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OntoSakai: On the optimization of a Learning Management System using semantics and user profiling

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ABSTRACT

This paper proposes recommendation services and user profiling features in Learning Management Systems (LMS) by means of a semantic intelligent system combining context information and expert knowledge. LMS users' context is represented through an ontology model called OntoSakai. It consists of four ontologies parceling different areas of the learning process: competences, users' profiles, learning tools and semantic classification of the elements in an LMS. Thus, we provide a standardized common vocabulary about LMS elements and academic tasks developed within these platforms. This model also enables inference processes about the behavior of LMS users. Indeed, our system incorporates an extensible set of expert rules to offer recommendation and user profiling services. This combination of context information and expert knowledge could be easily integrated with other systems in the academic world in order to promote the interoperability between them. Specifically, in this paper we integrate our proposal into Sakai, a well-known LMS for university-level. As a result of this integration, OntoSakai is able to generate users' profiles aimed at personalizing the use of LMS tools and to recommend resources to reach the optimum benefit in both lecturing and learning. As a proof of concept, a real case often detected in online students is shown as a running scenario where the services offered by OntoSakai could help them to improve their experiences and academic results.

1. Introduction

Learning Management Systems (LMS) have consolidated themselves as a flexible and dynamic tool for university-level learning worldwide in the last years. They are defined as a working environment for supporting content management and academic processes to both on-site and online students and lecturers. The increasing use of this kind of environment is allowing for a better academic training as well as an improvement of learning quality and cost (Kurt, 2011; Maldonado, Khan, Moon, & Rho, 2011). Despite all these advantages, some studies show that there are still several challenges to face before building complete and successful LMS environments. These challenges emerge mainly due to lack of knowledge about experiences and predilections of the myriad of students and lecturers that use LMSs with different abilities, preferences and working style (Bhuasiri, Xaymoungkhoun, Zo, Rho, & Ciganek, 2012; Chen, 2009; Sun, Tsai, Finger, Chen, & Yeh, 2008). Although different types of use indicators are available in most LMSs, the absence of tools to automatically interpret such information shifts this burden of work to lecturers, who must search for any possible correlation among use indicators and students' results in a tedious and handcrafted manner.

As a result of the aforementioned studies, two aspects are highlighted as the most immediate and affordable when improving an LMS: *personalization* and *recommendation*. On the first hand, personalization in LMS is focused on the adaptation of learning resources and services according to the students' real needs (Peter, Bacon, & Dastbaz, 2010). There are different (but non-exclusive) alternatives to achieve this personalization (Nadolski et al., 2009): content adaptation, browsing-centered, customized interfaces (especially for disabled people), and device-dependent interfaces. On the other hand, an LMS should also show a proactive behavior, namely to be able to recommend contents and services both to students – in their learning process – and lecturers – in their decisions on the course management (Heinrich, Milne, & Moore, 2009; Silva, Neto, Júnior, & Carvalho Muniz, 2012). As an example, an LMS with personalization and recommendation capabilities could be very useful when a student receives poor grades in a subject. In that case, the LMS could offer personalized

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assignments to help her identify her mistakes and recommend new contents to reinforce her knowledge.

One of the main alternatives to cope with the enhancement of LMS through personalization and recommendation services is based on context modeling by means of ontologies (Nganji, Brayshaw, & Tompsett, 2011; Srimathi, 2010; Teo & Gay, 2006; Yu, Nakamura, Jang, Kajita, & Mase, 2007). They enable formal and shared descriptions of terms related to LMS, which can therefore be processed and exchanged by software applications. Moreover, they allow the extraction of implicit knowledge derived from the classification and restrictions modeled in the ontology. All in all, ontologies are essential in a scenario where the semantic information should be taken into account. As the LMS records a large volume of data and events generated by the users, the semantics of such data and events could be captured and used as input in a context-aware system integrated into any LMS.

In this paper we follow the research line based on context modeling through ontologies as a solution to offer personalization and recommendation in LMS. In particular, we first study what tools are the most frequently used in these environments and what events are usually generated by these tools. Then we define an LMS ontology based on these indicators and combine it with a profile ontology and a competence evaluation ontology from our previous work (Cantabella, Muñoz, & Caballero, 2013). As a result, we obtain a knowledge model named OntoSakai able to represent semantic information about LMS components, students' and lecturers' profiles and academic results. Based on such a model, we define several expert rules aimed to build personalization and recommendation services. As a proof of concept, we integrate our context-aware system into Sakai,[1] a well-known LMS which is currently being used in our University.

The main contributions of this paper are threefold: (i) a study about the available LMS tools and events and how they relate most frequently to each other; (ii) an ontology to represent the main LMS concepts such as resources, assignments, announcements, discussion forums, etc. and their relationships; and (iii) a context-aware system composed of a knowledge model resulting of combining the aforementioned LMS ontology with profile and competence evaluation ontologies and expert rules aimed to offer personalization and recommendation services to LMS users. In this manner, it is possible to build an expert system by combining context information and expert rules since the semantic knowledge representation and the rule-based inference process associated to it enable simulating lecturer/student decision-making. For example, classification of students as participative/inactive or to recommend a student to read a related document when doing a home assignment could be automatically performed by our system as a lecturer would do during the course. Moreover, these decisions can be justified (i.e., it is possible to obtain arguments supporting a decision) by introspecting the rule chaining process (Muñoz & Botía, 2008). These justifications could be translated into a suitable language in order to explain lecturers/students their assigned profiles or recommendations.

One of the advantages of our proposal resides in the standardization of a knowledge model to represent the available information in an LMS. Thus, this model could be reused and extended for other LMS platforms different from Sakai with little effort (Simperl, 2009). Furthermore, thanks to the ontology alignment process (Ehrig, 2006) it is possible to integrate our ontology with other ontologies employed in the educational area (e.g., as it has been already done in this paper with an ontology about education competencies) or even with ontologies in the pervasive computing or smart environments areas (e.g., to integrate the user's current location, available devices, etc.) in order to further improve recommendation services. Finally, ontologies allow for other types of reasoning apart from the one based on expert rules used in this paper. As a matter of fact, a useful type of reasoning is ontology validation, which enables detecting contradictions and unsatisfiable concepts, among others.

The rest of the paper is structured as follows: Section 2 takes Sakai as reference to study the most relevant tools and events in LMSs. Section 3 describes in detail the OntoSakai project and the ontologies involved in it. Next, Section 4 explores the use of expert rules defined on OntoSakai to enable recommendation and personalization services. An illustrative running scenario showing OntoSakai in action is shown in Section 5. Section 6 talks about the most relevant proposals related with our work. Finally, Section 7 outlines the conclusions of the paper and some ideas for future work.

2. Sakai: an example of LMS

Sakai Collaboration and Learning Environment (Sakai CLE), hereafter Sakai, is one of the most extended LMS used to support teaching and learning activities (Dagger, O'Connor, Lawless, Walsh, & Wade, 2007). It was delivered as an open source platform in the late 2003 by a consortium consisting of the Universities of Michigan, Indiana and Stanford and the Massachusetts Institute of Technology (MIT). Sakai is a free educational software platform distributed under the Educational Community License. Nowadays, it is competing with other similar platforms business, such as Blackboard, WebCT and Moodle. This section explores the most relevant tools (see Section 2.1) and events (see Section 2.2) in Sakai related to our aim of personalization and recommendation.

2.1. Sakai tools

In order to guarantee the most frequently functions required by students and lecturers, Sakai provides a set of core tools that are adopted by virtually all institutions using Sakai. Sakai core tools can be grouped as follows:

- Communicative tools: Announcements, Messages, Schedule, News, etc.
- Collaborative tools: Discussion Forum, Wiki, Chat, etc.
- Content tools: Resources, Podcast etc.
- Evaluative tools: Assignments, Tests, etc.
- Monitoring tools: Site Stats, My Workspace, etc.

There are also several additional tools, called *contrib* tools, developed by the community and currently in use by many institutions. For example, `Big Blue Button`[2] is a *contrib* tool that enables universities and colleges to deliver a high-quality learning experience to remote students. In this sense, the proposal presented in this paper may be delivered as a new add-on tool for providing a high-level personalization and recommendation features.

All the available tools are not included in the course sites by default. A specific subset of both types of tools (core and contrib) can be used by lecturers in order to organize, monitor and control the courses in Sakai. Lecturers must orchestrate their courses deciding which, how and when the LMS tools should be used. These tools indicate to the students what type of content is available for each subject, how the individual tasks should be carried out, or the proximity of deadlines for assignments and tests, among others.

[1] http://www.sakaiproject.org/

[2] http://bigbluebutton.org/