Collaborative Ontology Construction Framework: An Attempt to Rationalize Effective Knowledge Dissemination

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***Abstract*—Ontologies are domain rich conceptualizations, which can be utilized for effective knowledge dissemination strategies. Knowledge dissemination plays a vital role in any industry. In this research, novel framework is designed and experimented for the collaborative ontology construction. With the iterative and incremental involvement of the domain specialists and ontologists rational process has been discussed and planned for the collaborative ontology construction. Additionally, existing shortcomings associated with the current ontology construction methodologies and frameworks also have been rigorously reviewed to identify the shortcomings. Henceforth the responses received from the domain specialists and ontologists, along with the gaps located from the literatures have been utilized as the backbone in designing this novel framework. Designed ontology increments have the potential of effective knowledge distribution once it`s coupled with technologies like chatbots. In this research, proposed framework has been deployed in three different domains and three different ontology increments have been created for each domain. Consequently, their efficacy have been tested with the involvement of domain specific stakeholders. Overall results have yielded an 82% of acceptance from the stakeholders.**

***Keywords*—Collaborative; domain-specialists; framework; methodology; ontologies**

I. Introduction

Knowledge is the fuel which drives current economies. Therefore, effective mechanisms on knowledge diffusion are very critical. This research discusses about construction of knowledge enriched ontologies for effective knowledge dissemination. Ontologies are human understandable and machine-readable cognitive conceptualizations associated with a specific domain [1]. Once an ontology is constructed with accurate domain associated conceptualizations, it could be utilized as a centralized resource for effective knowledge dissemination [2]. For an instance, if an ontology is constructed on the domain of COVID-19 pandemic, a chatbot can be coupled with it to ensure engaging knowledge distribution to educate varied populations. Nevertheless, capturing the expert human insights and construction of the ontology can be identified as a challenging yet very critical necessity to be accomplished precisely [3]. Because there are no fully automated mechanisms that exist so far for the ontology construction, hence it`s a complex philosophical task, which can only be handled effectively by humans [4].

This research emphasizes on a specialized framework for precise ontology construction amidst collaborative involvements. Because, deriving expert knowledge from humans with multivariate specialties and concisely evolving it to a level of cognitively enriched ontology is not an easy task [3-4]. However, the use case of knowledge distribution via a chatbot becomes operational only if the ontology creation is successful and accurate. Therefore, a systematic approach to efficiently gather knowledge from heterogeneous human experts for the purpose of collaborative ontology development can be characterized as a research gap that needs to be filled.

This research proposes "Collaborativity" framework to fulfill the aforementioned requirement. This novel framework comprises of separately defined dedicated modules to foresee numerous critical aspects associated with collaborative ontology construction. Governing module, operational module, traceability module and opinion aggregation module are such modules residing inside this framework. Those modules collaboratively communicate to streamline the opinion acquisition, process enforcement and decision logging for the enhanced traceability.

Opinion aggregation module utilizes a voting strategy to adequately represent the collaborative participation of all the involved stakeholders. All these strategies will eliminate the black boxes associated with the entire procedure and improve the clarity and the transparency of the entire workflow. Collaborative ontology engineering is the latest trend associated with the ontology construction. Though there are several collaborative ontology construction methodologies available, almost all of them have severe shortcomings. Those aspects will be discussed in detailed during the literature review section. In such setting, this novel framework can be identified as a significant contribution to the domain of collaborative ontology engineering.

II. Literature Review

Ontology construction is a complex process. It`s impossible to create an effective ontology from a one shot [5]. This makes, ontology construction procedures iterative and incremental [6]. Another important aspect to consider is the role separation of ontologists and domain specialists. Ontologists are the semantic tech specialists, who create and evolve the ontology as per the specifications and knowledge provided by the domain specialists [7]. Majority of the existing methodologies and

frameworks have not properly distinguished between the roles of ontologists and domain specialists. This leads to operational confusions amidst the ontology construction process. Below Tables 1 to 3 contain a comprehensive review on the deficiencies associated with second, third generation methodologies and frameworks respectively.

As reviewed above, though there are numerous methodologies and frameworks for the ontology construction, almost all of them have multiple weaknesses such as:-

1) Ambiguous workflows – This leads to operational glitches of the involved stakeholders.

2) Explicit instructions are not provided – Allows excessive freedom to the stakeholders to act as they wish. This tarnishes the process consistency.

3) Role duality issues – Roles of the ontologists and domain specialists are not clearly defined. This leads to lots of operational confusions, during the working of the methodology/ framework.

4) Poor logging of the operational decisions. This hinders lateral audits.

5) Absence of a mechanism to handle the collaborative communication flows occur between domain specialists and ontologists.

6) Irrespective of ontology construction being a cognitively enriched mental task; only engineering aspects are considered, ignoring the associated cognitive gravity.

TABLE I. SECOND GENERATION METHODOLOGY REVIEW

Significant second-generation Methodologies	Key deficiencies located on collaborative accomplishments
Methontology [8]	Lack of a clearly defined workflow causes many uncertainties such as; poorly organized activities, and issues with post-audit inspections. Additionally, there is no enough documentation of collaborative decisions made. The responsibilities of the domain experts and ontologists are not regulated.
TOVE [9]	The obligations of the domain specialists and ontologists are not specified. This casts doubt on the parties' ability to maintain interoperability and consensus causing operational glitches
IDEF5 [10]	The procedures for verifying ontology increments are not well-structured. In a group setting, how do you decide whether to move on to the next increment or repeat the same increment again? How does ideology collaboration between domain specialists and ontologists take place? Similarly, there are several process ambiguities.
Enterprise Model [11]	Very abstract and high-level. It is impossible to assess operational success due to a lack of standardized operating procedures (SOPs).
OTKM [12]	Roles of the ontologists and domain specialists are not clearly defined.

TABLE II. THIRD GENERATION METHODOLOGY REVIEW

Significant third-generation methodologies	Key deficiencies located on collaborative accomplishments
Diligent [13]	Users are given an overabundance of control. As a result, the controlled operational flows have been jeopardized.
SMOD [14]	Explicit work procedures are not defined. This allows excessive freedom for the stakeholders, jeopardizing process consistency.
Neon [15]	Many uncertainties, such as poorly coordinated operations and problems with post-audit inspections, are brought on by a lack of a clearly defined workflow. Decisions are not sufficiently documented, as well. There are no rules governing the duties of domain experts and ontologists.
Upon-Lite [16]	Explicit work procedures are not defined. This allows excessive freedom for the stakeholders.
AMOD [17]	The transition process of ontology increments is absent. Several hidden black boxes trigger; great deal of ambiguity.
CO_4 [18]	Poor processors. The roles of ontologists and domain specialists are not well defined.
$(KA)_2$ [19]	Poor processors. The roles of ontologists and domain specialists are not well defined.

TABLE III. FRAMEWORK REVIEW

Framework	Key deficiencies located on collaborative accomplishments
Semiotic [20]	Excessive ambiguity. No structured workflow for transparency and traceability.
RapidOWL [21]	Too lenient, which could jeopardizes the process consistency
Generic Ontology Development Framework [22]	Poor processors. The roles of ontologists and domain specialists are not well defined.
Platform Independent Ontology Development Framework [23]	Explicit work procedures are not defined. This allows excessive freedom for the stakeholders, jeopardizing process consistency.
Industry Relevant Ontology Development Framework [24]	Poor processors. The roles of ontologists and domain specialists are not well defined.
Systemology [25]	Poor processors. The roles of ontologists and domain specialists are not well defined.

The literature review conducted above clearly reveals the shortcomings associated with the existing methodologies and frameworks available for the ontology construction. Therefore, it can be justified as a research gap which requires to be addressed.

III. METHODOLOGY

As the outcome of this research, it suggests a novel framework capable of addressing aforementioned deficiencies. The overall research methodology followed for the construction and evaluation of this framework can be depicted in form of a process diagram as depicted in Fig. 1.

This framework is named as "Collaborativity", hence its main goal is to collaborate all viewpoints of the stakeholders in a methodical manner and trigger the ontology increment construction. The flow of this framework was developed through several trial-and-error tests with domain specialists, as well as it equips with remedies to the inadequacies found in existing approaches and frameworks discussed in the literature review section.

"Collaborativity" framework comprises of mainly four modules with designated responsibilities. Operational module comprises of a stepwise orchestration on the ontology increment construction. Each important insights generated during the operational module's steps are logged within the respective tracker sheets structures, belonging into the traceability module. This ensures transparency and assists in latter auditing requirements of the collaborative opinions of the involved stakeholders.

Governing module is mainly responsible for handling the cognitive perspectives and the workflow of the involved stakeholders. As a result of the fact that ontology development is a complicated cognitive process that involves several stakeholders from various domains, a methodical pipeline is required to efficiently handle the collaborative interactions and workflows that occur in the group environment.

The pipeline introduced inside the governing module is defined with the name "Synchronized Action Plan Meet." This is a time-boxed workflow, governing numerous cognitive and process specific tasks associated with the respective operational module`s phase. This process enforcement has been identified as very vital. Unless it could lead to biases and numerous opinion conflicts among the involved stakeholders. Therefore, governing module plays a vital role in addressing process consistency perspectives. The entire operation inside this framework is governed via pool of ontologists, who are designated with multiple roles as convener, timekeeper and documenter.

Opinion aggregation module is responsible in governing the phase-specific transitions inside the operational module. Fig. 2 depicts the operational workflow of the opinion aggregation module.

Governing module`s "Synchronized Action Plan Meet" process will be applied across all phases of the operational module. Henceforth, all stakeholder`s vote is inquired on the completed phase. If the vote percentage exceed more than 80% of the involved participants, a collaborative decision is taken for the transition to the next phase of the ontology increment construction. If the majority vote of the stakeholder`s do not exceed 80%, same phases is examined for shortcomings and reiterated with the suggested modifications. This way it ensures, transparency and collaborative participation of the stakeholders for the decisions reached in the forward movement of the ontology increment construction. This idea is enforced by the Power of 80% rule, which is strongly enforced in clinical trials associated with humanoid subjects.

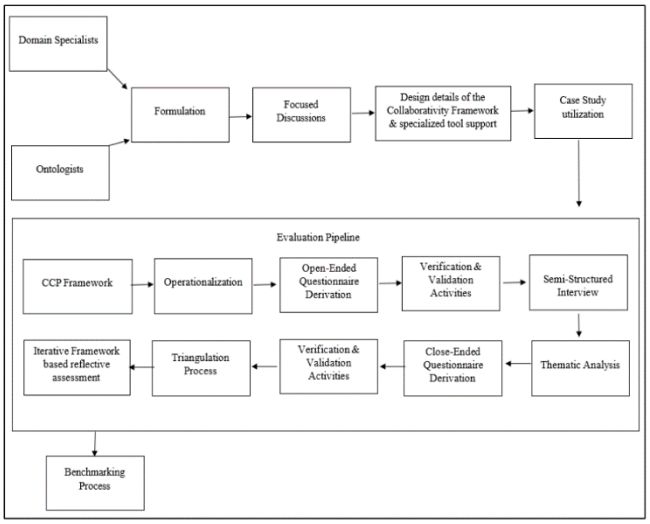

Fig. 1. Research Methodology Flow.

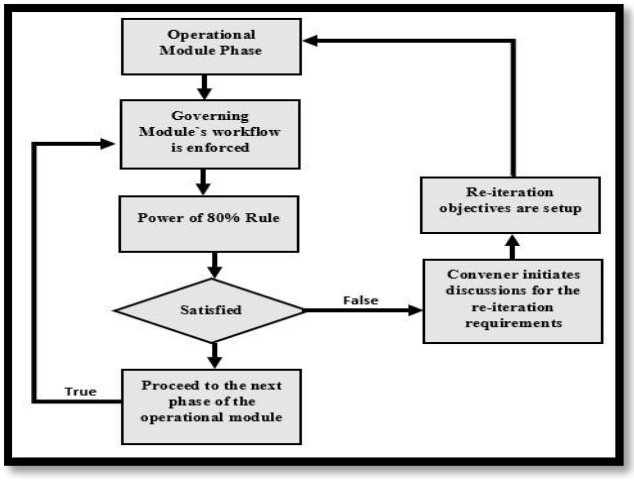

Fig. 2. Opinion Aggregation Module`s Workflow.

Fig. 3 denotes the roles of the governing module, operational module and opinion aggregation modules in conjunction.

Fig. 4 denotes the fixation of all four modules inside the Collaborativity Framework. Fig 4, denotes synchronized action plan meet workflows belonging inside the governing module, mapping between the operational and traceability module as well as the process enforcement of the opinion aggregation module.

It`s significant to emphasize, that each operational module`s step is executed as per the workflow enforced by the governing

module (i.e. synchronized action plat meet phase I and II). Subsequently, transition from one operational module step to the next is controlled by the process enforced via the opinion aggregation module. All collaborative decisions emerged during the stakeholder interactions are logged inside the traceability module`s tracker worksheets.

Once the framework`s structure is finalized, subsequently, it`s decided to apply the framework for three case studies to assess its operational efficacy in order to fulfil this requirement.

COVID-19, Criminal Law and Aquaculture domains were selected. Henceforth, "Collaborativity" framework was applied, and three different ontology increments were created. Henceforth, those were coupled with chatbots and with the involvement of the respective domain specialists' responses derived via the chatbots were reviewed as well as the structures of the constructed ontology increments.

Evaluation pipeline depicted in Fig. 1 was utilized for the assessment of the "Collaborativity Framework." CCP framework [26] and operationalization [27] procedures were utilized in combination to compile applicable sets of questionnaires. Once the basic versions of the questionnaires were complied, those were validated and verified for their reliability and accuracy.

Henceforth, controlled interview sessions with the respective domain specialists of the three fields were conducted using the compiled questionnaires and responses were recorded.

Consequently, the logged qualitative responses of the stakeholders were reviewed and analyzed using thematic analysis. Outcome of the thematic analysis was utilized to determine the most significant topics associated with the insights derived from the stakeholder`s interviews. Eventually, targeting the significant topics emerged from the qualitative interview responses, series of close ended questions were created again using the CCP and the operationalization procedures [26-27].

Combinations of the quantitative and qualitative questionnaires utilized for the experiment is as depicted in Fig. 5.

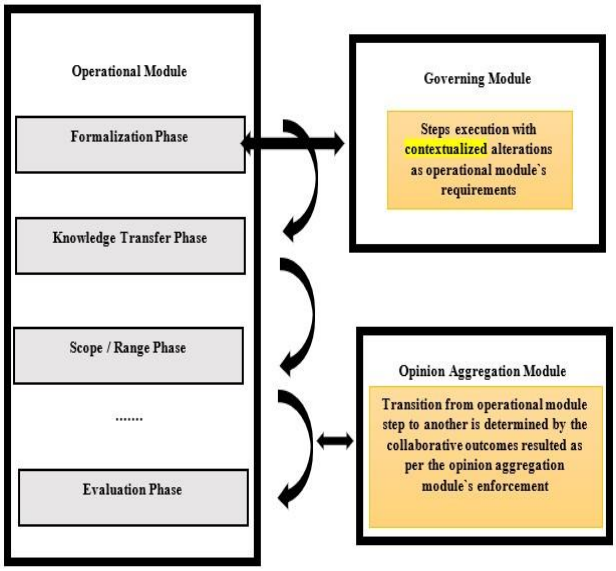

Fig. 3. Combinatory Roles of the Modules.

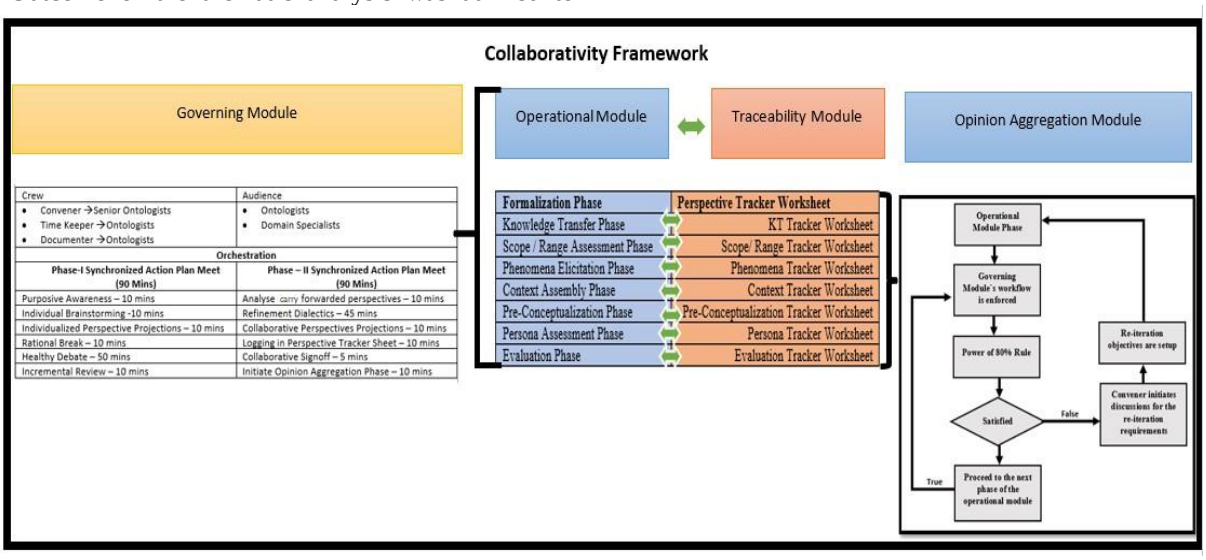

Fig. 4. Collaborativity Framework.

Qualitative Questionnaire	1. What observations have you made about existing frameworks applications on collaborative ontology construction? Please elaborate
	2. What observations have you made about the collaborativity framework`s role in collaborative ontology construction? Please elaborate
	3. What do you expect from a novel framework for collaborative ontology construction?
	4. Does this framework ensure collaborative insight? Please explain
	5. Does this framework ensure collaborative consensus? Please explain
	6. Does this framework ensure collaborative goals related to ontology increment construction? Please explain
Quantitative Questionnaire	1. How satisfied are you with the framework's collaborative insight enforcement?
	2. How satisfied are you with the collaborative consensus enforcement of the framework?
	3. How effective are the governing, operational, and opinion aggregation modules in controlling the framework's flow?
	4. How would you rate the overall operation of the framework?
	5. How effective are the "Action plan meets" for communication synchronization and framework`s target-oriented execution?
	6. How useful is the Dialectics step for communication synchronization?
	7. How useful is the Opinion assessment heuristic for collaborative communication synchronizations?
	8. How would you rate the overall communication synchronization enforced by this framework?

Fig. 5. Questionnaire Sets.

Reponses for the qualitative questions were retrieved via controlled interview sessions conducted. A special response grid depicted in Fig. 6 was used to record the responses for the quantitative questions.

10	20	30	40	50	60	70	80	90	100
Very poor	Fairly OK-Major revisions				Good & Acceptable- Few minor revisions			Exceptional	

Fig. 6. Quantitative Response Grid.

IV. Results and Discussion

Significant themes emerged out from the thematic analysis of the interview responses have been logged in Table IV.

Consequently, quantitative close-ended questions were formulated covering the themes emerged from the thematic analysis. Responses of qualitative feedback has been logged in Table V.

Henceforth, Cronbach analysis was performed to assess the reliability of the responses provided and the outcomes for the domains have been logged in the Table VI.

According to Cronbach reliability tests of the user responses, a Cronbach Alpha value ranging in between 0.65 – 0.95 is accepted as a reliable distribution [28]. Therefore, Cronbach reliability test confirms the reliability of the stakeholders` responses yielded, covering all three domains and the ontologists. Table VI denotes the reliability test distribution results.

Additionally, an ANOVA test also has been conducted to reveal the significance of the user responses and to confirm there are no significant statistical anomalies [29]. Table VII denotes the outcomes of the ANOVA test conducted.

As depicted in Table VII, P-value (i.e., 0.23) for the test conducted in greater than the standard alpha value of 0.05 [29]. Hence, it confirms, that the population has responded to the questionnaire without any outliers causing no statistically significant anomalies.

TABLE IV. Themes Revealed from the Thematic Analysis of Interview Responses

Qualitative themes emerged from the controlled interview session conducted on Collaborative Framework	Collaborative Goals
	Transparency of Operations
	Process Enforcement
	User Friendliness

TABLE V. Response Scores of the Close-Ended Questionnaire

Question Cluster	**Domain**	**Averaged Response Scores**
Collaborativity Framework	Law	88%
	COVID-19	85%
	Aquaculture	82%

TABLE VI. Cronbach Alpha Reliability Test Scores

Domain/Segment	Cronbach Alpha Value
Criminal Law	0.736
COVID-19	0.713
Aquaculture	0.728
Ontologists	0.702

TABLE VII. ANOVA Significance Test

ANOVA						
Source of Variation	SS	df	MS	F	P-value	*F crit*
Between Groups	167.458333		55.8194444	1.5690379	0.22806	3.09839
	3	3	4	3	8	1
		2				
Within Groups	711.5	0	35.575			
	878.958333	2				
Total	3	3				

Subsequently, a benchmark test has been conducted to assess the uniqueness associated with the Collaborativity framework. Eight existing and latest methodologies and frameworks have been utilized for this comparative assessment. Results associated with the benchmark test has been logged in the Fig. 7.

Finally, Iterative framework [30] has been utilized to triangulate and amalgamate all the experimental tests conducted against the research`s expectation. Iterative Framework is an established research framework utilized to consolidate multiple test experiments against the research`s expectations [30]. Table VIII denotes the application of the Iterative Framework for this research study.

Fig. 7. Benchmark Results.

TABLE VIII. APPLICATION OF THE ITERATIVE FRAMEWORK

Iterative Framework`s questions		Mapping Evidence
1. What are the data telling me?	•	Four important themes have been yielded from the thematic analysis conducted
	•	Averaged quantitative response score for all three domains: -85%
	•	Averaged Cronbach Alpha Reliability Score: - 0.72
	•	ANOVA Significance Score: -0.23
2. What do you want to know?	•	Overall effectiveness of the newly designed Collaborativity framework for ontology constructions in collaborative atmospheres.
3. Is there a dialectical relationship between 1 & 2	•	Yes. Mapping Evidences of Question 1, reflects the Question 2 , perspectives have been satisfied in a consolidated fashion.

V. CONCLUSION

This research paper discusses about the application of a newly designed framework for effective ontology increment construction on the collaborative group atmospheres. Efficacy of this framework has been tested using case study mechanism. Three independent case studies have been conducted on three different domains. Three separate ontology increments have been compiled and they were tested by the structure and practical applications. For the practical utilization test, the created ontology increments have been linked with chatbots and validity of the responses provided were assessed by the subject specialists.

COVID-19, ontology increment was tested by general physicians, based on the validity of the responses provided. Criminal Law increment and Aquaculture increment was tested by the respective experts in the fields. Once, these prototypes got evolved to the level of products, they can be effectively utilized to educate and disseminate knowledge on medical students, law students and zoology students. This practical application could immensely reduce the workloads of the university lectures, without penalizing the user experience of the students as well. Currently, the prototype version has yielded up to 82% of user acceptance.

This research contributes a novel ontology construction framework, addressing the deficiencies of the existing methodologies and frameworks. Additionally, its use cases are very valuable to all the fields where knowledge dissemination plays a vital aspect. In future, it`s expected to boost the power of this framework via integration computerized tool support as well.

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