Knowledge-Based Systems 22 (2009) 292–301

Contents lists available at ScienceDirect

Knowledge-Based Systems

journal homepage: www.elsevier.com/locate/knosys

Advanced ontology management system for personalised e-Learning

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ARTICLE INFO

Article history:
Available online 29 January 2009

Keywords:
Knowledge representation
Knowledge modeling
Knowledge maintenance
Knowledge reuse
Distance learning

ABSTRACT

The use of ontologies to model the knowledge of specific domains represents a key aspect for the integration of information coming from different sources, for supporting collaboration within virtual communities, for improving information retrieval, and more generally, it is important for reasoning on available knowledge. In the e-Learning field, ontologies can be used to model educational domains and to build, organize and update specific learning resources (i.e. learning objects, learner profiles, learning paths, etc.). One of the main problems of educational domains modeling is the lacking of expertise in the knowledge engineering field by the e-Learning actors. This paper presents an integrated approach to manage the life-cycle of ontologies, used to define personalised e-Learning experiences supporting blended learning activities, without any specific expertise in knowledge engineering.

1. Introduction

Knowledge modeling represents a significant activity, that is particularly difficult to perform due to its complexity. Nowadays, in computer and information science, knowledge representation, reuse and sharing are facilitated by the explicit use of ontologies. In [1], an ontology is an "explicit specification of a conceptualization". The term is borrowed from philosophy, where an ontology is a systematic account of existence. For artificial intelligence systems, what exists is what can be represented. Pragmatically, a common ontology defines the vocabulary with which queries and assertions are exchanged among agents. Agents can be both software agents and/or human agents.

Recently, we have seen an explosion of interest in ontologies as artifacts to represent human knowledge and as critical components in knowledge management, Semantic Web, business-to-business applications, and several other application's areas. Also in the e-Learning area there is a newly great interest in the exploitation of knowledge technologies.

Most of the current learning technology specifications are based on educational metadata: IEEE LOM [2] and ADL SCORM [3], for example, are the standards proposed for describing (and re-using) chunks of learning content annotated through metadata. Metadata is supposed to enable the reuse of these chunks by detailing the conditions of their initial deployment. However, the authors of [5,4] pointed out that such an approach failed to elicit cognitive behaviours and therefore the actual reuse. We believe that the use of ontologies in e-Learning can overcome these drawbacks.

In [6], some benefits from applying ontologies to e-Learning are well explained. The authors asserts that an ontology, formally and declaratively, represents the terminology of a specific domain, defining its essential knowledge. Ontologies are used to support semantic search, making possible to query multiple repositories and discover associations, between learning objects, that are not directly understandable. This is impossible or very complex with simple keyword- or metadata-based search supported by the current standards.

In this paper, we describe methodologies and techniques for supporting a community of experts in modeling educational domains (e.g. mathematics domain, English literature domain, etc.) through the management of convenient educational ontologies namely e-Learning ontologies and exploiting them in order to define and execute personalised e-Learning experiences within blended learning activities.

Blended learning is considered a learning approach defined by the effective combination of different modes of delivery and models of teaching and styles of learning [7]. Personalised e-Learning experiences represent a convenient way to complement face-to-face sessions within a whole blended learning experience. A personalised e-Learning experience could be very important when used for assessing the knowledge acquired by each individual learner during a face-to-face learning session and offering, in case of negative results, personalised remedial works able to fill the identified knowledge gaps with learning paths that best fits the needs, the cognitive state and the learning preferences of each individual learner. In the event that the personalised e-Learning experience can be built, packaged and deployed with an automatic process,

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doi:10.1016/j.knosys.2009.01.006

then the whole blended learning activity can become more effective and efficient.

Anyway, knowledge modeling through ontologies is a subjective process essentially, whereby different people that model the same domain, produce, in most cases, different ontologies depending on their sensitivity, their background, etc. In a distributed environment, such as communities of experts, harmonizing the work of all parties can be a relevant activity, in order to enrich and improve the available knowledge bases. For these reasons, we define a set of convenient techniques for versioning and harmonization of e-Learning ontologies. The current methodologies, developed in the e-Learning domain do not allow the integrated management of knowledge that meets all the requirements above mentioned. The proposed approach is conceived to allow the collaborative and shared management of the available knowledge, without having any specific proficiency in knowledge engineering taking into account aspects like ontology harmonization and ontology versioning. In particular, we focus on the collaboration approaches for ontology building and maintenance. More precisely, the most relevant contributions of our work are:

- The definition of convenient models to represent and exploit e-Learning ontologies in order to build and deliver personalised e-Learning experiences taking into account different cognitive states and learning preferences of learners.
- The definition of a set of tools for representing and managing e-Learning ontologies, within a community of teachers, tutors, mentors, etc. (without any expertise of knowledge engineering) through the features of an integrated framework;

The paper is organized as follows: Section 2 presents some related works; in Section 3 we describe our approach to build personalised e-Learning experiences through the use of ontologies; in Section 4 we describe the algorithms and the techniques to manage the life-cycle of e-Learning ontologies through our advanced ontology management system; in Section 5 a case study of an AOMS collaborative ontology construction session is presented. Finally, Section 6 concludes the work.

2. Background and related works

The importance of the knowledge modeling, to effectively organize the available e-Learning resources according to the particular needs of both teachers and students, has been advocated by many authors. Domain knowledge modeling is the basis for constructing domain concept structures and managing related course materials. Brase and Nejdl [8] have showed the increasing importance, in the e-Learning field, of knowledge modeling through metadata definition standards such as the learning objects metadata (LOM). However, these standards introduce the problem of incompatibility between disparate and heterogeneous metadata descriptions across domains, which might be avoided by using ontology as a conceptual backbone in an e-Learning scenario [9,6].

Various researchers (see for example [12]) have observed that e-Learning, even when properly designed and meta-tagged, will not realize full re-usability without the full benefits from the Semantic Web [10]. A number of systems have been developed to manage learning resources through the use of Semantic Web technologies.

A first example of these systems is the Edutella project [11]. It is an open source project based on RDF metadata, for P2P network users interested in the exchange of learning resources.

KGTutor, a knowledge grid based intelligent tutoring system [15], proposes a model for the construction of intelligent tutoring experiences in a more pleasant and effective way. The KGTutor is designed to provide better support to student centered distributed learning. Students' characteristics, such as previous knowledge and learning styles, are used to choose, organize, and deliver the learning materials to individual students. During the learning progress, the system can also provide objective evaluations and customized suggestions for each student according to their learning performance.

Another representative system that uses Semantic Web techniques in an e-Learning environment is the Courseware WatchDog [14]. It is a module of the larger project PADLR (personalised access to distributed learning repositories) [13] based on a peer-to-peer approach to support personalised access to e-Learning resource. The purpose of this framework was the creation of a software architecture helping teaching staff and students in the search and management of learning objects. WatchDog is completely ontology-based and uses clustering techniques to create personalised 'views' of the learning objects. Moreover, it has some techniques for the management of the evolution of ontologies related to the educational content.

These works show that the most relevant difficulty in the knowledge modeling for e-Learning is related to the creation and maintenance of Semantic Web structures (such as ontologies) which can be exploited not only to organize learning objects and to state their inter-relationship but also to build personalised learning paths and to maintain up to date students cognitive states. In particular, in the e-Learning area, there is still a lack of methodologies and techniques that allow the effective management of ontologies in particular addressing the most actual ontology research issues such as *Ontology Versioning*, *Ontology Harmonization* and *Collaborative Ontology Construction*.

The issue of ontology versioning is related to the nature of ontologies that are not static piece of knowledge, but evolve over time. Changes in domain's concepts, adaptations to different tasks, or changes in the conceptualization require modifications of the ontology. Ontology Versioning is the management of the changes which can occur to the ontologies in their life-cycle, more precisely, it is the ability to manage ontology changes and their effects by creating and maintaining different variants of the ontology. The evolution of ontologies can cause interoperability problems, therefore it is important to track changes that may occur to the ontologies because of: (i) changes in the domain, (ii) changes in the shared conceptualizations or (iii) changes in the specifications [16,17]. Ontology Harmonization, instead, is the ability to harmonize two or more ontologies in a unique ontology in order to enrich the available knowledge base. It is strictly related to two main issues such as ontology matching [18] for the recognition of correspondences between ontologies and ontology merging [19] for the actual fusion of those ontologies. Ontology Versioning and Harmonization are still open problems in the Semantic Web area, due to the complexity of ontology management. Our approach does not want to solve all these problems, but it is focused on the definition of a set of methodology that can be used to effectively manage ontologies in the e-Learning domain. In [20], the authors present a consistent methodology for the *Collaborative Ontology Construction* articulated in four different phases: preparation, anchoring, iterative improvement and application. Furthermore, in [29] is illustrated a report about detailed interviews with members of ten different ontology engineering projects. Interviews were conducted either on the phone or in person. Analyzing the report, it emerges the lack and the request for user-friendly tools able to support collaborative ontology construction orchestrating single-user asynchronous tasks.

Usually, two main collaboration modes [22] are adopted by ontology editing tools to support collaborative ontology development. The first one is the model where everyone accesses the same version of an ontology and changes are immediately visible to