Proposal of a Multi-agent System for Indexing and Recovery applied to Learning Objects

Jonas Vian, Ricardo Azambuja Silveira, Renato Fileto

1 Federal University of Santa Catarina, Brazil, jonas.vian@inf.ufsc.br
2 Federal University of Santa Catarina, Brazil, silveira@inf.ufsc.br
3 Federal University of Santa Catarina, Brazil, fileto@inf.ufsc.br

Abstract: There are a variety of specifications and metadata standards used to describe learning contents. A learning content, along with the file containing the descriptive metadata, constitutes the learning object. Learning objects can be stored in a repository and used in the process of teaching and learning. The heterogeneity of metadata standards used to describe learning objects creates difficulties to reuse of these objects. Applications that seek to recover learning objects cannot interoperate with different repositories, which contain objects described according to different metadata standards. This paper proposes a multi-agent system, wherein agents can index and retrieve learning objects that are contained in different repositories and described with different metadata standards. These agents use an ontology that is the result of the union of all the ontologies that contextualize the existing metadata standards.

Keywords: Interoperability, Learning Objects, Learning Objects Repositories, Metadata Standards, Multi-agent system, Ontologies, Ontology Matching.

1. Introduction

The technology-based education and training process, called e-learning, lends flexibility and interactivity to the process of teaching and learning. Essential to this process is the production of learning contents, which costs both money and time. Due to this cost, the possibility of reuse of learning contents has attracted the attention of research groups, organizations and institutions around the world.

The concept of LOs (Learning Objects) arose in response to the need to reuse the learning contents produced. However, the diversity of standards and specifications for the production and storage of LOs causes heterogeneity and creates difficulties in the interoperability between applications that store the LOs and applications that seek to reuse LOs already produced.
In order to facilitate greater reuse of LOs, this paper proposes a multi-agent system capable of recovering LOs independent of the standard used in their development.

The remainder of this paper is organized as follows. Section 2 reviews the major concepts and technologies involved in our proposal: LOs, metadata standards to describe LOs, multi-agent systems and ontology matching. Section 3 describes the proposed multi-agent system for indexing and recovering LOs in an heterogeneous environment, by matching ontological descriptions based on distinct metadata standards used to describe the LOs in different repositories. Finally Section 4 discusses related works and Section 5 concludes the paper by describing the contributions of our solution and some future work.

2. Fundamentals

2.1 Learning Objects

There are several definitions for Learning Object (LO); one of the most used is “any material, digital or not, that can be used, reused and referenced in the process of teaching and learning, supported by technology” [9]. For a LO to be located and reused, it must be described by a set of metadata, according to a specification. The package containing the content itself, as well as the metadata, should be stored in a repository, which is a structure that stores and permits the LOs to be found and used.

Several research groups around the world, created by renowned institutions, have studied and proposed specifications for LOs, for example, ADL (Advanced Distributed Learning) [1], Ariadne Foundation [3], AICC (Aviation Industry CBT (Computer-Based Training) Committee) [4], Dublin Core Metadata Initiative [7], IEEE-LTSC (Institute of Electrical and Electronics Engineers - Learning Technology Standards Committee) [9], IMS (Instructional Management Systems) Global Learning Consortium [10], and ISO (International Organization for Standardization) [11].

Among these specifications are the sets of metadata used to describe the LOs, such as AICC Metadata [4], Dublin Core [7], LOM (Learning Objects Metadata) [9], IMS LRM (Learning Resource Metadata) [10], ISO MLR (Metadata for Learning Resources) [11], models for construction of the LO metadata file such as IMS Content Packaging Specification [10] and models of reference for LO construction such as ADL SCORM (Advanced Distributed Learning Sharable Content Object Reference Model) [1].
2.2 Metadata

Metadata is information that allows contextualization of an object [9] and is used to recover and reuse it. The first set of metadata was the Dublin Core [7], which proposed to describe any content on the Web. From the Dublin Core, other initiatives appeared, more focused on learning content such as the LOM [9], whose development was initiated by IMS Global Learning Consortium [10] and by the Ariadne Foundation [3]. It was approved in 2002 by IEEE-LTSC [9], as LOM. Other research groups have identified some limitations in LOM, and they have proposed other sets of metadata to describe LOs. Among these groups are the JTC1/SC36 Committee of ISO (International Standards Organization) [11] and the AICC (Aviation Industry CBT (Computer-Based Training) Committee) [4].

2.3 Multi-agent System

An agent is a computer system situated in an environment and capable of performing autonomous actions in this environment to achieve its designed goals [26]. Another definition says that the agent is a software entity that runs continuously, unattended, in a particular environment, which is often inhabited by other agents – an entity capable of intervening in its environment in a flexible and intelligent way, without requiring constant human intervention or guidance. Ideally, the agent will operate continuously for long periods of time [5].

Agents are able to understand the environment in which they live through sensors and to act in that environment through actuators. They may also possess the ability to learn from their experiences, cooperate, communicate with other agents and move from one place to another [5].

A multi-agent system is a loosely coupled network of problem-solvers that work together to solve problems beyond their individual capacity. These problem-solvers are essentially autonomous, distributed and often heterogeneous in nature [26].

The multi-agent system elements must perform the following functions: cooperation, conflict resolution, negotiation, compromise, communication and interaction.

2.4 Ontology Matching

There are several ways to represent the conceptualization of a domain, and these representations are classified according to the formalism used. In order of expressivity, some examples these representations are dictionaries, taxonomies, data models, and ontologies [8]. An ontology consists of entities, which may be classes or concepts, instances or individuals, relationships or properties, data types and values [8], and is designed in a language capable of giving the necessary
formalism. There are many languages for building ontologies, among which the most salient is the OWL (Web Ontology Language) [8], which is a recommendation from the W3C (World Wide Web Consortium).

Ontology matching is necessary in various scenarios, according to Euzenat et al [8] and to the ontology matching web site [16]. The ontology matching process aims to find correspondences between entities in different ontologies [8]. A correspondence consists of a relationship with a degree of confidence between entities of two ontologies. Relationships may be the equivalence or other relations, such as consequence, subsumption, or disjunction, and the degree of confidence can be calculated in several ways - for example, range between 0 and 1, Boolean, probabilistic, or fuzzy.

The set of correspondences between two ontologies constitutes the alignment that results from the matching process and must be represented in a standard format, so that it can be used for interoperability between applications that use these ontologies [8]. With the alignment, it is possible to do the ontology merging, the translation of instances from one ontology to another, or the mediation of communication between applications with aligned ontologies, among other things [8].

3. The Proposed System

The use of different metadata standards to describe LOs in different repositories causes heterogeneity, and applications that seek to reuse these LOs must confront this heterogeneity.

The objective of the system proposed in this work is to provide for the LOs reuse. The system will be able to index and retrieve LOs in different repositories, which contain described LOs by different metadata standards. To do this, ontologies that describe the different metadata standards will be matched to produce a new ontology. The ontology resulting from this matching process will subsequently be used by agents that will index and recover LOs and display the LOs in a customized way for user. Figure 1 shows the outline of the system to be developed.
Figure 1 outlines the architecture of the proposed multi-agent system for indexing and recovering Learning Objects (LO) located in distinct repositories (Rep 01, Rep 02, ..., Rep n) and described with different metadata standards. These standards are conceptualized by ontologies, which, when integrated, result in the union of ontologies (Ontology), which is used by agents to index and recover objects. There is also a search interface, through which the user requests objects. Searcher agent receives search requests from users and exchanges ACL (Agent Communication Language) messages with indexer agents which search their indexes for related LOs. The searcher agent then displays the objects found in order of relevance for the user’s query and provides options for search refinement.

For the development of the system, various frameworks already established in the relevant areas can be used. For example, for ontology construction and integration, will be used the Protégé framework [20], and its plugin Prompt [19]. For modeling the multi-agent system, the O-MASE (Organization-based Multiagent System Engineering) methodology [17] will be used through the Eclipse’s plugin, AgentTool III [23]. For multi-agent system implementation, the JADE (Java Agent Development Framework) framework [12] will be used, because it follows the FIPA (Foundation for Intelligent Physical Agents) specifications [24]. The Jena framework [21] will be used for communication of multi-agent system with the ontology. The interface for LOs search will be developed with JSP (Java Server Pages) and Servlets, and the interface
communication with the multi-agent system will be made via XmlRpc Protocol [2]. All these frameworks and technologies will provide the support and formalism required to implement the system.

### 3.1 Current state of development

The development of the system is in its initial phase. Research into metadata standards for LOs, semantic indexing and semantic search are being completed and the multi-agent system is being modeled. Components of the system that are already being implemented include an agent that is able to retrieve the metadata of LOs located in a repository, independent of metadata standard used to describe the LOs, and the Web server that communicates with the multi-agent system to turn the system into a Web application.

The O-MASE methodology is being used for multi-agent system modeling, and the diagrams are being drawn from the Eclipse’s plugin, AgentTool III. This plugin allows the construction of several diagrams that make it possible to model processes defined by this methodology. Figure 2 shows a diagram of the agents, with their capabilities, services, roles, and protocols.

![Figure 2 Agents diagram, modeled on the AgentTool III](image)
Figure 2 shows the two types of agents that the system will have, as well as the communication protocols between them and the capabilities, services and roles that they will implement. The details of the protocols, services, roles and capabilities are modeled after specific diagrams available in AgentTool III.

Agents that extract the metadata have a behavior: with the repository path as their parameter, they examine all files contained in that location. If the file is a Zip file, which corresponds to the LO package, the Java API (Application Programming Interface) ZipFile is used to examine the contents of the package. The agent searches the Zip file for the manifest file (e.g. imsmanifest.xml), which contains the name of the file where the metadata are. To do this, it uses Java API JDOM (Java Document Object Model), which allows parsing of the XML file. Once it has name of the file containing the metadata, the agent uses the same API to examine the file and extract the metadata. For the initial test, the researcher used LOs produced by the EXElearning tool, which exports them according to the model SCORM, whose metadata standard is the LOM and whose imsmanifest.xml file points to the metadata file imslrm.xml. It also exports IMS packages, whose metadata standard is the Dublin Core and whose imsmanifest.xml file points to the metadata file dublincore.xml. With this, the agent accesses the metadata and their values and then uses these values and the ontology to index the LO.

The Apache Tomcat Web server will be used to build the Web interface based on servlets and JSP pages. XmlRpc protocol, implemented in a Java API, transmits XML encoding via remote process calls (RPC) and allows the Web interface to communicate with the multi-agent system. The servlet implements the XmlRpc client and the agent implements the XmlRpc server. A request of the JSP page invokes a servlet, which contains the client, and the client calls the server, which triggers a behavior in the agent.

4. Related Works

Silva et al. [22] used agents to develop intelligent LOs and focused on the learning environment as a multi-agent system, without addressing the reuse of LOs from different repositories.

The use of agents to index and retrieve information from the Web appears in such works as Peng et al. [18] and Wang et al. [25]. Others works, such as Carbonaro [6] and Lee et al. [14], use ontologies to retrieve information focused on learning environments, including the recovery of LOs, though only in a very specific domain.

The overview presented by Nash [15] shows the current state of art in the area of LOs and defines the role of the LOs’ repository. Nash also shows how the recovery is done in some existing repositories, demonstrating that recovery approaches are usually proprietary and closed.

The work of Laclavík et al. [13] presents agents that are able to reason with OWL ontologies. Thus, to the best of our knowledge, our proposal is the only one
to combine the use of ontology matching and multiple agents to cope with heterogeneities of the LOs descriptions based on different standards.

5. Conclusions

This work demonstrates that the use of LOs, which has attracted much interest from the scientific community, is of extreme importance to e-learning environments. Nevertheless the variety of specifications and standards produced in this area has created problems for the reuse of LOs already produced. This heterogeneity complicates the interoperability of applications with repositories containing objects described by different metadata standards.

The present proposal brings a solution to the problem of finding and reusing LOs through the use of an ontology that is the union of the ontologies of existing metadata standards. Supported by a multi-agent system, the system uses this ontology to enable interoperability among different repositories. In addition to providing for the reuse of LOs from different repositories, this solution will seek to improve the accuracy and coverage of the objects recovery by semantically indexing the LOs and improve the recovery performance, by conducting the search in the index, instead of directly on the object collections.

The solution presented for the recovery and reuse of LOs, once tested and evaluated, may be applied in other situations that require interoperability to recover objects with description heterogeneity that can be contextualized by ontologies. The proposal may also be integrated with an LMS (Learning Management System) so that the recovered objects may be used directly in the teaching and learning process.

References

Proposal of Multi-agent System for Indexing and Recovery applied to Learning Objects