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Development of Fuzzy Logic Control Ontology for E-Learning

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***Abstract*—**Nowadays, ontology is common in many areas like artificial intelligence, bioinformatics, e-commerce, education and many more. Ontology is one of the focus areas in the field of Information Retrieval. The purpose of an ontology is to describe a conceptual representation of concepts and their relationships within a particular domain. In other words, ontology provides a common vocabulary for anyone who needs to share information in the domain. There are several ontology domains in various fields including engineering and non-engineering knowledge. However, there are only a few available ontology for engineering knowledge. Fuzzy logic as engineering knowledge is still not available as ontology domain. In general, fuzzy logic requires step-by-step guidelines and instructions of lab experiments. In this study, we presented domain ontology for Fuzzy Logic Control (FLC) knowledge. We give Table of Content (ToC) with middle strategy based on the Uschold and King method to develop FLC ontology. The proposed framework is developed using Protégé as the ontology tool. The Protégé's ontology reasoner, known as the Pellet reasoner is then used to validate the presented framework. The presented framework offers better performance based on consistency and classification parameter index. In general, this ontology can provide a platform to anyone who needs to understand FLC knowledge.

***Keywords*—**Engineering knowledge, fuzzy logic control ontology, ontology development, table of contents.

I. Introduction

MANY private or public higher education institutes have practiced an e-learning environment as a secondary teaching method that supports the currently conventional teaching approach or as an educational medium for long-distance or off-campus programs. It is the rapid growth of Web technologies and the increasing number of Internet users in Malaysia have made the teaching and learning medium via the internet or "e-learning" environment so popular today. Generally, we learn or gain a new knowledge in the classroom for the theoretical approach. Then, the tutorial or the laboratory experiments are conducted for shaping the student's practical and hands on ability. Nowadays, lecturers or academicians prefer to use online tutorials or the e-learning environment in order to provide student assignments and even student activities. It offers a lot of benefits including less time spent in the classroom, especially for the question and answer sessions. However, in developing e-learning requires the fulfilment of several criteria, and one of them is quality content. This quality criterion can be solved by applying a question/answer system. The question and answer system offers a solution in providing better understanding for students in accomplishing the assignment.

There are several challenges in developing question and answer systems [3]. One of the challenges is how to establish a platform for providing data sources to the system. In order to handle the data sources challenge, ontology is found to be the best solution [23]. According to Gruber [4], an ontology is an "explicit specification of a conceptualization". Generally, ontology describes a conceptual representation of notions and their relationships within a specific domain. The purpose of an ontology is to provide a common vocabulary for anyone who needs to share information in the domain. Currently, ontologies are widely applied in many areas. Among these are in knowledge engineering, e-commerce, information retrieval, bioinformatics and many more.

In order to develop the framework of ontology, there are several things that need to be considered first. There are four main components of an ontology. The first component is known as class. Besides that, a concept, set and entity also refers to the same meaning with the class. This class represents a concept that comes from a broad sense. After that, the other component of an ontology is relations or also known as roles or properties. It represents a type of association between concepts of the domain. It is defined as any subset of a product of *n sets, P c E1 x E2 c E3 c ….. x En*. It can be instantiated with knowledge from the domain and express the concept attributes (also known as slots). One of the components of the ontology is known as formal axioms. It models the sentences that are always true and represent knowledge that cannot be formally defined by the other components. It is also verifying the consistency of the ontology itself or the consistency of the knowledge stored in a knowledge base. These formal axioms are very useful for inferring new knowledge. Meanwhile, the last component is called instances. These instances represent elements or individuals in an ontology. The relationship in ontology can only be done by instances.

The existing Uschold and King method [2] is known as one of the best and most popular methods for ontology development. It has been applied to various applications, as it is simple and easy to apply [1]. However, only a few applications in engineering knowledge have employed

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ontology, for example, the engineering requirement modeling ontology by Mukhopadhyay [16]. This is because ontology merely describes the domain where the engineering knowledge requires: a) Step-by-step guidelines; and, b) the instructions of the lab experiments. The domain knowledge that developed into ontology is more to non-engineering knowledge rather than engineering knowledge. By the way, medicine and chemistry are the most fields that have the ontology that both are the non-engineering knowledge based on the Protégé Ontology Library. Hence, it is challenging to develop ontology for engineering knowledge, especially for the FLC. Therefore, we present a fusion method in order to solve this problem. In this study, we proposed to fuse the middle out strategy based on the Uschold and King method with the ToC approach in developing the ontology for the FLC. The main reason for choosing these two techniques is based on the Fonou-Dombeu and Huisman [1] statement. The author has emphasized that the Uschold and King method [2] is easy to apply by novice ontology developers and promotes the fast development of domain ontologies. Meanwhile, the ToC refers to a list of contents or parts of the document or book that are organized in the arrangement. Afterward, this FLC ontology will be evaluated by an ontology reasoner known as the Pellet reasoner, which is a plugin for the Protégé reasoner.

The organization of this paper is as follows: In Section II, we will review and discuss the current methodologies of ontology development, and based on this, we suggest a combination of strategies on methodology in order to build the framework of FLC ontology. Meanwhile, in Section III, we explain the FLC ontology domain in detail. Following in Section IV, we construct FLC ontology step-by-step. In Section V, we evaluate the proposed design of the FLC ontology domain. Lastly, we talk about a conclusion and future works in Section VI.

II. Ontology Overview

A. Ontology

Ontology approaches is a hot topic nowadays, especially in the field of computer science or information technology. There is a variety of definitions that can be associated with ontology. In short, ontology is a concept to briefly describe knowledge. Ontology is so important, especially in knowledge representation because the identical comprehension of the knowledge that can be shared among people or software representative. It is also necessary for an expert system; in order to explore and interpret the domain knowledge until can be applied in the context of problem-solving. This section will observe what have been done in the methodology of ontology, ontology language, ontology tools, and ontology domain that was developed by the Uschold and King method.

B. Methodology of Ontology

Many researches have been proposed in the methodology of ontology. The literature review for the methodology of ontology has started with Unschold and King method [2], follow the Gruninger and Fox methodology [5], the Seven-Step Method [6], the Practical Approach [7], and the Knowledge Engineering Approach [8]. The selected approaches are suitable for the novice ontology developer and also suitable for the application independent.

C. Ontology Language

Ontology language is a regular or formal language that has been used in order to develop the ontology. This ontology language supports the process of encoding the information about particular domains. Nowadays, there are many ontology languages that have been drawn up to help the ontology developer to construct their ontology. However, according to [9], there are three languages that are actively used by developers including Resources Description Framework (RDF) [10], Resources Description Framework Schema (RDFS) [11] and Ontology Web Language (OWL) [12].

D. Ontology Tools

The purpose of ontology tools or the ontology editor is to give support to the building of the ontology, whether following a particular set of methodology or not. According to [9], ontology tools can be divided into two categories. The first category is the tools that map the model of the knowledge to the ontology language and is developed for the particular language. Meanwhile, the second category is the tools that separate the knowledge model from the ontology language. Here, we only focus on the ontology tools that involve most of the processes needed in order to build the ontology and support the integration of the ontology building activities such as Protégé, WebODE [9] and TopBrain Composer.

III. FLC as Ontology Domain

According to Protégé Ontology Library's website, there are many ontologies that are available in the format of OWL and Frame, and can also be shared. Most of them are in medicine, chemical, management, and health, but only a few in the engineering domain based on the Protégé Ontology Library. Here, we can classify the current ontology under the Uschold and King method of ontology development into two main groups of a domain, which are the non-engineering related domain and engineering related domain. There are several domains that can be categorized under the non-engineering related domain such as health, business, management and language. For the health domain, [18] has developed e-Health integration and interoperability issues. Apisakmontri et al. [14] also create the ontology of the Humanitarian Aid for Refugees in Emergencies (HARE). Meanwhile, in the management domain, [13] built the compliance management ontology, and [20] developed the Project knowledge management domain. In the language domain, [17] has developed lexical ontology for Arabic semantic relations, and the Ontology for a Communication Platform by [19]. Besides that, for the business domain ontology, the Enterprise Ontology of Business Process Crowdsourcing by [15] and Ontology Building and Pricing of Customized Product by [24] were developed. However, the engineering related domain has only one domain related, so far, which is known as engineering requirement modeling that developed by [16]. As a result, this paper also will develop a new ontology in the engineering related domain known as FLC. This FLC ontology will be developed and aims to increase the understanding of students about the FLC. The limitation for the FLC ontology domain is for engineering degree students.

IV. Design of FLC Ontology

This section explains further about the methodology that will be used to develop the framework of the FLC ontology domain. We used a combination of the Uschold and King method with the middle-out strategy and ToC approach. There are four steps involved in this methodology. The first step of the design of the FLC Ontology domain is identification of the purpose of the ontology and is followed by the second step, which is ontology capture. Then, the third step is a framework of FLC and is continued by the implementation of FLC ontology as the fourth step.

A. Step One: Identification of the Purpose of the Ontology

The first step is identifying the purpose of the ontology. The purpose of the ontology must be clarified very clearly. It is very important, because this purpose will guide the ontology structure. In this study, our purpose to develop FLC ontology is to provide a consensual knowledge of the FLC domain that will be used in the question and answering system. After identifying the purpose clearly, it is easy for us to take further steps on the FLC ontology development.

B. Step Two: Ontology Capture of the FLC Domain Knowledge

The next step is the core or important step in FLC ontology development. This step is called ontology capture. This step requires us to extract the FLC knowledge from the authoritative sources including lecture notes, textbooks and domain experts. In other word, this step is more to the description of FLC domain knowledge. We determine the relevant terms and concepts of the FLC domain, such as fuzzy logic, fuzzy set, membership function and many more.

- What is the definition of Fuzzy Logic?
- How many components in the Fuzzy Logic?
- How many membership functions are involved in the Fuzzy Set?
- Is the intersection operation a part of the Basic Fuzzy Set Operations?
- How many steps are involved in the fuzzy control of an inverted pendulum?
- Is the inference engine a part of the Fuzzy Control components?
- What is the advantage of the Fuzzy Control?

Fig. 1 The competency questions

Firstly, we need to construct the competency questions that can help us to extract the FLC knowledge. Fig. 1 shows the example of the competency questions. The competency questions are the list of possible questions that can guide us to extract the knowledge and can be used to evaluate the FLC which is held by the domain expert. At the end of this step, we will get the unclear relationship in the FLC ontology figure as shown in Fig. 2.

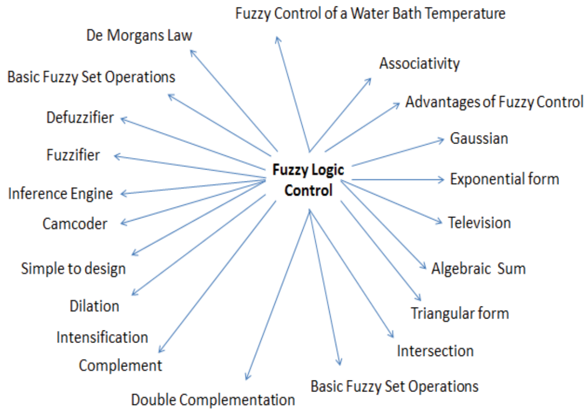

Fig. 2 The unclear relationship in the FLC ontology

C. Step Three: Build up the Framework of FLC Ontology

At this stage, we examined the previously unclear relationship that we have collected before and build-up the ontology framework. The extraction of the knowledge for this, FLC uses a combination of the two strategies. The first strategy is the ToC strategy. This ToC strategy can help in the process of extracting knowledge, especially for the FLC knowledge. The second strategy is the middle-out strategy. This middle-out strategy has been used by [2]. It first identifies the core concepts and then specifies and generalizes them into the other concepts as required, or in other words, to develop the class hierarchy. As we know, the FLC knowledge has a combination of descriptive knowledge and step-by-step knowledge. Generally, the ontology will eliminate step-by-step knowledge and highlight the descriptive knowledge, but it is required for the FLCs which have step-by-step knowledge. This is because it will make the FLC ontology domain incoherent or incomprehensible. Therefore, the ToC strategy is proposed and combines the middle-out strategy in order to overcome this weakness of the process of ontology development. These combinations will help us to identify and show the main concepts of FLC ontology. Fig. 3 shows the example of the ToC and is categorized for the use of the middle-out strategy.

Firstly, we need to understand the content of the FLC knowledge. We can use resources including lecture notes, textbooks and domain expert. With this combination of the strategy, we then identify the notions and relationships between the concepts in the FLC domain using the guidance of the ToC strategy. We can see the structure of the FLC knowledge from the list of the ToC. After we identify all the middle concepts, we move our focus to the top concepts and then on the bottom concepts, as shown in the Fig. 4. Finally, add the relationship between the concepts. These relationships represent interaction among concepts in the domain knowledge. Several basic relationships are used frequently in

FLC ontology, such as part-of, instance-of, attribute-of and much more. Fig. 5 shows the basic semantic relationship of the concepts of FLC ontology parts. In order to evaluate hierarchy, the competency questions will be used to check reasonability and practically of developing this FLC ontology, and to validate the hierarchy of the ontology.

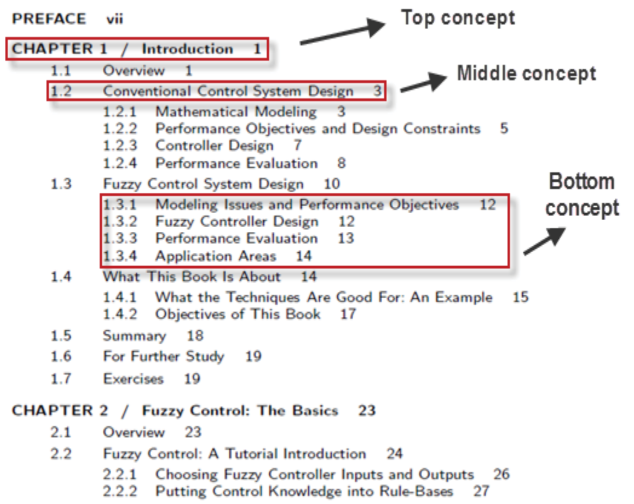

Fig. 3 Example of ToC

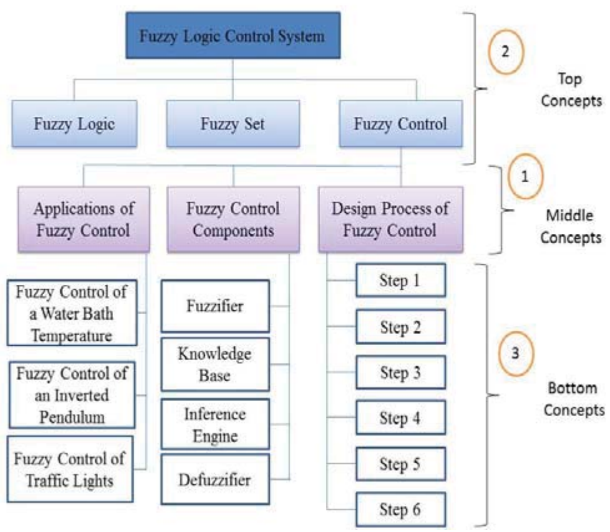

Fig. 4 Class hierarchy of FLC ontology

D. Step Four: Implementation of FLC Ontology

In this FLC ontology development, we have implemented OWL language using Protégé 3.5. The ontology editor in the Protégé 3.5 can be used to design concepts or classes and organize as a hierarchy. Here, we need to create naming conventions or to locate similar definitions together, like using lower or uppercase letters to name the terms, or writing the terms of the representation ontology in upper case. For the example, the terms of FLC knowledge will documented as fuzzyLogic, fuzzy_control, Fuzzy_Set and many more. Fig. 6 shows the FLC ontology by OWLViz plug-in in Protégé 3.5.

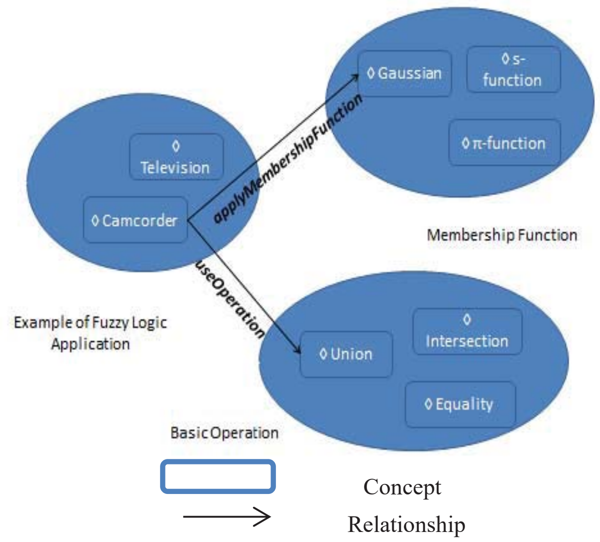

Fig. 5 Semantic concept map of FLC ontology

V. Evaluation and Results

The final stage after completing all the steps in the design FLC ontology development is the evaluation of the FLC domain ontology. According to Gomez-Perez *et al.* [21], we can state that this FLC ontology domain is subjective and can be directed to evaluate. Even so, the Protégé software has a plug in knowing as the Pellet reasoner that can evaluate the ontology. This Pellet reasoner is one of the most common reasoning engines that are used for reasoning with the Protégé OWL models. It is also can provide a balancing of functionality and accessibility [22]. It will check the consistency and classification of the FLC ontology domain. Based on the Pellet reasoner, Fig. 7 and Table I show the results of ontology consistency, while Fig. 8 and Table II show the results of ontology classification.

VI. Conclusion

In this paper, the FLC ontology for acquiring engineering knowledge for FLC is presented. FLC ontology can describe the FLC domain knowledge structure clearly. Besides that, this FLC ontology also can be used for any application system, such as information retrieval systems and information extraction systems.

After running the Pellet reasoner as the ontology reasoned on Protégé, it shows that the proposed FLC ontology is well defined and based on the better result of consistency and classification. The results show that the time taken for every parameter to do their own reasoning task. That means no error occurred during the reasoning. Otherwise, the results show an error for the ontology part that needs to be corrected.

We managed to develop an FLC ontology design which requires step-by-step knowledge using a combination of the ToC and middle-out approaches. The evaluation of this paper is to validate the performance using the Pellet reasoner based on two parameters, which are known as consistency and classification of the ontology.

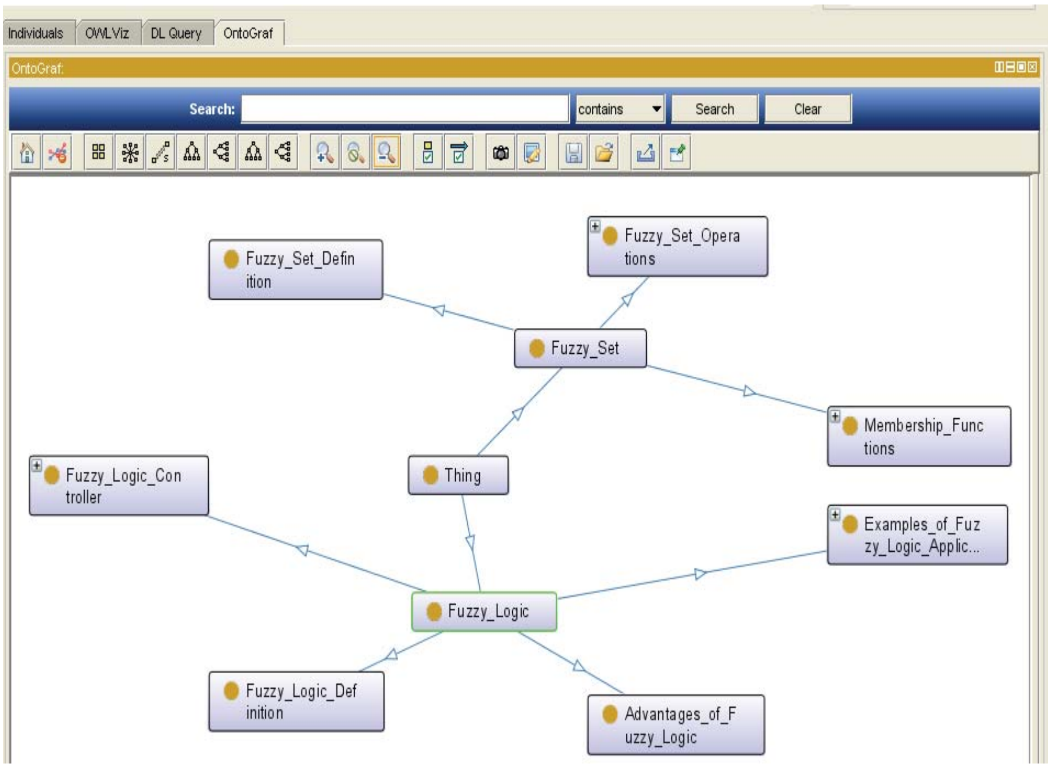

Fig. 6 The graph of a relationship that represents FLC ontology

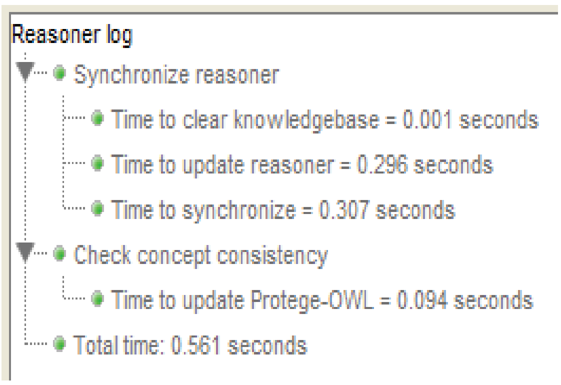

Fig. 7 The ontology consistency result of the FLC domain ontology by the Pellet reasoner

TABLE I
THE RESULT OF ONTOLOGY CONSISTENCY BASED ON PELLET REASONER

Parameter	Time	Quality of ontology
Clear knowledge	0.0001s	Good
Update reasoner	0.296s	Good
Synchronize	0.307s	Good
Update Protégé-OWL	0.094s	Good

TABLE II
THE RESULT OF ONTOLOGY CLASSIFICATION BASED ON PELLET REASONER

Parameter	Time to update Protégé-OWL	Quality of ontology
Check concept consistency	0.019s	Good
Compute inferred hierarchy	0.062s	Good
Compute equivalent classes	0.006s	Good

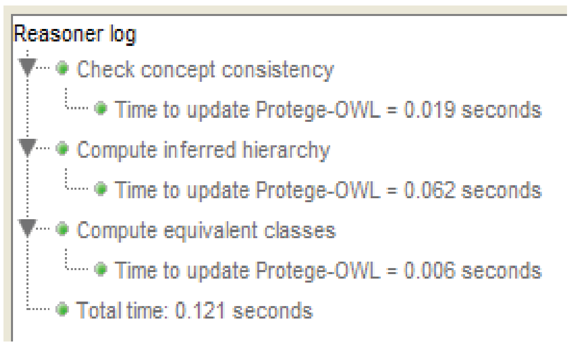

Fig. 8 The ontology classification result of the FLC domain ontology by the Pellet reasoner

In general, the FLC ontology domain is successfully developed, as it gives the best results on consistency and classification by offering without any error and reasonable processing time. For future improvement, we suggest developing a simple application that can run a simple query from the user to get the suitable answer.

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