Ontology-Based Framework in e-Learning Settings

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Abstract: This paper presents an ontology-based framework aimed at explicit representation of context-specific metadata derived from the actual usage of learning objects and learning designs. The core part of the proposed framework is a learning object context ontology, that leverages a range of other kinds of learning ontologies (e.g., user modeling ontology, domain ontology, and learning design ontology) to capture the information about the real usage of a learning object inside a learning design. We also present some learner-centered and teacher-centered scenarios enabled by the proposed framework in order to illustrate the benefits the framework offers to these key participants of any learning process.

Key-Words: Learning objects, Learning context, Learning design, Ontologies, Personalization.

1 Introduction

The recognition of the increased need for reusing learning content led to the adoption of a standard format for describing learning content with metadata, the widely known IEEE Learning Object Metadata Standard - IEEE LOM [3]. The use of its predefined set of metadata fields promotes exchange of learning objects (LOs) among different e-learning systems and content providers, and offers higher potentials for finding existing learning content (i.e. LOs). Even though the IEEE LOM standard was undertaken by the e-learning community to facilitate and foster interoperability and reuse of learning artifacts among different e-learning platforms, decisions about reuse involve a broad set of issues about content, context and pedagogy that cannot be fully expressed in the LOM’s metadata fields.

In order to be effective and bring expected learning results, LOs need to be organized in a pedagogically sound manner, according to an instructional plan, or a learning design. A learning design is about identifying necessary learning activities and assigning LOs to those activities in order to achieve the specified learning objective [4]. The idea of having a uniform method for expressing the design of the learning process began with the Educational Modeling Languages proposed by Koper [7]. This work evolved into the IMS Learning Design (IMS-LD) specification that provides a common set of concepts for representing learning designs, hence enabling the share and reuse of learning designs across learning systems. These two specifications were supposed to enable specification of learning designs (and learning objects) targeted for different learning situations, based on different pedagogical theories, comprising different learning activities where students and teachers can play many roles, and that can be carried out in diverse learning environments.

However, the abovementioned specifications/standards (i.e., IEEE LOM and IMS-LD) do not enable capturing all the information required for advanced learning services, such as personalization or adaptation of content in accordance with the students’ objectives, preferences, learning styles, and knowledge levels. The requirements for effective personalization include (but are not limited to) [2]:

1. Direct access to low-granularity content units comprising the structure of a LO;
2. Recognition of the pedagogical role played by each content unit in a specific situation (e.g., in a learning activity);
3. Awareness of the learners’ evaluations about usefulness of a specific content unit within a specific learning design;
4. Characteristics of learners that best fit a specific learning design.

Further, if adaptation or personalization is supposed to happen automatically, all of these requirements must be codified in some unambiguous manner. Finally, the learning specifications/standards do not provide space for any kind of teacher-directed feedback about the usefulness and appropriateness of a LO or a learning design for certain learning settings. However, such a feedback is quintessential in online learning environments.
where the teachers’ awareness of the learning process is significantly lower than in traditional classroom settings.

One strategy to address some of these shortcomings is suggested in the Ecological approach [8]. According to this approach, each time a user interacts with a LO, his/her user model is attached to the LO; as the time passes, user models accumulate around each LO stored in a repository. Annotation of a LO (i.e. assignment of metadata) is based on applying various data mining techniques on the data stored in the accumulated user models. However, metadata is generated only when needed and only for the needed purpose. In other words, the purpose determines which metadata will be generated and how – hence McCalla argues for the Pragmatic Web. This approach promises to provide purposeful metadata other than those prescribed by present learning specifications and standards. Next, the paper introduces the notion of the Learning Object Context as a kind of LO metadata that captures all the information that characterizes the specific situations (contexts) in which certain LO has been used. This idea is presented both at the conceptual level and at the level of formal representation, i.e., as an ontological framework (called LOCO). Some usage scenarios are also presented in order to illustrate the benefits of the proposed context-based approach.

2 Learning Object Context – Conceptual Model

Context-related data are essential for instructors. When learning content is assembled into larger objects or designs to be presented to learners many assumptions are made about the learners and the learning situation: assumptions about the learners’ experiences, skills, and competencies; about their personal preferences, learning styles, goals, and motivations; about the available time, etc. These assumptions are what we refer to as the context – the unique situation-related rules that implicitly govern how content should be structured into a flow of interaction for a particular learner.

To overcome the abovementioned shortcomings of learning specifications and enable capturing of context-related data, Ivanovic (2007) proposed an ontology-based framework, called LOCO (Learning Object Context Ontologies) [5], which consists of:

- Learning object content structure ontology – Formally identifies the information objects within a LO with the goal of making each component of the LO directly accessible.
- Learning design ontology – The design of the ontology was inspired by the IMS-LD Information Model (IMS-LD-IM, 2003). However, the ontology is general enough to support any other model of instructional design.
- Learning object context ontology – The LOCO-Cite is an ontology originally developed to promote the integration and reuse of LOs and learning designs [6]. The original conceptual model focused on using a Learning Object Context as a bridge between a LO (or one of its components) and the learning design in which the LO (or its component) was used.

Our subsequent efforts to utilize the elements of context for personalization of the learning process revealed that the LOCO framework needs to be further extended. Hence, we extended it to integrate connections to user modeling and subject domain ontologies as well as user evaluation information and other relevant data. These extensions are described in the next section.

LOCO-Cite Ontology

Aiming to further enhance the proposed formalization of the learning object context, we extended the LOCO framework to make use of a number of other types of ontologies relevant in the e-learning domain (Figure 1a). Specifically,
connections with those other relevant ontologies are established via an additional set of properties introduced in the LOCO-Cite ontology. The LearningObjectContext class, representing a specific context of use, is maintained as the central item of the ontology. A number of properties were introduced to enable formal description of a LO’s context-related (meta)data (Figure 1b).

The contentUnitRef property refers to the actual unit of content that is about. The range of this property is the alocomc:ContentUnit class, an abstract class defined in the ALOCoM Content Structure Ontology to formally represent a content unit of any granularity level. Therefore, even though we refer to the context of a LO, the ontology design enables for a more generic approach – it provides a common formalism for representing context-relevant metadata for content units of diverse levels of granularity.

The subjectDomain and domainTopic properties are aimed at representing the subject domain and the domain topic, respectively, that best describe the context of use of a specific LO. Specifically, the two properties link learning object context with an appropriate domain ontology and its concept represented in accordance with the W3C’s SKOS Core Specification (http://www.w3.org/2004/02/skos/core/). The SKOS Core ontology is aimed at formal representation of concept schemes (e.g. taxonomies, thesauri, controlled vocabularies) (Miles & Brickley, 2005) and contains an excellent variety of classes (e.g. concept scheme, concept) and properties (e.g. broader, narrower, prefLabel) that can be used to describe topics of a LO and their relationships.

The usedInLD property points to the instance of the ld:LearningDesign class as a formalization of the actual learning design the LO was used in. Here we assume that a repository of learning designs, represented in compliance with the ontology of learning design exists and is accessible. If such a repository does not exist, but an elementary set of data about the design of the unit of learning that the LO was used in is available (e.g. general pedagogical model it is based on, learning objective both general and domain-specific, targeted learners), an instance of the ld:LearningDesign class would be created and stored with the learning object context.

The usedInActivity property is actually a reference to the learning activity (ld:Activity) the LO was used within. The underlying assumption for this property (as for the previous one) is the existence of an ontology-based repository of learning designs that facilitates direct access to any activity of any learning design stored in it. Alternatively, an instance of the ld:Activity class needs to be created out of the available activity-related data and stored with the learning object context.

The isOfInstructionalType property relates the learning object context with the instructional/pedagogical role the LO assumed in the learning activity it was used in. The range of this property is alocomc:ContentUnit, the top level class of the ALOCoM Content Type ontology developed to formally represent different instructional types a content unit might have (Jovanović et al, 2006).

The userRef property refers to the user model of the learner who actually used the learning object in that specific learning context. Even though the ontology enables formal representation of relevant information about all participants in the learning process (content authors, teachers and learners), it is mostly focused on the representation of the learners’ features. The ontology defines formalisms for representing the learners’ basic personal data, their preferences regarding language, domain topics and content authors, their performance, as well as different dimensions of their learning styles.

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 userEvaluation property reports on the usefulness of the LO in the given context as perceived by its users. Even though this kind of user feedback is often neglected, we consider it highly important to capture the users’ opinion about a LO with respect to different evaluation categories, such as clearness, usefulness, and pro collaborative nature. Each category is modeled as a subclass of the UserEvaluation class, hence the inclusion of a new (different) evaluation category is made as easy as extending this class with a new subclass. Course players should provide support for this kind of feedback.
3 The Framework in Use

The proposed ontological framework is beneficial both for teacher-centric and learner-centric tools and systems. In this section we present some usage scenarios in order to illustrate the advantages of the suggested approach.

Learner-centric scenarios

Figure 2 illustrates the basic architecture of an adaptive educational system leveraging the capabilities of the presented ontologies for discovery, reuse and adaptation of LOs. The architecture comprises a repository of LOs and its accompanying repository of learning object context (LOC) data. The repository of LOCs stores learning objects’ context-related data in accordance with the LOCO-Cite ontology. The idea is that each object from the LO repository has its context data in the repository of LOCs. Being aware of the fact that right after being uploaded to the repository, a LO can not have any context-related data (as it has not been used yet), we introduce the notion of ‘artificial’ LOCs in order to alleviate the ‘cold-start’ problem. Since LOs are often designed for a specific purpose (i.e., intended use), their (prescriptive) metadata can be collected to seed the “artificial” LOCs. As the time passes and the LO is used in different courses (i.e. learning designs), its context data become available in the repository of LOCs.

During the learning process, the repository of LOCs can be searched for LOC instances that ‘match’ the requirements of the current learning situation (e.g., prerequisites, learning objectives, and available amount of time). These requirements can be expressed as a query using an ontology query language (e.g. RDQL [10]). Such a query should use the concepts/instances from relevant ontologies and/or taxonomies whenever it is possible, since their usage enables an advanced matching process. For example, if no LOC instance can be found that ‘has’ the required learning activity, an instance with a ‘similar’ activity can be used instead. The notion of similarity here is rooted in the ontologies used and semantic relations among their concepts. 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 (i.e. course/lesson plan) (s)he is taking. To put it differently, we suggest providing the learner with a custom ‘view’ (or a ‘virtual subsection’) of the LOs repository, generated in accordance with the requirements (e.g., prerequisites and learning objectives) of the current learning situation. The introduced notion of the custom ‘view’ is analogous to the well-known concept of view in databases that is used to protect the database users from the complexity of the underlying database schema. The learner is free to search and/or browse through that ‘virtual subsection’ of the LOs repository. This way the learners are given a substantial level of control over their learning process (i.e., we advocate in the active learning approach), whereas, at the same time, the usage of custom ‘views’ over the repository protects them from the cognitive overload. The learner’s searching/browsing behavior is tracked, as that data can be mined to infer the learner’s preferences, as well as some dimensions of his/her learning style. Based on the acquired insights into the learner’s preferences, the virtual subsection of the LOs repository for every subsequent activity the learner performs can be further customized. In other words, the customization would not be based only on the requirements of the learning activity, but also on the information inferred about the learner’s preferences/style. One should also note that each time a learner selects a LO from the repository of LOs, a learning object context instance is created in the repository of LOCs and all relevant context-related data for that usage are stored in it.

Furthermore, the information about the learners’ on-line communication and collaboration activities can also be used to improve the learners’ learning experience. In particular, by analyzing the context...
and the content of the messages exchanged in online discussion forums and chat rooms, a learning system can identify the problems some learners might have experienced and take appropriate actions. For example, having recognized that a learner is experiencing problems with a certain domain topic, the system can:

- recommend additional readings for the sake of clarifications (i.e., provides links to potentially relevant content that treats the unclear topics);
- suggest reading some postings from a specific discussion forum/chat room where the problematic issue was already discussed;
- suggest discussing the topic with some other learner(s) who knows the topic well, that is, with learner(s) who had high score on the quiz which tested the knowledge on that topic and/or related topics (where relatedness is inferred from the domain ontology).

**Teacher-centric scenarios**

Besides being beneficial for providing learners with personalized learning experience, the proposed framework and the reasoning that can be performed over it are also useful for generating feedback for other key participants in the learning process – content authors and instructors. Content authors are typically subject matter experts who create learning content, that is subsequently used by instructors (i.e., teachers) who wrap that content into a learning design. The proposed framework can be used to inform learning content authors about the actual usage of their content during the learning process. Likewise, the framework can be used to provide feedback to instructors about the learners’ activities, their performance, achieved collaboration level and the like. In both cases, the feedback helps improve the learning process. To support this statement, we give a few illustrative scenarios:

- If the majority of learners have spent a lot of time on some lesson and made frequent revisits to it, it is highly probable that the lesson is overly difficult for learners. This finding can be a signal for the content author to improve the expressivity of the content. It might also be a signal for the instructor to alter the applied instructional model (e.g., include more exercises or alter the lessons’ sequence).
- If the majority of learners who performed poorly on an assessment followed the same or similar learning trajectory (i.e., sequence of lessons), it might signal to the instructor that either more tutoring (i.e., explicit directing of learners activities) is needed or the learning trajectory should be restricted (e.g., by means of link hiding techniques).

Semantic annotation of lessons can further improve this feedback by helping identify semantically similar learning trajectories.

- If majority of learners answered incorrectly to the assessment question(s) about a particular domain topic and there were a lot of on-line exchanged messages discussing the topic in question as well as frequent revisits to the lesson(s) explaining the ‘problematic’ topic, then it is a clear signal that some alternations of the lessons’ content or way of teaching the respective topic are needed.
- The feedback may be generated out of analyzes of the learners online communication and collaboration. Being informed about how active students were in social interactions, the instructor can more easily decide how to alter his/her teaching approach to activate them more, or make them more focused on the relevant parts of lessons.
- Finally, the ontological framework facilitates visualization of the learning process, hence providing instructors with visual clues of the learning progress. For example, from the visual representation of the learning object’s context data, an instructor can easily perceive the suitability of that LO for different learning activities.

**4. Conclusions**

Aiming to enable advanced services for all key participants of the learning process (learners, content authors and instructors), we came up with the idea of learning object context (LOC) as a unique set of interrelated data that characterize a specific learning situation. The framework integrates several kinds of learning-related ontologies (e.g., user modeling ontology and content structuring ontology) in order to capture the information about specific context of use of a LO inside a learning design. Information of this kind can be rather useful for personalization of learning process. For example, during a learning session a query specifying the main features of the current learning situation can be sent to the repository of LOCs in order to identify LOC instances representing similar learning situations and from them infer the most suitable LOs for the present circumstances (e.g., learning objectives, learner’s preferences, and available time). Furthermore, the idea of personalized views over repository of LOs is presented as a benefit resulting from the proposed ontology-based framework.

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References:


