Application of Expert System with Fuzzy Logic in Teachers' Performance Evaluation

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***Abstract*— This paper depicts adaptation of expert systems technology using fuzzy logic to handle qualitative and uncertain facts in the decision making process. Human behaviors are mostly based upon qualitative facts, which cannot be numerically measured and hardly to decide correctly. This approach is an attempt to cope with such problems in the scenario of teachers' performance evaluation. An Expert System was developed and applied to the acquired knowledge about the problem domain that showed interesting results providing a sketch for students and researchers to find solutions of such types of problems. Through Fuzzy Logic we numerically weighted the *linguistic terms*, like; very good, good, bad, or high, medium, low or satisfied, unsatisfied by assigning priorities to these qualitative facts. During final decision making, key parameters were given weights according to their priorities through mapping numeric results from uncertain knowledge and mathematical formulae were applied to calculate the numeric results at final. In this way this ES will not only be useful for decision-makers to evaluate teachers' abilities but may also be adopted in writing Annual Confidential Reports (ACR) of about all the employees of an organization.**

Keywords— **Expert System, Fuzzy Random Variables, Decision Making, Teachers' Performance, Qualitative & Uncertain Knowledge.**

I. Introduction

Computer programs using Artificial Intelligence (AI) techniques to assist people in solving difficult problems involving knowledge, heuristics, and decision-making are called expert systems, intelligent systems, or smart systems [18]. An expert system can be designed based on a set of rules to determine what action to set off when a certain situation is encountered [24]. In other words expert system is such a technology that able the human being to collect & control the human experts' knowledge and expertise in a particular problem domain for further use to solve similar problems through computer system.

Experts of any fields are always few in numbers, expensive to consult and they have short time due to much work to do. So there is an urgent need of storing the expert's knowledge in the computer in such a way that have a great extent of knowledge of problem domain solving problems of the users and sparing experts for others works "unpublished" [2]. In this paper we discuss the teachers' performance evaluation through AI technology at higher education institutions of Pakistan. The proposed Fuzzy Expert System considering various aspects of teachers attributes, like research & publication, teaching learning process, personal skills & abilities, compensation, achievements & recognition etc that have deep influence on the teachers' performance in universities investigated by [1].

In this paper a fuzzy expert system's model is designed to combine the knowledge and expertise of human experts with reasoning capabilities that will provide a great support to executives for decision-making in educational institutions. This paper is organized as: the *section II* discusses the applications of expert system & fuzzy logic in teachers' assessment and education, *section III* briefly describes the teachers' evaluation, and *section IV* explains the proposed approach for the solution of the entitled problem.

II. Study Background

From last few decades, academics and researchers began to recognize the importance of expert system and its related concepts became one of the most popular topics related to decision making and knowledge management. From the beginning, expert systems have been developed in divers areas, like agriculture, chemistry, computer science, engineering, geology, medicine, space technology etc. [14]; and widely applied to various studies and issues, including performance assessment [3; 26; 27], commercial loan underwriting [19], logistics strategy design [11], farm productivity [25], mergers and acquisitions [28], defence budget planning [29], earthquake design [6], system dynamics [32], conveyor equipment selection [15], customer service management [9] and knowledge inertia [20]. For example, in [13] used the development and implementation of an educational tool based on knowledge based technology employing an expert system shell− a knowledge base system for postgraduate engineering courses. In [17] extract project WBS from the obtained mind map of brainstorming project team by artificial intelligence (AI) tools which is Prolog programming language. In [5] used expert system technology for providing developmental feedback to individuals from different ethnic minority groups. Melek and Sadeghian, [22] developed a theoretic framework for intelligent expert systems in medical encounter evaluation. Shen et al., [31] constructed an intelligent assessment system model and compared with the current assessment in education, this new intelligent assessment system expands the range of objects

for evaluation and takes some AI technologies to give more heuristic and intelligent assessments.

According to Zadeh [33, 34] variables words or sentences as their values is called linguistics variables and the variables that represents the gradual transition from high to low, true to false is called fuzzy variables and a set containing these variables is the fuzzy set. Fuzzy logic can be incorporated into expert system to enhance the performance and reliability of expert system in decision making. Fuzzy logic principals with expert system form a fuzzy expert system which is able to implement human knowledge & expertise with imprecise, ambiguous and uncertain data. Recently, many researchers worked on the applications of fuzzy logic in education & assessments. Chiang and Lin [10] presented a method for applying the fuzzy set theory to teaching assessment. Bai and Chen [4] presented a new method for evaluating students' learning achievement using fuzzy membership functions and fuzzy rules. Chang and Sun [8] presented a method for fuzzy assessment of learning performance of junior high school students. Chen and Lee [7] presented two methods for students' evaluation using fuzzy sets. Ma and Zhou [21] presented a fuzzy set approach to the assessment of student-cantered learning. In [30] presented a method for applying the fuzzy set theory and the item response theory to evaluate the learning performance of students. In "unpublished" [2] proposed an intelligent framework for teachers' performance evaluations in higher education.

The literature reveals that there is a vast potential of expert system and fuzzy logic in education as general and performance assessment, as a special.

III. Teachers' Performance Evaluation

The world is divided into developed and developing countries; the division is their capacity of educational and scientific attainment and its applications for economic progress and prosperity [16]. In developing countries, higher education is seen as an essential means for creation and development of resources and for improving the life of people to whom it has to serve. The problem with developing countries including Pakistan is that they have given a relatively low priority to higher education [23]. There are many reasons behind the poor status of Pakistan higher education. One of the top issues regarding the quality of higher education is the faculty (teachers) [23].

Permanent hired teachers in higher education's institutions especially in colleges did not update their knowledge and courses. They did the teaching as a routine activity and follow some particular books from years. Thus, students could not get updated knowledge and so fails to compete in market "unpublished" [2].

To put the existing teachers on track, it is very necessary to evaluate their performance, may be in quarterly, in semester or annually, depends upon the resources universities posses. Unfortunately, there exists no standard method for evaluating teachers' performance in higher education institutions or computerized solution that covers all factors affecting directly or indirectly the performance of university teachers. Although, the Higher Education Commission (HEC) has did lot of regarding quality assurance by establishing an idea of the Quality Enhancement Cells (QEC) in universities; but is rarely followed by universities due to time consuming manual process and availability of funds.

IV. Method

In this research, expert system was adopted using fuzzy logic principals for teachers' evaluation process. In [2] they have developed the knowledge acquisition tool for the teachers' assessment problem in the development of intelligent expert system. They have extracted a set of 99 attributes from literature that have influence on teachers' performance by any means in higher education; the extracted attributes were divided in to 15 groups.

TABLE I
Groups of Attributes (source: Amin & Khan (2009))

S. No	Main Groups of Attributes	Weights
1	Research Orientation	0.0753
2	Publication	0.0742
3	Teaching Learning Process	0.0729
4	Personal Abilities	0.0727
5	Responsibility & Punctuality	0.0726
6	Compensation & Rewards	0.0726
7	Professional Ethics	0.0720
8	Job Security & Environment Factors	0.0706
9	Supervision	0.0677
10	Administrative Skills	0.0674
11	Awards & Achievements	0.0605
12	Promotion Factors	0.0602
13	Organization Evaluation Policy	0.0577
14	Needs & Requirements	0.0550
15	Background Factors	0.0490
	Total weight:	**1.0000**

They have received responses from 25 highly qualified and well experienced subject experts from 11 different universities of Pakistan about the various factors that affect teachers' performance and also the experts' ranked these factors. The initial results and priority assigned to those factors are shown in Table-I.

The *Research Orientation* is ranked highest weight (0.0753) which indicates that research work is much more important than any other task in higher education. See Figure 1 for detail.

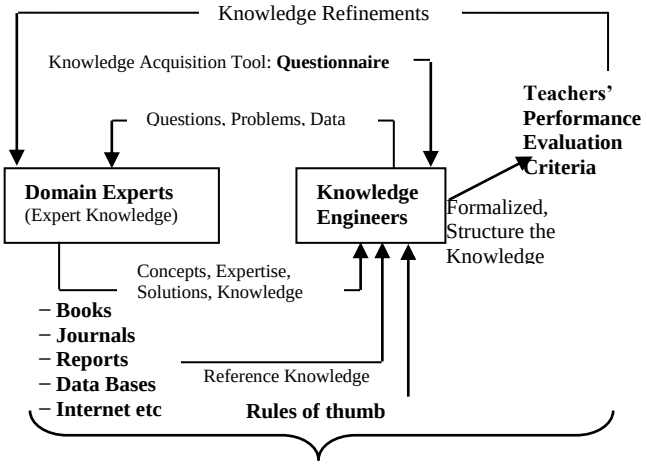

Fig. 1 Knowledge Acquisition Process [source: Amin & Khan (2009)]

In [33] developed an important logic concept that able researchers to measure the linguistic variables with ambiguous & uncertain knowledge into numeric values in decision making process for decision makers in real world problems. In this research, the author used the concept of fuzzy set and the membership functions to map the linguistic characteristics of teachers' performance that are either ranked High, Medium, or Low by the academic evaluators in higher education institutions. The degree of membership in fuzzy set is [1, 0], where '1' represents highest membership and '0'represents no membership. A fuzzy variable set and their membership value is defined as shown in Table-II.

TABLE II
FUZZY VARIABLES FOR INPUT PARAMETERS

Fuzzy variable	Degree of Membership
Very High	1.0
High	0.8
Medium	0.6
Low	0.4
Very Low	0.2
Null	0

The inputs data for a particular teacher's evaluation comes from various sources that may be research productivity & publications, academics awards & achievements, students' satisfactions, immediate head satisfaction, colleagues' opinions, and annual confidential report. Most of these inputs are in non-numeric or linguistic form. Therefore, a model is designed to process these inputs through fuzzy concept to support decision makers in teachers' performance assessment at higher education institutions.

As shown in Figure 2; the extracted knowledge is weighted according to the assigned priorities assigned by subject experts in the knowledge acquisition process and fuzzy concepts are then applied to handle the qualitative knowledge for efficient decision making possibility. All the fuzzy expert system components interact among each other to perform their functionalities achieving results. Let's take one group of attributes from Table-I with all its sub-factors along with assigned weights and compute the result for a particular case. Now observe Table-III, the maximum weight of all the teachers' performance criteria is 1.0000 and the selected main attribute got maximum weight as 0.0729; while its sub factors along with their weights are shown.

TABLE III
MAIN ATTRIBUTE ALONG WITH SUB-FACTORS

Teachers' Performance Evaluation in Higher Education Max Weight 1.0000		
Main Attribute	**Sub Factors**	
TEACHING LEARNING PROCESS Weight 0.0729	Proficiency in teaching	0.0054
	Personal Interest In Teaching	0.0075
	Presentation & Communications skills	0.0063
	Speaking Style & Body language	0.0050
	Content knowledge	0.0059
	Lecture preparation	0.0067
	Language command	0.0059
	Response to Student queries	0.0067
	Question Tackling	0.0050
	Courses taught	0.0038
	Students Performance	0.0029
	Work load	0.0046
	Fairness in marking	0.0071

The knowledge representation of the above main attribute with its sub-factors in fuzzy rules takes the following form.

```
IF proficiency_teaching is Very High THEN W= 0.0054
IF proficiency_teaching is High THEN W= 0.0043
IF proficiency_teaching is Medium THEN W=0.0032
IF proficiency_teaching is Low THEN W= 0.0022
IF proficiency_teaching is Very Low THEN W= 0.0011

IF personal_interest_teach is Very High THEN W= 0.0075
IF personal_interest_teaching is High THEN W= 0.0060
IF personal_interest_teaching is Medium THEN W=0.0045
IF personal_interest_teaching is Low THEN W= 0.0030
IF personal_interest_teaching is Very Low THEN W=
0.0015

IF present_Comm_skill is Very High THEN W= 0.0063
IF present_Comm_skill is High THEN W= 0.0050
IF present_Comm_skill is Medium THEN W=0.0038
IF present_Comm_skill is Low THEN W= 0.0025
IF present_Comm_skill is Very Low THEN W= 0.0013

IF style_body_language is Very High THEN W= 0.0050
IF style_body_language is High THEN W= 0.0040
IF style_body_language is Medium THEN W=0.0030
IF style_body_language is Low THEN W= 0.0020
IF style_body_language is Very Low THEN W= 0.0010

IF content_knowledge is Very High THEN W= 0.0059
IF content_knowledge is High THEN W= 0.0047
IF content_knowledge is Medium THEN W=0.0035
IF content_knowledge is Low THEN W= 0.0024
IF content_knowledge is Very Low THEN W= 0.0012

IF lecture_preparation is Very High THEN W= 0.0067
IF lecture_preparation is High THEN W= 0.0054
IF lecture_preparation is Medium THEN W=0.0040
IF lecture_preparation is Low THEN W= 0.0027
IF lecture_preparation is Very Low THEN W= 0.0013

IF language_command is Very High THEN W= 0.0059
IF language_command is High THEN W= 0.0047
IF language_command is Medium THEN W=0.0035
IF language_command is Low THEN W= 0.0024
IF language_command is Very Low THEN W= 0.0012

IF response_student_queries is Very High THEN W=
0.0067
IF response_student_queries is High THEN W= 0.0054
IF response_student_queries is Medium THEN W=0.0040
IF response_student_queries is Low THEN W= 0.0027
IF response_student_queries is Very Low THEN W= 0.0013

IF question_tack is Very High THEN W= 0.0050
IF question_tack is High THEN W= 0.0040
IF question_tack is Medium THEN W=0.0030
IF question_tack is Low THEN W= 0.0020
IF question_tack is Very Low THEN W= 0.0010

IF courses_taught is Very High THEN W= 0.0038
IF courses_taught is High THEN W= 0.0030
IF courses_taught is Medium THEN W=0.0023
IF courses_taught is Low THEN W= 0.0015
IF courses_taught is Very Low THEN W= 0.0008

IF student_perform is Very High THEN W= 0.0029
IF student_perform is High THEN W= 0.0023
IF student_perform is Medium THEN W=0.0017
IF student_perform is Low THEN W= 0.0012
IF student_perform is Very Low THEN W= 0.0006

IF workload is Very High THEN W= 0.0046
IF workload is High THEN W= 0.0037
IF workload is Medium THEN W=0.0028
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IF workload is Low THEN W= 0.0018
IF workload is Very Low THEN W= 0.0009

IF fairness_marking is Very High THEN W= 0.0071
IF fairness_marking is High THEN W= 0.0057
IF fairness_marking is Medium THEN W=0.0043
IF fairness_marking is Low THEN W= 0.0028
IF fairness_marking is Very Low THEN W= 0.0014
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The terms *Very High, High, Medium, Low, Very Low* are fuzzy variables on the basis the weight W varies. This is because the fuzzy membership function application which able the system to map qualitative variables as numeric one. Before entering input case to the fuzzy expert system, let's discuss the computational formula which was applied in fuzzy expert system for calculating decision making score.

To calculate the decision score of any single main attribute with its all sub factors the following summation formula is defined and used.

$$Ci = \sum_{n=1}^{m} PnWn \quad \text{..... (1)}$$

Where, Ci = i^{th} main attribute.
M = number of sub-factors in the i^{th} attribute.
Pn = Fuzzy value of n^{th} input parameter
Wn = Expert weight of the relative input parameter

TABLE IV
EXAMPLES OF INPUT CASES

Three different examples as input cases to the Fuzzy Expert system				
All Sub Factors		**Case A**	**Case B**	**Case C**
Proficiency in teaching	0.0054	H	M	L
Personal Interest In Teaching	0.0075	H	M	L
Presentation & Comm. Skills	0.0063	VH	H	L
Speaking Style & Body lang.	0.0050	M	L	M
Content knowledge	0.0059	M	L	M
Lecture preparation	0.0067	H	M	H
Language command	0.0059	VH	H	VH
Response to Student queries	0.0067	VH	VH	H
Question Tackling	0.0050	M	L	M
Courses taught (nature)	0.0038	M	M	L
Students Performance	0.0029	VH	M	M
Work load	0.0046	H	H	H
Fairness in marking	0.0071	M	M	M

The above input data (Table-IV) is entered to the Fuzzy Expert System; through a built-in interface of the system for computing decision score as shown in Figure-3. Numbers 5, 4, 3, 2, 1 entered as input representing 5=Very High, 4=High, 3=Medium, 2=Low, 1=Very Low. In Figure 3, the interface two buttons have also shown, i.e., ***Explain*** and ***Why*** which are available for explanation of inputs and reasoning capabilities respectively.

After completion of the input data the Fuzzy Expert System used the scale in Table-V, to rank the three cases A, B, C respectively.

TABLE V
DECISION MAKING SCALE TO A LINGUISTIC DESCRIPTION
(MAX WEIGHT 0.0729)

Fuzzy Expert system output	**Linguistic Description**
X< 0.0109	Poor
0.0109 ≤ X < 0.0.0218	Satisfied
0.0.0218 ≤ X< 0.0328	Good
0.0328 ≤ X < 0.0437	Very Good
0.0437 ≤ X < 0.0546	Excellent
X ≥ 0.0546	Outstanding

According to the developed scale in Table-V, the Fuzzy Expert System mapped the calculated numeric results of the three cases from qualitative input data into linguistic output description, as shown in Table-VI.

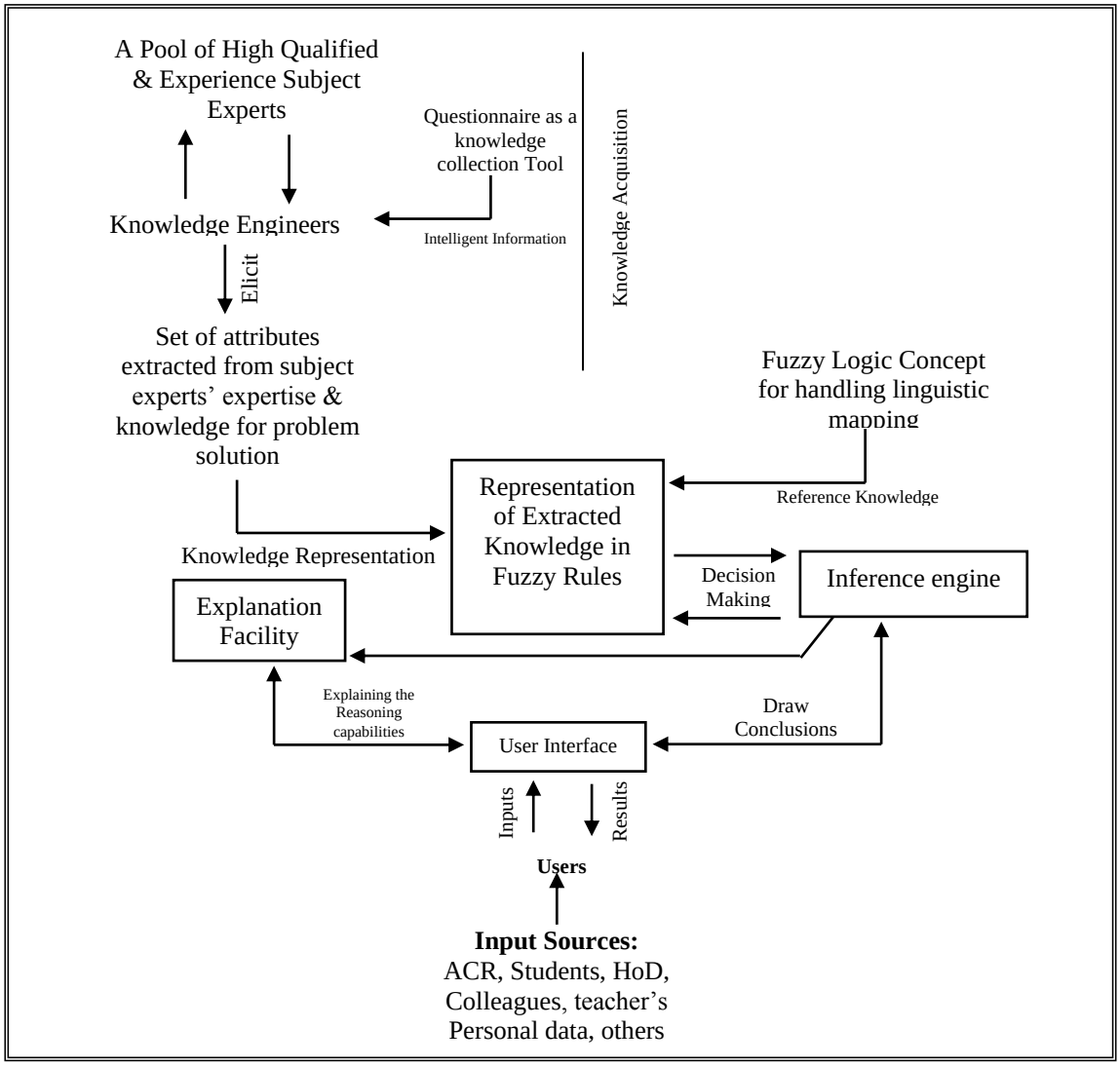

Fig. 2 Fuzzy Expert System Model

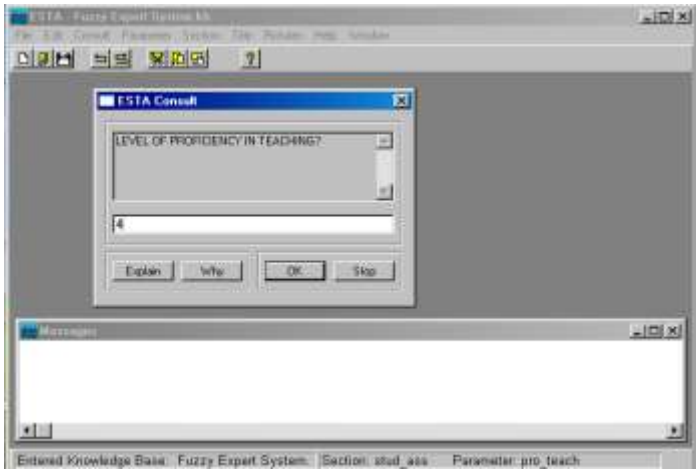

Fig. 3 User Interface

A	0.0573	Outstanding
B	0.0465	Excellent
C	0.0451	Excellent

TABLE VI

THREE CASES RANKING

Case	System Calculation	Description

V. CONCLUSION & FUTURE DIRECTION

Regular teachers' assessment is suggested to maintain quality in higher education; literature clearly depicts taht there is a vast potential of the applications of fuzzy logic & expert system in teachers' assessment. Expert system technology using Fuzzy Logic is very interesting for qualitative facts evaluation. A model of fuzzy expert system is proposed to evaluate teachers' performance on the basis of various key performance attributes that have been validated previously through subject experts. The fuzzy scale has been designed to map & control the input data values from absolute truth to absolute false. The qualitative variables are mapped into numeric results by implementing the fuzzy expert system's model through various input examples and provided a basis to use the system ranking for further decision making. Thus, the uncertain and qualitative knowledge of the problem domain have been handled absolutely through integration of expert system technology with fuzzy logic concept.

The proposed model produced significant bases for performance assessment and adequate support in decision making, so the research on the issue can be continued. Important aspect of this issue that could focus on in the future is the fuzzy expert system's model that could be extended to all type of employees' assessment in universities as well as in others government & private organizations.

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