Ontological Modelling for Intelligent e-Learning

Niki Aggelopoulou[1], Christos Pierrakeas[1,2], Alexander Artikis[3], Dimitris Kalles[4]
[1]Educational Content, Methodology and Technology Laboratory (e-CoMeT Lab), Hellenic Open University (HOU)
[2]Dept. of Business Administration, Technological Educational Institute (TEI) of Western Greece
[3]Institute of Informatics & Telecommunications, NCSR Demokritos.
[4]School of Science and Technology, Hellenic Open University (HOU)
{naggelop, pierrakeas, kalles}@eap.gr, a.artikis@iit.demokritos

***Abstract*— The evolution of scientific research as well as the development of the relevant technologies and methodologies in the area of distance learning fall within the scope of the objectives the Hellenic Open University whose mission is to provide distance education at both undergraduate and postgraduate level. To develop intelligent e-learning applications, we capture the semantics of the Computer Science module concepts with the use of ontologies, by following a specific methodology to build domain knowledge ontologies. We illustrate our approach by presenting the construction of the ontologies of the Artificial Intelligence & Expert Systems module.**

Keywords- Lifelong learnig, ontologies, artificial intelligence – applications, distance education

I. INTRODUCTION

For the Hellenic Open University (HOU), a web-based educational system has been playing an important role in the improvement of the quality of services, such as the quality of educational material, pedagogical approaches in e-learning environments and technological frameworks. The main goal is to use resources available on the Web through standards-based technologies in order to accomplish anytime, anywhere, and anybody learning [1].

Generating and populating ontologies are very active fields. Many projects use machine learning techniques for automated ontology construction (KnowItAll [2], OntoLearn [3]). Our approach is to use concept maps to generate ontologies, as exemplified by [3]. Some approaches for collaborative ontology development have been proposed by [4], [5], [6]. In these approaches, as well as in the proposed methodology, substantial cooperation between domain experts and ontology experts is required.

We present an approach for building ontologies for e-learning. . Ontologies provide the necessary armature around which knowledge bases should be built and set grounds for developing reusable Web-contents and applications. Education should pay close attention and accompanied with domain theories, like ontologies. Ontologies allow for the possibility to develop a more dynamic learning environment with better access to specific learning objects [7]. In addition to presenting the main concepts of the module in a structured way, students may derive facts about the module that are not explicitly modeled in the knowledge base. As an illustrative example, we use the Artificial Intelligence & Expert Systems module.

II. STRUCTURE & METHODOLOGY FOR ONTOLOGIES

We now elaborate on our methodology by demonstrating how it was applied to the Computer Science module concepts. We present an indicative case study that illustrates the application of the methodology. The aim is to demonstrate that the proposed methodology can be realized for the representation of a cognitive domain in order to be used in the context of an educational system such as that of the Hellenic Open University [8].

Artificial Intelligence & Expert Systems is a senior undergraduate module of Computer Science, where students have already advanced skills in Information Technology. Additionally, this particular unit has a relatively long tradition of utilizing a variety of asynchronous and synchronous e-learning technologies to support tutoring. The subjects covered in this module are**:** (1) Expert Systems, (2) Neural Networks, and (3) Genetic Algorithms. Tutors and learners participate in five face-to-face sessions, during an academic year.

We now present how we built the ontological model for the Artificial Intelligence & Expert Systems module, by following our ontology building methodology.

A. A Methodology for Building Ontologies

The development of an ontology requires collaboration between ontology experts and domain experts. Ontology expert is a person with special knowledge or skills in the development of building ontologies and domain expert is a person with special knowledge or skills in the domain area. We adopt the following five phases [8] for building our domain ontology:

1. Specification: Domain experts identify the problem and opportunity knowledge.

Specifically, domain experts:

- Analyze the educational problem.
- Determine the field of knowledge.
- Determine potential users of the ontology.
- Define usage scenarios.

  Ontology experts set competency questions and verify the procedure for determining requirements for the development of an ontology.

2. Conceptualization: The module tutors are divided into two teams. The first teams, using graphics tools, develop a map for the knowledge domain, by recording the fundamental concepts of the field, the hierarchy of concepts,

Draft

relationships between them and the properties of the concepts and relationships. The second team comments on the produced map in order to verify the proper recording of the concepts and their interrelationships. For the first part of the course, this iterative process lead to 6 conceptual maps with 107 main concepts and 13 relations.

Figure 1 shows a fragment of the map expressing Frame Systems. The conceptual map depicts 32 identified key relevant concepts (see the nodes of Fig. 1) and 5 relations (see the edges of Fig. 1; for example, "Description Logics *defines* Associative Network"). Figure 1 includes two common relations, *defines* and *represents*, denoting respectively meronomies and taxonomies. Each produced conceptual map is accompanied by tables explaining each relation and concept, including the properties that each relation satisfies, such as transitivity.

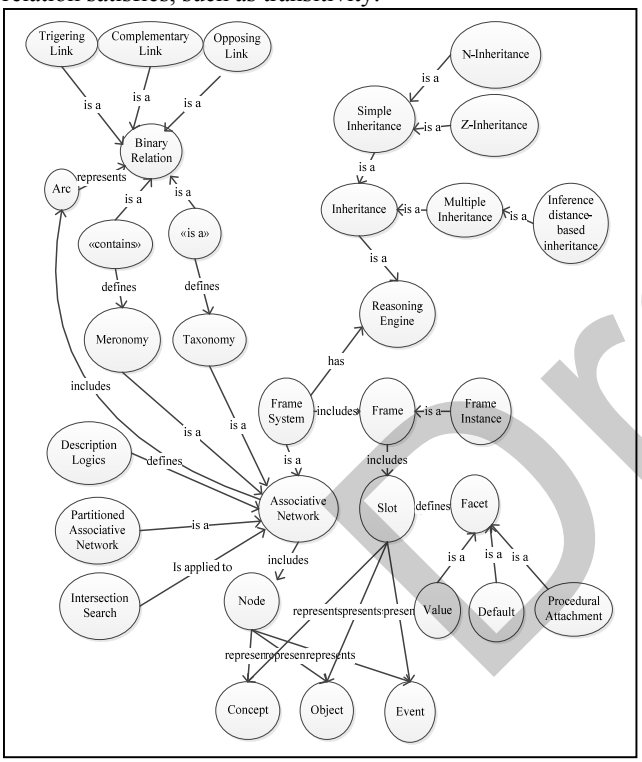

Figure 1.Part of the concept map expressing Frame Systems

3. Implementation: The purpose of this activity is the formulation of the concept model. There are several ontology development tools that implement concept model ontology in different languages. Our ontology experts utilize Protégé [9] to transform the conceptual map produced by the course tutors into a formal model by using the formal OWL language [10].

Figure 2 shows an OWL/XML/RDF syntax of relations between two classes and Figure 3 shows a part of Frame Systems concept map in Protégé. By expressing concept maps in OWL, the visual representations of the concepts of the course can be evaluated by using off-the-shelf automated reasoning tools (see the Evaluation step below).

```
<!-- http://eeyem.eap.gr/ontologies/pli31/ga1/ksa#PredicateLogic -->

<owl:Class rdf:about="http://eeyem.eap.gr/ontologies/pli31/ga1/ksa#PredicateLogic">
    <rdfs:label xml:lang="el">Κατηγορηματικήλογική</rdfs:label>
    <rdfs:label xml:lang="en">PredicateLogic</rdfs:label>
    <rdfs:subClassOf rdf:resource="http://eeyem.eap.gr/ontologies/pli31/ga1/ksa#KnowledgeRepresentationLanguage"/>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty rdf:resource="http://eeyem.eap.gr/ontologies/pli31/ga1/ksa#has"/>
            <owl:someValuesFrom rdf:resource="http://eeyem.eap.gr/ontologies/pli31/ga1/ksa#Semantics"/>
        </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty rdf:resource="http://eeyem.eap.gr/ontologies/pli31/ga1/ksa#has"/>
            <owl:someValuesFrom rdf:resource="http://eeyem.eap.gr/ontologies/pli31/ga1/ksa#Syntax"/>
        </owl:Restriction>
    </rdfs:subClassOf>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty rdf:resource="http://eeyem.eap.gr/ontologies/pli31/ga1/ksa#has"/>
            <owl:someValuesFrom rdf:resource="http://eeyem.eap.gr/ontologies/pli31/ga1/ksa#InferenceMechanism"/>
        </owl:Restriction>
    </rdfs:subClassOf>
</owl:Class>
```

Figure 2.Part of the OWL/XML/RDF syntax of the implement ontology

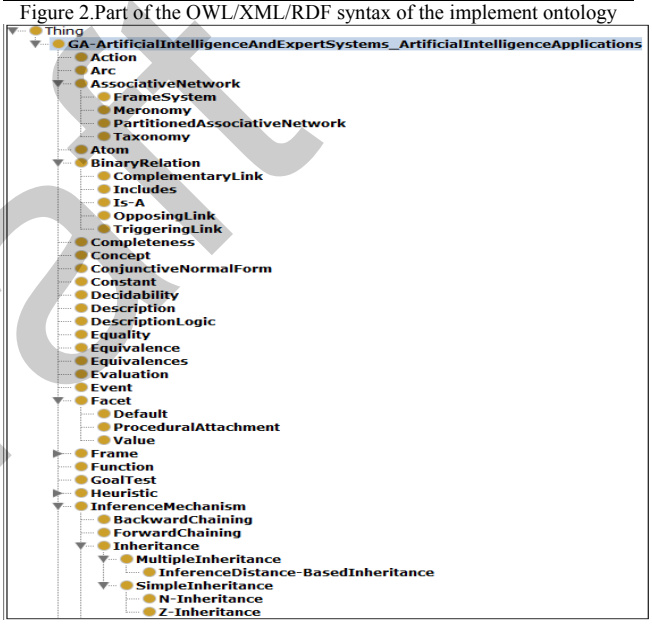

Figure 3.Part of the class hierarchy of the implemented ontology about the Artificial Intelligence and Expert Systems

4. Evaluation: Given the formal representation of the conceptual maps, it is now possible to evaluate the characterization of the course. For example, ontology experts may use software tools, like Pellet (http://clarkparsia.com/pellet/) or HermiT (http://hermit-reasoner.com/), to check whether the ontology is "meaningful", that is, determine whether each concept has instances. Moreover, it may be determined whether the ontology is "minimally redundant", that is, that there are no unintended synonyms, and that is "richly axiomatised", that is, that is contains sufficiently detailed descriptions. The ontology may be evaluated by ontology experts, domain experts, as well as students themselves. This is particularly helpful for understanding the material of a course.

Draft

5. *Documentation and maintenance*: To support future reference and maintenance, the concepts, relations and properties of the produced ontologies were appropriately documented.

III. Summary and Further Work

We illustrated how an ontology engineering process may be used for the development of visual and formal characterizations of a course. The phases of our methodology contains the writing of learning outcomes from domain experts, generation of concept maps, list of concepts from the domain experts, the writing of relations between concepts, list of properties of relations and documentation of concept maps with Web Protégé using the OWL language.

Students may use a range of freely available software tools to interact with the produced characterizations and therefore better understand the material of the course.

This work is part of an ongoing, ambitious effort to construct an ontology for the whole of the distance learning courses offered by the Hellenic Open University (http://ontologies.eap.gr/webprotege/).We expect that (parts of) this ontology may be customized with a small effort to serve the needs of a wide range of distance learning institutions.

The manual development of ontologies for (distance learning) modules is a time-consuming process. For instance, for the Artificial Intelligence & Expert Systems course five tutors had to invest a significant amount of time in order to produce the corresponding ontologies. To address this issue, we aim to investigate the use of machine learning techniques for constructing and refining in automated way ontologies from the syllabus of a course (books, slides, etc). This is particularly helpful in rapidly evolving fields such as Computer Science.

Acknowledgment

This research described in this paper has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) (Funding Program: "HOU").

References

[1] I. Bittencourt, I., S. Isotani, E. Costa, & R. Mizoguchi, (2008). Research directions on Semantic Web and education. *Interdisciplinary Studies in Computer Science*, *19*(1), 60-67.

[2] O. Etzioni, M. Cafarella, M.,D. Downey, S. Kok, A. M. Popescu, T. Shaked, S. Soderland, D. S. Weld & A. Yates (2004, May). Web-scale information extraction in knowitall:(preliminary results). In *Proceedings of the 13th international conference on World Wide Web* (pp. 100-110). ACM.

[3] R. Navigli, & P. Velardi (2004). Learning domain ontologies from document warehouses and dedicated web sites. *Computational Linguistics*, *30*(2), 151-179.

[4] N. F. Noy, & D. L. McGuinness, (2001). Ontology development 101: A guide to creating your first ontology.

[5] Knublauch, H., Fergerson, R. W., Noy, N. F., & Musen, M. A. (2004). The Protégé OWL plugin: An open development environment for semantic web applications. In *The Semantic Web–ISWC 2004* (pp. 229-243). Springer Berlin Heidelberg. (protégé).

[6] McGuinness, D. L., & Van Harmelen, F. (2004). OWL web ontology language overview. *W3C recommendation*, *10*(2004-03), 10.

[7] A. Kouneli, G. Solomou, C. Pierrakeas, & A. Kameas, (2012). Modeling the knowledge domain of the java programming language as an ontology. In*Advances in Web-Based Learning-ICWL 2012* (pp. 152-159). Springer Berlin Heidelberg.

[8] A. Kalou, G. Solomou, C. Pierrakeas& A. Kameas (2012, July). An Ontology Model for Building, Classifying and Using Learning Outcomes. In*Advanced Learning Technologies (ICALT), 2012 IEEE 12th International Conference on* (pp. 61-65). IEEE.

[9] M. Grandbastien, F. Azouaou, C. Desmoulins, R. Faerber, D. Leclet & C. Ouénu-Joiron (2007, July). Sharing an ontology in Education: Lessons learnt from the OURAL project.

[10] L. N. Cassel, G. Davies, W. Fone, A. Hacquebard, J. Impagliazzo, R. LeBlanc... & M. Pedrona (2007, December). The computing ontology: application in education. In *ACM SIGCSE Bulletin* (Vol. 39, No. 4, pp. 171-183). ACM.

[11] A. Ameen, K. U. R. Khan & B. P. Rani (2012, July). Creation of Ontology in Education Domain. In *Technology for Education (T4E), 2012 IEEE Fourth International Conference on* (pp. 237-238). IEEE.

[12] O. Fragou, I. Hatzilygeroudis, D. Kalles, & S. Likothanassis (2013, May). Implementing participatory design for developing a constructivist e-learning activity. In *EAEEIE Annual Conference (EAEEIE), 2013 Proceedings of the 24th* (pp. 157-162). IEEE.

Draft