Enhancing Learning Object Repositories with Ontologies

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Abstract. In this paper, we present a review on the use of ontologies in learning object repositories systems for searching and suggestion purposes, considering its adoption for the seaThings project that aims to promote the ocean literacy. We also describe the use case of the Cognix system and Agent-based Learning Objects - OBAA metadata standard for learning objects which is being implemented on a new learning objects repository. This system includes concepts from artificial intelligence such as agents and ontologies that aim to improve the search and so making the system more responsive. This paper also sugests how an ontology can be implemented, using metadata in learning object repositories to provide relevant aspects, such as interoperability, reuse, and searching.

Keywords: leaning object, repository, metadata, ontology, OBAA

1 Introduction

Digital learning, supported with different technologies and methodologies, allows new elaborations of Learning Objects (LOs) to increase over the years [14]. According to Vicari [16], LOs can be used in multiple contexts and combined to generate a brand new LO. They are usually cataloged by metadata in Learning Object Repositories (LORs) to their storage and delivery to improve use and reuse. LORs generally adopt a metadata standard or develop their own metadata to describe LOs and make them accessible for use in education.

However, LORs are usually isolated. They do not share their LOs descriptions and contents with other systems and applications. To improve this disadvantage, it is encouraged the use of metadata standards, shared vocabularies, and communication protocols (such as OAI-PMH[11] and REST API [11]). With

[11] http://www.openarchives.org/OAI/openarchivesprotocol.html

these technologies, it is possible for LORs to make them interoperable with each other, through federated search and other similar solutions.

IEEE-LOM [9] and Dublin Core [4] are wide-spreaded standards used to describe educational metadata in LORs. We can also cite the Agent-based Learning Objects (OBAA) [16], a metadata extension of IEEE-LOM that adds metadata to Technical and Educational categories. It also provides new segmentation and accessibility aspects. OBAA metadata standard is an effort for providing educational metadata supported by intelligent agents and ontologies.

Ontologies play an essential role in the evolution of the current Web, called Semantic Web or Web of Data, a Web understandable by humans and machines [13]. An ontology is defined by Guarino *et al.* as "a formal, explicit specification of a shared conceptualization" [7]. With the use of metadata as ontology, interoperability between systems can be efficiently achieved in the adoption of the Semantic Web through alignments between ontologies [2].

In the next section, we present the state-of-the-art in using ontologies in LORs. Then we describe the Cognix[12] system with the OBAA metadata standard as a LOR example. The seaThings project - Learning Objects to Promote Oceanic Literacy is mentioned, as a new Educational LOR combining Cognix and OBAA technologies. After that, some aspects of ontologies are discussed in the context of semantic web technologies. In the final section we conclude and present future perspectives.

2 Learning objects and ontologies in repository systems

2.1 Learning object definition

We can find many definitions for learning objects. For instance, the National Learning Infrastructure Initiative[13] define the concept as "modular digital resources uniquely identified and meta-tagged, that can be used to support learning". Other authors focus on the object-oriented programming (OOP) background, like the one presented by David A. Wiley [17] where "the main idea of 'learning objects' is to break educational content down into small chunks that can be reused in various learning environments, in the spirit of object-oriented programming". A wider concept is the one of Open Educational Practices (OEP) considered the use of Open educational Resources for teaching and learning to innovate the learning process [6].

Our definition for Learning Objects is that a Learning object is a "chunk" of digital information, in the paradigm of object-oriented programming, regarding teaching resources and student assessment, as showed in Figure 1. Learning Objects are represented in teaching techniques that draw upon open technologies and high-quality open educational resources (OER) to facilitate collaborative and flexible learning. In this work we propose the combination of LOR and OEP to create a new generation of Learning Objects integrating Artificial Intelligence (AI) concepts.

[12] https://github.com/cognitivabrasil/Cognix
[13] https://www.educause.edu/

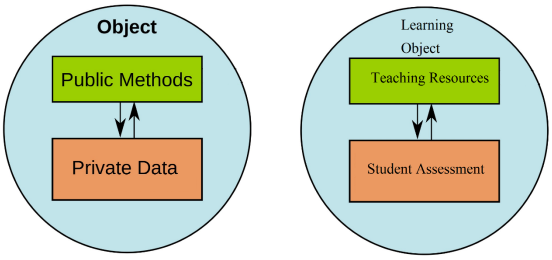

Fig. 1. Learning objects in the paradigm of OOP.

2.2 Ontologies in Learning object repository systems

There are many ways that ontologies can be applied in LORs. First, ontologies can be used to enrich the description of the LO metadata. It is also possible to use ontologies to cope with the interoperability among repositories. Along with user interaction, ontologies can improve recommendations, both for cataloging and for LO (re)use. An intelligent search also can be leverage with ontologies.

Rimaleet *et al.* [12] elaborated an approach based on two ontologies (course knowledge description domain and other to describe the LO representation). The approach is called OWL2XSLO and aims to automatically deliver an XML schema to create LOs based on ontologies to promote mobile learning.

An ontology-based model called EduSor has been built for the LO metadata by Kalogeraki *et al.* [8]. The model applies to reason about the student's learning process to evaluate the educational content of e-learning assessments. It also supports tutoring abilities and facilitates decision making.

Véron *et al.* [15] proposed an ontology solution for interoperability among LORs that employ distinguished metadata for LO description. The model transforms each metadata into a local ontology and then builds a concept mapping between local and global ontologies. The global ontology is a shared vocabulary for searching and storage.

A Web Service to recommend metadata filling based on templates and relevant-based suggestions for each template field was developed by Martínez-Romero *et al.* [10]. They also enriched the recommendations with ontologies to interconnect synonyms terms and to connect the plain text with an ontology definition.

An approach that allows an automatic and dynamic analysis of LORs have been present by Dorça *et al.* [5]. Ontology is responsible for modeling relations between LO attributes and learning styles. The approach aims to facilitate personal recommendations and provide LO clustering according to the student style.

3 The metadata standard OBAA

OBAA has been designed to extend and be compliant with the IEEE-LOM metadata standard. Aggregating several new metadata, OBAA provides Technical metadata to support different services and multiple platforms, such as Web, Digital TV, and mobile devices. It also features new educational metadata to describe interactions, didactic strategies, and learning content types. It also adopts accessibility metadata to describe LOs to people with special needs and offers Segmentation Table metadata for videos.

OBAA can also describe aggregated LOs, *i.e.*, a LO that reuses one or more previous LO. This can be done through the Relation metadata, which describes the kind of relation; where the resource is through an identifier; and provides a description of the relationship.

Different applications and services could combine with OBAA through specific metadata. For example, it is possible to identify associated ontologies by metadata, identifying the ontology language and location.

Cognix is one application developed for LOR using the OBAA metadata standard. The application has been updated to current technologies: Angular for frontend, Java to manage the backend through a REST API, and Solr for searching purposes.

Both OBAA and Cognix software are open initiatives, so it is possible to do customizations according to the LOR needs. In the next section, we will describe how the seaThings project uses these solutions and with ontological support.

4 Using semantic web technologies for ocean literacy improvement

The seaThings project is a multidisciplinary approach to promote ocean literacy. One of its objectives is to provide LOs about the sea to encourage teachers to use it in any subject they teach. For this purpose, a LOR will store the LOs and will interoperate with a repository federation which will include several pre-existing LORs. One of these pre-existing repositories is REDA[14] - Open Digital Educational Resources - a repository of digital educational resources available for teachers and students. It was created in 2016, by the Regional Education Bureau of the Azorean government, within the scope of the Integrated Plan for the Promotion of School Success - ProSucesso.

The ultimate success of all this kind of platforms will depend on a collaborative attitude from teachers. The seaThings project intends to support this collaboration adding AI tools agent based with ontologies. For this to be possible, aspects of LO authoring, recommendations, searching, and use data analysis are the main objectives of the project.

4.1 OBAA metadata for seaThings LOs

The metadata definition is a complex task that has to be updated through the LOR lifecycle. OBAA has a wide scope of coverage. So, a subset of OBAA was designed as an application profile metadata[15].

[14] https://reda.azores.gov.pt/
[15] http://edumar.uac.pt/metadata.html

This set of metadata was adapted from OBAA. It was incorporated into Cognix for the seaThings context. The components are suggestions of value spaces and metadata to describe areas of knowledge related to the proposed LO. It is important to mention that metadata with only one option is not shown to the user. As well as technical identifiers, and meta-metadata that are loaded by the Cognix application.

4.2 OBAA metadata ontology

The OBAA is a hierarchical metadata standard. It allows building sets of modularized ontologies that will compose the whole OBAA easily. The categories and subcategories can split into small ontologies with their classes, object properties, and data properties. Each ontology is a chunk of knowledge that aims to improve reuse and reasoning through axioms.

Chahdi *et al.* [3] defines an ontology using two conceptual building blocks: TBox (Terminology-Box), composed of concepts (classes), axioms and relations; and ABox (Assertion-Box), to describe individuals and its relationships.

The TBox description work was previously done with OWL (Web Ontology Language) by Behr [1]. The LOR must instantiate this to store relations and values of the metadata. In this way, each category and subcategory turn up into an ontology individual linked through object properties. Ontology data properties store metadata values.

Figure 2 illustrates how an ontology describes LO metadata for the General category. Other categories follow the same approach. After that, the LOR must attach the ontology Uniform Resource Identifier (URI) to the ontology location metadata and assign the ontology language used. Figure 3 shows instantiated individuals to store metadata.

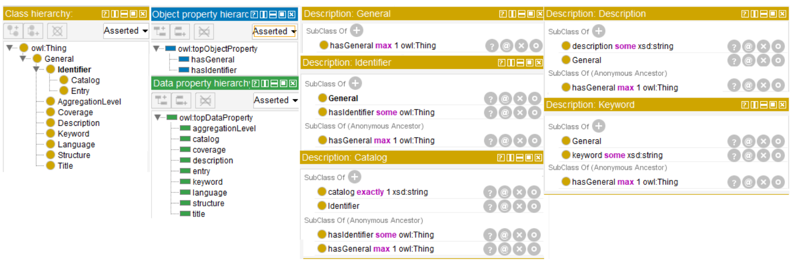

Fig. 2. TBox for some OBAA General category metadata.

5 Discussion

The main issue to applications is how to correlate LO metadata stored in the repository to other educational ontologies, which represent, for instance, the

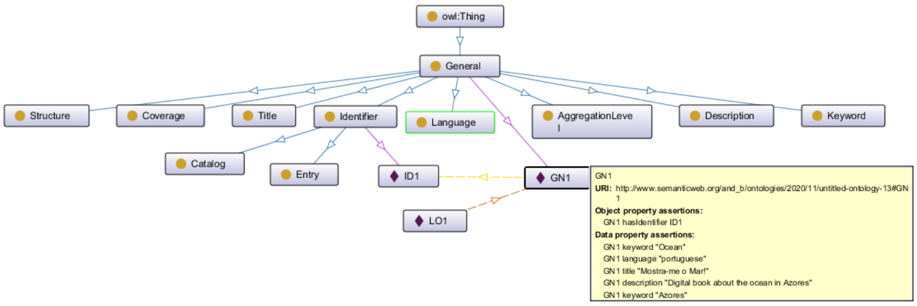

Fig. 3. ABox for OBAA General category metadata.

learning domains, teaching strategies, and other educational topics. The establishment of relations among metadata and educational ontologies, or among distinct but generally heterogeneous educational ontologies could be very complex.

Fortunately, some techniques can make this process easier, allowing the automatic or semi-automatic establishment of the relations among the ontologies. Ontology alignment is currently regarded as a fundamental mechanism for the integration of semantically heterogeneous databases and as an enabling technology to provide semantic searches on these databases.

Alignments of different ontologies can also expand the knowledge representation. For example, in the context of seaThings, it is intended to combine an ontology with scientific concepts about the sea with ontologies that make it possible to relate the metadata collected when registering the LO in the repository.

Another current issue is how the reuse of metadata descriptions could be handle. For example, how to link a previous set of authors to different LOs or how to stabilsh links for several LOs versions.

This interlinking of information is very important and must be stored accordingly by the LOR. It is also necessary to provide services for information gathering. For example, intelligent agents can classify the LOs according to a learning style, recommend a LO as complement material for some class, search for LOs, or do some other reasoning over the ontologies.

6 Conclusion and future work

Using ontologies in repositories promote the interlinking of data, expanding the knowledge representation. Researchers have focused on applying ontology-based technologies to improve the processes of localization, retrieval, cataloging, and reuse of learning objects. This scenario highlights semantic heterogeneity issues, creating an excellent opportunity to evaluate and explore ontology alignment techniques able to provide semantic integration among different ontologies.

This paper advocates the use of technologies based on aggregated ontologies to describe LOs metadata in a LOR in a semantic Web context. In addition, it also maintains interoperability with current LORs. For further work, a semantic search service will be developed, it is also intended to enrich knowledge representation with other ontologies allowing better recommendations, and include advanced alignment techniques insted of the common used approaches of word search, much more limited in contexts of fuzzy concepts.

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