Ontologies to Support Learning Design Context

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Abstract. This paper presents an ontology-based framework aimed at explicitly representing the context of the use of a learning object inside of a learning design. The core of the proposed framework is a learning object context ontology that leverages a range of other kinds of learning ontologies (e.g. domain, user modeling, learning design etc.) to capture the context-specific metadata. On top of that framework, we develop the architecture of an adaptive educational system, in order to illustrate the benefits of our proposal for personalization of learning design. Finally, we reflect on how two present educational tools (iHelp Courses and TANGRAM) correspond to the proposed architecture.

1 Introduction

The combined use of the IMS Learning Design specification (IMS LD) [3] and IEEE Learning Object Metadata standard (LOM) [2] enables one to specify learning designs and learning objects (LOs) targeted for different learning situations, based on different pedagogical theories, comprising different learning activities where students and teachers can play many roles, and carried out in diverse learning environments. However, they cannot enable more advanced learning processes, such as dynamic adaptation of content in accordance with the students' objectives, preferences, learning styles, and knowledge levels. Further, if adaptation is to happen automatically information must be codified in an unambiguous manner. Ontologies help increase the consistency and interoperability of metadata. The Semantic Web community has already developed a number of different kinds of ontologies that can be integrated in an ontological framework in order to enable adaptive use of LOs inside a learning design. Our proposal for such a framework is the main subject of this paper.

2 Learning Object Workflows

The complexity of the process of using LOs is described in this section in order to identify the main actors in that process, as well as the types of metadata that can be employed to facilitate the process. The principle actors are subject matter experts (who create the learning content and provide initial metadata for it), instructors (who search for, obtain, modify, then wrap a LO in a learning design), and learners (who end up consuming the LO). These actors use different tools to complete their tasks. A subject matter expert generally uses an authoring tool (e.g. a HTML editor) to create content. In the best case, this content is published to a LO repository and annotated with metadata. An instructor creates an instruction plan for the students she anticipates will take the course. Initially, the instructor sets out the learning objectives the students must reach, and subsequently searches LO repositories for topics related to the specified learning objectives. In addition, she considers materials from previously given lectures and courses, lecture materials provided by colleagues, and other traditional sources (e.g. libraries, the web, etc.). Searching is typically limited to keywords, however LOM-aware repositories may also allow the instructor more advanced search options, such as typical amount of time to complete material or age range of the intended recipients. Using her domain knowledge and a general idea of the kinds of students that will take the course (e.g. their knowledge level), the instructor chooses the appropriate LOs and integrates them into the course. How successfully a designer can do this depends on a number of factors including: if the course has an open or closed (restricted) set of students, if the instructor has some experiences with the course, as well as the diversity of the student set (the problem gets more difficult with each new learner trait the instructor wants to take into account).

There are a number of issues with this kind of workflow. First, the need to access multiple repositories increases the amount of time an instructor must spend building a list of candidate LOs for a particular purpose. Once this list is built, it still takes a fair amount of time for the instructor to evaluate the suitability of each resource for the given objective. Even if these resources are annotated with metadata, the designer needs to absorb this information, consider the value of the metadata given the context of the publisher of the metadata, and finally make a decision as to which object fits the circumstances best. Our anecdotal observations suggest that instructors spend a minimal amount of time looking at metadata records, and then begin to browse the learning content directly. After a short review of the content, the instructor typically begins to modify the content (and thus create a derived LO) instead of reviewing other pieces of retrieved content. Third, if the desire is for highly personalized systems, the instructor must repeat this process for each student, or at the very least for cliques of students. Even when the instructor tackles all these challenges, the objectives of the class might change and the process of creating content must begin anew.

Finally, all of the information in the system flows in one direction – towards the learner. Once a LO is found, evaluated, and used in a course its lifecycle typically ends. While the instructor may keep the object, along with any modifications they have made, it is rare to see metadata in repositories updated with the results of how effective the object was in teaching a particular topic. While some LO repositories, (e.g. MERLOT), do provide a forum for community feedback, none provides facilities for directly modifying LO metadata or even supplying an alternative record.

We instead argue that a more dynamic workflow can be achieved by increasing the communication between tools and actors in a learning environment. Key to realizing a more dynamic workflow is being able to represent the context of use of a LO. By associating a LO with a user model, the learning objectives it was used for, and the observed interactions a user had with the LO, the process of inspecting metadata can be changed from a database lookup into a process of reasoning. This changes both the target and the scope of metadata – instead of being aimed directly at end users, metadata is now aimed at computational agents who can make sense of this data for end users. The remainder of this paper explores the notion of context, and describes how we see this notion fitting into our current e-learning systems.

3 Learning Object Context

When learning content is assembled into a learning design, many assumptions are made about the learners and the learning situation, e.g. assumptions about the learner's competencies, preferences, learning style, goals, and motivation. These assumptions are what we refer to as the *context* – the unique set of characteristics of the learning situation that govern how content should be structured into a flow of interaction for a particular learner. Learning specifications such as IEEE LOM, and IMS LD provide metadata elements aimed at representing some of these assumptions (e.g. 'learning objective' in IMS LD). However, these elements are usually not broad enough to capture all necessary information for effective learning, and not formalized enough to provide for automatic adaptation. In our previous work we addressed these concerns by developed an ontology-based framework enabling formal representation of:

- *Learning object content structure* – ALOCoM Content Structure Ontology formally defines the structure of a LO with the goal of making each component of the LO directly accessible and thus reusable [4].
- *Learning design* – LOCO ontology, based on the IMS LD Information Model, formally defines the concepts and the relationships of IMS LD specification [6].
- *Learning object context* – LOCO-Cite ontology formalizes the concept of learning object context and was originally developed to promote the integration and reuse of LOs and learning designs [6].

Our subsequent efforts to utilize the elements of context for personalization of learning designs revealed that the LOCO-Cite ontology needs to be further extended. Hence, we extended it to integrate connections to user models, competencies, user evaluation information and other relevant data. Specifically, these connections are established via an additional set of properties introduced in the LOCO-Cite ontology. The *LearningObjectContext* class, representing a specific context of use of a LO, is maintained as the central item of the ontology. A number of properties were introduced to enable formal description of the LO's context-related metadata:

- The *isContextOf* property refers to the actual learning content (i.e. LO) that the context is about. The range of this property is the *loco:LearningObject* class, defined in the LOCO to formally represent a LO.
- The *usedInActivity* property is actually a reference to the learning activity (*loco:Activity*) the LO was/is supposed to be used within.
- The *userRef* property refers to the user model of either the teacher/instructional designer who assigned the LO to the specific learning context during the design process or the learner who actually used the LO in that context. The range of the property is the concept of user as defined in the user model ontology developed for the TANGRAM project (explained in more detail in [4]).
- The *dateTimeStart* and *dateTimeEnd* properties store data about the date and the time when the learner started and finished working with the LO. Hence, the time period the learner spent dwelling on the LO can be deduced.

- The *evaluatedWRT* property reports on the user's evaluation of the LO in the given context. Specifically, we defined five different dimensions of users' evaluations: character, clearness, usefulness, stimulation level and pro-collaborative nature. Values for these characteristics are codified using a five item Likert scale. Additionally, users are encouraged to tag the LO with any term that reflect their view of the LO in that specific learning context..

4 Architecture for Learning Design Adaptation

We developed the architecture of an adaptive educational system leveraging the capabilities of the presented ontologies for discovery, reuse and adaptation of LOs and learning designs. The architecture comprises a repository of learning objects (LOR) and its accompanying repository of learning object context data (LOCoR). The LOCoR stores learning objects' context-related data in accordance with the LOCO-Cite ontology. The idea is that each object from the LOR has its corresponding learning object contexts in the LOCoR. A LO gets its first context instance in the LOCoR when an instructor integrates it in the course during the design process. As the time passes and the LO is used in different courses, its learning object context instances become available in the LOCoR.

Besides a LOR and a LOCoR, the architecture also comprises a repository of learning designs represented in accordance with the LOCO. A learning design stored in the repository does not directly reference concrete LOs. Instead, a learning design and a LO are only implicitly related via the learning object context. During both course design and run time, the LOCoR is searched for learning object context instances that 'match' the key features of the learning situation (prerequisites, learning objectives, etc.). In that way the context related data help both teachers and students identify relevant LOs. The system does the search by submitting a query to the LOCoR. The query uses the concepts/instances from relevant ontologies and/or taxonomies whenever it is possible, since their usage provides for an advanced matching process. For example, if no learning object context instance can be found that 'has' the required learning objective (represented as the targeted competency), an instance with a 'similar' objective can be used instead (this similarity is inferred from the ontological representation of competencies). Accordingly, a course/lesson delivery system working on top of the aforementioned repositories is able to provide a learner with the best suited LOs for every learning activity specified in the learning design of the course/lesson plan she is following. To put it differently, we suggest providing the learner with a custom 'view' (analogous to those found in relational databases) of the LOR which is generated in accordance with the requirements of her current learning situation. The learner is free to search and browse through the customized view of the LOR. This way the learners are given a substantial level of control over their learning process (we believe in the active learning approach), whereas, at the same time, the usage of custom views over the LOR protects them from cognitive overload. The learner's browsing behavior can be tracked, and data from this tracking can be mined to infer the learner's preferences, as well as some dimensions of her learning style. Based on the insights acquired into the learner's preferences, the view of the LOR for every subsequent activity the learner performs is further customized. One should also note that each time a learner selects a LO from the LOR, a learning object context instance of that LO is created in the LOCoR and all relevant context-related data for that usage are stored in it.

5 Tools

The section describes two educational systems closely related to the proposed solution for adaptive use of LOs.

The first one is iHelp, a web-based suite of tools[1] that includes *iHelp Courses*, a standards-based learning content management system, an asynchronous discussion forum, and a synchronous chat system. iHelp Courses is deployed within the Department of Computer Science at the University of Saskatchewan and is used to deliver the introductory course in computing concepts for non-majors in both pure online and blended environments. The system enables instructors to deploy LOs and sequence them in different ways for different cohorts of students [1]. Content can also be associated directly with collaborative tools (e.g. discussion forums), hence allowing for context-specific collaboration between learners.

iHelp Courses keeps fine grained knowledge about learner interactions with LOs. Specifically, for every LO a learner has viewed the system knows how long she was viewing that LO, what interactions (via synchronous/asynchronous discussions) were undertaken, and the results of any quizzes associated with that LO. We are currently transforming the content of this large database of end use data to be compliant with the LOCO-Cite ontology. Our intention is to apply various machine learning and data mining algorithms on this end-use data in order to find interesting patterns of actual usage of LOs. For example, what kind of learners they are suitable for, which kinds of learning activities they suit the best, etc. Likewise, valuable information can be inferred about learners and their characteristics, preferences and interests.

The second system is TANGRAM, an ontology-founded adaptive learning environment for the domain of Intelligent Systems [5]. TANGRAM illustrates how Semantic Web technologies, particularly ontologies and ontology-based reasoning, enable on-the-fly assembly of personalized learning content out of existing content units[2]. Its principle functionality is to enable reuse of existing content units to dynamically generate new learning content adapted to a learner's knowledge, preferences, and learning styles. Additionally, the use of ontologies enable advanced searching of repositories using of Semantic Web reasoners. For example, one can search for a content unit of a certain type (as defined in the ontology of pedagogical roles, e.g. "definition"), dealing with a certain topic (from the domain ontology) and being at a certain level of granularity (as defined in the structure ontology, e.g. "slide"). Accordingly, TANGRAM provides students with quick access to a particular type of content about a topic of interest, e.g. access to *example*s of RDF documents or *definition*s of the Semantic Web. We intend to improve TANGRAM's personalization capabilities through the use of context related data.

[1] See http://ihelp.usask.ca for more information

[2] Content unit is an abstract concept aimed at representing content of any level of granularity.

6 Conclusions

Researching the potentials of personalized use of prominent learning technology efforts, we have developed a novel ontology (LOCO-Cite) for bridging them. This ontology makes use of several other kinds of learning-related ontologies in order to capture information about the context of use of a LO inside of a learning design. Information of this kind is useful for personalization of learning designs – for example, during learning design playback a query specifying the main features of the current learning situation can be sent to the repository of learning object contexts in order to identify learning object contexts representing similar learning situations and from them infer the most suitable LOs for the present.

Our future research will be focused around the implementation of this architecture with the hopes of leveraging the presented ontologies to enable personalization and reuse of LOs and learning designs within the iHelp Courses and TANGRAM environments.

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References

1. Brooks, C., Kettel, L., Hansen, C., Greer, J.., "Building a Learning Object Content Management System," *In Proc. of E-Learn 2005 Conference*, October. 24–28, 2005. Vancouver, Canada.
2. Duval, E. (Ed.), 1484.12.1: IEEE Standard for Learning Object Metadata, IEEE LTSC, 2002
3. IMS Learning Design Information Model. Version 1.0 Final Specification, rev.20, 2003, http://www.imsglobal.org/learningdesign/ldv1p0/ imsld_infov1p0.html.
4. Jovanović, J., Gašević, D., & Devedžić, "Dynamic Assembly of Personalized Learning Content on the Semantic Web," *In Proc. of the 3th European Semantic Web Conf.*, Budva, Montenegro, 2006, pp. 544-558.
5. Jovanović, J., Gašević, D., & Devedžić, V., "TANGRAM: An Ontology-based Learning Environment for Intelligent Information Systems," *In Proceedings Proc. of the 10th E-Learn Conference*, Vancouver, Canada, 2005, pp. 2966-2971.
6. Knight, C., Gašević, D., & Richards, G., "An Ontology-Based Framework for Bridging Learning Design and Learning Content," *Educational Tech. & Society*, Vol. 9, No. 1, 2006.