEMENT AND SYSTEM MODEL

RFID based Patient registration system is a good model that reads the electronic information of patients. PRS provides safety, satisfaction, and identification of patients. However, here are some issues with PRS. These are defined in semiformal way to describe detailed specifications required to implement a reliably secure system. Patient registration is of great importance at global level, so all the ambiguities and non-accuracy in patient registration must be dealt with great care. The main problem of building RFID based patient registration system is to remove ambiguities and inaccuracies in the system. Because the existing PRS systems are not verified using formal technique like VDM-SL. Thus, there is a need to generate a fully verified and accurate PRS. Therefore, we use

mathematical techniques for formal modeling and a detailed formal specification is developed for proving correctness of the system.

In our model, we have described the main problems of PRS which are patient identification, manual storage of patient information and tracking the patient location without ambiguities and inaccuracies. Currently, we have focused on inpatient and outpatient registration and assign smart card or bracelet to each of patients in our model. RFID tag is inserted into the bracelet or card which is assigned to patients. Each RFID tag consists of RFID number and that tag number is assigned to the patient. The patient record is stored against that RFID number. We have assigned bracelet containing RFID chip to the inpatient and assign card containing RFID chip to outpatient. Outpatient is the patient that visits the hospital and consults with doctor and inpatient is the patient which admits in the hospital. Receptionist makes registration of patients. In patient registration system, receptionist takes real time data from patients and attaches RFID tag to bracelet or card and assigns it to the patient. For inpatient registration receptionist check the bed availability for the inpatient and appointment time for the outpatient. UML based models are given below.

A. UML Use Case of Patient Registration System

A use case diagram represents the system actions and relationship among actors and use cases. Interaction between receptionist and patient registration system described through use case diagram. In PRS use case has a receptionist as an actor and performs some action. Use cases defined in UML diagram are Schedule patient appointment and login which includes parent use case patient registration that has two child use cases inpatient and outpatient registration. In use case diagram inpatient registration use case includes two uses cases in it that are assign room and RFID card to inpatient. Outpatient registration use case includes the use case assign card and schedule appointment as presented in Fig. 1.

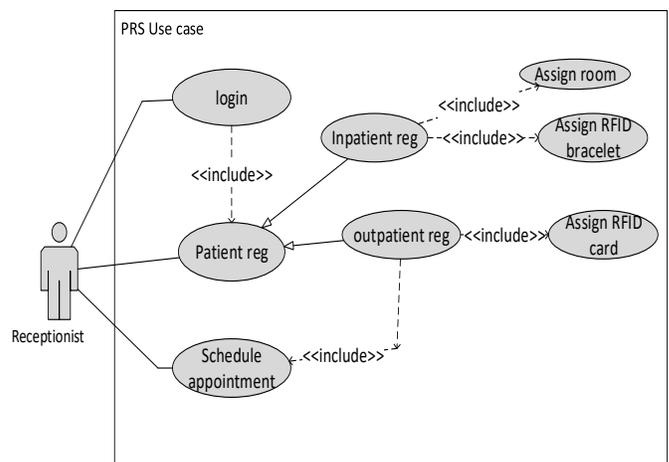


Fig. 1. Use case diagram of patient registration system.

B. UML Sequence Diagram of Patient Registration System

Sequence diagram shows the interaction between system objects. In our system, the diagram of outpatient registration shows the participants, receptionist, outpatient, system and the sequence of messages between them presented in Fig. 2.

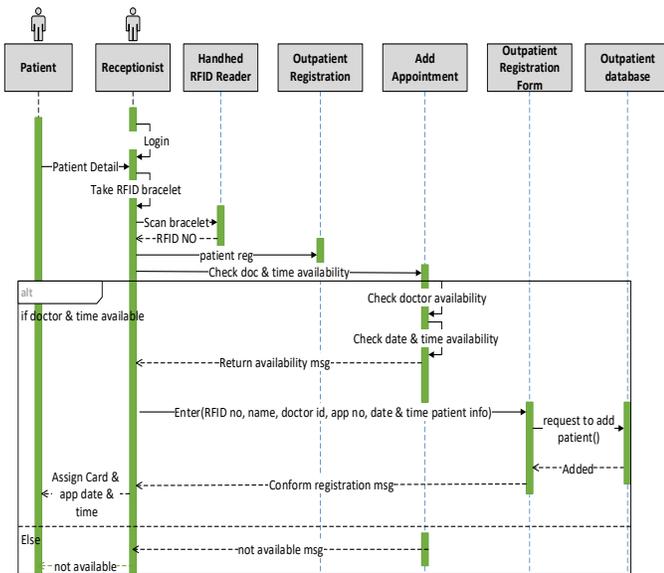


Fig. 2. Sequence diagram of outpatient registration.

Sequence diagram of Inpatient registration shows the interaction between receptionist, inpatient and system by sequence of messages between them presented in Fig. 3.

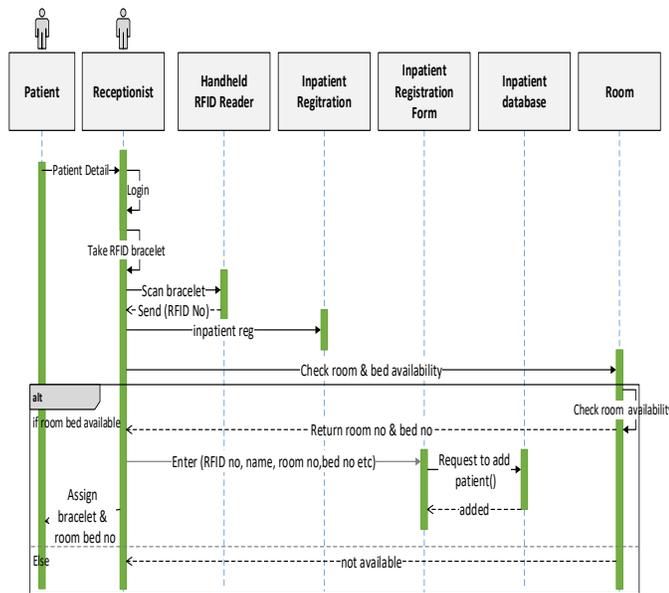


Fig. 3. Sequence diagram of inpatient registration.

C. UML Class Diagram of Patient Registration System

Class diagram represents the static structure of the RFID based patient registration system. Class diagram of patient registration system shows the set of classes and their relationship. The UML class diagram illustrates the dependencies of source code between classes. A class in PRS class diagram describes the functions and variables of the object that is a distinct entity in a program. The classes in a class diagram are organized in groups that share common attributes. The PRS class diagram is shown in Fig. 4.

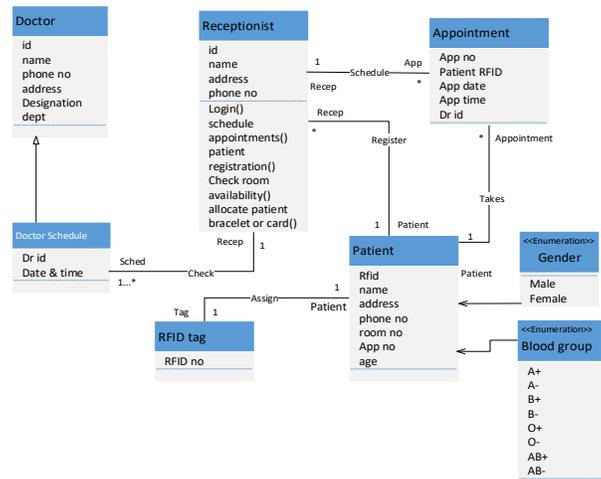


Fig. 4. Class diagram of PRS.

IV. FORMAL SPECIFICATION USING VDM-SL

UML based models are transformed into formal model by developing formal specification in VDM-SL. In use case diagram of the PRS receptionist is an actor or user of the PRS which is defined under *types* in VDM-SL specification. All use cases in use case diagram are transformed as operations in VDM-SL specification.

In sequence diagram the object with an actor is specified in VDM-SL as *types*. The object without an actor is defined as operation, self-messages of object are defined to invoke a function, incoming messages are used as an input and outgoing message represent the response of function or operation in VDM-SL.

In UML class diagram, class is transformed as composite type and attributes are defined as fields of that composite type in VDM-SL. The methods of a class are transformed as functions or operations. Enumerations are transformed into enumeration types containing each possible value in VDM-SL.

To implement this system, we need to know some information about the patient, doctor and receptionist therefore, we have defined the types which are used in the system. The attributes we have defined in UML class diagram are called the types in VDM-SL. The properties of inpatient, outpatient, doctor and user are specified as types.

Firstly, for authorized usage, a composite object *user* is defined occupying four fields. The first field is *uname* which is user name provided to each authorized user. The second field is *user_type* which defines the type of user like patient, receptionist or doctor and third one is *password* of the user.

```

types
name=seq of char;password=nat;
user_type=<patient>|<receptionist>|<Doctor>;
user::UName:name
User_type:user_type
Password:password;
    
```

Date is required to check the doctor availability at that date and required to store patient visit or admit date in hospital. Therefore, *date* is also a composite object in the system having

three fields. The first field is *day* which defines the day of the month. Second field is *month* which defines the month number and the third one is *year* which defines the current year.

```
day=nat;month=nat;year=nat;  
date::Day:day  
Month:month  
Year:year;
```

Time is required to check the available time slot for the patient appointment. Therefore, *time* is a composite object which having two fields. The first field *hour* defines the hour of the day and second field *Min* defines the minute of the hour.

```
hour=nat;min=nat;  
time::Hour:hour  
Min:min;
```

To meet doctor at specific time, appointments are used which are specified as composite object *appointment* having five fields. The first field *Docid* shows the id of the doctor patient wants to meet. The second field *Appid* shows the appointment id which identifies the patient appointment. The third and fourth fields define the date and time of appointment. The fifth one *Description* shows the detail of the appointment.

```
appointment::Docid:id  
Appid:id  
Date:date  
Time:time  
Discription:app_discription;
```

To identify the patients, RFID tags which are embedded in bracelet or card are used which are defined as composite object *prfid_tag* having two fields. The first field is *rtag* which defines the RFID tag having RFID number. The second field *atype* defines the assign type which is bracelet or card assigned to the patient at registration time.

```
assigntype=<bracelet>|<card>;  
prfid_tag:: rtag:rfid  
atype:assigntype;
```

The patient who visits the hospital and not hospitalized is defined as composite object *outpatient* having nine fields. The first field is *P_id* which shows card with RFID tag and patient record is being stored against this RFID number. The seventh field *History* shows the medical history about patient. The eighth field *Papp* defines the appointment of that patient and *visit_date* defines the date when patient visits the healthcare.

```
outpatient::P_id:prfid_tag  
Name:name  
Address:address  
Phone_no:phone_no  
Gender:gender  
Blood_group:blood_group  
History:p_history  
Papp:appointment  
visit_date:date;
```

When patients are admitted to the hospital, room is assigned to each inpatient. Room is defined as composite object having two fields. The first one represents the room number and the second field shows the bed number which is assigned to the patient at admission time.

```
room::room_no:nat  
bed_no:nat;
```

The patient who is hospitalized is described as composite object *inpatient* having nine fields. First field in inpatient is *P_id* which shows bracelet with RFID tag and inpatient record is being stored against that RFID number. The sixth field *prom* shows the room in which the patient is admitted. The field *Admitdate* shows the patient admission date when the patient is admitted in the hospital for treatment.

```
inpatient::P_id:prfid_tag  
Name:name  
Address:address  
Phone_no:phone_no  
Gender:gender  
Proom:room  
Blood_group:blood_group  
History:p_history  
Admitdate:date;
```

To represent the doctors, doctor object is used which is a composite type having two fields. The first field is *D_id* represents the doctor id to identify the doctor and the second field defines the name of the doctor.

```
id=nat;  
doctor::D_id:id  
Name:name;
```

To show the doctor availability in the hospital, doctor schedules are used which is defined as composite object *doctorschedule* having three fields. The first field defines the id of the doctor. The second and third fields define the date and time availability of that doctor.

```
doctorschedule::  
Did:id  
Ddate:set of date  
Dtime:set of time;
```

State of the system introduces permanent data which is used by the PRS functions and operations. The state of the system must have variables that stores data that is used by the system operations. In patient registration state *users*, *Doctor*, *Outpatient*, *Inpatient*, *rfid_tag*, *room*, *Appointment* and *Davailability* are variables of the system.

Invariants: Invariants are the conditions that must be fulfilled to use this system. Invariants of the PRS are defined as every tag must consist of an RFID number or it must not be empty. The doctor availability schedule should not be empty.

Initialization: Initialization in the system prescribes the condition that the system must fulfill when it comes into existence. So, in the Patient monitoring system the state variables *user*, *inpatient*, *outpatient*, *Rfid_tag*, *room*, and *Appointment* are set to empty at system starting state.

```
tag=rfid;  
state Patientregistration of  
users:set of user  
Doctor:set of doctor  
Inpatient:set of inpatient  
Outpatient:set of outpatient  
rfid_tag:map rfid to assigntype  
Tag:set of tag  
Room: set of room  
Appointment:set of appointment  
Davailability:set of doctorschedule
```

```
inv mk_Patientregistration (-,-,-,-,t,-,-  
,da)==t<>{} and da<>{}  
init mk_Patientregistration(u,d,i,o,rt,-  
,r,a,da)==u={}and d={}and i={}and o={} and  
rt={|->}and r={}and a={} and da={}  
end
```

There are different functions involved in PRS. To check the doctor availability, *chkdavail* function is used. This function takes set of, doctor schedule, doctor id, time and date as input. First of all, doctor id that must match the doctor id. If pre-condition is true, then post condition executed. In post condition first of all it is checked that if the doctor id is in the doctor availability schedule then it is checked that the entered date and time is in doctor availability schedule.

```
chkdavail(din:set of doctor,did:id,dav:set of  
doctorschedule,dt:date,tm:time)rep:reply  
pre forall d in set din &d. D_id=did  
post exists da in set dav &  
da.Did=did and  
if exists d in set dav &  
d.Ddate={dt} and  
d.Dtime={tm} then rep=<Successfull> else  
rep=<Fail>;
```

To check the time availability of new appointment *chktimavailability* function is used. This function takes list or set of appointments, doctor id, date and time as an input and checks that the given date and time of that doctor is not reserved for another patient.

```
chktimavailability(appointmnt:set of  
appointment,did:id, dt:date, tm:time)rep:reply  
pre true  
post forall a1 in set appointmnt &  
a1.Docid=did and  
if (a1.Date<>dt and a1.Time<>tm) then  
rep=<Successfull> else rep=<Fail>;
```

To check availability of a room *chcroomavailability* function is used. It takes list of inpatients, list of rooms, room number and bed number as an input and checks that the room bed number is not assigned to another patient.

```
chcroomavailability(patient:set of  
inpatient,roomin:set of  
room,rno:nat,bno:nat)rep:reply  
pre exists r in set roomin &  
r.room_no=rno and  
r.bed_no=bno  
post if forall p1 in set patient &  
p1.Proom.room_no<>rno and  
p1.Proom.bed_no<>bno then rep=<Successfull>  
else rep=<Fail>;
```

Operations describe the functionality and real working of the system on specific inputs. All functionalities of the system describe through the functions and each task of the system is defined by a distinct operation. The VDM-SL specification of PRS operations are described below.

The *login* operation is used to provide the authorized access of the different users to the system. This operation defines that the users of the system are already stored in the system and takes username and password of the user as an input, and then the username and password is matched with the stored

username and password if both are matched then the user is permitted to use this system.

```
login(un:name,upaswr:password)rep:reply  
ext rd users:set of user  
pre true  
post forall u in set users &  
if u.UName=un and  
u.Password=upaswr then rep=<Successfull> else  
rep=<Fail>
```

For taking the RFID number from RFID tag, scanning is provided. Therefore, *scantag* operation is used for this purpose. Scan tag operation takes the tag as an input and returns the RFID number of that tag as an output.

```
scantag(tagin:tag)output:rfid  
ext rd Tag:set of tag  
pre tagin in set Tag  
post output=tagin;
```

For assigning RFID bracelet to inpatients and RFID card to the outpatients, *assigntag* operation is used. The *assigntag* operation takes RFID tag and type which should be card or bracelet as an input. The tag must be scanned which is pre-condition of the function. If pre-condition is successful then attach tag with type and check that if the tag type is card, then assign it to the outpatient and if the type is bracelet then assign to the outpatient.

```
assigntag(tagin:rfid,typein:assigntype)rep:reply  
ext wr rfid_tag:map rfid to assigntype  
wr Outpatient:set of outpatient  
wr Inpatient:set of inpatient  
pre scantag(tagin)=tagin  
post rfid_tag= rfid_tag munion {tagin|-  
>typein} and  
if typein=<card> then Outpatient=Outpatient  
union { mk_prfid_tag(tagin,typein ) } else if  
typein=<bracelet> then Inpatient=Inpatient  
union {mk_prfid_tag(tagin,typein ) }and  
rep=<Successfull> else rep=<Fail>;
```

To schedule appointments, *Addappointment* operation is used. In this function first of all check that appointment id is unique, which is pre-condition in this operation. Then the doctor and his time availability are checked by calling doctor availability and time availability functions and then appointment is added.

```
Addappointment(did:id,apid:nat,dt:date,tm:time  
,dis:token)rep:reply  
ext wr Appointment:set of appointment  
rd Doctor:set of doctor  
rd Davailability:set of doctorschedule  
pre forall a in set Appointment &  
a. Appid<>apid  
post if  
chkdavail(Doctor,Davailability,did,dt,tm)=  
<Successfull> and  
chktimavailability(Appointment,did,dt,tm)=<Suc  
cessfull> then  
Appointment=Appointment~ union  
{mk_appointment(did,apid,dt,tm,dis)} and  
rep=<Successfull> else rep=<Fail>;
```

To register the outpatient, *outpatientreg* operation is used. This operation registers the outpatients by adding the detail of

outpatient. First of all, checks that the patient is not already registered and the user that performs the patient registration should be receptionist and must be login. Then assign RFID card to the patient by calling its function, add appointment of that patient by checking date and doctor availability, by calling add appointment operation in outpatient registration and register the patient by adding all other information, RFID number and appointment of that patient.

```

outpatientreg (un:name, up:password, did:id, apid:
id, dt:date, tm:time, apdis:token, ptag:rfid, pname
:name, address:address, phone:phone_no, pgendr:g
ender, pblood:blood_group,
phistory:p_history, asstype:assigntype, visdate:
date) rep:reply
ext wr Outpatient:set of outpatient
rd users:set of user
rd Tag:set of tag
rd Appointment:set of appointment
pre forall o in set Outpatient &
o.P_id.rtag<>ptag and
exists U in set users &
U.User_type=<receptionist> and
login(un, up)=<Successfull>
post if assigntag (ptag, asstype)=<Successfull>
and
Addappointment (did, apid, dt, tm, apdis)=<Successf
ull> then Outpatient = Outpatient ~
union{mk_outpatient (mk_prfid_tag (ptag, asstype)
, pname, address, phone, pgendr, pblood, phistory, m
k_appointment (did, apid, dt, tm, apdis), visdate)}
and rep=<Successfull> else rep=<Fail>;

```

To register the inpatients *inpatientreg* operation is defined. This operation registers the inpatient by adding the detail about inpatient. First of all, it is checked that the patient is not already registered and the user that performs the patient registration should be receptionist and must be login. Then it is checked that room is available for patient by calling *chkroomavailability* function. If room availability is true then assign RFID bracelet to the patient by calling *assigntag* operation, and then add the patient by adding RFID, room, bed number and other information about the inpatient.

```

inpatientreg (un:name, up:password, ptag:rfid, pn
ame:name, address:address, phone:phone_no, pgend
r:gender, rno:nat, bno:nat, pblood:blood_group, as
stype:assigntype, phistory:p_history, admitdate:
date) rep:reply
ext wr Inpatient:set of inpatient
rd users:set of user
rd Tag:set of tag
rd Room:set of room
pre forall i in set Inpatient &
i.P_id.rtag<>ptag and
exists U in set users &
U.User_type=<receptionist> and
login(un, up)=<Successfull>
post if
chkroomavailability (Inpatient, Room, rno, bno)=<S
uccessfull> then
assigntag (ptag, asstype)=<Successfull> and
Inpatient = Inpatient ~ union {mk_inpatient
(mk_prfid_tag (ptag,

```

```

asstype), pname, address, phone, pgendr, mk_room (
rno, bno), pblood, phistory, admitdate)} and
rep=<Successfull> else rep=<Fail>;

```

V. FORMAL ANALYSIS OF PRS

The Patient Registration System is formally proved by VDM-SL Toolbox. The specification of PRS is verified by syntax checker, type checker, C++ code generator and pretty printer. The syntax checker demonstrates that the written specification is according to the syntax of the VDM-SL. The type checker checked out the misuse of values. The C++ code generator creates the similar C++ code and the pretty printer identified the errors in the PRS specification. The identifying errors in specification are removed by upgrading the properties of invariants and pre/post conditions. The main advantage of VDM-SL is detecting all the ambiguities and gaps in objects as compare to other semiformal languages like UML. VDM-SL provides the more detailed, refined model and algorithm verification of the system as compare to semiformal languages. The analysis of PRS is presented in Fig. 5.

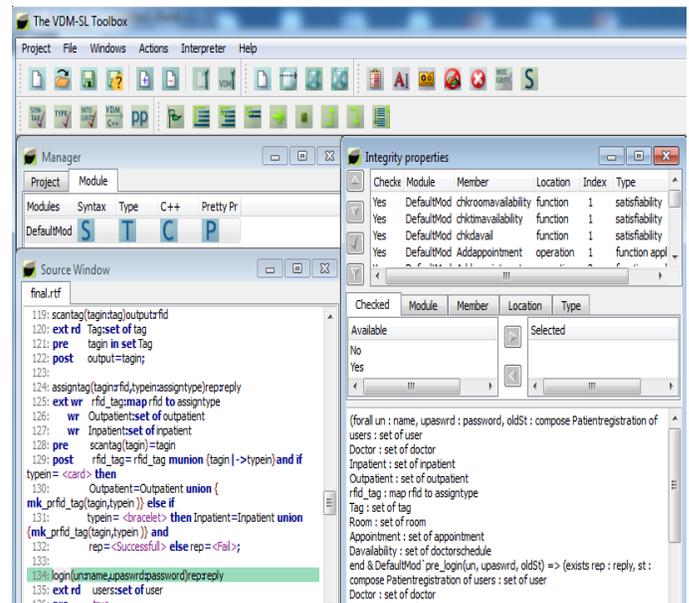


Fig. 5. Analysis of correctness of PRS.

VI. CONCLUSION

The UML based model of the Patient Registration System (PRS) is presented for the semi-formal representation. UML based model of the system describes the functionality of the system. Previous systems just use UML model for developing the system but the UML model does not give assurance about the correctness of the system. The VDM-SL gives the assurance about the correctness of the system. So, the detailed analysis of the PRS is done by using VDM-SL. The generated formal specification of PRS has been examined by VDM-SL Toolbox. Run time errors are discovered by allowing dynamic checking and discovering errors in specification are eliminated by enhancing the properties of invariants and pre/post conditions. The Patient Registration System will help to build cost effective and correct system.

In future we will focus on including extra functionality to the system such as embedding sensors with RFID tags to handle the emergency situation and prove its correctness using VDM-SL. That would provide unambiguous, correct and cost-effective system for patients.

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Adaptive Multilayered Particle Swarm Optimized Neural Network (AMPSONN) for Pipeline Corrosion Prediction

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Abstract—Artificial Neural Network (ANN) design has long been a complex problem because its performance depends heavily on the network topology and algorithm to train the set of synaptic weights. Particle Swarm Optimization (PSO) has been the favored optimization algorithm to complement ANN, but a thorough literature study has shown that there are gaps with current approaches which integrate PSO with ANN, including the optimization of network topology and the unreliable weight training process. These gaps have caused inferior effect on critical Artificial Intelligence (AI) applications and systems, particularly when predicting plant machinery and piping failure due to corrosion. The problem of corrosion prediction in the oil and gas domain remains unanswered due to the lack of a flexible prediction method which targets specific damage mechanisms that caused corrosion. This paper proposes a hybrid prediction method known as the Adaptive Multilayered Particle Swarm Optimized Neural Network (AMPSONN), which integrates several layers of PSO to optimize different parameters of the ANN. The multilayered PSO enables the method to optimize the network topology and train the set of synaptic weights at the same time using a hierarchical optimization approach. Through detailed discussion and literature study, the damage mechanism focused in this research is the CO₂ corrosion and the dataset for this research is obtained from the NORSOK empirical model. The proposed AMPSONN method is tested against BP, MPPO and PSOBP methods on an industrial corrosion dataset for different test conditions. The results showed that AMPSONN performs best on all three problems, exhibiting high classification accuracies and time efficiency.

Keywords—Corrosion; damage mechanism; prediction method; artificial neural network; particle swarm optimization

I. INTRODUCTION

According to the American Petroleum Institute (API), the oil and gas industry is one of the largest and most capital-intensive industries in the world. There are currently more than tens of millions of kilometers of oil and gas pipelines being installed and used daily across the globe [1], [2]. Most of the pipelines in use are made of steel as they deliver the safest means to transport large quantities of oil and gas related products. Despite the use of insulation on these steel pipelines, they are still prone to deterioration when exposed to various damage mechanisms over time [2]-[4]. Damage mechanisms

affecting a certain pipeline depends on the environment in which the pipeline is installed and also the material being transported.

Throughout the years, the API has documented a list of over 60 of these damage mechanisms under API RP 571, which includes CO₂ corrosion, sulfidation corrosion, amine acid corrosion and many more. Damage mechanisms eventually lead to corrosion and the pipeline is subjected to leakages and ruptures, resulting in major financial losses and poses substantial health, environment and safety hazards to the surrounding ecosystem [5], [6].

Therefore, operators have for a long time practiced regular inspection on pipelines to ensure that they operate smoothly and to minimize the risk of accidents [7], [8]. These inspections make use of historical corrosion data and prediction methods are used to predict and monitor the state of pipelines to determine preventive actions to be taken ahead of a potential incident. Despite the effort, pipelines are still failing and pipeline incidents are still occurring throughout the globe, bringing about deadly consequences [9].

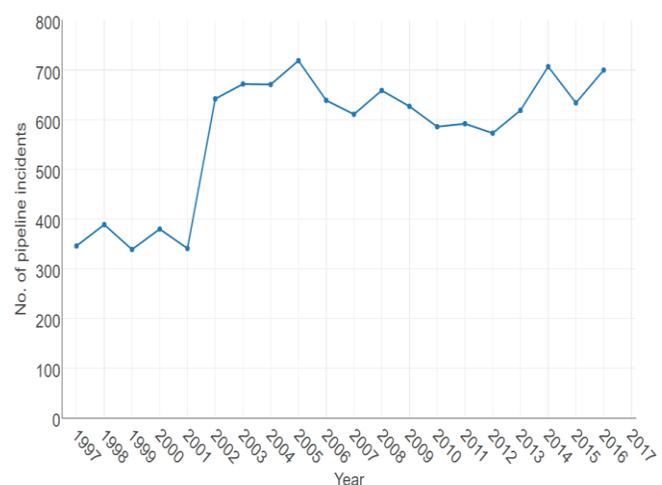


Fig. 1. Pipeline incident count from years 1997-2016 [10].

Fig. 1 shows the annual total of oil and gas pipeline incidents that happened between the years 1997 to 2016, as

collected by [10]. Although there is an intermittent pattern of increase and decline, it can be seen that the overall trend of pipeline incidents is increasing. During an expert interview with Staff Corrosion Engineer from a Malaysian oil and gas company [11], he stated that pipeline corrosion affects Malaysia severely and accounts for over 35% of pipeline failures and incidents. It was revealed that the main reason behind the failure of existing prediction methods used in the oil and gas domain to address the problem of corrosion is due to the different forms of damage mechanisms. Each damage mechanism affects corrosion in their own unique way, which makes it difficult to model their relationship.

Pipeline incidents always bring about casualties and it is therefore of paramount importance to have a solid and good way to monitor and predict the state of corrosion. Thus, this project hopes to develop the AMPSONN method which could adapt to design the most optimum ANN to predict the corrosion severity caused by different damage mechanisms.

II. LITERATURE REVIEW

A. Artificial Neural Networks

Artificial Neural Networks (ANN) are powerful mathematical models and universal approximators that have been used to solve various real-world problems. Among all types of ANNs, multilayered perceptron (MLP) is considered as the best, and consists of three layers; the input layer, hidden layer and output layer, with every layer comprising of several neurons. The neurons are connected to each other by a set of synaptic weights, which consists of values representing the strength of the connection. During the training process, the ANN continuously adjusts the values of these weights until a certain termination condition is achieved, usually measured by the error value of the network or the number of maximum iterations.

Although various learning algorithms have been suggested for the training of ANNs, the most popular technique used to train the ANN is still the backpropagation (BP) algorithm [12]-[14]. The BP algorithm has a good acceptance by the community because of its robustness and versatility while providing the most efficient learning procedure for MLP networks [15], [16]. In addition, it is a gradient-descent algorithm which adjusts the weights of ANN by using gradients of their error. Hence, the adjustments done on every weight depends on how much they affect the final output, and this offers a more refined local searching capability while looking for the global minimum [17]. The BP algorithm iterates through the same dataset over and over again until the network converges. Generally, as the number of trained epochs increases, the accuracy of the ANN to predict the output increases, at the cost of a longer training time.

B. Existing Works on ANN

Table 1 shows the comparison between six recent works on the ANN model for prediction in various domains. From all

the six papers [12]-[14], [18]-[20], there is an agreement that a major problem that most ANN researchers are facing is in initializing the ANN topology. According to Saima et al. [20], the influence of the network topology on the final output is tremendous despite not having a direct interaction with the external environment. The influence the network topology on the output is consequently reflected in the form of other problems such as the slow convergence [12], [13], [19] and getting trapped in a local minimum [18], [19]. Currently, there have been no formally established methods to determine the optimal topology of an ANN for any given problem, especially in the number of neurons in the hidden layer. If the number of neurons is inadequate, it may result in underfitting, meaning that the neural network is unable to learn all the information contained in the dataset. Conversely, an overabundance of neurons in the hidden layer leads to overfitting, a situation in which the neural network captures the noise of the training data, negatively impacting its ability to predict new data [20]. Some literature [21]-[24] offer rules of thumb methods or guidelines for selecting the number of hidden neurons by using any value between the number of input and output neurons, but a good topology cannot be decided solely based on the number of inputs and outputs.

TABLE I. TABLE OF COMPARISON BETWEEN EXISTING WORKS ON ANN

Authors	Domain	Problems Identified	Suggested Future Work
Supriyatman et al. [13]	Oil and gas	Manual selection of topology. Slow convergence.	Identify related parameters to be used to improve accuracy.
Ren et al. [14]	Oil and gas	Manual selection of topology.	-
Sinha & Pandey [12]	Oil and gas	Manual selection of topology. Slow convergence.	Improve convergence rate.
Zhang et al. [18]	General	Number of nodes in the hidden layer affects accuracy and time efficiency. BP algorithm can easily get trapped in a local minimum.	Improve convergence rate by implementing global search algorithms.
Mohammadi & Mirabedini [19]	General	BP algorithm can get trapped in a local minimum. Slow convergence.	Improve convergence rate by implementing exploration algorithms.
Saima et al. [20]	General	There is a major problem in establishing the ANN topology.	-

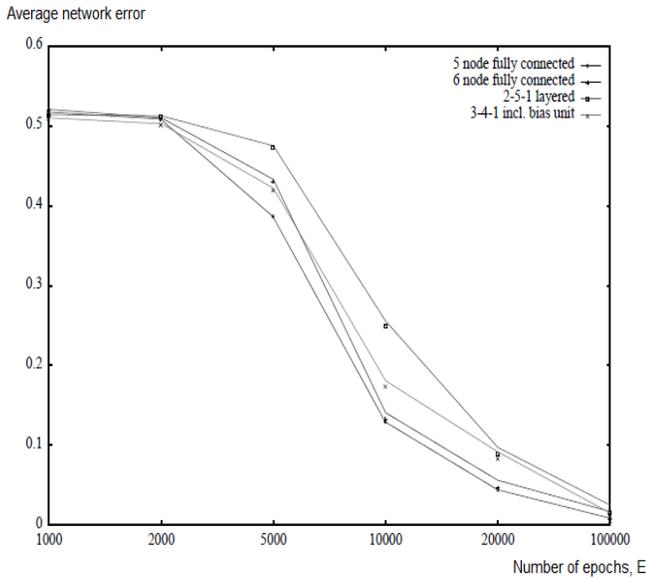


Fig. 2. The learning curve of ANN models of varying topologies [25].

Thus, in all three researches within the oil and gas domain [12]-[14], the selection of ANN topology has been done manually, through trial and error of all possible topologies, and selecting the best performing ANN. Another highlighted problem is the slow convergence of the ANN model [12], [13]. Zhang et al. [18] referred to this problem as an inherent problem of the BP algorithm, as it exhibits a very strong local but poor global searching capability. Thus, the BP algorithm has a high tendency to get trapped in a local minimum while searching for the global minimum [17]. Even in cases when global minimum can be achieved, the entire training process takes a long time to complete and the convergence rate is low. A research [25] has shown that different network topologies affect how long an ANN takes to learn.

Fig. 2 shows the learning curve of four different ANN models with varying topologies. Despite being given the same number of training epochs, each model has different average errors and they learn at different rates. It is therefore possible to implement a form of optimization algorithm that can perform selection of an optimal network topology which converges faster, instead of a manual selection [25]. In [12], [13], [18], [19], authors have proposed several suggestions for future work, such as to have a better research that identifies the right input parameters for specific damage mechanisms when training the neural network and to improve the convergence rate of the model.

C. Particle Swarm Optimization

Particle Swarm Optimization (PSO) is chosen as the global optimization algorithm to be employed in this research. Although various optimization algorithms were developed in the recent years, population-based evolutionary algorithms remain the most popular, due to their reliability in approximating non-linear problems [26], [27]. PSO has particularly been the favored algorithm as interaction between the swarm particles has shown to be highly effective in finding the global optimum in high-dimensional search spaces [28],

[29]. PSO has also been found to be faster and exhibit a higher computational efficiency as compared to other optimization algorithms [30]-[32]. However, researchers [29], [33], [34] argue that the performance of optimization algorithms depend on several factors, such as the data set involved, type of problem to be optimized, and the selection of parameters. Therefore, there is no way to generalize the performance of different optimization algorithms. Hence, the choice of PSO in this research is heavily weighted with respect to ANN optimization. We have selected PSO to be employed because research done on integrating PSO to optimize various aspects of the ANN is more active compared to other optimization algorithms such as Genetic Algorithm (GA) and Ant Colony Optimization (ACO) [35]. This enables a more thorough literature study to be done when studying existing hybrid methods that have been developed. In addition, PSO is increasingly being used alongside ANN and machine learning applications because it is relatively easier to implement and provides more robustness [28], [36].

The PSO algorithm [37], [38] is a bioinspired optimization method for continuous nonlinear functions as originally proposed by Eberhart et al. [39]. It is based on the behavior of bird flocks in search of food in a search space, and every individual move with respect to their personal best experience and the social best experience of the entire flock. The population can be thought of as a collection of particles i where each represents a position, x_i in a multidimensional search space as denoted by the dimensionality, D . At every iteration, the particles are evaluated based on a fitness function, to identify the global best position p_g , and also their personal best position p_i so far. Based on these components, all the particles would update their position within the search space using a velocity function, v_i at every iteration until an optimum position or solution is found. The velocity function is given as

$$v_i(t + 1) = \omega v_i(t) + c_1 r_1 [p_i(t) - x_i(t)] + c_2 r_2 [p_g(t) - x_i(t)], \quad (1)$$

where ω is inertia weight which governs the rate of search space exploration; c_1 and c_2 are acceleration coefficients; r_1 and r_2 are uniformly distributed random numbers between [0, 1]. The velocity, v_i is controlled between the range of $[v_{min}, v_{max}]$. By updating their velocity in this way, particles are able move to a more optimized position, $x_i(t + 1)$ by the formula

$$x_i(t + 1) = x_i(t) + v_i(t + 1) \quad (2)$$

In the case of using PSO for ANN weight training, every particle represents a set of synaptic weights, which are encoded into a vector as shown in Fig. 3.

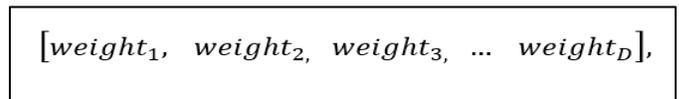


Fig. 3. A vector containing the set of synaptic weights.

D is the dimensionality, or the total number of synaptic weights in the ANN, and can be calculated with the equation

below, with I , H and O representing the number of input neurons, hidden neurons and output neurons respectively.

$$D = (I \times H) + (H \times O) \quad (3)$$

D. Existing Work on PSO with ANN

The first paper by Armaghani et al. uses PSO to completely replace BP as the training algorithm for ANN in the field of geoscience. The findings of their research showed that PSO can evolve the set of optimal weights to achieve an accuracy of 93% on the test dataset. However, the authors did not incorporate any forms of topology optimization in their research and the selection of topology is done via trial and error.

In the second paper, Dang & Hoshino introduced an improved version of PSO, which shall be referred to as Modified Particle Swarm Optimization (MPSO). In their research, MPSO incorporates a method proposed by Shi & Eberhart [41] which reduces the inertia weight, ω linearly over the course of iterations, to further improve the searching capability of PSO. By promoting exploration in early iterations and convergence in later iterations, it has been experimentally proven to increase the swarm performance when trying to look for the optimum solution [41]. The equation below shows how the inertia weight can be reduced linearly, given that w_1 and w_2 are the largest and smallest values for the inertia weight respectively, $MAXITER$ is the maximum number of iterations, and $iter$ is the current iteration number.

$$\omega = (w_1 - w_2) \times \frac{MAXITER - iter}{MAXITER} + w_2 \quad (4)$$

Besides, Dang & Hoshino proposed for a new component to be added into the velocity update equation in (1), which is called a seed factor, $Pseed$. Seed factors of all particles are randomly generated when the algorithm is initialized, and would help to pull the particles to the initial positions of the seeds. The main purpose of adding the seed factor as a third component in the velocity update equation is to help reduce the possibility of the PSO algorithm from getting trapped in a local minimum [40]. The new velocity update equation used in the MPSO algorithm is shown below:

$$v_i(t+1) = \omega v_i(t) + c_1 r_1 [p_i(t) - x_i(t)] + c_2 r_2 [p_g(t) - x_i(t)] + c_3 r_3 [Pseed_i(t) - x_i(t)] \quad (5)$$

From the results of their paper, Dang & Hoshino have proven that their proposed MPSO method outperforms the basic PSO method in terms of accuracy and time efficiency.

The third paper by Koochi & Groza [35], studies the integration between PSO and BP in terms of the weight training process under a method known as Particle Swarm Optimization with Backpropagation (PSOBP). Instead of using classical BP or classical PSO to fully train an ANN, Koochi & Groza divided the ANN training phase into two, the initial and final phases. The initial training phase is done solely using PSO and terminates at an accuracy of 90%, which is a common threshold which most researchers consider a method to have high accuracy [17], [18], [35]. The final training phase is then done using the BP algorithm to perform

a local search around the promising particle to further improve its accuracy. In their study, the ANN was able to exhibit a final accuracy of 98%. The authors have proved that the performance of ANN can be improved by adopting the strong global search capability of PSO to speed up the earlier stage of training and the strong local search capability of BP to refine the final training stage.

TABLE II. COMPARISON BETWEEN EXISTING WORKS ON PSO WITH ANN

Authors	Novelty	Findings	Gaps
Armaghani et al. [17]	Uses PSO to perform weight training on ANN instead of BP.	ANN trained using PSO has a higher convergence rate than ANN trained using BP.	Topology selection is still unoptimized. Training done using PSO may get trapped in a local minimum.
Dang & Hoshino [40]	Introduces Modified Particle Swarm Optimization (MPSO), which includes a seed component into the velocity update equation.	MPSO displayed a better performance than classical PSO.	Topology selection is still unoptimized. Training done using PSO may get trapped in a local minimum.
Koochi & Groza [35]	Introduces Particle Swarm Optimization with Backpropagation (PSOBP). PSO is used in initial phase of training, which then is then switched to BP.	PSO helps to speed up the earlier stages of training, and improves the overall convergence rate.	Topology selection is still unoptimized. Training done using PSO may get trapped in a local minimum.

After studying all three papers, several gaps in the literature have been identified, as shown in Table 2. Firstly, all the authors, Armaghani et al. [17], Dang & Hoshino [40] and Koochi & Groza [35] included the implementation of PSO for weight training purposes and did not implement any form of ANN topology optimization. In their studies, the best ANN topology is still decided by using trial and error, with multiple ANN models of varying topologies being developed and trained to find the one with the best performance. Besides, the range of number of hidden neurons used to develop the multiple ANNs during the trial and error is limited to (3, MNN), where MNN is the maximum number of hidden neurons that the ANN can have. The equation to calculate MNN is given by (6) [38], [42].

$$MNN = (I + O) \times 2 \quad (6)$$

However, no studies have shown that the optimum number of hidden neurons resides within the range (3, MNN) and ANN initialized within this range might not yield the best possible result. Therefore, our proposed method would implement a

layer of topology optimization using PSO within a larger search space than what is used in these three studies.

Secondly, in all three studies, there exists a training component which is solely done using PSO. In the first and second paper, the authors have used PSO to completely replace the original BP algorithm as the training method, while in the third paper, PSO is used solely to initially train the ANN until 90% accuracy. Although PSO has reported success in various problems, there are researches which have shown negative results for PSO used in training. Several studies [18], [19] have shown that while PSO demonstrates strong global searching capabilities, its local searching capability around that global optimum is poor. It is proven that ANN training done solely using PSO achieve convergence very slowly during the later stages of training and would exhibit a poor overall time efficiency. The PSO algorithm also has a disadvantage of easily getting into a local minimum when applied in a high-dimensional search space due to its poor local searching capability around the most optimum particles [18], [20]. This shows that training done solely using PSO in high-dimensional search spaces may not be fully reliable. Thus, our proposed method will involve modifications done within the PSO itself to improve its local searching capability.

E. Significance of Study

According to a report by the Institute of Energy Technology, most oil and gas corporations and operators base their current predictions on mechanistic and empirical models [43]. These are developed using data from laboratory testing as well as field data for calibration, and have an advantage which lies in the thorough calibration of the model from laboratory experiments and are verified over a range of data to be safely used with a high confidence within this range of data.

However, mechanistic and empirical models require a long time to be developed and must be backed with years of field experience. A good example of such model is the NORSOK-506 empirical model, which is currently used as a standard for Norwegian oil and gas corporations to predict corrosion under CO₂ corrosion damage mechanism, which has been developed over the past 40 years [43]. Due to the long and thorough process needed to calibrate mechanistic and empirical models, researchers have started to shift their focus towards ANN, which learns faster and does not require as much understanding of the phenomenon. However, as studied in Section II (B), even the most current ANN models developed for corrosion in the oil and gas domain [12]-[14] still depend on trial and error for the establishment of an optimum topology.

Therefore, current prediction methods in the oil and gas domain are still unable to address the problem of having multiple damage mechanisms due the limitations of methods used and researchers chose to target only the more critical damage mechanisms in their studies [5]. The fact that over 60 damage mechanisms exist to cause corrosion [44] should not be overlooked and corrosion prediction for a particular pipeline must be done while taking into account the specific

damage mechanism which is affecting the pipeline. This is because different damage mechanisms affect corrosion in different ways and the number of operational parameters to inspect individual mechanisms varies. Hence, corrosion prediction for a damage mechanism must be done using a model that has been trained for it [11].

This research would be significant for the oil and gas industry by developing a flexible prediction method that can adapt to target different corrosion damage mechanisms to produce an accurate prediction for whichever damage mechanism that requires prediction. A more detailed analysis of this method will be discussed in Section III.

III. METHODOLOGY

A. Proposed Methodology

As studied in Section II, there are gaps in the literature where a novel algorithm and method can be established. To overcome these gaps, we have identified several improvements that can be made by integrating PSO together with ANN in our AMPSONN method.

Firstly, the problem of manual topology selection can be solved by implementing a layer of optimization, where the global search capability of the PSO can be used to design multiple ANN candidates in a large search space. From Section II, we have studied that the main problem in selecting a suitable ANN topology lies in the number of hidden neurons, H while the number of input neurons, I and output neurons, O can be obtained from the dataset used for the training. Therefore, every particle in the PSO is an ANN which has a different topology depending on the value of H which it is holding, before being trained to identify its performance as compared to all other particles based on certain fitness functions. Through PSO iterations, the particles would have searched through the search space to find a more optimal value of H while maintaining a memory of the best value of H so far. When the PSO terminates, the most optimum value of H would be used to design the topology of the final ANN to serve as the prediction method.

Secondly, to overcome the unreliability of BP and PSO when used separately as ANN training algorithms, we have formulated a novel training approach to capitalize the strong global searching capability of PSO with the strong local searching capability of BP. We propose to improve the searching efficiency of the classical PSO algorithm by providing it with additional gradient-descent information with the use of BP at every single iteration. As mentioned by [18], [19], the PSO is a very promising searching algorithm which has a weakness when it comes to performing local search to attain the global minimum. Although several improvements have been proposed to improve the PSO algorithm over the years, which includes the MPSO [40] and PSOBP [35] algorithms which we have covered in Section II, the capability of the PSO to perform on its own remains an issue and the tendency to become trapped in some undesirable local minimum increases when size of the dimension to be optimized increases. This would become a problem in this research as the size of the dimension increases as the value of

H is increased, due to the increase in number of synaptic weights in the ANN.

Therefore, our proposed training algorithm utilizes BP within each PSO iteration as the BP algorithm offers a more refined local search, by adjusting every single weight value in terms of how much they contribute to the calculated error. We believe that by integrating BP within the PSO itself, our proposed training algorithm would have a more efficient and superior searching capability as compared to PSOBP which only utilizes BP after PSO has completed iterating.

until the objective function of the masterswarm is satisfied. Once the layered PSO has completed its iteration, the obtained masterswarm and subswarm global bests would be the optimized ANN topology and initial weight vector respectively. With that, an optimized ANN will be designed for the research. This ANN will then be trained using BP, a method guaranteed to stop at the global minimum point to fine-tune the weight vectors to achieve an intended level of classification accuracy.

IV. EXPERIMENTATION AND RESULTS

A. Experimental Setup

Table 3 shows the selection of parameters used for the experiments. The parameters for BP, MPSO, and PSOBP algorithms are based on configurations done by their respective authors. On the other hand, the parameters for our AMPSONN algorithm are adopted partially from other authors and through sensitivity analysis. For the masterswarm, the number of maximum iterations is set to 10 with a population size of 5, which would be enough for all the particles to search through most of the search space within the range (3,50). For the subswarm, the number of maximum iterations is set to 100 as inspired by [35], while the population size is set to 10 after performing an optimization run using different values.

TABLE III. EXPERIMENT PARAMETERS FOR THE TESTED METHODS

Method	BP	MPSO	PSOBP	AMPSONN
Maximum BP Iteration	5,000	-	2,000	2,000
Maximum PSO Iteration	-	200	100	10 (Masterswarm), 100 (Subswarm)
Population Size	-	200	200	5 (Masterswarm), 10 (Subswarm)
Initialized Weight Range	(0,1)	(-4,4)	(-1,1)	(-1,1)
BP Learning Rate	0.3	-	0.3	0.3 (PSO run), 0.15 (BP run)

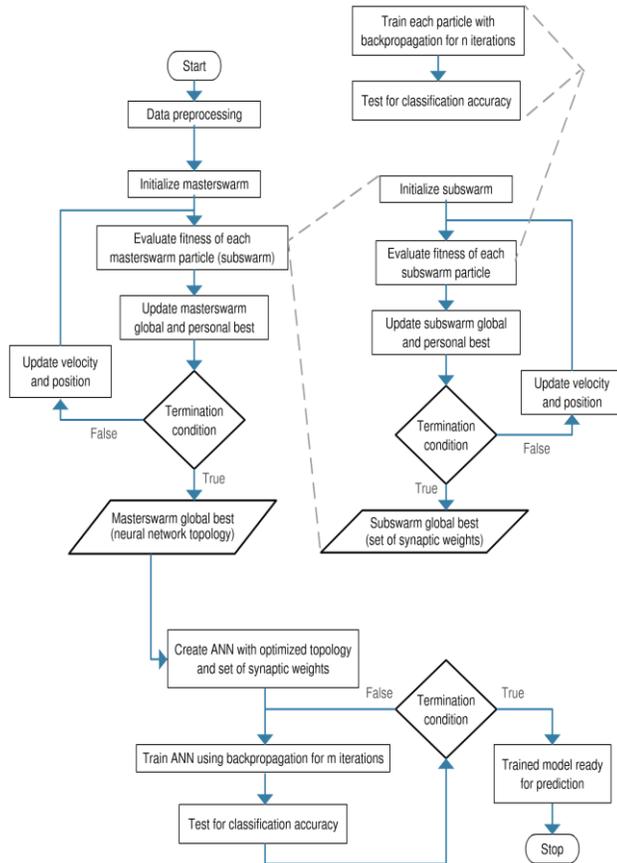


Fig. 4. The flowchart of AMPSONN.

Fig. 4 shows the flowchart of the Adaptive Multilayered Particle Swarm Optimized Neural Network (AMPSONN). It starts from data preprocessing, where the corrosion data is normalized and divided into a training set and a validation set. Next, the layered PSO initializes a masterswarm, in which every particle of the masterswarm is a swarm by itself, called a subswarm. The goal of the subswarms is to provide the best initial weight vector, for a given topology that is given by the masterswarm particle, through a combination of PSO and BP algorithm. The purpose of combining PSO and BP in the training is to provide initial weight vector that will not get stuck in a local minimum, and is a promising solution to the global minimum. In each iteration of the masterswarm, all subswarms would complete an entire optimization run on the objective function and return their fitness value back to the masterswarm. The masterswarm would then continue to iterate

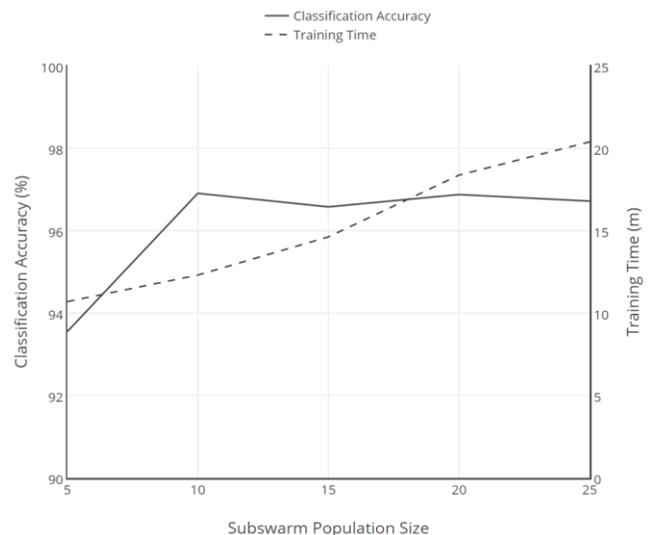


Fig. 5. Sensitivity analysis on the optimal subswarm size.

Fig. 5 above shows sensitivity analysis done to determine the optimal subswarm population size for our AMPSONN method. The increase in subswarm population size shows a linear increase in time taken to train the method. The performance of the method, as denoted by the classification accuracy, shows improvement as the subswarm population size is initially increased from 5 to 10, after which further increments to the population size show no significant improvements in performance. Therefore, the optimum value for the subswarm population size is set as 10.

B. NORSOK Corrosion Test

The first test is done by testing the performance of the AMPSONN, PSOBP, MPSO and BP methods on NORSOK corrosion dataset. Since the AMPSONN method optimizes its own ANN topology during runtime, which differs from PSOBP, MPSO and BP which require manual initialization during compile time, several considerations will be taken into account for this test. To provide an unbiased result for the BP, MPSO and PSOBP methods, all three methods are initialized with all possible values of *H* within the range (3,14). The range of (3,14) for the value *H* is the range of number of hidden neurons which the researchers would consider initializing their methods with, as determined by [38], [42] in (6). The best performances of the three methods out of all of their possible topologies are compared to the best performance of AMPSONN across 10 repetitions.

From Table 4 and Fig. 6, we can see that the AMPSONN method outperformed the other three methods in terms of classification accuracy and also training time. AMPSONN can be said to have reached the global minimum by achieving the highest, 97.1% accuracy during the training, with the second highest being the PSOBP method at 93.85%, followed by BP at 91.23% and lastly, MPSO at 86.55%. The close values between the accuracies of testing and validation sets of each method shows that none have suffered from overfitting. The BP, MPSO and PSOBP methods were able to achieve high accuracies, but are still far below that of the AMPSONN method. This signifies that they may have become trapped in local minimums, which supports findings by [18], [19] who stated that training done using PSO may not always be reliable. This also explains why the three methods took more than 40 minutes to train, while AMPSONN completed its training in under 12.77 minutes. The long time taken by the other methods indicates that their trainings were completed after their maximum number of iterations were reached, while AMPSONN terminated the training earlier after having met the PSO termination conditions. By using PSO to design an optimized topology for the base ANN model, the method was able to select a value of *H*, which is neither too large or small. The value of *H* which is selected is optimum, and provides the right number of synaptic connections to support the mapping of relationships between variables in the NORSOK generated dataset. With the right number of synaptic connections, the optimized ANN was able to avoid being underfitted or overfitted, and produces the best performance over the complexity of the network. Therefore, optimization of topology has enabled the AMPSONN to improve its accuracy

and time efficiency in comparison to the other unoptimized method.

TABLE IV. RESULTS OF THE NORSOK CORROSION TEST

Method	Training Time (m)	Classification Accuracy on Validation Set (%)	Classification Accuracy on Testing Set (%)
AMPSONN	12.77	97.1	96.7
PSOBP	48.2	93.85	93.37
MPSO	45.2	86.55	87.67
BP	50.05	91.23	90.89

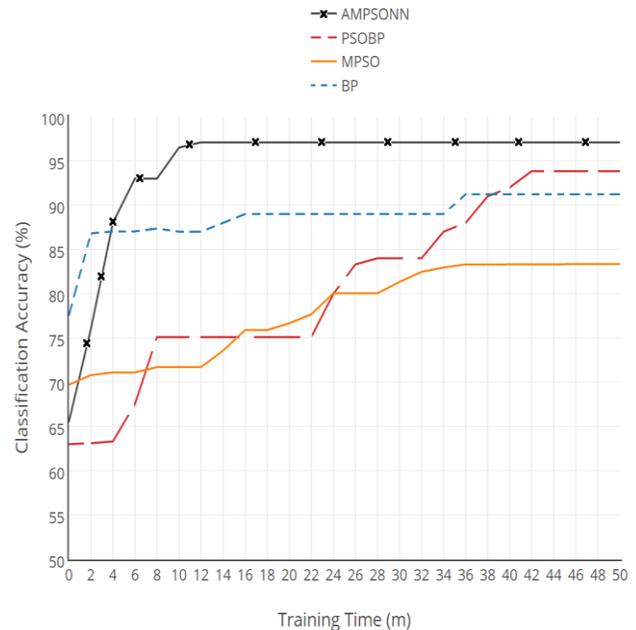


Fig. 6. The training curve of all methods showing accuracy improvement over time.

TABLE V. CALCULATED SPEEDUP PROVIDED BY AMPSONN AGAINST OTHER METHODS

Method	Speedup
PSOBP	$\frac{48.2}{12.77} = 3.77 \text{ times}$
MPSO	$\frac{45.2}{12.77} = 3.54 \text{ times}$
BP	$\frac{50.05}{12.77} = 3.92 \text{ times}$

Table 5 shows the speedup in terms of training time provided by the AMPSONN method against the PSOBP, MPSO and BP methods. From Table 5, it can be concluded that there is a very significant speedup provided by the AMPSONN method, calculated at above 3.5 times against the other three methods.

C. Optimized Topology Test

To further test the improvement in performance of the AMPSONN method, an optimized topology test was carried

out. The optimized number of hidden neurons, H selected by the AMPSONN method will be used to initialize the BP, MPSO and PSOBP method for another round of evaluation on the NORSOK corrosion dataset. This serves as a test to evaluate if the other three methods could perform better than the AMPSONN method if they were provided with an optimized topology. This test would also be significant to show the speedup capability provided by the novel integration of BP into every iteration of subswarm in our proposed AMPSONN method.

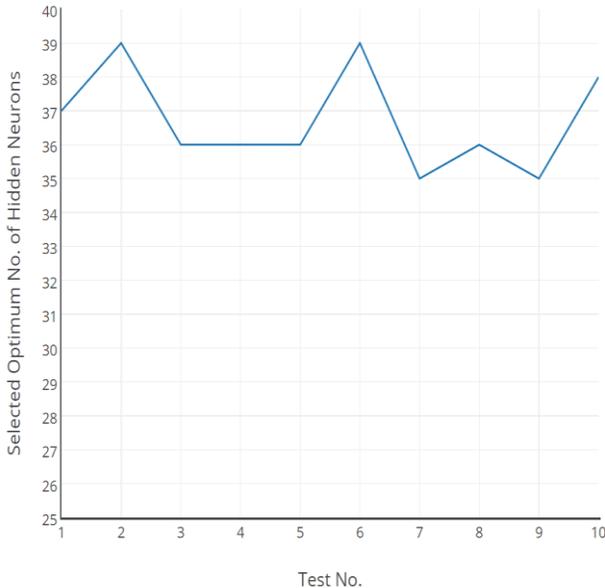


Fig. 7. The number of hidden neurons selected by AMPSONN method across 10 tests.

Fig. 7 shows the optimum number of hidden neurons, H that was selected by the AMPSONN method across 10 repeated tests. It can be seen that despite the AMPSONN method being given a search space of (3,50), all the selected values of H are very close to each other and are optimized within the range of (35,39). This indicates that our proposed AMPSONN method is consistent across repetitions, and the classification accuracy achieved is not purely a case of lucky initialization into a position near the global minimum. The selected range of H within (35,39) also showed that the optimum value of H , is outside the initialization range that most researches [18], [21]-[24], [38] have considered in their research.

From Fig. 7, the value of 36 has been selected to be the optimum H for 40% of the time, and this value was used to initialize the BP, MPSO and PSOBP methods. The best performances of the three methods across 10 repetitions are recorded and compared against that of the AMPSONN method. The results for this test are tabulated in Table 6.

TABLE VI. RESULTS OF THE OPTIMIZED TOPOLOGY TEST

Method	Training Time (m)	Classification Accuracy on Validation Set (%)	Classification Accuracy on Testing Set (%)
AMPSOBP	12.77	97.1	96.7
PSOBP	19.62	95.31	95
MPSO	50.07	81.33	81.7
BP	58.03	93.57	93.73

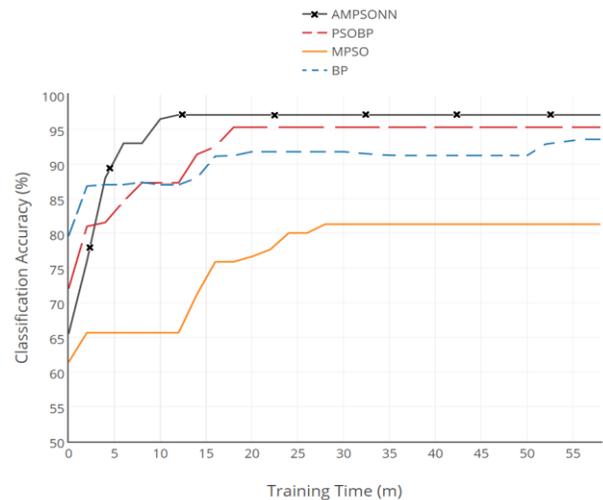


Fig. 8. The training curve of all methods during the optimized test.

Table 6 and Fig. 8 show the results of the BP, MPSO, PSOBP and AMPSONN methods with optimized topologies. It can still be seen that AMPSONN still performed better than the other methods, scoring an accuracy of 97.1%, followed closely by PSOBP at 95.31%, BP at 93.57% and MPSO at 81.33%. By optimizing the topology instead of a manual selection, we can see that the performance of BP and PSOBP have improved significantly, and have managed to obtain accuracies higher than their best accuracies obtained during the previous test. This result is fully supported by Saima et al. [20], who stated that the topology of an ANN greatly affects the performance of the method, regardless of the weight training algorithm used. In terms of training time however, the optimized BP method ended up taking more time to converge in comparison to its unoptimized state, while the optimized PSOBP method was able to save time needed to converge than previously. This is because the BP method is a standalone method while the PSOBP method uses PSO to optimize the earlier stages of training. Therefore, as the number of hidden neurons, H is increased from within a range of (3,14) to 36, it

incurs more computation effort for the classical BP algorithm in every epoch of training while not affecting PSOBP as much, because the latter only uses BP during the later stage of training. On the other hand, the performance of the MPSO method has not improved even after an optimized topology has been provided. The method is still trapped in a local minimum, and is supported by findings from [20], stating that purely training an ANN using PSO in a high-dimensional search space has a high tendency of getting trapped in a local minimum.

Overall, the proposed AMPSONN method exhibits the best performance over the other methods after optimization, with the lowest training time of 12.77 minutes, followed by PSOBP at 19.62 minutes. This result has proven another important point. With BP, MPSO and PSOBP methods optimized with an optimum topology, this test has taken the AMPSONN masterswarm component out of the picture and set all methods on an equal footing. However, their performance lag behind the AMPSONN method, proving that the weight training (subswarm) component of AMPSONN is more optimized than the other three methods. Although both AMPSONN and PSOBP integrate the PSO algorithm together with BP algorithm, only AMPSONN incorporates BP training into the earlier training stage as well as the later stage of training. By training the subswarm particles with several epochs of BP in every iteration of the subswarm, the particles were to learn faster while being able to capitalize on the ability of PSO to avoid local minimum. The gradient descent information provided by BP has allowed the particles to adjust each synaptic weight with respect to their contribution to the network error, before the next iteration of PSO. This relationship has allowed the method to perform a better local search in between global searches.

With that, the AMPSONN method has shown to be able to save on computational time needed in order to converge to the global minimum. Therefore, the overall performance of the method is attributed to both the topology-optimizing masterswarm as well as the weight-optimizing subswarm.

TABLE VII. CALCULATED SPEEDUP PROVIDED BY AMPSONN AGAINST OTHER METHODS IN THE OPTIMIZED TEST

Method	Speedup
PSOBP	$\frac{19.62}{12.77} = 1.54 \text{ times}$
MPSO	$\frac{50.07}{12.77} = 3.92 \text{ times}$
BP	$\frac{58.03}{12.77} = 4.54 \text{ times}$

Table 7 shows the speedup in terms of training time provided by the AMPSONN method against PSOBP, MPSO and BP methods for the optimized topology test. From the table, the speedup provided by AMPSONN against MPSO and BP is still significant, with 3.92 times against MPSO and 4.54 times against BP. AMPSONN shows a very positive speedup of 1.54 times against PSOBP, even after PSOBP is developed with an optimized topology.

V. CONCLUSION

This research presented a novel approach to predicting the severity of pipeline corrosion by targeting damage mechanisms individually. After conducting a thorough literature study, a framework which utilizes the combination of PSO and ANN algorithms were used to establish a flexible hybrid method which adaptively designs and trains an ANN until it is fully able to model a given damage mechanism. The hybrid model proposed in this research was compared with other hybrid prediction models based on their classification accuracy and time efficiency. The comparisons are aimed to demonstrate that combining PSO and BP algorithms lead to improved performance over other prediction models in the case of predicting corrosion data of CO₂ damage mechanism. Results obtained have proven that the proposed AMPSONN method has in fact, demonstrated a better performance as compared to BP, MPSO and PSOBP methods. The proposed use of a masterswarm has been justified when an optimized topology allowed the AMPSONN method to achieve accuracy rates higher than the other methods, as well as improving the performance of the other methods when optimized. The proposed use of a subswarm which integrates BP to add gradient-based local information into every iteration of PSO for ANN weight training has shown to outperform that of a pure PSO. The results have also revealed that the AMPSONN method shows a better performance even when the topologies of all methods are optimized, and when the size of training set is reduced. The adaptive multilayered PSO approach has proven itself to be a promising solution to target various individual damage mechanisms.

For future directions for this research, we suggest to incorporate additional ANN parameters into the masterswarm for optimization, such as the transfer function. Although most researchers argue that logistic is sufficient for most cases, some researchers have started to research into optimizing transfer functions [38] for different types of problems. It would be interesting to observe the effect on the performance of the whole method and the improvement on its adaptiveness at the same time. It is also possible to use more datasets in the testing of the AMPSONN method to prove its effectiveness in other application areas. As the field of data analytics and prediction is constantly growing, there is a need to fine-tune new algorithms to adapt to more real-world applications, such as image processing [45] and prediction in the medical field [46].

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Implementation of Pattern Matching Algorithm for Portable Document Format

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Abstract—Internet availability and e-documents are freely used in the community. This condition has the potential for the occurrence of the act of plagiarism against an e-document of scientific work. The process of detecting plagiarism in some cases seems to be done manually by using human power so that it has the potential to make mistakes in observing and remembering the checkpoints that have been done. The method used in this research is to represent two sets of objects compared in the form of probability. In order for the method to run perfectly, the Rabin-Karp algorithm is applied, wherein Rabin-Karp is a string matching algorithm that uses hash functions as a comparison between the searched string (m) and substring in the text (n). If both hash values are the same then the comparison will be done once again to the characters. The resulting system is a web-based application that shows the value of the similarity of two sets of objects.

Keywords—Pattern matching; Rabin-Karp algorithm; data mining; web

I. INTRODUCTION

Plagiarism turns out to infect developing countries like Indonesia. Some recent cases are even found in developed countries like the United States. The difference is that developed countries impose sanctions that do not play games with plagiarism, while Indonesia still seems shy to impose tough sanctions because most of the scientific work has not been protected by *Hak atas Kekayaan Intelektual (HaKI)* then plagiarism is classified as an academic crime that including as ethical violations and difficult to be criminalized. As the first step to prevent a similar case is needed how to detect the possibility of such plagiarism in the college environment that is primarily on the final outcome of undergraduate candidates and undergraduate thesis of master degree and doctoral dissertation candidates who are prone to plagiarism [1].

There are two main classes of methods used to reduce plagiarism: methods of preventing plagiarism and methods of detecting plagiarism. Prevention methods of plagiarism include ritual punishment and complementary procedures of plagiarism explanation. This method has a long-term positive effect, but it takes a long time to implement because they rely on social cooperation between different universities and departments to reduce plagiarism [6]. Plagiarism detection methods include manual methods and software. They are easy to implement but have a momentary positive effect. Both methods can be combined to reduce cheating and cheating. Although software

is the most efficient approach to identifying plagiarism, the final assessment must be done manually [7].

To minimize the practice of plagiarism, detection of writing is required. To overcome the practice of plagiarism, it is not enough to simply remind the students that plagiarism is not well done. The detection of plagiarism practices is the best solution so that the fraudulent actions can be minimized. However, manual detection is difficult to do because of a large amount of writing. So the system needed to detect plagiarism. Methods for detecting plagiarism can be classified into three methods: full-text comparison method, fingerprinting document method and keyword equality method [1].

Rabin-Karp algorithm is a string-matching algorithm that uses hash functions as a comparison between the search string (m) and substring in a text (n). The Rabin-Karp algorithm is based on the fact that if two strings are equal then the hash value must be the same. But there are two problems that arise from this, the first problem is that there are so many different strings, this problem can be solved by assigning multiple strings with the same hash value. The second problem is not necessarily a string that has the same hash value matching to overcome it for each string that is assigned to do string matching by BruteForce [1], [3]

II. RESEARCH METHOD

Similarity measurement methods have been developed with various methods applied. Although each method has its own way of measuring but the results to be achieved remains the same that is to create a system that can measure the level of similarity in the text string in an optimal and effective [1].

There are three kinds of techniques that are built to determine the value of similarity (similarity) of documents, such techniques are [1], [2]:

- Distance-based similarity measure, which measures the similarity of two objects in terms of the geometric distance of the variables enclosed within the two objects. Distance-based similarity methods include Minkowski Distance, Manhattan/City Block Distance, Euclidean Distance, Jaccard Distance, Dice's Coefficient, Cosine Similarity, Levenshtein Distance, Hamming Distance, and Soundex Distance.
- Feature-based similarity measure, which is to calculate the level of similarity by representing the object into the form of features that want to be compared. The feature-

based similarity is widely used in classifying or pattern matching for images and text.

- Probabilistic-based similarity measure, which calculates the level of similarity of two objects by representing two sets of objects that are compared in the form of probability. Includes Leibler Distance Kullback and Posterior Probability

Rabin-Karp algorithm is included in the category from left to right. The Rabin-Karp algorithm implements a hash function that provides a simple method to prevent the time complexity $\Theta(m^2)$. There are four categories of comparison process [3]:

- From right to left
- From left to right
- In specific order
- In any order

The key to the efficient Rabin Karp algorithm is in its hash value selection. One well-known and effective way is to treat each substring as a number on a specific basis. The hash function should provide at least four properties [4]:

- Able to perform computing efficiently
- High string discrimination
- The hash function $(s[i+1\dots i+m]=s[i\dots i+m-1]-s[i]+s[i+m])$ should be easy to compute from:

a) Hash $(s[i\dots i+m-1])$

b) Hash $(s[i])$

c) Hash $(s[i+m])$

- The Rabin-Karp algorithm marks the following steps:
 - a) Apply hash function
 - b) The preprocess phase in the time complexity $\Theta(m)$ and time constant
 - c) Search phase in time complexity $\Theta(m)$
- $\Theta(n+m)$ estimates the active time

III. PROPOSED SYSTEM

We use the Rabin-Karp algorithm to compare the pattern of files uploaded with servers on the server. This comparison yields a percentage value of the similarity of uploaded files to files contained on the server. This comparison is performed by preprocessing steps shown in Fig. 1: case folding, tokenizing, filtering and stemming.

A. Case Folding

In this process, we make changes to the words in the document into lowercase (a to z) [4].

B. Tokenizing

We do a cut to the input string based on the specified delimiter. Characters other than letters will be considered as delimiters and will be omitted or deleted for the process of getting text compiler words. From this process will be

generated words string or text compilers or often called tokens or term [4].

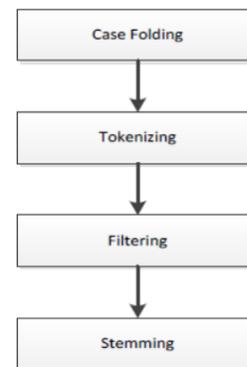


Fig. 1. Preprocessing.

C. Filtering

We remove the words that have been registered into the stop-word or stop-list. Stop-word is the words that often appear in the text in large numbers and is considered to have no significance [3].

D. Stemming

This process we do to get the basic word from a word. Stemming Nazief-Adriani is a stemming algorithm created by Bobby Nazief and Mirna Adriani [8].

E. Rabin-Karp

By seeing that the two strings are the same, the hash value must be the same. But there are two problems that arise from this, the first problem is that there are so many different strings, this problem can be solved by assigning multiple strings with the same hash value [5].

F. Similarity Value Measurement

Measuring similarity and distance between two information entities is a key requirement for the discovery of information. The first stage is dividing the word into k-grams. Second, group the term results from the same k-grams. Then to calculate the similarity of the word set then used the formula 1 Dice's Similarity Coefficient for the word pairs are used [9].

$$S = \frac{(2 \times G)}{(A + B)} \times 100 \quad (1)$$

G. Similarity Value Percentage

To determine the similarity between existing documents 5 types of understanding percentage similarity [5]:

- 0%: the 0% test result means the two documents are completely different in both the content and the sentence as a whole.
- < 15%: Test results less than 15% means the two documents have little in common.
- 15 - 50%: Test result means that the document includes a moderate plagiarism.

- > 50%: Test results over 50% means it can be said that the document detects plagiarism.
- 100%: Test results with a percentage value of 100% indicate that the document is a plagiarism because from the beginning to the end have the exact same content.

IV. RESULT

At the beginning of the application selected one of the detection methods, namely detection by using the title, the content of the content as in Table 1 below:

TABLE I. TEXT OF THE FILE

Text1	Berisi Text 1
Text2	Isi Dari Text 2

The first process, the process of preparation is done the tokenizing process, filtering and stemming process results shown in Table 2 below:

TABLE II. TOKENIZING, FILTERING AND STEMMING RESULTS

Text1	berisitext1
Text2	isitext2

The second process as shown in Table 3 below is a process of parsing K-gram with length K = 4.

TABLE III. RESULTS OF K-GRAM PARSING

No	Parsing Teks 1	Parsing Teks 2
1	beri	isit
2	eris	site
3	risi	itex
4	isit	text
5	site	ext2
6	itex	...
7	text	...
8	ext1	...

Here is a hashing calculation by converting char to decimal based on ASCII with K-gram = 4 and Modulo = 101. The result of this hashing calculation is shown in Table 4.

Pattern = 'beri'

$$\text{Hashing} = 98 * 103 + 101 * 102 + 114 * 101 + 105 * 100 = 109345 \text{ mod } 101 = 63$$

$$\text{Remainder} = 109345/101 = 1082.623762 = 109345$$

And so on.

TABLE IV. CALCULATION RESULTS MODULO AND REMAINDER

P	Text 1		P	Text 2	
	H	R		H	R
beri	63	109345	isit	1	117666
eris	41	113565	site	6	126761
risi	10	125755	itex	65	117730
isit	1	117666	text	55	127416
site	6	126761	ext2	80	114210
itex	65	117730			
text	55	127416			
ext1	79	114209			

The third process shown in Table 5 below is the result of calculating the values found in Table 4 that are matched by matching string by taking the value of match yes.

TABLE V. STRING MATCH RESULTS

P	Text 1		P	Text 2		Match
	H	R		H	R	
itex	65	117730	itex	65	117730	Yes
text	55	127416	text	55	127416	Yes

The fourth process, to obtain similarity level information is weighted using Dice's Similarity Coefficient [10]:

$$\begin{aligned} P \text{ Similarity} &= ((4*2)/(8+5))*100\% \\ &= (8/13)*100\% \\ &= 61.53846154\% \\ &= 61.54\% \end{aligned}$$

The similarity values obtained from Text 1 and Text 2 are 61.54% and it can be said that the document detects plagiarism. With the time required in comparing text1 and text2 is 0.08 seconds. Testing the system produces the output as shown in Fig. 2 and 3 below:

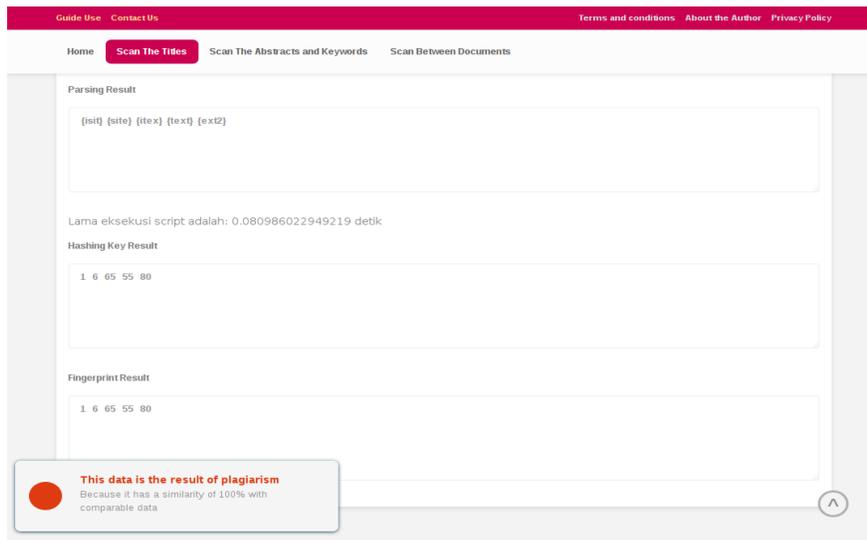


Fig. 2. Results of parsing, hashing key and fingerprint against PDF docs on our system.

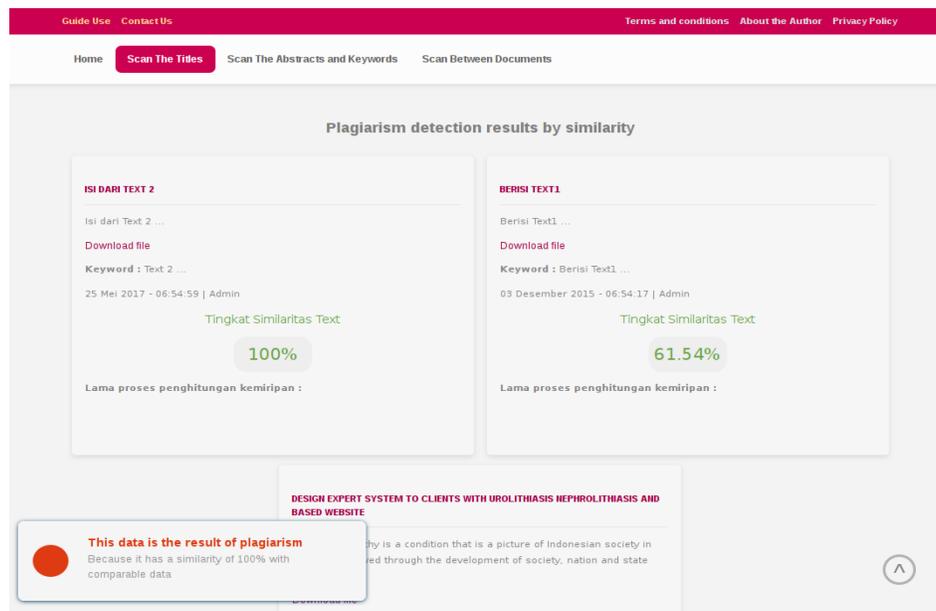


Fig. 3. Notice of plagiarism with color and result percentage of similarity in our system.

V. CONCLUSION

Based on the series of tests we have done, our system can provide a true value of scientific paper data by using k-gram and hashing parsing to find matches of the same word or phrase in the document being tested. Rabin-Karp algorithm modification of time processing process similarity (running time) better. The system has been able to check the title of scientific papers, abstractions or documents comparable with the existing comparative documents on the database with accurate. The checking system at document similarity level with Rabin-Karb algorithm gives a result of similarity percentage and detection notification.

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Collective Movement Method for Swarm Robot based on a Thermodynamic Model

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Abstract—In this paper, a distributed collective movement control method is proposed for a swarm robotics system based on an internal energy thermodynamic model. The system can move between obstacles with a changing aggregation suitable for confronting obstacle arrangements in an environment. The swarm robot shape is a fixed aggregation formed by virtual attraction and repulsion forces based on the proposed method. It follows a leader agent while retaining its shape. When the swarm robot aggregation shape cannot be maintained during movement through narrow spaces with obstacles, the swarm robot flexibly changes shape according to that of the local environment. To this end, it employs virtual thermal motion, which is made possible with directives and enables continuous movement. A simulation confirmed the capability of the proposed method in enabling the solidity and flexibility collective movement of swarm robots. The results furthermore showed that the parameter setting range is important for applying the proposed method to collective movement.

Keywords—Swarm robotics system; solidity and flexibility collective movement; thermodynamics; distributed control

I. INTRODUCTION

Swarm robotics systems implement swarm intelligence in multi-robot systems. These systems are thereby suitable for cooperative and parallel tasks and are thus expected to have applications in real-world tasks, such as object transportation and environment exploration. To realize these applications, swarm robotics systems must be capable of flocking motion and collective movement, in which many agents move simultaneously as a flock in various environments [1]. During such movement, all agents must cooperate to change the aggregation shape. The systems must also have “scalability” [2]; that is, the system can be controlled even if the number of active agents change. In other words, the system must be capable of collective movement and maintaining or changing the aggregation shape in accordance with the environment without requiring information about all agents.

In recent years, many studies of multi-robot system flocking have employed cooperative control, whereby numerous agents given random velocity vectors produce a common motion by setting the acceleration to zero and the velocity vector to a constant other than zero [3]-[6]. To enable this control, [3], [4] achieved the convergence of all agents to motion of a virtual agent (virtual leader) using the dynamic pinning control algorithm (DPCA). In addition, [5] achieved fixed flocking by interactions without using the above-mentioned reference agent; a model prediction control (MPC)

method for a multi-robot system was employed. These control methods enable collective movement at a constant velocity in a certain direction; however, they do not address obstacle avoidance. The study in [6], on the other hand, considered obstacle avoidance. Obstacle avoidance and movement to a target in cooperation with other agents using the potential functions of aggregation, obstacle avoidance, and trajectory were achieved. This approach involves a simple numerical calculation. Thus, the calculation of one agent is small. Nonetheless, the environment and route information as known information are required.

Next, we focus on studies about collective movement for multi-robot systems. Considering the environment with obstacles, the study provides control to move a changing or maintained aggregation shape in accordance with the environment [7]-[11]. To achieve this goal, [7]-[9] proposed collective movement that flexibly adapts to the environment by applying dynamics systems, such as fluid dynamics and analytical mechanics. These methods are similar to the approach presented in [6]. In all of these methods, it is necessary to know in advance the global environment information, such as the goal point and/or obstacle points. However, since the formation is constantly updated according to the swarm and surrounding environment, it is difficult to maintain a certain shape. References [10,11], on the other hand, achieved collective movement to maintain the given formation by assigning each agent a position in which the agent should fit. This control requires global coordinates and information to provide a fitting position. Therefore, the number of controllable units depends on the computing capacity of the central control unit and the network performance.

Flocking motion respectively using MPC [5] and the potential function [6], as well as collective movement applied to a dynamics model [7]-[9], are distributed control methods that produce common actions or movement to a known target point based on global information. Consequently, it is difficult for an operator to freely control the swarm in real time. Flocking motion using DPCA [3], [4] and the formation control model [10], [11], on the other hand, can solve this problem. However, this approach does not consider obstacle avoidance and distributed control, and it lacks flexibility, which is a feature needed to accommodate a swarm robot.

In this paper, we therefore propose a collective movement method for distributed control that compensates the limitations of the respective dynamics and formation control model. To realize this objective, our approach is based on the microscopic

viewpoint of thermodynamics and deals with quantitative states, including solid, liquid, and gas. Of these states, the solid and liquid phases have the solidity required to fix a shape and the flexibility to change a shape. Therefore, if they are applied to a swarm robot, it is possible to maintain a formation and adapt it to an environment by interactions based on local information. The proposed method controls the internal energy and knowledge of the phase transition [12] to control these states. In addition, we herein propose a collective movement method controlled by a leader (one real agent) by applying the properties of internal energy since thermodynamics do not consider object movement.

This paper is structured as follows: Section II introduces the thermodynamic models we focused on. In Section III, the swarm robot deal with this paper and some variables for the proposed method are defined. Section IV presents approaches for applying the thermodynamic models to agents and proposes control models. Next, Section V describes the parameter design for the proposed model. Section VI presents the performance evaluation of a collective movement by the proposed method, and Section VII concludes this paper.

II. THERMODYNAMICS MODEL

The micro-dynamics of thermodynamics mainly include interactions between molecules and the thermal motion due to heat input from outside the system. Molecules move by using the internal energy obtained from these components. Internal energy produces various intermolecular interactions. Among these interactions, this study focused on the Lennard-Jones potential. This potential converges at a position where attractive and repulsive forces are in balance according to the distance between the molecules, and this potential serves to promote collective aggregation. The equation of this potential model is given as

$$\varphi(r) = 4\varepsilon \left[\left(\frac{\sigma}{r} \right)^{12} - \left(\frac{\sigma}{r} \right)^6 \right] \quad (1)$$

where r is the relative distance between molecules; exponents 12 and 6 are strength parameters of attractive and repulsive forces; ε denotes a parameter that gives the depth of potential; and σ represents the molecule diameter. Differentiating this potential model with respect to the distance gives the motion model φ' of the molecule [13], which has a balanced distance r_0 where the momentum is $\varphi'(r_0) = 0$.

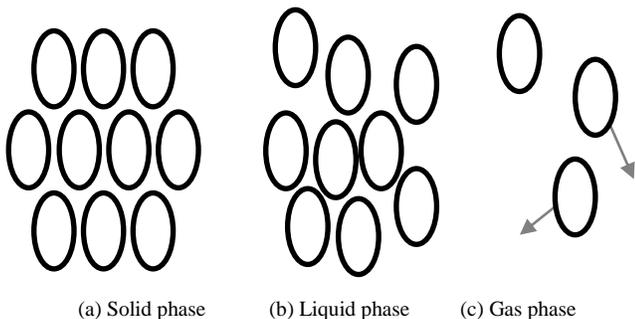


Fig. 1. Molecular structure of each phase. Circles indicate molecules.

Brownian motion is random oscillatory molecular motion produced by the internal energy resulting from heat input from outside the system. This motion arises from random oscillatory motion $F(x, t)$ due to collisions with neighbors caused by heat. As this motion occurs in the entire aggregation, it may cause a change in the quantitative state. Brownian motion is proportional to the temperature, and it is given as

$$K(T) = kT = \frac{1}{2} mF^2(x, t) \quad (2)$$

Where, T is the absolute temperature of the molecule; m denotes the mass; and k represents a molecule-specific parameter, such as thermal conductivity.

The internal energy, W , is given by a simple expression that combines the potential according to the distance between molecules and the thermal energy as a function of temperature:

$$W = \varphi(r) + K(T) \quad (3)$$

As described above, the internal energy of the molecule combines the actions of collective aggregation and state change. Therefore, the swarm energy is determined by the temperature, which is the magnitude of the state change.

Three basic states exist in thermodynamics: the solid phase (Fig. 1(a)), in which the temperature is very low and only the potential works; the liquid phase (Fig. 1(b)), in which the temperature is relatively higher and both the potential and thermal energy work; and the gas phase (Fig. 1(c)), in which the temperature is very high and the potential does not work.

By applying these states to the swarm robotics system, “solidity,” “flexibility,” and “discreteness,” which are the respective features of each state in thermodynamics, can be mathematically expressed and realized.

III. SWARM DEFINITION AND PRELIMINARIES

The swarm robotics system uses identical mobile robots that can move flexibly and omnidirectionally. These robots have a distance measurement function for adjacent robots and obstacles and a communication function for adjacent robots. Furthermore, these robots are circular for minimizing the distance measurement error in the distance measured from all directions. Robot swarm consists of followers, which employ a distributed interaction based on thermodynamics, and a leader, which moves freely by following the followers. In addition, each robot has anonymity and is not assigned an identifier.

It is desired that a swarm robot is initiated with a starting state from cluttered velocities and positions, such as in flocking [3]-[6]. However, since the present approach involves the solid and liquid phases of thermodynamics, the initial shape is already aggregated and is a hexagonal-lattice shape of the most stable structure. This shape can be easily changed to other lattice shapes (triangle, square, etc.) by adjusting the density of the network topology [14]. Furthermore, the hexagonal-lattice shape is stabilized during collective movements, which was also confirmed in the control models proposed by Shimizu et al. [7] and Pimenta et al. [9].

Each agent is assumed to apply thermodynamics, the diameter is σ , and the maximum moving speed is V_{max} . The

distance measurement function should be able to obtain the local coordinates in the range of r_{max} , where the attractive force of the Lennard–Jones potential becomes the maximum ($\varphi''(r_{rm}) = 0$). Agent i identifies adjacent agents $\forall j \in RS$ and obstacles $\forall l \in OS$ within its sensing range, and it measures the shortest distance r_{ij} and r_{il} to them.

The swarm robotics system can use centralized or distributed communication management. However, centralized management causes communication delays and communication packet losses because the communication traffic increases with the number of robots. Therefore, we adopt communication between adjacent agents within each sensing range. However, the leader must have a global communication function to receive a command from an operator.

IV. PROPOSED METHOD

Based on the thermodynamic model, we propose a collective movement method for the swarm robotics system that provides solidity and flexibility in the solid and liquid phases. To achieve this objective, the aggregation, obstacle avoidance, and collective movement algorithms must be considered [15]. Therefore, the proposed model consists of a collective aggregation model that changes the aggregation shape according to the environment by using the internal energy as in (3). It also consists of a collective movement model that moves the swarm by the ratio of the potential change according to the leader’s direction. This model requires both leader and follower models.

In Section II, we outlined the energy dimension thermodynamics. However, velocity and/or motion must be addressed to control swarm robot movement. Let us consider the velocity from the internal energy represented in (3). On the right, the potential term is velocity φ' by differentiation. Although the thermal energy term is motion by solving (2), we consider that the phase transition is related to both momentum ratios and we control temperature T as motion. The motion of each agent is determined by

$$\begin{cases} \dot{p}_i = v_i \\ v_i = f_i^P + f_i^T \end{cases} \quad (4)$$

where p_i and v_i are the position and velocity of any agent i . In v_i , f_i^P is a potential model and f_i^T is a thermal energy model. These models are herein presented.

A. Collective Aggregation Model

To maintain the aggregation shape, the swarm robot must maintain a constant distance between agents and change the aggregation shape according to the environment. We use the Lennard–Jones potential to maintain the constant distance between agents, and we employ thermal energy to change the aggregation shape by obstacle avoidance. This model uses controlled variables in each model to form an aggregation according to the local environment. Fig. 2 shows a schematic representation of the proposed approach.

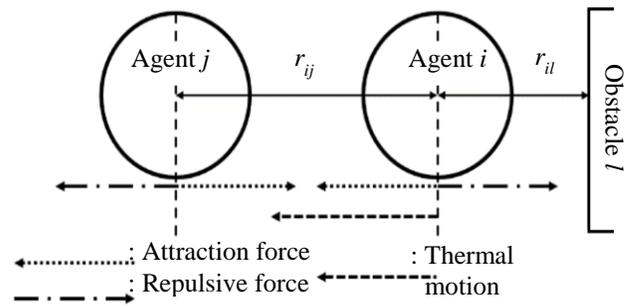


Fig. 2. Outline of the clustering model.

1) *Potential Model*: This model determines the motion of any agent i based on the Lennard–Jones potential to maintain the distance to the neighbor constant. The motion model of the agent is given as

$$\varphi'(\vec{r}_{ij}) = \sum_{j \in RS} \frac{4\varepsilon}{\vec{r}_{ij}} \left(12 \left(\frac{\sigma}{\vec{r}_{ij}} \right)^{12} - 6 \left(\frac{\sigma}{\vec{r}_{ij}} \right)^6 \right) \quad (5)$$

Where, \vec{r} is a distance vector. This model is required for designing the maximum value of the attractive force as the maximum moving speed. This is because the maximum value of the repulsive force diverges to infinity and the maximum value of the attractive force is a constant. Therefore, ε is designed to be the maximum moving speed at distance r_{rm} , where attractive force is the maximum, $\varphi''(r_{rm}) = 0$, and is given as

$$\varepsilon = -\frac{169}{504} \cdot \left(\frac{26}{7} \right)^{\frac{1}{6}} \cdot \sigma \cdot V_{max} \quad (6)$$

Equation (5) sets the upper limit for the maximum moving speed.

2) *Thermal Energy Model*: The thermal energy model supplies virtual heat to obstacles and realizes the addition and divergence of energy according to temperature. By controlling the amount and direction of energy divergence, the agent can avoid obstacles and change the aggregation shape. The change in temperature (thermal energy) caused by Brownian motion (2) over time can be expressed by Newton’s law of cooling. When this law is expressed as an integral of elapsed time t , it is given as

$$T(t, T_{env}(t)) = \frac{-k}{e^{kdt}} \int_{t=0} (T(t-dt, T_{env}(t-dt)) - T_{env}(t)) dt \quad (7)$$

Where, $T(t, T_{env}(t))$ is the temperature of the target object, and $T_{env}(t)$ is the environment temperature at t .

Each agent can control the amount of energy (i.e., motion). In the proposed method, this energy is used for avoiding obstacles. To apply this model, the surroundings of obstacles are defined by a virtual temperature distribution with obstacles as heat sources. The respective temperatures of an agent and environment increase as an agent approaches an obstacle. We thus propose a model that controls the motion of agent i according to this environmental temperature, which is given by

$$T_i(t, T(r_{il})) = \frac{-k}{e^{kdt}} \int_{t=dt} \left(T_i(t-dt, T(r_{il})) - \frac{\sum_{l \in OS} T(r_{il})}{|OS|} \right) dt \quad (8)$$

$$T(r_{il}) = \begin{cases} V_{\max} - 2 \frac{V_{\max}}{\sigma} r_{il} & ; r_{il} < \sigma \\ 0 & ; else \end{cases}$$

This motion is controlled from zero to V_{\max} by the temperature distribution model $T(r_{il})$.

Meanwhile, Bilbeisi et al. proposed the ‘‘agoraphilic’’ algorithm [16], which determines the collision avoidance direction according to the surrounding environment. This method can be applied to the swarm robot in this paper. To confirm the basic movement, the agents diverge in the normal direction to an obstacle. When multiple obstacles are present, they diverge in the synthesized vector direction of the temperature distribution.

B. Collective Movement Model

When the Lennard–Jones potential in (5) operates between two agents, the convergence point is the center value of the distance between them. This does not serve as an interaction to enable collective movement; however, it is an important function in thermodynamics and it is necessary to retain it. Therefore, a ratio is set to the potential, and an approach is adopted that enables movement by changing the convergence point while retaining the thermodynamics effects. We hence present a collective movement model based on distributed control using leader directivity for relating this deviation and agent followers that convey the relationships.

1) *Collective Movement Model for Followers:* To follow the movement of the leader, each follower must act more strongly than the leader and the follower near the leader. This collective movement can be achieved by converging the deviation caused by the movement of the leader. Therefore, each follower must know the direction in which this deviation has occurred (the presence of the leader) from an adjacent agent.

We propose a recursive numbering algorithm that dynamically provides one agent’s distance from the leader. This algorithm assigns reference numbers N_L and N_i to the leader and follower i , respectively, according to the algorithm

$$N_i = \min(N_j | j \in RS) + 1 \quad (9)$$

Where, N_j is the number of each element in the neighbor set RS. This algorithm sets a follower’s number by adding one to the smallest value from among its neighbor set. It can recursively provide the distance and direction between the leader and all followers, as shown in Fig. 3.

We propose the following potential model in which the bias is changed by using this number:

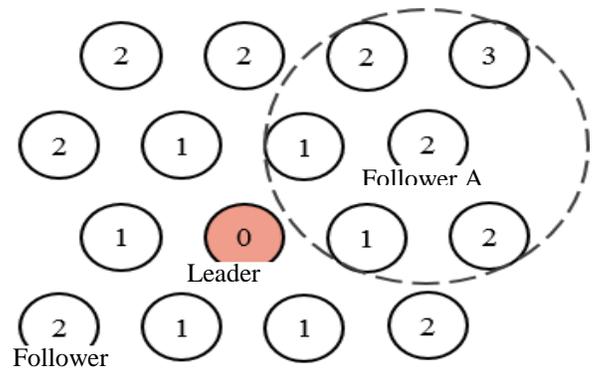


Fig. 3. Numbering algorithm for collective movement. For example, follower A communicates a number with neighbors in the dashed circle, and it is assigned a ‘‘2’’ by adding one to the smallest number ‘‘1’’ in its neighbors. This recursively produces the distance and direction of the robot unit between the leader and all followers.

$$\phi'_F(\vec{r}_{ij}, N) = \sum_{j \in RS} \delta_i(N_j) \frac{4\epsilon}{\vec{r}_{ij}} \left(12 \left(\frac{\sigma}{\vec{r}_{ij}} \right)^{12} - 6 \left(\frac{\sigma}{\vec{r}_{ij}} \right)^6 \right) \quad (10)$$

$$\delta_i(N_j) = \begin{cases} P_r & ; N_i = N_j + 1 \\ 1 & ; N_i = N_j \\ P_w & ; else \end{cases}$$

This potential model is the same as the bias model δ_i introduced in (5). The bias value set by the bias model can follow the leader if $P_r \geq 1 \geq P_w \geq 0$ is satisfied.

By applying the model $v_i = \phi'_F(\vec{r}_{ij}) + T_i(t, r_{ij})$ used by this potential model to the internal energy in (4), the follower follows the leader.

2) *Collective Movement Model for the Leader:* The leader must cooperate with the follower’s velocity model. Because the model is considered dependent on the ratio (P_r to P_w) of the potential, the leader engages in control by giving a coefficient to adjust the controlled value from the operator. It is given as

$$v_L = P_{ope} \cdot \vec{v}_{ope} \quad (11)$$

Where, \vec{v}_{ope} indicates the mobile vector commanded by the operator (movement controlled value ranges from zero to V_{\max}). By limiting this controlled value by P_{ope} , we cooperate with the movement of followers. P_{ope} must satisfy $0 < P_{ope} < 1$. Because it is clear that this parameter is related to P_r and P_w set by the follower’s model, it will be verified and discussed in detail in the described experiments.

V. PARAMETER DESIGN

The parameters of the proposed model are shown in Table 1. Table 1(a) presents the robot specifications. The sampling frequency should be sufficiently high. The parameters of the proposed model (Table 1(b)) are designed and determined according to the robot performance.

TABLE I. PARAMETERS IN THE PROPOSED METHOD

(a) Parameters of the Robot			
Parameter	Symbol	Condition	Setting value for simulation
Diameter	σ	> 0	30 pixel
Maximum moving speed	V_{max}	> 0	200 pixel/s
Sampling frequency	f_s	> 0	500 Hz

(b) Parameters of the proposed method			
Parameter	Symbol	Condition	Setting value for simulation
Heat transfer rate	k	> 0	0.002
Reinforcement coefficient	P_r	> 0	Variable or 1.5
Weaken coefficient	P_w	$> 0, \leq 1$	Variable or 0.5
Coordination coefficient	P_{ope}	$> 0, \leq 1$	Variable or 0.5

Here, k is directly related to the speed of heat propagation, that is, the speed of collision avoidance. Therefore, this parameter is set based on $1/f_s$ because the set value is the rate of the speed change in the sampling interval. Moreover, P_r , P_w and P_{ope} can be arbitrarily set. Considering the normal Lennard-Jones potential in (5), it is recommended that $P_r + P_w = 2$ be satisfied.

VI. SIMULATIONS

The performance of the proposed method was verified by a collective movement simulation using swarming of two-dimensional omni-directional mobile robots. The specifications of the robot to be generated are given in the setting value column in Table 1. For the performance assessment, we evaluated the characteristics of movement parameters P_r , P_w and P_{ope} . Then, we confirmed that the swarm robot that set parameters based on the evaluation collectively moved.

A. Characterization of Collective Movement Parameters

Characteristics of parameters P_r , P_w and P_{ope} relating to the collective movement were evaluated. The evaluation method calculated the error between the barycentric coordinates of the follower swarm and the leader coordinates after the swarm robot with the leader at the swarm center moved linearly 300 pixels. If its error was close to zero, it could be determined that the swarm moved while maintaining the aggregation shape. Since this evaluation did not consider the success rate of the collective movement, it was calculated as five times the average. The number of robots was 217 units (1 leader, 216 followers), and the initial shape was an ideal hexagonal-lattice with the leader as the center of gravity.

The result for each ratio (P_r to P_w) of the 0.1 interval to satisfy $P_r + P_w = 2$ are shown in Fig. 4. From the results, there are points where the shape clearly changes in any of the setting values, and it is possible to move collectively at P_{ope} below this point. Since P_{ope} determines the moving speed of the swarm, it is directly linked to the movement efficiency. Therefore, when the difference between P_r and P_w is large, its efficiency is good. Considering the relation of P_r , P_w and P_{ope} , the upper limit of the design of P_{ope} is around the ratio to the normal time given by P_r and P_w : $(P_r - P_w)/2$. An approximate calculation can be performed when designing with consideration of the collective movement efficiency. However, it is necessary to consider that $P_r - P_w$ is 1.1–0.9 to 1.4–0.6, and 2.0–0.0 are smaller than this

relation, and 1.0–1.0, 1.5–0.5, and 1.9–0.1 are larger than this relation.

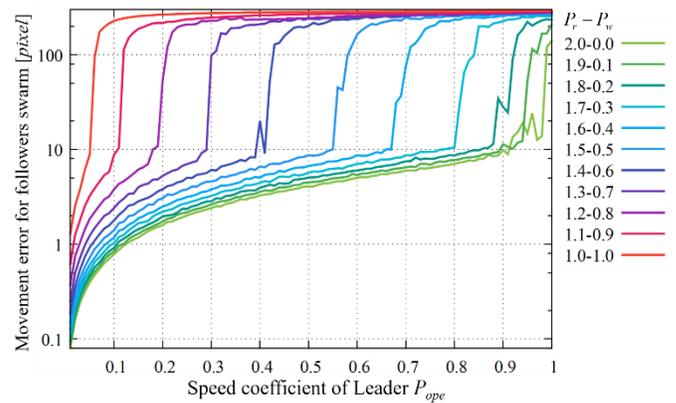


Fig. 4. Parameter characteristics in collective movement. In any ratio, the function shape changes when the error is around ten. Collective movement can be achieved in a function below this value.

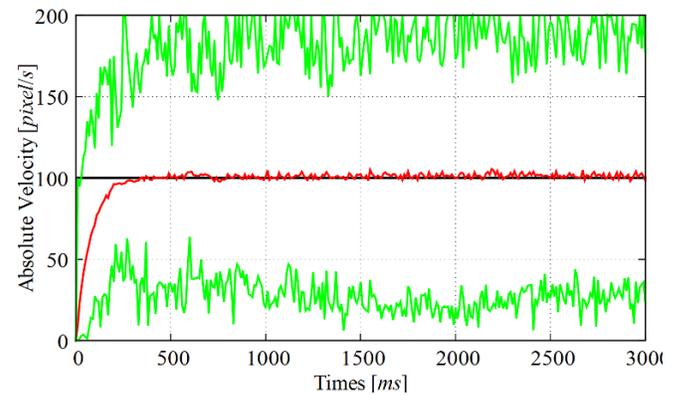


Fig. 5. Velocity chart of a leader and followers. The black line denotes the leader's velocity, which moves at 100 pixel/s; the red and green lines are the followers' average velocity and maximum/minimum velocity.

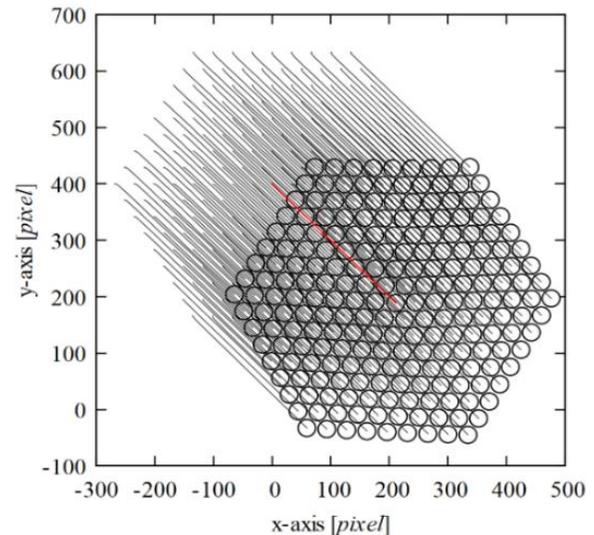


Fig. 6. Trajectory of the swarm robot applying the proposed method in an open environment. The circles are the final positions of each agent. The line extending from the circle center is the trajectory of the agent (the red line is the leader; the black line is the follower).

VII. CONCLUSION

Fig. 5 and 6 show the velocity and coordinates when P_r , P_w is set to 1.5, 0.5, which is the median value of the parameter setting range, and P_{ope} is set to 0.5 as a state of collective mobility. In Fig. 5, because the followers change velocity independently of the leader's velocity, there is always a large error. Nevertheless, the average value converges to the leader's velocity. Additionally, because the trajectory is similar between the leader and followers in Fig. 6, the collective movement maintaining the shape is achieved.

B. Collective Movement in an Environment with Obstacles

In the previous experiment, we confirmed the state of the collective movement using the median of the parameters. Here, we compare the "synthetic" collective movement by the proposed method. The proposed method enables movement while maintaining the aggregation shape in an open environment, and it enables movement of the aggregation by changing the shape in an environment with obstacles. To verify these functions, the swarm robot collectively moved in the environment shown in Fig. 7(a), and the latter state was observed (the former state was already observed in the previous experiment).

The results of Figs. 7(a) and (b) show that a part of the swarm that detected the obstacle (that is, the thermal energy increased), moved to the rear of the aggregation and achieved collision avoidance. Next, the results in Figs. 7(c) to (d) show that the agent avoiding obstacle re-aggregated, formed a hexagonal-lattice, and moved.

From the results of the previous experiment and this experiment, the proposed method achieved collective movement with both solidity and flexibility. However, when avoiding obstacles, some agents collided with other agents and/or obstacles. This is because the upper limit of the proposed model depends on the maximum moving speed of the agent; there is not sufficient motion to handle it. Therefore, this problem must be solved by virtually enlarging the agent's diameter.

In this paper, we proposed a swarm-robot collective movement method that does not require global information based on a thermodynamic model. The proposed method enables collective movement of a swarm in both a clear environment and one with obstacles by operating an agent. The method is expressed by a local mathematical model conveying solidity and flexibility. It focuses on the internal energy, which is the micro-operation of thermodynamics. These solidity and flexibility properties enable realization of swarm-robot collective movement while maintaining a formation and changing an aggregation shape corresponding to obstacles. In addition, the swarm can collectively move by moving one unit (leader) controlled by the operator.

Simulation results showed that the proposed method moved the whole swarm robot while maintaining the aggregation shape in an open environment, and it flexibly changed the shape in an environment with obstacles. It was determined that the collective movement efficiency of the method can be adjusted by the ratio of the potential model required for the collective movement. Thus, the method is expected to be applicable to searching unfamiliar environments. In the future, consideration of remote operation, environmental condition recognition, and other attributes is needed to complete this application system.

Limitations exist, however. Agents collided with other agents and/or obstacles in an environment with obstacles. Because the proposed method was limited to the robot's maximum velocity, it thus did not ideally work. This problem must be solved before actual machine experiments. One solution may be to virtually expand the agent diameter. Furthermore, this study did not examine parameters and functions for thermal motion, and the operation of the shape changing is unconfirmed. These aspects will be addressed in future work.

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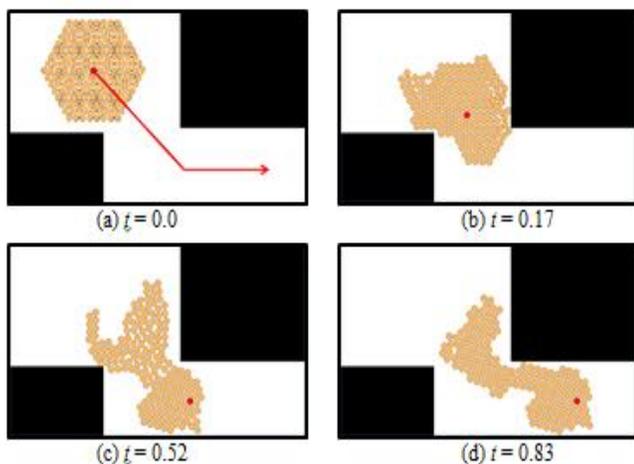


Fig. 7. Time series variation of environment with collective movement. t is the elapsed time. Red circle and yellow circles are the leader and followers, and black rectangles are obstacles. The leader moves along the red arrow while following the followers.

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Optimization and Simulation Approach for Empty Containers Handling

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Abstract—Container handling problems at the container terminals are NP-hard problems. In this paper, we propose a new handling operation's design and simulation of empty containers, taking into account the interrelated activities at the container terminal. This simulation have been built using a doubled trailer. It moves containers from quayside to yard side or the opposite depending on the flow in container terminal, and it is used to optimize the cycle time and to improve the efficiency of the other equipment. Our interest is to test this new model first for empty containers. The proposed model is applied on a real case study data of the container terminal at Tanger Med port. This new design was developed using Arena software and verifying the strength of materials constraint for the loaded containers. The computational results show the effectiveness of the proposed model, where the cycle time of the port equipment have been reduced by -58%, and the efficiency has been increased where +47% of the moves in container terminal was achieved.

Keywords—Container terminal; design; doubled trailer; simulation; arena; strength of materials; quay

I. INTRODUCTION

Port container terminals are an important and crucial link between several intermodal transport modes. The important increase of containers volume handled at the container terminal (CT) was the root cause of the diversification of technologies and equipment used to facilitate the internal transition inside the CT. The majority of the ports are adapted to this new mode of transport by creating dedicated terminals in charge of loading and unloading container vessels as well as the storage and transfer of containers to trains or external trucks. Thus, the competition between container terminals become more and more important, and the CT authorities are obliged to improve the quality of their services to meet the needs and targets of their customers. The major concern of a CT is to provide more container handling capacity and improve the efficiency of its equipment.

A CT is a temporary storage space, where vessels berth in port terminal to unload inbound containers during the import operations and pick up outbound containers during the export operations, otherwise move containers from one vessel to another in case of transshipment. The concept of using containers has been standardized worldwide, an ISO standardized metal box is used to transport goods between continent, the most famous ones are: TEU, 40feet and 45feet (TEU: 20 feet equivalent units). They can be stacked then on top of each other following a 'last-in, first-out' (LIFO)

strategy. Once the containers are transferred from the seaside to the yard side via internal vehicles, the yard crane will store them in a specific location based on certain criteria: destination, estimated departure time, weight and size. The below Fig. 1, shows the complete process and the equipment used in CT: quay cranes to unload inbound and pick up outbound containers, internal trucks to transfer containers between quay side and yard side, yard cranes to store and drop containers from the yard blocks, and finally external truck (XT) for customer delivery (gate) Razouk, Benadada and Boukachour (2016) [1].

Inbound containers are unloaded from the vessel using the last in first out strategy (LIFO), then some containers can be stored in the yard blocks at the bottom of the stack, in order to search them some unproductive movement are needed. The containers received in inbound process may contain goods or can be empty, which is our focus on this paper. Due to lack of accurate information, containers can be stacked in the wrong order. This reduces the productivity of the cranes and creates additional tasks (reshuffles) with no added value. Therefore, the transfer and the handling of containers become the first bottleneck in the port operations process. According to Stahlbok and Voss (2008) [3], the existing activities in a container terminal can take place in two main areas: the quayside and the yard side. Several literature researches are dealing with quayside, see below Fig. 2.

There are three main decision levels in container terminal problems: 1) Strategic decisions are long-term decisions that include the structure of the terminal, handling equipment and handling procedures. 2) Tactical decisions are medium-term decisions that are interested in determining the number of quay cranes, yard cranes, straddles, etc. 3) Operational decisions are short-term decisions and include the process to be followed by the quay cranes, the yard cranes, straddles, etc.

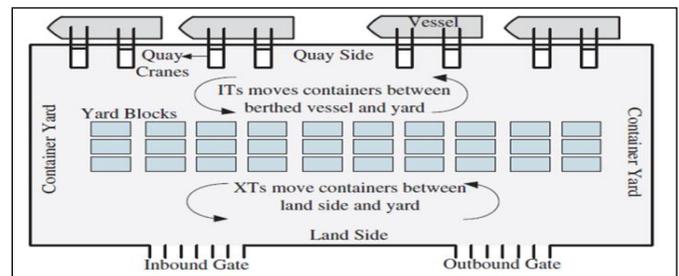


Fig. 1. Main area of container terminal [2].

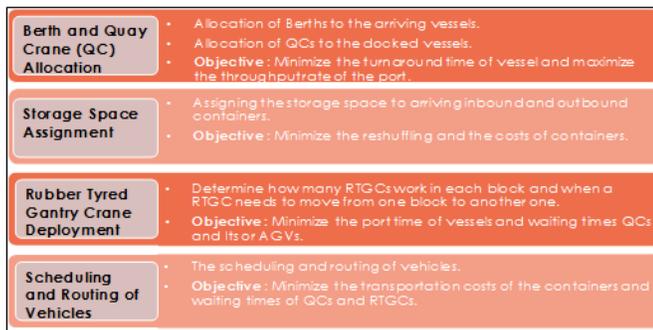


Fig. 2. Decision problems in container terminal [4].

As the port of our study is already built, and the equipment already known, we will try to focus in this paper on the operational operations. Our main objective is to optimize the related cost: minimize the cycle time of quay cranes (QC), improve the efficiency of the internal trucks and the empty handler (EH) equipment and increase the number of moves per hour. For inbound and outbound empty containers, we study the impact of the current single trailer on the cycle time of the other equipment such as QC and EH. Then we measure and simulate the new cycle time result of using doubled trailer to transfer empty containers, the other type of containers will be treated in future works. The impact of our new model is well seen, where we optimizes the operation time by 54% and increase the number of moves by 48%.

II. LITERATURE REVIEW

In this paper, we focus on the assignment of empty containers to the allocated space in the yard, the transfer between the quay and the yard side simulated with doubled trailer, and we measure later the impact on the cycle time and the efficiency of the other equipment used. Each yard area has a specific level to store empty containers; the stored empty containers on the last tier of the stacks must leave earlier to avoid unproductive movements (reshuffles, housekeeping). Thus, the objective is to place the received empty containers in an increasing order according to their departure time and their destinations Razouk, Benadada and Boukachour (2016) [5], and to reduce the number of the reshuffles by eliminating the housekeeping in the yard blocks (moves ~ 0) and to improve the efficiency and cycle time of the port equipment.

A. Assignment of Group of Containers

The main idea of the related research is to propose methods to assign groups of containers to storage locations, based on the vessel destination, departure time, and type of containers. A Simulated Annealing based heuristic for this problem is proposed by Huang and Ren (2011) [6] that require enumerating all possible assignment permutations for the three container groups of import containers, result is not compared with existing storage policies and didn't include the simulation approach. Jeong et al. (2012) [7] define a method to decide how many import containers will be stored in each block, the consigned strategy take into account only the destination of containers characteristics are not considered (e.g. case of empty containers). Nishimura et al. (2009) [8] propose a new MIP, and they use a new heuristic to minimize the weighted total container handling time. No additional constraint for the

destination type or the type of the stored containers is considered. Razouk, Benadada and Boukachour (2015) [9] proposes a new formulation of the yard optimization problem and they used the consignment approach to assign containers, they used simple trailer but they did not treat the empty containers management. Therefore, our aim is to define specific formulation for empty containers and to use the consignment approach to assign them to the allocated space in the yard.

B. Optimization and Simulation of the Yard Blocks

Said and El-Horbaty (2015) [10] presents an approach using discrete-event simulation modeling to optimize solution for storage space allocation problem they didn't present any specific case for the empty containers nor include the different container characteristics they focused their work on the various interrelated container terminal handling activities. Kotachi et al. (2013) [11] presents a generic discrete-event simulation that models port operations with different resource types including rubber tyred gantry cranes (RTG), quay cranes, trucks, arriving and departing ships they didn't include in their simulation approach the type of trailer used nor the container characteristics.

A container yard used as a buffer for transshipment, discharging and loading containers, and is divided into blocks and bays. The yard optimization problem (YOP) defines the assignment of storage area (sub-blocks) to import and export containers at the containers terminal, the aim of YOP is to obtain a better space utilization of the yard, maximizing the throughput of the terminal and minimizing vessels handling time.

Several methods have been applied to solve the YOP separately without taking into account the different containers terminal activities. In our paper, we use the result of the resolution method of our mathematical model (optimization) as an input of our simulation model. Thus we proposes a new model using optimization-simulation modeling to optimize solution for the YOP, taking into account all interrelated containers terminal management activities. The proposed approach is applied to a real case study data of container terminal at Tanger Med port.

III. EMPTY CONTAINER MANAGEMENT PROCESS

In this paper, we assume that berth of the vessels and the assignment of the quay cranes is performed. Therefore, we start our analysis from the discharge of containers from the vessel by the quay cranes case of import, or after the pick-up of containers from the Automated Terminal Trailer (Att) to be loaded in the vessel later on.

A. Transfer Zone

Horizontal transport used to move containers between functional areas. Att is used to transfer containers between quay and yard side, but they are not capable of handling containers inside those areas. Therefore, the yard cranes (YC) start later on the loading and unloading operations once the container arrives to the yard area. This requires a good synchronization between the Att and the YC to avoid wasting time and creating unproductive movements.

The simplified process for unloading:

- 1) ATT are waiting under the QC at the quayside
- 2) The QC affect the container to the first ATT in the queue
- 3) The ATT transfer the container to the assigned position
- 4) The YC already exists on the associated Block on the Yard waiting for the container or treating another one
- 5) The ATT arrives
- 6) The YC handles the container and puts it in its assigned position on the Yard (bay, block)
- 7) The empty ATT comes back to the dock

The simplified process for loading will be the inverse of the previous process, which means that we will start by the reaching the container from the yard side and send it by the ATT to the quayside to be loaded in the assigned vessels. As already mentioned we will focus on the empty containers, so the process is more or less the same as the loaded containers, the only difference is that the empty containers will be handled in a separated area using the Empty handler instead of the yard cranes.

B. Yard Area : Yard Cranes (RTG : Rubber Tyred Gantry) and Empty Handlers (EH)

At the port where we did our study the yard, is divided into 5 columns from 1 to 5 and 12 rows from A (Alpha) to M (Mike) which gives a total of 59 rectangular Blocks. These Blocks are divided into bays, each bay may contain a maximum of five containers stacked in a vertical way.

Therefore, each container position is defined by five parameters: block, row, column, bay and level. In addition to this - and for safety reasons - the Yard contains a predetermined flow direction for equipment, to manage the flow of traffic according to the management rules (Fig. 3). This Yard is segregated according to a Yard strategy. In order to facilitate the operations, the containers of the same service and same nature (empty, full, refrigerated, dangerous) are stored together.

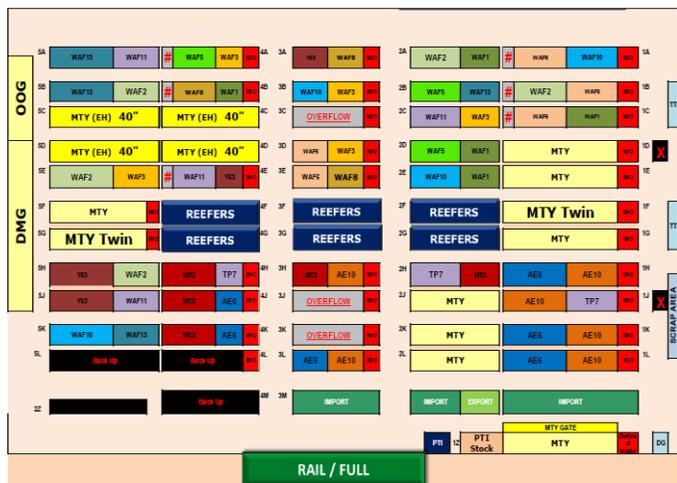


Fig. 3. Yard strategy of our port of study [12].

We creates a specific zone for the empty containers at the right of this figures where empty containers will be stored and handled by the EH. For the empty containers the maximum

level per yard bay is three instead of five for full containers. The reason behind is that the form of RTG offers a considerable advantage, it can easily move on the yard above the blocks to pick or drop off containers from the yard bay.

C. Our Case of Study

In our simulation, we will not consider the vessel allocation process nor the assignment of equipment. Since our scope is already defined: the vessel is already in the quay. A quay crane, five ATT and an Empty Handler, handles the containers. We will focus only on the loading and unloading processes of the containers, because our aim is to show the impact of proposing doubled ATT, during these operations, on the cycle time of the QC and to the productivity of EH.

The first empty container 40 is unloaded and transferred to the stack inside the storage area of the CT. If the EH is available, the container is transferred and the container inventory in the stack is adjusted. If not, the container is placed in the queue. The below figures shows in detail the unloading process of the empty containers. The process of loading will be the inverse of the presented process. MTY is the storage space assigned to the empty containers; we have one EH assigned to the MTY space (Fig. 4).

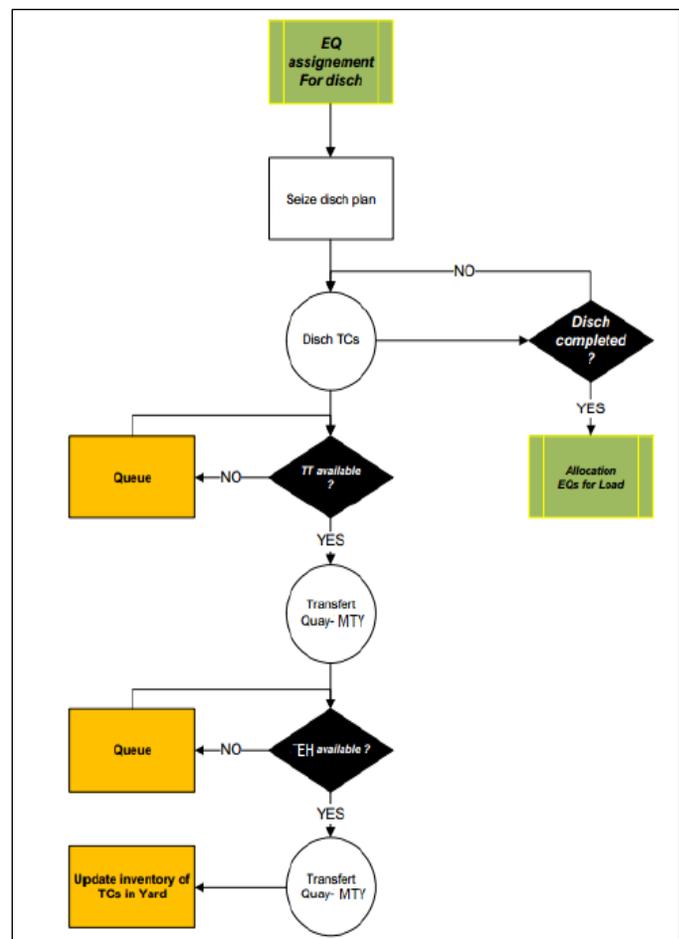


Fig. 4. Unloading process for the empty containers [13].

A deep analysis of the detailed cycle time per operation is presented below; we measure the Overall Equipment

Effectiveness (OEE) of the ATT (Fig. 5). GMPH is defined as a ratio between the total moves of containers and the working hours of the QC. We can see that the ATT lost most time at the quay and yard side in queue waiting for containers, or waiting for containers to be unloaded or loaded depending on the process.

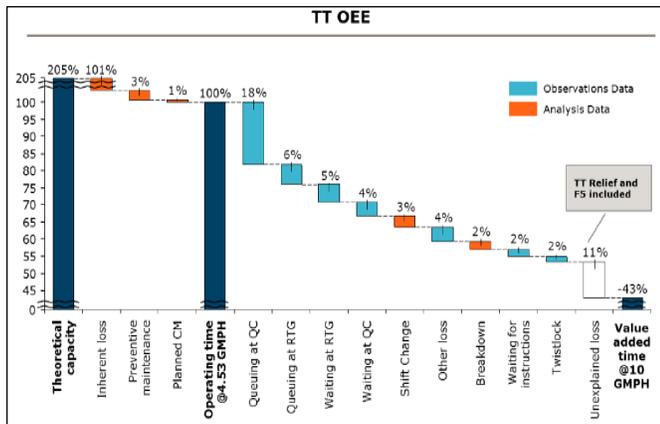


Fig. 5. Overall equipment effectiveness of ATT.

To simulate a random phenomenon such as the cycle times of a machine, statistic distribution laws must be used, the values generated by these laws must be close to the maximum values taken during the actual operation of the system. Our conclusion is that the design of the new ATT will optimize the queue time at the quay and yard side, and will improve the volume of the transferred containers. We present in our simulation the number of moves per hour using the doubled ATT.

IV. MATHEMATICAL FORMULATION

A. Proposed Model

We will use the model already presented by Razouk, Benadada and Boukachour (2016) [14] to build a model that is adapted to the empty containers handling and we adapt it to our case of study. In other words, the objective is to optimize the profit which corresponds to the productivity of the EH and minimize the cycle time of quay cranes and increase the container moves by using doubled ATT. The type r of containers in our model is set to 40 feet containers; we keep the model, as is it to generalize it for other type of empty containers later on.

$$\text{Max} \sum_{k=1}^N \sum_{b=1}^B \sum_{r=1}^R \sum_{e=1}^E C_k^b X_{bk}^{re}$$

The current model is a multi-objective model, which subscribe the profit maximization related to our case of study. The cost C_k^b is a composition of the below sub-objective:

- Min QC(CT): Defines the minimization of the current cycle time of the quay crane measured.
- Min ATT(CT): Defines the minimization of the current cycle time of the ATT measured. This cycle time includes the waiting time and the queue time at the QC & EH. The transfer time is not taken into account as we

assume that the sample and doubled ATT will have the same technical characteristics.

- Min EH(CT): Defines the minimization of the current cycle time of the EH measured.
- Max ATT(K): Defines the maximization of the number of containers transferred by the ATT.

This objective function is subject to the below constraints:

$$\sum_{k=1}^N \sum_{r=1}^R \sum_{e=1}^E X_{bk}^{re} \leq C_b ; b \in \{1, \dots, B\} \quad (1)$$

$$\sum_{b=1}^B \sum_{r=1}^R \sum_{e=1}^E X_{bk}^{re} = 1 ; k \in \{1, \dots, N\} \quad (2)$$

$$\sum_{k=1}^N \sum_{r=1}^R \sum_{e=1}^E (R_k - r_b) X_{bk}^{re} = 0 ; b \in \{1, \dots, B\} \quad (3)$$

$$\sum_{k=1}^N X_{bk}^{re} = 1 ; b \in \{1, \dots, B\}, r \in \{1, \dots, R\}, e \in \{1, \dots, E\} \quad (4)$$

$$(t_k - t_k') (X_{bk}^{re} - \sum_{e=e'+1}^E X_{bk}^{re}) \leq 0, b \in \{1, B\}, \forall r, \forall e, k \neq k' \quad (5)$$

$$\sum_{k=1}^N X_{bk}^{re} \geq \sum_{k'=1}^N X_{bk'}^{re+1} ; b \in \{1, \dots, B\}, r \in \{r, \dots, R\}, e \in \{1, \dots, E\} \quad (6)$$

$$\sum_{k=1}^N \sum_{b=1}^B A_b \leq C_A ; \forall A ; \forall T \quad (7)$$

$$X_{bk}^{re} \in (0, 1) \quad (8)$$

In the constraint (1) we define a total free positions per each yard bay, so the total number of the assigned empty containers must not exceed the numbers of free positions (this number is known at the beginning of the planning horizon). Constraint (2) ensures that each container is stored in a unique position during the planning horizon. Constraint (3) ensures that the size of the bay and the stored container is the same in each planning horizon. As we are only considering the 40 feet empty containers, this constraint will have more sense when we will includes the other type of containers. It will be used to define a clustering of the available containers, based on their size and type, and then we can allocate in the storage area a specific space to those containers (consignment strategy). Each free position in the storage space can have only one container stored at a time; this is what the constraint (4) represents. The estimated departure time is also known for each inbound and outbound container, we will consider it during the containers storage in the stacking area (5). The constraint (6) avoids empty positions between the stored containers. Constraint (7) is to ensure that the assigned containers to the ATT don't exceed the allowed capacity.

B. Input Data

Our port of study "Tanger Med Port" offers 800 meters of quay length with a depth of 18 meters for 450 meters and 16 meters for the remaining 350 meters, 40 hectares of land and it has own direct access by highway. The terminal equipment have 8 quay cranes, 26 RTG, 5 Empty Handler, and 55 trucks. The data used in this study was obtained from Tanger Med Terminal Port. The yards name, type of storage yards at Tanger Med container terminal are presented in Fig. 3. Capacity of storage yards = 1.800.000 (TEUs) (twenty-foot equivalent unit).

The terminal operators received the EDI file before the final arrival of the vessel, which contains the ship name & ID,

ship length, stowage plan, and number of containers to be unloaded & loaded, operation type (unload/load/transshipment), size and type of containers, operation time (start/end), expected arrival time, berthing, and departure from port, destinations ports.

In this study, we use the version 14 of the ARENA simulator, which allows a smooth development of the model, and an easy access to the different modules as well as a great flexibility for external data. In addition, multitudes of statistical distributions are available to represent as much as possible the variability of the modeled phenomenon. The problems being studied are stochastic, dynamic and discrete, using the input analyzer, which use the historical data as input, the average square error and the Kolmogorov-Smirnov test as parameters. The result of this test is a value between one and zero for a parameter p which makes it possible to test the null hypothesis (H_0), which states that two distributions laws comes from the same random distribution function, a value of p less than 0.05 indicates a poor correlation between the data and the distribution law. While a value greater than 0.10 shows good correspondence between the two data series and validates H_0 [15].

V. COMPUTATIONAL RESULTS

As already mentioned, the result of our mathematical model for which we use Cplex as solving method, will be used as input to our simulation model.

The operational data models are based on a real case study data of container terminal at Tangerang port, for one-week operation from the first until December 7, 2016. This data represents a 16 vessels arrival with containers of different sizes (20, 40 & 45) and different types (full, empty, reefers) and either local or transshipped container. Implementation of the model was run with i5 CPU 2.4 GHZ, 8.0 GB RAM, Windows 10.

The above result have been obtained using the new proposed ATT which verifies the strength of materials constraints and which can transfer from two to four containers at the same time (Fig. 8), if we attach two trailer to the same truck. The structure of this doubled ATT is defined below.

C. Interpretation of the Obtained Results

In Table 1, the total number of the handled containers either for inbound or outbound or transshipment from different types and destinations expressed as global teus. The restow via yard column define the number of moves needed to redesign the storage area in order to put the containers in the right order to avoid unproductive moves. In the next column, we have the number of moves needed to unload, load and balance a specific vessel. The last two column contains the operation time per vessel either using the current model, or using the new model, which use the doubled ATT. We can see that the operation time have been optimized in the second model, which gives the opportunity to treat vessels on time and increase the number of moves related to other port operations.

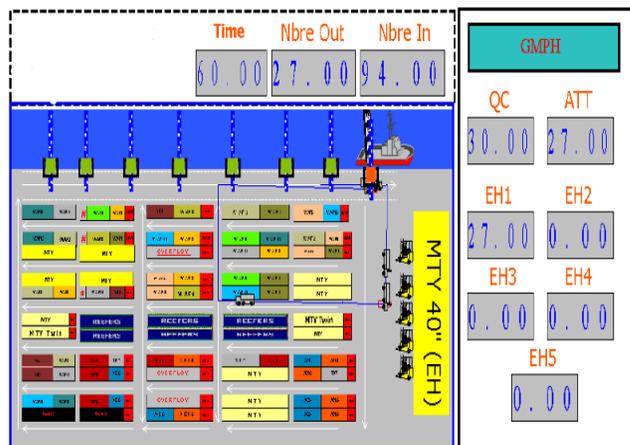


Fig. 6. Screenshot from container terminal from Arena: Actual Model.

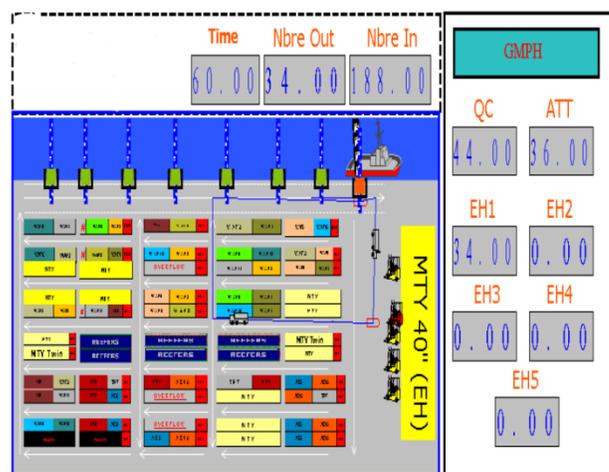


Fig. 7. Screenshot from container terminal from Arena: New Model.



Fig. 8. Structure of the new ATT.

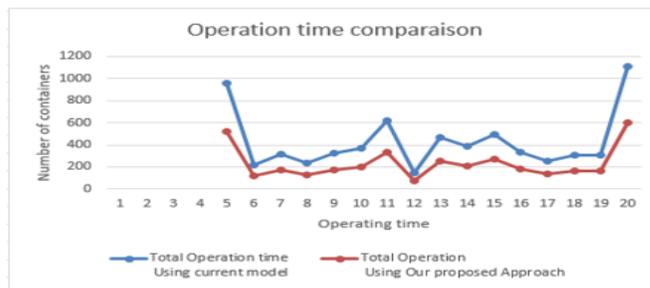


Fig. 9. Handling time comparison: old and new model.

TABLE I. CONTAINER TERMINAL ACTUAL OPERATION VS OPERATION WITH THE PROPOSED MODEL

SQ.	Date	Service	Discharge															Load															Restow Via Yard			Teus	Total Moves	Total Operation time Using current model	Total Operation Using Our Approach	
			Empty			Full									Empty			Full																						
			20'	40'	45'	Local			Transshipment						20'	40'	45'	Local			Transshipment																			
						DC	RF	DC	RF	DC	RF	DC	RF	DC				RF	DC	RF	DC	RF	DC	RF	DC	RF														
1	1/12/16 11:16	AE10	0	2	0	7	0	25	1	0	382	4	331	116	0	23	158	0	933	1742	0	0	0	1	0	596	1	237	16	0	2	18	20	7282	4615	960	518			
2	1/12/16 17:12	WAF2	206	411	0	0	0	0	0	0	143	0	30	0	0	0	0	0	0	0	0	0	0	1	0	244	0	175	58	0	0	36	0	2015	1304	220	118			
3	2/12/16 5:49	WAF5	345	279	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	39	0	89	61	0	0	0	0	1244	814	315	170			
4	2/12/16 7:48	WAF3	407	1	0	0	0	1	0	0	98	0	98	0	0	0	0	0	0	0	0	0	0	0	0	49	0	21	5	0	2	14	0	836	696	234	126			
5	2/12/16 10:39	WAF7	265	238	0	0	0	0	0	0	69	0	1	2	0	0	0	0	0	0	0	0	1	0	0	225	2	123	18	0	0	0	0	1326	944	325	175			
6	2/12/16 21:34	TP7	0	0	0	70	0	55	0	3	478	0	409	7	29	0	0	0	0	0	0	0	0	0	0	1	0	25	1	0	4	0	2	1615	1084	367	198			
7	3/12/16 12:39	ME2	0	131	0	35	0	49	1	0	657	4	537	11	0	14	1	0	112	184	0	7	1	23	1	0	182	1	154	199	0	0	6	0	3607	2310	620	334		
8	3/12/16 18:00	WAF6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	171	0	309	4	0	0	0	0	799	495	142	76			
9	4/12/16 8:20	AEB	0	0	0	1	0	5	0	0	465	8	540	22	1	0	0	0	0	0	0	0	0	0	0	241	0	102	0	0	4	74	2	2607	1663	467	252			
10	4/12/16 21:11	WAF13	9	419	0	20	0	14	2	0	122	1	53	2	0	0	0	0	0	0	0	0	0	0	0	262	2	244	90	0	4	0	0	2072	1244	387	208			
11	5/12/16 13:32	WAF1	585	349	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	312	1	284	88	8	2	4	0	2374	1641	498	268			
12	5/12/16 15:45	WAF9	73	141	0	0	0	1	0	0	231	0	35	10	0	0	18	9	218	370	6	0	0	0	0	0	0	0	0	0	0	0	0	8	12	0	1734	1132	332	179
13	5/12/16 21:00	TP7	0	0	0	0	0	0	0	0	23	0	44	77	0	0	0	6	41	445	0	0	0	3	0	4	0	30	148	0	2	34	0	1644	857	256	138			
14	6/12/16 12:47	Y63	0	0	0	23	0	0	0	0	286	0	140	2	0	0	0	0	0	80	0	0	0	0	200	1	299	9	19	0	0	0	1608	1059	309	166				
15	7/12/16 14:49	WAF13	1	406	0	0	0	0	0	0	106	2	4	21	0	0	0	0	0	0	0	0	0	0	0	187	3	244	40	0	22	4	0	1759	1040	307	165			
16	7/12/16 19:24	AE10	0	0	0	3	0	13	0	0	283	2	226	205	0	8	8	0	1543	1409	0	0	0	5	0	0	548	1	122	10	0	18	384	88	7346	4876	1108	598		
																																			39868	25764	6847	3689		

The measured GMBH from the next figures has been improved between the classical model and the new model of ATT. This could be achieved thanks to the decrease and optimization of the operation time. The increase of the number of moves per hour indicated in the (Fig. 6) shows that the total number of inbound containers and outbound containers has been increased also (Fig. 7) using Arena software [15]. The cycle time of the EH and QC has been improved which demonstrates well the effectiveness of the proposed model, that optimizes the operation time by 54% and increase the number of moves by 48% (Fig. 9).

VI. CONCLUSION AND FUTURE WORK

In this paper, we present a new concept of optimization and simulation of the yard optimization problem in container terminal using simulation approach for empty containers, taking into account other interrelated port terminals management activities. The collected data comes from a real case study from Tanger Med Port. Obtained results prove the effectiveness of our model in container terminal where we optimize the operation time by 54% and increase the number of moves by 48%.

In the future works, we will generalize this model for other type of containers, and we will study the impact on the port terminal activities, the optimization technique will be combined to the simulation technique to provide accurate values for the resolution of the mathematical model.

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Traffic Signs Recognition using HP and HOG Descriptors Combined to MLP and SVM Classifiers

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Abstract—Detection and recognition of traffic signs in a video streams consist of two steps: the detection of signs in the road scene and the recognition of their type. We usually evaluate globally this process. This evaluated approach unfortunately does not allow to finely analyze the performance of each step. It is difficult to know what step needs to be improved to obtain a more efficient system. Our previous work focused on a real-time detection of road signs, by improving the performances of the detection step in real time. In this paper, we complete the work by focusing on recognition step, where we compare the performances between histogram projection (HP) descriptor, and the histogram-oriented gradient (HOG) descriptor combined with the Multi-Layer Perceptron (MLP) classifier, and the Support Vector Machine (SVM) classifier, to compute characteristics and descriptors of the objects extracted in the step of detection, and identify the kind of traffic signs. Experimental results present the performances of the four combinations of these methods “Descriptor-Classifer” to identify which of them could have high performance for traffic sign recognition.

Keywords—Traffic signs detection and recognition; Histogram of oriented gradient (HOG); Support Vector Machine (SVM); Histogram projection (HP); Multi-layer perceptron (MLP)

I. INTRODUCTION

As an important road safety facility, traffic signs allow to regulate road traffic, by indicating the conditions of the road, guiding the pedestrians, driving safely, etc. Therefore, research issue on traffic sign real time detection and recognition is very important for driving assistance. In recent years, traffic sign recognition becomes an important research direction due to the rapid development of intelligent transportation system. Generally, works in this issue like [4]-[6] adopt a two-step approach, a detection step and a recognition step. These works evaluate globally the process; this unfortunately does not allow analyzing the performance of each step separately.

Our objective is to analyze each step separately, to stop on its weaknesses and propose solutions to correct and improve the performance of each one, and subsequently improve the performance of the overall system.

In our works [1]-[3], we focused on the step of detection of traffic signs, by evaluating their performances on a set of images of traffic scene (offline mode), and in real-time by using a camera (online mode). In this paper we continue the work by focusing on the step recognition of the traffic signs to evaluate and improve its performances.

The work presented in this paper, focuses on recognition step, where we design and implement an efficient method to identify traffic signs. We compare the performances between histogram projection descriptor, and the histogram-oriented gradient descriptor combined with Multi-Layer Perceptron (MLP) classifier, and the Support Vector Machine (SVM) classifier, to compute characteristics and descriptors of the objects extracted in the step of detection, and identify the kind of traffic signs. Experimental results present the performances of the four combinations of these methods “Descriptor-Classifer” to identify which of them could be more efficient for traffic sign recognition.

II. HISTOGRAM PROJECTION TECHNIC AND HISTOGRAM-ORIENTED GRADIENT TECHNIC

A. Histogram Projection (HP)

Blobs which are extracted by the traffic signs detection system (TSDS) [3] are color images with 64x64 pixel size, and for the three layers R, G and B we will get 12288 pixels, this great amount of data will delay the recognition system if we use it as an input vector for the classifier. To reduce the amount of data processed by the classifier, we apply a simple smoothing on the blobs, by using the Gaussian filter, the use histogram projection (HP) technic [2] for each color channel, for both vertical and horizontal.

So, points CX_i on the horizontal axis are computed by:

$$CX_i = \frac{1}{255} * \frac{1}{64} \sum_{j=1}^{64} C_{i,j} \quad i = 1,2, \dots, 4 \quad (1)$$

Moreover, points CY_j on the vertical axis are computed by:

$$CY_j = \frac{1}{255} * \frac{1}{64} \sum_{i=1}^{64} C_{i,j} \quad j = 1,2, \dots, 4 \quad (2)$$

$C_{i,j}$ is the intensity of the pixel (i, j) in the layer C.

C is the red layer R, green layer G or blue layer B,

CX_i and CY_j values are between 0 and 1.

The new input vector has 384 normalized elements, the 64 elements of CX_i and 64 others of CY_j for the three layers RGB. This is 32 times lower than the amount of initial data.

B. Histogram Oriented Gradient (HOG) Technic

The original HOG technic introduced in 2005 [7], as a feature descriptor of image. The idea of HOG is based on gradient direction; it consists in calculating the histogram of

oriented gradient in local area of blob extracted from the detection step.

The algorithm steps are shown as follows:

Image preprocessing: firstly, converting the extracted color blobs into gray, then using the Gamma correction for normalization, reducing the illumination influence, and suppressing noise.

Gradient calculation: calculating the gradient of image in horizontal and vertical direction of blobs using Sobel edge operator. The formula for the calculation is:

$$G_x(x, y) = H(x + 1, y) - H(x - 1, y) \quad (3)$$

$$G_y(x, y) = H(x, y + 1) - H(x, y - 1) \quad (4)$$

Where $H(x, y)$ is value of the pixel,

$G_x(x, y)$, $G_y(x, y)$ are respectively gradients at the vertical and horizontal direction of pixel (x, y) .

Therefore, gradient magnitude $G(x, y)$ and gradient direction $a(x, y)$ of pixel (x, y) formulas are cited below:

$$G(x, y) = \sqrt{G_x^2(x, y) + G_y^2(x, y)} \quad (5)$$

$$a(x, y) = \tan^{-1} \left(\frac{G_y(x, y)}{G_x(x, y)} \right) \quad (6)$$

HOG does not need to extract the feature of the whole picture. We can divide the image into great number of cells, and then calculate the gradient or edge direction histogram of each pixel in all cells. Meanwhile, we could take several cells to form a block in order to increase the performance of the algorithm. To obtain the feature of gradient direction, several blocks could be taken to compose a connected graph, then we normalize the gradient of each cell in these blocks.

III. MLP AND SVM CLASSIFIERS

A. MLP Classifier

Multi-Layer Perceptron (MLP) is the most used type of Artificial neural networks (ANN) [9], these are the biologically inspired simulations implemented on the computer in order to perform certain specific tasks like, classification, pattern recognition etc. ANNs are often used in machine learning. It was introduced in the 1940s and it was abandoned because of the inefficient training algorithms used and the lack of computing power. Recently, with the development of computers, especially the computing power, and the storage capacity, they have started to be used again, and several technics are developed to improve the ANNs performances

The MLP includes at least three layers. One input layer; one or more hidden layers and one output layer. Each layer contains one or more neurons directionally linked with the neurons from the previous and the next layer. Fig. 1 represents an example of a 3-layer perceptron with three inputs, two outputs, and the hidden layer including four neurons.

All the neurons in MLP are similar. Each of them takes the output values from several neurons in the previous layer as input and passes his response to several neurons in the next layer.

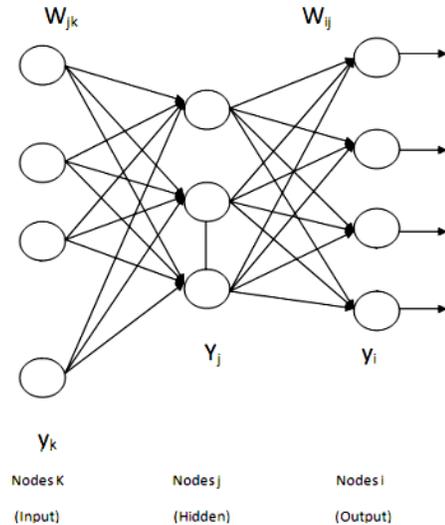


Fig. 1. Typical architecture of a MLP neural network.

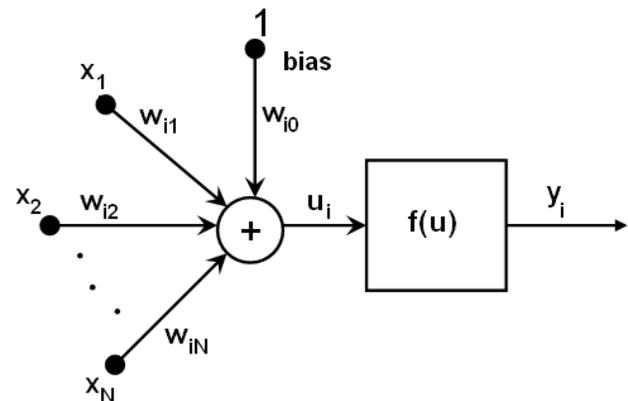


Fig. 2. Computing process in a neuron.

In each neuron the values, retrieved from the previous layer, are summed up with certain weights plus the bias term. The sum is transformed using the activation function f that may be also different for different neurons (Fig. 2). In other words, given the outputs x_j of the layer n , the outputs y_i of the layer $n+1$ are computed as:

$$u_i = \sum_j (w_{i,j}^{n+1} * x_j) + w_{i,bias}^{n+1} \quad (7)$$

$$y_j = f(u_i) \quad (8)$$

The activation function that used in this paper is binary sigmoid function, which is defined as:

$$f(x) = \beta * \frac{1 - e^{-\alpha x}}{1 + e^{-\alpha x}} \quad (9)$$

MLP learns iteratively by adjusting its weights and bias to yield desired output. Several learning algorithms are developed for this task, the most common of them are the gradient descent and the back-propagation, they use a gradient search technique to minimize the mean square error (MSE) between the actual and the desired net outputs.

$$MSE = \frac{1}{l} \sum_{j=1}^N (y_j - \hat{y}_j)^2 \quad (10)$$

Initially a small random weights and internal thresholds are selected for training the MLP. All training data are repeatedly given to the net that adjust their weights after every trial using Information distinguishing the right class until weights converges and the (MSE) is reduced to an acceptable minimal value.

B. SVM Classifier

SVM initially introduced by Cortes and Vapnik in [8], are conceived to solve the binary classification problems. For a given training sample set S , with n data training samples. For x_i the feature vector of training samples and y_i the label of training samples, where $y_i = 1$ and $y_i = -1$, determine the two types of training samples:

$$S = \{(x_i, y_i) | x_i \in R_d, y_i \in \{-1, 1\}\}_{i=1}^n \quad (11)$$

Finding an optimal hyperplane $h(x)$, is the basic idea of SVM, this hyperplane should separate two classes of labels of training data, and should be as far as possible from the members of the both classes. Data can be linearly separable in this case. The format of the hyperplane function is as follows:

$$h(x) = sgn(w \cdot x + b) \quad (12)$$

- w is the normal to the hyperplane,
- x is the input vector,
- b is the deviation.

when data cannot be separated by a linear function, the solution is to map the input vector x into a high dimensional space $\varphi(x)$, if there is a “kernel function” satisfied $K(x_i, x_j) = \langle \varphi(x_i), \varphi(x_j) \rangle$, we can calculate only the kernel function $K(x_i, x_j)$ instead to compute $\varphi(x_i)$. The most used kernel functions in SVM are the polynomial, the radial and the sigmoid kernel functions whose formulas are shown as follows:

- Polynomial kernel function:

$$K(x_i, x_j) = [\gamma(x_i, x_j) + bias]^t$$

- Radial basis kernel function:

$$K(x_i, x_j) = \exp(-\gamma \|x_i - x_j\|^2)$$

- Sigmoid kernel:

$$K(x_i, x_j) = \tanh(\gamma(x_i, x_j) + bias)$$

- γ is the width of the kernel function,
- $bias$ is the bias coefficient,
- t is the order of polynomial.
- x is the given input vector.

The decision function is:

$$h(x) = sgn(\sum_{i=1}^{N_s} a_i y_i K(s_i, x) + b) \quad (13)$$

- $a_i \geq 0$
- N_s is the number of support vectors,
- s_i is the support vector,
- $K(s_i, x)$ denotes kernel function.

IV. EXPERIMENTAL AND ANALYSIS

A. Experimental Environment

In this work, we propose four methods for the recognition system:

- Multi-layer perceptron classifier with the histogram projection descriptor (HP-MLP).
- Multi-layer perceptron classifier with the histogram oriented gradient descriptor (HOG-MLP).
- Support-vector-machine classifier with the histogram projection descriptor HP-SVM.
- Support-vector-machine classifier with the histogram oriented gradient descriptor HOG-SVM.

To train and test these proposed methods, the traffic signs images database¹ used in this paper contains 300 color images with natural background in under variable conditions, and with 1300x800 pixels size. We use the traffic signs detection system (TSDS) presented in our previous work, to extract traffic signs, resized to 64x64 pixels, and after eliminating the insignificant blobs, we proceed to a manual classification of traffic signs blobs depending to shape and to color.

Four color-shape datasets are generated: red-circular signs dataset, red-triangular signs dataset, blue-circular signs dataset, and blue-quadrangular signs dataset.

These datasets are prepared to train and to test the methods HP-MLP, HOG-MLP, HP-SVM and HOG-SVM, which constitute the recognition system. The process for preparing datasets of traffic signs is presented in Fig. 3.

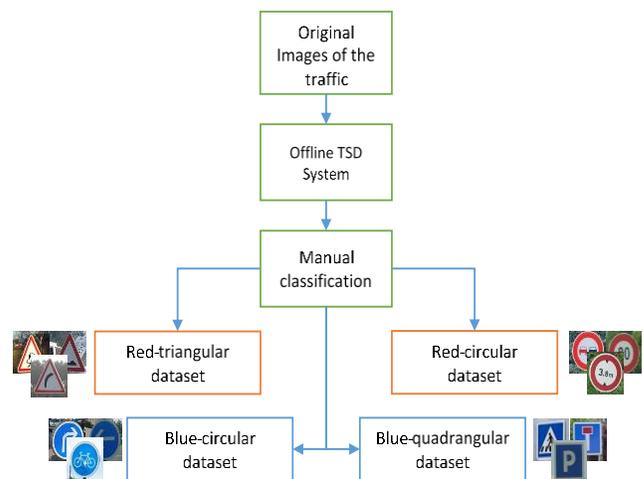


Fig. 3. Process for preparing the traffic signs dataset.

¹ DATASET, THE GERMAN TRAFFIC SIGN DETECTION BENCHMARK, <http://benchmark.ini.rub.de/?section=gtsdb&subsection=dataset> 2013

The traffic sign global dataset generated composed of 2535 blobs of traffic signs, classified in 49 classes. 1724 blobs are used for training our classifiers and, 811 blobs for the test.

To evaluate the performance of these methods, the implementing environment is based on a Desktop computer with Intel® Core™ i3 CPU M370 @ 2.40GHz processor, 4Go memory, and using Microsoft Visual Studio 2012 and OpenCV library 2.4.4 as the software platform.

B. Descriptor-Classifer Recognition Methods

In the stage of training, we use HP and HOG to extract de descriptor of each element in the training color-shape datasets, these descriptors are to train the MLP and the SVM classifiers, and we do same for each color-shape dataset.

In the stage of testing, we extract the HP and the HOG descriptors from elements of dataset of testing, and we use the correspondent trained MLP and SVM classifiers, to predict the class of the given traffic sign. The framework of training and testing this method is shown in Fig. 4.

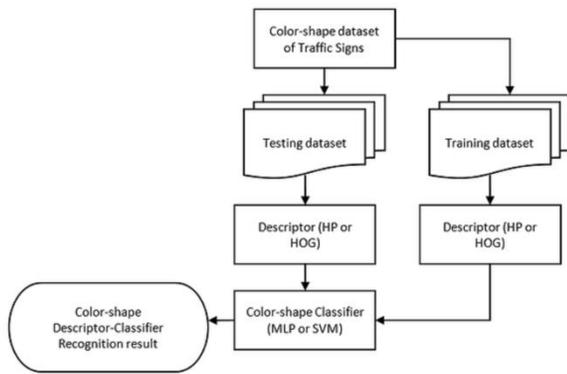


Fig. 4. Framework for training and testing descriptor-classifier recognition method.

C. Descriptor-Classifer Recognition Methods

Results of the four recognition methods are presented in the following figures:

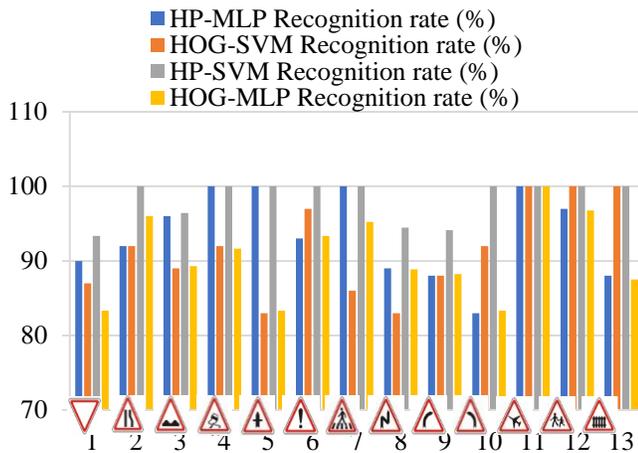


Fig. 5. The Performances of HP-MLP, HP-SVM, HOG-MLP and HOG-SVM using a red triangular Road Signs dataset.

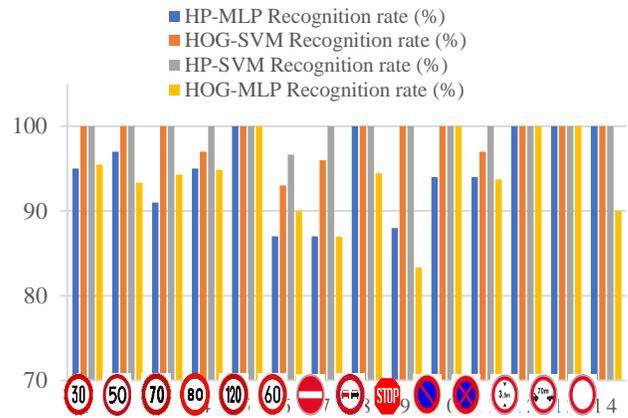


Fig. 6. The Performances of HP-MLP, HP-SVM, HOG-MLP and HOG-SVM using a red circular Road Signs dataset.

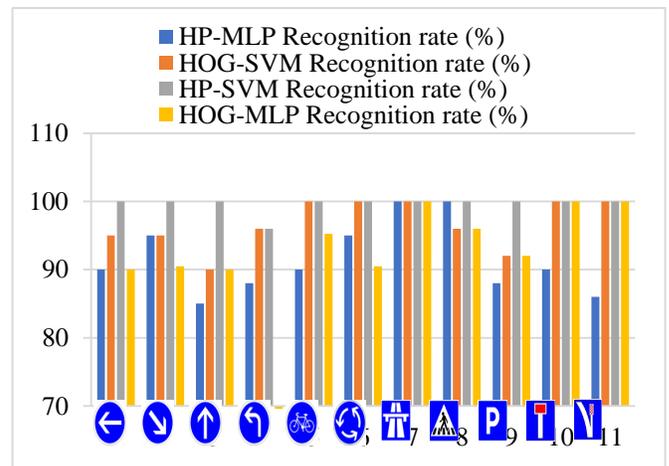


Fig. 7. The Performance of HP-MLP, HP-SVM, HOG-MLP and HOG-SVM using a blue circular and quadrangular Road Signs dataset.

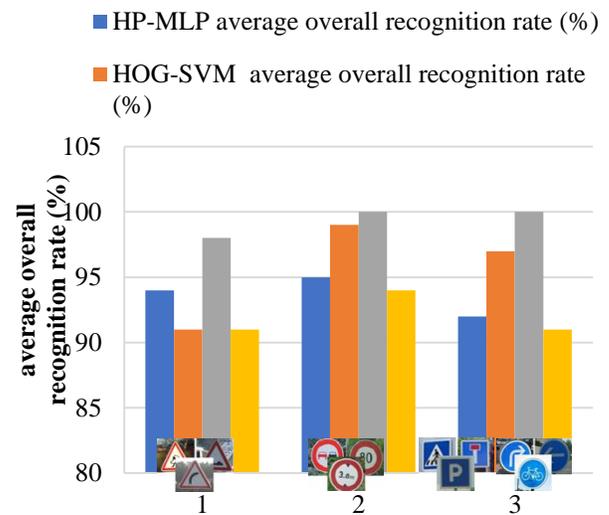


Fig. 8. The average overall recognition rate of HP-MLP, HP-SVM, HOG-MLP and HOG-SVM.

The results presented in Fig. 5, 6 and 7, shows that the HP-SVM method is more efficient than the other methods for all tested kind of traffic signs, with an average overall recognition rate of 99,33% as shown in Fig. 8.

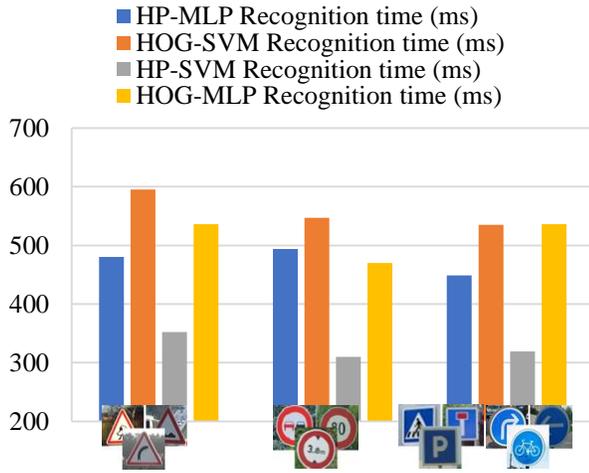


Fig. 9. The average overall recognition time of HP-MLP, HP-SVM, HOG-MLP and HOG-SVM.

The HP-SVM method, as is shown in Fig. 9 HP-SVM, in addition to its efficiency in recognizing traffic signs, has a competitive processing time compared to the other methods. This will facilitate a future real-time implementation of traffic sign recognition system.

The performance of HP-SVM is due to the right choice of the amount of data processed and delivered by the HP Descriptor. The compromise of the speed and the efficiency of recognition of the traffic signs are controlled by the size and representativeness of the information delivered by the chosen descriptor.

Above all, as is shown by the experimental results, HP-SVM method compared to the author methods, achieve the highest accuracy for recognition of all kind of traffic signs, it could be used as a core of recognition step, and combined with the detection system developed in the previous work [3] for the

detection step, to evaluate the performance of an entire system of detection and recognition of road signs.

V. CONCLUSION

This work presented a comparative study of four methods, designed and developed for a traffic sign recognition system. These methods are combinations of two descriptors HP and HOG and two classifiers MLP and SVM.

The study concluded that the HP-SVM method presents a competitive performance with respect to the accuracy of recognizing traffic signs and processing time, this makes it the appropriate method to be used in our traffic signs recognition system (TSRS), and to be combined with our TSD system, to build a robust real-time traffic signs detection and recognition system, which will be the aim objective of a future work.

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Model Driven Development Transformations using Inductive Logic Programming

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Abstract—Model transformation by example is a novel approach in model-driven software engineering. The rationale behind the approach is to derive transformation rules from an initial set of interrelated source and target models; e.g., requirements analysis and software design models. The derived rules describe different transformation steps in a purely declarative way. Inductive Logic Programming utilizes the power of machine learning and the capability of logic programming to induce valid hypotheses from given examples. In this paper, we use Inductive Logic Programming to derive transformation rules from given examples of analysis-design pairs. As a proof concept, we applied the approach to two major software design tasks: class packaging and introducing Façade design. Various analysis-design model pairs collected from different sources were used as case studies. The resultant performance measures show that the approach is promising.

Keywords—Transformation model; software design models; transformation rules; inductive logic programming

I. INTRODUCTION

The problem of transforming the requirement analysis models into software design models can be viewed as a model transformation problem. Designers utilize their engineering knowledge to perform this specific kind of transformation. In this paper, we capture such knowledge through learning the transformation rules from available pairs of requirement analysis models (e.g., domain model or conceptual class diagram) and corresponding software design models (e.g., component diagram or package diagram). The approach of learning a model transformation from provided examples is referred to as Model Transformation by Example (MTBE) [1]. The examples, in this context, represent pairs of the transformation requirements/design models.

Model Driven Development (MDD) considers a sequence of several kinds of models as the primary artifacts of the development process as they contain the needed information that supports its different phases. Those models may be derived from each other via automated transformation. The models are structured conforming to particular models called meta-models. Implementing models transformation requires an intense knowledge about MDD including the meta-models and the environment of the model transformation.

Practically, machine learning (ML) techniques can be used to deduce the transformation rules from the available set of examples [2]. ML techniques have been applied in different domains, including software engineering [3]-[8]. Inductive

logic programming (ILP) is one of the machine learning techniques that provide mechanisms for inducing valid hypotheses from given examples and background knowledge of the domain of interest [9], [10]. Rules have been used widely as a powerful way for representing knowledge. However, in the domain of model transformation, authoring the transformation rules is not a trivial task. It might be easier for the domain expert to provide examples of the transformation rather than introducing consistent and complete rules. Thus, it is desirable to utilize the accumulated experience by automatically capturing the transformation rules from examples [11].

The primary contribution of this paper is to define a methodology, with an associated tools-chain, for the incremental design of model transformation rules. The increments in the rule design are automatically derived by defining positive and negative examples on a given training set of models (i.e. learning models). As a secondary contribution, we propose the application of such an inferred set of model transformation rules in order to refactor actual domain/conceptual artifacts (referred as “analysis models”) toward design solutions. These contributions are interesting for both the communities working on Model Driven Engineering and on Software Engineering, and the context defined here with their solution may be worth for the attention also to a wider audience from others communities.

In a particular, we use ILP to automatically capture the expertise manifested in previous analysis-design pairs, and consequently, represent such expertise in a form of declarative rules. These rules can be applied to a new design problem to suggest a possible design to given analysis models. Such design suggestion can be adopted “as is” by the designer or at least be reviewed and refined by the designer before adoption. In either cases, this would offer effort saving and, accordingly, cost reduction. Moreover, this would offer indirect reuse of best practice that would in turn improve quality. We applied the approach to various case studies collected from different sources. A considerable part of the data have been used for training to induce rules regarding two major software design tasks: class packaging and introducing Façade design.

The rest of this paper is organized as follows. Section II introduces the needed technical background. Section III reviews the literature survey, while Section IV introduces the proposed transformation system. Section V describes the transformations tasks. While Section VI demonstrates the

conducted experiments, Section VII discusses the findings and the open issues. Finally, Section VIII concludes the paper.

II. TECHNICAL BACKGROUND

In this section, we give the background necessary to follow the rest of the paper.

A. Model Driven Development Transformations

The goal of this work is to facilitate the transformation from the analysis models toward the software design models by reusing previous experience. That is, based on the given requirements, the existing requirement-design pairs from previous systems can be utilized to build the new system's design. Indeed rule-based transformation approaches rely on transformation rules that were obtained empirically [12]. However, it might be a difficult task to define, express, and maintain the transformation rules, particularly for non-widely used formalisms. That is, it is most important to gather the knowledge in a form of rules, not only to decide about the transformation language [13], [14]. Thus, the objective of this paper is to use ILP, discussed next, to capture such transformation rules.

B. Inductive Logic Programming

ILP can be seen as the intersection of machine learning and logic programming. An ILP problem is defined as follows: Given a background theory B , and a set of examples E (represented as ground literals) that consists of positive E^+ and negative E^- examples, the target is to find a hypothesis H such that $\forall e^+ \in E^+ : B \cup H \models e$ and $\forall e^- \in E^- : B \cup H \not\models e^-$ [9], [10]. Thus, the problem of learning a particular hypothesis can be designed as a search problem through a space of models [15]. To perform a search two main strategies were used: generate-and-test and data-driven. In both, the applied algorithms can proceed either bottom-up or top-down. A combination of those strategies and algorithms can be exploited. Examples of ILP systems are FOIL [16], GOLEM [17], PROGOL [18], ALEPH [19] and others. ALEPH (A Learning Engine for Proposing Hypotheses) employed in this work, has different evaluation functions and search strategies that can be applied, and it has been applied successfully in many domains [20]-[25].

III. LITERATURE SURVEY

In this section, we present a literature survey that addresses two views presented below. It is noteworthy that the terms transformation links, transformation mappings and transformation traces have been used interchangeably in the literature to refer to the links between the artifacts in the source model and their corresponding artifacts in the target model. In the rest of the paper, we use the term transformation mapping.

A. Model Transformation by Examples Approaches

MTBE approach has been initiated by Varró [1], where he derives the transformation rules from an initial set of examples that includes interrelated source and target models. The user provides the examples, and then the developers refine the derived rules. The transformation rules are produced using an ad-hoc algorithm by utilizing transformation mapping and corresponding meta-models. Balogh and Varró [21] improve the original work of Varró by using ILP instead of the original

ad-hoc heuristic. Nevertheless, a semi-automatic process needs interacting with the ILP inference engine and requires detailed transformation mappings. Wimmer et al. [26] generates ATL (ATLAS Transformation Language) rules [27] with using transformation mappings to assist the derivation of model transformation rules. Dolques et al. [28] use Relational Concept Analysis [29] to derive commonalities between the source and target meta-models and transformation mappings. However, the transformation patterns cannot be executed directly. This approach was extended by Saada et al. [30] to learn transformation patterns from the examples, then those patterns are analyzed, filtered and transformed into operational transformation rules. Some MTBE approaches generate n-to-m transformation rules. In [31], [32], the rules are generated from meta-models to satisfy some developer constraints. ATL has been used to implement the generated rules. Another many-to-many rules generator proposed by Faunes et al. [13]. They adapted genetic programming to generate transformation rules expressed in Jess, a fact-based rule language. Jess¹ is a tool for building a type of intelligent software i.e., expert systems.

In conclusion, the conducted survey revealed that most of the approaches that derive transformation rules use transformation example pairs and, with the exception of one work [13], all of them use transformation mappings. In addition, to the best of our knowledge none of the current approaches address the problem of transforming requirement analysis models into software design models. Moreover, most of MTBE approaches require the source, target models and their meta-models as well as the detailed mapping between these models to derive the transformation rules. Unlike these MTBE approaches, our approach aims to use the minimal inputs, the source and target models only, to derive the transformation rules. The most similar work to ours is [21]; however they differ in many facets. First, they considered the problem of transforming class diagrams into relational schema models that is different from our problem of transforming analysis models into design models. Second, they also used the connectivity analysis that is considered as transformation mappings at the meta-model level. In contrast, the approach presented in this paper requires only the concrete models without meta-models or connectivity analysis.

B. Using Inductive Logic Programming to Generate Rules

ILP has been widely utilized for discovery of concept and classification in data mining algorithms. In concept discovery, the idea is to induce rules based on the existing data. For classification, according to the given data, general rules are generated and used for grouping the unseen data. In reality, ILP has been successfully applied to a wide range of real-world problems in different domains since it is concerned with the induction of logic theories from examples [33]. In particular, ILP has been used in solving software engineering problems [21], [34].

IV. ILP-BASED TRANSFORMATION SYSTEM

Our proposed transformation system comprises of three main components. Fig. 1 demonstrates the system's components and other supporting functions. It is a generic

¹ <http://www.jessrules.com/jess/index.shtml>

structure where different ILP systems can be employed to induce rules [34].

ILP systems often start with a preliminary pre-processing stage and ends with a post-processing stage [35]. ALEPH requires that the given information should be in the form of clauses. Thus, the preprocessing step in our transformation system focuses on the conversion of the UML models (given in XMI format) into first order logic predicates. XMI stands for XML (Extensible Markup Language) Metadata Interchange. It is an Object Management Group standard for exchanging metadata information via XML. XMI is considered as the de-facto standard format used commonly as an interchange format for UML models.

TABLE I. defines a set of predicates used to represent the UML models artifacts. In our work, each used example pair consists of two UML models: source and target. The former is translated to be the background knowledge, whereas the latter is used to present the positive examples. The given UML models have no negative examples. In such cases, Closed World Assumption (CWA) [36] is used to generate the negative examples. An intermediate step between the rules generation and rule application is considered to translate the rules generalized by ALEPH into fact-based rule language. Finally, the post-processing stage concentrates on improving the efficiency by removing the redundant clauses in the induced theory.

A. Transformation Rules Generation and Generalization

Generally, the transformation problem needs a set of transformation rules in order to cover all the aspects in the

transformation problem. The transformation rule here is used to analyze a particular aspect of the analysis requirements given as input and synthesize the corresponding software design to be presented as output. In this context, the transformation system can be encoded as a set of transformation rules $R=\{r_1, r_2, \dots, r_n\}$. Each rule can be encoded as a pair of promise and conclusion $r_i=\{P, C\}$ where P is the analysis artifacts to search for in the source model and C is the design artifacts to instantiate when producing the target model.

Algorithm 1 demonstrates the steps we follow to generate the transformation rules. Using ALEPH system, an independent run is performed to produce hypothesis or more for a single predicate from the given examples with background knowledge. To run the ALEPH system, there is a need to feed three files containing the knowledge background, the positive and the negative examples. What is significant limitation in most of the current ILP systems is the need to predefine the target predicate before starting the learning process. Two parts included in the background knowledge rules structure and artifacts descriptions. The former guides the construction of a single rule, while the latter describes source models artifacts. Although the same knowledge background file can be used in different runs, the modes (*modeh* and *modeb*) declarations need to be adjusted to help determine what type of rules to learn. While *modeh* describes the head of the target hypothesis, *modeb* describes the atoms expected to appear in the target body. TABLE II. shows examples of two different inputs.

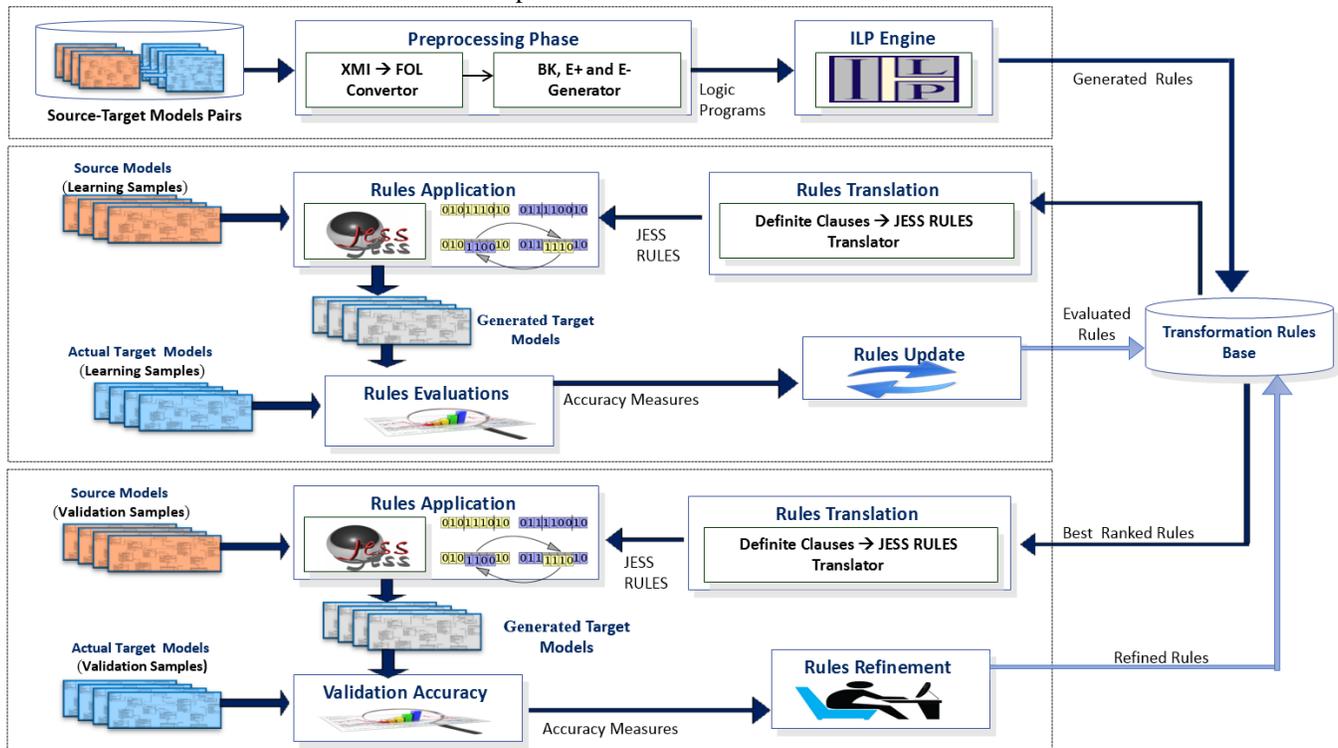


Fig. 1. Architecture of the proposed transformation system.

TABLE I. PREDICATES FOR THE BACKGROUND KNOWLEDGE REPRESENTATION

Predicate	Meaning
package(p)	It defines p as a package.
class(c)	It defines c as a class.
packagehasClass (p, c)	Class c is located into a package p.
classhasOperation(c, op)	Class c has an operation op.
classhasAttribute(c, a)	Class c has an attribute a.
inheritance(c1, c2)	Class c2 is a subclass of class c1.
association(c1, c2)	Class c1 keeps a reference to class c2 where both classes are located in same package.
associationAcrossPackages (p1, c1, p2, c2)	Class c1 keeps a reference to class c2 where both classes are located in different packages p1 and p2.
packageOfClasses({set of classes})	A set consists of one or more class classes located in one package.
interface(p, f)	A package p has an interface f that links the classes located in package p to the classes placed outside of package p to minimize the external relations.

B. Rules Translation and Application

All the induced rules are initially stored in the rule base (RB) in logic programs form. These are then translated into jess script. When a new instance of source model (i.e. requirement analysis) is presented, the models are converted to logic program.

Algorithm 1: Background knowledge and Examples Creation

Input: Pairs of source & target models $ST = ((s_1, t_1), \dots, (s_n, t_n))$.
Output: Background knowledge K ,
 Groups of positive examples PE

```

1:  $B \leftarrow \emptyset$ 
2:  $E \leftarrow \emptyset$ 
// Convert each  $st \in ST$  into logic predicate
3: Repeat Until  $ST = \emptyset$ 
4:   convert  $st_i = \{s_i, t_i\}$  into logic fact such that:
5:      $B \leftarrow B \cup s_i \quad \forall s \in S$ 
6:      $E \leftarrow E \cup t_i \quad \forall t \in T$ 
7:    $ST = ST \setminus (s_i, t_i)$ 
8: end repeat

//Classify the examples in  $E$  into different groups
9:  $PE \leftarrow \emptyset$ 
10:  $i = 1$ .
11: Repeat until  $E = \emptyset$ 
12:   Create new group  $pe_i$ 
13:   Pick the first example  $e_1$  From  $E$  s.t.
        $pe_i = pe_i \cup e_1$ 
        $E = E \setminus e_1$ 
14:   For all the remaining examples in  $E (e_2 \dots e_n)$ 
15:     check similarity of predicate and arity of  $(e_j, e_1)$ 
16:     if similar then
        $pe_i = pe_i \cup e_j$ 
        $E = E \setminus e_j$ 
17:   end for
18:  $PE = PE \cup pe_i$ 
19:  $i = i + 1$ 
20: return  $B$  and  $PE = \{pe_1, \dots, pe_n\} (1 \leq n \leq E)$ 

```

Applying the translated rules on the new source model means that rule(s) might fire when some facts satisfy its conditions. Firing a rule means some facts are asserted or some others may be retracted. The obtained facts, after application, are supposed to represent the corresponding software design, shown in Algorithm 2.

Algorithm 2: Transformation Rules Generation

$ST = \{S, T\}$: Pairs of source and target models
 K : Knowledge background
 $E = \{E^+, E^-\}$: Positive and negative examples
 TR : List of derived transformation rules induced

Input: Initial set of RD
Output: A set of TR such that TR derived from E and K
 Call the files creation procedure (specified in Algorithm 1)
 // Convert the constructs $s, t \in ST$ into a logic predicate

```

1: Let  $E^+ \leftarrow \emptyset$ 
2: Let  $B \leftarrow \emptyset$ 
3: Repeat until  $RT \neq \emptyset$ 
4:   Convert  $st_i = \{s_i, t_i\}$  into logic predicate s.t.
        $B \leftarrow B \cup s_i \quad \forall s \in S$ 
        $E^+ \leftarrow E^+ \cup d_i \quad \forall d \in D$ 
   End while
   // Generate The transformation rules  $TR$ 
    $TR \leftarrow \emptyset$ 
   Repeat
   Create three files required by ALEPH such that:
   file.b  $\subset B$ , file.f  $\subset E^+$ , and file.n  $\subset E^-$ 
   ALEPH induces a rule  $R = (LHS, RHS)$ 
    $TR \leftarrow TR \cup R$ 
   Until  $\exists R \in TR, \forall d_i \in E^+$ 
   Return  $TR$ .

```

Algorithm 3: Transformation Rules Evaluation

RQ: New instance of requirements analysis (XMI format)
 SD: Corresponding software design (XMI format)
 TR: List of derived transformation (Clauses)
 JR: List of the transformation rules in JESS script
 F: A set of predicates representing RQ artifacts Facts

INPUT: A new instance of RQ
OUTPUT: SD corresponds to given RQ

// Translate TR into JESS rules

```

1.  $JR \leftarrow \emptyset$ 
2. While  $TR$  not empty do
3.  $\forall tr_i \in TR$  translate  $tr_i$  into  $jr_i$ 
4.  $JR \leftarrow JR \cup jr_i$  where  $jr_i = \{P, C\}$ 
5.  $TR \leftarrow TR / tr_i$ 
6. End while
// Convert the given requirement models into logic predicates
7.  $F \leftarrow \emptyset$ 
8. While RQ not empty do
9.  $\forall rq_i \in RQ$  convert  $rq_i$  into a predicate  $f_i$ 
10.  $F \leftarrow F \cup f_i$ 
11.  $RQ \leftarrow RQ / rq_i$ 
12. End while
13. Feed  $F$  and  $JR$  to the Transformation System
    (Java application + Jess Engine)
14. Based on  $F$ , for each  $jr_i$  whenever  $P$  is satisfied => Fire  $jr_i$ 
15. New  $F_i$  is asserted  $F \leftarrow F \cup f_i \quad \forall$  existing fact  $f_i$  is removed
16. Convert resultant  $F$  to XMI format (SD)

```

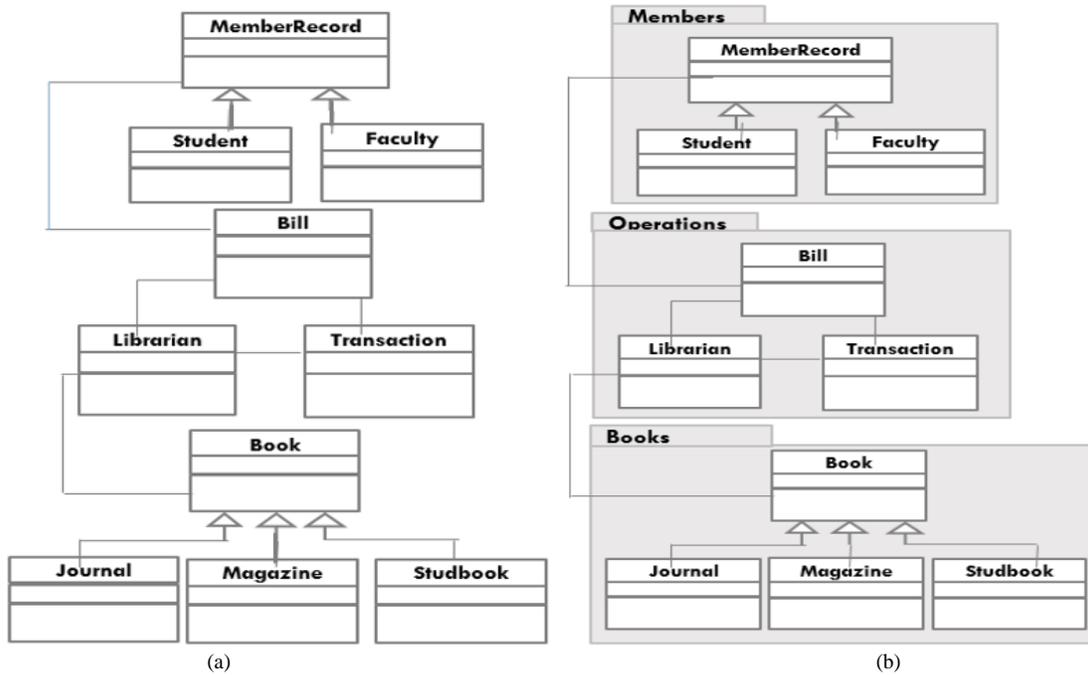


Fig. 2. The UML class diagram for analysis-design pair (a) the source model (requirement analysis) and (b) the target model (software design).

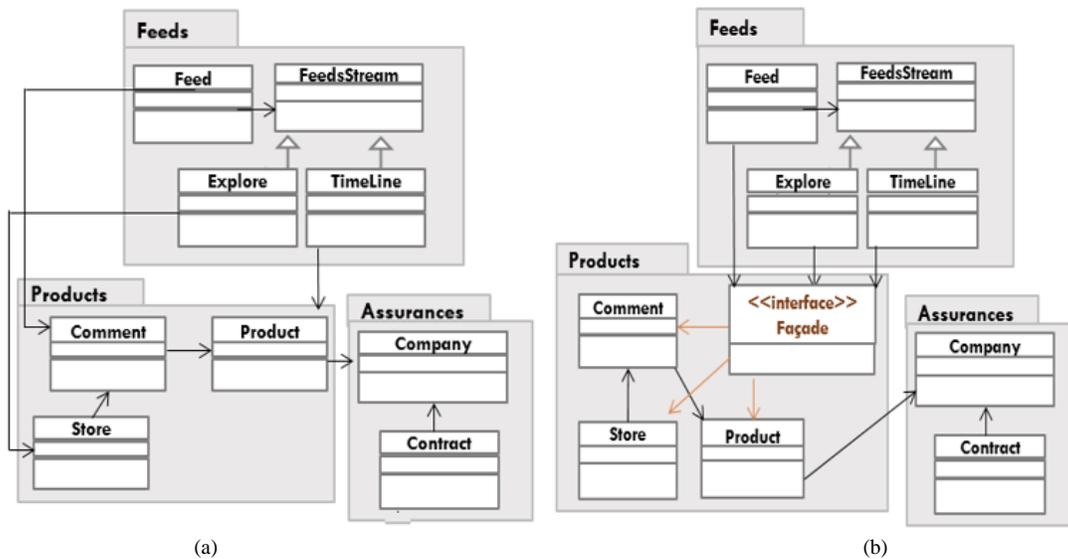


Fig. 3. Part of class diagram of application (a) the source model and (b) the target model.

C. Rules Evaluation and Refinement

Before and after the rules application, different measures were used to evaluate their performance. Completeness and consistency measures refer to the positive and negative examples covered by the induced rules. This can indicate the accuracy of the induced rules based on the learning examples. Furthermore, the transformation designer can validate the correctness of the produced rules after applying them on additional test cases. The rule-created target model can be compared to the actual target for the sake of performance evaluation of the transformation rules. Several performance measures, shown in Algorithm 3, are used in this context (more details are given in Section B).

Human expert evaluation for the resulted design can be considered. This type of evaluation may help to update the priority of the rules application. In addition, expert feedback would help refining. Expert opinions may contribute to the rule base by adding new rules or relaxing the application of others. Here, we allow automatic assignment of priorities to the rules where the higher the application frequency, the higher the priority. The number of positive examples used to induce the rule determines the rule priority. That is the higher number of positive examples the higher the priority. Thus, each rule starts by initial priority equals to the number of positive examples used to induce the rule; this priority is then tuned based on the rule's application frequency and input from experts.

V. SAMPLE TRANSFORMATION TASKS

This section is dedicated to explain the two transformation problems investigated in this work. In the following, we describe each case study briefly.

A. Packaging Class Diagram

One of the common tasks when moving from analysis to design is the task of structuring the system classes into packages [37]. During the analysis phase, the class diagram depicts all the classes used in the system and the relations between them. The aim is to develop highly cohesive and loosely coupled packages. In this experiment, we use our proposed approach to learn packaging rules from analysis-design pair examples. Together Fig. 2(a) and (b) represent a simple example of the analysis-design pair. They show the analysis model of one of the used examples along with the corresponding initial design model respectively. The initial design model shows the analysis model after introducing the packages (This example has been used in [28] to introduce the initial idea).

B. Introducing Façade Design

It is considered another high-level software design activity: introducing façade design. It is common for a class in a particular package to have external relations with classes in other packages. The Façade design pattern is used to simplify the interaction process and improve the overall design coupling and cohesion. A façade provides a one “point of contact” to a package of classes (i.e., component). It hides the implementation of the component from its clients, making the component easier to use. In addition, it results in loosely coupled software. For this design task, we used several examples to derive a rule for introducing façades to packages. Fig. 3 depicts one of such examples. It shows a class diagram that has many inter-packages relationships making the design highly coupled and less maintainable. To overcome this problem the designer introduces façades as another step of transformation from requirement analysis to software design. Based on the presented examples, ALEPH generalizes a hypothesis as shown in TABLE III.

VI. EXPERIMENTS

This section is dedicated to the setup of the experiments performed in this work to produce a set of rules. The objective of these experiments is to provide a proof-of-concept that the proposed approach can be used to build a transformation system from requirement analysis to software design.

A. Problem and Solution Representations

The given UML models are presented in XMI format. To induce a general hypothesis using ALEPH, we converted the problem, represented by XMI models, to logic programs comprised two part: background knowledge and positive examples. TABLE II. demonstrates the conversion of the UML model presented in Fig. 2 and 3; with background knowledge and positive examples, respectively. In addition, the generated negative examples under CWA.

TABLE II. THE PROBLEM REPRESENTATION WRITTEN IN ALEPH (I.E., PROLOG SYNTAX)

Input Type	Packaging Class Diagram
Types and Modes Declarations	<pre>:- modeh(*, packageOfClasses(+class, -class, -class, -class)). :- modeh(*, packageOfClasses(+class, -class, -class)). :- modeb(*, inheritance (+class, -class)). :- modeb(*, association (+class, -class)). :- modeb(*, inheritance (+class, -class)). :- modeb(*, association (+class, -class)). :- determination (package/4, inheritance/2). :- determination (package/4, association/2). :- determination (package/3, inheritance/2). :- determination (package/3, association/2).</pre>
Background Knowledge	<pre>class(book). class(journal). class(magazine). class(bill). class(librarian). class(transaction). class(StudyBook). class(memberRecord). class(student). class(faculty). inheritance(book, journal). inheritance(book, magazine). inheritance(book, studyBook). inheritance(memberRecord, faculty). inheritance(memberRecord, student). association (book, librarian). association(librarian, transaction). association(librarian, bill). association((bill, transaction). association(book, memberRecord). association(memberRecord, bill).</pre>
Positive Examples	<pre>packageOfClasses (book, studyBook, magazine, journal). packageOfClasses(memberRecord, faculty, student). packageOfClasses (librarian, bill, transaction).</pre>
Negative Examples	<pre>packageOfClasses (memberRecord, studyBook, bill). packageOfClasses(book, student, librarian). packageOfClasses (magazine, faculty, transaction).</pre>
Input Type	Introducing Façade Design
Types and Modes Declarations	<pre>:- modeh(*, packaheHasFacade(+package, interface)). :- modeb(*, packageHasClass(+package, +class)). :- modeb(*, packageHasClass(-package, -class)). :- modeb(*, associationAcrossPackages(-package, -class,+package, +class)). :- determination (packaheHasFacade/2, associationAcrossPackages/4). :- determination (packaheHasFacade/2, packageHasClass/2).</pre>
Background Knowledge	<pre>package(feeds). class(feed). class(feedsStream). class(explore). class(timeLine). association(feed, feedsStream). inheritance (feedsStream,timeline). inheritance(feedsStream, explore). package(products). class(comment). class(store). class(product). association(comment, product). association(store, comment). package(assurance). class(company). class(contract). association(contract, company). associationAcrossPackages(feeds, feed, products, comment). associationAcrossPackages (feeds, explore, products, store).</pre>
Positive Examples	<pre>packaheHasFacade(assurance, façade).</pre>
Negative Examples	<pre>packaheHasFacade(products, façade). packaheHasFacade(feeds, façade).</pre>

TABLE III. THE SOLUTION REPRESENTATION

Example	Induced Rule
Packaging Class Diagram	<p>$\text{packageOfClasses}(A,B,C) \leftarrow$ $\text{inheritance}(A,B), \text{inheritance}(A,C).$</p> <p>When there is an inheritance relation between the classes A and B, these two classes are grouped together in one package</p>
	<p>$\text{packageOfClasses}(A,B,C) \leftarrow$ $\text{association}(A,B), \text{association}(A,C), \text{association}(B,C).$</p> <p>When three classes A, B and C have association relations, such that class A is linked to class B, and Class C, also, Class B is linked to Class C, and then the three classes can be grouped in one package.</p>
	<p>$\text{packageOfClasses}(A,B,C,D) \leftarrow$ $\text{inheritance}(A,B), \text{inheritance}(A,C), \text{inheritance}(A,D).$</p> <p>When three classes A, B, C and D have the presented relationships, such that class A is the parent of classes B, C and D then the four classes can be grouped in one package</p>
Introducing Façades Example	<p>$\text{packageHasFacade}(A,B) \leftarrow$ $\text{packageHasClass}(C,D),$ $\text{associationAcrossPackages}(C,D,A,E).$</p> <p>When there is a class D, which is placed in a package C, has a reference to another class E placed in a different package A, a façade interface B is introduced to the destination package A.</p>

In TABLE III. the second column represents samples of the rules produced by ALEPH system based on the predefined modes and given examples. In this set of rules, LHS (left-hand side) represents the conclusion (introduce a package) in order to group different classes into a single package wherever RHS (right-hand side) which is the premise is satisfied.

B. Solution Evaluation

For the problem solved by ILP-based systems, usually the performance can be measured by grouping the results as true positive (TP), true negative (TN), false positive (FP) and false negative (FN). The equations demonstrated in Algorithm 3 are collected during experimentation. We focused on validating the generated artifacts. To do that, we compared the generated artifacts with the actual ones provided as part of the given pair. As shown in algorithm 3, we used five different measures in the conducted experiments. Although we considered two transformation tasks, here is an explanation how we evaluate the solution in the task of packaging the classes.

TP refers to the correctly placed classes in the created package p_j while TN refers to the classes that are not placed in p_j correctly. FP indicates the extra classes placed in p_j while they do not exist in p_i . Finally, FN indicates the number of classes that are exist in p_i but not placed in p_j . As a last step, we calculate the average across all packages for all the measures. It is worth mentioning that, for the experiments related to the second task, it was not applicable to calculate TN so we exclude some measures.

TABLE IV. DATASETS STATISTICS

Artifacts	Min	Max
Packages	3	27
Classes and Interfaces	10	151
Relationships	11	188

When validating the generated packages, we need to pay attention of their content. Let $AD = \{p_1, p_2, \dots, p_n\}$ be the number of packages of the actual design. Let $GD = \{p_1, p_2, \dots, p_m\}$ be the number of packages of the corresponding rule-created (generated) design, where m could be less than, equal to, or greater than n. In AD each p_i consists of a number of classes $c_{i1}, c_{i2}, \dots, c_{ik}$ and the corresponding package p_j in GD may consists of the same, more or less classes $c_{j1}, c_{j2}, \dots, c_{jl}$.

C. ALEPH Settings

ALEPH has many settings to adjust the search process, and the ones we perform the experiments with are explained in this section. We use default ALEPH settings. Different search strategies (such as heuristic, depth first) have been used; however the results obtained were comparable. All presented results in the following came from these settings.

D. Datasets

The datasets used in the experiments comprises around 34 systems. Each system consists of the analysis and design models. These cases were collected mostly from academic projects, examples from textbooks, and by reserve engineering. Each system consists of analysis/design pair. In turn, each design system comprises at least three packages. The total number of packages in the base is 217 while the total number of classes and interfaces is 1540. TABLE IV. shows brief statistics of the systems' artifacts i.e., packages, classes, interfaces, and relationships such as association, generalization, aggregation and others.

E. Experimental Results / Quantitative Validation

This section shows the results obtained from the two conducted experiments by using the described datasets. The available examples were divided into learning set and validation set in the ratio 2:1. Each set has been selected randomly with ensuring that no system has been selected twice.

During learning phase, all the 22 learning systems have been used as input to generalize a set of transformation rules that have been evaluated later in two ways to select the best rules. Then the final rules were validated against the validation set which consists of 12 systems. Samples of the induced transformation rules are demonstrated in TABLE V.

1) Measuring the packaging rules performance

We measured the performance of the induced rules individually. The performance of each rule was measured by applying the rule on all systems in one run. Fig. 5 shows two types of experiments that were conducted to measure the rules performance. In one experiment, shown in Fig. 5(a), individual rule performance was evaluated by applying the rule on all the learning systems, batched together. The rules showing low performance have been retracted from the rules base to avoid impact the overall system performance, e.g. rules 9-10. Then a

genetic algorithm-based procedure was used to find subsets of remaining rules that gives the best results against the learning systems one by one. Fig. 5(b) presents the accuracy measures for the learning systems.

This experiment paid attention for the number of times each rule was considered to give the best accuracy with each system. Fig. 4 shows the percentage of times the rules applied. We aim here to provide a kind of score of each rule that assist selecting the rules in the future when apply the rules on real applications that have no the actual target model. To rank the rules, we need for assigning these scores (discussed in Algorithm 3). Then the rules were applied on the validation systems based on their ranking.

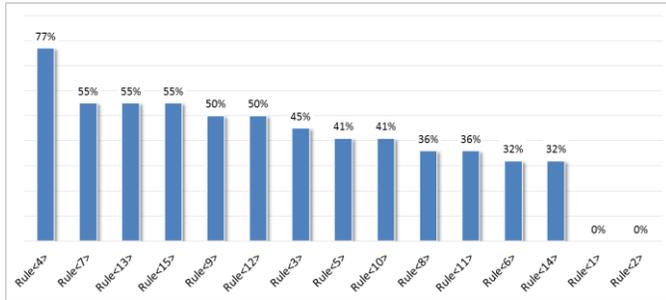


Fig. 4. Rules ranked according to the frequency of application.



TABLE V. SAMPLES OF THE INDUCED TRANSFORMATION RULES

Task	Induced Transformation Rule
Packaging Class Diagram	<code>packageOfClasses(A,B) ← association(A,B).</code> <code>packageOfClasses(A,B) ← inheritance(B,A).</code>
	<code>packageOfClasses(A,B,C) ← association(A,B), association(C,A).</code> <code>packageOfClasses(A,B,C) ← inheritance(B,A), association(A,C).</code> <code>packageOfClasses(A,B,C) ← inheritance(C,A), inheritance(C,B).</code> <code>packageOfClasses(A,B,C) ← association(B,A), association(C,A).</code>
	<code>packageOfClasses(A,B,C,D) ← association(A,C), association(C,B), association(A,D).</code> <code>packageOfClasses(A,B,C,D) ← association(A,D), association(C,A), association(C,B).</code> <code>packageOfClasses(A,B,C,D) ← inheritance(B,A), inheritance(B,C), inheritance(B,D).</code> <code>packageOfClasses(A,B,C,D) ← association(C,A), association(C,D), association(B,C).</code>
Introducing Façades	<code>packageHasFacade(A,B) ← packageHasClass(C,D),</code> <code>associationAcrossPackages(C,D,A,E).</code>

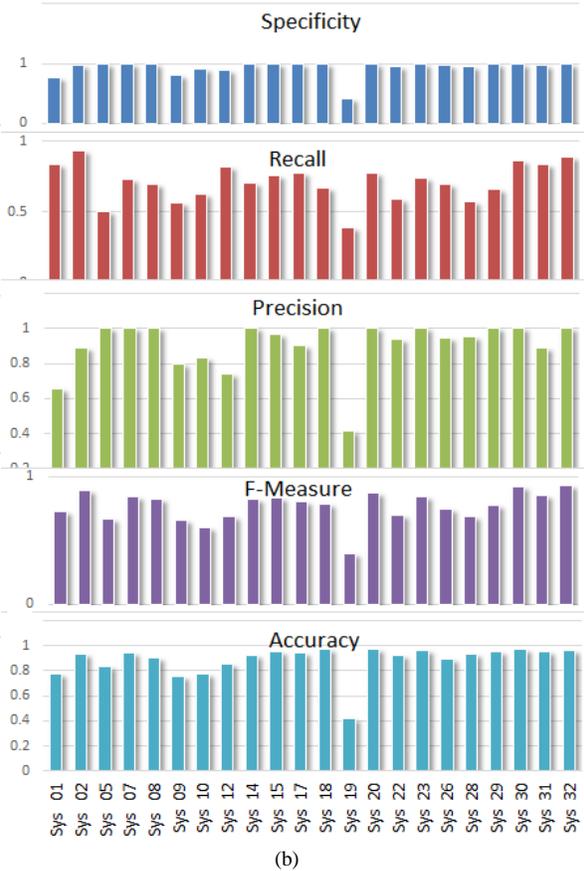


Fig. 5. (a) Individual rule application- overall systems, (b) GA-procedure - learning systems.

2) Validating the best induced rules

The final rules resulted from the learning phase have been validated in this experiment against the set of validation systems. According to the rules scores, this experiment started by applying first two rules then added one rule each run. Fig. 6 demonstrates the overall average of accuracy measures resulted from validation using 12 systems with different number of rules. Obviously the performance was stable when considering 3, 4 or 5 rules, since we considered the best rules came from two-ways evaluations. Increasing or decreasing the number of rules vary from one system to another, i.e., some systems have a steady accuracy measures starting for different number of rules, while accuracy measures of others improved/impacted when adding more rules. However, these changes are slightly small, thus the overall average shows a comparable values. When applying all the rules the performance was impacted because the rules 1 and 2 were included. The two rules can group classes from different packages together. Thus we noticed that their applications frequencies equal zero when using learning samples.

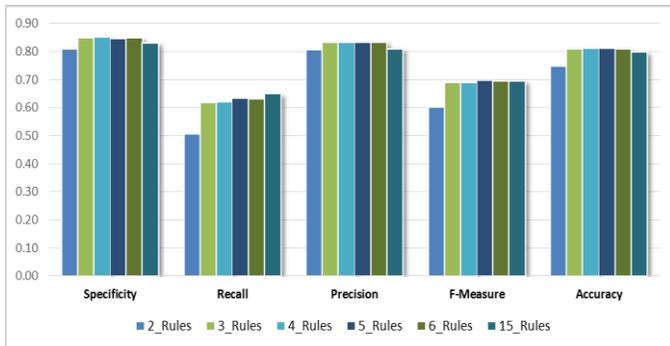


Fig. 6. Average of accuracy measures with different number of rules - validation systems.

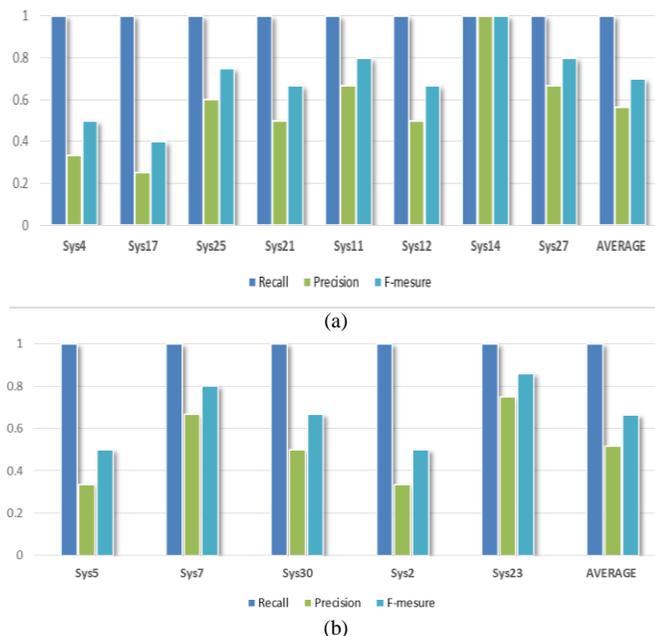


Fig. 7. Accuracy measures of applying façade rules (a) learning results, (b) validation results.

3) Accuracy measures of Façades rules

For introducing Façade design pattern only 13 systems, that use this practice, have been used for learning and validation in the ratio 2:1. The learning systems present different forms of using Façade. Nevertheless, ALPEH induces only one rule for all training data. When ALEPH generalizes the target clause, it looks for the minimal number of atoms that can cover the given examples. When generalizing the given learning examples, the learner considers only the type of relations not the count. Thus the problem is seen like this; when a package p has an external relation linked to one of its classes, add a façade to the package p. Fig. 7(a) shows the accuracy measures when applying the induced unique rule on eight learning systems. It is worth mentioning that, only three measurements used for this experiment because there are true negatives can be collected here. In the same way, the induced rule has been applied on the validation systems. Fig. 7(b) demonstrates the accuracy measures when applying the rules on the validation systems.

VII. DISCUSSION

Although ALEPH has been used widely in the literature, the induced hypotheses in the tackled problems have small arity in their head predicates. For instance, the arity of *packageOfClasses(X,Y)* is two. ALEPH requires to specify each argument type and whether it is input (+) or input (-) as used in TABLE II. The types should be maintained also in the body predicates. In our context, the arity of *packageOfClasses* changes based on the number of classes located on the corresponding package. Thus, there is a need to adjust the used modes and types in each run. This caused a problem when having a large arity. Owing to the space limitation of this paper, we ignore these details. During rules induction phase, we noticed that when providing examples of packages having five classes or more, it was not possible to generalize hypotheses for such examples. Another observation is that, ALEPH needs at least two similar examples to generalize a hypothesis. If no similar patterns are seen in the given examples while training, it will not be possible to synthesize the right output. In reality, for one example has a large arity, the opportunity to find another example having the same number and type of relations is low. On the other hand for the examples consist of two/three classes, all the examples have been covered. Inversely, the opportunity to find a similar example is better where the possible relations among the classes are limited.

Moreover, it is noticeable the measures presented in Section E vary from one system to another. The reason behind that is the nature of the used examples to generate the transformation rules. For example, the performance in case of Sys 19, presented in the learning, was the worst. This system has 28 classes placed in 4 packages. When learning the rules it was not possible to learn such rules as explained above. In the other hand, the relations among the classes are not easy to be covered by the already induced rules. The application of the rules follows their ranking which shows their how many times they were selected to get the best accuracy. When applying the rules against the validation set, small set of rules can give a comparable accuracy measures. When adding more rules means that, more classes can be grouped in incorrect packages.

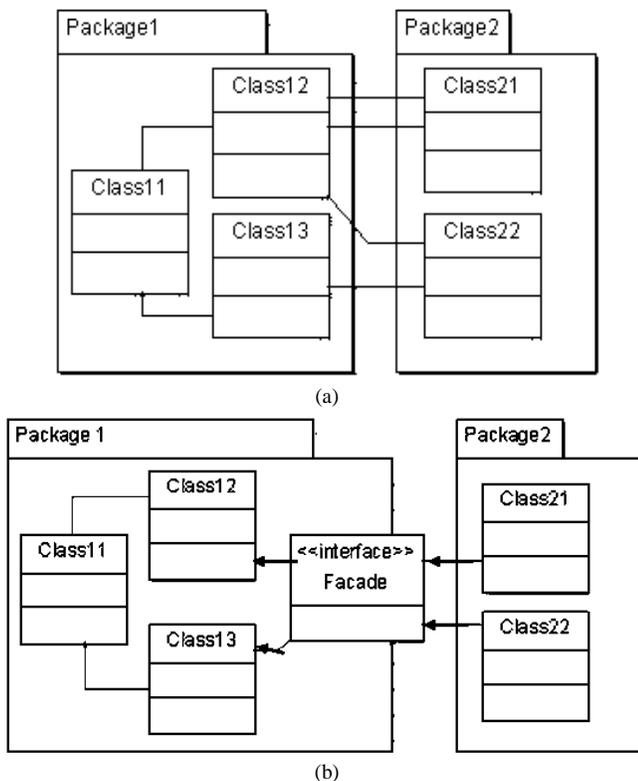


Fig. 8. Example to show the drawback of the derived rule.

Another observation, the number of the rule-created interfaces in the different learning and validation systems is either equal or more than the number of interfaces in the actual design. Thus, we get a full recall in almost all the cases, shown in Fig. 6. The reason behind that is that the rule will introduce an interface between two packages whenever there is a relation between their classes.

A. Threat to Validity

The main threats to validity, as with any software engineering research, are the data scarcity and the bias of the datasets selection. Another dimension of scarcity we encountered is the need to use source/target pairs. It is noteworthy here different resource have been considered to collect the datasets (student projects, textbooks, reverse engineering). Using different sources helps ensuring that the datasets are collected in unbiased manner. In addition, selecting randomly learning systems that are different from the validation set would give the results of the experiments some credibility as not being biased. Nevertheless, this does not necessarily mean that the derived transformation rules are complete. Another threat to validity of this work is the incompleteness in terms of transformation problems coverage. We have considered two major designs activities to show the power of ILP in generalizing rules in MDD context. Future effort will try to make contact with some potential software houses to allow using their repositories and expertise in evolving a generic transformation system. The scalability of the approach will be tested more realistically in this case.

B. Open Issues and Future Work

In this section, we discuss some open issues related to the usage of ALEPH system to derive analysis-design transformation rules. Almost all the current ILP systems, including ALEPH, enforce modes declarations for any clause hypothesized by the ILP system. That is, it is supposed to predefine the head and body of the target hypothesis.

ALEPH system uses the given background knowledge along with the given examples to generalize rules. Thus, it expects more than one positive example to learn the rule, otherwise it returns the unique positive example as it is (i.e., without induction of rules). However, occasionally, generating a rule from just one example might be desirable for future improvement as more examples emerge, as with the case of incremental learning. In the conducted experiments, many examples have not been covered using ALEPH because the relations represented are unique i.e. no similar example especially for the packages have many classes.

Our experiments revealed that when two artifacts have more than one relation of the same type (e.g. association). ALEPH induces a rule that considers only the type of the rule regardless of the number of instances. That is, when two artifacts (packages or classes) have two (or more) associations connecting each other, ALEPH shows only the type of the relation not their counts. This has an impact on the generated mappings since the number of associations among a set of artifacts surely influences corresponding design decisions. A simple example is shown in Fig. 8 to give a glance of this shortcoming. Fig. 8(a) (source model) depicts that there are four relations linking "Package1" to "Package 2". Based on these relations, a facade is introduced shown in Fig. 8(b) (target model). However, the induced rule by ALEPH considers only the type of the relation and ignores the count of the relations. Clearly, as manifested in this example, the count is important factor for introducing facades. For further discussion of the recorded limitations in this context, the reader may consult our recent work [38]. In future work, there is a need to investigate more the aforementioned open issues and to find appropriate solutions.

VIII. CONCLUSION

Different model transformation by examples (MTBE) approaches have been proposed in the literature. However, none of the proposed approaches tried to tackle the analysis-design transformations problem using ILP. Moreover, none of the proposed approaches considered reusing designers' expertise manifested in previous design effort in proposing design options to given software requirements. In this work, we target building a software design-support system by using ILP to induce transformation rules from available requirement/design pairs. The idea is to use existing knowledge (manifested in the given examples) to automatically derive a set of model transformation rules.

We conducted experiments using 34 systems with different sizes and form different sources. The systems were divided into learning and validation sets. The obtained performance

measures show that the approach is promising. The more examples presented to the system, the more trustful rules the system can generate.

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Software Refactoring Approaches: A Survey

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Abstract—The objective of software refactoring is to improve the software product's quality by improving its performance and understandability. There are also different quality attributes that software refactoring can improve. This study gives a wide overview of five primary approaches to software refactoring. These are two clustering approaches at class level and two at package level, as well as one graph transformational approach at class level. The research also compares the approaches using several evaluation criteria.

Keywords—Software refactoring; refactoring tool; machine learning; hierarchical clustering; graph transformations

I. INTRODUCTION

Due to its properties in a real-world environment, as well as changes to requirements, software needs to evolve, leading to both improvements and alterations. Therefore, the software becomes increasingly complicated and changes from its original design in some way. Adding features generally deteriorates the product's design, and the program therefore becomes more complex as it evolves. Consequently, the product's quality decreases [1][2][3]. This means maintaining the code is a vital task, as it decreases the software's complexity. The maintenance of software is considered one of software development's major parts.

A vital kind of maintenance is a process called refactoring. This is defined as a method for restructuring a current software system or body of code. This refactoring is carried out in the system/code of the internal structure to carry out improvements without altering external behaviour. As a result, software projects using the refactoring process discover reductions in the code base's complexity[2]-[4].

Crucially, there is no single definition of software refactoring that is universally accepted. It is merely the process of altering the internal structure of a software system without changing its external behavior [5][6]. In doing this, the refactored code can have optimised object-oriented features, including encapsulation, polymorphism, and inheritance, that can improve the quality of the code's maintainability, reusability, and modifiability. Software refactoring's key purpose is, in most cases, to improve the quality of a program by decreasing any shortcomings in quality, such as code smells, anti-patterns, and anomalies [7][8][9].

Therefore, the most significant motivation for refactoring is to increase the software product's quality. The major quality aspects of a software product are its understandability, extensibility, and maintainability, which can be developed by software refactoring without changing the software product's functionality [10].

It is vital to point out that the refactoring process consumes time. It also reduces the internal complexity of software because it requires an effort to first identify where to carry out the process in a given system/code and then a decision about what refactoring approach is the best to apply [11]. Furthermore, a common concern is the effect the process has on the program's performance, as the change may make it run more slowly [12]. In addition, it means the software is more capable of performance tuning [13].

Over the past fifteen years, researchers have contributed a great deal of knowledge and many concepts to the field of software refactoring, which cover various angles and different phases of software development activities, such as software design, requirement analysis, integration, implementation, maintenance, and testing [14]. The term *software refactoring* is very much associated with, and used regularly in, coding activity (generally known as code refactoring). It is therefore necessary to gain the right skills, knowledge, tools, and techniques to benefit fully from software refactoring [13], [14].

A wide range of techniques and formalisms are proposed in software refactoring to deal with restructuring and refactoring, such as software metrics, graph transformations, and assertions. This refactoring can be carried out either manually or by using various supporting tools. Many of the available tools can automate the different aspects of refactoring [15].

A number of recent papers on the three fundamental software refactoring approaches, including the clustering approach at class level, the clustering approach at package level, and the graph transformations approach, will be presented in this short survey work. In addition, we will provide a comparison between the represented software refactoring approaches based on various existing evaluation criteria.

The structure of this paper is as follows: Section 2 will provide a literature review of the different software refactoring approaches and classify them according to their refactoring levels; Section 3 will list the evaluation characteristics; Section 4 will provide discussions and a comparison between the different approaches; and finally, Section 5 will explore a conclusion and future directions.

II. SOFTWARE REFACTORING APPROACHES

The software refactoring approaches presented here include a clustering approach at the class level, a clustering approach at the package level, and a graph transformation approach. We will both list and summarise them throughout this section. We

will also describe the mechanisms and features for each of the approaches.

A. Software Refactoring at the Class Level using Clustering Techniques

There are two important concepts at the software design stage, which are coupling and cohesion. The first of these, coupling, represents the various interdependencies among the software modules. However, a model's relative functional strength is indicated by its cohesion. Therefore, a software design should ideally possess low coupling and high cohesion.

The authors' objective in [16] was to use clustering techniques of different kinds that help to both maximise cohesion and minimise coupling. This means that software designers can easily refactor the software code at the class level. To maximise cohesion and minimise the coupling process, it is necessary to move some of these methods from one class in a system to another. The authors, therefore, used two approaches.

The first is refactoring at the class level. This is achieved by clustering a fixed number of different classes, which means there is a movement of the method from one class to another. The total number of classes, however, remains unchanged before and after refactoring. There are potential changes to the number of classes in the second approach, therefore, the number of classes in a system can be different before and after refactoring.

Clustering is a technique generally used to group all similar data sets into the same cluster. Other dissimilar entities, however, are grouped into different clusters. The greatest advantage of such a technique is that it can help to identify items that are unstructured.

A method to identify unstructured software code at the class level was proposed by the authors. In the method, a total of three different clustering techniques were utilised for identification. These three are the single linkage algorithm (SLINK), as well as the complete-linkage algorithm (CLINK) and the weighted pair group method, which uses arithmetic averages (WPGMA). An additional algorithm used is the adaptive k-nearest neighbour (A-KNN), and a comparison between the A-KNN technique and the other three clustering techniques (SLINK, CLINK, and WPGMA) was performed by the authors. The results of this comparison show that software structuring at the class level that uses A-KNN has a competitive performance with lower computational complexity when compared to the other clustering techniques, SLINK, CLINK, and WPGMA.

1) The authors' clustering process

All the entities, as well as the attributes, must be specified in the clustering process. Entities are those items needing to be grouped. It is considered that the methods are those entities in software refactoring taking place at the class level process. The authors decided that the methods are entities, as the main computational elements of the classes are done in the methods. The entities are the methods necessary to put them into clusters.

To put clustering entities into clusters, all the features and attributes of these entities must be extracted. These features and attributes are utilised to measure the relationship between two entities and how closely they are related. The entities and the methods in the case are all similar if they share more common features and attributes. The authors consider the class data members as features for the entities. The number of times the method has accessed the data members is known as the feature value.

The authors used an entity-feature matrix to represent the relationship. The rows found in this matrix represent the methods and columns that represent the data members. In this matrix, there are three types of matches utilised for any two of the entities. The first type is n-0/0-n. This means that the two entities have no-match, and so are dissimilar. The second type is n-m. This means that the two entities share at least one feature. The third type is a 0-0 match. Here, the two entities have no feature that is accessed by them. Generally, two methods will be in the same class if they are found to share many of the features. This means they are closely related to each other and this process will make the code more cohesive.

To measure the similarity between the two entities/methods, the authors used a coefficient known as a resemblance coefficient. This is used to determine the similarity of the matrix's values. The formula for the resemblance coefficient is given by:

$$\text{Coeff} = \text{similarity actor} / (\text{similarity actor} + \text{dissimilarity actor})$$

The authors used three clustering techniques for the data clustering, which are SLINK, CLINK, and WPGMA. These are examples of agglomerative hierarchical clustering methods. The agglomerative process begins with the entities/methods taken as individual clusters. At each step, the closest pair of clusters merges until only one of the clusters is left.

The difference between the three techniques is in the way the distance between the clusters is computed. The distance between the nearest pair of elements is the distance between the clusters in SLINK. The similarity between the two clusters in CLINK is the similarity between their most dissimilar members. The average of the various distances between all the pairs of elements is the distance between the clusters in WPGMA.

The authors, besides using these clustering techniques, used the A-KNN algorithm. The first step of A-KNN is the same as in the previous techniques, as it considers each method as a cluster. As an additional step, the algorithm utilises a labelling approach. Thus, each method has a unique label that can be used as an identifier to the cluster. There are different values of K that can be utilised in the A-KNN algorithms. The major advantage of the A-KNN algorithm is that it reduces the number of computations when compared with the previous algorithms.

2) Two refactoring approaches at the class level used by the authors

The authors used two approaches for refactoring at the class level.

a) Refactoring at the class level that uses clustering with a fixed number of classes

The total number of classes remains unchanged in the system with this approach, both before and after refactoring. The entities are those methods that need to be put in a cluster and the classes are the clusters. Therefore, the number of clusters is the number of classes needed in the system. A method is assigned to a class based on the similarity value. The value is calculated by the number of instances utilised by the methods. So, if method X uses a total of three instances from class A and two instances from class B, method is assigned to the cluster that represents class A.

As an overview of this similarity matrix, each of the methods will be in a row and each of the classes will be in a column. The similarity matrix value between the method and the corresponding class is the total number of instances of this class used by this method.

b) Refactoring at class level by utilising clustering with an adaptive number of classes

There will be potential changes to the number of classes in this approach. The total number of classes in a system may be different both before and after refactoring, so there are no restrictions on the number of classes in this approach.

3) Results

The authors conducted experiments to find out how effective their proposed approaches proved to be. Both approaches were software refactoring at the class level. When a comparison of these two approaches was made, the authors found that the first approach (Approach1) gave the same distribution for the methods inside the classes as was the case in the original source code. This method can, therefore, be used as an automatic method to check the consistency between the distribution for the methods inside the classes in the original source code and the distribution that was produced by Approach 1.

They found that the second approach (Approach 2) suggested there was a different distribution for the methods inside the classes which decreased the value of the lack of cohesion in methods (LCOM) metric in the system. This approach, therefore, increases the original code's quality.

Thus, the first approach is generally both easier and more simple than the second one. Furthermore, the first approach does not require any extra effort or computation. The second approach, however, improves the original code's quality and provides better refactoring suggestions than the first one.

B. Software Refactoring at the Package Level using Clustering Techniques

The authors' objective in [17] was to carry out an investigation of software refactoring at the package level, which was done by utilising clustering techniques. This research helps to identify any ill-structured packages, and their approach helps to create a balance between intra-package cohesion and inter-package coupling. Thus, software designers who use the authors' approach can refactor their software easily at package level. In the same way as the previous

paper [16], a comparison is made of the behaviour of four differing techniques, which are SLINK, CLINK, WPGMA, and A-KNN, but this time it is to identify any ill-structure at the package level instead of the class level.

1) Clustering process

The same clustering process was used as in [16], but with a different context. Classes are chosen as entities for software refactoring at the package level. This means that the entities are the classes that need to be put into clusters. At the class level, however, the methods are chosen.

The attributes of the entities must be extracted in order to put these entities into clusters, as stated in [16]. The relationship between the two entities is indicated by their features. So, if the two entities share features that are more common, they will be similar. The authors utilised the methods as attributes for the entities/classes for refactoring at the package level, however, they used class data members as attributes of refactoring at the class level. The number of times the class accessed the method that was represented by an attribute was used for the features value, while the number of times the method accessed data members was the feature value for refactoring at class level.

With the package, the number of times that class was used as a class attribute inside it indicates the similarity between a package and a class. In other words, at class level, the similarity that exists between a method and a class is the number of times that class is used by the method.

The authors used the entity-feature matrix to represent the relationship between the entities and corresponding features. The rows of this matrix represent the classes in the packages and the columns represent the methods, but for refactoring at class level, the rows in this matrix represent the methods and the columns represent data members. The authors used the same coefficient as in [16] to measure the similarity between two classes, which is a resemblance coefficient.

2) Two approaches for refactoring at the package level used by the authors

The authors used two approaches for refactoring at the package level:

a) Clustering with a fixed number of packages

There is movement of a class from one package to another in this approach, but the number of packages is unchanged. Therefore, the total number of packages is the same in the system before and after refactoring.

b) Clustering with a variable number of packages

There is movement of classes between the packages in this approach, with possible changes to the number of packages. Therefore, the total number of packages in a system may be different before and after refactoring. There is no restriction on the number of packages in a system in this approach. Therefore, new packages can be created and existing packages deleted after refactoring by this approach. More packages are necessary if there is a low similarity between the classes, and fewer are necessary if there is a great deal of similarity between the classes.

3) Results

When the A-KNN algorithm is used in the first approach, it increases the number of connections inside the package, and therefore improves cohesion as a result. This algorithm also decreases the number of connections to other packages, which means that the amount of coupling between the packages is reduced. The authors' conclusion was that A-KNN improves software quality by both minimising package coupling and maximising package cohesion.

In the second approach, all three clustering techniques—SLINK, CLINK, and WPGMA—suggest the same solution. Also, the number of connections both inside and outside the packages is not changed by these three different techniques. The number remains the same both before and after the refactoring process. In other words, the A-KNN technique changes this number to increase package cohesion and decrease package coupling. Thus, software quality is improved by software refactoring at the package level by using A-KNN clustering with a variable number of packages. After carrying out a deep analysis of the results obtained, the authors concluded that A-KNN shows a competitive performance with lower computational complexity when compared to the three clustering techniques, SLINK, CLINK, and WPGMA.

C. Graph Transformation Approach to Refactoring

The paper primarily considers the methods and concepts from the graph transformation theory to locate the dependencies between the various refactoring steps. The graphs are used as abstract representations for most of the model. As is evident, a graph contains a set of vertices V , as well as a set of edges E . It is important to highlight here that an edge in E has both a source and a target in V . Thus, the programs are represented as graphs to make them more understandable and refactorings correspond to the graph transformations' production rules. The authors point to the use of graph transformations as a way of reasoning about the dependence that exists between refactorings. Moreover, the graph transformation approach aids in the sequential dependencies analysis between refactorings [18], [19].

To improve the design, we need to discover the correct sequence of refactorings from a given set of refactorings. To do this, the construction graph must be set by representing the set of proposed refactorings as nodes in the graph (G). The edges of the graph represent the various dependencies or conflicts that exist between the different refactorings in the set of refactorings that is proposed. After this construction graph has been completed, there is a highly formal way to represent all the potential interactions between the refactorings. This constructed graph will help by giving a clear summary of the refactorings proposed. It also enables us to find the dependencies between them, as well as their form and critical pair analysis technique.

The graph transformation rules, which are $p: L \rightarrow R$, are used to detect the dependency between the instances of type graphs. In these rules, L is the left-hand of the rule and R is the right-hand. L represents the preconditions of the rule in the transformation rule, while R describes the post conditions. There is an intersection between L and R that must be very

clearly defined. The preconditions and post conditions have to be formulated, as was previously mentioned, and then checked both before and after the refactoring process is applied [20], [21]. The steps taken by the authors were:

- To represent the system as a graph.
- To represent the model refactoring as a graph transformation.
- To represent the individual refactoring steps as the nodes of a graph. "The edges represent the dependencies or the conflicts between the refactorings in the proposed set of refactorings."
- To search for an optimal path that represents the best possible sequence of the refactoring steps. "Searching problem for optimal sequence" by using metaheuristic algorithms.

The authors of this paper [20] have focused on working out how the refactoring process can be formulated as a graph. Thus, they have proposed a local formulation of this refactoring that is based on graph transformation. The authors used the graphs to represent the software architectures at the class level in this research work. For the formalisations of the refactoring operations, the graph transformation was used. Their primary goal was to provide an automated process to select refactoring sequences that are appropriate and to formulate this as an optimisation problem by utilising the ant colony optimisation (ACO). This is a paradigm for the design of metaheuristic algorithms for the various combinatorial optimisation problems.

III. EVALUATION CHARACTERISTICS

In section 2 we described the software refactoring approaches. In this section, we will list the evaluation characteristics (see TABLE I) that we used in the comparisons between the approaches.

A. Objective

This characteristic will determine the objective and aim of the approach. For example, the authors propose approach X, as they want to address maintainability, and someone else would like to address another performance issue.

B. Level of Refactoring

This will determine what the aim of the software refactoring approach is. It will, therefore, determine whether this proposed approach will address the appropriate refactoring level. Here, the approach that is proposed should determine the appropriate level of refactoring to apply.

C. Tool-Supported "Supportability"

The best way to refactor software code is, in most cases, manual refactoring because altering these codes requires human consideration. The refactoring tools can improve the quality of software, aiding in carrying out automated changes in the software code. The tool-supported characteristic will, therefore, indicate whether the proposed approach possesses a tool support. If so, the main characteristic of this tool is highlighted, such as its usability or efficiency.

TABLE I. DEFINITION OF THE EVALUATION CRITERIA

Characteristic	Brief description
Objective	<ul style="list-style-type: none">• Determines both the aim and the objective of the approach• What is the author's main objective in using this approach?• What do they aim to reach?• What performance issues do they want to achieve with this approach?
Level of refactoring	<ul style="list-style-type: none">• Determines what the proposed approach is addressing, and at which refactoring level• At which level is it appropriate to apply the refactoring?
Supportability	<ul style="list-style-type: none">• Indicates whether the proposed approach possesses tool support• Is this a tool-supported approach?
Constraint	<ul style="list-style-type: none">• Describes what occurs to the software artifacts while the software refactoring processes are taking place• How many software artifacts are there before and after the refactoring process?
Underlying concepts	<ul style="list-style-type: none">• Which algorithm type is used by the approach?
Complexity	<ul style="list-style-type: none">• Determines the complexity of an approach; a higher complexity approach uses both a complex formula and an algorithm• How complex are the refactoring steps?• What is the complexity of the algorithms used?
Validity	<ul style="list-style-type: none">• Determines whether the proposed approach is a valid one or not; explains whether the approach can be applied to the real system• Is this a valid approach?• Can the approach be applied to the real system?

D. Constraint

A software artifact is an element of a software project, which includes images, class, documentation, modules and package. This evaluation characteristic, therefore, highlights the total number of artifacts there are before as well as after refactoring.

E. Underlying Concepts

This characteristic indicates the algorithm type that is used in the proposed software refactoring approach.

F. Complexity

If the software refactoring approach uses a complex formula and algorithm, the approach is said to have a higher complexity. This means the complexity measures how complex the refactoring steps are.

G. Validity

The characteristic of validity will determine whether the proposed approach is a valid one or not. Therefore, it will explain whether this approach can be applied to the real system.

IV. DISCUSSION

An important criterion for evaluating the different approaches is objectivity. This characteristic determines both the aim and objective of the approach. The main objective of the clustering approach is similar at both the class and package

levels. The aim of clustering at the class level is to identify the unstructured software code and then structure it in an improved way that can make it much more understandable. This would, as a result, give it high maintainability. The aim of clustering at the package level is to identify ill-structured packages and find a balance between package cohesion, on the one hand, and package coupling, on the other. The primary objective of the graph transformations approach is to improve the system's performance (scalability).

When it comes to the level of refactoring, the first method proposed in the first paper clearly addresses the software refactoring done at class level. The authors [16] used two approaches for refactoring, and both are at class level. The authors [17] also used two approaches for the second method of software refactoring, and both were at the package level, which helped to identify the ill-structured packages. Therefore, it is at the package level that the graph transformations approach will most likely address the architectures at class level.

Generally, the clustering approaches do not have a fully tooling, supported "supportability" at both the class and package levels. They are using some tools in the intermediate steps, but there is no tool to do the whole of the refactoring process completely. The graph transformations approach uses the GT tool.

In terms of the constraints, we will highlight what happened to a number of the software artifacts while the software refactoring processes were taking place. The total number of classes remained the same before and after refactoring when it came to refactoring at class level. In this instance, clustering was used with a fixed number of classes, but there is no restriction on the number of classes when refactoring is done at class level, where clustering is used with an adaptive number of classes. At package level, where there is clustering with a fixed number of packages, the total number of packages remained the same both before and after the refactoring process. There is, however, no restriction on the number of packages with a variable number of packages. It is most likely that the graph transformations approach will increase the number of classes after the refactoring process has been completed.

For the underlying concepts, the authors used the clustering algorithms, SLINK, CLINK, WPGMA, and A-KNN, for the task of clustering and to compare the behaviour of four different algorithms. The authors concluded that, in both cases, A-KNN showed a competitive performance with a computational complexity that was lower when compared with SLINK, CLINK, and WPGMA. The graph transformations approach utilises the theory of graph transformation as one of its main concepts.

The characteristic of complexity indicates what algorithm type is used by the software refactoring approach that is proposed. The first and second methods, with their differing approaches, are using different clustering algorithms. The results obtained reveal that the software structuring, by using A-KNN, shows a competitive performance with a lower computational complexity when compared with the other clustering algorithm. The question is still "What is the best

value of k to choose?" The findings indicate that the best results were achieved with $k=3$, however, this may not always be the case. It is difficult to map the class in the graph transformations approach and to define the precondition and post condition.

We can see that in the validity aspects, the clustering approach may not be valid. This is because the approach for the test at class level was carried out on an open source system. That project is called CSGestionnaire. Even at the package level, the test was done on the Trama project. Generally, we can say that these approaches are still valid for the small system, but this is not the case when it comes to the real complex system.

V. CONCLUSIONS

The technique of software refactoring can transform the different types of software artifacts to enhance the internal structure of the software without affecting its external behaviour. Refactoring is usually applied to improve the quality of the software after several features have been added. Researchers in this field have studied the various angles of refactoring and developed the right levels of evidence, skill, and knowledge. They have also published their findings in journals and conference papers to make them accessible to everyone.

This study's main purpose was to highlight some of the main challenges faced in software refactoring. Furthermore, the five refactoring approaches were discussed. These were two clustering approaches at class level and two at package level, as well as the graph transformations approach at class level. The evaluation characteristics that were used to compare the approaches were also described. Finally, researchers have contributed a great deal to the software refactoring field over the last 15 years, but there are many unresolved issues that will need to be addressed in the future. The gaps that have been identified and the significant contributions that have been made can guide researchers regarding the best areas on which to focus. This can save time and effort as well as resources, and reduce the need to reinvent the wheel.

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Investigating Clinical Decision Support Systems Success Factors with Usability Testing

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Abstract—Clinical Decision Support Systems (CDSS) have been used widely since 2000s to improve the healthcare quality. CDSS can be utilized to support healthcare services as a tool to diagnose, predict, as well as to provide clinical interpretation, alert, and reminder. There are many researches of CDSS implementation on literatures but not many of them present the evidence of CDSS successful implementation. In spite of the potential use of CDSS, there are some researches that reveal the failures of CDSS implementation. This paper contributes to CDSS development by investigating and exploring CDSS success factors with usability testing. The testing involves participants from different types of backgrounds (physicians, IT developers, and students). The participants are being asked to experience three different CDSS to predict cardiovascular risk factors. The result of the research shows that involving different type of users give more insight to design process. It can be concluded that user center design is very critical to produce successful CDSS.

Keywords—Clinical decision support systems; success factors; user; usability testing

I. INTRODUCTION

The background of this research starts from the widespread development and use of information technology to support decision making in the health field, also called as: Clinical Decision Support System (CDSS). This study aims to find out the understanding of CDSS from the perspectives of physicians (such as: doctors and prospective doctors/medical faculty students) as well as understanding from the information technology staffs (such as: IT developers, lecturers and students of information technology department). We also investigate the public's understanding of clinical decision support system. The physician/medical staff is chosen as representative of the experts from the content, i.e. health perspectives, while IT developers as the representatives of expert who develop the CDSS.

This research is important to find out the extent to which CDSS usage and benefits from participants' point of view. The focus of CDSS application in this study is for the detection of chronic diseases, i.e.: cardiovascular disease. Chronic diseases provide a greater public health burden than

acute illness because it requires more visits and medications [1]. Thus the use of CDSS for chronic diseases prediction is expected to reduce the cost of treatment and finally can decrease the mortality caused by chronic diseases. In this paper we compare three CDSS to predict cardiovascular risk using usability testing. Those three CDSS have different interface and indicators to perform calculation of cardiovascular risk factors.

The rest of the paper is organized as follows. Section 2 provides a brief review of existing CDSS research. Section 3 presents the method used in this research and Section 4 describes our findings. Finally in Section 5, we conclude the paper and state our future work.

II. CLINICAL DECISION SUPPORT SYSTEM

A. CDSS Application

CDSS is a tool with electronic media used to determine diagnosis, clinical interpretation, trends, alerting, reminder, predictive analysis with applications (services or interfaces) which is connected to the data. Another definition of CDSS is system that provides information to medical personnel, patients or individuals or populations, to produce faster, more efficient, better health outcomes for both individual health services and the health of a population [2]. From the above definition, it can be concluded that CDSS has the main objective to support various clinical functions, such as: providing documentation and clinical coding, organizing clinical complexity, storing and maintaining patient databases, tracking patient orders, monitoring and tracking health condition, as well as used for preventive measures disease.

In the following discussion, we present some examples of CDSS applications that have been developed and implemented in the real world, as follows:

- ATHENA. Athena is a CDSS application developed in 2002 as a tool to provide guidelines for people with hypertension. Athena helps patients in controlling blood pressure and recommends appropriate treatment options for patients. Athena also provides information

on hypertension medications and protocols related to hypertension management. The Athena system is designed independently so that it can be integrated with various electronic medical record systems (Electronic Medical System/EMS); thus Athena can adapt in various health information systems. The effectiveness, accuracy, and success of Athena's implementation have been studied and examined in various studies [3], [4]. It can be concluded that the use of Athena supports the effectiveness of treatment for hypertension disease.

- ISABEL. Isabel is an application for web-based decision support system developed in 2001. Isabel can be used by patients of all ages, from birth to old age. The Isabel database provides a wide selection of major specializations, such as internal medicine, surgery, obstetrics and gynecology, pediatrics, geriatrics, oncology, toxicology and bioterrorism. Isabel produces a diagnosis for a set of clinical features, such as: symptoms, signs, test results and investigations, followed by recommended medication recommendations. The Isabel system is linked to the EMR to make it possible to extract an existing diagnosis as well as for patients with other specific data. The system also provides features to help clinicians answer their questions with the latest information and knowledge from textbooks and journals. Isabel has been extensively validated and shows good results for improving clinical cognitive abilities, improving patient safety and improving the quality of patient care [5].
- LISA. Lisa is a CDSS consisting of two main components: (1) A decentralized Oracle database: it contains all patient information about the treatment schedule, blood test results and toxicity, prescribed dosage of medication. The Lisa database is accessible to health professionals from different sectors and locations; (2) Web-based decision support module, using PROFA technology as an application development guide. In this module contains information on treatment dose advice and focused on long-term care related to disease whose treatment doses should be monitored and adjusted continuously; as the effects of treatment vary between patients with each other (e.g. for chemotherapy treatment). Lisa is important for different type of therapy, as many cases of dosage errors in medical practice [6]. Author is [7] mention that Lisa has been evaluated and accepted by clinicians.

B. Relevant Research: Assessment of CDSS Application

Discussion of some of the above CDSS applications provides an understanding that computer-based CDSS has been applied since the early 2000s, even since the 1970s computer-based CDSS has been developed extensively [8]. Coeira in [8] also discusses several categories of computer-based CDSS based on the following objectives:

- Increase patient safety. CDSS has benefit for healthcare services by reducing medical errors, avoiding medical

advice as opposed to protocols, improving treatment sequences and tests.

- Improve the quality of health services. The usage of CDSS provide benefit by increasing the service time directly to patients, improving the regularity of use of guidelines and clinical procedures, accelerating and improving the use of the latest clinical findings, improving clinical documentation and patient satisfaction.
- Improve the efficiency of health services by reducing service costs by processing faster demand, reducing examination costs due to duplicate tests, reducing medical advice errors, repetition or error treatment patterns, and promoting the use of low-cost generic drugs that have similar effectiveness with non-generic drugs.

Fig. 1 shows the results of research on the benefits of CDSS conducted by the State of Victoria in Australia (Victorian State) [2]. It shows that top three benefits of CDSS from are: (1) reduction of time in health-care processing, (2) increasing the order of treatment related to administrative issues, (3) lowering the cost of paper forms. This shows that CDSS has a lot of potential for clinicians and health care providers to make decisions, although there are still many doubts from clinicians to use CDSS.

Despite of many potentials generated by CDSS as we have previously discussed, the CDSS impact on daily clinical practice is less likely to produce the desired results [8], [9]. Therefore building a CDSS is a challenging process because theoretical knowledge is not sufficient in its implementation in the field. Thus, this study is conducted to investigate the users' understanding of CDSS's benefits, but also to identify what factors lead to CDSS success and failure. Furthermore, the results of the study are expected to improve the efficiency of CDSS development and use in the practice of daily health services.

Other research also mention that the CDSS has been developed since 40 years ago, but the use of CDSS is still not fully utilized because it still does not meet the expectations of the organization [2]. Bright et al also mention that despite the argument that the use of CDSS can improve the quality of health services but evidence supporting this is lacking [9].

There is a research related to CDSS implementation that has been published in the Victorian Health Design Forum Report [2] discusses some of the weaknesses of CDSS in the area of clinical decision-making. The biggest factor that makes clinicians often hesitates or reluctant to use CDSS because clinicians trust their decision on "computer-based technology," but clinicians are still the ones responsible for clinical decisions, based on available information. Another CDSS weakness is the high price of CDSS systems, including development costs, maintenance costs, and training and support costs. Time required by the CDSS to interpret the data also contributes to CDSS weakness, and also the system can be accessed by multiple login so that the system must be developed into a trusted and effective system.

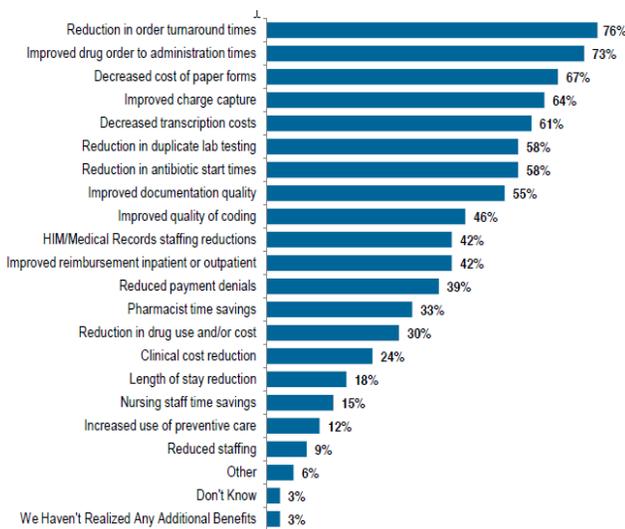


Fig. 1. Benefits of CDSS [2].

A Dutch CDSS study found that 65 percent of respondents (doctors and non-doctors) say that CDSS can make mistakes; 90 percent of respondents said that suggestions and recommendations produced by the CDSS should be checked again; and 79 percent said that those responsible for patient care were clinicians, not CDSS [2]. Nevertheless, 80 percent of respondents say that CDSS can generate suggestions and recommendations that help the performance of clinicians. Fig. 1 shows the benefits of CDSS based on research result.

Another study conducted by Bright et al. found that both commercial and local CDSSs were effective in improving the health care processes, however evidence of the advantages of CDSS use in terms of clinical, economic, workload and work efficiency decisions varied greatly [9]. Thus the impact of CDSS should still be examined and evaluated further.

Author in [10] found that about 45 percent of computer-based medical information systems fail because of the user's refusal to use them, even though technology in the system has been developed comprehensively. Other causes of CDSS failure include lack of computer skills, lack of motivation to change or add CDSS features, and loss of professional autonomy to maintain the use of CDSS. There is also evidence that CDSS services are not always used while available, due to lack of motivation from physicians to use them in clinical decision making [11].

There are related evidences that the usability of CDSS should be evaluated since it is determined as the successful implementation of CDSS [12], [13]. Authors in [12] evaluate usability of CDSS by conducting two phases of usability testing. Phase one employed think-aloud method to investigate positive outlook of the CDSS; while phase two evaluate the improvements of the CDSS based on the phase one feedback. The result of the study shows that usability evaluation using think-aloud protocol analysis and near-live clinical simulation are very successful as assessment method in order to refine the CDSS's usability and workflow. Authors in [13] find out that CDSS evaluation using usability engineering principles is very important to identify interface problems. The usability

evaluation conducted by Graham et al. [13] involves emergency physicians which then analyzed with structured method. They conclude that, user involvement should be putting into the early stage of software design.

Based on several findings of CDSS benefits and weaknesses, we carried out this research to investigate the success and failure factors of CDSS application, as discussed further in Sections 3 and 4.

III. METHOD

The research's design is descriptive analytical resulted from a qualitative research. The data obtained from 45 participants involved in usability testing using questionnaire and three CDSS application as instruments. To find the potential problems and benefits in CDSS applications, we employ usability testing. Usability defined as to what extent a product can be used by specified users to effectively, efficiently, and satisfactory perform tasks in order achieving specified goals [14].

After the usability testing performed, we gather 10 respondents in a Focus Group Discussion (FGD). In general, the process in this research is divided into three stages, i.e.: (1) data collection, (2) data processing, and (3) analysis and presentation of data.

A. Data Collection

The data collection method in this research uses survey methods with questionnaire as instruments. This is done because the survey results can provide data such as: behavior, feeling, trust, behavior, knowledge, ownership, personal characteristics, as well as other descriptive matters. The survey results may also provide data on the association. Questionnaires were distributed directly to respondents by collecting selected respondents and asking the respondents to use CDSS applications and fill out questionnaires based on behavioral scale. The Likert scale is used to find out the respondent's behavior using ordinal with value 1 to 5, i.e.: 5 for strongly agree, 4 for agree, 3 for hesitate, 2 for disagree, and 1 for strongly disagree.

Focus Group Discussion (FGD) is conducted after the survey method is completed, participants invited in the FGD are those included in the sample. FGD is a research technique for collecting data through individual comments and group interactions for a specific topic. FGDs are used to test the consistency of answers in the previous survey. Thus, the FGD is useful for data collection and simultaneously used as a validation of the questionnaire results, moreover FGD is useful to explore the thoughts of group of individual. Authors in [15] suggest that a sufficient number of efficient FGDs are three. However, in this research we involve 10 participants in our FGD.

The participants in this research consist of eight physicians, five IT application developers, and thirty two students from various background (we consider these students represent public). Thus, in total there are forty five participants required to take part in the study. Participants would also be required to provide demographical information, such as: age, gender, occupation, number of years in working

experience, highest educational degree obtained, information and computer literacy, and knowledge of CDSS. An initial meeting with the participants to introduce the research objective was held before the research. After that, participants are given access to experience three CDSS application for cardiovascular risk prediction. The discussion result of the research is presented in Section 5 of this paper.

B. Data Processing

After the data has been collected then it processed using statistical software. The qualitative data obtained from FGD results. Although FGD also has a biased tendency (e.g. one's opinion may be influenced by group opinion or vice versa), we still choose this method because we are interested in individual opinions and group opinions through interaction among respondents. In a group, one's opinion can trigger thoughts and ideas from other individuals so that they can dig in more input than if only interviewed individually. The questions in FGD only focus on the experience of the participants (usability testing) in using CDSS, and explore participants' opinions regarding the advantages and disadvantages of CDSS.

The question in the survey also should fulfill reliable measurement scale with Alpha-Cronbach value > 0.70 [16]. A measurement instrument is said to be reliable when it gives a consistent score result on each measurement. A measurement may be reliable but invalid, but an unbiased measurement is not valid if it is not reliable. This means that reliability is a necessary condition but not sufficient for validity. With reliability analysis, it can be seen the relationship between the question items in the questionnaire. Alpha-Cronbach value is used as internal consistency index of the overall measurement scale, thus the items in questionnaires which less than Alpha-Cronbach Value should be revised or deleted.

C. Data Analysis and Presentation

The data gathered from the research then analysed using Wilcoxon signed-rank test. Wilcoxon signed-rank test is non-parametric statistical hypothesis test used for comparing two related samples. By using Wilcoxon signed-rank test, we can find out the preference of participants. In overall, the questionnaire consists of five parts, i.e.:

- **Part 1** participant's profile: name, occupation/job description (e.g. physician, IT developer, student), age, gender, last education obtained, years of experience in last occupation.
- **Part 2** information and computer literacy: skills in using computer, time in using the Internet, knowledge of CDSS.
- **Part 3** experience of users while using CDSS application during usability testing: how the CDSS application support the work, the benefits and the weaknesses of the CDSS application to support the daily work.
- **Part 4** user's feedback of CDSS application, for components: readability, content design, navigation and help, efficiency and flexibility, and error recovery.

- **Part 5** user's opinion of CDSS application after using it

IV. RESULT AND DISCUSSION

We recruit the participants of our research from different occupation and education background, i.e.: physicians, IT developer, also students from medical and IT school from our private university, as shown as in Fig. 2. The participants in our research consist of 45 people, with gender composition of 78% female participants and 22% male participants, as described in Fig. 3.

The age of range of participants are varied from 19 to 35, with mean 22.03 years old (deviation standard 3.745). All of participant has no background knowledge of CDSS, although all of them have good computer and internet literacy. In a week, the participant using internet averagely 26.45 hours, minimum 2 hours and maximum 144 hours per week.

After the participants fill in the demographical information, then they are being asked to experience the CDSS applications. We provide three CDSS application, namely: Application A, Application B, and Application C. Fig. 4, 5, and 6 shows the applications' interface.

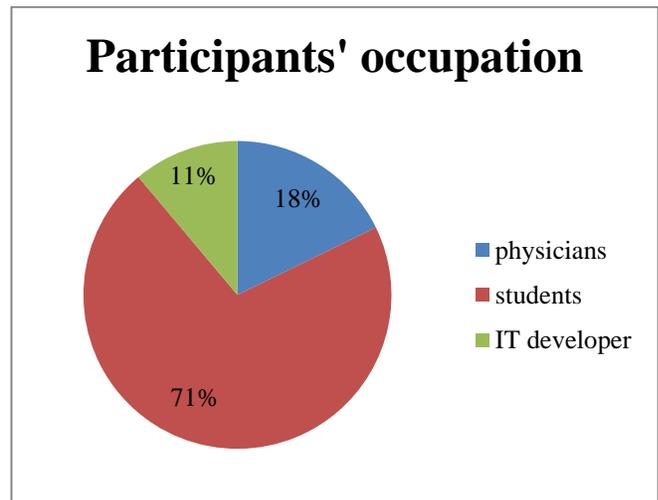


Fig. 2. Participant's occupation in graphical diagram.

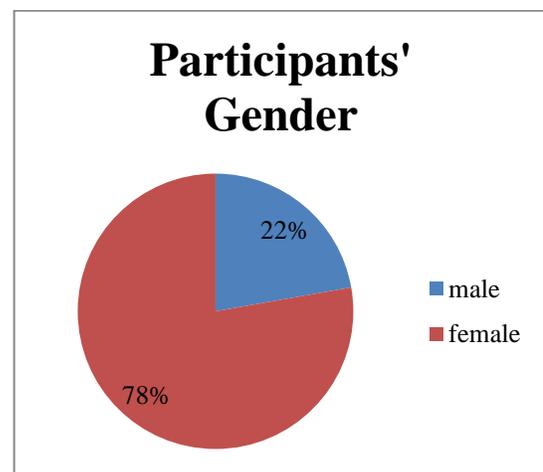


Fig. 3. Participant's gender in graphical diagram.

A. Application A

This application is developed to calculate cardiovascular detection risk for individual with range of age 30-75 years old, and never been diagnosed atherosclerotic disease. This application has result in percentage as a result of calculation from Framingham, Joint British Societies (JBS)/British National Formulary (BNF), and ASSIGN.

This application uses six variables to calculate cardiovascular risk factors, i.e.: (1) age, (2) gender, (3) smoking status, (4) systolic blood pressure (mmHg), (5) total cholesterol (mmol/L), (6) HDL (mmol/L). The prediction is a result of calculation of ten years period from present time. Fig. 4 shows the interface of application.

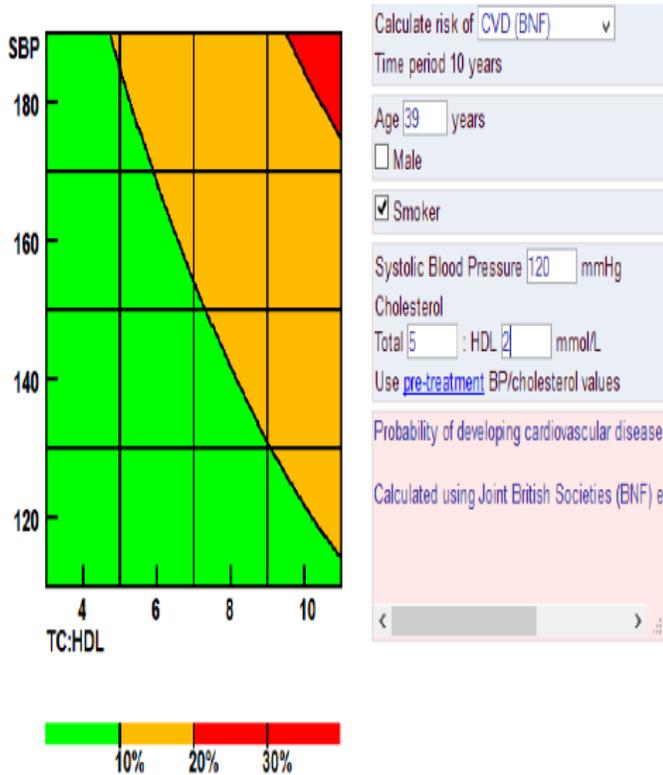


Fig. 4. Interface of CDSS application (A).

B. Application B

Application B is a calculator to predict cardiovascular risk based on guidance from The National Heart, Lung, and Blood Institute (NHLBI) in the United States. NHLBI develops research, training, and education program to increase public health awareness and public health quality, related to heart, lung, and blood disease all over the world.

This application uses seven variables, i.e.: (1) age, (2) gender, (3) total cholesterol, (4) HDL, (5) smoking status, (6) systolic, (7) hypertension treatment status. The prediction is a result of calculation of ten years period from present time. Fig. 5 shows the interface of application.

Information about your risk score:

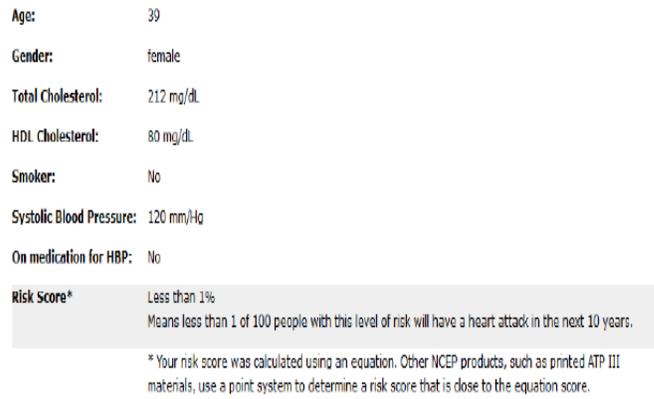


Fig. 5. Interface of CDSS application (B).

C. Application C

Application C is kind of CDSS to predict cardiovascular risk based on guidance developed by The National Vascular Disease Prevention Alliance (NVDPA) Australia. NVDPA is an organization as a result of joint collaboration from four important health organizations, i.e. Diabetes Australia, the National Heart Foundation of Australia, Kidney Health Australia, and the National Stroke Foundation.

This application uses eight indicator variables to calculate risk factor of cardiovascular disease, which are: (1) age, (2) gender, (3) systolic blood pressure, (4) total cholesterol, (5) HDL cholesterol, (6) smoking status, (7) diabetes status, (8) ECG LVH. Fig. 6 shows the interface of application.

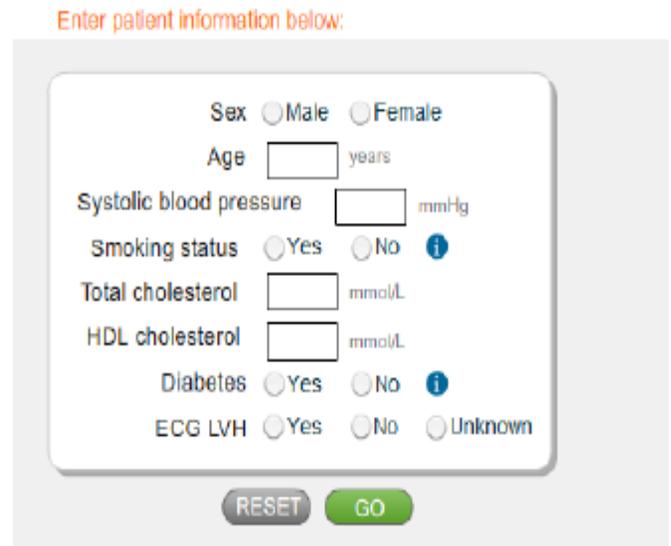


Fig. 6. Interface of CDSS application (C).

Table 1 present the variable indicators used by each CDSS application and top five opinions from the participants gathered from open question in the questionnaire and validated through FGD. The table compares three CDSS application, based on the variables and opinion gathered from participants.

TABLE I. USABILITY TESTING RESULT

App	Variables	Opinion from participants
A	<ol style="list-style-type: none"> Age Gender Smoking status Systolic blood pressure (mmHg) Total cholesterol (mmol/L) HDL (mmol/L) 	<ol style="list-style-type: none"> The user interrupts with the advertisements Not enough explanation to use the application The design of application should be more attractive The result of calculation is not easy to read Too many inputs (more complex than others)
B	<ol style="list-style-type: none"> Age Gender Total cholesterol HDL Smoking status Systolic Under treatment of hypertension status 	<ol style="list-style-type: none"> Enough explanation to use The application has feedback as expected The application provide sufficient details of inputs The design of application should be more attractive The application is quite simple and easy to use
C	<ol style="list-style-type: none"> Age Gender Systolic blood pressure Total cholesterol HDL cholesterol Smoking status Diabetes ECG LVH 	<ol style="list-style-type: none"> Best design among others Simple and attractive design The units of measurement should be compatible with general use The accuracy of the result should be tested Support physician work

We also rank the CDSS application based on the questionnaire, using Wilcoxon signed-rank test. We use Wilcoxon signed-rank test to compare the rank between two application, i.e.

- 1) Application B and C
- 2) Application A and B
- 3) Application A and C

Wilcoxon signed-rank test result between application B and C:

$$H_0 : \eta_{cvdrisk B} = \eta_{cvdcheck C}$$

Has given value of $z = -1.441$. Thus, we do one-tailed test, having hypotheses as follows:

$$H_i : \eta_{cvdcheck B} > \eta_{cvdrisk C}$$

We find that $p\text{-value}$ equal to $\frac{0.150}{2} = 0.075$, which is not less than $\alpha=0.05$, thus H_0 is accepted.

Conclusion: $\eta_{cvdrisk B} = \eta_{cvdcheck C}$ or the median score from participants for application B is equal to application C.

Wilcoxon signed-rank test result between application A and B:

$$H_0 : \eta_{cvdrisk A} = \eta_{cvriskcalculator B}$$

Has given value of $z=-0.961$. Thus, we do one-tailed test, having hypotheses as follow:

$$H_i : \eta_{cvriskcalculator A} > \eta_{cvdcheck C}$$

Thus, $p\text{-value} = \frac{0.337}{2} = 0.1685$, which is not less than $\alpha=0.05$, thus H_0 is accepted.

Conclusion: $\eta_{cvdrisk A} = \eta_{cvdcheck B}$ or the median score from participants for application A is equal to application B.

Wilcoxon signed-rank test result between application A and C:

$$H_0 : \eta_{cvdcheck C} = \eta_{cvriskcalculator A}$$

Has given value of $z=-2.308$.

Thus, we do one-tailed test, having hypotheses as follow:

$$H_i : \eta_{2 cvdcheck C} > \eta_{3 cvriskcalculator A}$$

Thus, $p\text{-value} = \frac{0.021}{2} = 0.0105$, which less than $\alpha=0.05$, therefore H_0 is rejected.

Conclusion: $\eta_{cvdrisk C} > \eta_{cvdcheck A}$ or the median score from participants for application C is bigger than application A.

From all of the test result above, we then validated the result by performed FGD. The FGD consists of 10 participants which randomly chosen from previous participants. It is confirmed that CDSS C is the best CDSS application chosen by the participants, followed by application B, and A. Fig. 7 shows the graphical information of CDSS usability comparison result.

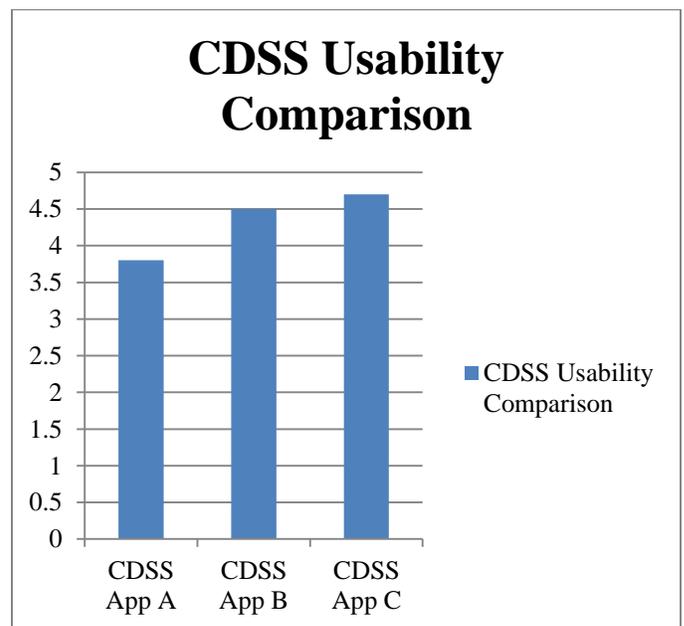


Fig. 7. Participants preference of three different CDSS.

V. CONCLUSION

This research provides contribution to evidence-based usability knowledge for CDSS. As the result of this work, we can develop usability guidelines and knowledge in order to implement a successful CDSS. We also identify several components that should be carefully considered and designed to optimize the benefit of CDSS.

The most important thing in designing CDSS is to understand who the users are. In this research, we have three different types of users, i.e.: physician, IT developers, and students as representative of public. Those three different types of users have different focus in assessing CDSS's usability, as shown in Table 2.

TABLE II. USABILITY ASSESSMENT FOCUS OF THREE TYPES OF RESPONDENTS

Physicians	IT developers	Students
The accuracy of CDSS result	The design of CDSS	Sufficient explanation to use the CDSS
Support physician's work in diagnosing patients	Simplicity and easy to use	Provide feedback while experiencing the CDSS
Unit system should be compatible with environment	The design should be attractive to use	Less complexity (less input), user friendly

Based on the findings in our research, we can conclude that the most important thing to implement a successful CDSS knows the users. Each type of user has different focus while experiencing the CDSS. Therefore, physicians, CDSS developers, patients, and public should be included in user center design in iterative design processes to share opinion and recommendations.

Our future work is to develop the CDSS application using guidelines that has been found from this research. The application then will be tested in real environment as comparison to this research.

ACKNOWLEDGMENT

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Design and Simulation of Adaptive Controller for Single Phase Grid Connected Photovoltaic Inverter under Distorted Grid Conditions

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Abstract—This paper presents an adaptive controller for single-phase grid-connected photovoltaic inverter under abnormal grid conditions. The main problem associated with the controllers of the grid-connected inverter is that they are tuned for some assumed values of the electrical grid parameters. However, when the parameters, such as voltage and frequency are changed or the grid is subjected to uncertain distortion, these controllers unable to track those variations of the grid parameters and handle the output power within the allowable limit. To overcome such problem, a suitable control strategy is proposed, which is based on frequency adaptive current control and an accurate grid detection. For validity confirmation, a controlled 3KW system, with specific features was designed and simulated. The simulation results confirmed that the strategy is an effective way of control.

Keywords—Single phase grid-connected photovoltaic inverter; adaptive controller; grid parameter variations

I. INTRODUCTION

The continuous increasing demands for electric energy, combined with the environmental pollution caused by the conventional electric energy generating units, has led to a worldwide concern on the grid-connected photovoltaic system (GCPVS) [1], [2]. Nowadays a high penetration of single-phase transformerless inverter really raises the concern about photovoltaic (PV) integration of low voltage. It is expected that the future of a single-phase GCPVS can not only maintain the stability and the quality of the grid but also have some ancillary functions, such as reactive power support and fault ride through capability. In that case, reliable control strategies and synchronization technique should be ready for PV applications [3]. The limitations in the classical controllers of the grid-connected inverter are that they mainly tuned for some assumed values of the electrical grid parameters. However, the parameters such as voltage and frequency can change. Therefore the control should be able to track those changes [4] in order to maintain the desired output current. A control structure for a single-phase single-stage grid-

connected PV system using a proportional-resonant (PR) current controller is proposed in [5]. The current injected into the grid has a low total harmonic distortion (THD) and unity power factor under different levels of insolation of sun. However, the control is tuned for 325V/50Hz voltage and frequency parameter. Moreover, the system efficacy is not confirmed for voltage or frequency other than this input parameters. A control strategy for a single-phase PV inverter is presented in [6]. The synchronization in this strategy is made with the so called dual transport delay based PLL (DTDPLL) controller. The performance of proposed DTDPLL controller is validated under varying frequency conditions. Though, it is not mentioned that this technique can be used under distorted grid conditions.

The main objective of this paper is to present an adaptive and effective controller for a single-phase single-stage transformerless inverter of PV system under abnormal grid conditions like the distorted grid. The proposed control strategy is based on the accurate grid detection and synchronization, in which the grid frequency is obtained by the simple method. The method is based on counting the period of the half cycle with respect to the zero-crossings of the grid voltage, thus the information of the frequency of the fundamental is estimated. Then, the frequency information inside PR current controller is online provided, using the estimated value. However, significant line voltage distortion can easily corrupt the output of a conventional zero-crossing detection (ZCD). Therefore, the ZCD of the grid voltage needs to extract its fundamental component at the line frequency. This task is made by a bandpass filter without delay. Additionally, the grid voltage amplitude information is obtained by the traditional method of RMS calculation.

This paper is organized as follows: In Section 2, the requirements of the grid-connected PV system is highlighted. In Section 3, the significance of the penetration of single-phase transformerless inverter for the grid-connected system is described. The control strategy of the single-phase grid-

connected PV system inverter is presented in Section 4. To verify the proposed strategy, a controlled 3KW/50Hz GCPVS, with specific features was designed and simulated, using

PSIM software tools. The simulation results are interpreted in Section 5. The conclusion is addressed in the last of this work.

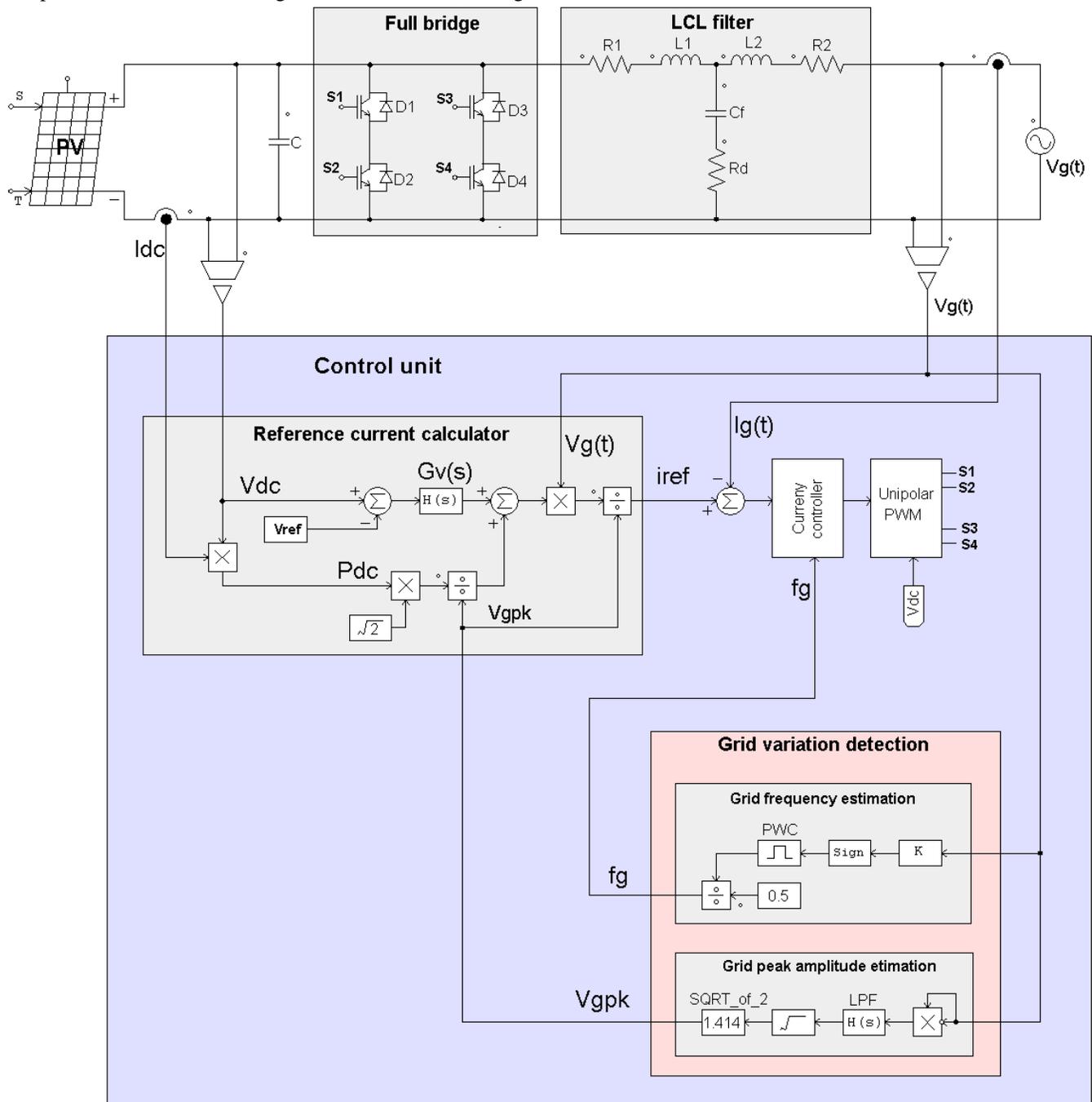


Fig. 1. Single-phase single-stage transformerless inverter of grid-connected PV system

II. REQUIREMENTS OF GRID-CONNECTED PV SYSTEM

The photovoltaic system connected to the grid involves two major tasks: a) it must be ensured that the solar panels are operated at maximum power point tracking (MPPT); and b) the injected current into the grid ($i_g(t)$) has to comply with some specific standards that are regulated by the utility in each country such as IEEE 1547.1-2005, VDE0126-1-1, EN 50106, and IEC61727. These standard deal with matters like total

harmonic distortion (THD) and individual harmonic current levels, injected DC current level and leakage current, the range of voltage and frequency for regular operation, power factor (PF) ...etc. [7]. The main requirements for the inverter to be connected to the grid are [7]-[9]:

- Voltage magnitude and phase of inverter must be same as a grid.

- The inverter output frequency must match the grid frequency.

III. SINGLE-PHASE GRID-CONNECTED INVERTER OF PV SYSTEM

While most of the current research concentrates on large-scale PV system (LSPVS), there appears to be the market for small-scale PV power generation has grown rapidly [9]. In addition, the market of residential PV power generations has grown rapidly in recent years by the encouragement of local governments and utility companies. Some authorities of renewable power have been launched stimulation programs to provide opportunities for homeowners, farmers, and small business owners to develop renewable electricity generation projects. With the help of such stimulation programs, a growing market exists for residential PV inverters. Many companies such as National Semiconductor and Enphase are expanding their business in the area of residential PV inverters.

Unlike LSPVS, residential PV (RPV) system require the inverters to be small, low-power and single-phase units [10]. The RPV, particularly low-power systems (up to 5kW), are becoming more important worldwide. They are usually private systems where the owner tries to get the maximum system profitability. So issues such as reliability, high efficiency, small size and weight, and low price are of great importance to the conversion stage of the PV system [11]. Aiming towards the achievement of this goal, the transformerless inverters are widely used. There are, many topologies of transformerless full-bridge inverters have been proposed [7], [12]-[14]. However, each of those topologies has some advantages and disadvantages, and it is difficult to narrate which topology is better than other. Therefore, the selection of a topology with low components can lead to less complexity of control, and more reliability and efficiency [7].

IV. A CONTROL STRATEGY FOR SINGLE-PHASE SINGLE-STAGE FULL BRIDGE INVERTER TOPOLOGY

The circuit structure of a simple inverter topology of PV system with included output filter and control parts are shown in Fig. 1. The series connected L_1+R_1 , L_2+R_2 and C_f+R_d that compose the LCL-type filter, attenuate the harmonics injected into the grid generated from the inverter with the pulse width modulation (PWM) technique [15], [16]. The DC output of the PV array is connected to the inverter through a filter capacitor (C_{dc}) in order to limit the harmonic currents in the array. The current controller sets the inverter output current, such that the desired reference current is injected into the grid. A synthesized AC output voltage is produced by appropriate switching control and consists of a controlled series of positive and negative pulses that correspond to the positive and negative half cycles of a grid sinusoidal waveform.

A unipolar PWM technique with a carrier frequency of 25 KHz is used as the switching controller. This is because this switching technique offers a higher efficiency and higher power output than bipolar switching technique [17].

A. Reference Current Calculator

The reference current calculator shown in Fig. 1 is used to convert the maximum extracted power from PV array to maximum current. The reference current (i_{ref}) is obtained in accordance with PV power per grid voltage parameters, as given by (1).

$$i_{ref} = I_{ref} \times ((u_g(t), v_g(t)) / V_{gpk}) \quad (1)$$

Where,

$$I_{ref} = (V_{dc} - V_{ref}) \times G_v(s) + (P_{dc} \times \sqrt{2}) / V_{gpk} \quad (2)$$

Where, I_{ref} is the DC reference source current, i_{ref} is the AC reference current, V_{dc} is the DC link voltage, V_{ref} is the reference voltage of the PV panels, $G_v(s)$ is the transfer function of the proportional integrator (PI) DC voltage controller, P_{dc} is the DC input power, $u_g(t)$ and $v_g(t)$ are the instantaneous grid voltage with and without filtering respectively, and V_{gpk} is the grid voltage peak amplitude.

The amplitude of the I_{ref} is generated on the basis of the error between the dc link voltage (V_{dc}) and the reference voltage (V_{ref}) of the PV panels. The maximum power point tracking (MPPT) algorithm is commonly used to vary V_{ref} according to the environmental conditions in order to keep the operating point of the PV panels close to the maximum power point. However, in this work, V_{ref} is assumed a fixed value close to the V_{dc} and MPPT will not be discussed in the paper.

B. Current Controller

It has been demonstrated in [4] that the proportional-resonant (PR) controller gives better steady-state and dynamic performance when compared with the classical PI controller. The PR controller tracks the current, introducing an infinite gain (G_{PR}) at a selected resonant frequency (ω_0) and it is expressed, as given by (3) [15].

$$G_{PR} = K_p + K_i \times s / (s^2 + \omega_0^2) \quad (3)$$

Where, k_p & k_i are the proportional and integral gain, respectively.

However, the infinite gain of the controller at ω_0 leads to an infinite quality factor of the system which cannot be achieved in either analog or digital control implementation. Furthermore, since the gain of an ideal PR compensator at other frequencies is low, it is not adequate to react either to grid amplitude or frequency variation [10].

C. Frequency Adaptive PR current Controller

The frequency adaptive PR (FAPR) controller is based on that, the frequency information inside the PR is online provided by the frequency estimator, (Fig. 2). In this way, the control system can be adapted to the frequency changes [4].

D. Grid Variations Detection

The grid variations detection unit is used to detect the values of the specified parameters (f_g, V_{gpk}) and to provide the reference current calculator with detailed information of the parameter changes [3], [4].

As shown in Fig. 1, it consists of two main parts, voltage peak amplitude calculator, and fundamental frequency estimator (GFE). In GFE (shown in Fig. 1), the sign function converts the ideal sinusoidal signal to a square wave with respect to the zero cross of the input signal. Then the pulse period counter (PWC), counts the period of the half cycle ($T/2$) of the input signal*. After that, the frequency is calculated by the “ $1/(2(T/2))$ ” formula. The V_{gpk} value is achieved by using the traditional method of RMS calculation.

When the ideal sinusoidal $v_g(t)$ is assumed, the grid detection structure presented in Fig. 1 is quite adequate to perform the control performance. The synchronization is accurately achieved with respect to the fundamental, as shown in Fig. 4.

When the distorted grid is assumed, an inaccurate synchronization occurs. The GFE cannot choose the exact zero cross point of the fundamental from many zero cross points existed in the input voltage signal, thus an incorrect value of grid fundamental frequency (f_g) can be provided. As a consequence, the adaptive tuning of the PR controller with respect to its resonant frequency ω_0 cannot be obtained. As a result of this, the current injected into the grid ($i_g(t)$) does not exactly have the same phase as the fundamental component of the grid (Fig. 5). This is, in turn, inconsistent with the requirements mentioned in Section 2. Therefore an accurate grid detection and synchronization is required.

E. Accurate grid detection and synchronization

The structure of the accurate grid detection is introduced in Fig. 3. The structure is based on adaptive bandpass filter (ABPF) with no delay (also called second-order generalized integrator (SOGI)) [4].

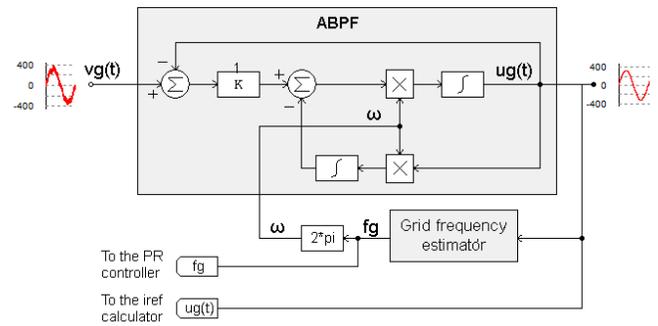


Fig. 3. Structure of the accurate grid detection.

The f_g and V_{gpk} values are estimated according to the filter output voltage signal ($u_g(t)$). The component $u_g(t)$ has the same phase and amplitude as the fundamental of the input voltage signal ($v_g(t)$), as it can be seen from Fig. 6.

The adaptive tuning of the ABPF is frequency dependent, thus an inaccurate synchronization can occur when grid frequency has fluctuations [4]. Therefore, the resonance frequency of the ABPF is adjusted online using estimated voltage frequency (ω) as provided by GFE.

V. SIMULATION RESULTS AND DISCUSSION

To confirm the control strategy analysis in the previous sections, a GCPVS shown in Fig. 1 with considering the parameters listed in Table 1, was designed and simulated, using (PSIM) software tools.

Fig. 4 shows a perfect performance of the system when $v_g(t)$ is assumed pure sinusoidal. As shown in the top of Fig. 4, the output power remains within the limit boundary of the PV power, even if the V_{gpk} changes from 240 to 320V at 0.5s, the insulation changes from 1000 to 700(W/m²) at 1s or the frequency changes from 50 to 55Hz at 1.5s.

Fig. 5 shows the output waveform of the system when the distorted grid is assumed and without using accurate grid detection. It is obvious from the figure that neither the $i_g(t)$ in phase with the $v_g(t)$ nor the estimated frequency equal the fundamental. Fig. 6 shows how the ABPF is able to generate a clean voltage signal $u_g(t)$ using a highly distorted input signal. As presented in Fig. 6, the $u_g(t)$ has the same phase and amplitude as the fundamental of the input signal. Fig. 7 shows a comparison of the $i_g(t)$ phase and the phase of the grid when ABPF is used.

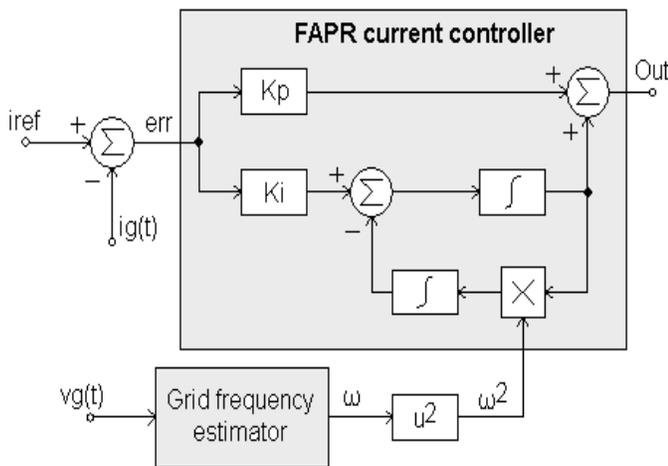


Fig. 2. Frequency adaptive PR current controller.

TABLE I. LIST OF PARAMETERS USED IN SYSTEM SIMULATION

Item	Parameter	Value
PV array	Module in Series and Parallel	23 and 2
	Irradiance and temperature	700-1000(W/ m ²), 25C°
	PV Output voltage	400V
	PV reference voltage (Vref)	390V
	Output power	3KW
Inverter	Switching frequency	25KHz
LCL filter	L1=L2 and R1=R2	3mH and 0.02Ω
	Cf and Rd	4.7μF and 10Ω
Grid	Voltage and frequency	240-320V and 45-55Hz

* <http://www.Powersimtech.com>.

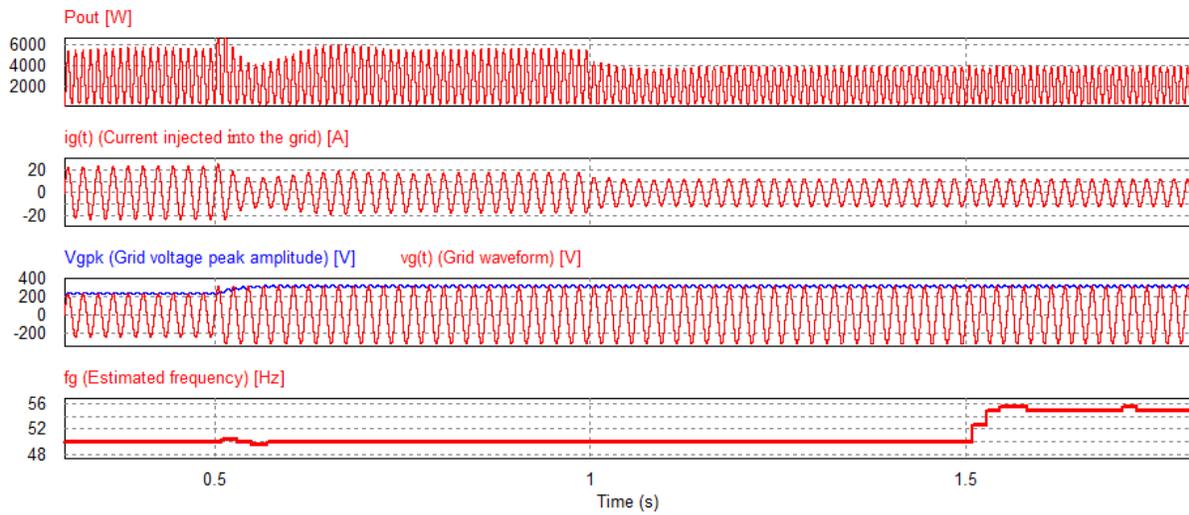


Fig. 4. System output waveform with pure grid assumption.

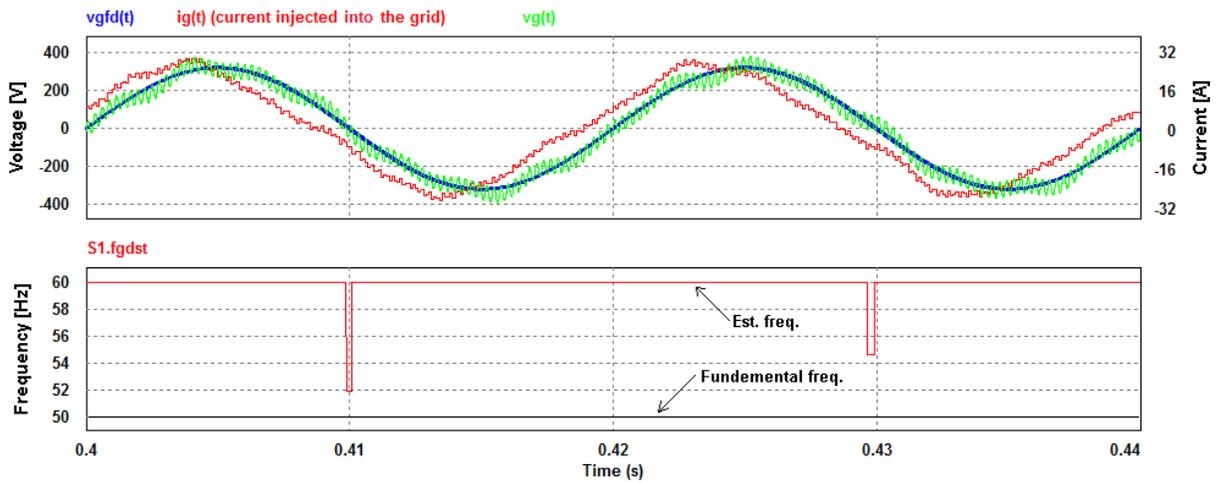


Fig. 5. System output waveform when the distorted grid is assumed and without using accurate detection: (top) Phase of the $ig(t)$ vs the actual phase of $v_g(t)$, (down) Estimated frequency vs fundamental grid frequency.

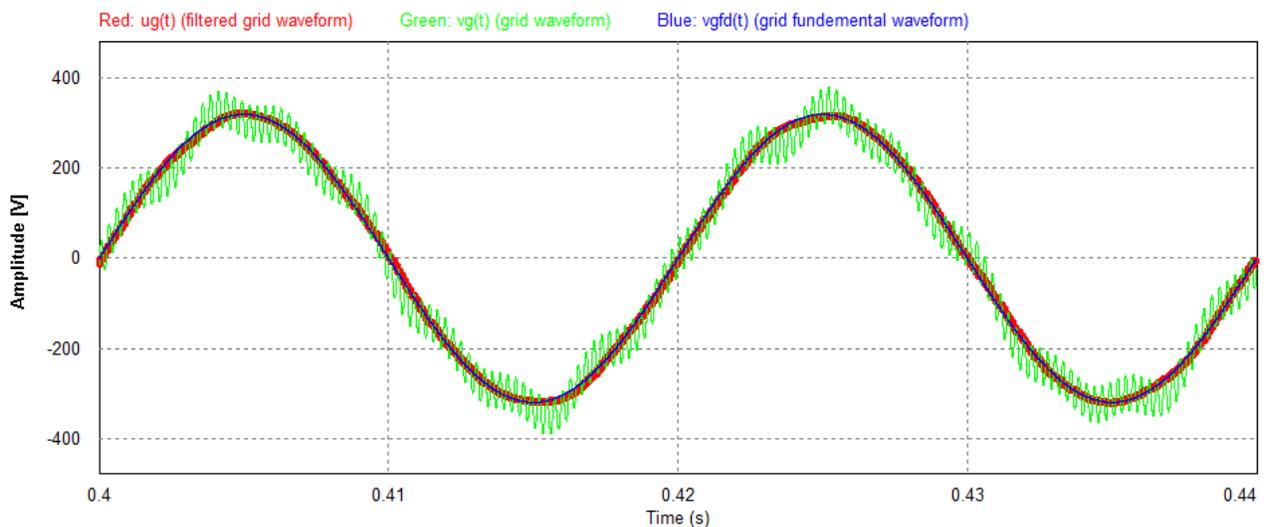


Fig. 6. Phase and amplitude of the ABPF output vs distorted $v_g(t)$.

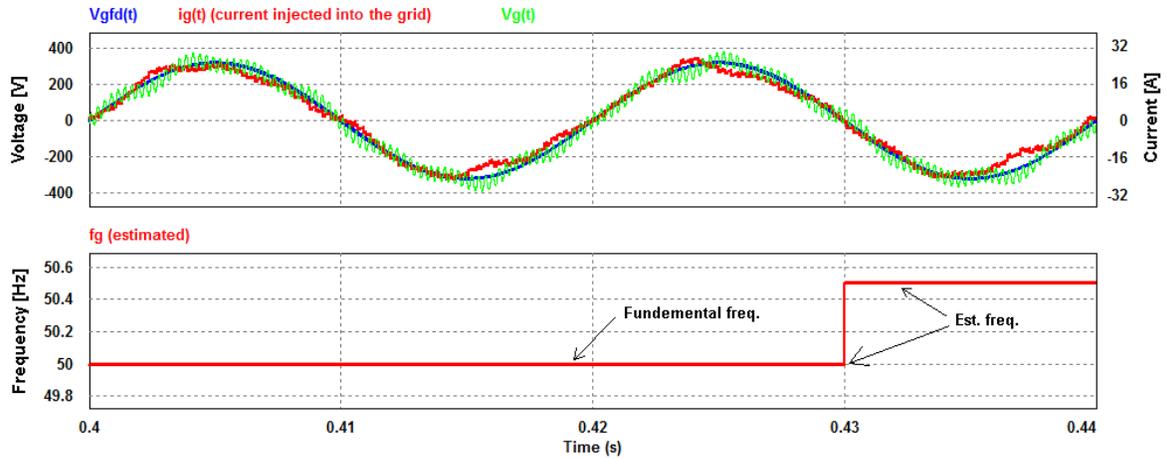


Fig. 7. System output waveform when the distorted grid is assumed and with using accurate detection: (top) Phase of the $ig(t)$ vs the actual phase of the $v_g(t)$, (down) Estimated frequency vs f_g .

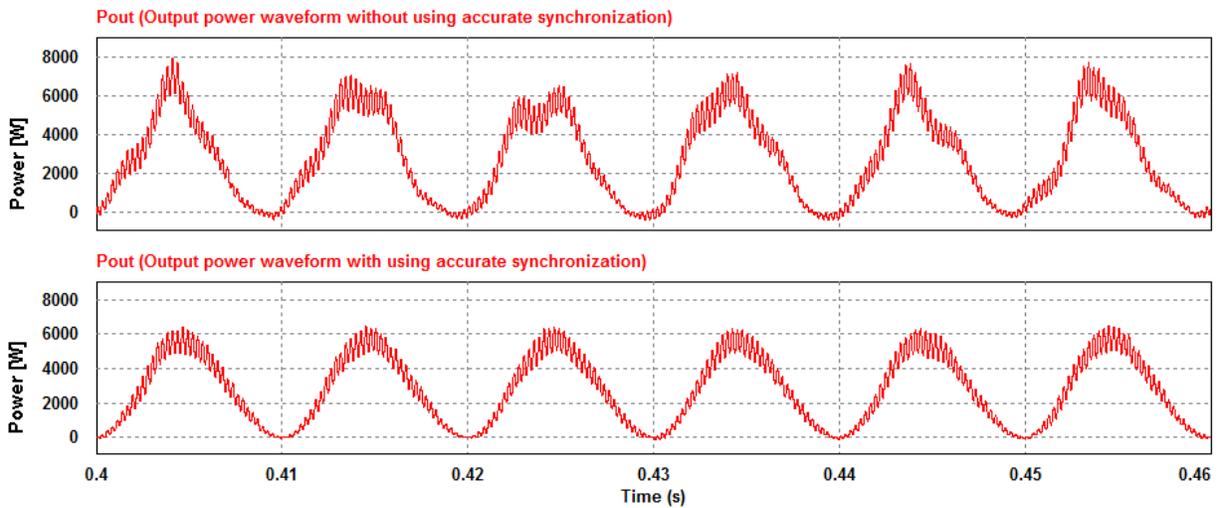


Fig. 8. System output power behavior when distorted grid is assumed: (top) Without using accurate grid detection, (down) With using accurate detection.

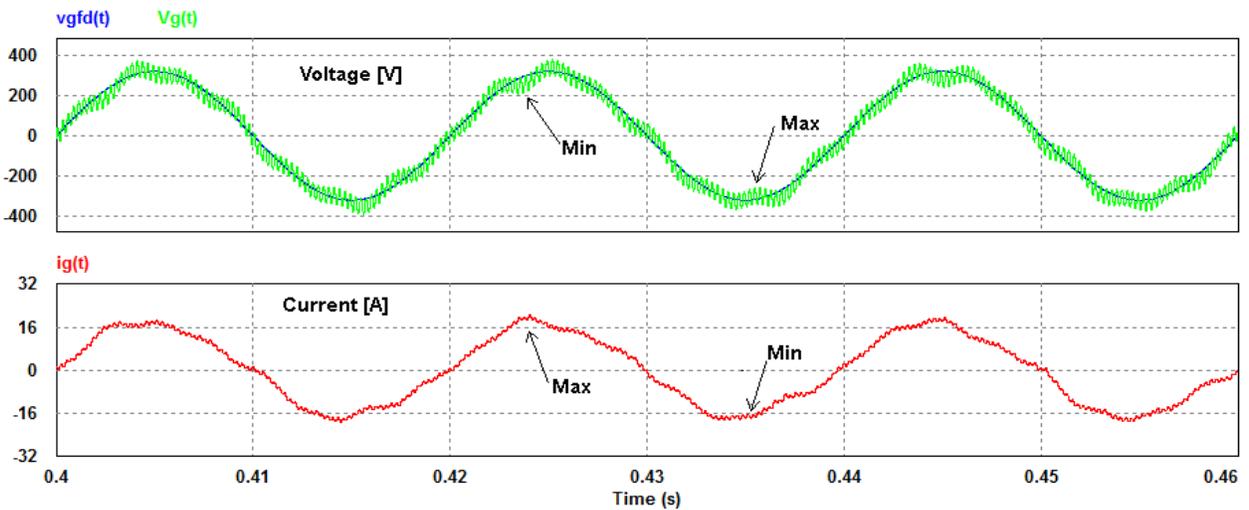


Fig. 9. Instantaneous behavior of the $ig(t)$ vs instantaneous deviation of $v_g(t)$ around the fundamental.

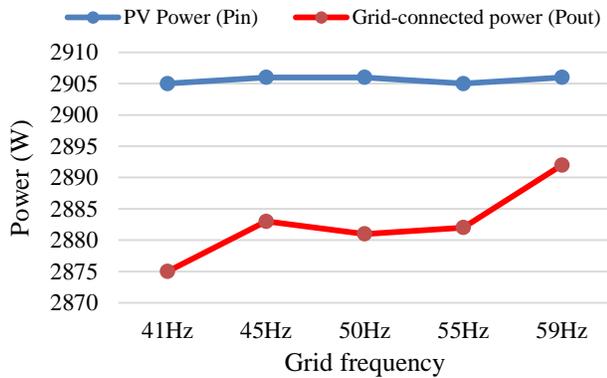


Fig. 10. Grid-connected power vs frequency.

As it can be seen from Fig 7, the $i_g(t)$ and $v_g(t)$ are in the same phase whereas the estimated frequency is consistent with fundamental.

Fig. 8 shows the behavior of the output power for the case when the distorted grid is assumed. It is obvious from the lower part of Fig. 8 that the output power waveform is more regular with using accurate grid detection. The interpretation of this regularity is that the deviation of the grid around the fundamental waveform ($v_{gfd}(t)$) is compensated by an opposite one in the inverter output current, as indicated in Fig. 9. These in turn yield to the improvement in the output power wave shape.

In order to show the dynamic performance of the proposed control strategy under frequency variation, simulation results of the grid-connected power (P_{g-c}) under different grid frequency are shown in Fig. 10. It can be observed that the (P_{g-c}) is kept within the slight change when the grid is having other than 50Hz frequency.

VI. CONCLUSION AND FUTURE WORK

This paper presents an adaptive controller for single-phase transformerless inverter of GCPVS under grid abnormal conditions like the distorted grid. An interesting alternative topology using a single-stage inverter, where the dc-dc converter is avoided, has been demonstrated. The advantages of the one-stage inverters are good efficiency, a lower price, and easier implementation. It has been addressed that when the grid-frequency has fluctuations, problems in regulating the current injected into the grid occur. As a solution to these problems, an adaptive tuning of the PR controller with respect to the grid fundamental component has been made. When the distorted grid is assumed, a significant limitation of the synchronization can occur. To overcome this limitation an accurate strategy of control has been introduced. The strategy based on extracting the fundamental component of the grid without delay. For validity confirmation, a controlled 3kW system was designed and simulated, in which the parameters shown in Table 1 is considered. The simulation results confirmed that the proposed strategy is an effective way of a GCPVS control under grid variation conditions.

Future work will try to improve the performance of the system with implementing MPPT embedded algorithm in the inverter and verify the proposed system practically.

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A Short Review of Gender Classification based on Fingerprint using Wavelet Transform

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Abstract—In some cases, knowing the gender of fingerprint owner found in criminal or disaster scene is advantageous. Theoretically, if the number of the male and female fingerprints in a database is equal, then the identification process of a fingerprint on that database would be two times faster. Some methods have been used to classify gender based on the fingerprint. Most of the method is based on ridge density. This method showed good result. However, it is sensitive to the location of the fingerprint area where ridge density is determined. This paper reviews some literature that used wavelet transform to generate features of a fingerprint. As far as what we found in literature, the number of papers on this topic is very limited. However, based on the literature we reviewed, wavelet transform gives some advantages compared to ridge density counting.

Keywords—Fingerprint; gender; ridge density; wavelet transform

I. INTRODUCTION

It is desirable to find features that can be used to determine people's gender. In general, it is believed that male and female have unique physical characteristics, such as fingerprint, palmprint, and face. Even in [1] and [2] writers reported that male and female shows the difference in the way they talk or walk. When gender can be detected based on their physical characteristics, unknown criminal or victims of natural disasters can be identified faster.

As one of the biometrics means, the fingerprint commonly classified into five major classes, namely whorl, left-loop, right-loop, arch and tented arch. It is advantageous when fingerprints further classified based on the gender of its owner. Furthermore, when the gender of the fingerprint is known then extracting and matching modules can be developed properly [3].

Many researchers have taken a close look to find fingerprint features that can be used to classify gender. They commonly determine ridge related features [4], [5], analyze frequency domain [6], and implement 2D Discrete Wavelet Transforms [7].

In this paper, we reviewed some literature that used wavelet transform to classify fingerprint based on its gender. Before that, we shortly reviewed some literature that used ridge features to do the same goal.

II. GENDER CLASSIFICATION BASED ON RIDGE DENSITY

Fingerprint has some features such as core, delta, ridge, and bifurcation, as seen in Fig. 1.

Core and delta, when existing, their relative position can be used as a feature. Ridges have more features such as thickness, orientation, and density. Meanwhile, bifurcations have orientation angles. These features are very helpful when the classification is done manually. However, when the classification is conducted manually, some preprocessing are needed.

Some researchers choose ridge density as a feature to classify gender. Acree [8] questioned if there is a gender difference in ridge density. To find the answer, he used 400 fingerprints picked randomly from 100 Caucasian males, 100 females, 100 African American males and 100 African American females within the age range of 18 – 67. He reported that women tend to have higher ridge density than men. Furthermore, he wrote that a ridge density of 11 ridges/25 mm or less tends to be a male, whereas fingerprint with a ridge density of 12 ridges/25 mm or greater tends to be the female.

In India, Gungadin [9] observed a relationship between gender and ridge density by using 250 male and 250 female fingerprints taken in Karnataka, the southern part of India. He chooses the upper area of fingerprints within a square of 5 mm × 5 mm to determine the ridge density. He reported that fingerprint having less than 13 ridges/25 mm² more likely owned by a male, whereas a fingerprint having more than 14 ridges/25 mm² is more likely owned by a female.

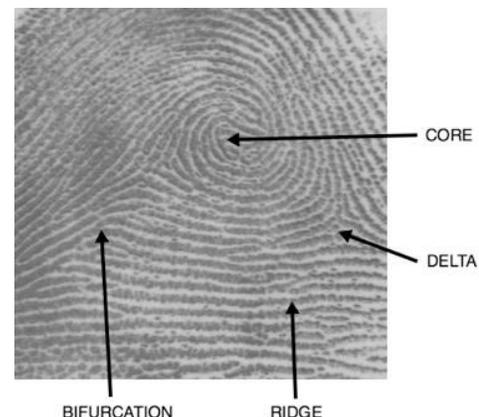


Fig. 1. Fingerprint features.

He claimed that the result supported the hypothesis that male fingerprints tend to have lesser number of ridge compared to females.

In Spanish, Gutierrez-Romero, et al. [10] tried to prove that gender differences based on fingerprint do exist. They collected all ten fingerprints of 100 males and 100 females of Spanish as a sample. To determine the ridge density, they used a square of $5\text{ mm} \times 5\text{ mm}$ area in three well-defined locations, namely radial, ulnar and lower. The result of their research demonstrated that significantly women tend to have higher ridge density than men.

The research of gender classification based on fingerprint was conducted in some countries, such as in sub-Saharan region [11], Turkey [12], [13], Thai [14], Malaysia [15] and much more.

All of the researchers mentioned above admitted that their findings are in a limited area. However, they believed that their finding is applied to another areas or countries. One of the advantages of this method is that classification can be done directly without using classification method.

Most of the methods chosen the specific location of the fingerprint and calculation of the ridge density calculated manually. Computer technology used only to enlarge fingerprint images and to calculate the result. When this method is applied in a computer program, needs much computation.

It is advantageous if all feature extraction and classification can be processed entirely using a computer. In this case, frequency domain analysis shows promising method. One of the methods is wavelet transform.

III. GENDER CLASSIFICATION BASED ON WAVELET

Wavelet can be used to extract features of the fingerprint. Extracting fingerprint features using wavelet decomposition gives some advantages. Today there are some wavelet transformations available. Furthermore, codes or even toolboxes available in major programming languages. These are some reasons why some researchers proposed the method to classify gender based on the fingerprint.

The role of transformation or decomposition is to generate some values that can be used to standardize the threshold. By using the threshold, classification can be done. The process of features generation using wavelet is as follows. Fingerprints are decomposed using a wavelet and resulting in some components. The number of components determined by the wavelet that used and the level of decomposition. Today there is some wavelet that can choose, such as Haar, Daubechies. The resulted components are used as a feature vector. By using the vector, the fingerprint can be classified using any classification methods.

Follows are some paper that reported the use of wavelet transformation to classify gender.

Shinde and Thepade [16] surveyed some gender classification based on a fingerprint that using wavelet decomposition. They analyze the gender of an individual by implementing Discrete Wavelet Transform (DWT) and

Singular Value Decomposition (SVD). The feature is generated by extracting the energy of all the sub-bands of DWT combined with the spatial features of non-zero singular values of the SVD of the fingerprint. They used 1000 fingerprints composed of 500 male and 500 female samples respectively. To clarify the gender, they implemented K nearest neighbor (KNN). The result of their work showed that the method gave accuracy up to 80.40% for male and 76.84% for female.

Kaur and Mazumbar [6] using Fast Fourier Transform (FFT), Discrete Cosine Transform (DCT), and Power Spectral Density (PSD) to generate fingerprint features. They argued that these transformations generate most of the information of the spatial domain image. This information can be used as features to estimate the gender by comparing them with predefined values. To prove the hypothesis they used 220 fingerprints composed of 110 female and 110 males. The predetermined values are set based on 50 chosen female and male fingerprints. The result of their research showed that the method gave 90% accuracy on 110 female samples and 79.09% on 110 male samples.

Gnanasivam and Muttan [17] implemented level 6 Discrete Wavelet Transform (DWT) and Singular Value Decomposition (SVD) to classify gender based on the fingerprint. They combined the energy of sub-band of DWT and the spatial features of non-zero singular values obtained from SVD as input to K nearest neighbor (KNN). They implemented the method to classify 3570 fingerprints composed of 1980 male and 1590 female fingerprints. All fingerprints are taken from all ten fingers. They used 2/3 of them to train the system, and the rest was used in the classification stage. They reported that the method achieved an accuracy of 91.67% for male and 84.69% for female. Furthermore, they reported that little fingerprints showed higher success rate compared to other fingers.

Tom and Arulkumaran [7] used 2D- Discrete Wavelet Transform (DWT) combined with Principal Component Analysis (PCA) to generate a vector feature. By using this feature, they classify gender fingerprints by implementing the minimum distance method. They used fingerprints of 200 males and 200 females of various age groups. They reported that the success rate of the method is around 70%.

IV. DISCUSSION AND CONCLUSION

So far the common method to gender classification based on a fingerprint are use ridge density. They showed good result and used in some different countries. However, the methods need some preprocessing to enhance the clarity of the fingerprint. The enhancement is needed because most of the classification process was done manually. Although some researchers used automatic classification, however, the result was lower compared to manually classification.

Implementing wavelet transform to classify fingerprint based on its gender is promising. Some literature reported that wavelet transformation gives good result in generating features.

The methods can be implemented without using preprocessing. The methods work in the frequency domain, so the position or the orientation of the fingerprint are relatively

irrelevant. The computation of wavelet decomposition is fast, and application or toolbox for that purpose is available.

ACKNOWLEDGEMENT

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An Optimal Load Balanced Resource Allocation Scheme for Heterogeneous Wireless Networks based on Big Data Technology

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Abstract—An important issue in heterogeneous wireless networks is how to optimally utilize various radio resources. While many methods have been proposed for managing radio resources in each network, these methods are not suitable for heterogeneous wireless networks. In this study, a new management method is proposed which provides acceptable service quality and roaming rate, reduces the cost of the service, and utilizes big data technology for its operation. In our proposed scheme, by considering various parameters such as the type of the service, the information related to the location of the user, the movement direction of the user, the cost of the service, and a number of other statistical measures, the most suitable technology for radio access will be selected. It is expected that besides improving the decision making accuracy in selecting the radio access technology and the balanced distribution of network resources, the proposed method provides lower roaming and lower probability of stopping roaming requests entering the network. By considering the various service classes and various quality of service requirements regarding delay, vibration and so on, this can be useful in optimal implementation of heterogeneous wireless networks.

Keywords—Heterogeneous wireless networks; radio resource management; quality of service; big data technology; decision making

I. INTRODUCTION

Now-a-days, various technologies with various goals are proposed for wireless access. For instance, local wireless networks using the IEEE 802.11 standard, wireless urban networks using IEEE 802.16 standard, and cellular mobile networks (4G); considering that these networks vary based on bandwidth, the type of access to media, and the security they provide for the users [1], [2]. However, heterogeneous combinatory networks provide the possibility of optimizing access everywhere and under various conditions by maximizing the utilization of the facilities of these technologies. Previously, decision making for connecting to the network was up to the network and roaming only occurred when the signal was weak. However, in heterogeneous wireless networks, when the possibility of accessing the internet for the users is possible through more than one network, the users select the best type of access for their connections in real time.

In other words, before the introduction of next generation heterogeneous wireless networks, selecting the radio station was done by the network and the only criterion was the strength of the received signal [3]. However, the fact that the user can select not only from stations with the same technology, but also from heterogeneous technologies with various features is a new possibility which creates new challenges [7], [8]. While usually the high bandwidth of local wireless networks such as 802.11 is very important for data transmission, due to the small coverage area, these networks are only available in hotspots such as hotels and libraries, forcing the moving user to return to the mobile network. While WiMAX networks provide acceptable bandwidth and quality of service, the significant distance between the stations and the different frequency and technology used for transmitting information increase the power consumption of the user utilizing this technology and if the battery of the user's device is very low, they can connect to the mobile network without losing the connection in order to consume less power [11]-[15]. Moreover, using ad hoc networks and the Bluetooth technology, they can connect to a modem and keep the connection with a very low power consumption. In heterogeneous access network, all the advantages of each one of these networks is effectively available in a combinatory network and the main goal of heterogeneous wireless networks is the realization of the concept of 'Always Best Connected'. In other words, users select the best option among the provided service based on their conditions [9], [10]; an option which is proportionate to their preferences and requirements so that they can utilize the best facilities. Accordingly, the user will pay the lowest price for the best possible quality of service. There are various decision making parameters for variable conditions of each running application and the conditions of the networks and the device of the user. If the system is to consider physical parameters, such as quality of signal and the bit error, as well as the requirements of the user in selecting networks with lower cost and lower congestion, the decision making problem will be a multi-dimensional problem with conflicting objectives. Furthermore, selecting the best network must be based on policy, priority, and the sensitivity of these criteria as well as the effects it has on more general goals such as the load distribution. Another issue in heterogeneous wireless networks

is the nature of distributed access. In heterogeneous networks where even selecting the various access technologies of the network is up to the users, we have to meet the general goals of the network such as balanced load or optimized service, meaning that we are faced with a distributed optimization problem. The balanced allocation of load among the networks and the stations will not only prevent congestion but also lead to balanced utilization of network resources. The users themselves are also willing to select the best network regarding load and congestion so that they can receive the best quality of service. However, the user will not consider only one criterion; they care about other local criteria such as the degree of power consumption, the quality of service, the movement of the user, and so on. Therefore, the outcome of users' decisions and strategies and their effects of the general goals of the network operators, such as balanced load, must be considered and modelled. Overall, the decisions the user makes for receiving the best quality with the lowest cost lead to the formation of general network goals. The general network goals such as balanced load, increasing the revenue of operators, and increasing the overall productivity of the network must be considered along with the decision goals of the user. Hence, modeling and the distributed optimization analysis mentioned above are very important in next generation wireless access networks [5], [6].

In this study, we will discuss the problem of load allocation in next generation mobile networks based on data analysis methods such as big data method and roaming among mobile networks and WLAN. The rest of this paper is organized as follows. In Section 2, we review the research literature described in this paper. In Section 3, the importance of big data is stated for the proposed model. In Section 4, the proposed model is described in details. The evaluation results have been discussed in Section 5. Finally in Section 6, the conclusion and future work are expressed.

II. RELATED WORK

The main problem in the study is allocating load to femtocell users and roaming from the mobile network to WLAN. Hence, at first the user's device connects to the mobile network and if the mobile network is not able to provide the selected service to the user's device for any reason whatsoever, the process of roaming to WLAN initiates [12]. On the other hand, when for any reason such as the occurrence of an accident or event, the number of subscribers in that location is too large, using big data, it is intelligent enough to manage roaming from one network to another considering the network resources and the event that happened in that location. In this study, the roaming from mobile to WLAN occurs if necessary. In other words, if it can lead to improved quality, it will be considered necessary. Therefore, ideally this operation must occur when we are sure of improved quality. The important issue in heterogeneous wireless networks is how to utilize various radio resources. While there are many methods for managing radio resources in each network separately, these methods are not suitable for heterogeneous wireless networks [17], [18]. Hence, a new concept has emerged as the continuous management of radio resources [4]. The continuous management of radio resources refers to a set of function for effective and coordinated utilization of radio resources in

heterogeneous networks. Methods for selecting RAT, which includes algorithms for selecting Rat at the beginning of a session as well as selecting RAT when shifting running communication from one RAT to another Rat (vertical roaming), are the main element of managing radio resources in heterogeneous wireless networks. Having reviewed the studies related to managing resources in heterogeneous wireless networks, the following methods can be extracted: first, methods for designing the optimal target function, and second, the theoretical methods which pursue goals other than the simple optimization of a function. The fuzzy method and the game theory are instances of the second set of methods which analyze problems such as competition, collaboration and optimization for a number of selfish decision makers and extract an optimal model for the entire system. Various studies utilize fuzzy logic for decision makings related to inter-network roaming and resource allocation. The advantage of these methods is that they carry out the decision making without requiring detailed and explicit data. Decision making for selecting the optimal network is a multi-dimensional decision making problem and it is a type of approximate inference. Table 1 illustrates an example of fuzzy decision rules.

TABLE I. FUZZIFIED PARAMETERS

C={Economic, Normal, Expensive}
B={Poor, Med, Good}
RSS={Low, Normal, High}
U={Insensitive, Ordinary, High QoS}
D={Low, Med, High}

The game theory models the interaction among the players for reaching common resources. Hence, it is suitable for modeling the management of radio resources. This study classifies the cells into concentric rings with the radius of where . The distance between each two rings is called a zone. Then, for each status of the system, which is denoted using the number of users in each zone (a non-collaborating game is designed. The profit function is based on the throughput in each zone which depends on the total number of mobile users in it and the number of those who use WiMAX or 3G networks. In a non-collaborating game, the optimal solution is the Nash equilibrium where the strategy of the players dictates that no player receives more profit from changing its strategy unilaterally (while the strategies of others remain constant). Therefore, the selected strategy of each player is the optimal solution for the strategies of other players [20]-[22].

The study models the issue of selecting a network for users facing competitive operators using non-collaborating games among the users. This game belongs to a class of games called 'swarm game'. The equilibrium points in this game are calculated and their quality will be evaluated based on the nominal throughput of the networks and their interference level. In all the above studies, the game is carried out based on geographical division of the location into zones or areas (each

one based on a model) and then modeling the congestion level in that zone or area, which is a function of the number of users in each zone. The Nash equilibrium point in game models provides the best possible way of distributing the users among these geographical zones. The issue is that such a model is suitable for pre-design stages; for instance, when selecting the locations for radio stations and they do not discuss the willingness to improve equilibrium points for preventing congestion and besides modeling bandwidth, other important requirements of the users such as power consumption exerted by each network on the users or the difference between the nominal bandwidth of each network, which is very important in decision making, are not considered. In other words, the contribution of users in creating congestion or their need for bandwidth is considered equal, which is not true for modern data networks.

III. IMPORTANCE OF BIG DATA IN THE PROPOSED MODEL

In the selected architecture of the proposed scheme, the information related to the users and the conditions of the network reach the network's core layer through uplink and through a network defined process, the decision making based on data analysis in this level of network will be carried out. Naturally, a part of the network's core is responsible for data analysis and decision making, known as the main switching unit. Based on the above figure, this switching unit in third generation networks is the SGSN and in next generation networks such as 4G and NGMN, it will be SGW and MME switching units. Therefore, in the first stage, a capacity for storing the user data with a large volume in the network core must be considered; in the next generation mobile networks which work based on IP, these data will never reach the switching unit. However, when we are willing to use data analysis techniques for network defined decision making, we will naturally need the uplink information. In case the current registers available in the network core are not able to store this volume of data, we have to consider a separate register in the network which provides the required capacity and is also able to quickly connect to the switching center. In this case, we have to add a section to the network core where data analysis based on big data technology is carried out. In Fig. 1, we will discuss the proposed idea in more details.

In this paper, by using the methods of huge data analysis, our purpose will be obtaining to the self-optimization limitation in multi carrier networks. After surveying the presented models, it will be tried to present solutions for some present challenges in the mobile networks field of new generation. We will pay attention the suggested model. In this model, we have tried to cover the present defects in past designs. General framework of this design has been formed from different parts that have linked like block diagram to each other. These parts can be interpreted in relation with a self-organized system with the technology of huge data. But, in continuance, we will pay attention for complete surveying of suggested idea in the framework of this diagram block.

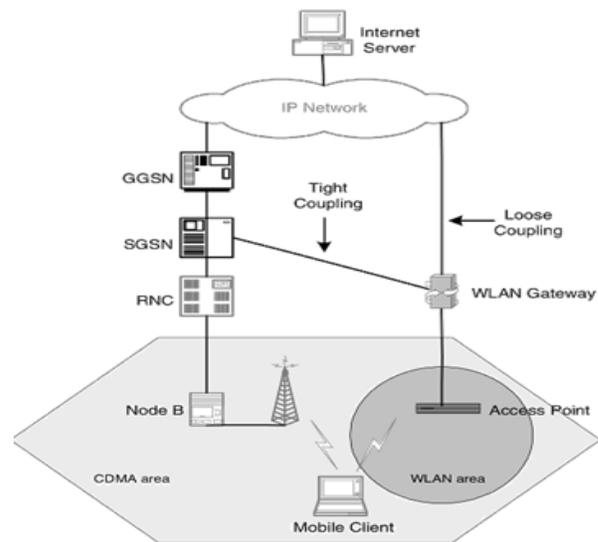


Fig. 1. The Importance of Big Data in the Proposed Model.

It should be noticed that because our work field is mobile networks of new generation, so, it is natural that also our way of receiving information will be the way of Up Link of network from linked things to Femtocells and also different users till the core network [3]. All of received information will be used for analyzing of determination of rate accuracy of dedicated sources till we have suitable control on internal and external interference rate. Next, we will survey physical model of Femtocell layer. In this study, we have tried to present an approximate model of optimization relation that has been used in the layer structure of multi carrier network. The next step in self-optimization networks, by certain approaches that there is measuring management and is able for learning, will be introduced based on past and present observations. This is the method of self-organized networks that are not limited by pre-introduced algorithm and in this pattern, one part of the network are able to arrange any sudden conditions. In this design, we have observed a capability that has been introduced according with this new approach till the nodes of a network also can have the ability of teaching. With performing the algorithms of machine learning, they will be able for exchanging information and teaching each other that will accelerate the process of self-teaching and will cause to faster convergence. Movement towards the changes of fifth generation not only there is in accessible radio network but also there is the section of core of network that its new approach makes possible the designing needed network for presenting services accordance with the users and increasing sets. The trend is like this that separating hardware and software and the movement of functions is one second. In order to extending the presented model to real conditions, it is necessary to observe the network obligations in different conditions and different periods. As we observed in surveying past works, the affairs that have been posed in the field of optimizing mobile networks and presenting a self-optimization model, it performs the intelligence of network only through analyzing KPI

telecommunication efficiency parameters, and they neglect effective non-telecommunication parameters in distributing network traffic and transferring network bar, and based on, the destructive outcomes that there are in mobile networks due to environmental and social factors, will not be considered in this kind of designs. In order to implement the plan to self-optimization based on data analysis, we divide the self-parameters into two general following categories. Our purpose is reaching to the self-optimization pattern that in this design one part of the network, based on supervision on the parameters of these two groups, can predict the conditions of its future and to estimate the rate of its needed sources according network bar in every part of the network. The pattern that we will present from self-optimization will contain two parts of three parts in performance of self-organized systems.

IV. PROPOSED MODEL

A. User Mobility Model

In this study, a movement model based on probabilities according to [15] is considered for the user. Accordingly, the probability of the user exiting the hotspot in their session is denoted by and the probability that they enter a hotspot is denoted by Moreover, the probability that the user is a vehicular user (with a lot of movement) is shown as and the probability of the user being a non-vehicular user is shown as.

Considering low values for identifies a hotspot scenario for a company where users will stay in the hotspot area (their own company) for a very long time. In contrast, high values for indicate a public area covered by WLAN (e.g. airports) where users are moving in and out all the time.

Under equilibrium conditions, the average number of users exiting the hotspot and the average number of users entering this area will be equal [16]. Therefore, we will have:

The values of and play a significant role in analyzing the VHO process in HWN environments. For vehicular users we will have a very high velocity, so we assume that the probability of them changing their location from outside a hotspot to inside a hotspot is. Consequently, we will have:

Using conditional probability and (5), the probability that the user is non-vehicular and the probability of them changing their location will be calculated as follows:

The main characteristic of this method is considering various parameters such as the type of user services, the type of user’s movement, the current location and the future location of the user in the decision making process. Using this information, JRRM can make optimal decisions in order to prevent repetitive and unnecessary handovers, reducing the cost of services for the operators, which will be very important in implementing heterogeneous wireless networks. Another characteristic of this method is ensuring the quality of services for the users and maintaining the stability of user services.

B. RAT Selection Algorithm based on Location and User Mobility

In this JRRM algorithm, the necessary decisions for selecting an appropriate RAT are made according to the information it has gathered. RAT selection algorithm consists

of three stages, as it is shown is the Table 2. JRRM entity receives the request for a new call.

JRRM requests for the location-related information and user mobility from the units of location register and location predictor of the user. According to the gathered information by the JRRM unit and the rules that come in the following, the most appropriate RAT for the session will be selected.

1) If the user is outside the hot-spot area, resource management will be done in LTE by the available radio resource management unit.

2) Otherwise, for an automotive user that is in the hot-spot area, LTE will be selected for different resource management so that the repetitive VHO which may happen due to the frequent automotive user mobility is prevented from.

3) The RAT service type will be selected for a non-automotive user that is in the hot-spot area.

If the condition (service type=non-immediate service) is on, IEEE 802.11 will be selected for the user due to the high-bandwidth and low-service cost. Otherwise, if the condition (service type=immediate service) is on, an appropriate RAT will be selected according to the relevant information in regards to user location prediction.

As in case it is predicted that the user has left the hot-spot area, IEEE 802.11 will be selected for him/her (so that service resistibility is guaranteed) otherwise LTE will be an appropriate option for the user so as to prevent from an unnecessary VHO.

TABLE II. PROPERTIES OF THE VHO ALGORITHM

	Big data analysis for location prediction unit	Big data analysis for location registration unit	
User terminal Type of service	JPRM Type of user service Type of user movement The current and future locations of the user		
	User location		Outside hotspot
	Inside hotspot		
	Type of the user through big data analysis		Vehicular user
	Non-vehicular user		
Non-real-time	Type of user service		
	Real-time		
	Future location of the user through big data analysis		
802.11 RRM	Staying in hotspot	Leaving the hotspot	LTE

Continuing the explanation of this flowchart, in case the WLAN network finally is considered as the target network, the capacity of this network must be considered. In case the capacity of this network isn’t providing our needs for the entrance of new users and using the WLAN network resources,

we should inevitably select the cellular network as our target network.

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Continuing the explanation of this flowchart, in case the WLAN network finally is considered as the target network, the capacity of this network must be considered. In case the capacity of this network isn't providing our needs for the entrance of new users and using the WLAN network resources, we should inevitably select the cellular network as our target network [19].

C. Multi-Dimensional Decision-Making

The proposed pattern that was presented in this paper is based on a set of multi-dimensional decision-making procedures. In this pattern, one of the packets of the network is used based on three basic parameters of the service type provided, the expense of service provision as well as user mobility type and of course in the assumed decision-makings, the number of vertical inter-systemic handovers are supposed to decline.

Each one of the aforementioned indices can to different efficacy coefficients have the required effects directly on the decision-making related to the selection of handover.

As it was suggested, in the assessment of the functional pattern of the proposed scheme, using the concepts of Big Data

is proposed as our leading approach toward achieving optimization in the network. The effect of some of the intended parameters is emerged as the determination of a threshold limit in the network. Also the effect of some of these parameters can be analyzed in a Fuzzy way as Fig. 2.

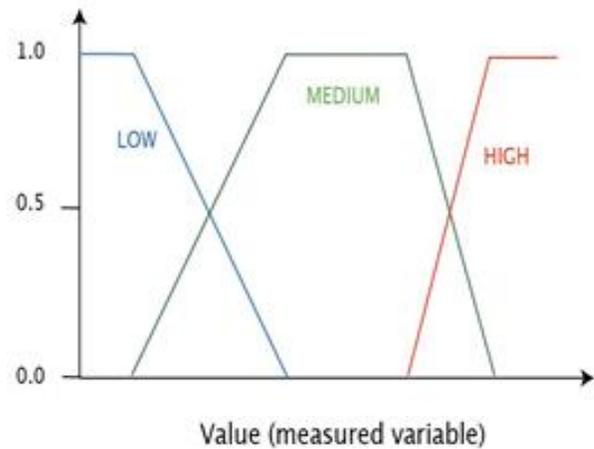


Fig. 2. A typical fuzzy values.

This decision-making pattern (NFDE) for the selection of an optimal network is a multi-dimensional, approximate and indefinite logic problem which is an appropriate candidate to be solved based on Fuzzy Nervous method. NFDE is expanded exactly based on Adaptive Fuzzy Logic System (AFLS). AFLS is a type of Fuzzy Logic System (FLS) that has fuzzifying and defuzzifying units. Its structure is similar to the traditional FLS but its rules are derived and extracted from a known educative data. In other words, its parameters can be educated just like in a nervous network method but along with its structure in a Fuzzy Logic System Structure.

Central defuzzifier is a very famous method for defuzzification but can't be used in NFDE by its calculated expense and prevents from using back-propagation education algorithm. The proposed AFLs include an alternative defuzzification method based on the FALCON model shown by Altug. NFDE feed-forward structure based on FALCON. NFDE is created when 1) the mobile host identifies and then specifies a new radio link, 2) the priority of the user changes, 3) a request for a new service is made and 4) there is a declination in the new signal or a complete signal loss from the current radio link.

Definition of membership functions: in choosing the best network in a change of vertical signal transfer, applying an appropriate parameter from different layers both on the user-side and on the system-side is required. The used features for NFDE includes financial costs (C), network bandwidth (B), RSS (R), user priority (U) and network delay (D). As a result, the revelation of a better control is possible by increasing the number of Fuzzy sets but this issue will reinforce the complexity of NFDE. Membership functions must be adaptable toward environment change in order to maintain its usefulness. The system behavior is relied on Fuzzy rules and membership functions significantly so as to describe decision-making rules. NFDE features are defined as the following.

V. EVALUATION RESULTS

We have had an experimental investigation about the differences WLAN and UMTS based on their functionality per predefined constant values for some effective parameters in which, Cost, Bandwidth, Transmission Rate and Delay have an impressive role in this scenario.

As it can be seen in the result in the Table 3, the differences will be deeply dependent to the coefficient of these parameters.

TABLE III. THE IMPACT OF INDICATORS IN PHAZIZATION

	C(Cent/Kb)	B (Mbit/s)	R (dBm)	D (ms)
WLAN	0.001	11	+38	1.25
UMTS	0.220	0.5	-100	18.54

By doing repetitive simulation, below vector has been achieved as coefficient which can be used in next simulations.

$$W = [0.0625, 0.0791, 0.0211, 0.0981, 0.4991]$$

By considering the achieved coefficient for various parameters which are used in simulation, we arranged a wide evaluation for these two networks in which the combination of these two networks considered as a heterogeneous network. As Table 4 has shown, the functionality of the provided network has been related to the kind of service and the application type.

TABLE IV. THE SIMULATION RESULTS OF THE PROPOSED MODEL

Network	Application Type	Service 1	Service 1
WLAN	Min	0.775	0.011
	Max	3.675	0.055
	Ave	1.470	0.029
UMTS	Min	6.944	0.900
	Max	68.690	1.699
	Ave	19.721	1.191

In order to assess the results of suggested plan, we will try to analyse the output of performing suggested model in a cluster with five base station and 15 cells in KPI mode. Due to a lot of population concentration in two half of the year, this cluster can, as a suitable field for surveying the output of suggested model, be considered. By surveying KPI in primary half that the concentration of population is high, there has been observed this network from the attitude rate of sources and efficiency is in a suitable condition. Now, in the second half that the rate of population concentration is decreasing, if the sources of network are used like past, the rate of the efficiency of the network will be criticized. In these conditions, the presented optimized model, in order to devoting signalling sources to the traffic sources and increasing rate of transferring data, will have an approach based on decreasing the rate of signalling load. Due to this reason, by decreasing handover attempt rate, practically the rate of frequency interferences have been decreased and the quality of channels will increase, and anymore there is no need to create more signalling for creating new neighboring relations. For this reason, by hardening the threshold of handover, we possibly decrease the rate of signalling relations related to transferring service from one site to another site.

Mentioning this point is necessary that the number of users to be high, there are need for so many handover in the network; because the traffic load of network must be arranged based on the rate of present sources in every point. But in a condition that the number of users to be down, every cell can, in most cases, prepare its needed sources under its zone, except fluid users that in most cases of servicing to them, is along with handovers.

As it is observed in Fig. 3, with increasing the threshold of decision making for handover, the rate of handover attempt will be decreased noticeably. In continuance of effects, this change will be surveyed in the levels of other parameters KPI.

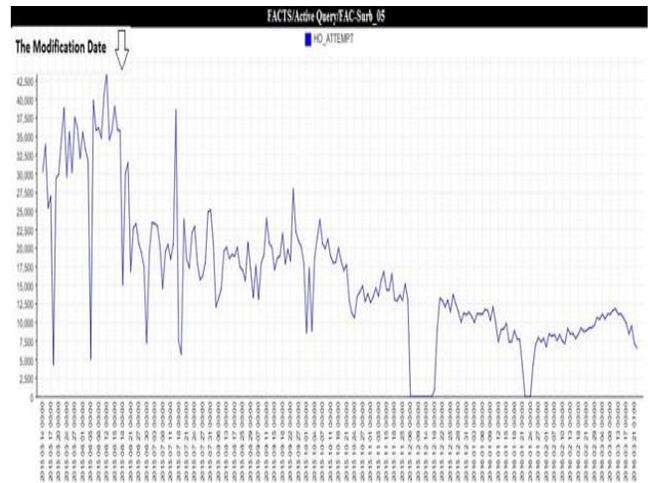


Fig. 3. Decreasing the rate of handover attempt in period of assessing cluster, before and after doing changes.

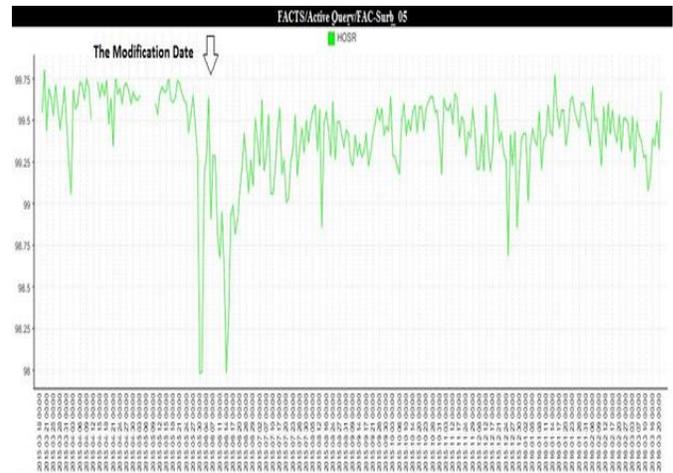


Fig. 4. The handover success rate before and after doing modifications.

With regard to this point that the number of demands have been decreased noticeably for handover, but, successful rate of handover (HOSR) only has been decreased a few percent. As it is observed in Fig. 4, this rate of reduction, will not have negative effect on the efficiency of the network. And but, main effectiveness of hardening conditions of handover is in reducing the load of signalling in the network. It is clear in Fig. 5 that after doing this changing in network, the load of signalling has had reduction % 30 that this case, for getting to

an optimized network can be very significant. With regard to these conditions, we can devote unusable sources of network signalling to traffic channels for transferring data.

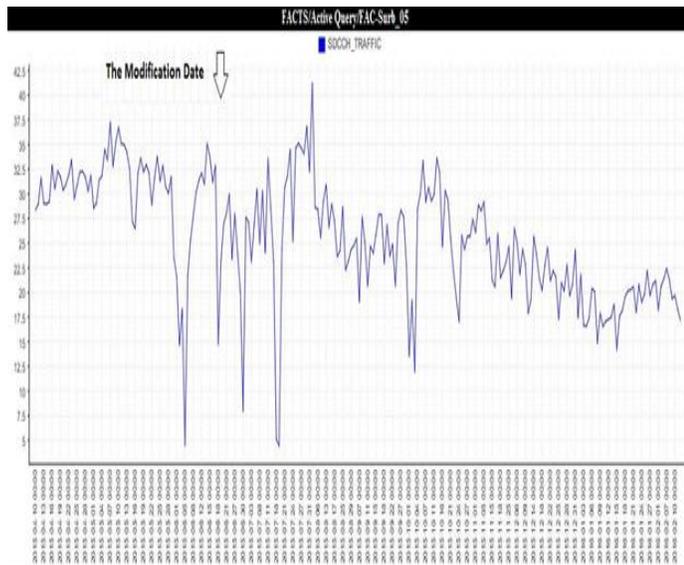


Fig. 5. 30 percent reduction of average rate of traffic load in signalling channels for every site of cluster.

VI. CONCLUSION AND FUTURE WORK

In this paper, a new method of Joint Radio Resource Management was proposed which aside from providing a desirable service quality, decreases the vertical handover rate and service cost. In the considered scenario, both the immediate and non-immediate services are considered. In this paper, we tried to deal with optimization of traffic distribution in heterogeneous networks on two levels. On the first level, this issue will be done by selecting an appropriate RAT and on the second level, by establishing the user connection to the specified Femtocell's cells during the process of optimization. Using Big Data technique will have tremendous effects on prediction feasibility and better future decision-making about network load distribution which this decision-making will be done during user-level and network-level processing.

Future work could include extending the proposed method for other application such VANET. Another area of research related to this research is the adaptation of proposed method for distributed and cloud environments.

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Forced-Driven Wet Cloth Simulation based on External Physical Dynamism

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Abstract—Cloth simulation remains challenging for past two decades. There are several factors that contribute to this challenge such as, internal and external forces, water, oil and other fluid elements. This paper focuses on simulating wet cloth by considering external forces and water element. Initially, the mass spring technique is used to produce cloth sheet that is composed from collection of matrix point that connects to the spring, then external and internal forces are applied into cloth surfaces. The inner strength is represented by stiffness between springs of cloth particles, while outside forces depend on wind pressure and mass of object that rely on gravity. The wet cloth simulation is started by adding the fluid component into the textile elements which will affect the mass of the cloth itself. The cloth will absorb significance quantity of fluid that will distress the tension between spring particles inside cloth. The experiment has been conducted by simulating the cloth while absorbing the fluid which is controlled by particular equation. It has shown that saturation level of cloth is changing as well as the texture turn to be darker compared to dry cloth. The darkest color of cloth reflects the highest saturation level of the cloth. It also means that cloth cannot absorb more fluid since it is already full in term of capacity. The evaluation is conducted by comparing the dry and wet cloth in terms of motion and physical appearance. It is concluded that the proposed method is able to simulate the convincing wet cloth simulation with high Frame per Second (FPS) rate and realistic motion and appearance. The future work can focus on simulating interaction between fluid and cloth elements to see spoil scene, or washing cloth that remain challenging.

Keywords—Wet cloth simulation, fabric; mass spring; fluid; wind; gravity forces

I. INTRODUCTION

Cloth is attached into daily human life. In order to simulate the cloth, the textile types and its element should be considered and taken into account when do simulation. The cotton or spandex will have different texture and behaviour when come to the simulation. Currently, most of the researchers are focusing on studying the fluid effects toward fabric in real time simulation. Salazar et.al have mention that reducing the cloth rendering complexity by optimising collision detection with AABB collision detection technique [1]. While [2] already touch wet cloth simulation by rendering fluid with absorbent textiles. He used Smoothed Particle Hydrodynamic was used as

a method for fluid mechanism, then combined with Fick's Law for computing translation diffusion [2]. The simulation successfully made the fluid spreading toward cloth fabric in real time with convincing appearance. Other researchers tried to focus on geometric technique for producing surface pieces that cover the cloth bending. They also provide sewing typical in deformation weave design and stitching effect like in real world [3]. Mongus et al. have suggested a method to simulate various fabrics (cotton, spandex, wool or silk) by considering its structure, weight and other factors [4]. Cloth and fluid are perfect combination when it comes to realistic simulation, however due to its complexities a lot of aspects remain challenging [4]. Chen et al. have made significance progress by simulating cloth with wet effects. They are fitted the wet cloth into virtual human to see the behaviour of bending and crumpling [6]. As a result, they mention that friction between cloth surface and self-collision detection is major contribution for their works. In addition, underwater cloth simulation [6], soaking technique for fabric [2] and absorbent behaviour of fluid when passing through textile were also studied as well [7]. Despite of previous studies, this research focuses on presenting unique cloth behaviour which is joining the fluid factors, gravity and wind pressure. The simulation of saturated fabric that blowing up by wind and pulled by gravity is the main contribution of this research.

II. RELATED WORKS

Cloth modelling has been used as an interactive application in 3D movies, game, advertisement, fashion application. A lot of researchers have been conducted since early 1980, however the deformation model when virtual human moving is very complex and challenging. The main problem is how to render smooth surface while maintaining the fabrics complexity which is composed of warped fibres. The inner strength between cloth fibres is determined by physical factors that can make textile has wrinkle or buckle. Those factors can be simulated can be simulated to produce folding effects and other effects that appear in real world. However, the complexity of the technique during rendering as well as mathematical assimilation is not an easy task to produce a fabric. For almost two decades cloth simulation still struggle with physic force simulation, collision handling between cloth elements (self-collision) and other external object [4], [5]. Fast cloth simulation should consider

all external forces to provide dynamic simulation in efficient ways without affecting the performance of cloth appearance [8]. It is known that cloth model can be represented in two dimensional array as shown in Fig. 1. The coordinates from each matrix elements are representing the points of cloth surface. The flexible mesh physical simulation takes into account the elastic spring that joins these nodes. This model presumes that new node positions are generated due to the forces applied to mesh mass-points nodes, to guarantee the required balance among these mass nodes. This approach is common for many cloth animation contributions because meshes are easy to manipulate and efficient to describe deformations as described by Jiang Wang et al. [9]. The interaction between fluid and cloth in real time also draw attention of researcher on studying these interactions [10].

Virtual reality requires several components such as cloth, hair, weapon and etc. The impression of facial expression with emotional aspects determines the believability of virtual human [11]-[17]. Despite the collision detection inside cloth fabrics, other researchers also studied collision avoidance to improve the behavior of virtual human inside the environment [18]. Tracking the human body was introduced to the science knowledge to provide better interaction using body gesture, voice or speech recognition that known as natural interaction [19], [20]. In addition, markerless tracking enable human to make interactive interaction with real world planar in real time by using gyroscope and inertia sensor [21]-[23].

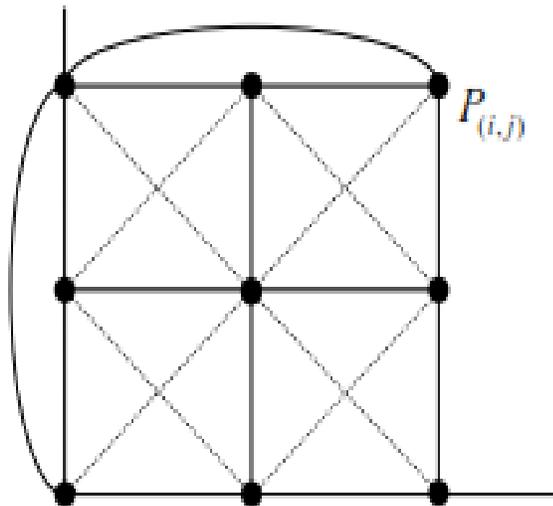


Fig. 1. Mesh strategy for cloth modelling [9].

III. RESEARCH METHODOLOGY

The process will be started from conducting critical analysis to discuss the important issues of the wet cloth simulation topic. The complete process is reflected at Fig. 2.

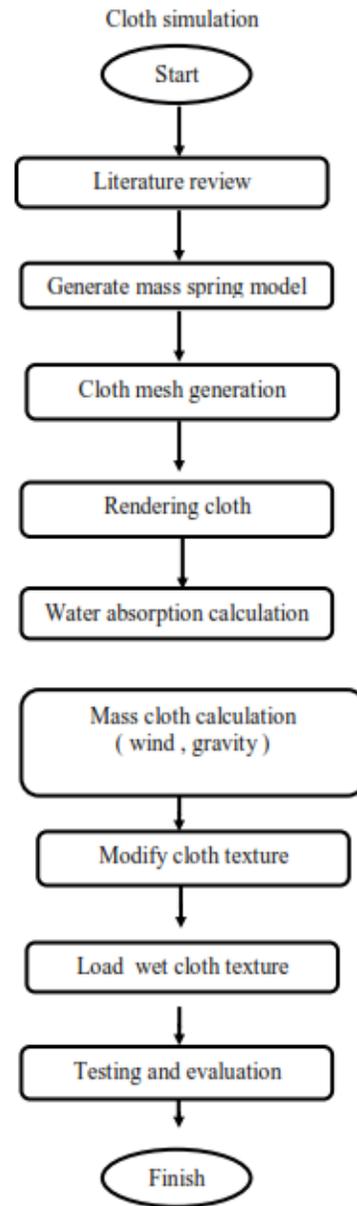


Fig. 2. Methodology.

This stage will explain how to generate textile, which is the first component of functioning simulation of cloth. The method used in this research is famous for its strength and ease of implementation and low cost clothing simulation. It's called Mass Spring Model which uses the idea of masses being linked in mutually style through springs. There are three types of springs used to build the body of textile, bend, stretch and shear. It's called Mass Spring Model which uses the idea of masses being linked in mutually style through springs. Fig. 3 explains the types of springs.

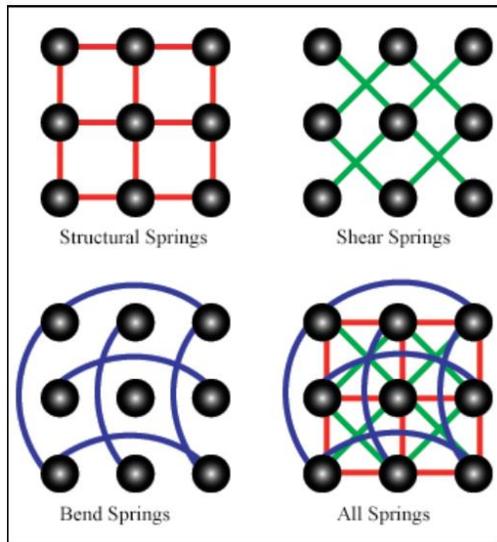


Fig. 3. Types of Spring [24].

A. Cloth Mesh Generation

The flexible form in this work is a net of practical masses every one being coupled to each other by masses springs of extension that didn't have similar value or zero, association among closed mass is grouped in following diverse mode. Fig. 4 shows the process of mesh in the following three steps:

- Mass[i,j] with [i+1,j] then mass[i,j] with [i,j+1] bind to spring known as **mechanical spring**.
- Mass[i,j] with [i+1,j+1] then mass[i+1,j] with [i,j+1] bind to spring known as **shear spring**.
- Mass[i,j] with [i+2,j] then mass[i,j] with [i,j+2] bind to spring known as **flexion spring**.

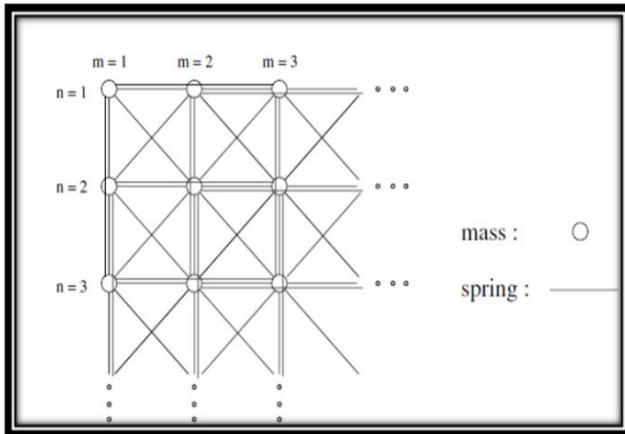


Fig. 4. Mesh between masses and spring [24].

B. Water Absorption Calculation

When cloths are soaked with water, this indicates to get interaction between the water and cloth particles, resulting increasing in the weight of cloths because if attached amount of water in cloth particles. This physical process is nominated as absorption. The quantity of absorbed water is different from cloth type to another. In this work, we will adopt cotton as the

basis for calculating the amount of water absorption. Previous researchers calculated absorption amount for water through the saturation, the mass from component in one integration which is computed through (1) [5].

$$m_i = m_i + t \frac{\partial m_i}{\partial t} \quad (1)$$

Where m_i is the weight rate of the mass i at time t. In deliquescent modelling investigate; this fluid stream is classically simulated as a dispersal procedure. We study the water imbibition's process and the mass model changing process as following:

$$Q = \partial(1 - e^{-t/a^3}) \quad (2)$$

Where Q the amount of water that absorbed through time t. ∂ is the parameter of the weight in soaked case per gram, θ is the hygroscopicity factor constant that possible to be gotten from the fabric component research data, and t is the typical time of the water absorbing process. Ultimately the following equation can be concluded:

$$\frac{\partial m_i}{\partial t} = \frac{\partial Q}{\partial t} = \frac{\partial}{\theta} * e^{-t/10} \quad (3)$$

Each surface of cloth consists of many triangles and forces will affect each triangle on cloth surface as shown in Fig. 5. The wind pressure effect toward cloth is calculated based on algorithm described in Fig. 6.

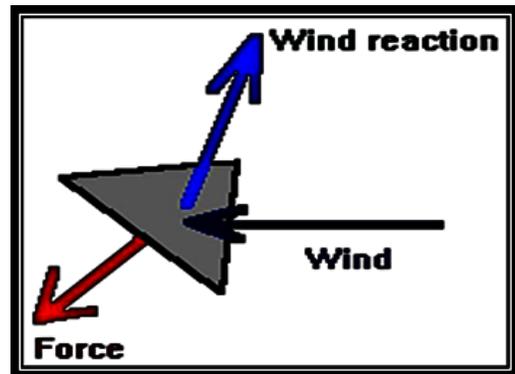


Fig. 5. Force and wind reaction toward cloth surface.

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Pseudocode : Calculating wind behavior
VECTOR: force
VECTOR: normal
VECTOR: wind
set force vector to (0,0,0) on all points
on cloth
loop through all triangles
force = unitvector(normal) *
dotproduct(normal, wind)
add force to all points making up this
triangle
end of loop
loop through all points on cloth
add gravity to force, add force to
velocity,
end of loop
    
```

Fig. 6. Pseudo code for wind force calculation.

IV. RESULT AND DISCUSSION

This research is aimed to provide efficient and effective methods of simulating wet cloth and to study the external forces which affect the wet cloth's behaviour, such as wind and gravity forces by using mass spring model. This section explains how to construct the structure of the cloth sheet and describes how to apply the technique that is used to generate the cloth particles. It also displays how to apply wetting model on the cloth in terms of adding fluid to the cloths and how the wetting model will affect the clothes behaviour through changing the mass and the texture colour. The diagram of wet cloth rendering process is described at Fig. 7.

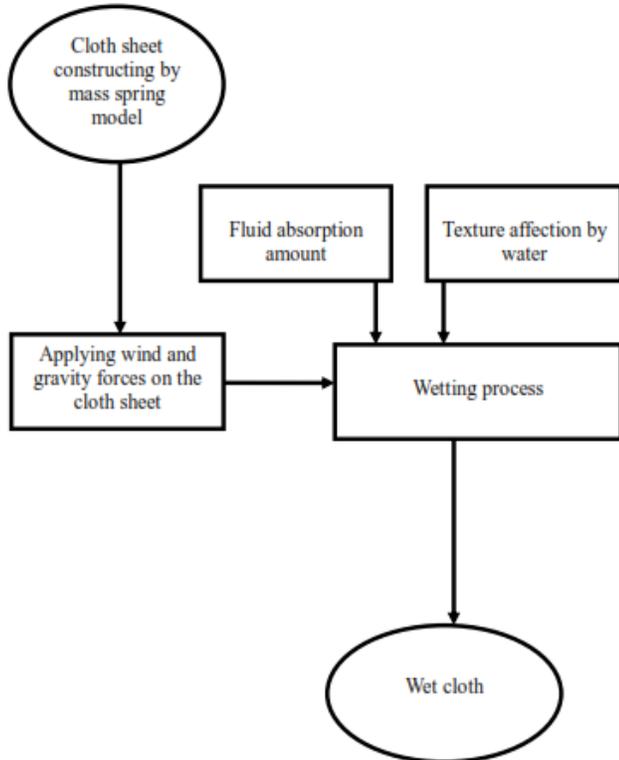


Fig. 7. Flow chart for wet cloth rendering.

A. Mass Spring Model

In 1988 and 1995, Hamann and Parent were the first how introduced Mass spring model. Then, it was further improved by Provo (1995). Mass spring is a technique used in this research to generate clothes patches. In this model the cloth sheet is initialized by a matrix of balls connected by springs. It is one of the most important techniques used widely to simulate cloth in computer graphics applications. The cloth model is embodied through a network of particles of known mass that are linked by a sequence of spring-dampers. The ball in cloth simulation can be described clearly in Fig. 8.

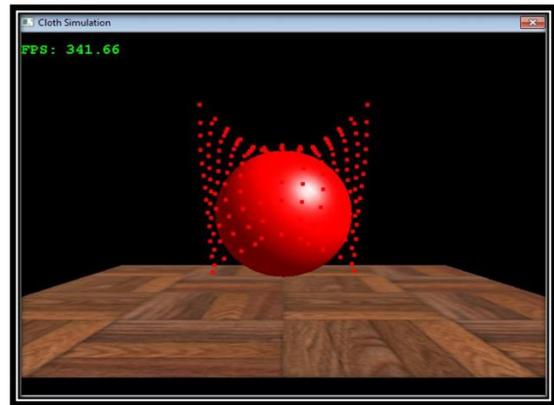


Fig. 8. Clothes ball represented as mass in open GL.

The springs would be the structural aspects of the model and resist the different loads which are put on the particles. Once the simulation is started, each spring's relaxation length is placed towards the original entire spring. The mass values from the contaminants and also the spring constants are based on the consumer. Fig. 9 shows the springs make connection between the balls to create cloth's particles.

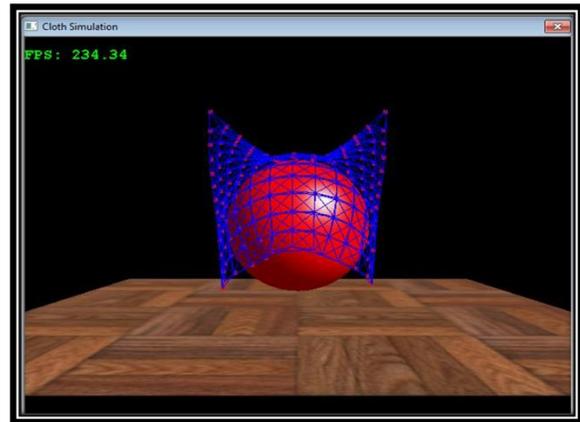


Fig. 9. Interaction between cloth particle in wireframe model with ball.

The masses and springs are set up by Newton's Second Law of Motion. The simulation is advanced incrementally to configuring the cloth sheet. This perspective represents the structure of cloth represented by mesh. Intuitively, this structure will be under the environmental effects that give the cloth properties like the stretching, bending and shearing.

B. Dynamic Forces

In the spring model the cloth is simulated as grid. As explained earlier, the springs connect the nodes while the forces are applied on the nodes to generate an animation. The system is a mesh of $m \times n$ masses. At time t every mass has position $P_{ij}(t)$. Fig. 10 shows the masses as matrix of balls.

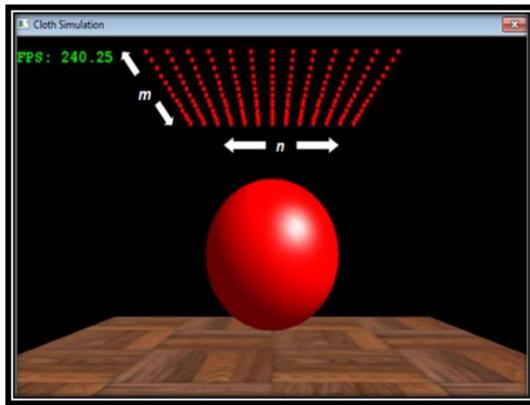


Fig. 10. Mesh of masses $m \times n$.

$$F_{ij} = M_{aij} \quad (4)$$

Where M is the mass at point $P_{ij}(t)$, and aij is the acceleration caused by the force $F_{i,j}$. The forces $(F_{i,j})$ can be internal and external forces. Internal forces epitomized by the Tensions of interconnected springs, while the external forces will be gravity and wind.

C. Forces Calculation

The basic effect of the internal forces is the Tensions of interconnected springs, which can be calculated by Hock low.

$$F = K \bullet U \quad (5)$$

Where F is the considered force, U is the deformation (change from the essential position) of the flexible body subjected to the force F , and K is the spring constant. The internal force is the resultant of the tensions of the springs linking $(P_{i,j})$ to its neighbours.

$$F_{int}(P_{i,j}) = -\sum_{k,l \in R} K_{i,j,k,l} \left[\frac{l_{i,j,k,l} - l_{i,j,k,l}^0}{|l_{i,j,k,l}|} \right] \quad (6)$$

Where:

- R is the set regrouping all couples (k, l) such as P_k, l is linked by a spring to $P_{i,j}$,
- $l_{i,j,k,l} = P_{i,j}P_{k,l}$.
- $l_{i,j,k,l}^0$, j, k, l is the natural length of the spring linking $P_{i,j}$ and $P_{k,l}$.
- $K_{i,j,k,l}$ is the stiffness of the spring linking $P_{i,j}$ and $P_{k,l}$.

Fig. 11 shows the initial position for the springs. When the cloth sheet begin move, springs position and tension value will change.

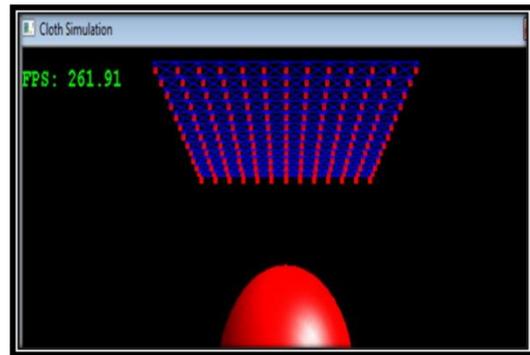


Fig. 11. Spring aspect in the initial positions.

In the initial stage of the springs in mass spring model, the springs are in the neutral length assigned by the user randomly. However, the aspect will be different after applying the internal forces on the springs as shown in Fig. 12.

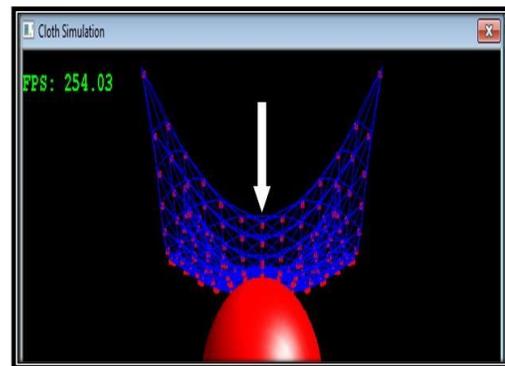


Fig. 12. Spring aspect after deformation.

D. Gravity Forces

The external forces that applied on the cloth sheet in this work are the forces of gravity and wind. The gravity will accelerate the woven cloth toward the bottom, and the wind will change the directions according to the wind resource. Consequently, this work has two different situations (dry, wet). Gravity and wind affect will be applied to change the physical properties in both dry and wet cases. This study work was based on earlier findings on the influence of gravity and wind forces on cloth and the mathematical method which applied to the cloth.

The gravity forces will have effect on the cloth behaviour and physical properties. The impact of gravity forces will increase the speed of cloth landing. In cloth simulation by using mass spring model, gravity influence will be applied on each particle of the cloth. Fig. 13 shows the gravity action on the cloth sheet.

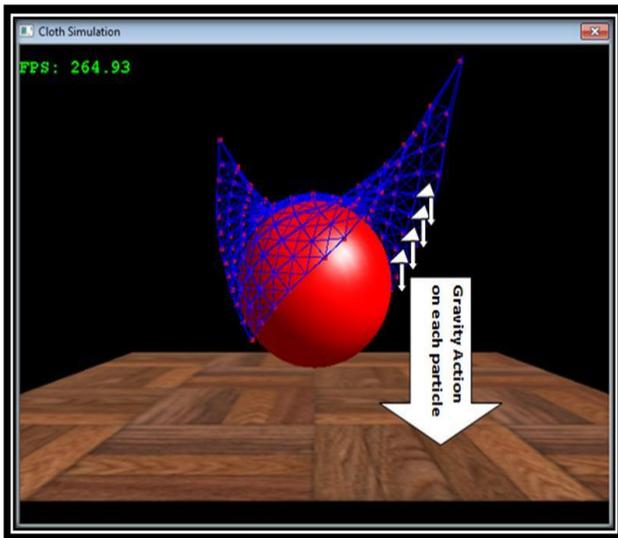


Fig. 13. Gravity forces for each particles.

To calculate the gravity forces acceleration on each of the cloth particle, the following (7) should be applied:

$$F_{gr}(P_{ij}) = M_g \quad (7)$$

Where $F_{gr}(P_{ij})$ is the gravity forces for particular point, g is the acceleration of gravity, M is the mass. There are two different scenarios that show the gravity effect in this work. The first scenario will be in case of dry cloth while the second scenario will be in case of wet cloth. In relation to dry cloth, the gravity influence will be less compared to wet cloth because the cloth weight will be in the latter. The different gravity effect in both cases (dry, wet) will be explained and discussed in detail in the evaluation section.

E. Wind Forces

Wind forces in this work are another type of external forces that are applied on the cloth. Wind forces will affect each particle as the gravity forces. The wind influence will be shown according to the wind source. To calculate the wind force, cloth sheet must be broken down into triangles. This process is already done since the cloth is described by array of mass point connected by springs as maintained in the methodology section. Wind forces affection will be calculated for each triangle. By applying variable values to the wind vector, different aspects will be shown in each implementation phase. Different scenarios with different variable values employed in this work to test the wind forces influence on the cloth sheet. Consequently, three values respectively (0.5, 1.0, 1.5) are applied to introduce three aspects of wind force showing the effect of stronger wind every time with higher values. In Fig. 14 (a) wind force value is (0.5) applied on wind vector, the aspect of the cloth affected by the wind forces show the affection is less than (b),(c) scenarios with wind force values 1.0 and 1.5, respectively.

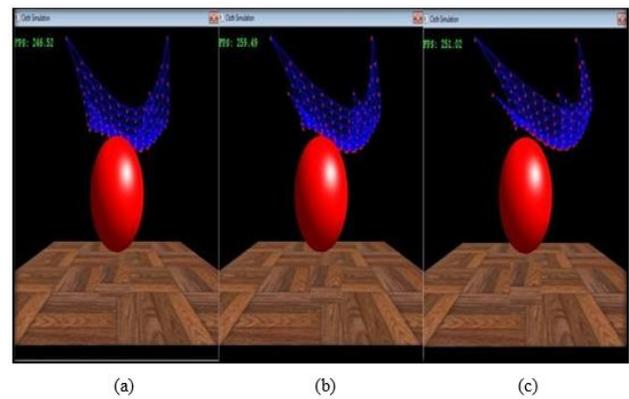


Fig. 14. (a): Cloth with low wind value, (b): Cloth with medium wind value, (c): Cloth with high wind value.

F. Geometric Collision Test

Collision handling is one of the most important steps in cloth simulation. The goal of computer graphics simulations is achieving better image in terms of its similarity to reality. When the garment interacts with the virtual environment, it needs proper handling of the cloth particles collision. In wet cloth simulation of this work, the scenario deals with animated cloth sheet. By using Mass Spring technique the collision can be detected between the cloth points in a very explicit way.

Mass Spring Model is used to simulate cloth animation and collision handling and detection. If t is inside the current time step, a proximity test is conducted using the position of the points at t . Given points X_1, X_2, X_3, X_4 , with velocities V_1, V_2, V_3, V_4 , and defining $X_{i,j} = X_i - X_j$, the time t when the points will be coplanar are the roots of the cubic (8).

$$(X_{2,1} + tv_{2,1}) \times (x_{3,1} + tv_{3,1}) \cdot (x_{4,1} + tv_{4,1}) = 0 \quad (8)$$

G. Fluid Absorption

This section describes the cloth wetting model, and explains how the interaction occurs between the fluid and cloth particles in steps. In which the cloth wetting is a result for several physical actions, such as weight increments, color changes and thus different behaviors. This work shows how the coupling between the cloths sheet, which is considered as cotton, and the fluid, which is considered as water. The wetting model will be summarized by three steps. First is the cloth absorption of the water, second is the texture affection after getting wet and finally the behavior and rendering.

The absorption applied in this work through testing different values reaching to the saturation level where there is no more absorption. Saturation level extracted from [5] work by physical experiment applied on different types of clothes. Table 1 covers the experiment of [5]. This experiment has been done on three type of cloth which is cotton, coarse wool and high absorption fabric. Cotton absorption value of [5] experiment which is 0.84 considered as the standard value for the current work.

TABLE I. FABRICS PARAMETER OF ABSORPTION[5]

Parameters	Cotton(g/m ²)	Coarse wool(g/m ²)	High absorption Fabric(g/m ²)
θ	0.84	1.24	2.492
a3	8.844	4.8936	3.3803

TABLE II. MASSES VALUES FOR THE CLOTH PARTICLES DURING WETTING PROCESS

Time in (second)	Original Mass in (gram)	Mass after wetting in (gram)
1	0.01	0.093
2	0.093	0.176
3	0.176	0.259
4	0.259	0.342
5	0.342	0.425
6	0.425	0.508
7	0.508	0.591
8	0.591	0.674
9	0.674	0.757
10	0.757	0.84

Absorptions values applied through particular time, every time the mass increases with the same value of gravity. The mass modification simulates wet cloth and makes it in the saturation level implemented into 10 phases of the cloth particles masses. Table 2 describes the experiment values where, the initial cloth particles mass referred as the original mass and the cloth particles after effect by the fluid referred as after wetting mass. Table 2 describes the mass change during 10 second period of simulation.

When the cloth particles interact with fluid, the particles mass will increase until arrive to the saturation level. Fig. 16. represents the resulted cloth in saturation situation. When the cloth particle arrives to the fullness, cloth particles will not absorb and not effected and the cloth texture changed to the darkest color. Fig. 15 refers to the saturated cloth where, the cloth sheet had effected by the fluid and the cloth texture changed to the darkest color. Also the tension forces between the springs are affected by the new masses. The springs which connect between the particles are stretched as clarified in Fig. 15.

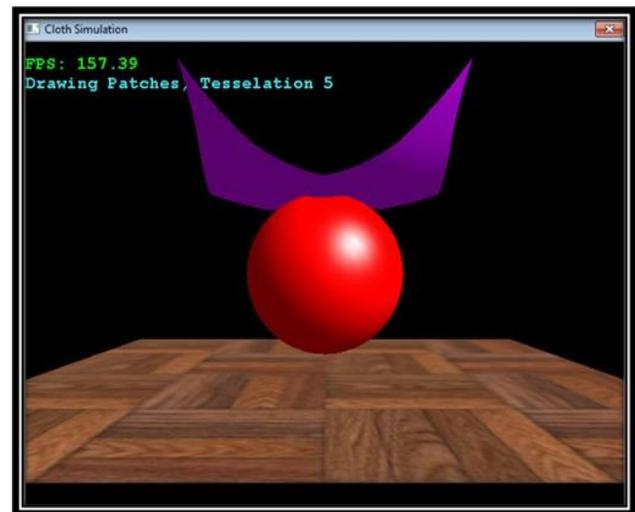


Fig. 15. Cloth in saturation mode.

H. Texture Change after Wetting Process

The texture color in cloth simulation reflects the real scene, where if cloth sheet is dry the texture color should be natural, and if the cloth sheet is wet the color will be darker as proofed in a previous research [5]. Wet cloth in this work was given concentrations of the texture color according to the absorption amount during 10 seconds of time. The color concentration increases to darker by increasing the absorption amount until reaching the moistened color completely. Fig. 16. describes the changes in the cloth texture color according to the wetting amount. The first scenario shows the texture with low concentration while the second and third scenarios refer to the texture after increasing the wetting amount. The color goes darker comparing with the first scenario. Finally, the fourth scenario represents the cloth texture in saturation case where the color has reached the highest concentration.

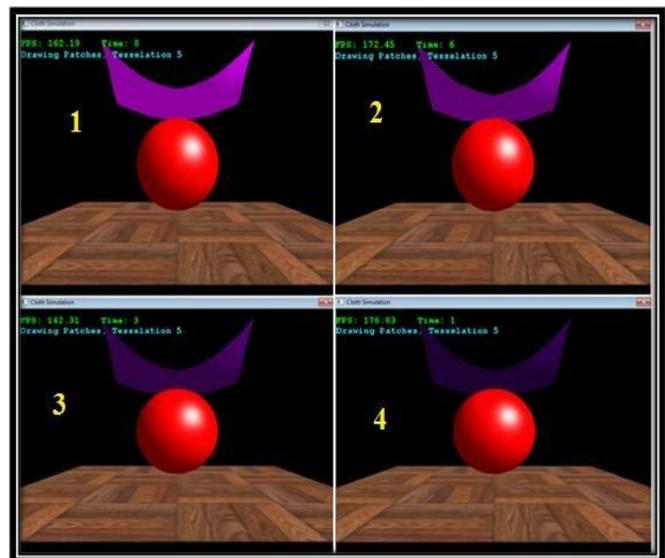


Fig. 16. Cloth texture change from dry to wet.

1. Evaluation

The first test in FPS has been done to the dry cloth to show the difference between the frames dry cloth case. Fig. 17 clarifies the dry cloth frames as extracted from the FPS where, the frames were measured according to the time in second. The trend shows that there was a significant increment of mass since starting of rendering then slowly dropped in the following time.

After applying the wetting model, the FPS measurements were affected by the variation of the physical properties which were added through new frames. Because of the variables scenarios applied to check the behavior after every time of masses changes considerations with the gravity, many tests should be applied to show the FPS for those scenarios. The first test was done on the first wetting value as shown in Fig. 18, where the mass has been increased by 0.093g which was obtained from the experiment values [5] which are mentioned in Table 2. Wet cloth frames were tested by applying 4 different values of masses changing in the wetting experiment. The values were taken from Table 2 as the (first is 0.093g, fourth is 0.342g, seventh is 0.591g and tenth is 0.84g).

In wet cloth simulation, the cloth in natural situation spent 4 second to arrive the floor, while the wet cloth in saturation situation spent 2 second to arrive at the same destination. Therefore, saturated cloth requires half the time compared to dry cloth time during simulation. Wet cloth behavior is shown clearly in Fig. 19. Cloth appearance also seems different due to the affection of the fluid on the cloth. Fig. 20 shows that FPS increased rapidly at the beginning of rendering then dropped slightly and stayed steady for a period of time. At the end of rendering time, FPS dropped then rose up again. This rapid change was to the mass change of each element of cloth.

The second test conducted in this work was the behavior test. The difference between dry and wet cloth has some views like the external appearance, the physical properties and the behavior mainly when an animation occurs. There were two tests conducted to show different behaviors.

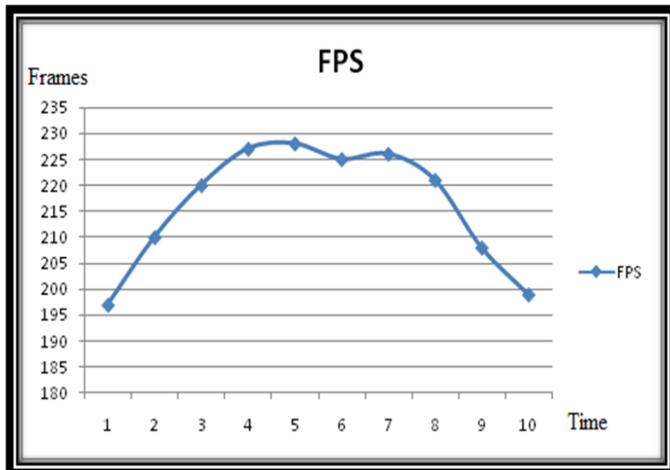


Fig. 17. FPS for dry cloth rendering.

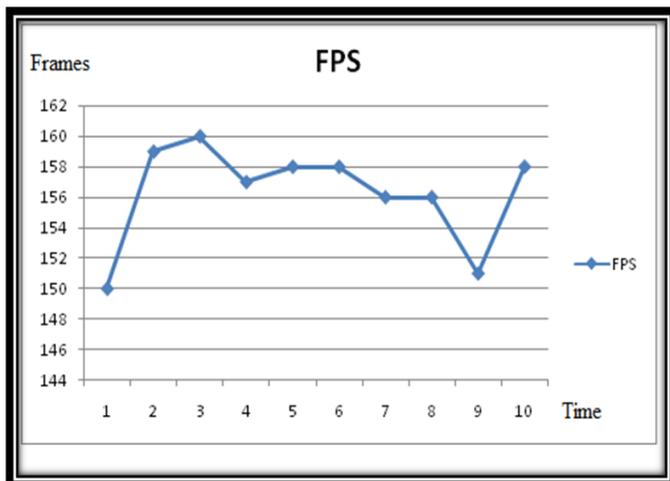


Fig. 18. FPS for wet cloth rendering.

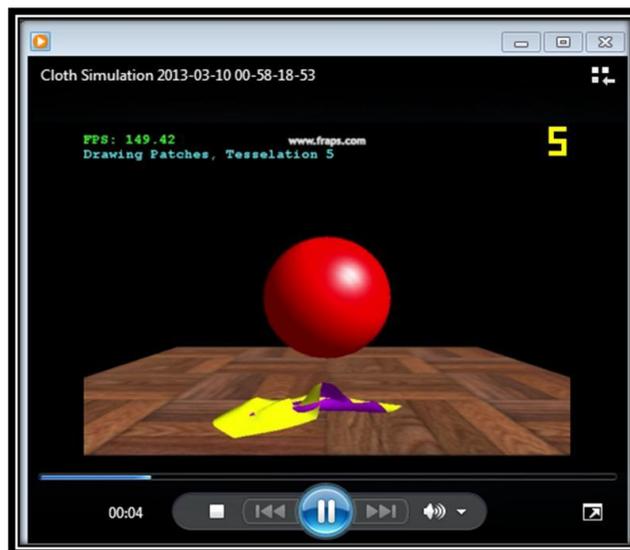


Fig. 19. Dry Cloth simulation in physical test.

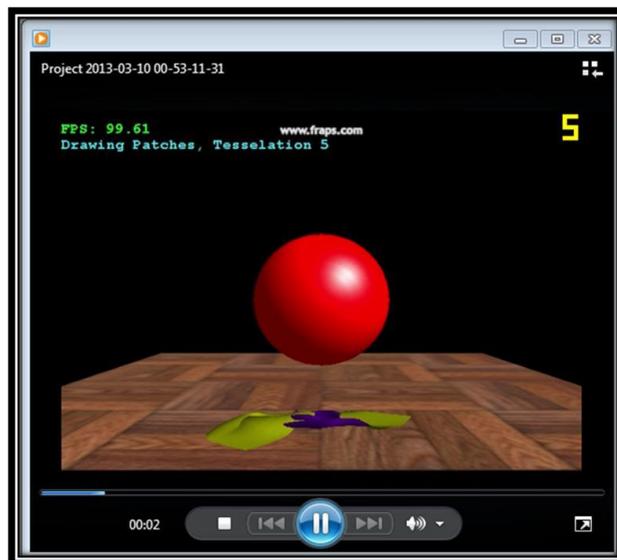


Fig. 20. Wet Cloth simulation in physical test.

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The first presented the dry cloth behavior and the presented the wet cloth. The aims of these tests were computing the time of cloth sheet arriving to the floor. The wet cloth should be faster due to the heavier weight. Fig. 20 presents the first test for the dry cloth by showing the cloth view during the moment of its arrival to the experimental environment floor.

V. CONCLUSION

This work presents an approach for simulating cloth affected by internal and external forces. Mass spring model was used to simulate cloth. It gave high flexibility to change or modify the garment properties. Also it enabled cloth particle to deal smoothly with the external influences that could affect the simulation process, Mass Spring model also was shown as a credible approach to simulate wet cloth. Furthermore this model also showed agreeable method to simulate the forces influence especially when there is an animation.

The study was conducted to achieve two goals. First goal has been achieved by introducing the wet/dry cloth simulation technique starting by cloth structuring, fluid absorbing, texture color transformation and wet/dry cloth behavior in term of animation and appearance. Second goal has been achieved by simulating the forces action and its effect on cloth appearance. The realization of mass spring under the external forces of wind and gravity technique was successfully done in it was done with wet and dry cloth simulation. The technique had sufficient ability to give graceful aspect of high realism and obviousness wet/dry cloth simulation. This technique can show clearly the influence of the external forces like gravity and wind in cloth simulation.

This work also showed the cloth affection by absorbing different values of fluid can give variables wet cloth simulation aspects. During cloth wetting process handling, textures color transformation has been described clearly. Wetting technique explained the relation between textures color and the weigh modification. Where, the experiment proved that the cloth surface color converts to darkness during the absorption process stages. The experiment showed that, in the saturation level, the cloth texture color was in the darker concentration and the texture did not change after reaching the saturation. Finally evolution proved that the wet cloth has different behavior from the dry cloth in term of animation. The experiment of behavior indicated that the dropping rate is double the time faster than dry cloth. In other words, the wet cloth needs half the time of the dry cloth to arrive to the floor. The future work is handling the wet cloth simulation with self-collision detection for virtual human, where the wrinkle effects are created and self-collision detection need to be computed in complete ways.

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Tsunami Warning System with Sea Surface Features Derived from Altimeter Onboard Satellites

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Abstract—A tsunami warning system based on active database system with satellite derived real-time data of tidal, significant wave height and ocean wind speed as well as assimilation data of sea level changes as one of the global risk management systems is proposed. Also, Geographic Information System (GIS) with free open source software of PostGIS is proposed for active database system. It may be said that the proposed tsunami warning and evacuation information provided system is recommendable.

Keywords—Active database system; ocean related data stream; assimilation data; altimeter onboard satellites; Geographic Information System (GIS), tsunami

I. INTRODUCTION

There is a strong desire for disaster warning systems to mitigate disaster as well as secondly disaster, for the warning systems for earth quake, tsunami, flooding, hurricane and so on. Important thing for that disaster mitigation is the timeliness and comprehension. All the required data and information must be collected in a timely manner and transmit warning related information in a comprehensive manner. Thus, online database system, or active database¹ and Geographic Information System (GIS)² are needed for that. Thus, the system for making warning should include the followings:

- 1) gathering disaster related data as a data stream,
- 2) calculating and extracting information for making decision of warning from the data stream, and
- 3) transmit the warning information to the peoples who are living in the dangerous areas which contains information for evacuation as well as disaster recovery. For such warning systems need the followings:
 - Active database systems [1].
 - The required real-time data for decision making of warning and evacuation.
 - Communication links [2] which allow acquisition of the real-time data and transmit warning information [3]-[5].

One of the key issues on active database systems is query creation. There is some query create software for SQL³ based database systems. Customizing GIS system for disaster

warning system is the other key issue [6], [7]. Other than these, interface between GIS and the existing database systems [8] and communication media are another important issue. The following section describes the proposed ocean related disaster warning system followed by customizing the existing GIS system. Then an example with satellite derived sea level, significant wave height and wind speed data for tsunami warning system is proposed together with assimilation⁴ data based warning system.

II. PROPOSED METHOD

A. Proposed Tsunami Warning System

The proposed tsunami warning system is composed with the following four components,

- 1) data acquisition system,
- 2) data stream acquisition and active database system,
- 3) decision making software, and
- 4) alert/warning and evacuation related data and information transmissions.

Automated alert/warning system that enables real time warning of tsunamis would enable timely evacuation from possibly hazardous coastal areas, save precious human lives and avoid miseries for millions. A tsunami warning preparedness and evacuation system is proposed as is shown in Fig. 1. Tidal height, Earthquake event, Sea level changes and the other sea surface conditions can be gathered from the satellite data servers, tsunami warning center and handheld pager, mobile phone cameras. Key issue here is active database which allows real-time data access between data and information server.

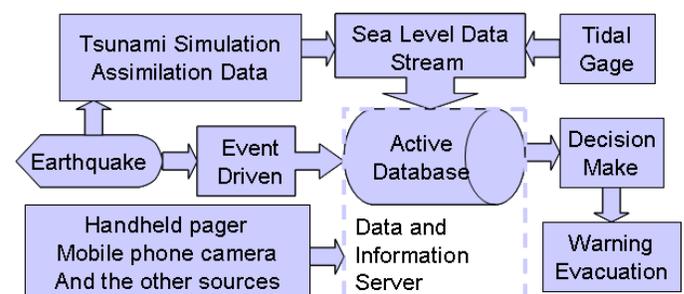


Fig. 1. Tsunami warning and evacuation information with map attributes provides system.

¹ https://en.wikipedia.org/wiki/Active_database

² <https://www.gislounge.com/>

³ <https://dev.mysql.com/downloads/>

⁴ <http://www.dictionary.com/browse/assimilation>

The sea level changes measuring device needs to be so small that people can carry it anywhere. It could be connected to mobile phone or handheld mobile terminals for real time information about the tsunami and guiding people to safer locations from the tsunami would occur. The integrated system would provide information about sea wave height and direction, using the same data as that used for modeling tsunami (assimilation data). A handheld mobile terminal with a mobile phone and General Packet Radio Service: GPRS⁵ or Worldwide Interoperability for Microwave Access: WiMAX⁶ and or WiMax2 is used to develop a wireless GIS.

This system will also comprise advance gadgets such as Bluetooth GPS and a digital camera. An internet map server is developed which contains GIS data on coastal zone land use land cover maps with all attributes. These maps are updated using high resolution satellite data.

The server is interfaced with a coastal hydraulic modeling system. Coastal hydraulic modeling system⁷ receives sea level changes data from the measuring towers at regular interval in a real-time basis. This data is used for forecasting wave height and direction at different locations along with the coastline. This information is served online in real time, and is displayed on handheld system or mobile phone in the form of a simulated map.

In the event of a tsunami, the system is forecast a warning for coastal areas about to be inundated, including the time at which the tsunami is expected. The most important feature of the system in the event of evacuation is that this module is display a map with safer locations and roads to reach those locations. Data Acquisition System

Disaster related real time data has to be gathered and acquired in a timely manner. Revisit cycle of the satellite orbit, more than 10 days is far from the required period for disaster warning, every 10 minutes or so. Although data assimilation is available, mesh size of assimilation data is coarse, every 30' or so and time interval, hourly is much longer than the required period.

The most desirable data acquisition system would be dedicated system for the specific disaster. For instance, tide gages on the tower situated at the possible areas of the tsunami for tsunami warning system. Along with the fire ring in the Pacific Ocean, there are possible areas of earth quake followed by tsunami. Therefore, if the tower is set along with the possible coastal areas, then disaster due to tsunami might be mitigated.

B. Data Stream Acquisition and Active Database System

Free Open Source Software: FOSS of GIS, Post GIS is a possible candidate of GIS system [10]. Table 1 shows widely available GIS systems. For active database system creation, PostGIS⁸ with MapServer⁹ is selected.

TABLE I. COMPARISON AMONG MAPSERVER, POSTGIS AND GRASS GIS

Tool	Category	Functionality	Remarks
Map Server	Web Mapping engine	Thematic and the other maps generation and services	Useful tool for map services
Post GIS	RDBMS middle ware extension	Space retrievals extending data types to the PostgreSQL	Useful tool for geological retrieval services
Grass ¹⁰ GIS	Client based GIS software	Geological contents management	Useful tool for construction and edition of the contents
QGIS ¹¹	Improved all mighty GIS software	All the GIS functionality Python plug-in API	Latest version is 2.1.8 ¹²

PostGIS is one of the extensions of PostgreSQL. Therefore, it can be used for active database and is appropriate for customizing for tsunami warning. The required systems are as follows:

1) PostgreSQL¹³

This is a FOSS of relational database system with SQL : Structured Query Language. One of the options is PostGIS which is GIS extension of PostgreSQL. This includes a good interface to the GIS database with MapServer, Web mapping engine and Database access with PHP and MapScript

2) MapServer(PHP/MapScript)

This is PHP¹⁴ based interface to database with PHP. Retrievals are then available through PHP Web page. When submit queries then the retrieved results are displayed from the database table.

3) MapScript¹⁵

Map engine allows displaying the retrieved results superimposing the other existing thematic maps. It consists of multiple layers. Raster and vector data of maps, meshed data and images through the PHP web browser.

It can be used with MapServer which allows display maps. Map engine allows display the retrieved results superimposing the other existing thematic maps. Multiple layers are available to show on the display. Raster and vector data of maps, meshed data and images can be seen on the PHP web browser.

MapServer international version (i18n) (i18n Version of Mapserver: Package) is used for displaying map data. MapServer 4.0.1 source code and patch for the international use is installed. PostGIS allows store the objects in concern to the GIS database. PostgreSQL extension of PostGIS supports

⁵ <https://www.lifewire.com/general-packet-radio-service-817466>

⁶ <https://mobile-wimax.jp/about/index.html>

⁷ <https://archive.org/details/coastalhydraulic00huds>

⁸ <http://postgis.net/>

⁹ <http://mapserver.org/>

¹⁰ Geographic Resources Analysis Support System: GRASS,

https://ja.wikipedia.org/wiki/GRASS_GIS

¹¹ <https://ja.wikipedia.org/wiki/QGIS>

¹² <http://qgis.org/ja/site/forusers/visualchangelog218/index.html>

¹³ <https://ja.wikipedia.org/wiki/PostgreSQL>

¹⁴

[https://ja.wikipedia.org/wiki/PHP_\(%E3%83%97%E3%83%AD%E3%82%B0%E3%83%A9%E3%83%9F%E3%83%B3%E3%82%B0%E8%A8%80%E8%AA%9E\)](https://ja.wikipedia.org/wiki/PHP_(%E3%83%97%E3%83%AD%E3%82%B0%E3%83%A9%E3%83%9F%E3%83%B3%E3%82%B0%E8%A8%80%E8%AA%9E))

¹⁵ <http://www.mapserver.org/mapscript/>

fundamental functions for analysis of GIS objects and spatial R-Tree index of the GiST base¹⁶.

PostgreSQL can be downloaded from the following URL:
<http://www.postgresql.org/>.

PostGIS is source code tree of the PostgreSQL and can be installed by using the definition of installation process of the PostgreSQL. Also, PostGIS can be compiled with GNU C, GCC and/or ANSI C compiler. GNU Make, gmake and/or make can be used for making the PostGIS.

Geometry is a fundamental PostGIS spatial data type used to represent a feature in the Euclidean coordinate system. Therefore, PostGIS allows displaying geometric relations between the target event data onto an arbitrary map and the other satellite derived imagery data.

GNU make is the default version of make. Version can be confirmed with "make -v". Make file of PostGIS will not be processed properly when the different version of make is used. Proj4 is the library of the map projection conversion tools as one of the options of the PostGIS. Proj4 is available from the following URL; <http://www.remotesensing.org/proj>.

As for the utilization of Mapserver, Minnesota Mapserver is the internet Web mapping server and is compatible to the mapping server specification. Mapserver is available from the <http://mapserver.gis.umn.edu/>. Web Map specification of OpenGIS¹⁷ is available from the following URL; <http://www.opengis.org/techno/specs/01-047r2.pdf>.

The sample application is derived from a real-world application that requires complex interactions between the database and the application server. There are three processing scenarios represented in the sample:

- 1) Making an HTTP call from Programming Language: PL/SQL to activate a Java Servlet
- 2) Using advanced queuing (AQ) to activate a Message-Driven Bean (MDB)
- 3) Using AQ to notify a Java client application of changes in the database.

This is key issue for the active database of the proposed tsunami warning system.

C. Warning and Evacuation Related Data and Information Transmissions

Mobile phone with 10km reachable WiMAX/WiMAX2: worldwide interoperability for microwave access of IEEE802.16 with 75 Mbps in maximum based on OFDM¹⁸: orthogonal frequency division multiplexing would be one of the most possible and considerable medias [9]. Warning information and comprehensive evacuation information with map and location attributes can be displayed onto WiMAX/WiMAX2 mobile phone. Java application seems to be the most appropriate programming language for WiMAX/WiMAX2.

III. EXAMPLE OF THE OCEAN RELATED DISTER WARNING SYSTEM

A. Preparation of Dataset

An attempt is conducted focusing mainly on ocean related disaster which corresponds to ocean related energy resources explorations as an example. Experimental results with significant wave height, ocean wind speed, geoids potential data which are derived from the altimeter onboard TOPEX/Poseidon¹⁹ and Jason²⁰ satellites show potential usability on the customizing of PostGIS.

Create the database containing geoids, tides, ocean winds, wave height and so on from the NASA/JPL PODAAC²¹ (Topex/Poseidon and Jason satellites data) by extracting the geo-referenced and time stamped data from the PODAAC. Access to the database through PHP and Mapscript then display the retrieval results of the appropriate ocean areas for the ocean energy exploration on the PHP web browser

B. Examples of Tsunami Related Data

There are some tsunami warning related research works [11]-[14]. Also, There are some GIS related research works as well [15]-[24].

Fig. 2 shows an example of the retrieved result of the significant wave height, sea level and wind speed in the Japanese vicinity for Jan 1 to Dec 31, 1998.

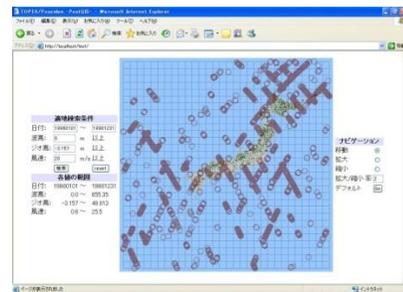


Fig. 2. An example of the retrieved result of the significant wave height, sea level and wind speed in the Japanese vicinity for Jan 1 to Dec 31, 1998. Translation, enlargement, and shrinking are available for the system.

The data are acquired from the NASA/JPL PODAAC of TOPEX/Poseidon data. Revisit cycle of the TOPEX/Poseidon satellite is 10 days so that it would not be enough data for the tsunami warning. It, however, is useful tool for ocean energy exploration. Appropriate location for the electricity power generation with ocean wind, tidal effect, and wave height can be found with the proposed free GIS system.

Also, hourly data stream of wind speed, Sea Surface Temperature: SST, and dynamic height as well as vertical profile of the sea water temperature and the other meteorological data provided from TOGA-TAO web site²² of NOAA/PMEL/TAO project office²³ is attempted for PostGIS as an active database system.

¹⁶ <http://grobbase.com/t/postgresql/pgsql-sql/029bqmhvkv/t-tree-gist-or-b-tree-i-will-need-it>
¹⁷ <http://www.sophia-it.com/content/Open+Geospatial+Consortium>
¹⁸ <http://e-words.jp/w/OFDM.html>

¹⁹ <https://en.wikipedia.org/wiki/TOPEX/Poseidon>
²⁰ <https://sealevel.jpl.nasa.gov/missions/jason1/>
²¹ <https://podaac.jpl.nasa.gov/>
²² <http://toga-tao.de.websiteprofile.net/>
²³ <https://pmel.noaa.gov/>

Fig. 3 shows dynamic height data at the nine different location in the TOGA-TAO ocean area at middle of the Pacific Ocean in the equatorial region as the data stream as of tsunami occurred on 26 December 2004 (marked with the red circle). After the tsunami hit, dynamic height raised a couple of centimeter and dropped a few cm after all. This is an indication of the tsunami measured at the 300 km apart from the earth quake occurred area.

Fig. 4 shows the wind speed, SST, and dynamic height at the specific location in the TOGA-TAO area before and after the tsunami hit Indonesia, Thailand, etc. occurred on 26 December 2004. Although just daily data are available at this time, if the sea level gages with mobile phone are situated at the appropriate areas, then sea level data are transmitted to the active database server site every minute. Thus, tsunami warning and evacuation information will be provided to the public, then the peoples who are living tsunami disaster is suspected areas can receive the information with the pagers and/or mobile phone with GIS capability.

There are some of required data for finding appropriate locations of ocean energy utilizing electric power generation plants. Namely,

1) Topex/Poseidon

Topex/Poseidon was launched on August 10 1992. This is the joint mission between U.S.A. and France. Specific features are the followings,

- Microwave altimeter
- Non-sun-synchronous
- Inclination: 66°
- Global coverage within 10 days

Fig. 5 shows Topex/Poseidon observes ocean surface along with its orbit.

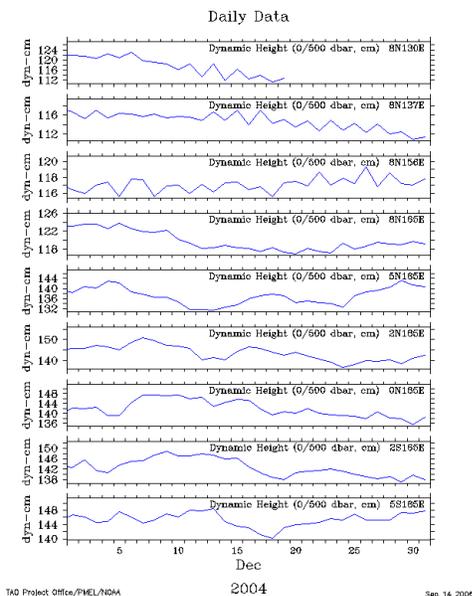


Fig. 3. Dynamic height at 9 different locations in TOGA-TAO area as of the tsunami hit Indonesia, Thailand, etc. occurred on 26 Dec. 2004.

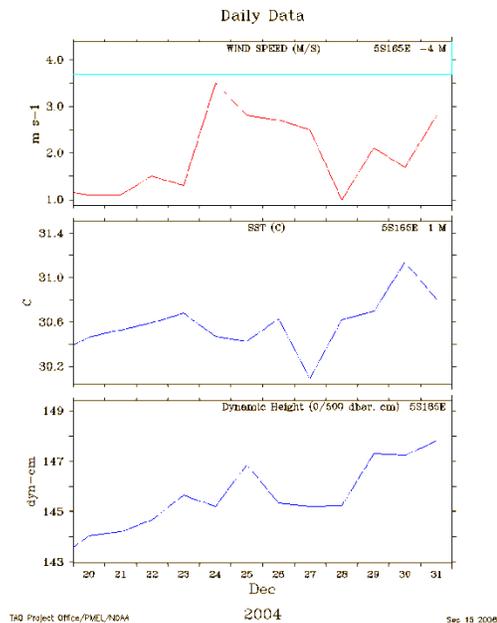


Fig. 4. Wind speed, SST, and dynamic height at the one of the location of TOGA-TAO before and after the tsunami hit.

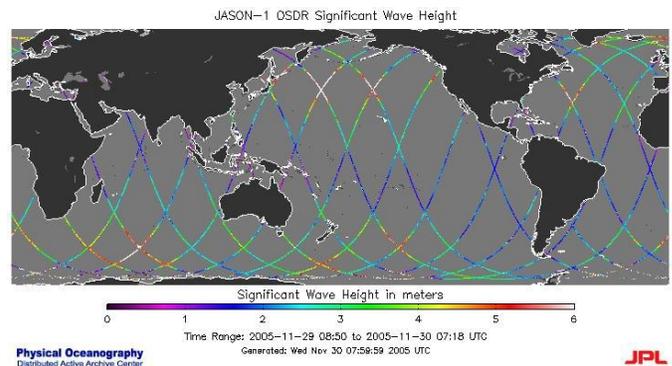


Fig. 5. Topex/Poseidon observes ocean surface along with its orbit.

2) Scatterometer

Ocean wind direction and speed can be estimated with scatterometer data. One of the scatterometers onboard satellites is SeaWinds²⁴ on Advanced Earth Observing Satellite: ADEOS-II²⁵. This Scatterometer is onboard Quick scat satellite. SeaWinds on QuikSCAT Level 3 Daily Gridded Ocean Wind Vectors (JPL Version 2) data are available from the https://podaac.jpl.nasa.gov/dataset/QSCAT_LEVEL_3_V2.

Major specification of SeaWinds is shown in Table 2.

Fig. 6 shows geoid potential and wave height is estimated with the altimeter onboard Topex/Poseidon satellite. Follow-on project of Topex/Poseidon is Jason project. One of the product of Jason satellite based altimeter is shown in Fig. 7. This is a sea surface height anomaly observed from Jason-2 and Jason-3 measurements for 10 days, from 14 November 2017 to 24 November 2017. A large sea surface height anomaly is observed at the equatorial Pacific Ocean areas.

²⁴ <http://winds.jpl.nasa.gov/missions/seawinds/>

²⁵ http://en.wikipedia.org/wiki/ADEOS_II

TABLE II. MAJOR SPECIFICATION OF SEAWINDS

Radar:	13.4 gigahertz; 110-watt pulse at 189-hertz PRF
Antenna:	1-meter-diameter rotating dish producing 2 spot beams sweeping in a circular pattern
Mass:	200 kilograms
Power:	220 watts
Average Data Rate:	40 kilobits per second

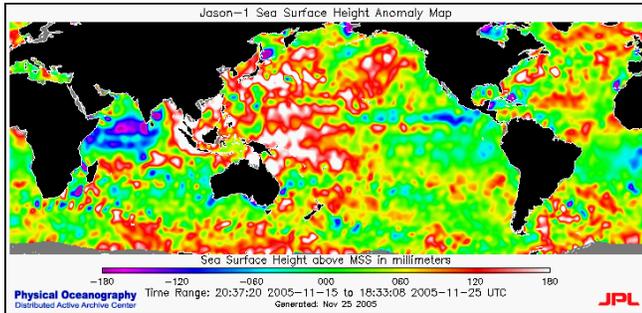


Fig. 6. Geoid potential and wave height is estimated with the altimeter onboard Topex/Poseidon satellite.

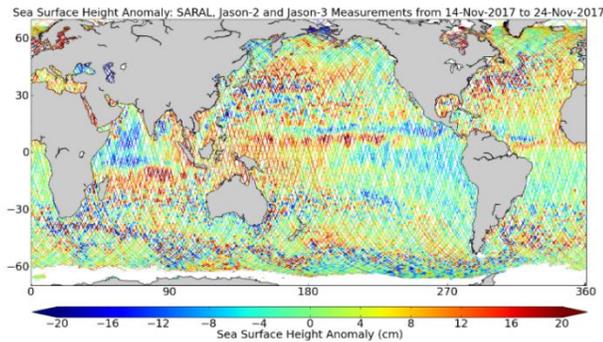


Fig. 7. Sea Surface Height Anomaly: SARAL, Jason-2 and Jason-3 Measurements from 14-Nov-2017 to 24-Nov-2017.

Along with satellite orbit, scatterometer observes ocean surface as shown in Fig. 8. Global coverage can be done. Then ocean wind direction and speed are estimated as shown in Fig. 9(a), (b).

Five days average of wind speed and vector wind is shown in Fig. 9(a) while five days average of dynamic height (21) and winds are shown in Fig. 9(b), respectively.

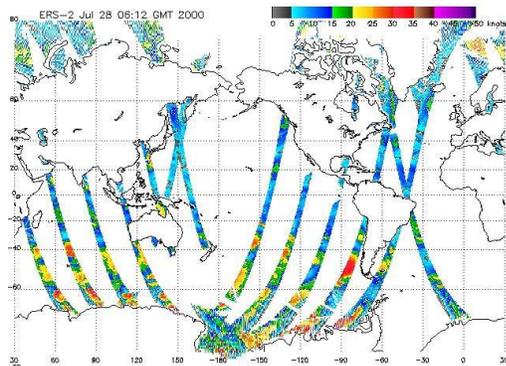
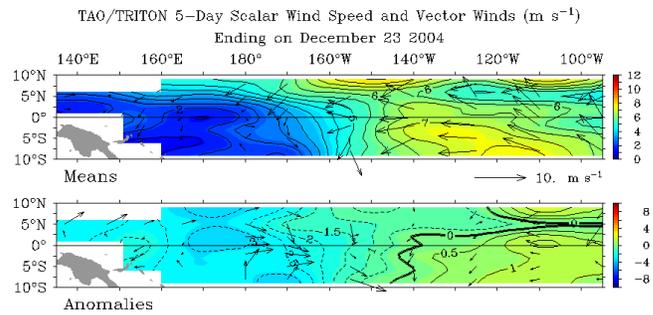
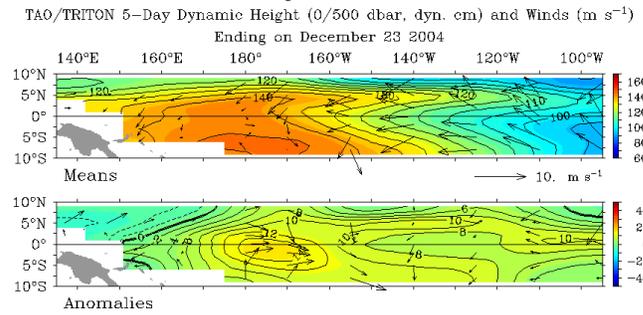


Fig. 8. Example of scatterometer observed ocean wind along with satellite orbit.



(a) Wind speed and vector winds



(b) Dynamic height and winds

Fig. 9. Example of estimated ocean wind direction and speed.

Thus, the most of required information, tidal situation, sea level height, geoid potential, ocean winds, and so on which is required to a Tsunami warning is gathered from the earth observation satellite, SeaWinds, Topex/Poseidon and MODIS onboard Terra and Aqua EOS satellites.

IV. CONCLUSION

A tsunami warning system based on active database system with satellite derived real-time data of tidal, significant wave height and ocean wind speed as well as assimilation data of sea level changes as one of the global risk management systems is proposed. Also, Geographic Information System: GIS with free open source software of PostGIS (extension of PostgreSQL) with Mapserver through the PHP is proposed for active database system. Also, it is confirmed that the most of functionalities of PostGIS (Submission of queries, retrievals of the appropriate data from the database, display the retrieved results on the PHP web browser). Furthermore, image processing and analysis are also available and can be applied to the retrieved data.

It is also found as the followings:

- 1) It is easy to customize the PostGIS (extension of PostgreSQL) with Mapserver through the PHP.
- 2) It is confirmed that the most of functionalities of PostGIS (Submitting of queries, retrievals of the appropriate data from the database, display the retrieved results on the PHP web browser).
- 3) Image processing and analysis are also available and can be applied to the retrieved data.
- 4) Most of required information, tidal situation, sea level height, geoid potential, ocean winds, and so on which is

required to a Tsunami warning is gathered from the earth observation satellite, SeaWinds, Topex/Poseidon and MODIS onboard Terra and Aqua EOS satellites.

Furthermore, it may say that the proposed tsunami warning and evacuation information provides system is recommendable.

Further experimental study is required to realize the proposed tsunami warning system in particular for practical use of the proposed tsunami warning system.

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Information Security and Learning Content Management System (LCMS)

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Abstract—The learning environment has recently undergone a quantum leap due to rapid growth in information technology. This development has allowed the e-learning environment to take advantage of electronic tools to improve teaching methods using LCMS. The emergence of many e-learning institutions has accelerated the adoption of information and communication technology without taking due care and understanding of security concerns. LCMS is a new learning method that ultimately relies on the web in its implementation. This article argues essential elements of information security (IS) that require application through the information management system. On other hand, the paper also identifies anti IS measures that can boost IS within the information management system.

Keywords—E-Learning; LCMS; LMS; CMS; information security (IS)

I. INTRODUCTION

E-learning is a term that shows the utility of the IT to help boost the educational system between the teacher and the learner, also, electronic services that share similar characteristics, such as electric business, electronic government, and electronic health record. The behavior of the users of electronic services varies according to the nature of the roles and needs of electronic services. E-learning focuses users (teacher and student) on how to take advantage of e-learning for education and learning purposes [5]. Users of e-learning may require extended periods when doing e-learning compared to other electronic services.

E-learning depends on the use of electronic applications using the Internet and processes. It includes the application of e-learning system and learning tools via the Internet network and virtual classrooms. The e-learning content design over the Internet depends on the individual to acquire new knowledge and technological means to support the process of building education system [4].

LCMS based on the design, creation, and development of content or curriculum; it gives and supports authors, instructional designers, and materials specialists the ability to create, develop and modify learning content more efficiently. So that it is easy to control, collect, distribute and reuse them to suit the elements of the educational process: from the trainer, trainee, instructional designer and expert to the course [6].

The information security is the recent topic of interest and study with specialists all over the world. All educational institutions realize that the task of the value of information

must be given to them and protect them from unauthorized individuals. Thus, information security is no longer marginalized, but a necessity in all educational institutions and corporations.

The work of information security specialists, many of the research in educational environments have not been focused on with great interest and especially IS applications in the LCMS environment [1]. Therefore, we must protect information because of the high sophistication of information that threatens the security of information technology.

Information security is very important in the LCMS because the main advantage that distinguishes between LCMS, LMS and CMS environments is the degree to which content management uses mail tools and gradual transfer to monitoring and trust in the educational system, and giving them access to the Internet to communicate between teacher and learner at any time and in any Place [2], so it requires educational institutions to take all steps and measures to ensure that all available information is correct and safe [3].

The initial part of this paper argues the status of LCMS definition, benefits, challenges and Information Threats on Internet, which are deemed securely in the content of education and defy in the application of LCMS.

In another part of this article consideration at IS in the LCMS. Issues such as legitimate new users (authorized), the reliability about the content of education, access to it, and there are also other things, all you need to protect information requirements in a request to preserve the prosperity of the LCMS process. Finally, the article discusses the possible essential elements of IS, which require application through the LCMS, as well as determine the anti-information that can enhance information security within the LCMS security.

II. LITERATURE SURVEY

A. Learning Management Systems (LMS)

LMS is a software program designed to help manage, track and evaluate training, learning, continuing education, and all learning activities in educational institutions. It is, therefore, a strategic solution for planning, description and managing all aspects of learning at the facility, including live broadcasts, virtual classes (distance learning) or instructor-directed courses, which will make educational activities that are separate and isolated from each other become fully integrated. On the other hand, LMS does not focus too much on content,

neither regarding its composition nor reuse nor even regarding content development. [11].

LMS provides the infrastructure through which learning content has delivered and managed. It provides a set of software tools that perform a variety of tasks related to managing online learning and performance management. The LMS is an Internet-based software that performs the following functions: publishing, managing, defining paths and writing reports [7].

The interaction between the learner and the content includes registration of the student in the program, enrollment in the specific courses and activities, many entries into the online learning space such as virtual rooms and learning laboratories, tracking, participation and progress in performance, registration of marks. The interaction between the learner and the teacher includes communication, reception, and transmission of information: e-mail, instant messages, discussion, dialogue, virtual rooms and learning labs, the development of information related to the educational material such as a description of the course, On feedback from students and faculty [10].

B. Content Management Systems (CMS)

CMS system is a function used in small businesses, where there is a need to design contained within the system. It can be found on the CMS through forums and e-mail and chat [11].

CMS also works to support educational or academic courses. Where the instructor can set up a website and download the required documents in standard style such as Microsoft Word, PowerPoint, etc. when switching to web content. This requires some skills courses in this field, a standard the most suitable for trainers or teachers. It also supports the effectiveness of distance learning through virtual classrooms, where trainers to disseminate the core content that learners practice through the efficiency of the required learning method required, and then teachers to oversee the educational system. CMMS is a set of practical measures applied to identify appropriate teaching tools to interact with participants in educational institutions (teacher and learner) [10]. These rules aim to manage: access to data users, gather and share ideas and information, to help store data, select content, replication, and reporting preparation.

CMS represents news, discussion forum, file upload center, web directory, guestbook, management messaging, search engine email. A unique news system, specially programmed for the operation, is used. The program allows adding news in HTML style and can attach a picture to the report, display an image of the section that the story belongs to, or even add no image at all [12]. This is due to its overwhelming and CMS emphasis as a system based on e-learning component. Information courses on an ontological basis and discussion, such as, theses and scientific research, and many scenarios that we can use as a touch in e-learning.

C. Learning Content Management System (LCMS)

LCMS shows a multi-user environment for professionals, designers, and others in creating, configuring, processing, storing, retrieving, and using the management and delivery of

digital educational content from the primary data repository [9].

LCMS is the upgraded generation of the LMS, but it increases the ability of many authors to participate in the creation, storage, use and reuse of learning content modules. The content management system can have considered as part of the Web-based learning structure. Therefore, when LCMS has called, it means a computer program that facilitates computer and Internet learning and has a branch within a broader family known as e-learning. At the same time, the LCMS is one of the types of Content Management System (CMS), which is, in turn, multiple applications that facilitate the design, testing, and dissemination of electronic content on the Internet [11]. Fig. 1 illustrates typical modular architecture components for the application. Implementation has divided into different parts: touch. Commonly used to identify application entities (ex, users, courses, resources, etc.); Operation - Used by requesting mail operations; Business Logic - is responsible for all actions that take place behind the scene. LCMS. Data class - Uses business logic of touch to extract and store data [20].

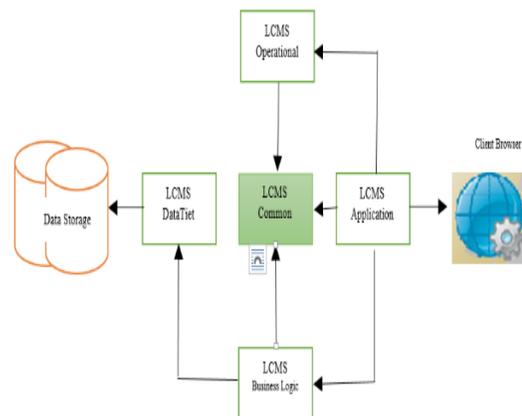


Fig. 1. LCMS's conceptual design.

D. Features of LCMS, LMS, and CMS

The three types of applications of educational institutions have a lot of capabilities and common characteristics. Table 1 provides a summary of the main advantages that educational institutions need to manage job content and learning, and to identify the range of functions they supply for CMS or LMS. It may be more or less per application for each group property. Such as you may have a dominant application feature (R) e-content, limited education (L), LCMS has an umbrella covering both LMS and CMS. Therefore, when LCMS is called, it means a computer program that facilitates computer and internet learning and has a branch within a broader family known as e-learning. At the same time, the LCMS has one of the types of CMS, which is, in turn, multiple applications that facilitate the design, testing, and dissemination of electronic content on the internet. Table 1 is a set of critical of Donatello's explorer and the Learners Hall to have an impact [13], [14], content presentation and efficiency, delivery evaluation, integration with other applications in the educational institution [15]. Content presentation, effectiveness, and delivery evaluation in the educational system, see Table 1.

TABLE I. FEATURE OF CMS, LMS, AND LCMS [13], [14]

Features	Functionality (R: Robust, L: Limited)		
	CMS	LMS	LCMS
Educated management		R	L
Content Management	R		R
Create content	L		R
Manages sessions led by coach		R	
course catalog		R	L
Recording System		R	L
Talent management		R	L
Launch and track e-learning		R	L
The establishment of assessment and evaluation, and Notes		R	R
Library to search for executable content for reuse	R		R
Cooperation / asynchronous learning tools		L	R
Integration with HR applications		R	
Locate and Deliver Specific Content to a Learner	R		R

LCMS asserts management/authoring content and includes many attributes and advantages of a learning management system. It is a program used to control and smooth cooperating electronic meaning between the teacher and the learner's design. In recent years, LCMS has associated with learning management system [8]. Learning Systems Management provides an environment that enables the organization to plan the provision of content and the management of educational activities according to the service of the trainees. It also supports authoring systems and is easily integrated with CMS. The LMS has combined with LCMS by usual technical standards. LMS handles all content management tasks from storing content in the repository, assembling and decompiling material, engaging content within a traditional learning plan, and monitoring learners' performance during the course [7].

III. LEARNING CONTENT MANAGEMENT SYSTEM BENEFITS

LCMS systems include the design and development of e-learning, especially in educational institutions, which include a large number of teachers and many educational topics and delivery [19]. There are many benefits of using LCMS are:

A. LCMS regulated in one place

Instead of e-learning content to be learned and benefit from the distributor on hard drives and different hardware engines, you can store all your courses e-learning in one place. LCMS reduces the risk of losing valuable information and easy to set up your e-learning path. Each member can be either a teacher or a learner access to information if you use a learning management system based on a cloud, as characterized by store information only on the remote server making the nature of the work of learning management systems compatible with the standard online collaboration between teacher and learner.

B. Provides unlimited access to e-learning materials

Once downloaded courses private e-learning on your LMS and dissemination, and learners have the right to unlimited access to the information they need. The main reason is why the LCMS is essential for global audiences in different time zones.

C. Easily advance learner performance tracks

The benefits of LCMS give you the ability to track the progress of the learner and to make sure their performance. For example, if a learner on the Internet is not able to complete the e-learning scenario successfully, you can help them provide extra resources to improve their performance.

D. Reduces the education and development costs

LCMS allows reduced coach travel costs and rental training site over the Internet, and the decisions of the e-learning printed.

E. Reduces the learning and development time

LCMS can reduce training and education Times online, by giving learners only online information they need directly and orderly. Instead of having to sit through a training course online prolonged for half an hour or more.

F. Organizations keep up to date with compliance systems

Must comply with the dates of the institution to which he belongs and with the current compliance systems, where learning invaluable management tool. However, using the learning management system in educational institutions gives you the ability to add compliance with the new standards for an informative course on the Internet in a matter of minutes.

G. Quickly and easily expands e-learning courses

If you want to add additional courses online course for your e-learning, you can only access the learning management system and make adjustments required without re-repeating the course of learning the entire mail.

H. Integrated social learning experiences

The benefits of LCMS are that it facilitates the integration of social learning in e-learning strategy. Since LMS is already, you can include links to pages Facebook, Twitter and LinkedIn groups, and educational forums on the Internet that could be helpful to students and learners.

IV. CHALLENGES IN THE LCMS

Participants in the touch system must ensure that they have the various tools, equipment, and software necessary in the LCMS application. Technical levels vary between teachers and learners, as the low level of professional participation of participants represents a significant challenge to the content of education. This requires addressing the problem through the work of workshops and training courses commensurate with each level of trainees.

The application of LCMS in educational institutions is a qualitative leap in the education process for both teachers and learners. The educational system sends professional staff to specialized training centers accredited by the educational agency and are off-site where the sculpture is clear from the time and place of learning. The successful use of the LCMS program requires that all participants be encouraged to apply for the program with helping rewards and incentives. LCMS needs active and successful support from managers and supervisors throughout the institution.

To activate the effectiveness of online learning learners need to be committed to applying for the LCMS program without interruption, which leads to difficulty in a confrontation in retrieving and practicing the application again, as it takes time to identify the latest apps and updated developments on LCMS and this can be challenging.

The LCMS approach requires that it depend on the design of the learning content, rather than relying solely on the delivery of the instructional material. Teachers must recognize the strategic development of education, and more use that is significant and development of educational content is essential. All participants should follow up and train all participants on how to use the LCMS program and develop their skills [16].

V. INFORMATION SECURITY AND THREATS

A. Information Security

The term information security, the first thing that comes to mind is the need to maintain the confidentiality and protection of information from intrusions and threats from other companies that may threaten the security of data. The most important obstacles facing the application of e-businesses and the fear of penetration and the information system and the following Privacy Information and beneficiaries loss. Information security in information system as an aspect of information security and the integrity of confidential information and ensure its survival, non-deletion or destruction [3].

The fact is that maintaining the confidentiality and protection of information is just one of the aspects of security; where specialists believed that the computer information security consists of the same degree of importance of three elements. These components are:

1) Data confidentiality

This aspect includes all the necessary measures to prevent unauthorized information confidential, and examples of the information that is keen to privacy: personal information, education and information on a particular educational institution, the financial situation of the organization, and military intelligence.

2) Data Integrity

Does not concern us in this aspect to maintain the confidentiality of information, but what concerns us is to take the necessary steps to protect the knowledge of the change measures, and there are many examples of this demand has been hand publish the lists of accepted names which have applied to work with, it is likely someone deletes some of the names, and the inclusion of names instead, causing a lot of confusion and embarrassment to the party concerned.

3) Availability

Maintaining the confidentiality of information integrity is essential, no doubt, but this information become worthless if it is entitled to see it cannot have reached, or that access to it needs to be for a long time, and take the attackers various means to deprive the beneficiaries of the access to information, one of these methods to delete the same information, or to

attack the devices that store information about where and paralyzed the work, shows Fig. 2. [18].

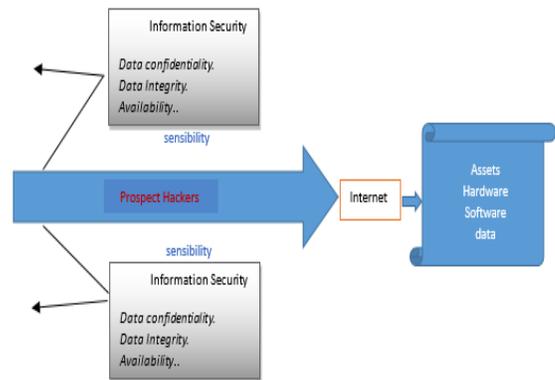


Fig. 2. Elements of information security.

B. Information Threats on the Internet

In light of the information and communication technology, individuals and institutions of all kinds and to get the many benefits of this information is to get them quickly and accurately. There are many methods followed by educational systems to protect the network from threats, including programs and equipment, including information and data, and there are methods of protection of data carried out locally through the cloud which contains the applications of security on the site of network equipment or by remote communication [17]. The following are the most prominent threats that may have exposed to information, which are as follows:

- 1) Intentional and unintentional software attacks (Viruses, thread, macros, and refusal of service), and technology used, software, failure of errors (bugs, coding problems, gaps unknown).
- 2) Intentional fault or human failure or unintentional (Accidents, employee errors).
- 3) Deliberate LMS traps of spying or overrun. (Non-authorized) (Unauthorized incoming or data) Gathering.
- 4) The statute of deliberate vandalism, and Failure of hardware or artistic mistake, and business intentional information theft.
- 5) Settlement of ideological ownership: (piracy and intellectual rights of authors and abuse).
- 6) The quality of the distractions provided by the service providers: (electricity and service issues WAN).
- 7) Use old technology, and deliberate extortion business information: (blackmail for disclosure of data).

VI. INFORMATION SECURITY AND IMPLEMENTATION OF LCMS

Information security as a science that works to protect information from the threats that threaten it or the barrier that prevents it from being attacked by providing the necessary tools and means to protect it from internal or external risks. To

keep the educational process going high. Also, there is a good return on investment and employment. The objectives of the Learning Management System are to provide education and a learning management system for all. Ensuring the availability and integrity of information is the primary objective of any organization about information security and protection against external threats. LCMS aims to provide the required safety information to users without any outgoing risks [3]. Implementation of the information system in the information management system is to ensure access to the touch environment by authorized users when needed. Also, lack of access to information has a significant impact on users of e-learning services and e-learning providers. Some features affect touch is privacy and security for international mail delivery and collaborative education [17], and data against potential security incidents. These anti-information security measures are:

A. Authentication

The process by which the identity and user data are verified and verified by the teacher or learner before giving them access to system resources, depending on the access controls used such as passwords.

B. Authorize

The process in which the information to have accessed, the operations to have performed or the services to have used are permitted only by the rights and authorizations granted to the user. As such as anti-security information needs to obtain an access control license.

C. Confidentiality

Ensure that information is handled only by authorized parties.

D. Safety

It means keeping data from modification or modifying it from people who are not authorized to access it. When someone intentionally or unintentionally changes, deletes, or violates the integrity or harm of essential data files, which is not permitted, this is a violation of the integrity of the data.

E. Availability

Ensure that information systems remain available and that the necessary data is available or can be retrieved for use when needed.

F. The accuracy of information

The accuracy of the information indicates that the error-free and valuable information provided by the user to hold at the request of the user who expects.

G. Useful information It is worth mentioning.

That the aim of this information to be useful Information in the form of a readable does not make sense, and therefore not fit for a particular purpose.

H. Possession of information

Referred to the quality, the presence, or the right of ownership or control of information and acquisition requirement, Fig. 3 shows an application IS for LCMS. In

preparing a model for LCMS for the student, the information required by users has provided via the Internet.

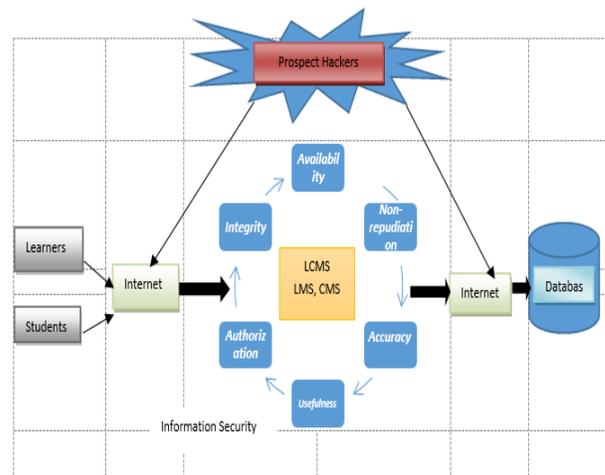


Fig. 3. Application IS for LCMS.

Information security records specific events, such as e-mail access (in an e-mail server), or the process of verifying passwords that occur in the system - whether a computer, network or database - and automatically for the ability to audit through tracing. The situations in which these systems pass, in addition to the process of reviewing the work and externally

VII. FRAMEWORK

E-learning environment requires LCMS framework that can serve as evidence to support supplier in a concept of IS management in the learning content management system. LCMS scope must be seen in the context of LCMS to contain all elements of the appropriate characteristics necessary when the general framework for education-mail mode, it is required to identify threats and attacks in e-learning and work on them to include the prosperity of frames LCMS. The context should consist of e-learning various detailed information on the policies and the ensure process and procedures and organizational structures in the LCMS environment, and to identify the functions of software and hardware to promote the implementation of the security and confidentiality of the information. Also considered is requiring maintenance required procedures and amendments.

VIII. CONCLUSION AND FUTURE WORK

Learning Content Management System faces many challenges as we mentioned earlier in the implementation of tools and programs, notably the problem of security and safety information. Security elements, such as the data confidentiality, Data Integrity, and availability of training courses and data in space and time, these factors help to build LCMS setting safe and reserved. Furthermore, the learners advantage from the existence of an active and reliable LCMS setting, and they can take advantage of the growing e-learning, and be a good and profitable investment in entrepreneurship.

LCMS was grown and evolved very fast. Benefits provided by increasing the number of beneficiaries of e-learning. Still, function LCMS expansion relies difficult on the network.

Another hand, as the web has become a space for forbidden action, they are placed under the LCMS threats to non-members and groups and outlaws unauthorized and illegitimate. The Security elements, such as the data confidentiality, Data Integrity, and availability of the information and materials in LCMS setting demand that there be a set of features and attributes anti, such as IT security appliances and software, and must have implemented. However, it has considered a way inadequate. Moreover, the group of international solidarity standards and the security of IT applied to support the best in the successful implementation of IS in the LCMS setting.

The future work on this topic is to develop the LCMS Information Security Introduction Model further. The trial will be the next focus on the application in the real world situation. It will also focus on benchmarking and cloud computing comparisons for other web services. This proposed form has many benefits that can solve many problems related to the LCMS environment successfully.

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Examining Software Intellectual Property Rights

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Abstract—Intellectual property rights (IPR) of computer software is the right to assign the software to its creator, not limited to time and space, and non-transferable. Proving IPR of the creators of computer software requires a rigorous review of the ways in which these rights may be violated. The present study was conducted by comparing two populations in Iran with the aim of identifying the level of familiarity and observance of software IPR: 1) 96 software engineers member of IEEE Association and 2) 386 students randomly. Results are analyzed by SPSS software and the validity of the results is verified using T-test. By comparing the results, it was concluded that the first population significantly observed these cases more. Then a model was presented for protecting software IPR so that the challenges are reduced. This research is the completion of our previous work that was discussed as a future work.

Keywords—Software intellectual property rights (IPR); software piracy; copyright; patent

I. INTRODUCTION

Since 1970, ethics in software engineering has been trying to define ethical boundaries in computer technology. The attempt to elaborate ethical boundaries in software engineering has created explicit rules. This question arises for software engineers whether a particular act is ethical or not.

Under the IPR law of computer software creators, both in the form of an invention and in the form of a copyrighted work, legal support is provided for software. A small percentage of software in the world is Software Invention. Currently, most software is available in copyright. The importance of paying attention to software infrastructure is when businesses are now virtual and software-based. Thus, any weakness in software protection will be accompanied by the weakening and lack of development of these businesses, which, besides manufacturers, will also deprive consumers of their benefits.

The weakness in software support directly affects corporate profits and software sales decreases legally. Business Software Alliance reports these losses annually. Assessments presented based on private data from BSA group such as Microsoft and Intel indicates that this includes both software and hardware. However, the weakness in software support is far more likely to affect not only companies but also has long-term effects on the economy. If copyright are not perceived, the motivation for innovation that makes software newer and more efficient reduces [1].

However, discerning why population participates in this illegitimate acting increase the success of corporate or state measures. Considering this and to better understand what

causes misuse of software, this article first examines these cases in the population, analyzes and compares them, and then classifies the factors relevant to the subject. In addition, a model to protect IPR of the software will be suggested. It determines how each of these factors affects IPR of the software. By doing so, we hope to provide a perspective helping corporations and governments plan better policies and practices to deal with this subject.

In the following, Section 2 shows related works. Section 3 details the objectives of this work, while Section 4 determines the measurement, sampling and data collection. The methods of analysis and analysis of achieved results are provided in Section 5. The effective factors in software piracy are given in Section 6, the conclusion is given in Section 7 and finally, we discuss future research of this article in Section 8.

II. RELATED WORKS

Software piracy damages software producers, creates unfair competition for companies, and leads customers to many security risks, including malware, security breaches, and loss of information [2].

In [3], many analytical techniques have been proposed regarding software development to detect software piracy. Software badge is a unique feature that can be used to identify the application. If in another program exactly the same sign is used, it is considered as a copy.

The Internet Business Patent supports a conceptual and software business model and does not require a physical implementation as a requisite for a traditional patent. The US courtroom has destroyed all barriers to software patents. These slow changes to extend the domain of software patents have reduced the productiveness of software copyright from a practical standpoint [4].

However many researches have studied software inventions, some have centralized on the economic aspect of copyrighted work. In [5], copyright law has been reviewed from an economic point of view.

In [6], the economic role of software patents, the use of software patents and stock market information in the duration from 1980 to 1999 were examined and it was shown that software patent court decisions had a negative impact on software products, and software industry does not profit from such resolves. As well as, [7] shows the indirect results for the implementation of US software, the acquisition of whose ownership of software patents was sponsored by venture capital firms.

III. SIGNIFICANCE AND OBJECTIVESASE

In this research, we have tried to examine the level of familiarity with IPR of software and its observance, and how much IPR is tangible and familiar to population has been analyzed. Considering that the violation of software IPR is increasing, it is essential to analyze this reason to provide solutions to stop them. Our purpose in this study is to inspect the ethical challenges of the intellectual property of software and, based on the results, present feasible solutions for betterment of the situation, and finally present a model for protecting software IPR.

IV. METHODOLOGY

A. Measurement

The tool for measuring variables and indicators in this research is the questionnaire. Also SPSS software is used to analyze data. The questionnaire is designed so that all observation of software IPR can be considered. Using the Likert scale [8], one can assign score to each of these questions and finally rate their questions and indices. The final score of the questions and indices is also calculated by averaging each one [9]. Now, with this assessment way it is possible to compute the indices received by the combination of different questions by means of averaging the results. Table 1 presents the challenges presented in this study.

TABLE I. THE CHALLENGES USED IN THIS STUDY

Ethical issues	Number of questions	Questions
violation of software IPR (Copyright)	11	1-11
violation of software IPR (Trademarks)	1	12
violation of software IPR (Trade Secrets)	2	13, 14
violation of software IPR (Patent)	2	15, 16
Other issues of violation of software IPR	3	17-19

B. Sampling and Data Collection

The statistical population of this study contains two populations in Iran 1) 96 software engineer's member of IEEE Association and 2) 386 students randomly. Participation in responding the questionnaire is done voluntarily and absolutely anonymous.

V. DATA ANALYSIS AND RESULT

A. Methods of Analysis

The reliability of the questionnaire is measured by using Cronbach's alpha [10] coefficient. The Cronbach's alpha value of this study questionnaire is 0.706 which shows the acceptable reliability of this questionnaire.

The validity of the questionnaire is measured by using Bartlett Test of Sphericity [11] and KMO¹ index [12] which is shown in Table 2.

TABLE II. KMO AND BARTLETT'S TEST

Kaiser – Meyer- Olkin measures of sampling adequacy	0.712
Bartlett's test of sphericity	
Approx. chi- square	358.312
Significance	0.001

¹ Kaiser-Meyer-Olkin

In this study, Bartlett Test of Sphericity is significant at a significance level of 0.05 because significance $P < 0.05$ and also the KMO value is desirable. Therefore, the questionnaire is Valid.

B. Analysis of Achieved Results

In this study, T-test [13] was used to examine the accuracy of the results. Table 3 sums up the results regarding the respondents' attitudes towards the ethical orientations to issues of software IPR in the population of the members of the IEEE Association.

In Table 3, descriptive statistics, including mean scores and standard deviations (SDs) for each statement, are given. The overall mean for the 19 statements is 3.13, which is above the midpoint (3), thereby indicating a moderate level of awareness in protecting software IPR among the respondents. The highest mean (3.90) is for statement 1: "I do not intentionally use software that has been illegally obtained or kept". The standard deviation for this statement is 1.22. Statement 16: "I do not give my thoughts and ideas for software design to anyone else" has the second highest mean, at 3.87, and a standard deviation of 1.06. Statement 10: "I do not offer the software produced with the participation of others exclusively" has the third highest mean, at 3.61, and a standard deviation of 1.32. Statements 2, 7 and 4 report the lowest means, respectively. Statement 2, with a mean of 2.07 and a standard deviation of 1.23, reads: "I buy the software I need legally". The second lowest mean is for statement 7, which has a mean of 2.18 and a standard deviation of 1.18, it reads: "I deal seriously with people who use the software illegally". The third lowest mean is for statement 4, which has a mean of 2.28 and a standard deviation of 1.43, it reads: "I advise friends and relatives to use the software legally.". For Indicator of Copyright, different attitudes are indicated by the respondents' feedback on statements 1-11. The mean for the 11 statements is 2.99 and a standard deviation of 1.21, which is under the midpoint (3), thereby indicating at the bottom level of awareness in protecting software IPR among the respondents. Therefore, for this Indicator high levels of concern are reported. They show the highest concern in statement 2: "I buy the software I need legally", followed by statement 7: "I deal seriously with people who use the software illegally". Low levels of concern are reported for statement 1: "I do not intentionally use software that has been illegally obtained or kept", followed by statement 10: "I do not offer the software produced with the participation of others exclusively". For Indicator of Trademarks moderate levels of concern are reported (with a mean of 3.22 and a standard deviation of 1.42), statement 12, with a mean of 3.22 and a standard deviation of 1.42, reads: "I do not use the title and badge of software for my software". For Indicator of Trade Secrets Low levels of concern are reported (with a mean of 3.53 and a standard deviation of 1.30), Statement 13, with a mean of 3.59 and a standard deviation of 1.27, reads: "I help my colleagues understand the working standards, methods to keep confidential information and general security considerations." and Statement 14, with a mean of 3.47 and a standard deviation of 1.34, reads: "I keep confidential information in my work environment that is kept in accordance with the rules" For Indicator of Patent Low moderate of concern are reported (with

a mean of 3.28 and a standard deviation of 1.03), Low levels of concern are reported for Statement 16, with a mean of 3.87 and a standard deviation of 1.06, reads: “I do not give my thoughts and ideas for software design to anyone else” and They show

the highest concern in Statement 15, with a mean of 2.69 and a standard deviation of 1.08, reads: “I do not use the thought of others to produce software in my own name”.

TABLE III. ETHICAL ORIENTATIONS TO ISSUES OF SOFTWARE IPR IN THE POPULATION OF THE MEMBERS OF THE IEEE ASSOCIATION

No	Questions	Mean	SD	SA	A	I	D	SDi
1	I do not intentionally use software that has been illegally obtained or kept.	3.90	1.22	39.6	34.37	7.29	13.54	5.21
2	I buy the software I need legally.	2.07	1.23	4.1	11.46	19.79	16.67	47.92
3	I do not give anyone the software I paid for on request.	2.71	1.22	10.42	15.62	25	32.29	16.67
4	I advise friends and relatives to use the software legally.	2.28	1.43	9.37	15.62	16.67	10.42	47.92
5	I do not trust software that is illegally produced.	3.31	1.28	25	16.67	31.25	17.71	9.37
6	I remind people who are not aware of illegal use of software.	3.11	1.07	10.42	22.92	43.75	13.54	9.37
7	I deal seriously with people who use the software illegally.	2.18	1.18	4.1	11.46	19.79	27.08	37.50
8	I do not make publicly available software I have bought legally.	3.43	1.33	22.92	35.42	16.67	11.46	13.54
9	I do not attribute to myself the software I have provided.	3.22	1.32	20.83	25	21.87	19.79	13.54
10	I do not offer the software produced with the participation of others exclusively.	3.61	1.32	34.37	25	16.67	15.62	8.33
11	I do not change software I have legally bought to create new software.	3.08	1.37	21.87	15.62	28.12	17.71	16.67
12	I do not use the title and badge of software for my software.	3.22	1.42	27.08	16.67	22.92	17.71	14.58
13	I help my colleagues understand the working standards, methods to keep confidential information and general security considerations.	3.59	1.27	32.29	21.87	27.08	10.42	8.33
14	I keep confidential information in my work environment that is kept in accordance with the rules.	3.47	1.34	32.29	17.71	23.96	16.67	9.37
15	I do not use the thought of others to produce software in my own name.	2.69	1.08	4.1	15.62	42.71	19.79	17.71
16	I do not give my thoughts and ideas for software design to anyone else.	3.87	1.06	36.42	26.04	28.12	7.29	2.08
17	I accurately express the software specifications I work with and prevent false claims, deception, and lies.	3.36	1.10	18.75	20.83	45.83	7.29	7.29
18	I fully validate the software work of the customers and refrain from illegal validation.	3.55	1.19	28.12	21.87	34.37	8.33	7.29
19	I inform the customer about of the security weakness of the software I am working on by the company I am working on.	2.92	1.28	14.58	16.67	31.25	20.83	47.92
Mean of all statements: 3.13								

SD: Standard deviation, SA: Strongly agree (%), A: Agree (%), I: Indifferent (%), D: Disagree (%), SDi: strongly disg. (%)

TABLE IV. ETHICAL ORIENTATIONS TO ISSUES OF SOFTWARE IPR IN THE POPULATION OF STUDENT

No	Questions	Mean	SD	SA	A	I	D	SDi
1	I do not intentionally use software that has been illegally obtained or kept.	2.83	1.08	7.51	15.54	42.23	22.02	12.69
2	I buy the software I need legally.	2.06	1.04	2.59	10.36	10.36	43.52	33.16
3	I do not give anyone the software I paid for on request.	2.99	1.19	11.66	24.61	25.65	27.20	10.88
4	I advise friends and relatives to use the software legally.	1.98	1.05	2.59	5.96	20.72	28.76	41.97
5	I do not trust software that is illegally produced.	1.84	1.18	5.96	5.44	10.36	23.32	54.92
6	I remind people who are not aware of illegal use of software.	1.95	1.25	7.77	5.70	11.92	23.32	51.29
7	I deal seriously with people who use the software illegally.	1.37	0.91	1.04	5.44	5.18	4.92	83.16
8	I do not make publicly available software I have bought legally.	2.77	1.10	5.44	24.35	22.54	36.79	10.88
9	I do not attribute to myself the software I have provided.	3.19	1.15	14.77	22.54	40.41	11.66	10.62
10	I do not offer the software produced with the participation of others exclusively.	2.04	1.37	13.21	2.84	7.77	26.94	49.22
11	I do not change software I have legally bought to create new software.	1.35	0.86	2.07	2.07	5.70	8.55	81.61
12	I do not use the title and badge of software for my software.	3.08	1.19	13.47	25.65	25.12	26.94	8.81
13	I help my colleagues understand the working standards, methods to keep confidential information and general security considerations.	3.09	1.08	10.36	25.65	32.64	25.39	5.96
14	I keep confidential information in my work environment that is kept in accordance with the rules.	2.93	1.12	11.14	13.99	44.82	17.36	12.69
15	I do not use the thought of others to produce software in my own name.	1.46	0.99	3.37	3.63	5.44	10.88	76.68
16	I do not give my thoughts and ideas for software design to anyone else.	3.27	1.19	19.95	19.95	36.79	14.51	8.81
17	I accurately express the software specifications I work with and prevent false claims, deception, and lies.	3.39	1.16	23.06	19.17	39.12	11.66	6.99
18	I fully validate the software work of the customers and refrain from illegal validation.	3.08	1.09	13.47	17.36	38.86	24.35	5.96
19	I inform the customer about of the security weakness of the software I am working on by the company I am working on.	3.34	1.18	20.21	23.83	32.64	16.06	7.25
Mean of all statements: 2.53								

Also, in Table 4 is presented the respondents' attitudes towards the ethical orientations to issues of software IPR in the population of student.

The overall mean for the 19 statements is 2.53, which is under the midpoint (3), thereby indicating a low level of awareness in protecting software IPR among the respondents. The highest mean (3.39) is for statement 17. The standard deviation for this statement is 1.16. Statement 19 has the second highest mean, at 3.34, and a standard deviation of 1.18. Statement 16 has the third highest mean, at 3.27, and a standard deviation of 1.19 ; Statements 11, 7 and 15 report the lowest means, respectively; Statement 11, with a mean of 1.35 and a standard deviation of 0.86. The second lowest mean is for statement 7, which has a mean of 1.37 and a standard deviation of 0.91. The third lowest mean is for statement 15, which has a mean of 1.46 and a standard deviation of 0.99. For Indicator of Copyright, The mean for the 11 statements (1-11) is 2.21 and a standard deviation of 1.03, which is under the midpoint (3), thereby indicating at the bottom level of awareness in protecting software IPR among the respondents. Therefore, for this Indicator high levels of concern are reported. They show the highest concern in statement 11, followed by statement 7. Low levels of concern are reported for statement 9. For Indicator of Trademarks moderate levels

of concern are reported (with a mean of 3.08 and a standard deviation of 1.19. For Indicator of Trade Secrets high levels of concern are reported (with a mean of 3.01 and a standard deviation of 1.08), Low levels of concern are reported for Statement 13, with a mean of 3.09 and a standard deviation of 1.08 and They show the highest concern in Statement 14, with a mean of 2.93 and a standard deviation of 1.12. For Indicator of Patent Low of concern are reported (with a mean of 2.37 and a standard deviation of 0.99), low levels of concern are reported for Statement 16, with a mean of 3.27 and a standard deviation of 1.19 and They show the highest concern in Statement 15, with a mean of 1.46 and a standard deviation of 0.99.

For general, by comparing the results of population of the members of the IEEE Association and population of student, it was concluded that the members of the IEEE Association significantly observed these cases more.

C. Checking the Achieved Results by using a Single-Sample T Test

In Table 5, the analyses of each index (the mean score assigned to each index) for the IEEE members using a single-sample t test are presented.

TABLE V. T TEST RESULTS FOR THE INTELLECTUAL PROPERTY INDICES OF THE SOFTWARE (IEEE MEMBERS)

Index	Mean	SD	D	Statistics T	significance P	CI
violation of software IPR (Copyright)	2.99	1.21	- 0.01	- 0.078	0.938	2.74 to 3.22
violation of software IPR (Trademarks)	3.22	1.42	0.22	1.506	0.135	3.15 to 3.73
violation of software IPR (Trade Secrets)	3.53	1.30	0.53	4.012	0.001	3.26 to 4.32
violation of software IPR (Patent)	3.28	1.03	0.28	2.674	0.009	3.21 to 3.77
Other issues of violation of software IPR	3.27	1.16	0.27	2.357	0.021	3.23 to 3.79

D: The difference between the mean score and the value of 3, CI: 95% confidence interval for the average response

For the Trade Secrets violation index, the mean value of the scores is 3.53, which is 0.53 units up than the value of 3, and the significance of the t-test at the 95% confidence level (Significance $P < 0.05$) indicates that the mean response of the individuals to the Trade Secrets violation component has a significant difference with the value of 3 and according to the 95% confidence interval, the mean response rate in the community with a 95% probability is within the range of 3.26-4.32. Since the questionnaire options are defined so that the responses indicating the violation of the Trade Secrets of others tend to the large numbers (Smaller than 3) it is concluded that the violation of Trade Secrets is low among the members of the IEEE Association because firstly, the mean response of individuals is up than 3 (to the " Strongly agree " or non-violation of Trade Secrets), and secondly, the mean value is significant compared to the number 3 (Significance $P < 0.05$) [9].

Similar to the abovementioned analysis and the data in Table 5, the violation of patent among the members of the IEEE Association is lower than the mean level.

For Copyright index, the mean value of the scores is 2.99, which is 0.01 units less than the value of 3, and the insignificance of the t-test at the 95% confidence level (Significance $P \geq 0.05$) indicates that the mean response of the individuals to the Copyright violation component has not a

significant difference with the value of 3 and according to the 95% confidence interval, the mean response rate in the community with a 95% probability is within the range of 2.74 - 3.22. it is concluded that The Copyright violation is average among the members of the IEEE Association because according to the above test the mean value is not significant in comparison with the number 3 (Significance $P \geq 0.05$). Similar to the abovementioned analysis and the data in Table 5, the violation of Trademarks is average among the members of the IEEE Association [9].

In Table 6, the analyses of each index for the population of student are presented.

Similar to the abovementioned analysis and the data in Table 6, for the Copyright violation index, the mean value of the scores is 2.21, which is 0.79 units down than the value of 3, the violation of Copyright is high among the members of student. In similar fashion:

- The violation of patent among the student is higher than the mean level.
- The Trade Secrets violation is higher than the mean among the student.
- The violation of Trademarks is average among the student.

TABLE VI. T TEST RESULTS FOR THE INTELLECTUAL PROPERTY INDICES OF THE SOFTWARE (POPULATION OF STUDENT)

Index	Mean	SD	D	Statistics T	Significance P	CI
violation of software IPR (Copyright)	2.21	1.03	- 0.79	- 15.016	0.001	1.33 to 1.53
violation of software IPR (Trademarks)	3.08	1.19	0.08	1.327	0.185	3.04 to 3.28
violation of software IPR (Trade Secrets)	3.01	1.08	0.01	0.236	0.814	2.92 to 3.13
violation of software IPR (Patent)	2.37	0.99	- 0.63	-12.506	0.001	1.64 to 1.84
Other issues of violation of software IPR	3.27	1.12	0.27	4.694	0.001	3.11 to 3.65

VI. EFFECTIVE FACTORS IN SOFTWARE PIRACY

Two points of view can be considered for copyrights; the first point is that copyrights are incentives for creative production. The second point is that copyright is considered as a commodity for the consumer, who seeks to use it for free or at a negligible cost. Using this argument, it can be concluded that developed countries are struggling to secure the first view to have the copyright of their own works; on the other hand, in developing countries there is an attempt to reach a second view to have access to the copyright easier and at a lower cost. As the results of this study suggest, the copyright in Iran is not to be respected as well, and individuals have free access to software and some other copyrighted works free of charge. This challenge also requires growth, education and cultural developments. Also, the infrastructures ness to be corrected and punishments should be considered for the violation of copyright [9].

In this section, the effective factors in software piracy will be presented in the light of a study of previous research, which by controlling these factors, software piracy can be reduced. These factors are shown in Fig. 1. Accordingly, if in a society, these factors are controlled together at an acceptable level, software IPR will be implemented at an acceptable level.

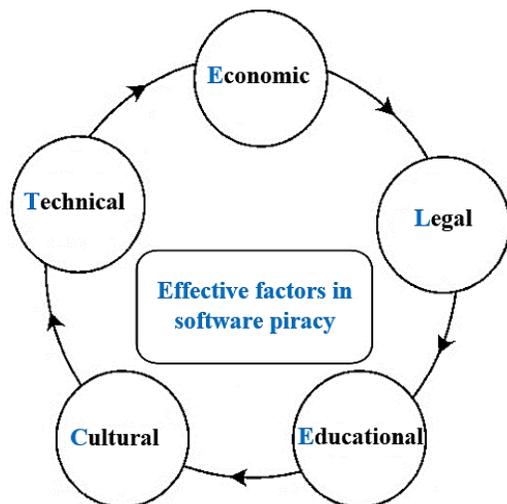


Fig. 1. Factors affecting protecting software IPR.

A. Economic Dimensions

Gross Domestic Product (GDP) is one of the factors leading to software exploitation and theft. In previous studies, the effect of software piracy on economic development has been investigated. In [14], it has been shown that levels of software piracy can increase economic development.

On the contrary, in [15], researchers found that the strict preservation of IPR would increase economic growth.

In [16], a study has been conducted in which 71 countries have been considered as population to analyses the relation between revenue release and software piracy. The results of their analysis using quintile shares showed that software piracy and software abuse exist in America, the Caribbean, East Asia, and the Pacific. It was also shown to exist in the middle and lower classes in Central Asia and Eastern Europe, and eventually in the upper classes in Western Europe and North America. Using the results, they found that in general, the inequality of negative revenue is related with software piracy.

Moreover, the amount of awareness and infrastructure required are necessary to do this. Higher Human Development Index is manifested not only in individual characteristics, but also in the infrastructure sector, for example, the infrastructure of Internet communications. Thus, as a conclusion in this regard, one can state that the higher human development index reduces the software theft or at least can strengthen this behavior.

B. Legal Dimensions

Legal cases and setting explicit rules affect software piracy. International organizations as well as governments can prevent software piracy by executing copyright contracts and increasing legal knowledge of individuals.

Unfortunately, in Iran, copyrights are not respected as they should. In this regard, the government must enforce strict rules and even take heavy fines from offenders [9].

In terms of intellectual property, the results showed that the policies of Internet Service Providers (ISPs) and, in general, the Internet and domestic policies in some countries, such as Iran, are different than other countries. As mentioned, In Iran, strict software policies are not enforced, and individuals can download software and related items freely, while these policies are strict in some countries and people cannot access these data easily. Also the effective codes of ethics as well as correct policies should also be considered [9]. In this section, the research results are consistent with other researchers' findings [17]-[21].

In [22], using a population of students of a faculty of public administration consisting of 319 students, the influence of religious factors, awareness of individuals as well as legal factors in software piracy were studied in a variety of ways and in a controlled environment. The results showed that religious factors affect people's decision on software piracy, which was the result of previous research as well. In addition, the results showed that the legal factors were not effective. Moreover, it

was shown that informing people on the legal consequences of violating IPR could help reduce software piracy.

C. Educational Dimensions

According to the conducted studies and the results obtained from this study, it can be concluded that ethics in information technology can be trained to influence the individuals. Given that there is no mandatory syllabus for students in bachelors and master and PhD course in Iran on ethical issues in information technology, such a program seems essential to cope with the ethical challenges of IT [9]. Previous investigations also prove this claim [23]-[25].

The low level of training leads to software piracy. In [26], [27], the secondary education of people over the age of 25 years was studied. Their results showed that more training reduced software piracy.

One view is that educated people have more knowledge for software piracy, so they pay less. If we consider this, software stealing should naturally increase. However, the second view is that educated people are more aware of the nature and, ultimately, of the work, which is punishable by law.

D. Cultural Dimensions

Hofstede's cultural dimensions indicate the existence of levels of software piracy. Using the questionnaire and its distribution in a population, [21] was conducted on the effect of religious beliefs on software piracy and it was concluded that religious behavior decreased digital theft.

In [28], "Software piracy due to deprivation" was examined. This study showed that a reason for software piracy could be the lack of a proper financial status that would allow people to steal the software.

The rise in the price of legal software, as well as illegal sale by unauthorized agents at lower prices is one of the key factors in software piracy. This can be beneficial for non-virtual companies carrying out this.

E. Technical Dimensions

Different methods of software protection such as cryptographic mechanisms affect the level of software piracy. The type and quality of access to the Internet and its cost affect the access to the software. In [29], [30], using a population (219 professional users and 575 amateur users), software and hardware protection against unauthorized copying of the software was analyzed using a survey. The results showed that none of the protections has a significant impact on the level of theft. The only promising result was that some hardware protections are a better solution to the problem of software piracy, and at least amateur users are not able to break and abuse it. However, today, strong hardware locks are used that have reduced the possibility of software piracy. Protection and security of IP addresses also lead to higher costs for software piracy and generally, the software steal is reduced.

VII. CONCLUSIONS

In this study, the cases related to software IPR ownership were investigated using two different populations. The results showed that the statistical community of IEEE software engineers significantly observed IPR more compared to the

students. Then, a model was introduced that, if implemented in a community of this model, the violation of software IPR will reduce.

VIII. FUTURE RESEARCH

As mentioned, this research has studied to examine the level of familiarity with IPR of software and its observance, and how much IPR is tangible and familiar to population has been analyzed among an academic setting. Further research can consider on non-academic statistical samples.

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Dimensionality Reduction using Hybrid Support Vector Machine and Discriminant Independent Component Analysis for Hyperspectral Image

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Abstract—Hyperspectral image is an image obtain from a satellite sensor. This image has more than 100 bands with a wide spectral range and increased spatial image resolution, providing detailed information on objects or materials that exist on the ground in a specific way. The hyperspectral image is well suited for the classification of the earth's surface covering due to it. Due to the features of the hyperspectral data, then lately research related to trend hyperspectral data tend to increase. The transformation of the reduction of the dimensions of the original data into a new dimension reduction chamber is often done to overcome the problem of 'curse of dimensionality' in which its dimensions tend to increase exponentially. Data is mapped from the original data to a lower dimensionless space through a dimensional reduction procedure which must display the observation input effectively. Therefore, in this research we proposed a hyperspectral dimension hybrid reduction method which adopted Support Vector Machine (SVM) and Discriminant Independent Component Analysis (DICA) techniques to reduce original data in order to obtain better accuracy. By using SVM+DICA is used to reduction dimension hyperspectral images. In this research, we use KNN as classifier. From the experiment obtained that value of average accuracy is 0.7527, overall accuracy is 0.7901, and Kappa is 0.7608 for AVIRIS dataset.

Keywords—Classification; discriminant independent component analysis; support vector machine; hyperspectral image

I. INTRODUCTION

Experiments using Hyperspectral imagery are recently widely performed. Hyperspectral image has very high resolution, providing detailed information about objects or materials that exists on the ground in a specific way. The hyperspectral image is well suited for the classification of the earth's surface coverings due to it. Due to the features of the hyperspectral data, recent research related to hyperspectral data has increased rapidly. The dimensional data reduction transformation of observational data into a new dimension reduction chamber intended to address the dimensionality curse of dimensionality dimension tends to increase exponentially [1]. Data are transformed from original data to lower dimension space through dimensional reduction procedures which must display the observation input effectively. The effectiveness of observations and dimensional space of reduction is measured by the criteria defined in various dimensional data reduction algorithms. Many techniques to reduce dimension data are Principal Component

Analysis, Linear Discriminant Analysis [2], Independent Component Analysis (ICA) [3], and Discriminant Independent Component Analysis [4] which is an extension of the ICA.

PCA dimensional data reduction method uses Eigen value decomposition to obtain orthogonal projections, also called principal components, minimizing squared errors between original and projected data. LDA have function criteria through the covariance matrix in class and between classes such as matrix between the maximized class and the matrix in the class that is minimized to obtain better separation in the reduction chamber [5]. ICA obtains a projection vector that is statistically independent of observational data through criteria representing independence such as Kullback-Leibler (KL) divergence, mutual information (MI) and correlation. DICA in [4] represents a methodology for combining both ICA and Fisher Linear Discriminant functions in order to construct feature extraction methods through variable projection where variables are projected through maximum independence. In the previous experiment we use independent component analysis with particle swarm optimization as contrast function as a dataset feature reduction [10].

Moreover, the organization of this paper is as follows. In Section I, the background of this research is presented. In Section II it explained material and methodology are consists of input dataset, hybrid SVM + DICA, and accuracy assessment. Section III is specifically explained about result and discussion. Section IV presents conclusion of this research.

II. MATERIAL AND METHODOLOGY

This research is more deeper and study about data dimension reduction and classification especially on remote sensing hyperspectral image data, reviewing other journals or libraries relating to dimensional reduction and image classification both nationally and internationally. This research based on idea Moon [6], [11], where is SVM and ICA used to dimensionality reduction in cancer dataset. Researchers also conducted a more detailed literature review of support vector machine methods for hyperspectral image classification, conventional dimensional data reduction methods available and reviewed existing constraint optimization techniques. In this research we will look for the values of OA, AA and K of the proposed method. Then the results are compared with other existing methods such as PCA, ICA, and DICA.

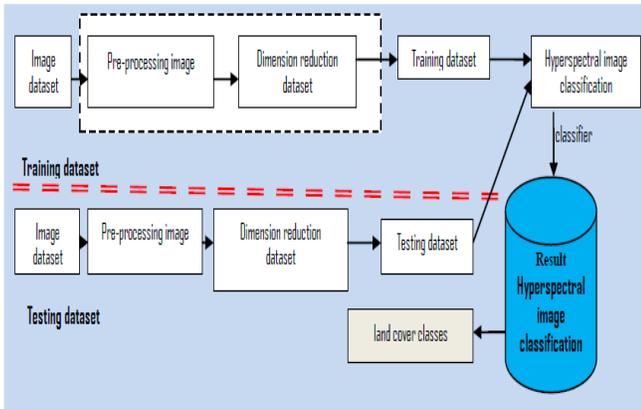


Fig. 1. Overview data dimension reduction using hybrid support vector machine and discriminant independent component analysis method.

A hybrid dimension reduction method was adopted which adopted the use of SVM as the robust dimension reduction criterion through the process of redundancy of data redundancy. Based on SVM, linear orthogonal subspace-based SVM and DICA are built here, as well as non-linear non-correlated subspace-based SVM and DICA are also built in this study. Furthermore, researchers conducted experiments to implement the proposed hybrid method in programming language by utilizing computer software. Detail diagram of the system overview to be constructed in Fig. 1.

A. Input Dataset

In this experiment we use data obtained from AVIRIS sensor, namely Indian Pines image. Image is taken in 1992 from Northwestern Indiana region. Original image has 145 x 145 pixels with 220 bands. After reduced some bands containing noise and water absorption, image has only 190 spectral bands used in this study. Wavelength between 0.4 to 2.5 This image contains 16 corresponding classes. Fig. 2 show the image of Aviris Indian Pines [7].

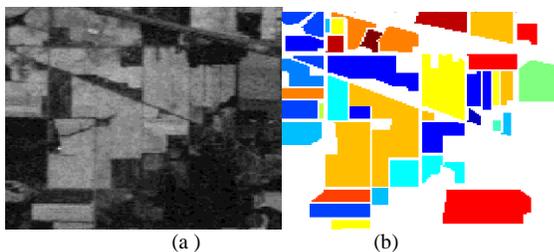


Fig. 2. Aviris Indian Pines dataset (a) composite color 3-band (R,G,B), (b) Ground truth.

B. Hybrid SVM + ICA

The purpose of this step is to apply dimension reduction data method using hybrid SVM + DICA method.

1) Discriminant independent component analysis

In the Discriminant independent component analysis (DICA) method, multivariate data with lower dimensions and independent features are obtained through Negentropy maximization [4]. In DICA, the Fisher criterion and the sum of marginal negentropy independent features are extracted by maximizing simultaneously. Therefore, DICA incorporates

representational models with Discriminant models to obtain better classification.

Negentropy is a statistical estimate of non-Gaussian random variables [11]. An approach of marginal negentropy can be written as (1).

$$N(y_i) \approx c_1(E(H^1(y_i)))^2 + c_1(E(H^1(y_i) - E(H^2(y_i) -)))^2 \quad (1)$$

In the equation (1), H^1 represented non quadratic odd function and H^2 represented non quadratic function even. The general elections for a random vector with symmetrical distribution (normal):

$$H^1(y_i) = y_i^3 \quad (2)$$

$$H^2(y_i) = \frac{1}{a_i} \log \cosh a_i y_i, 0 \leq a_i \leq 1 \quad (3)$$

$$H^2(y_i) = \exp\left(\frac{y_i^2}{2}\right) \quad (4)$$

Maximization of the marginal quantity of Negentropy with covariance unit can be obtained through the Lagrange equation in the following form:

$$L_a(W) = \sum_{i=1}^k \left[E(H(w_i^T z)) - E(H(v)) \right]^2 + \sum_{i=1}^R \beta_i (w_i^T w_i - 1) \quad (5)$$

The target functions in equation (5) are maximized so features can be obtained. Optimization problems to maximize criterion function for classification and negentropy performance of independent features simultaneously can be written as follows:

$$L_a = L_a(W) + c\phi(W, Z, A) \quad (6)$$

Where c is a constant, ϕ is a function to measure efficient classification from features Y given A , $L_a(W)$ same with β_i . Learning rule in the following form:

$$\Delta w_i = \eta(\gamma_i E(Z_g(w_i^T Z)) + k \frac{\partial \phi(W, Z, A)}{\partial w_i} + 2\beta_i w_i) \quad (7)$$

$$\beta_i = -\frac{1}{2} \gamma_i E(y_i g(y_i)) \quad (8)$$

$$\gamma_i = 2 \left[-\frac{\sum_{n=1}^N \exp(-\frac{y_{in}^2}{2})}{N} + \frac{1}{2} \right] \quad (9)$$

Perform a symmetric orthogonal of the matrix

$$W \leftarrow (WW^T)^{-1/2} W \quad (10)$$

Measurement of classification performance function as follows:

$$\frac{\partial \phi(W, Z, A)}{\partial w_i} = \sum_{i=1}^R \log \frac{w_i^T S_B w_i}{w_i^T S_W w_i} = \sum_{c=1}^C \log \frac{N_c(\mu_{ic} - \mu_i)^2}{\sum_{c=1}^C N_c \sigma_{ic}^2} \quad (11)$$

$$\mu_{ic} = \frac{1}{N_c} \sum_{n \in \text{Class } c} y_{in} \cdot \sigma_{ic} = \frac{1}{N_c} \sum_{n \in \text{Class } c} (y_{in} - \mu_{ic})^2 \quad (12)$$

In the gradient method, to maximize ϕ , need a descent computation from ϕ based on the vector base W , which is conducted as follow:

$$\frac{\partial \phi(W, Z, C)}{\partial w_i} = 2 \sum_{c=1}^C \sum_{n \in \text{class } c} (A_{ic} - B_{ic}) z_{in} \quad (13)$$

$$A_{ic} = \frac{(\mu_{ic} - \mu_i)}{\sum_{c=1}^C N_c (\mu_{ic} - \mu_i)^2}, B_{ic} = \frac{(y_{in} - \mu_{ic})}{\sum_{c=1}^C N_c \sigma_{ic}^2} \quad (14)$$

Furthermore, it can be written that the DICA algorithm is as follows [8]:

Algorithm 1: DICA Algorithm [8]
 1) . Centered observed data X
 2). Whiten center observed data to get orthonormal features Z
 3). Initialization $W = W_0 || W_0$
 4). Get features DICA in R space by $Y = W^T Z$
 5). Update using equation (6)
 6). Calculated Symmetric orthogonal $W = (W W^T)^{-\frac{1}{2}} W$
 7). If sum of Negentropy from y_i and Discriminant $\phi(W, Z, A)$ are konvergen then iteration stop. Else, back to step 4).

2) Hybrid SVM and DICA

Diagram of the proposed method is show in Fig. 3. In this diagram, $X = \{x_i \in R^n, \forall_i\}$ as a dataset, $Z = \{z_i \in R^n, \forall_i\}$ is data that projected based on X , $W = [w_1, w_2, \dots, w_m]$ is mapping matrix where $w_i \in R^n$ and $1 \leq m \leq n$, $W_{i,j} = [w_i, \dots, w_j]$ where $1 \leq i \leq j$ is sub matrix W and l , where $1 \leq l \leq m$, represented sum of features based on risk minimization mapping, $l = 1$ for two class dataset such that $W = [w_1]$ as vector. In this diagram, symbol \oplus indicated that two sub matrix, $W_{i,l}$ dan $W_{l+1,m}$ are concatenation matrix's $W = [w_1, \dots, w_m]$.

Sub matrix $W_{i,l}$ is adopted from risk minimization W as a part of W to directly considered supervised classification information as an intermediate step enabling optimization of risk and independence of data separately through the projected data set Z of X over w_i , where $i = \{1, 2, \dots, l\}$ for independence maximization.

Linear mapping W is generated from sequential process risk minimization to independence maximization as seen in Fig. 3.

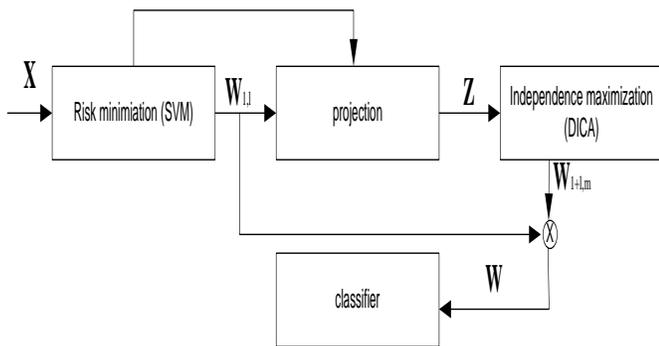


Fig. 3. Framework hybrid SVM and DICA method.

a) Risk Minimization

In risk minimization, $W_{i,j}$ has column vector representing direction of decision surface on classification process. In Support Vector Machine (SVM) there is an outcome that meets minimum structural risk by maximizing margin

separation through quadratic constraint problems with duality for binary classification problems, which can be expressed in (15).

$$\alpha^* = \text{argmin} \left\{ \frac{1}{2} \alpha^T Q \alpha - \alpha^T \mathbf{1} \right\} \quad (15)$$

$$\text{Depend on } \sum_{i=1}^N \alpha_i y_i = 0, 0 \leq \alpha_i \leq C$$

Where $\alpha = [\alpha_1, \dots, \alpha_N]^T$ and $\alpha_i, i = 1, 2, \dots, N$, that denotes multiplier Lagrange suitable to pair data i that is (x_i, y_i) with x_i as sample data and $y_i \in \{-1, 1\}$ denotes the class index for the separation problem of the two classes. N is the number of samples of the training data set. $Q = [q_{ij}]$ is a matrix $N \times N$ where $q_{ij} = y_i y_j \langle x_i, x_j \rangle, i, j \in \{1, 2, \dots, N\}$. While $\mathbf{1}$ represents a column vector consisting of a value of 1 N . C is the relaxation parameter of SVM to tolerate a certain level of empirical error in margin determination during training. The optimal output determination is established through:

$$w^T x + b = 0. \quad (16)$$

Where $w = \sum_i \alpha_i^* y_i x_i \in R^n, b \in R^1$ to take $w^T x = 0$ parallel to origin intersection in R^n . w is main information of decision process. In this paper, w is used as part of W on the proposed SVM + DICA methods.

b) Data Projection

Set of mapping vectors data obtained by structural minimization process ($W_{1,l}$) and independence maximization ($W_{l+1,m}$). Mapping vector obtained from this process without redundant information to construction of space span along ($W_{1,l}$) and ($W_{l+1,m}$). At least redundancy results from pair-wise orthogonality between w_i and w_j where $i \in \{1, 2, \dots, l\}$ and $j \in \{l+1, 2, \dots, m\}$. The pair-wise orthogonality is also depicted through $W_{1,l} \perp W_{l+1,m}$ or same with $W_{1,l}^T W_{l+1,m} = 0$.

Middle step in SVM + DICA framework is data projection component, allows for mapping vectors obtained from structural risk minimization and independence maximization to get minimum correlation. This is done through projection of data given X into a subspace that satisfies $W_{1,l}^T x = 0$, yielding the projected data, ie Z , such that subsequent independence maximization process based on Z is at least influential or correlated with process previous structural risk minimization. After data projection procedure, the projected data Z , will lose information along direction of $W_{1,l}$, which indicates that decision information through $W_{1,l}$ is no longer valid in projection subspace. However, the projection ensures that some mapping vectors of structural risk minimization, $W_{1,l}$ and independence maximization, $W_{l+1,m}$, have no correlation since $W_{1,l} \perp W_{l+1,m}$.

When data projection into subspace, orthogonal to decision hyper planes of structural minimization, $W_{1,l}$, is written as a constraint of optimization problems as follows:

$$z^* = \text{argmin}_z \|x - z\|^2 \text{ Subject to } W_{1,l}^T z \quad (17)$$

Where z represents data projected into an orthogonal subspace $W_{1,l}$, and parallel to decision hyper planes. Due to the orthogonality between $W_{1,l}$ and some components in decision plane, the structural risk minimization and

independence minimization are isolated and displayed individually by independence between multiple pairs w_i and w_j , $i \in \{1, 2, \dots, l\}$, $j \in \{1 + 1, 2, \dots, m\}$.

Furthermore, equation (6) solved by using Lagrange optimization, $\lambda \in \mathbb{R}^1$ as follows:

$$L(z, \lambda) = \|x - z\|^2 + \lambda^T W_{1,1}^T z \quad (18)$$

By taking partial derivatives of L against z and λ , we find equation:

$$\frac{\partial L(z, \lambda)}{\partial z} = -2(x - z^*) + W_{1,1} \lambda = 0 \quad (19)$$

$$\frac{\partial L}{\partial \lambda} = W_{1,1}^T z^* = 0 \quad (20)$$

From sum of equation (19) and (20) can be obtain matrix:

$$\begin{bmatrix} 2I_n & W_{1,1} \lambda \\ W_{1,1}^T & 0 \end{bmatrix} \begin{bmatrix} z^* \\ \lambda \end{bmatrix} = \begin{bmatrix} 2x \\ 0 \end{bmatrix} \quad (21)$$

Where I_n identity matrix is n dimension. z^* is form of the projected Z dataset.

c) Data independence maximization

The search intelligence maximization for a linear non-orthogonal coordinate system having axes is established through both the first statistical order and higher than the original data. As an unsupervised feature extraction method in the proposed framework, independence maximization is applied to the projected data set Z when the data representation capability through independence maximization. It's likely to result in better unsupervised classification accuracy compared with other conventional unsupervised feature extraction methods. Independence maximized by adopted approximated negative entropy criterion, because it is efficiently both error and computational, as one of the variants of several ICA. The negative entropy approach can be written as:

$$w_i^+ = E\{zg(w_i^T z)\} - E\{g'(w_i^T z)\} \quad (22)$$

Where is w_i^+ is temporal approximation independent component, $i \in \{1 + 1, 2, \dots, m\}$. g is a derivative of a non-quadratic function introduced in [6], and $g(u) = \tanh(au)$, g' is a derivative of g , and $g'(u) = \text{asech}^2(au)$ can be written as:

$$W_{l+1,m} = W_{l+1,m}^+ [(W_{l+1,m}^{+T} W_{l+1,m}^+)^{-1/2}]^T \quad (23)$$

Where is $W_{l+1,m}$ is a representation of decorrelated mapping based on $W_{l+1,m}^+ = (w_{l+1,1}^+, \dots, w_m^+)$ maximization.

C. Accuracy Measurement

Evaluation of classification accuracy of y will be done by classification accuracy assessment which is looking for Kappa (K), overall accuracy (OA) and average accuracy (AA) value [9].

III. RESULT AND DISCUSSION

Aviris Indian Pines dataset is a multiclass in the nature that used in this experiment dimensionality reduction purpose. The number of features or dimensions is reduced to 95% due

to hybrid method. The k nearest neighbor algorithm is used for the classification accuracy which is our performance metric. Some other metrics' are also used for this which are Kappa (K), overall accuracy (OA) and average accuracy (AA) value. Above all the parameters are calculated by the use of confusion matrix. From experimental result we can show that proposed hybrid technique are performs extremely well. The result of classification accuracy shows better than other methods such as PCA, ICA, DICA, and SVM+DICA. Result of Classification show in Fig. 4 and Table 1. We can see that value AA is 0.7527, OA is 0.7901, K is 0.7608 when using SVM +DICA as reduction dimensionally methods. Similarly we can see when using PCA methods only, value of AA) is 0.7501, OA is 0.7450, and value of K is 0.7410.

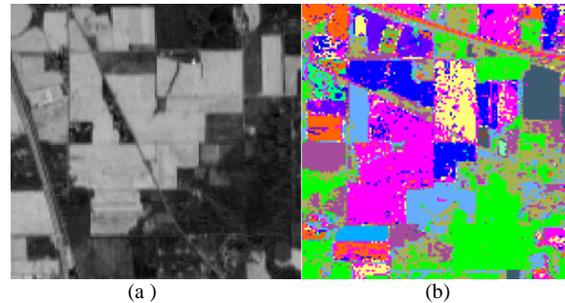


Fig. 4. Aviris Indian pines (a) 10 independent component (IC) using SVM+DICA method (b) Result classification.

TABLE I. ACCURACY CLASSIFICATION USING THE PROPOSED HYBRID METHOD

Methods	OA	AA	K
PCA	0.7510	0.7450	0.7410
ICA	0.7316	0.7203	0.7356
DICA	0.7820	0.74.10	0.7580
SVM + DICA	0.7901	0.7527	0.7608

IV. CONCLUSION

Based on the results of research that has been done, it can be concluded things as follow: We have reviewed and implemented a hybrid method for reducing dimension of hyperspectral image data using support vector machine (SVM) and discriminant independent component analysis (DICA). KNN is used to be classifier in this experiment. The value of AA is 0.7527, OA is 0.7901, and K is 0.7608 when classification done by using SVM+DICA dimensionality reduction on AVIRIS dataset. Therefore, this is required formation of appropriate method for reduction of image data dimension for classification process so that obtained higher accuracy compared to previous method such as only use PCA, ICA, DICA. Furthermore the researcher wants to use this proposed method for image segmentation based on bio-inspired algorithm for hyperspectral image.

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NoSQL Racket: A Testing Tool for Detecting NoSQL Injection Attacks in Web Applications

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Abstract—A NoSQL injection attack targets interactive Web applications that employ NoSQL database services. These applications accept user inputs and use them to form query statements at runtime. During NoSQL injection attack, an attacker might provide malicious query segments as user input which could result in a different database request. In this paper, a testing tool is presented to detect NoSQL injection attacks in web application which is called “NoSQL Racket”. The basic idea of this tool depends on checking the intended structure of the NoSQL query by comparing NoSQL statement structure in code query statement (static code analysis) and runtime query statement (dynamic analysis). But we faced a big challenge, there is no a common query language to drive NoSQL databases like the same way in relational database using SQL as a standardized query language. The proposed tool is tested on four different vulnerable web applications and its effectiveness is compared against three different well known testers, none of them is able to detect any NoSQL Injection attacks. However, the implemented testing tool has the ability to detect the NoSQL injection attacks.

Keywords—NoSQL; injection attack; web application; web security; testing tool

I. INTRODUCTION

The recent advance in cloud computing and web applications has created the need to store large amount of data in multi-different databases that provide high availability and scalability. In last years, more and more of companies have adopted different types of non-relational databases, commonly referred to as NoSQL “Not only SQL” databases, and as the applications they serve emerge, they gain wide market interest. The NoSQL databases are not relational by definition and therefore they do not support full SQL functionality, instead of relational databases, they trade consistency and security for performance and scalability. As increasingly sensitive data is being stored in NoSQL databases, security issues become growing concerns [1]-[3].

In this paper we propose a web based tool named “NoSQL Racket”. This tool has ability to detect and prevent NoSQL injection attacks in web applications.

II. RELATED WORK

Many researchers have contributed in the area of NoSQL security. Bryan Sullivan [4] explained security issues related to NoSQL databases and differences with relational databases, and what extra set of issues need to be considered when designing and developing systems using these types of data stores. He discussed injection techniques against MongoDB and then moved on to compelling examples of server-side JavaScript injection using Node.js as an example. He discussed risky constructs to look for, during code review and ways to avoid some typical pitfalls.

Soel S. et al. [5], describes the design and implementation of Diglossia, a tool detects code injection attacks on server-side Web applications generating SQL and NoSQL queries. To detect injected code in a generated query, Diglossia parses the query in tandem with its shadow and checks that the two parse trees are syntactically isomorphic, and all code in the shadow query is in shadow characters and, therefore, originated from the application itself, as opposed to user input.

Okman, L. et al. [1], discusses two of the most common NoSQL databases (Cassandra and MongoDB) and outlines their main security weaknesses and problems.

IBM eBook report [6], it provides a basic introduction to the topic of NoSQL and its rapid growth and adoption. In addition to, it’s focus on two primary areas around data security and protection, and how “IBM InfoSphere Guardium” solutions can help with both of them.

Adrian Lane [7], it examining security for “big data” environments, reviewing built-in protections and weaknesses of these systems which are depending on the Hadoop framework and the other common NoSQL databases (Cassandra, MongoDB, Couch, Riak, etc.).

Amreen and Dadapeer [8], Present a reversible watermarking algorithm to provide the security for NoSQL by using a unique watermark to mark the data and by using

reversible watermarking technique which allows recovery of original data along with the embedded watermark information.

Aviv Ron and Alexandra Shulman-Peleg [9], Present a few techniques for attacking NoSQL databases such as injections and CSRF. Also, they present methodologies to mitigate these attacks.

III. INJECTION ATTACKS TYPES

“The OWASP Top 10” [10] and “The 2011 CWE/SANS Top 25” [11] lists injection attack as the most common security risk to web applications. Injection is an entire class of attacks that rely on injecting data into a web application in order to facilitate the execution or interpretation of malicious data in an unexpected manner. Examples of attacks within this class include Cross-Site Scripting (XSS), SQL/NoSQL queries, Header Injection, Log Injection and Full Path Disclosure.

OWASP 2010 defines injection as follows:

“Injection flaws occur when an application sends untrusted data to an interpreter. Injection flaws are very prevalent, particularly in legacy code, often found in SQL queries, LDAP queries, XPath queries, OS commands, program arguments, etc.”[12].

But this definition was modified several times by OWASP from 2013 to 2017 and ended up defining injection which includes NoSQL and became as follows:

“Injection flaws occur when an application sends untrusted data to an interpreter. Injection flaws are very prevalent, particularly in legacy code. They are often found in SQL, LDAP, Xpath, or NoSQL queries; OS commands; XML parsers, SMTP Headers, program arguments, etc.” [10], [13].

Injection attacks have ruled in the top of web application vulnerability reports for much of the past decade. The OWASP Top 10 Project (2013, 2017), which tests and evaluates the most critical threat categories against web applications, places ‘Unvalidated Input’ in the top spot, followed by the related XSS Flaws and Injection Flaws in 3th and 8th place respectively. The CWE/SANS Top 25 Most Dangerous Software Errors list also places high risk on the same issues [11].

Injection attacks can be classified according to OWASP into the following types:

- Blind SQL Injection.
- Blind XPath Injection.
- Buffer Overflow.
- Format String Attack.
- LDAP Injection.
- OS Commanding.
- SQL Injection.
- SSI Injection.
- XPath Injection.

- NoSQL Injection.

But for the purpose of this paper, we will be focusing on NoSQL injection attack and will be discussed in the following section.

IV. NOSQL INJECTION ATTACK

NoSQL injection refers to an injection attack through the placement of malicious code (like other web attack ways) in NoSQL statements through web page input controls. The attacker takes the advantage of poorly filtered or not correctly escaped characters within part of NoSQL statements and injects arbitrary data into a string that’s eventually run by the NoSQL database engine (e.g. a login form) as shown in Fig. 1.

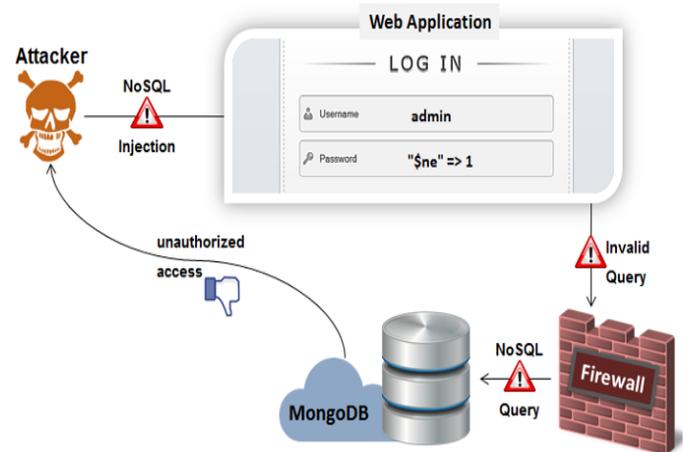


Fig. 1. NoSQL injection attack in web applications.

Through vulnerable Web applications, attacker can get unauthorized access to a NoSQL database, and can modify or delete data. Currently almost all NoSQL databases such as MongoDB, Hadoop/HBase, Cassandra, CouchDB, and Riak are potentially vulnerable to NoSQL injection attacks. NoSQL injection attack can occur in web applications through some methods, such as Injection through web page input controls and cookie files.

Web based forms allow somewhat access to back-end NoSQL database to allow adding or modifying the stored data. Any web form, even a simple login form, signup form or search box (where user can input or modify data), might provide access to back-end NoSQL database. This means that there is a high probability for injecting malicious code and attacker can bypasses firewalls and endpoint defenses.

The common reason that a web application is vulnerable to NoSQL injection is incorrect filtering and poor validation for user input. Web forms are quite common to collect data from user. So, practically it is not suitable to lock all the entry points to bar NoSQL injection attackers. To prevent attacks, web developers must apply proper filtration/validation on all forms. For more clarifying, we will show in the following an example for NoSQL injection attack.

Let’s suppose that some PHP web application requests through the screen a user name and a password to access a private area. The application will pick these values and it will

collect a query to send to the NoSQL database (e.g. MongoDB).

The MongoDB collection “regusers” contains two documents for authorized users as shown in Fig. 2.

The PHP webpage might look like Fig. 3.

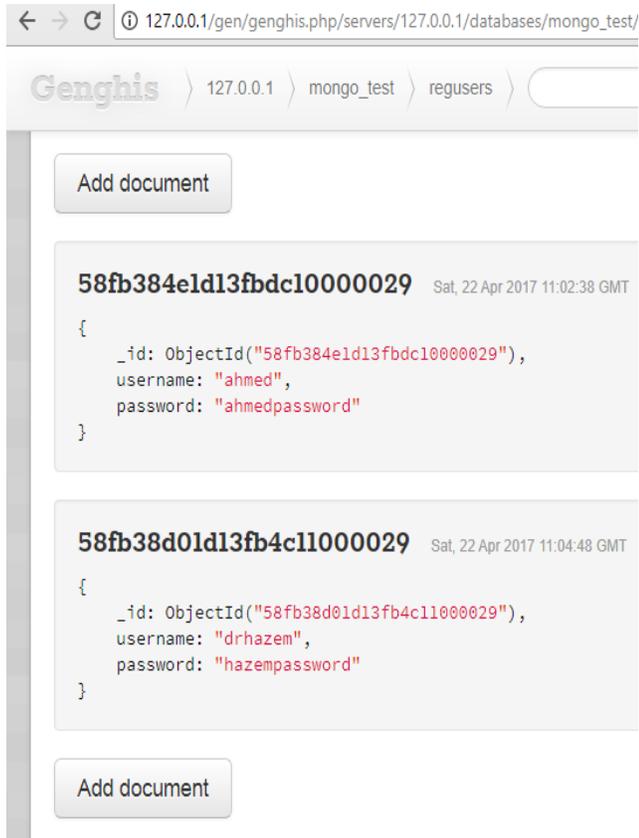


Fig. 2. MongoDB collection “regusers”.

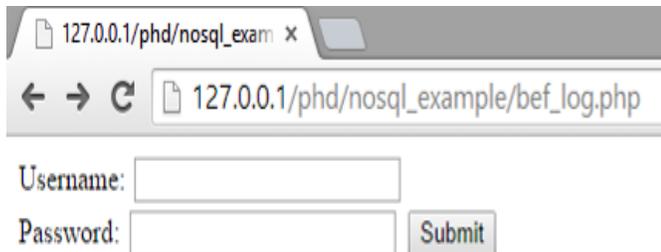


Fig. 3. PHP login webpage.

Supposing that is a PHP script selects a document from MongoDB. The following NoSQL query string verifies a username and password combination is valid or not:

```
$collection->find(array("username" => $_GET['username'],
"password" => $_GET['password']));
```

In this case, attacker user can write some texts that will be sent to the NoSQL database (MongoDB) without any verification. Given the case of a malicious user, he could write in the password field the string "\$ne" =1 as shown in Fig. 4.

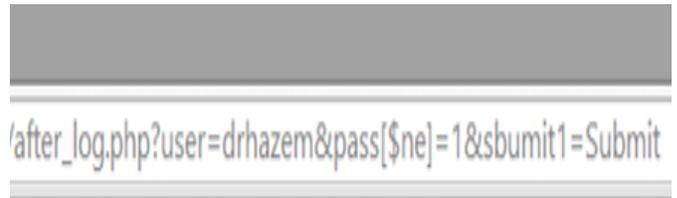


Fig. 4. NoSQL injection in password field.

In this case, the resulting query will be as follows:

```
$collection->find(array("username" => "drhazem",
"password" => array("$ne" => 1)));
```

“\$ne” selects the documents where the value of the field is not equal to “1”. So, this query will produce the same result as if the admin user had introduced their password correctly. According to this example, the web application will allow the access to administration area to a user who doesn’t know the proper password.

V. PROPOSED TESTING TOOL “NOSQL RACKET”

There are now over 225 NoSQL databases available for use with web applications. Each one offers different features and limitations. So, we faced a big challenge because there is not a common language between web applications and NoSQL databases [10].

For this reason, our proposed tool offers a general testing mechanism for detecting all NoSQL injection attacks without depending on specific syntax and data model. To overcome this challenge, we will create a simple database table named “Driverstbl”. The table “Driverstbl” contains all query string forms and its types such as reserved keywords, logical operators and relational operators as shown in Table 1.

TABLE I. “DRIVERSTBL”

NoSQL Database Type	String Type	Syntax
MongoDB	Reserved keywords (RK)	db
MongoDB	Reserved keywords (RK)	find
MongoDB	Reserved keywords (RK)	update
MongoDB	Operator(OP)	\$and
MongoDB	Operator(OP)	\$exists
MongoDB	Operator(OP)	\$ne
and so on for other “String Types” in MongoDB.		
CouchDB	Reserved keywords (RK)	getDatabaseInfos
CouchDB	Reserved keywords (RK)	getDoc
CouchDB	Reserved keywords (RK)	storeDoc
CouchDB	Operator(OP)	&&
CouchDB	Operator(OP)	in
and so on for other “String Types” in CouchDB and so on for other NoSQL Database Types (Cassandra, Amazon DynamoDB.)		

Each code query statement and runtime query statement transformed into comparative patterns format depending on “Driverstbl” table as shown in Fig. 5.

The “NoSQL Racket” testing tool returns an array that contains the number of repetition for each string stored in “Driverstbl” table. Supposing the following PHP script in static code state is S1 and the same code statement in dynamic state is S2:

```
S1:$collection->find(array("username" =>
$_GET['username'],
"password" => $_GET['password']));
S2:$collection->find(array("username" => "drhazem",
"password" => array("$ne" => 1)));
```

According to “Driverstbl”, The “NoSQL Racket” testing tool generates the following patterns for S1, S2:

```
S1 pattern: Array ( [0] => Array ( [0] => PK [1] => find [2]
=> 1 ) [1] => Array ( [0] => PK [1] => array [2] => 1 ) [2] =>
Array ( [0] => OP [1] => => [2] => 2 ) ).
```

```
S2 pattern: Array ( [0] => Array ( [0] => PK [1] => find [2]
=> 1 ) [1] => Array ( [0] => OP [1] => $ne [2] => 1 ) [2] =>
Array ( [0] => PK [1] => array [2] => 2 ) [3] => Array ( [0] =>
OP [1] => => [2] => 3 ) ).
```

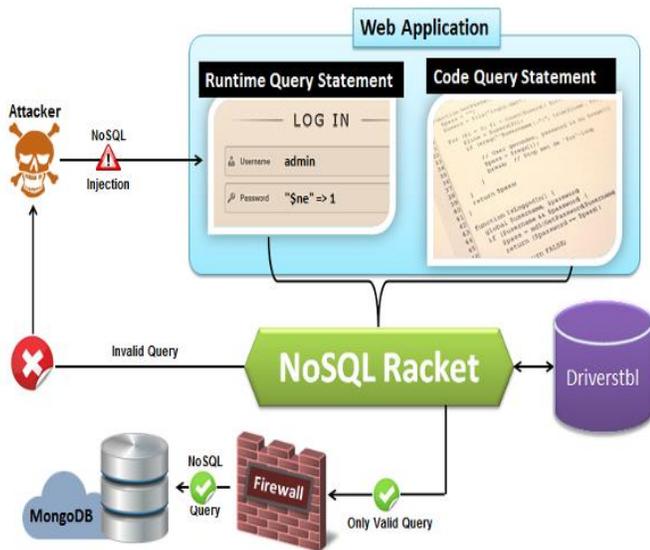


Fig. 5. NoSQL injection in password field.

After generating patterns for each query statement code (S1) and query statement in running state (S2), The “NoSQL Racket” will check the matching between generated patterns as shown in the following algorithm:

Step 1: Get Code Query Statement (S1) and Runtime Query Statement (S2).

Step 2: Let DBT= NoSQL database type.

Step 3: Connect to nosql dbs and select all “String Type” and “Syntax” from “Driverstbl” table where NoSQL Database Type = DBT.

Step 4: Group and count words in S1 and S2 according to selected data in Step3.

Step 5: Generate patterns for each statement S1, S2.

Step 6: Set Inj =0

Step 7: For each item in S1 and S2 patterns, repeat until end of items.

Step 7.1: If S1[i] not equal to S2[i],then set Inj =1

Step 7.2: Go to Step 7.

Step 8: If Inj =1, then display error page and stop running, else continue running & execute query.

According to the results of matching patterns and input values, there are two decisions:

If the patterns are matched, the web application will continue running.

If the patterns are not matched, the web application will be terminated and the proposed algorithm displays an error page.

VI. EXPERIMENTS AND RESULTS

To investigate the effectiveness of the proposed tool “NoSQL Racket”, we will examine the detection ability through a comparative study with the most powerful testers for example, Netsparker, Vega and Skipfish. On the other hand, we will use four versions of web pages in our comparative study which covers all NoSQL databases types which are Document based, Column oriented and Key-valued. Each version connected to different NoSQL database which are (MongoDB, Cassandra, CouchDB and Amazon DynamoDB).

Also, we will examine the performance for our proposed tool “NoSQL Racket” through performance testing tool called “LoadComplete”.

A. Detection Ability Comparative Study

Four PHP web scripts are used for examination purpose and all of them are vulnerable for NoSQL injection attack. These scripts execute after submitting the user login button. When user is submitting with correct username and password against each NoSQL database, output will be “Authorized User”, but on the other wise if any one of the field or both are incorrect then the output will be “You are not authorized”.

1) *MongoDB Detection Ability Results:* In MongoDB, it is possible to inject NoSQL keywords into submitted data from the login webpage. This could for example look like this

```
http://127.0.0.1/phd/MongoDB/after_log.php?user=ahmed
&pass[$ne]=1&sbumit1=Submit
```

“\$ne” selects the documents where the value of the field is not equal (i.e. !=) to “1”. So, this query will produce the same result as if the admin user had introduced their password correctly. According to this example, the web application will allow the access to administration area to a user who doesn't know the proper password.

The login web page scanned by giving URL to each following scanner tester tool:

Netsparker testing results are figured out and shown in Fig. 6.

Skipfish testing results are figured out are shown in Fig. 7.

Vega testing results are figured out and shown in Fig. 8.

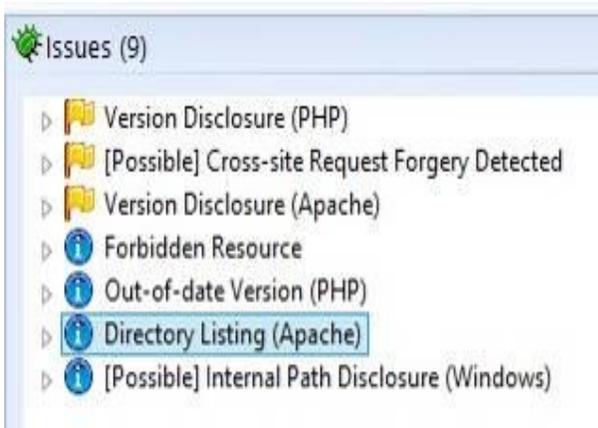


Fig. 6. Netsparker testing results for MongoDB.

Issue type overview - click to expand:

- PUT request accepted (2)
- Query injection vector (3)
- Shell injection vector (2)
- Interesting server message (6)
- HTML form with no apparent XSRF protection (1)
- Directory listing restrictions bypassed (2)
- Response varies randomly, skipping checks (2)
- Incorrect or missing charset (low risk) (7)
- Incorrect or missing MIME type (low risk) (3)
- Directory listing enabled (13)
- Resource not directly accessible (2)
- New 404 signature seen (7)
- New 'X-' header value seen (4)
- New 'Server' header value seen (1)

NOTE: 100 samples maximum per issue or document type.

Fig. 7. Skipfish testing results for MongoDB.

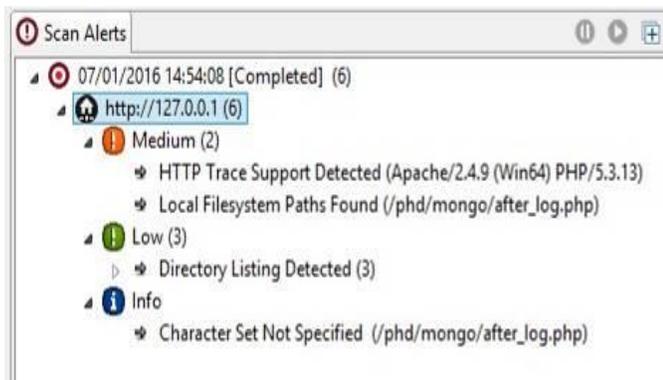


Fig. 8. Vega testing results for MongoDB.

“NoSQL Racket” testing results are figured out and shown in Fig. 9.



Unable to complete your request

NoSQL Injection attack has been detected

from Value:

Action: your request rejected
(Go Back)

Fig. 9. “NoSQL Racket” testing results for MongoDB.

The login web page scanned by giving URL to Netsparker, Vega and Skipfish and none of them detect any issues related to NoSQL Injection. But when “NoSQL Racket” used, the NoSQL injection attack detected and testing results are figured out and shown in Fig. 9.

2) *Cassandra Detection Ability Results:* In Cassandra, The attacker may enter any user name and a password of: ali'; DROP COLUMNFAMILY 'users

This results in a CQL query of:

(select * from reg_users where username = ali and password = ali'; drop columnfamily 'users', ['usern' => , 'passw' => ali'; drop columnfamily 'users])

The login web page scanned by giving URL to Netsparker, Vega and Skipfish and none of them detect any issues related to NoSQL Injection. But when “NoSQL Racket” used, the NoSQL injection attack detected and testing results are figured out and shown in Fig. 10.

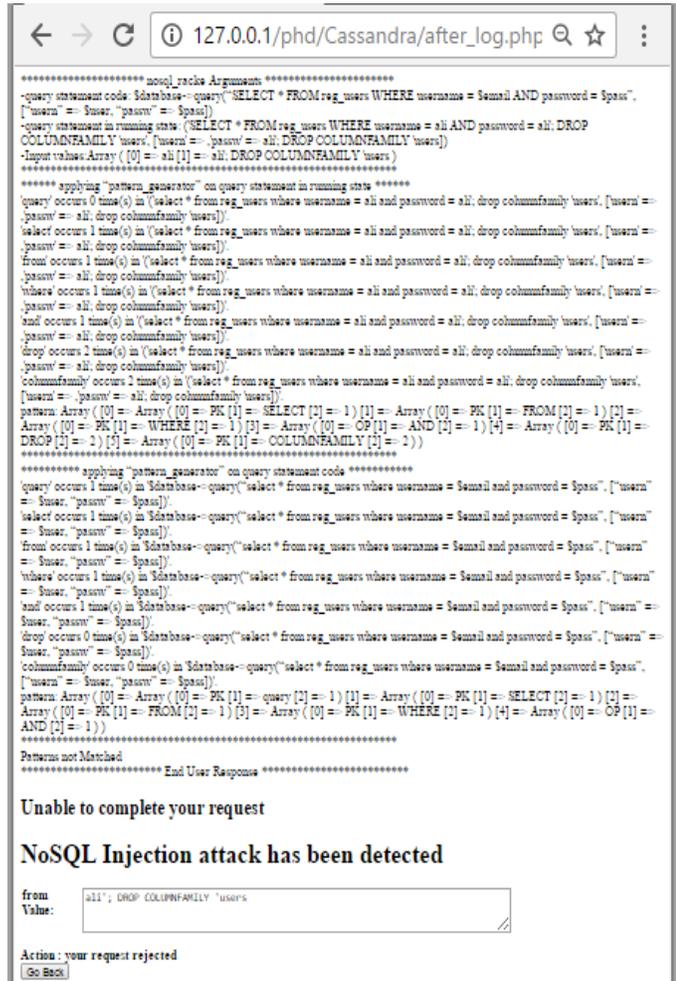


Fig. 10. “NoSQL Racket” testing results for Cassandra.

3) CouchDB Detection Ability Results: In CouchDB, The attacker may enter any user name and a password of: "or 1=1

This results in URL query of:

http://127.0.0.1/phd/CouchDB/after_log.php?user=test&pass=%27%27or+1%3D1&submit1=Submit

The login web page scanned by giving URL to Netsparker, Vega and Skipfish and none of them detect any issues related to NoSQL Injection. But when “NoSQL Racket” used, the NoSQL injection attack detected and testing result is figured out are shown in Fig. 11.

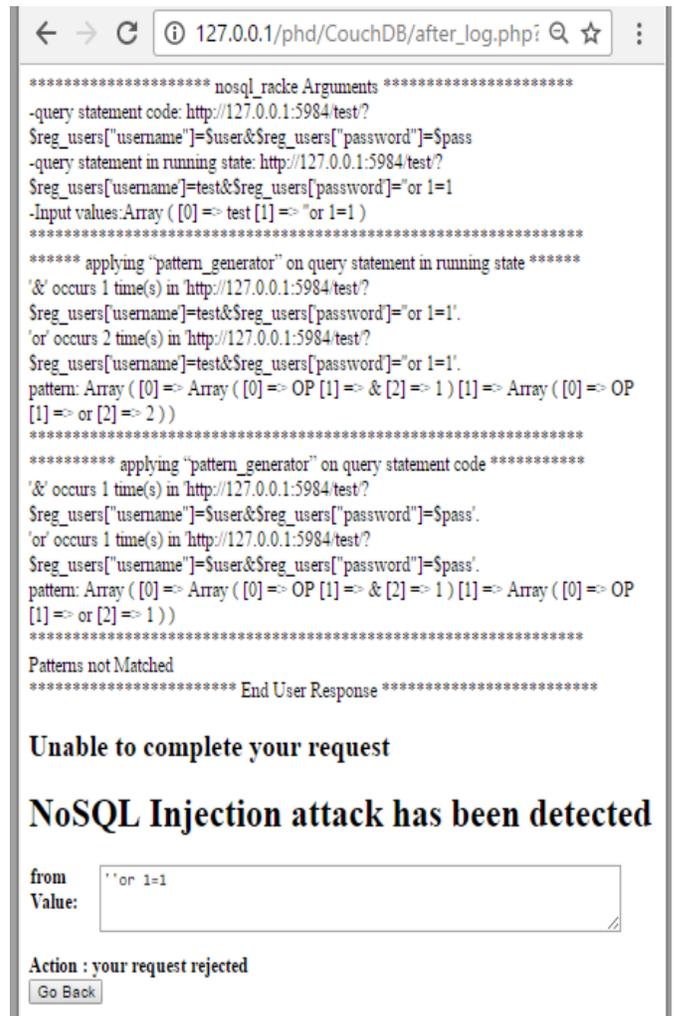


Fig. 11. “NoSQL Racket” testing results for CouchDB.

4) Amazon DynamoDB Detection Ability Results: In Amazon DynamoDB, it is possible to inject NoSQL keywords into submitted data from the login webpage. This could for example look like this:

http://127.0.0.1/phd/AmazonDynamoDB/after_log.php?user=ahmed&pass[\$gt]=1&submit1=Submit

“\$gt” selects those documents or keys where the value of the field is greater than (i.e. >) the specified value. Thus above statement compares password in database with empty string for greatness, which returns true. According to this example, the web application will allow the access to administration area to a user who doesn’t know the proper password.

The login web page scanned by giving URL to Netsparker, Vega and Skipfish and none of them detect any issues related to NoSQL Injection. But when “NoSQL Racket” used, the NoSQL injection attack detected and testing result is figured out are shown in Fig. 12.

```

***** nosql_racke Arguments *****
-query statement code: $client->getItem(array("TableName" => "usr_reg", "Key" => array("useremail"
=> array( Type:STRING => $usrId), "password" => array( Type:STRING => $password))))
-query statement in running state: (array(TableName => "usr_reg", Key => array("useremail" => array(
Type:STRING => ahmed), "password" => array( Type:STRING => Array))))
-Input values: Array ( [0] => ahmed [1] => Array ( [$gt] => 1 ) )
*****
***** applying "pattern_generator" on query statement in running state *****
'tablename' occurs 1 time(s) in (array('tablename' => 'usr_reg', 'key' => array('useremail' => array(
type:string => ahmed), 'password' => array(type:string => array))))).
'array' occurs 5 time(s) in (array('tablename' => 'usr_reg', 'key' => array('useremail' => array(
type:string => ahmed), 'password' => array(type:string => array))))).
'key' occurs 1 time(s) in (array('tablename' => 'usr_reg', 'key' => array('useremail' => array(type:string
=> ahmed), 'password' => array(type:string => array))))).
pattern: Array ( [0] => Array ( [0] => PK [1] => TableName [2] => 1 ) [1] => Array ( [0] => PK [1]
=> array [2] => 5 ) [2] => Array ( [0] => PK [1] => Key [2] => 1 ) )
*****
***** applying "pattern_generator" on query statement code *****
'tablename' occurs 1 time(s) in $client->getItem(array("tablename" => "usr_reg", "key" => array("useremail"
=> array( type:string => $usrId), "password" => array( type:string =>
$password))))).
'array' occurs 4 time(s) in $client->getItem(array("tablename" => "usr_reg", "key" => array("useremail"
=> array( type:string => $usrId), "password" => array( type:string => $password))))).
'key' occurs 1 time(s) in $client->getItem(array("tablename" => "usr_reg", "key" => array("useremail"
=> array( type:string => $usrId), "password" => array( type:string => $password))))).
pattern: Array ( [0] => Array ( [0] => PK [1] => TableName [2] => 1 ) [1] => Array ( [0] => PK [1]
=> array [2] => 4 ) [2] => Array ( [0] => PK [1] => Key [2] => 1 ) )
*****
Patterns not Matched
***** End User Response *****

Unable to complete your request

NoSQL Injection attack has been detected

from Array
Value:
Action : your request rejected
Go Back
    
```

Fig. 12. “NoSQL Racket” testing results for Amazon DynamoDB.

The following Table 2 shows the comparison of detection ability for all testing tools with the proposed tool “NoSQL Racket” over the four NoSQL databases which are used in testing process.

TABLE II. COMPARISON OF DETECTION ABILITY FOR ALL TESTING TOOLS

NoSQL Databases \ Testing Tools	MongoDB	Cassandra	CouchDB	Amazon DynamoDB
Netsparker	x	x	x	x
Vega	x	x	x	x
Skipfish	x	x	x	x
The proposed tool “NoSQL Racket”	✓	✓	✓	✓

According to scanning results, the most common application injection scanners such as Netsparker, Vega and Skipfish not are able to detect any issues related to NoSQL Injection. However, the proposed implemented approach was able to detect the NoSQL Injection attack.

B. Performance Testing for “NoSQL Racket”

Performance testing is performed on the “NoSQL Racket” using LoadComplete testing tool. The LoadComplete testing tool is the desktop tool for load, stress, testing of website and web application.

The testing process is applied by increasing the number of concurrent users every one second. In this work test is firstly conducted for single user. Then number of concurrent users is increased by 50 concurrent users every one second. The testing environment consists of a machine running Windows 8.1- x64 with Intel core i7 processor and 8 GB RAM. The testing results can be shown in the following graphs:

Load Graph: The graph shown in Fig. 13 shows the relation between the number of concurrent users and the test execution time. As showed in the graph, it is observed that the proposed tool “NoSQL Racket” can load 50 simulated concurrent users every one second.

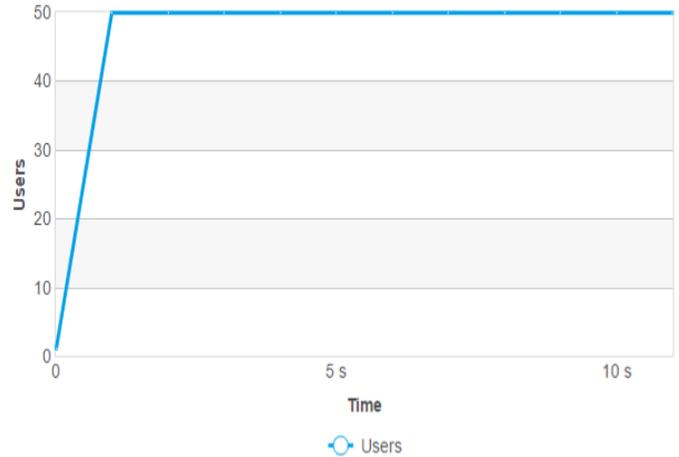


Fig. 13. Load graph.

Passed Requests Graph: The graph shown in Fig. 14 shows the relation between the number of concurrent users, the number of successfully passed requests and test execution time. As showed in the graph, it is observed that the proposed tool “NoSQL Racket” can pass 47 requests successfully from 50 requests every one second.

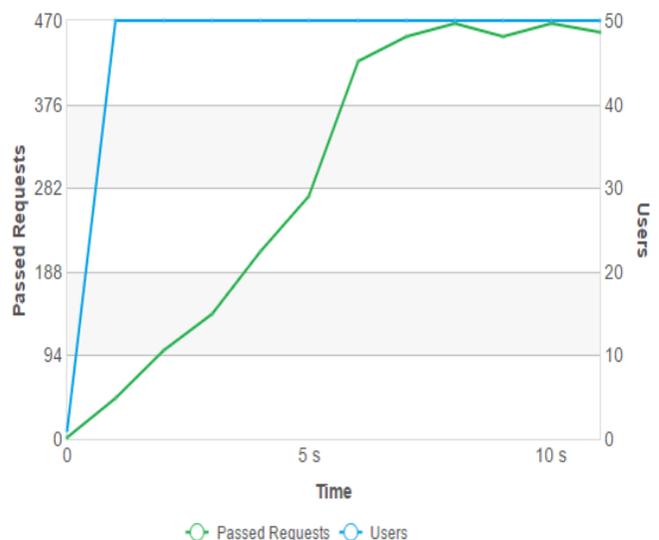


Fig. 14. Passed requests graph.

Warnings and Errors Graph: The graph shown in Fig. 15 shows the relation between the number of concurrent users, the number of web pages simulated with warnings and errors and the test run time. As showed in the graph, no any warnings or errors are detected.



Fig. 15. Warnings and errors graph.

Page Load Time Graph: Page load time is the time period to download the web page content, including all the HTML tags, images, scripts, CSS files, and so on. The graph shown in Fig. 16 shows the relation between the page load time and the number of concurrent users. As showed in the graph, the maximum page load time is 850 ms and the average page load time is 75 ms.

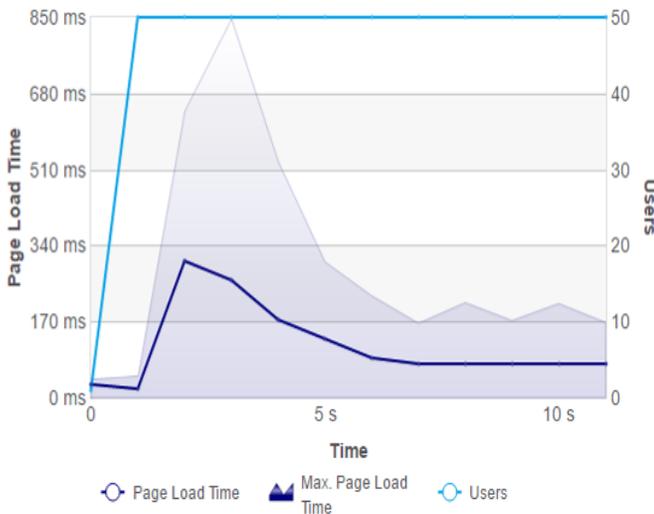


Fig. 16. Page load time graph.

Request Transfer Speed Graph: The request transfer speed refers to the speed of data transfer when the request was sent to the server.

The graph shown in Fig. 17 shows the relation between the number of concurrent users, the Request transfer speed metric and test execution time. As showed in the graph, the slowest speed for the requests transfer is 200 kB/s.

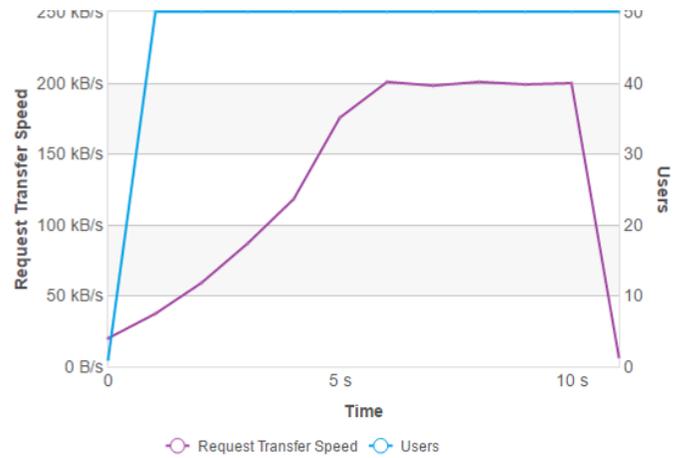


Fig. 17. Request transfer speed graph.

Response Transfer Speed Graph: The Response transfer speed refers to the speed of data transfer when the server sent back the response.

The graph shown in Fig. 18 shows the relation between the number of concurrent users, the Response transfer speed metric and test execution time. As showed in the graph, the slowest speed for the responses transfer is 1.52 MB/s.

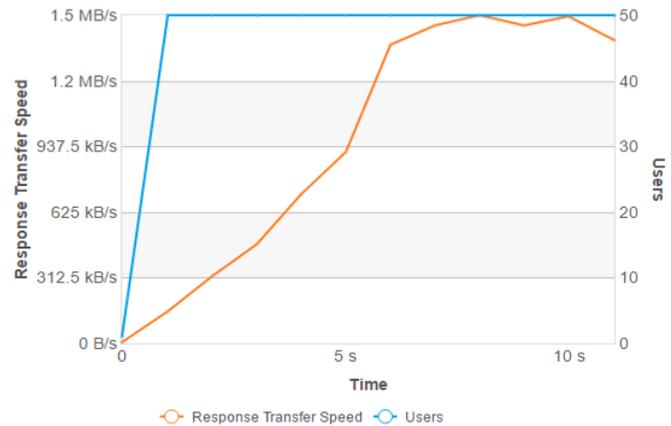


Fig. 18. Response transfer speed graph.

VII. CONCLUSION

This paper has presented a testing tool for detecting NoSQL Injection attacks which is called “NoSQL Racket”, this tool implemented as a PHP function. If no any NoSQL injection attacks detected, it will continue running for the nosql query; if it fails and one or more NoSQL injection attacks detected, it will display error page and stop running for the nosql query.

The proposed tool “NoSQL Racket” has been applied on four different NoSQL Databases which are MongoDB, Cassandra, CouchDB and Amazon DynamoDB. Also, its ability for detection and prevention has been compared with the most powerful web application testing tools which are Netsparker, Vega and Skipfish. According to the scanning results, none of mentioned tools has been able to detect NoSQL

Injection attack. However, the proposed implemented approach has the ability to detect the NoSQL Injection attack.

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