# Dynamic Selection of Learning Objects Based on SCORM Communication

João de Amorim Junior(✉) and Ricardo Azambuja Silveira

PPGCC – UFSC, Florianópolis, Brazil
joao.amorim@iate.ufsc.br, ricardo.silveira@ufsc.br

**Abstract.** This paper presents a model to select Learning Objects in e-learning courses, based on multi-agent paradigm, aiming to facilitate the learning material reuse and adaptability on Learning Management Systems. The proposed model has a BDI multi-agent architecture, as an improvement of the Intelligent Learning Objects approach, allowing the dynamic selection of Learning Objects. As the first steps of our research, we implement a prototype to validate the proposed model using the JADEX BDI V3 platform. Thereafter, we extends the framework to allow the communication of the agents with SCORM standard resources, making possible to build enhanced dynamic learning experiences.

**Keywords:** Dynamic learning experience · Intelligent learning objects · SCORM

## 1 Introduction and Related Works

Adaptability and reuse are important aspects that contribute to improve learning process in virtual learning environments [1]. The former relates to different students' profiles and needs. An adaptable system increases the student understanding, taking into account its knowledge level and preferences [2,3,4]. The latter means that it is unnecessary to develop new resources if there are others related to the same learning purpose [4,5]. Some computational tools improve the teaching-learning process, i.e.: (1) Intelligent Tutoring Systems (ITS) - applications created for a specific domain, generally with few adaptability and interoperability [6]; (2) Learning Management Systems (LMS) - environments used to build online courses (or publishing material), allowing teacher to manage educational data [1], [7,8]; and (3) Learning Objects (LO) - digital artifacts that promotes reuse and adaptability of resources [9]. LO and LMS provide reusability, but they usually are not dynamically adaptable [8,9]. This article presents our research that seeks the convergence of these different paradigms for the development of intelligent learning environments and describes the mechanisms of an Intelligent Learning Objects' dynamic presentation model, based on communication with SCORM (Sharable Content Object Reference Model) resources [19, 20].

There are analogous studies that provides adaptability to learning systems. Some examples extend the LMS with distinct adaptive strategies, such as conditional jumps [8], Bayesian networks [3] or data mining [7]. Other researches are not integrated with


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a LMS, and use diversified ways to adapt the learning to the students' style, i.e.: ITS [6], recommender system [2], genetic algorithm [10] and swarm intelligence [11].

Moreover, there are some similar works based on the Multi-Agent System (MAS) approach resulting on smarter applications [12,13]. Some of them combine LMS and MAS to make the former more adaptive [14], and another is a dynamically adaptive environment, based on agents that are able to identify the student cognitive profile [14]. These related works identify the student's profile applying questionnaires in the beginning of the course or by clustering the students according to their assessments performance. Additionally, we observe in these papers that the attachment of new LO to the system is not possible without teacher intervention. The educator needs to configure previously all the possible course paths for each student style, what could be hard and take so much time [3]. Further, the attaching of a new LO to the course involves modifying its structure, resulting in limited adaptability and reuse.

In order to produce more intelligent LO, we have proposed in previous researches the convergence between the LO and MAS technologies, called Intelligent Learning Objects (ILO) [15]. This approach makes possible to offer more adaptive, reusable and complete learning experiences, following the learner cognitive characteristics and performance. According to this approach an ILO is an agent capable to play the role of a LO, which can acquire new knowledge by the interaction with students and other ILO (agents information exchange), raising the potential of student's understanding. The LO metadata permits the identification of what educational topic is related to the LO [9]. Hence, the ILO (agents) are able to find out what is the subject associated with the learning experience shown to the student, and then to show complementary information (another ILO) to solve the student's lack of knowledge in that subject.

## 2 ILOMAS

The proposed model integrates MAS and LMS into an intelligent behavior system, resulting on the improvement of the related works, leading to dynamic LO inclusion. The objective of the new model called Intelligent Learning Object Multi-Agent System (ILOMAS) is to enhance the framework developed to create ILO based on MAS with BDI architecture [16], extending this model to allow the production of adaptive and reusable learning experiences taking advantage of the SCORM data model elements. The idea is to select dynamically ILO in the LMS according to the student performance, without previous specific configuration on the course structure. The proposed model achieves reuse by the combination of pre-existed and validated LO whose concept is the same of that the student needs to learn about, avoiding the building of new materials. Moreover, the course structure becomes more flexible, since it is unnecessary to configure all the possible learning paths for each student profile.

The solution's adaptability is based on the ability to attach new LO to the LMS (that was not explicitly added before) as soon as the system finds out that the student needs to reinforce its understanding on a specific concept. This is automatically identified through the verification of the student assessment performance (i.e.: grade), on each instructional unit, or by student choice, when the learner interacting with the LO.

It is important to clarify that the approach does not use student' learning profile (i.e.: textual, interactive [2]) as information to select LOs. The scope of this research is to consider only the learner performance results (grades, time of interaction, sequencing and navigation). The ILOMAS is composed by agents with specific goals, and capable of communicating and offering learning experiences to students in a LMS course, according to the interaction with these students, taking advantage of the SCORM standard's features [19]. The ILOMAS architecture needs two kinds of agents:

- LMSAgent – Finds out the subject that the student must learn about, and passes the control of the interaction with the student to a new ILOAgent. Its beliefs are data provided from the LMS database, i.e.: the topic that the student must learn about.
- ILOAgent – Searches for a LO on the repository (related to the topic obtained from the LMSAgent), and exhibits it to the student. Besides, monitors the interaction between the student and the LO, which means the analysis of the data received from the SCORM communication. Depending on the analyzed data (beliefs), the agent will deliberate the exhibition of another LO (course with dynamic content).

The JADEX BDI V3 (V3) platform was chosen to implement the agents based on the BDI architecture [12,13]. The design of ILOMAS includes the characteristics of e-learning courses deployed on LMS (as MOODLE [7]), which means an environment accessed mostly from Web Browsers. The Java Servlets and JSP technologies are the bases of the interface between the client side (student) and the server side (agents' environment), getting benefits of the V3 services communication structure [13]. A non-agent class based on the Facade design pattern [17] keeps the low coupling between the MAS layer and the external items (front-end and servlets).

A first prototype was developed and tested with emphasis on the MAS development, instead of visualization issues (such as LO formats or graphical user interfaces) [18]. The simulation of a learning situation resulted on a different LO retrieved from the repository. This new LO had the same subject as the previous LO shown. It was not explicitly defined in the database that the student should have watched this new LO (only the topic was defined, no specific LO), so the MAS obtained the related LO dynamically, taking into account the metadata elements declared in IEEE-LOM [9].

### 2.1 ILOMAS and SCORM Integration

The extension of ILOMAS to use the SCORM standard [19,20] raises reuse, dynamic sequencing, and interoperability on learning environments. The SCORM specification defines a set of API functions, which allows the communication among the student, the LO and the LMS. This API admits that the ILOMAS uses the data model elements to define the student's knowledge level, and to evaluate the status of the current experience. Some available elements are the learner's answers to quizzes (result), the elapsed time since the beginning of the interaction (latency), the weighting of the interaction status relative to others, and a description of the LO's objectives [19]. If the learner demonstrates difficult in some subject (i.e.: wrong answers in sequence on the SCORM quiz, or take a long time to interact with the LO without any progress), it is possible to make decisions based on the historical received data.

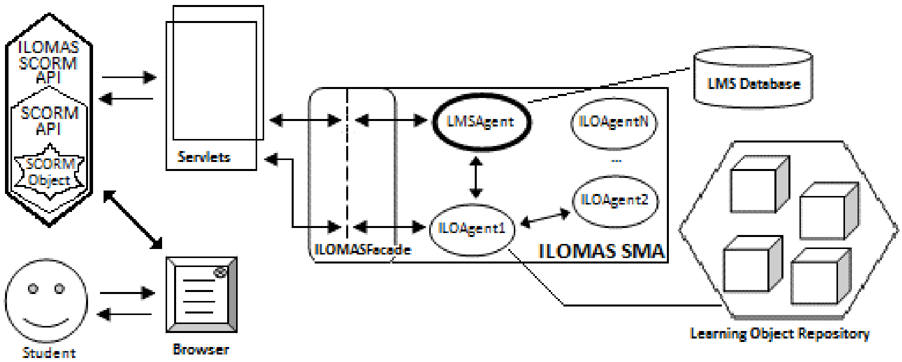


**Fig. 1.** ILOMAS SCORM Web architecture

The main desire defined to ILOAgent is to solve the student's lack of understanding about the subject. Thus, when the data received from SCORM points to a learner difficulty (error), the ILOMAS deliberation process (based on the JADEX engine [13]) dispatch the goal related with this objective. The ILOAgent's belief base stores the data received, and the deliberation process defines that the student needs to view a new (different) LO when the student selects an incorrect answer. This is the moment when the system achieves a dynamic learning situation, because a new LO not defined previously becomes part of the course structure. From the student's point of view (and even the teacher's point of view) the accessed object was just one, but with several contents (a larger LO composed dynamically by other smaller).

To validate this new version of the platform (SCORM integrated), we used some SCORM objects (on the version SCORM 1.2) about Social Security Laws (Public Law course). The learning interaction takes place in a custom LMS developed with limited features, only to test purposes. The implemented SCORM integration to ILOMAS was tested to reproduce distinct learning situations (Table 1): student that selects all the corrected answers (Student 1), another that misses all questions (Student 2), and one who increases understanding on the subject during interaction (Student 3). Each time that a student makes a mistake, the ILOMAS identifies the understanding problem and suggests another related LO to fill the learning gap (Fig. 2).

**Table 1.** ILOMAS SCORM preliminaries evaluation tests

| Student | Quiz Errors | Previously Configured LO | New LO Offered | Dynamic Behavior |
|---|---|---|---|---|
| Student 1 | 0 | 1 | 0 | No |
| Student 2 | 4 | 1 | 4 | Yes |
| Student 3 | 1 | 1 | 1 | Yes |

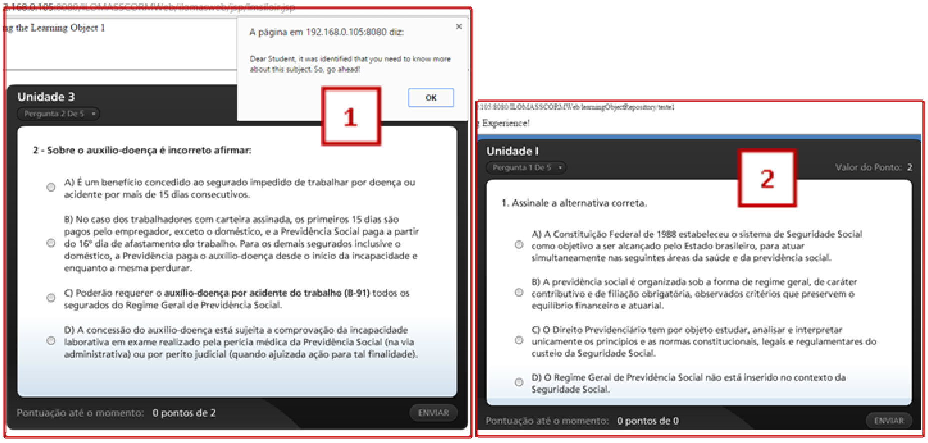


**Fig. 2.** The ILOMAS SCORM Web application execution: (1) The moment of the identification that the student needs another LO (wrong answer); (2) New LO exhibition

## 3 Conclusions and Future Work

This research resulted on a prototype implementation to verify the proposed model and its feasibility, followed by the execution of some evaluation tests. The SCORM API implementation gives to ILOMAS the ability of monitoring the overall communication between the LO and the learner, getting benefits of the SCORM data model element (i.e.: interaction status and time of the current learning session).

Future work leads to enhance the analysis of the received SCORM elements, taking into consideration the history of the student's experiences, and to explore all the SCORM data model elements in the process of determining if the learner needs to view a new LO. Another improvement would be the integration of ILOMAS with some MAS based recommender system for indexing and retrieving the related LO within the repository [21]. Finally, future work involves building a new plugin to integrate the ILOMAS inside the MOODLE LMS, and testing the application with different learning situations inside a LMS production instance, with real students.

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