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A Review on Ontology Development Methodologies for Developing Ontological Knowledge Representation Systems for various Domains

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Abstract—The success of machine represented web known as semantic web largely hinges on ontologies. Ontology is a data modeling technique for structured data repository premised on collection of concepts with their semantic relationships and constraints on domain. There are existing methodologies to aid ontology development process. However, there is no single correct ontology design methodology. Therefore, this paper aims to present a review on existing ontology development approaches for different domains with the goal of identifying individual methodology's weakness and suggests for hybridization in order to strengthen ontology development in terms of its content and constructions correctness. The analysis and comparison of the review were carried out by considering these criteria but not limited to: activities of each method, the initial domain of the methodology, ontology created from scratch or reuse, frequently used ontology management tools based on literature, subject granularity, and usage across different platforms. This review based on the literature showed some approaches that exhibit the required principles of ontology engineering in tandem with software development principles. Nonetheless, the review still noted some gaps among the methodologies that when bridged or hybridized a better correctness of ontology development would be achieved in building intelligent system.

I. INTRODUCTION

Web of knowledge popularly known as semantic web has attracted research attentions over some decades. Semantic web, technically denoted as web 3.0 and which can be simply described as web of meaning [1] does not exist in parallel with the existing web (web 2.0) but would gradually evolves from it [2]. The existing web is not machined understandable and therefore not in cooperation with users especially as regards precise information retrieval. However, semantic web promises cooperation between people and machines [3,4,5]. Therefore, in order to achieve this promising trend, a prime technology called ontology becomes indispensible [6]. Semantic web and Ontologies are promising technology outlined for knowledge modeling and capable of inference for designing intelligent systems [7,8].

Technically, based on the field of Computer Science, ontology is a logical theory that is normally encoded using knowledge representation languages such as, First Order Logic (FOL), very popular Web Ontology Language (OWL) [9]. Ideally, Ontology is a data modeling technique for structured data repository

premised on collection of concepts with their semantic relationships and constraints on a chosen area of knowledge (domain). The real power of ontologies lies in its ability to build relationships among classes and instances, and to assign properties to those relationships that enable inferences [10,11,12]. Similarly, one of the popular definitions of ontology [13,14] is that of [15] which states that ontology is an explicit and formal specification of a conceptualization. The term "explicit" means the concepts and constraints of the real-life scenario are clearly defined. The term "formal" stresses the fact that ontology is all about a structured repository, in order words machine understandable. The term "conceptualization" denotes abstract model of a real-life scenarios through which appropriate concepts are identified.

The real-life scenarios may be agriculture, medicine, sports, religion, arts and entertainment and the rest. These scenarios are otherwise known as Domains [16,17]. Consequently, ontology is a shared understanding of some domain of interest which may be used as a unifying framework to solve problems of real-life situations [18]. The term "shared" is a notion that clearly shown that ontology is involved in the technique for solving a real-life problem. Furthermore, Ontology as a semantic model serves as a platform for accurate data integration and exchange. That is, ontologies have the capacity to address the problem of data inconsistency in a (distributed) system [19].

Ontology Development

Researchers used ontology to describe common vocabulary in any domain for information' sharing and reuse [20]. Besides, in order to achieve an inference based design for real-life scenarios, a comprehensive data model called ontology for standardizes terminologies is required [21]. It is also important to know the rationale behind ontology development. They are as follows: to share common understanding of the structure of information among people or software agents, to enable reuse of domain knowledge, to make domain assumptions explicit, to separate domain knowledge from the operational knowledge, and to analyze domain knowledge [22,23].

To develop ontology which is an iterative engineering process is actually tedious and time consuming [24] and expectedly, requires methodology like any software development. However, there is no standard methodology for developing ontology [25,26]. Similarly, [22] made it clear that there is no single correct ontology design methodology, hence which to follow is a matter of choice by the ontology developer. Nonetheless, in order to develop ontology that satisfy the principle of reusability and semantic-stability; activities such as predevelopment, development and post development must be duly considered [19]. Based on the sizeable numbers of literature duly reviewed in this paper, the popular methodologies used by developer include: Noy and McGuiness methodology, Gruninger and Fox's

methodology, Methontology among others, NEON inclusive [27].

In addition to methods for developing ontology, ontology representation languages and editors (ontology management tools) also form part of the process of ontology development [28]. However, this review is limited to ontology development's methodologies because it serves as the bedrock of ontology development process. The choice of ontology management tools to implement the chosen method depends on the level of expressiveness for the proposed ontology. The ontology representation languages include OWL (both version 1 and 2) [29,30,31], RDF [32,33,34], RDF Schema [35,36,37], DARPA Agent Markup Language and Ontology Interchange Language (DAML+OIL) [38,39] and the rest of them.

In this paper, we categorized these languages as World Wide Web Consortium (W3C) standard while XML Topic Map (XTM) [40]– another ontology linguage is categorized as Standardization for International Organization (ISO) standard. Among the W3C standard language, OWL is reportedly most popular because of its expressiveness [32,41,42]. The ontology editor tools also include Protégé [43,44,45,46], FAO AGROVOC Concept Server Workbench Tool [47,48]; OBO-Edit [49,50]; SWOOP [51,52]; Apollo [53,54]; IsaViz [55,56]; TopBraidComposer [57,58] and citrus ontology developed from scratch using Gruff on AllegroGraph [59].

However, it is important to mention that the prime objective of this review is to analyze and compare the activities of the existing ontology development methodologies based on some significant criteria. Such as, activities of each method, the initial domain where the methodology was adopted, subject granularity and usage across different platforms. And at the end, achieve the goal of identifying individual methodology's weakness and suggests for hybridization in order to strengthen ontology development in terms of its content and constructions correctness.

II. LITERATURE REVIEW: ONTOLOGY DEVELOPMENT METHODOLOGY

In this section, the methodologies for ontology development are reviewed. Methodologies indicate set of guiding principles on how the identified activities in the process of ontology design are duly carried out. Hence, the needs to develop ontology based on existing or new methodologies cannot be overemphasis [60,61]. However, ontology developers are still confronted with the challenges of generic standard methods of building the knowledge representation owing to the inadequacies according to the standard required of software development guilding principles [62,63]. The Cyc project designed for creating sizeable knowledge-based systems was the first ontology development methodology recorded and published by [64]. The methodology is described in three stages [21].

Some of the methodologies have a long time standing history in ontology development. To this end, in the late twentieth century, [65] in their survey work examined some methodologies for developing ontology. They include TOVE (Toronto Virtual Enterprise) – an ontology engineering process of six approaches; Enterprise Model Approach which consist of four stages; Methontology consists of seven phases of engineering process; KBSI IDEF5 consists of five approaches. Others include SENSUS, MENELAS, ONIONS, Ontolingua and others. Similarly, [66] presented the most frequently used methodologies for ontology development. Methodologies presented includes Gruninger and Fox; Menthontology; Uschold and King; SENSUS. The author analyzes and compared these methods with the popular software development process called IEEE Standard 1074 – 1995.

Whenever the needs for ontology development occur, some pertinent questions from both ontology's engineers and domain experts concerning methodologies and other relevant ontology management tools call for attentions. This is because the correctness and consistency of ontology largely lies on its methodology which demands lot of experiences and skills. Questions such as, which methodologies mostly preferable to develop ontology from scratch or reuse existing ontologies and logical sequence of tasks to perform in the process of ontology development [67]. Conversely, [19] asserted in their work that the existing methodologies for ontology development fall short of comprehensive coverage for different activities, such as pre-development, development and post-development.

From literature, some ontologies are designed by combining the activities of two methods such as Methontology, Gruninger and Fox methodologies [68,69,70].

Generally speaking, most ontology development methodologies is described as an iterative ontology engineering process in that, alteration or modification can be invoked upon at any stage of the process regardless of current stage of development. An iterative development process in the ontology engineering phase was followed to design domain based soccer ontology in the research work of [71]. Reference [72] in their bid to described an ontology development methodology based on ontology iterative process that would be incorporated with protégé, equally reported the existing famous approaches which includes Gruninger and Fox that again developed TOVE; Noy and McGuiness with example of wine ontology; Methontology of Fernandez, and Uschold and King.

During the process of ontology development [73,74,75], there are three different strategies to identified ontology's concepts in any given domain [76]. These are: top-down, middle-out and bottom-up strategies. A top-down approach first identified the most abstract concepts and then, specialized into more specific concepts. A bottom-up approach first identified the most specific concepts and then generalized into more abstract concepts. While the middle-out approach, first identified the most important concepts and then generalized and specialized into other concepts [67]. The next sections specifically

reviewed the following ontology development methodologies: Gruninger and Fox's methodology, Menthontology approach, Noy and McGuiness approach, Uschold and Kings Approach, and FAO-Based Approach.

Gruninger & Fox's Methodology

It is a first-order-logic based method proposed by [77] to developed knowledge based systems (ontology). It is a formal method that draws the strength of classic logic. In that, it serves as a step to transform informal scenarios into formal languages. Its activities includes, identify motivating scenarios and formulize informal; specify terminology of the ontology within a formal language; set out the competency questions to determine the scope of the ontology; specify axioms and definitions for the terms in the ontology and establish conditions for characterizing the completeness of the ontology [67,78,79,80]. The method was initially designed to developed ontology under business enterprise related domain. But, today the method has been adopted across diverse of various fields of studies. For instance; [25] developed farmer- centric model (ontology) in agriculture domain to represent farmers' information needs in identified context for Sri Lanka farmers by adapting the technique of Gruninger & Fox's methodology. OWL2-DL was used for implementation. Middle-out strategy was used to classify the main concepts of the ontology design. Also, the methodology formed an integral part of [81]'s University ontology.

A key aspect of this methodology has to do with its evaluation activity, referred to as set of Competency Questions (CQs) that aid in validating and checking the correctness of ontology design and equally to define the its scope. Use of formal modeling techniques is significant at this point [82,83]. More so, the method majorly form part of combined methodologies approach owing to this strength (that is, CQs) [68]. However, it was pointed out in the paper of [19] that considering level of coverage as criteria for this method (TOVE); it lacks support for ontology mapping and versioning. [68,84] also observed that the method do not have the capacity to provide complete details of the activities and techniques employed in them. More importantly, one of the core principles of ontology is reusability. It was observed that none of its activities represents the principle. However, the FAO-Based method provided for the reusability principle which is refer to as ontology evolution as post development activities into consideration.

Methontology Methodology

It was developed in the Artificial Intelligence Lab in Madrid for constructing ontologies either from scratch or reusing existing ontologies from ontology' servers. It was designed on webODE and ontoEdit as ontology management tool [21]. Initially, the approach was a consequent of the knowledge obtained from developing chemical ontology. The step-wise activities of the approach are: specification – where the aim of the ontology has to be identified, knowledge acquisition – knowledge has to be extracted from different sources,

conceptualization – domain terms as concepts or relations are identified; integration – super concepts either classes or properties are related to one another, implementation – ontology representation language is required, evaluation and documentation [85,86,87].

Reference [88] adopted the methodology to develop a Graduation Screen Ontology (GSO) and implemented by OWL-DL and Protégé Similarly, [89] adopted the methodology to design ontology for Active Fall Protection System as domain. [90] validated the method and reported that it offers a clear and detailed systematic approach to ontology development method; whose activities supports and complies with software development life cycle. Although, [91] in their review affirmed that there is no generic standard for ontology development. However, the study revealed through the analyzes and comparison of some notable number of methodologies based on some criteria such as type of development, reusability support, strategies for identifying concepts remarked Methontology as outstanding method. [92] equally regarded it as popular and classic method.

The exceptional credit of Methontology is further affirmed in the work of [68] which described the activities of the method to be in full compliance with IEEE standard for software development process. Furthermore, frequently used methodologies for ontology development were reviewed in the research work of [93]. Among the approaches reviewed and compared are Uschold and King; Gruninger and Fox (who proposed another methodology called TOVE); Methontology and UPON by [94]. Finally, Methontology was adopted by the researchers for building the proposed semantic conflict detection ontology that exist between messages of web services. The choice of Methontology was influenced as a result of its development process which the authors claimed to be an IEEE standard 1074-1999.

Similarly, [95] claimed that Methontology is the best among others with detailed activities for development process. Nonetheless, the methodology is not without some notable shortcomings. For example; activity for carrying out evaluation at a pre-development stage lacks in Methontology but present in Gruninger and Fox.

Noy and McGuiness Methodology

Noy and McGuiness also an iterative method, is based on some fundamental rules. The method presented seven steps of developing ontology. They are as follows: determine the domain and scope of the ontology, consider reusing existing ontologies, enumerate important terms in the ontology, define the classes and the class hierarchy, define the properties of the classes, define the value of the slots and create instances [22]; [96,97]. The authors consistently used wine ontology to depict the methodology. [76] developed ontology for cash crop farmers' market in Nigeria where Noy-McGuiness method was employed owing to its simplicity. Top-down approach as strategy for identifying concepts was used. The ontology was developed and evaluated by protégé tool query and Export Tab plug-in using set of competency questions.[98] equally adopted the methodology to design their proposed ontology in software maintenance.

[99] adapted Noy-McGuiness and [100] to describe a six step development process to create antimicrobial prescription ontology and implemented it using Protégé-OWL. That is, the ontology is developed in the domain of antimicrobial-microorganism. Similarly, in the work of [101] the first four activities of Noy and McGuiness method were fused into the proposed ISI method to develop the ontology structure for the domain of natural disaster management.

Uschold and King Methodology

The method was conceived from the knowledge resulted from the development of enterprise ontology [18]. The authors proposed four activities during the process of ontology development. These are: to identify the purpose of the ontology, to build the ontology, to evaluate ontology, and to document it. After a period of time, the method was enhanced via the proposed three strategies for identifying the main concepts in the ontology [102]. In addition to the enterprise ontology project using this method is also the development of Waste Water Ontology (WaWO) in the domain of waste water treatment [103].

FAO-Based Methodology

The FAO-Based method for ontology development proposed in the work of [104] is described in five phases. The paper reviewed ontology-based methods to construct agricultural knowledge management system and equally explore some of its key technologies. However, the existing popular methods were reported in the review not to have certification or recommendation and do not gain a wider acceptance. To this end, a method for agricultural ontology construction premised on the methods applied by Food and Agriculture Organization (FAO) for AGROVOC and AOS was proposed.

The method has the capacity to structure the functional description of domain ontology and equally determine and infer relation that exists between concepts. The authors reported that future research is needed for the implementation of the proposed framework. FAO of the United Nations is saddled with the responsibilities to curtails hunger and under nutrition. But, a very important activity like terminologies specification of ontology is equally not part of ontology design process of FAO-Based method.

Besides these popular methodologies arose from literature which has earlier reviewed in these previous sections, the researchers tend to modify them and adapt to model various domains. For example, [105] presented a six step methodology in agricultural domain. [106] in their rice domain based ontology, proposed a five stage method. [107] in their work proposed a synthesized methodology for taxonomy design in the domain of construction contractual semantics. [108] presented a systematic methodology in which ontology in the domain of Intelligence Transportation Systems would be developed. [109] proposed a ten step-wise ontology

development methodology labeled as Yet Another Methodology for Ontology (YAMO) for food domain. Similarly, [110] proposed also a ten step methodology to develop ontologies for two domains. Also, [111] in their research to develop ontology presented a two step methodology in the pattern of top down design approach.

More so, according to [112], comparison of some important ontology methodologies based on some criteria were carried out. Consequently, a methodology that hinges on the principles of Methontology was proposed to develop ontology based on multilingual terminology resources domain. In addition, [113] acknowledged the similarities that exist among numerous methodologies. These were combined into three major steps of ontology process to develop what is called Data Mining Optimization Ontology. In the case of [114], Unified Process for Ontology (UPON) and Methontology ontological methods were analyzed. Thus, it was reported that the former is the appropriate approach for developing their textile supply chain based ontology.

III. RESEARCH METHODOLOGY

The first motivation for this review was the fact that ontology is proving its strength as a model for complex knowledge representation which has to be achieved via established methodology. Ontology design without methodology as not expected in software engineering principle result to unethical practice called ontology hacking. Even though, there is no affirmatively correct ontology design methodology [23], system include that of ontology has to be designed based on certain approach. Therefore, this research aims to review ontology development methodologies considering their strengths and limitations based on literature and open them for further studies based on content analysis review method.

This paper considers a wide spectrum of publications related to ontology design methodologies, ontologies design for domain, modeling complex knowledge representation ontologically, ontology-based information retrieval techniques, ontology management tools and host of others via reliable online publications. Analysis of the literature is motivated by the pertinent theoretical insights and limitations of formal techniques in ontology design methodologies [19,91]. Methodologies' domains, subject granularity, ontology created from scratch or reuse and methodologies used across different platforms are some of the criteria considered for analysis.

IV. DISCUSSION

Considering the literature reviewed in this paper, we categorized ontology development methodologies into two types: The Foundation ontology development methodologies and The Derivative ontology development methodologies. The former are the popular set of the methodologies which have been applied across different domains. They are described as basic methodologies which have yielded significant results in ontology

development. Although, not without limitations. The latter are adapted methodologies for both generic and specific area of knowledge. The activities or phases of the Derivative ontology development approaches such as [11, 104,105] and FAO-Based are derived from the Foundation ontology development approaches just as the name implies.

More so, this paper considered three set of criteria for analysis. The criteria are functions of ontology's contents design correctness and metrics of evaluations as defined standards for software (ontology) engineering principles. They are listed as follows:

i.   First Criteria – This set contain the initial domain of the methodology, current domain where methodologies are applied more frequently used ontology management (both ontology's editors and languages) tools for the methodologies and the strategy used for identifying ontology's concepts during development.

ii. Second Criteria – The second set of the criteria include ontology created from scratch or reuse, knowledge area (domain), ontology's language and editor, methodology and type of ontology language.

iii. Third Criteria – This is the last set of criteria. It includes subject granularity and methodologies used across different platforms (W3C and ISO).

Table1 presented the analysis of the foundation methodologies based on the reviews considering the initial and current domains where the methodologies were applied as part of the first criteria earlier mentioned.

Table 1. Analysis of the Foundation Ontology Development Methodologies

Methodologies	Initial Domain of the Methodology	Current Domain where Methodology is Applied
Gruninger & Fox	Business Enterprise Related Domain	Generic (Any Domain)
Methontology	Chemical Ontology	Generic (Any Domain)
Noy and McGuiness	Wine Ontology	Generic (Any Domain)
Uschold and King	Enterprise Ontology	Generic (Any Domain)

As shown in the Table 1, the methodologies were applied to modeled ontology for the various initial domains. But presently so far from literature; they are used to model ontology for any domain. For example, Gruninger – Fox and Noy – McGuiness were used to modeled ontology in Agriculture domain [25,76] and Biomedical domain [99]. Waste Water Ontology (WaWO) was developed using Uscholds and King [103]. In addition, based on the number of literature where over One hundred high impacts articles were reviewed in this paper, it was discovered that middle-out approach appears to be more frequently used strategy for identifying ontology's concepts both in Methontology and Gruninger-Fox methologies. Top-down strategy was popular with Noy and McGuiness methodology. For

Uschold and Kings Methodology, it cannot be clearly pointed out. It appears to be the least popular method out of the four. Similarly, out of the dozens of ontology management tools (both open-source and proprietary) available, OWL and Protégé are more used for implementing the methodologies by developers despite the fact that webODE and ontoEdit were designed for Methontology.

Furthermore, based on the reviewed literature; Table2 presented some ontologies modeled for various domains taken the second set of criteria into consideration.

Table 2. Analysis of Ontologies Design for Different Domains Based on the Second Criteria

Literature	Domain	Created from Scratch or Reuse	Methodology	Ontology's Language and Editor	Type of Ontology Language
Anusha, et al. (2015) [25]	Farming	New	Gruninger & Fox	OWL2-DL and Protégé	Web Based Ontology Langauge
Bonanci, et al. (2016) [105]	Agriculture (Reused of SWEET and Cuahsi concepts)	Reused	Bonanci, et al	OWL2-DL and Protégé	Web Based Ontology Langauge
Aree et al (2009) [106]	Rice ontology	New	Aree et al	OWL and AGROVOC CS WB	Web Based Ontology Langauge
Wei et al, (2012) [11]	Agriculture Pest Ontology	New	DSRM	OWL and Protégé4.0	Web Based Ontology Langauge
Godspower and Esingbemi (2016) [76]	Cash Crop	New	Noy and McGuiness	OWL and Protégé	Web Based Ontology Langauge
Soner et al, (2012) [71]	Soccer	New	Soner et al	OWL2-DL and Protégé	Web Based Ontology Langauge
Jianwei et al, (2015) [59]	Agriculture (Citrus ontology)	New	Jianwei et al	RDF/S, Gruff and TopBraidComposer	Web Standard language
Tiffani et al, (2012) [99]	Antimicrobial-Microorganism	New	Noy-McGuiness and Arp	OWL and Protégé	Web Based Ontology Langauge
Jinsoo et al, (2008) [88]	Graduation Screen Ontology (GSO)	New	Methontology	OWL-DL and Protégé	Web Based Ontology Langauge
Rizwan and Aida (2013) [68]	Quran Ontology	New	Gruninger & Fox and Methontology	OWL-DL and Protégé	Web Based Ontology Langauge

From Table2, different methodologies were used to model ontologies for various domains. For instance, while Gruninger-Fox, Methontology, Noy-McGuiness methodologies were adopted; [59,106] were also adapted. In the same vein, some developers chose to merge two methodologies to design ontology for example, Gruninger and Fox and Methontology [83,90,91,93]. In order to show that ontology is still an evolving area of study, from the literatures, ontologies are often created from scratch and OWL is described as Web Based Ontology Language [115].

Finally in this section, Table3 presents ontology development methodologies based on subject granularity and usage across different platforms (W3C and ISO) as the third criteria.

Table 3. Comparison of Ontology Development Methodologies Based on the Third Criteria

Methodology	Subject Granularity	W3C Standard		ISO Standard
		RDF/RDFS	**OWL**	**XTM**
Gruninger and Fox	Set out the competency questions to determine the scope of the ontology	less frequent	more frequent	infrequent
Methontology	Specification	less frequent	more frequent	infrequent
Noy and McGuiness	Determine the domain and scope of the ontology	less frequent	more frequent	infrequent
Uschold and King	To identify the purpose of the ontology	less frequent	less frequent	infrequent
FAO-Based	Determination of ontology purpose and scope	less frequent	more frequent	infrequent

Ontology developer must ensure to precisely and explicitly define the subject granularity. Subject Granularity depicts scope [116]. It specifies a well defined scope of ontology's domain. Achieving this goal would definitely enhance ontology's correctness. For instance, ontology's domain proposed to be agriculture, may be further defined to be crop - cereal or tuber of a crop, maize, maize's disease, or a precise aspect or characteristic of a maize. This criterion is very significant in ontology development. It is described as precautionary measure because it disambiguates ontology's domain and ensure a valid knowledge representation model. This in turn produces a precise ontology which enhances semantic annotation for ontology-based information retrieval. However, a technique may be established to achieve this criterion.

Therefore, from Table3 each methodology has its own activity to define subject granularity. But it was reported that Gruninger and Fox mostly used a mathematical model (First-Order-Logic or Description Logic) to validate its competency questions in order to strongly establish the purpose and scope of ontology's domain. More so, on these criteria set, we look at the frequencies of applying ontology language (RDF/S, OWL and XTM) for implementing the methodologies. The following keys were used to present what we discovered during the course of literature review.

- more frequent – meaning it is more frequently used by ontology developers or researchers
- less frequent – meaning it is fairly (less frequently) used compared to other methods
- infrequent – meaning it is rarely (not frequently) used

In conclusion of this section, this review further proposes a hybridization of Gruninger and Fox, Methontology and FAO-Based methodologies as represented by Fig.1. This is to strengthen their limitations by combining activities in compliance with [19] recommendation while modeling ontology.
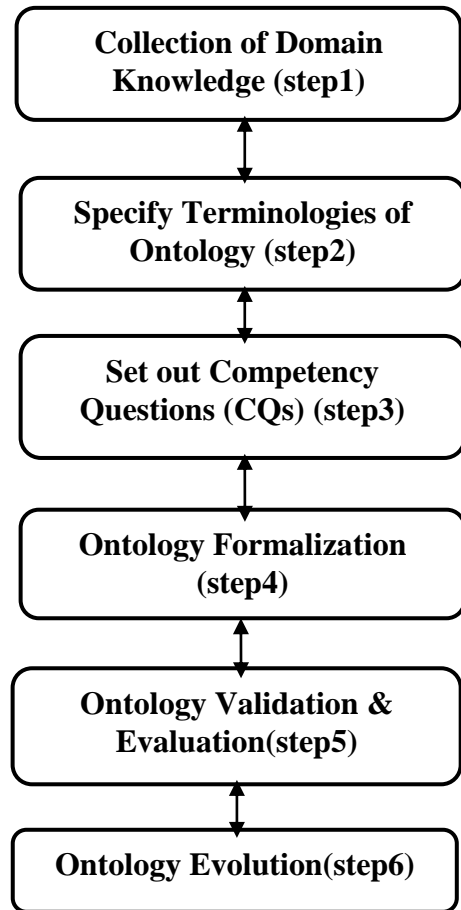

Fig.1. Proposed Ontology Development Methodology

Activities or steps 1 to 3 that is, collection of domain information, specification of ontology's terminologies and setting competency questions satisfy the pre-development recommendation. Ontology formalization and ontology validation or evaluation activities satisfy the development stage. And the ontology evolution satisfies the post-development recommendation. Furthermore, Table4 presented a comparative analysis that depicts the relationship of the proposed method against the existing frequent methodologies considering the required recommendation and standard of developing ontology according to [19].

Table 4. Relationship of the proposed method against the existing methodologies

Methodologies	Pre-Development Activities			Development		Post-Development Activities
	Collection and Analysis of Domain Information	Specification of Ontology's Terminologies	Setting of Competency Questions (Using Logics)	Ontology Formalization	Ontology Evaluation	Ontology Evolution
Gruninger-Fox	✓	✓	✓	✓	✓	✗
Methontology	✓	✓	✗	✓	✓	✓
FAO-Based	✓	✗	✗	✓	✓	✓
Proposed Hybridized Approach	✓	✓	✓	✓	✓	✓

Keys:
- ✓ Denotes activity explicitly present in the methodology
- ✗ Denotes activity not explicitly present

V. SUMMARY AND CONCLUSION

This paper reviews the ontology development methodologies for designing and implementing ontology as a complex knowledge representation model for any knowledge area (domain) by ontology researchers and developers. This research work, categorized the methodologies into two types. They are: Foundation and Derivative methodologies. For example, Gruninger-Fox and FAO-Based methods are categorized as foundation and derivative respectively. Tools (such as Protégé, Apollo, OWL, RDF, XTM) for implementing the methodologies were briefly analyzed and compared. The paper presented three categories of criteria for analysis and comparisons.

The first analysis took into consideration four criteria. These are: the initial domain of the methodology, current domain where methodologies may be applied, frequently used ontology management tools (both ontology's editors and languages) for the methodologies and strategy for identifying ontology's concepts during development. The second comparison and analysis took into consideration five criteria. Namely, ontology created from scratch or reuse, knowledge area, ontology's language and editor, methodology and type of ontology language. And the third analysis considered two criteria. They as follows: subject granularity and usage across different platforms. Subject granularity among other criteria considered in this research is significant. Similarly, the review paper classifies the ontology representation languages into two standards: the W3C and ISO standards.

In conclusion, Gruninger and Fox, Methontology, Noy and McGuiness include FAO-Based methodologies have demonstrated potentials for ontology development however, not without limitations which call for research attention. For example, subject granularity of proposed domain have to be clearly defined if ontology correctness and validity should not be compromised or trade off. In this work, we suggest that agriculture for instance, should not be a defined subject for domain owing to its broadness and undoubtedly, vast of its inexhaustible knowledge or data. A particular domain can still be broken down into some granules, model ontologically and finally merge if necessary for further work. Similarly, OWL is highly explored when implementing methodologies among its contemporaries. This is owing to its expressivity in terms of concepts' relations and axioms. This fact is verified by over one hundred literature we considered in this review. In contrast, XTM has a low application. Nonetheless, this research brings to the attention of ontology developers that the ontology development methodologies along with knowledge representation languages presented and reviewed in this paper are cross platform. That is, they may be implemented in any (W3C or ISO) standard.

Based on the review, conclusion is equally drawn that ontology is still an evolving area of study so also its technologies. Despite the hundreds of existing ontologies; most developers still create new ontology from scratch despite its tediousness. This equally serves as a call for research attention in the area of ontology mapping and population. More so, we suggest in this paper as a matter of further study that the problem of domain or subject granularity definition owing to natural languages ambiguities or word mismatch can be handled by considering enhancement to the existing semantic databases. For example, WordNet can be improved as a result of its limitation in senses return of word inflected forms. AGROVOC is another database for agriculture domain. All these can assist in synonyms or polysemous concepts of domain. Thereby, increases the correctness and validity of ontology design.

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