A Use Case Diagrams Ontology That Can Be Used as Common Reference for Software Engineering Education

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Abstract- In recent years, several studies have shown that ontologies and technologies based on ontologies can be used to bridge the worlds of practice and education. These approaches are considered very important fields of educational technology research. In this paper, we present a domain ontology concerning Use Case Diagrams (UCD) that we developed in an attempt to provide common reference for the creators of training / educational material in a Software Engineering course. For its construction we used an approach that combines certain existing methodologies and includes the collaboration of expert software engineers, who eventually evaluated positively the ontology to cover adequately all aspects of UCD design. The proposed ontology can be used either as part of an experimental e-learning application for the description and management of competencies, learning goals and learning material about the cognitive field of Object-Oriented Analysis, or as a design reference for UCD terms and properties. In this paper we shortly describe our ontology and the methodology we used to create it.

Keywords- Ontologies; Use Case Diagrams; Software Engineering; Education

I. INTRODUCTION

In recent years, several studies have shown that ontologies and technologies based on ontologies can be used to bridge the worlds of practice and education. These approaches are considered very important fields of educational technology research.

An ontology is a formal specification of a field of knowledge [5]. It provides the basic concepts of the field described, their relationships, and the terminology used to refer to the concepts and relationships and can be used as a common framework for communication between people, systems and organizations, facilitating the sharing, interoperability and resource reuse [16]. Each ontology represents a specific and subjective view of a domain, and the construction of a certain ontology is done to address certain needs.

In the last years, there have been created many ontologies for use in modern e-learning applications, which can be grouped into a) ontologies which describe domain knowledge (educational domain knowledge ontologies) as those mentioned in Sosnovsky & Gavrilova (2006), Bianchi et al. (2009), Grandbastien & Huyinh Kim Bang (2008), Albano et al. (2007), Paquette (2007), Van Assche (2007), etc., b) ontologies for describing competencies of learners and learning objectives, as those mentioned in the work of Sicilia (2005), Paquette (2007), Van Assche (2007) and Schmidt & Kunzmann (2007), c) ontologies to describe learning processes, activities, teaching scripts, modules, didactic paths, etc. (Rius et al., 2008; Knight et al., 2006), d) ontologies for describing Learning Management Systems (Shrimathi, 2010) and e) ontologies for educational metadata as that mentioned by Bianchi et al. (2009).

Most ontology based applications used in e-learning systems include some domain ontology. One very common use of such an ontology concerns the semantic annotation of learning objects, educational activities and generally of digital learning resources, so as to facilitate the sharing and reuse of them. Domain ontologies can also be used for the organization, the visualization and the navigation in the field of knowledge [3]. The domain ontologies used in several applications vary, regarding detail and educational focus, according to the requirements of the application.

In this work we present an educational domain knowledge ontology for the

description of Use Case Diagrams (UCD), which is part of the domain of Object Oriented Analysis. In the rest of the paper, we shortly describe our ontology, the methodology we used to create it and we present some of its possibilities, through its use as part of an experimental e-learning application.

II. METHODOLOGY FOR THE CREATION OF THE UCD ONTOLOGY

There are several methodologies concerning the construction of ontologies, which can be distinguished in collaborative and non-collaborative, application-dependent and application-independent, manual, semi - automatic and automatic, etc. The methodology we followed, is a combination of activities of existing methodologies, namely those of Uschold & King (1995), Holsapple & Joshi (2002) and Noy & McGuinness, (2001). More specifically, as a basic framework for the creation of our ontology we used the four phases proposed by Holsapple & Joshi (2002) (a) Preparation, b) Construction of an initial ontology, c) Iterative improvement and d) Application). The first phase includes specifying the purpose for which the ontology is constructed, the knowledge domain to be described, the expected users, and the design criteria and evaluation standards. In the second stage an initial ontology is constructed. In the third stage, the initial ontology is collaboratively evaluated and improved, with the assistance of experts in the field. The fourth stage involves the application of ontology and its possible improvement. However, as the second stage is considered very general, we used the methodologies of Uschold and King (1995) and that of Noy & McGuinness, (2001) for the construction of the initial version of the ontology.

As mentioned before, the methodology we used to create the UCD ontology is based on an existing collaborative methodology that engages a group of experts in the creation of the final version of the ontology. In our case, the group of experts consisted of six Professors – Consultants of the Hellenic Open University teaching the course "Software Engineering", which includes the topics of UML Language and Use Case Diagrams. The choice to use a collaborative methodology as well our choice of experts, aim to the creation of an ontology that reflects and combines different views of the field of use case diagrams, hoping that this will foster its future acceptance and use.

Below we describe the construction of the UCD ontology.

A. *Preparation*

In this phase we defined the specifications of the ontology, as described below.

Use: The ontology will be used for classification and recall of learning resources. Also, the ontology will answer basic queries concerning the cognitive field. **Domain:** Use case diagrams. **Users**: The ontology will be used directly by designers of the e-learning applications and indirectly by learners and educators who will use these applications. **Evaluation standards:** Accuracy, completeness and consistency in relation to the scope described, and given the impending educational use.

B. *Construction of the initial ontology*

To create the initial version of the UCD ontology we used the tasks proposed in the methodology proposed by Uschold and King (1995) (ontology capture, ontology coding, integration of existing ontologies). Initially, we investigated for existing ontologies with the help of search engines like Swoogle and searched in ontology repositories, but we did not find any ontology for the description of the field of UCDs and thus we created the ontology from scratch. For the selection of concepts and relations of the ontology and given the imminent use of ontology in applications for Higher Education, we studied relevant training materials (presentations, notes, lesson plans) from the Hellenic Open University and other universities, as well as books on Object-Oriented Analysis and Use Case Diagrams and recorded the basic concepts mentioned in this material and the relationships between these concepts. For ontology coding we defined classes and their hierarchy, properties and individuals, according to the methodology proposed by Noy & McGuinness, (2001). To code the ontology we used the Protégé platform and as the ontology representation language we used OWL.

C. *Iterative improvement*

The procedure followed for the evaluation and iterative improvement of the ontology was completed in four stages. The evaluation criteria we set initially (accuracy, completeness, consistency in relation to the scope and given the imminent use of ontology) were incorporated in this process. As mentioned before, this phase is based on evaluation of the ontology by a group of experts, in our case six Professors of the Hellenic Open University.

Stage 1: Each expert was sent an evaluation form, which included the analytical presentation of the initial ontology and they were asked to freely make additions, changes and comments of the field. **Stage 2:** A new version of the UCD ontology was built, based on the changes, the additions and the comments of the experts. **Stage 3:** The new version of the UCD ontology was re-evaluated with the use of a new evaluation form that was completed during an organized meeting with the experts. **Stage 4:** The final version of the UCD ontology was build, using the results of the evaluation of stage 3.

D. *Application*

We used this ontology as part of an experimental e-learning application which we tested using the Protégé platform.

E. *Evaluation of the methodology*

The procedure we followed to construct the UCD ontology, was a time consuming procedure, even though the domain we described was relatively limited. That was partly because of the large number of the experts involved and the consequent difficulty to coordinate them during the evaluation stages. This makes the specific approach ineffective to describe larger topics or to build large numbers of ontologies.

III. THE UCD ONTOLOGY

Below we shortly describe the UCD ontology.

In figure 1 one can see the hierarchy of classes of our ontology. In the first level of the hierarchy we encounter (among others) the class UML diagram and the class Use case diagram element. The class UML diagram is father class of the class Use_case_diagram, which is the basic concept of our ontology. The class Use_case_diagram_element contains the elements that one can see in a use case diagram. More specifically it includes the classes Actor, Relationship and Use case. The class Actor is further analyzed in human actor and Automated system actor, who in turn is divided into Software system and Hardware device actor.

The class Relationship is further analyzed in the classes Actors_relationship (the relationship between actors), Usecase_actor_relationship (the relationship between actors and use cases) and Use_cases relationship (the relationship between use case).

Our ontology includes other concepts which are not elements of use case diagrams, but are associated with them, as for example the concepts System, Functional Requirement, System Environment, System Behavior, Extension Point, UseCaseDiagram Use, System Boundary, etc. Apart of the key concepts that relate directly to the field of Use Case Diagrams, we have also included in the ontology concepts from a broader conceptual framework, as subclasses of the class Other_UCD_domain_related_concepts.

Examples of such concepts are the classes Modelling Language, Software development, Software development approach, etc. Due to lack of space these elements are not depicted in the hierarchy of figure 1.

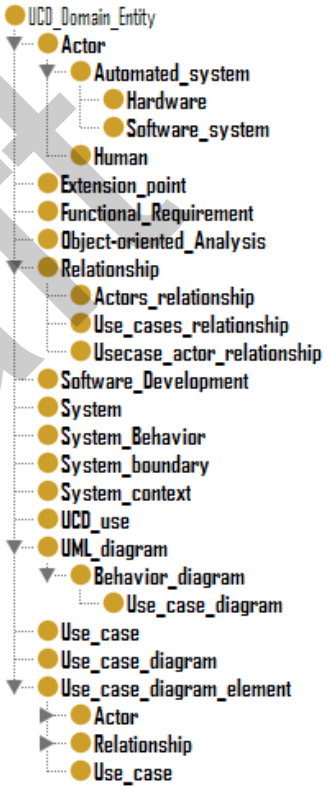

Figure 1. The class hierarchy of the UCD ontology

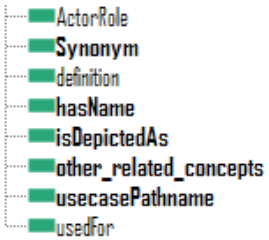

Figure 2. The data properties of the UCD ontology

In figures 2 and 3 one can see the properties of the classes of the ontology. These properties are divided in data and object properties. Data properties accept as values simple data (literals) whereas object properties

accept as values individuals of other classes and constitute the cognitive relations between the classes of the ontology. Finally, in figure 4 we see a Use Case Diagram (individual of the class Use_case_diagram) for a restaurant that was created using the ontology in order to describe the actual use case diagram depicted in figure 5.

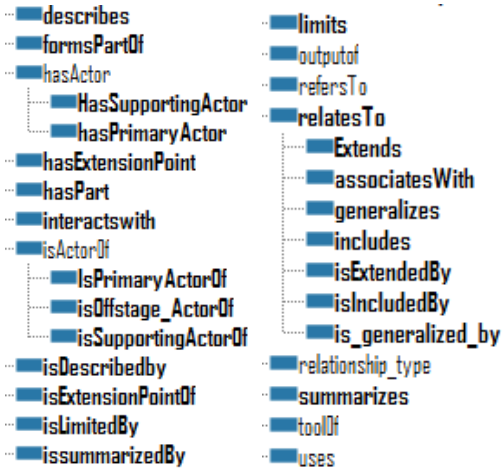

Figure 3. The object properties of the UCD ontology

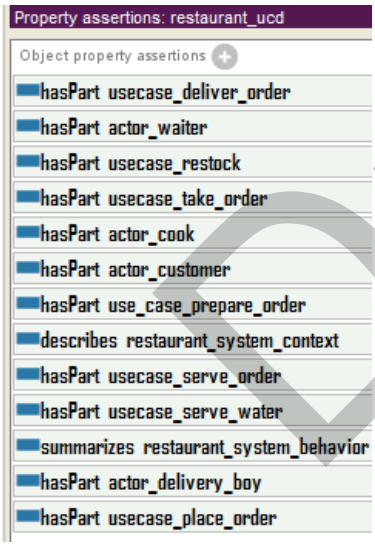

Figure 4. An individual of the class Use_case_diagram to describe a use case diagram for a "Restaurant"

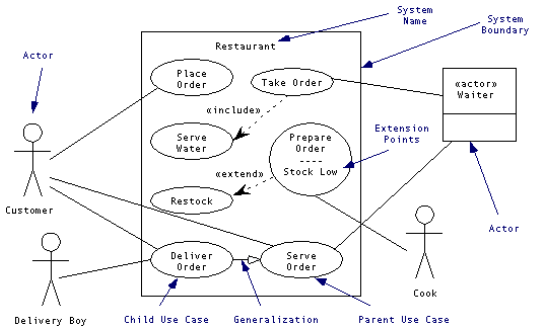

Figure 5. The actual use case diagram "Restaurant"

IV. USAGE SCENARIOS OF THE UCD ONTOLOGY

The proposed ontology can be used either as part of an experimental e-learning application for the description and management of competencies, learning goals and learning material about the cognitive field of Object-Oriented Analysis, or as a design reference for UCD terms and properties.

More specifically, the ontology can provide:

a. Answers to queries about the domain of the Use Case Diagrams in general

For example if the query "What are the elements that compose a use case diagram?" is posed, the ontology will return three elements (use case, actor, relationship). In figure 6 we can see the query and the answer of the ontology, in the Protégé environment.

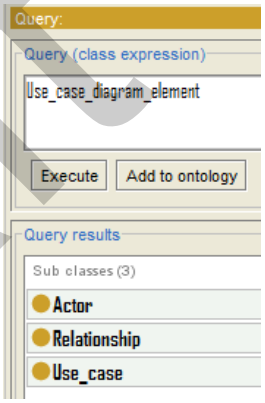

Figure 6. Querying the UCD ontology

b. Answers to queries about a specific Use Case Diagram

For example we could pose the query "Which are the use cases of the use case diagram "restaurant"?". In figure 7 we can see the query and the answer of the ontology, in the Protégé environment. As we can see the ontology returns six use cases as an answer to the query.

c. Annotation of learning objects and learning goals

We used the vocabulary provided by the UCD ontology to connect learning goals and learning objects to the concepts of the ontology. This was done by using the concepts of the ontology as values for the learning objects' and the learning goals' metadata, within an experimental e-learning application we created with the Protégé platform. Additionally, the cognitive relations between the concepts (classes) of the ontology, combined with rules we have added and

automated reasoning allow for the dynamic enrichment of the connections. These connections can then be used to answer the queries.

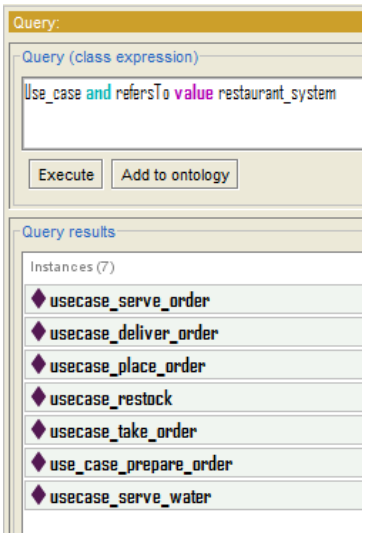

Figure 7. Querying the UCD ontology

In figures 8 and 9 we can see examples of semantic annotation of a learning object and a learning goal with the use of the UCD ontology, in the protégé environment.

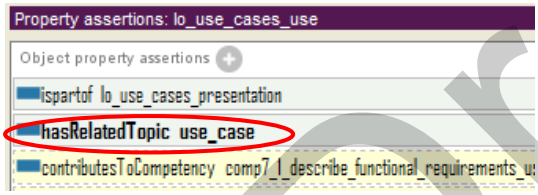

Figure 8. The learning object lo_ use_cases_usesis connected to the topic use_case

The semantic annotation of learning resources using concepts that come from ontologies is considered a practice that enhances the accuracy of queries.

d. Organization, visualization and navigation in the domain of knowledge

The ontology we developed can be used as an index to the knowledge related to Use Case Diagrams. Users can pose queries about specific UCD terms and the ontology can return their relationship with other UCD terms, as well as pointers to related learning objects. Finally, with the help of Protégé plugins, the domain concepts of UCD can be visualized in a comprehensive way.

e. Description of use case diagrams

The UCD ontology, as already mentioned, can be used to describe any use case diagram. Above we have seen an example of the description of a UCD concerning a system called Restaurant, using the Protégé platform. This feature can be used to help students practice the creation of UCD, either using the Protégé platform or alternative interfaces that ask the student to fill in information about a specific use case diagram. For example the student may be asked to construct a UCD by defining **the elements** of a specific use case diagram, which according to the knowledge about UCD included in the ontology are the use cases, the actors and their relations.

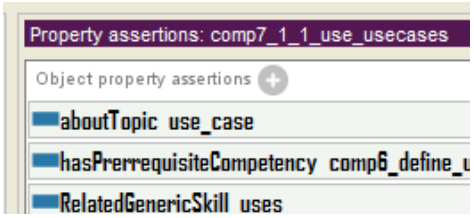

Figure 9. The learning goal comp7_1_1_use _use cases is connected to the topic use_case through the relationship "aboutTopic"

V. ONTOLOGY EVALUATION

As mentioned before, the Use Case Diagram ontology was used as part of an ontocentric application for the management of learning goals and learning objects concerning the field of Use Case Diagrams. This experimental use showed that it fulfils the standards set in the first stage of its creation, as it can help to the semantic annotation and retrieval of learning resources, such as learning objects and learning goals, and it can answer queries about the field of Use Case Diagrams.

Through the use of the ontology we also came to some conclusions concerning the semantic detail of the ontology. More specifically, our ontology includes detailed semantic relations between the concepts of the Use Case Diagram field and therefore can handle detailed queries concerning the field. These relations are general in that they have no educational perspective and are used to fully describe the field. However, the experimental use of the ontology showed that most of the existing relations were not used in our queries, which leads us to think that maybe such semantic relations are not so essential in applications like ours. On the contrary queries concerning pedagogical relations between concepts of the field were left unanswered, revealing the need for such relations to be added. Example of such relations might be that of prerequisite concept, wider concept, narrower concept etc. For example if a concept is considered part of another concept (using the appropriate relation) then this could help (by the use of an appropriate query) to choose the concept we want to present first to the learner according to the approach we want to use.

Considering all the above, in cases that a massive construction of educational domain ontologies is intended and in order to affectively use resources, in our opinion, the emphasis should be given to the inclusion of relations between concepts that can be used pedagogically instead of general semantic relations, which could be added later.

VI. CONCLUSIONS AND FUTURE WORK

Through the experimental use of the Use Case Diagram ontology, as part of an e-learning application, we came to the conclusion that it fulfils the requirements that he had defined, as it can help to the semantic annotation and retrieval of learning resources, such as learning objects and learning goals, and it can answer queries about the field of Use Case Diagrams. There were also some conclusions drawn concerning the semantic detail of the ontology as well as the methodology to create it

Taking the above under consideration, in the near future we plan to extend our work and construct new ontologies and to use them in real conditions as a part of e-learning applications to support courses in Higher Education.

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