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Ontological Approach in Knowledge Based Recommender System to Develop the Quality of E-learning System

Saman Shishehchi, Seyed Yashar Banihashem, Nor Azan Mat Zin, Shahrul Azman Mohd. Noah

Department of Information Science, Faculty of Science and Information Technology, University Kebangsaan Malaysia, Selangor, Malaysia

Abstract: The rapid growth of Internet technology and the explosion of educational resources, show the increasing importance of e-learning systems. Despite the importance of these systems, they suffer from the enormous learning materials. In recent years, recommender systems appeared to improve the quality of learning. Such systems were used in learning systems to provide the facilities during the learning process and help learners with a more accurate learning. Different recommendation techniques such as collaborative filtering, content based and the hybrid filtering were employed for e-learning domain. In addition to the importance of learner's needs in the learning process, also the training method for recommended learning materials should be important in this learning process. This paper aims to develop the knowledge based personalized e-learning recommendation system based on ontology. Furthermore, this study discusses about appropriate recommendation technique based on learning system characteristics. The first significant property of this study is the common ontology for learner and learner materials. The second property is referring to the developed pedagogy pattern for this recommendation. The learning materials filter according to the prerequisites of the learner request and learner's knowledge. Learner can ask any activities such as example or description, by using graphical user interface.

Key words: e-learning, ontology, recommender system, pedagogy, knowledge based recommendation.

INTRODUCTION

Nowadays, e-learning systems have many advantages(Shishehchi, Banihashem *et al*. 2010) comparing to the conventional learning systems. Face to face learning is the known property in conventional learning systems. Learners should spend enormous time and cost when they work with the system while e-learning systems allow learner to access electronic materials and learn everything as virtual classrooms (Yu, Nakamura *et al*. 2007; Shishehchi, Banihashem *et al*. 2010). The most beneficial feature of e-learning system is its independence to classroom and platform. The biggest problem in e-learning systems is the similarity of finding results for every learner with the same request (Tang and McCalla 2005). E-learning systems are expected to provide the suitable learning materials for learners however they cannot meet this expectation due to the similarity of learning material finding. This problem is caused by the lack of personalization (Tang and McCalla 2005). Many researchers put effort to provide personalization mechanisms for e- learning system. Personalized systems consider learner preferences, interests, and browsing behaviors in providing personalized services (Chen, Lee *et al*. 2005; Chen and Duh 2008). The personalized e-learning recommender system provides different recommendation for the learners with the same request. This recommendation is according to the learner interest, preferences and knowledge background. E-learning recommendation systems can be useful for learner and educator (Prieto, Menéndez *et al*. 2008).

They help learners to find the appropriate learning content and make a recommendation to improve the learning quality. These systems sometime perform as an educator and sometime help the educator to improve the speed of learning in the class (Prieto, Menéndez *et al*. 2008). Recommender systems are few in e-learning domains in contrast to other domains, but the common recommendation technique is collaborative filtering (Basu, Hirsh *et al*. 1998; Burke 2002; Drachsler, Hummel *et al*. 2007). This technique recommends learning materials which were applied by learners in the past. This recommendation is based on learner behavior such as rating and implicit histories (Drachsler, Hummel *et al*. 2007). The content based filtering (Basu, Hirsh *et al*. 1998; Burke 2002; Drachsler, Hummel *et al*. 2007) is the second applied technique in e-learning recommendation. This technique is not depended to other learners and recommends materials similar to the ones in which learners had preferred in the past (Drachsler, Hummel *et al*. 2007). The functioning of both collaborative filtering and also content based depends on historical data set. New learner with the few ratings makes the problem for this approach since the collaborative filtering need to set of learners with the rating information. Some of the researchers have preferred to compose both collaborative filtering and content filtering. This recommendation calls hybrid filtering.

Corresponding Author: Saman Shishehchi, Department of Information Science, Faculty of Science and Information Technology, University Kebangsaan Malaysia.

Knowledge based recommendation is another recommendation technique. However, this technique has been used less compared to the mentioned techniques. The knowledge based technique aggregates the knowledge about the learners and materials to apply them in the recommendation process. The knowledge engineering is one of the most important topics in this approach (Burke 2000; Pan, Wang *et al*. 2010). The recommendation techniques suffer from several problems that are briefly mentioned. One of the problems is called "cold-start" or "ramp-up" (Burke 2002; Adomavicius and Tuzhilin 2005; Ochi, Rao *et al*. 2010; Pan, Wang *et al*. 2010). This problem is caused by lack of sufficient learner information in the past. The second problem is referring to new object. Since the new object does not have enough rating therefore recommendation cannot be done easily. This problem is known as "early rater" [8]. The lack of knowledge about the user's preference causes the "overspecialization" problem which recommendations only include the objects which learner knows about their resemblances(Pan, Wang *et al*. 2010). Inadequate rating information makes another problem which named as "rating sparsity" (Adomavicius and Tuzhilin 2005). Materials which the learner is interested in may not be suitable for them (Tang and McCalla 2005), so the rating system cannot provide appropriate recommendations. To summarize, a comparison between various recommendation approaches is presented in Table 1. An attempt is made to develop knowledge based recommendation considering ontology (Logic and Languages). We use the term ontology to refer to the classification structure and instances within a knowledge base. Our ontology consists of knowledge about learner and learning materials. Since the pedagogy is very important in the learning quality, hence we developed our pedagogy pattern. Our recommendation system employs this pattern to recommend the suitable materials. The rest of paper is organized as follows. Section 2 describes the background of research; Section 3 discusses about some conditions for selecting the suitable technique for learning systems; Section 4 lists some related works; Section 5 describes the materials and method of this study and finally we bring the conclusion and future works in the sections 6 and 7.

Background:

Knowledge Based Recommendation:

Knowledge based recommender system relies on domain knowledge and knowledge about the learners [10]. Extract the learner's knowledge and knowledge about the learning materials, is the main task in knowledge based recommender system (Lu 2004; Shishehchi, Banihashem *et al*. 2010). Knowledge-based recommender systems do not put effort to build long-term generalizations about their users. They prefer to generate a recommendation based on matching between user's need, preferences and set of items available (Lu 2004). Considering this compression in table 1, it seems that the knowledge based recommendation can be the suitable technique for e-learning recommendation. This approach does not involve the sparsity problem and also the overspecialization problem since this approach is independent of another user and statistical evidence (Lu 2004). Furthermore, this approach is sensitive to changing learner interest and learner preferences and also doesn't have any dependency to rating information. Knowledge-based approach does not need an initial database of learner's preference (Li and Murata 2010) and also is able to exploit the knowledge about the learning domain to offer the best solution to the learners (Santos and Boticario 2009). However, it aims to generate the suitable recommendations and reasoning about what learning materials of the domain meet the learner's need (Santos and Boticario 2009). This type of recommender system needs to the knowledge engineering (Lu 2004). Knowledge engineering is those of Controversial issues in this approach in which are performed by using some techniques. Knowledge representation is one part of knowledge engineering. There are various approaches to represent the knowledge. Since knowledge engineering plays the vital role in the knowledge based technique, we will use the ontology to represent all required knowledge in the system. Considering to knowledge engineering, learner profile can cover some part of knowledge about learner.

Learner Profile:

Learner profile or user profile is either knowledge based or behavior based (Middleton, Shadbolt *et al*. 2004). The known approaches for knowledge extraction for the learner are interviewing or questionnaire. Knowledge-based approaches engineer static models of users and dynamically match users to the closest model(Middleton, Shadbolt *et al*. 2004). The behavior based learner profiling is dynamically, because this

approach extracts the learner knowledge through some dynamic techniques (Logic and Languages; Middleton, Shadbolt *et al*. 2004). In this study, we apply both knowledge based and behavior based ones. Some parts of learner`s profile is static and another part is dynamic. To extract the learner profile is static and obtain another information about the learners are dynamic. Learner profile consists of learner information, learner history, learning style and knowledge background.

Table 1: Comparison of recommendation techniques.

Approach name	Domain Knowledge	Cold start problem	Early rater	Sensitive to preference change	Historical data set	Knowledge engineering	Rating sparsity problem	Set of user	overspecialization
Collaborative filtering (Burke 2002; Adomavicius and Tuzhilin 2005; Ochi, Rao *et al*. 2010; Pan, Wang *et al*. 2010)	—	✓	✓	—	✓	—	✓	✓	—
Content based (Burke 2002; Adomavicius and Tuzhilin 2005; Ochi, Rao *et al*. 2010; Pan, Wang *et al*. 2010)	—	✓	—	—	✓	—	–	—	✓
Knowledge based (Burke 2000; Burke 2002; Adomavicius and Tuzhilin 2005; Ochi, Rao *et al*. 2010; Pan, Wang *et al*. 2010)	✓	—	—	✓	–	✓	–	—	–

Why Ontology?:

Ontology is one of the approaches for knowledge representation. Ontology has some advantages that encourage researchers to use it. The most important advantage is the reusability and share ability (Shishehchi, Banihashem *et al*. 2010). Ontologies enable us to share the domain and the knowledge between applications (Yu, Nakamura *et al*. 2007; Shishehchi, Banihashem *et al*. 2010). Ontologies create machine-understandable descriptions of learning resources and provide the personalization and adaptively.

How To Find The Suitable Recommendation Technique For Learning Systems?:

Recommender systems are domain dependent (RECOMMENDER). The used recommendation method in one domain cannot be used in another domain(RECOMMENDER). This occurs owing to two reasons. Firstly, the diversity of recommendation technique, and secondly the consistency between demands of domain and recommendation technique (RECOMMENDER). Considering the various domains, the demands will be different and each of the demands adjusts to specific recommendation technique (RECOMMENDER). Therefore, considering the high efficiency of applied recommendation technique in the e-commerce domain, they employ in e-learning domain. The education domain, the learning material can represent through two way; the formal learning and informal learning (RECOMMENDER). In formal learning all learning materials observe the academic places like the university or school rules. This kind of learning is structured but informal learning does not follow any rules and any structure. This type of learning can follow any learning

material and curriculum in the world. According to these classifications, the recommendation system and their technique will be different. In structural learning the pedagogy play the key role in the recommendation but in informal learning almost each learning resource can employ. Ontology is very useful for the structural e-learning domain because we can classify the learning material.

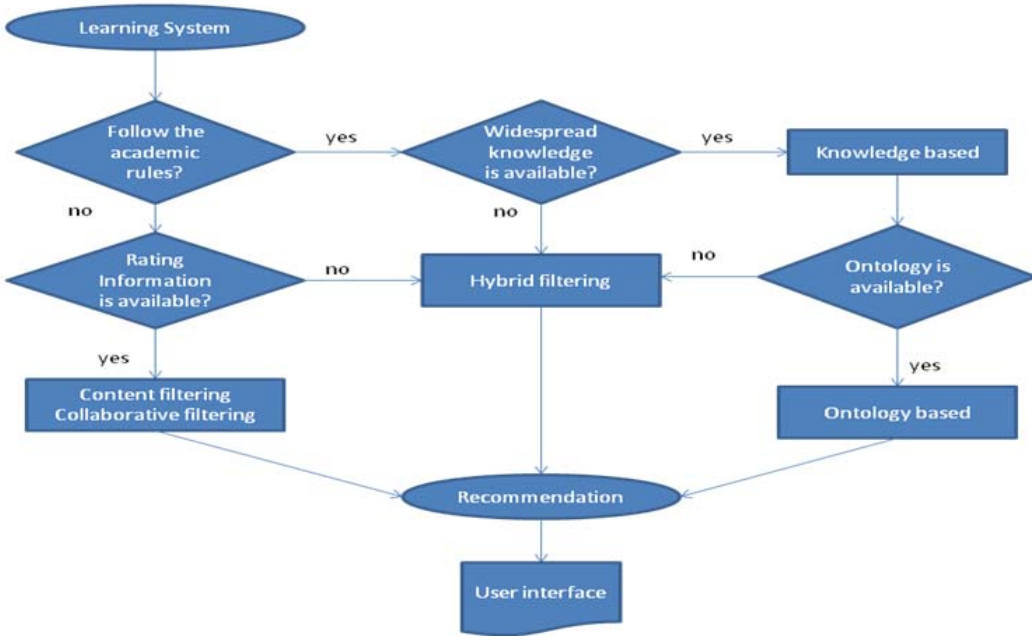

Fig. 1: Flowchart of suitable recommendation technique.

To create the ontology, we can get help from the expert people in the academic places. Fig 1 shows the suitable recommendation techniques based on existing conditions in the learning systems.

Related Works:

In this section, we are about to mention some of the previous related works due to ontology based recommendation system in e-learning.

Hendrik (RECOMMENDER) presents a recommendation system for e-learning. The applied technique in this system is the composition of ontology based and collaborative filtering. This system is able to select one of the applied recommendation techniques based on learner current situation.

Zhiwen and his colleagues (Yu, Nakamura *et al*. 2007) develop a recommendation system for context-aware e-learning based on ontology. This recommendation system deals with the knowledge related to the learner, content and learning domain. Three ontologies are available for this system such as learner ontology, domain ontology and learning content ontology. The semantic relevance between learning material in the learning content ontology and learner ontology occur by using conceptual graph. They believe that learning content recommendation is a new topic with the emergence of e-learning.

Manuel and his friend propose the recommender system to assist the teacher in the learning design practice. They create two ontologies. The first one represents knowledge that helps to explain how the student perceives, gathers and uses the received information. The second one represents the knowledge about teaching techniques. The second ontology consists of good practices, orientation criteria, suggestions and frequent learning difficulties. The recommendation process considers to three parts; course classification, instructional design recommendation and Learning object recommendation(Prieto, Menéndez *et al*. 2008).

Shen (Shen and Shen 2005) suggest the learning content recommendation based on ontology, which utilizes sequencing rules to connect learning objects. The rules define from the knowledge base and competency gap analysis.

Tsai, *et al* (Tsai, Chiu *et al*. 2006) design a framework for ontology based personalized adaptive system in e-learning. Their recommendation algorithm is based on preferences and neighbor interest.

Henze, *et al* (Henze, Dolog *et al*. 2004) create three ontologies to develop the recommendation system.

Learner ontology, domain ontology and observation ontology in their research are so important.

Furthermore, they used reasoning mechanism over distributed RDF annotation. This system performs Querying and transforming RDF model using rule language.

Sieg, *et al* (Sieg, Mobasher *et al*. 2007) and Gao, *et al* (Gao, Yan *et al*. 2008) perform the quite similar research. This is ontology based and they used spreading activation model to discover user's interests. The learner ontology creation is shown in these researches.

MATERIAL AND METHOD

We develop the ontology to store the needed knowledge for system to use them during the recommendation process. The Protégé 3.4.3 is used for creation ontology. Making a semantic relationship among learning material is the next process in this system. The known relationship among materials in learning systems is prerequisite relation. We make this relationship through the creation of some object property in ontology. The some semantic query (Prud'Hommeaux and Seaborne 2006) should be defined to run each sent request from the learner. The pedagogy pattern also will create and finally the user interface creation in the last process in this method.

This study focuses on two important subjects as following:

- The created ontology, The proposed pedagogy pattern and User interface

Ontology:

Unlike most of the previous related works, we prefer to create ontology. This ontology has two levels which are high and low levels. The high level includes two main classes while the low level refers to all subclasses and instances. Two main classes cover all knowledge about learners and learning material's knowledge. In this ontology, we classify the knowledge as two clusters; knowledge of learner and knowledge of learning material by two separate classes.

- Learner class
- Learning material class

The high level of ontology is presented in Fig 2.

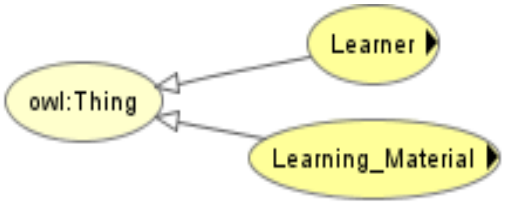

Fig. 2: The high level of ontology.

One of the main classes in the ontology is the knowledge of the learner who covers all personal information about learner, learner's knowledge background, learner history and learning style. The learner class of this ontology has four subclasses:

- Learner profile
- Learner history
- Learner knowledge background
- Learning style.

The learner profile includes two subclasses the first one is personal information which includes the name, family, age, gender and email address; the second subclass is academic information such as degree and major. This part of ontology performs statically by questioner and the rest of information extract dynamically. The learner history consists of all interactions between system and learner such as the visited learning material and the logging time and logout time. The learner knowledge background means the learning material that learner knows about them and the amount of knowledge in each of mastered learning material. We develop the specific algorithm to extract the mount of knowledge for each of mastered learning materials, however discussing these algorithms are beyond the topic of this study. The learning style points to favorite approaches of learning. This class classifies these learning materials into three subclasses; text, video and picture.

The second main classes in the ontology related to learning material and some information about them. This class consists of two subclasses; learning practice and learning topic. All learning material classifies the learning topic also some quizzes and examples are in the learning practice class. These quizzes and examples are related to each of the learning rubrics. The low level of ontology is shown in Fig 3.

Fig. 3: The low level of ontology.

Proposed Pedagogy Pattern:

Pedagogy pattern in this study is defined as the style of the teaching way. Each teacher follows a different style during the teaching process. Since recommender systems can play the role of teacher so each of the recommendation systems have different teaching style. We propose the new teaching approach for the recommender system. First of all, learner defines the question based on learner`s need. The recommendation process will start by analyzing this question. The learner's question can be about the learning of each learning topic. The request analyzing process is divided into three sub-processes:

1. To extract the prerequisites of learning topic that is entered as learner request.
2. To check the background of learner' knowledge due to current question.
3. To check the learning style of learner.

All learning topics are associated together by some predefined object properties in the ontology. The most important property is "HasPrerequisite".

This property determines which learning topics are the prerequisite for other learning topics. This relationship is provided by some expert people in the learning domain.

Checking the background knowledge has a certain condition. The first entrance of the learner has been differentiated with the next entrance. This occurs on the grounds that the system does not have any information about the learner knowledge in the first login, so the system should evaluate the learner knowledge. This process performs according to an algorithm that is not mentioned in this study. Applying this algorithm, the knowledge background of the learner based on learner request store in the ontology then the system can use them for the next entrance. We present the process of this section in Fig.4.

Based on the result of the process1, system has some learning topics as prerequisites for the current request. Furthermore, according to the second process, the level of learner knowledge in each learning topic has been set. Now the system will remove prerequisites in which have the medium or master level of knowledge and keep the learning topic that learner is weak in. Finally, the learner should learn these learning materials to reach the given request. In this part, the process with number three, play the important role in order to obtain the learning style from the ontology and show the recommended content, based on the favorite learning style for a current learner. Furthermore, the learner can request any activity from the system through the user interface such as example, quiz and exercise. Working with the ontology and looking for any content performs with the semantic search. When the learner asks some examples or any activities from the system, the predefined semantic search will run and subsequently the learner can see the result.

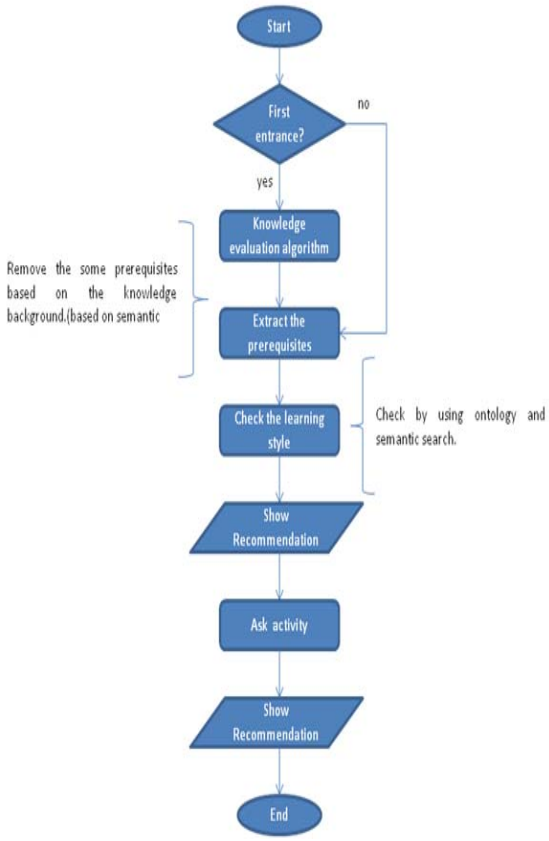

Fig. 4: Flowchart of proposed pedagogy.

User Interface:

User interface plays an important role in this system because the learner can interact with the system through the user interface. The user interface provides some facilities for a learner to work with the system. Learner can change the information in the learner profile; ask any request from the system, order any activities from the system with any favorite learning style. When the learner selects the learning activity and asks the learning style for the activity, then the system runs the predefined semantic query on the ontology and returns the desired output (See the Fig. 5).

The most recognized semantic query is SPARQL (Prud'Hommeaux and Seaborne 2006). We should define a query to run each of the semantic processes in the system. We show the sample of query to return the learning style and learning activity based on learner selection as Fig 6:

The output of this query is some text activities for the "WebPage" learning topic. In this example "?y" means the result, "Webpage" show the current learning topic and "HasActivity" refers to object property that makes the relationship between learning content and the learning activities.

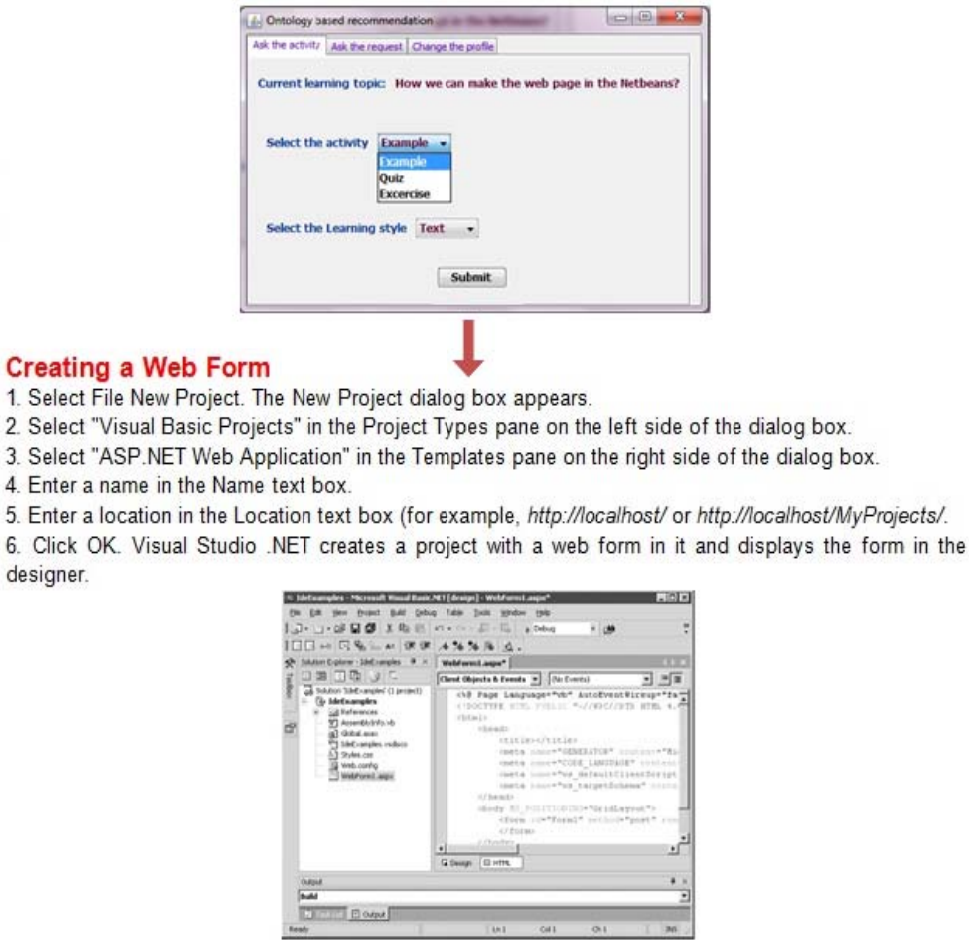

Fig. 5: The scheme of user interface.

```
PREFIX VB:<http://Learning#>
SELECT ?y
WHERE {
Learning:WebPage    Learning:HasActivity      ?y.
            }
```

Fig. 6: Flowchart of proposed pedagogy.

Conclusion:

Due to the comparison among recommendation techniques in the e-learning domain, which is shown in table 1, we realized that the knowledge based recommender systems is more suitable for learning domain. The knowledge based recommendation needs a widespread knowledge about the learner and the learning domain. Our recommender system is based on ontology and recommends some learning material to a learner based on the learner's request. In this system, we develop the pedagogy pattern for learning system. The recommendation system performs based on this pedagogy. To extract the prerequisites, check the background of learner' knowledge and check the learning styles of the learner are sub-process in the pedagogy pattern. The developed user interface for this system makes the interaction between learner and system easier. Learners can modify their own profile, ask any learning activities and learn any learning topic by using this user interface. All learners' requests from the system lead to the running of predefined query. This query is defined by SPARQL and run in protégé 3.4.3.

Future Works:

Considering the importance of education systems as well as the e-learning recommender systems, we consider to add some more criteria to filter the recommendation. These criteria can be the favorite learning time for the learner. Therefore, learner can select the suitable learning time from the system afterwards so that the system recommends based on that certain time.

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