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An Agent-Based Approach for Supporting Ubiquitous Learning

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Abstract— A mobile learning environment provides students with a teaching method that would be not possible to be performed in a conventional web-based course. The use of Learning Objects (LOs) in a standard way consists of an effective way to allow, among other features, content reuse and interoperability between different Learning Management Systems. However, a problem that occurs frequently is the unsuitability of the content to the context in which the student is inserted. A context-aware mobile learning support environment allows to solve this problem. Thus, this paper presents an agent-based approach to context-aware recommendation of LOs in order to enhance the teaching process in mobile learning.

Index Terms— Mobile learning, Learning objecs, Learning management Systems, Agent, Context-aware.

1 Introduction

DISTANCE Education (DE) is a mode of teaching and learning which has been growing quite some years ago. The developments of computer networks, the improvement of the processing capability of personal computers and the advance of multimedia technologies, among other factors, contributed to the creation of this scenario. However, despite consisting of an effective teaching method, still presents some challenges, among which can be highlighted the need for a computerized support appropriate to the characteristics of each person. Through this support is possible to automate increasingly the process of learning, making the teacher a facilitator, ceasing to be the main source of information and passing to drive the learning process [1].

One of the ways to provide DE is through the use of mobile devices, this modality is known as mobile learning. This way of providing education allows that students and teachers can take advantage of the resources offered by mobile technologies. One of these benefits is the possibility to access, view and provide content irrespective of time and from any location [2].

However, even with the benefits offered by mobile learning, the particular characteristics of each student should be considered, including the resources which they hold. This is necessary not only to provide content that meets the needs of students, but also to provide content in an appropriate way to the constraints of mobile devices since they have distinct and limited resources. In this context, arises the concept of context-aware environments. This kind of environment fits to the user, considering information provided by the selfsame user, beyond those captured dynamically from his interaction with computing devices [3].

For the purpose of developing context-aware environments in the learning domain, called Ubiquitous Learning Environments (ULE) [4], it is essential that educational content be created in a standardized manner. Thus, it is possible that a Learning Management System (LMS) shows the contents properly and reuse content in different contexts and from different repositories. Furthermore, it is possible to combine different contents, which, in turn, improves the production process and, consequently, reduce its costs [5]. An effective way to standardize educational content is through the use of Learning Objects (LOs), which consist of small units of content that can be used, referenced and reused during a learning process [6], [7].

Given the relevance of the topic, the present work has as its general goal to provide a learning environment, through the use of mobile devices, to help and fit the needs of the students, according to characteristics of the context in which they are inserted.

This paper is divided into seven sections. Section 2 presents an overview of multiagent systems (MAS) to support learning. Section 3 describes the learning objects, as well as the standards used in their development. Section 4 presents the concepts and inherent characteristics in ubiquitous learning environments. Section 5 discusses related works. Section 6 describes the agent-based approach proposed in this paper and the role of each agent. The last section presents our final remarks and a discussion of future works.

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2 Use of Agents in Learning Support Systems

In despite of different definitions of agents that can be found in the literature, there is still no consensus on the issue. However, it is possible to construct a concept from the definitions given by researchers.

According to [8], agents are autonomous software entities that perceive their environment through sensors and that act upon that environment through actuators, processing information and knowledge. A multiagent system (MAS), in turn, consists of a set of autonomous agents that collaborate to solve a problem which would be impossible to solve with just one agent.

Agents can be constructed in various ways. They can be agents of software or hardware, static or mobile, persistent or non-persistent, reactive or cognitive (intelligent). According to [1], one of the most important classification of agents is in relation of them to be reactive or cognitive. Reactive agents are agents that select actions to perform based solely on current perception, not considering the historical of perceptions. Since they do not have memory, they are unable to plan future actions. The cognitive agents are more complex since they have an explicit representation of both the environment and the other agents. This agent type has memory, which enables it to plan future actions based on situations that took place previously [8], [1].

Also according to [8], another feature to be taken into consideration is the rationality, which is influenced by four factors: i) performance measure (it defines the success criteria); ii) prior knowledge of the agent; iii) actions that the agent can perform; and iv) following perceptions captured by the agent so far. Faced with these elements, it is possible to conceptualize a rational agent as one which, for each possible sequence of perceptions, selects an action that will maximize its performance measure, given the evidence provided by the sequence of perceptions and any internal knowledge of the agent [8]. Considering this definition, one can realize that is not always that a rational agent will make the best decision possible, but one that improves its performance measure.

Intelligent agents can perform various tasks in context-aware learning environments, such as i) monitoring the activities of the student in the learning environment, ii) automatically capture information from the dynamic context of the student, iii) recommend interest content for that student, among others. Before the increase in the number of students who interact with learning support systems, the use of agents to perform these tasks become extremely important, mainly due to the fact that they are complex tasks for the facilitators to manage from distance.

3 LEARNING OBJECTS

An important concept regarding the educational content used in DE is the Learning Object (LO). According to Learning Technology Standard Committee - LTSC, from the Institute of Electrical and Electronics Engineers (IEEE), a LO is an educational material entity, digital or not, that can be used for learning, education or training [7].

According to [9], there are seven characteristics of LOs, while for [10] there are four properties presented by LOs. Table 1 shows a comparison between the LOs properties presented by these authors.

TABLE 1
PROPERTIES OF A LEARNING OBJECT

Properties of LOs	Description	[9]	[10]
Reusability	A LO can be reused several times in different learning environments.	X	X
Acessibility	A LO can be easily accessed by the Internet to be used in various locations.	X	X
Interoperability	A LO can be used and managed across different hardware platforms, web browsers and operating systems, allowing effective exchange among different systems.	X	X
Durability	A LO can be used and reused regardless of technology changes.	X	X
Adaptability	A LO can be adapted to any learning environment.	X	---
Granularity	The LO content must be fragmented to facilitate its reuse.	X	---
Metadata	The LO content can be described with properties of an object, such as title, author, date, subject, description, etc.	X	---

Thus, a LO, beyond the content itself, has a structure containing metadata that allows, through its elements and attributes, describing its contents, its format, how that content is presented, beyond other information (content author, creation date, educational data, etc.). This metadata is created based on standards that will be presented in Subsection 3.1.

In summary, the central idea of the concept of LOs is to allow educational designers build relatively small educational components that can be used in different learning contexts. In other words, they are digital contents that enable or facilitate reaching an educational goal and their reusability [11].

3.1 Learning Objects Standards

Despite the benefits of using LOs, it should be also considered the problems faced in creating digital LOs. [5] describes a series of difficulties that are faced while creating digital LOs: i) definition of the navigational structure; ii) adequacy of the contents of a print media to electronic media; iii) assistance to the pedagogical aspects of teaching; iv) integration of LO with different types of DE environments; and v) high cost of authoring tools' licenses.

To solve these problems, LOs standards are used. According to [12], these standards are a way of organizing the data of a LO to provide communication among different computing environments, as well as ensure its accessibility and usability, and also to provide interoperability. The authors report that these patterns are divided according to their functionality in: metadata, packaging, interface and communication and integration standards.

The metadata standards are used in the resources' identification, aiding in the filtering of a search and retrieval of a record or a LO [12]. An example of the meta-

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data's standard is the LOM (Learning Object Metadata) [7], which was developed by LTSC [6]. The purpose of this standard is to facilitate search, evaluation, acquisition and use of LOs, both by students and instructors, or even automated software processes. Additionally, this standard also facilitates the distribution and exchange of LOs, allowing the development of catalogs and inventories considering the diversity of linguistic and cultural contexts in which the LOs and their metadata are reused. By specifying a common data schema, this standard ensures that the connections of LOs have a high degree of semantic interoperability [7]. Data elements describe a LO and they are grouped into categories. The basic metadata's structure of the LOM is defined in nine categories, as shown in Table 2 [7].

TABLE 2
LOM STANDARD CATEGORIES AND THEIR DESCRIPTIONS

Categories	Description
General	It gathers general information describing the LO as a whole.
Lifecycle	It groups the features related to the history and current status of LO, beyond the aspects that affected the LO during its evolution.
Meta-Metadata	It gathers information about the instances of the metadata itself (instead of LO that the metadata's instance describes).
Technical	It gathers the characteristics and technical requirements of the LO.
Educational	It gathers the educational and pedagogical characteristics of LO.
Rights	It describes the intellectual property rights and conditions of use for LO.
Relation	It gathers the characteristics that define the relationship between the LO and other related LOs.
Annotation	It provides feedback on the LO educational use and information about when and by whom the comments were created.
Classification	It describes the LO with regard to a system of particular classification.

An integration standard, as the name implies, unifies in a reference model different types of standards, such as metadata standards, packaging, communication and interface, developed by other organizations [12]. The integration standard SCORM (Sharable Content Object Reference Model), developed by ADL (Advanced Distributed Learning) [10], integrates a set of technical standards, specifications and guidelines designated to attend the requirements of high level of SCORM - systems and accessible content, interoperable, durable and reusable. The content in SCORM standard can be distributed to students through any LMS that is compatible with and use the same version of SCORM [10].

In this paper we will use LOs developed according to the SCORM standard, both because it is a widespread standard and it is also composed of a series of other standards. Thus, we can enjoy the best benefits offered by each standard.

4 UBIQUITOUS LEARNING ENVIRONMENTS

An ubiquitous learning environment may be understood as a context-aware mobile learning environment, providing most adaptive contents for learners. Context awareness describes a paradigm in which the context of a user is considered to define his profile [3], [14]. There is no consensus about the definition of "context". This one is specific of the application and the desired intention, requiring the identification of functions and properties of the individuals' domains [3], [13], [14].

Context can be defined as information consisting of properties that combine each other to describe and characterize an entity and its role as a computer-readable form [3], [14].

The location is crucial to the context of the student in an environment for ubiquitous learning. However, the context includes more than just the location. A wide range of context factors combine themselves to form a context definition. Almost all information available at the moment of interaction can be seen as contextual information, among which stand out [3], [15]:

• The various tasks required from users;

• The wide range of devices that combine to create mobile systems with associated infrastructure services;

• Resources availability (e.g. battery status, screen size, network bandwidth, etc.);

• Resources in the neighborhood (e.g. accessible devices and servers);

• The physical situation (e.g. temperature, air quality, brightness level, noise etc.);

• Spatial information (e.g. location, orientation, velocity, acceleration etc.);

• Time information (e.g. time of day, date, season, etc.);

• Physiological measures (e.g. blood pressure, heart rate, respiratory rate, muscle activity etc.).

The list above, though not exactly contain all the information that can be considered, is used to demonstrate the inherent complexity of the context, its specific nature of domain and difficulty to define and measure it [3]. In an attempt to reduce this complexity, [14] defines two general types of context: i) static context (named customization), which concerns a use case in which a user profile (context) is created manually and the user is actively involved in the process and having an element of control; and ii) dynamic context (named personalization), which refers to the condition in which the user is seen as passive, or at least with a little less control. In this case, the system monitors, analyzes and reacts dynamically to user behaviour and the identified role.

Many context-aware mobile learning applications

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(ubiquitous learning environments) use learning contexts in order to appropriately adjust or suggest content and activities for students [2]. However, these works do not consider the capabilities of mobile devices, what compromises a more precise definition of the context of students.

5 Related Works

Multiagent systems (MAS) have been widely used in educational environments. This technology can provide an aid to learning environments, making these environments more proactive and autonomous. MAS can be useful, for example, in developing a context-aware feature in a learning environment.

In [2], it is described a context-aware mobile learning environment architecture consisting of three main components: the learner profile, a personalization mechanism and a LO repository. The learner profile stores his mobile learning preferences, gotten through a questionnaire answered by the learner, in which he indicates preferred location of study, noise level and time of day. The personalization mechanism gets this profile and matches its information with the current values detected by the context-aware technologies. Then, the personalization mechanism compares all information obtained with the metadata of LOs available in the repository. The system then recommends appropriate LOs for students in accordance with their context characteristics.

In [16], it is described an ubiquitous learning architecture for supporting student to learn English as foreign language in order to prepare for TOEFL (Test of English as a Foreign Language). The system provides adaptive content for different learners based on context-awareness, considering location, time, manner as well as learner's knowledge. This is possible through suggested topics as well as test questions. [16] also describes CAMLES (Context-Aware Mobile Learning English System) prototype, that allows the learner to receive adaptive materials for TOEFL anytime in anywhere with mobile phone. The main difference of our work for the last one is the fact that our approach considers the definition of context, beyond the student's profile information, information of available physical resources such as connection type, format (video, audio, etc.) supported by the mobile devices.

6 An Agent-Based Approach for Recommending Context-Aware Learning Objects

The agent-based approach proposed in this paper is presented in Figure 1. According to this approach, three types of agents are proposed: Student Agent (SAg), Recommender Agent (RAg) and Interface Agent (IAg). The SAgs are responsible for monitoring the activity of students in the learning environment and sending to RAgs static and dynamic information of the student's profile. These information are recovered from the ontology of static and dynamic context respectively. The RAgs are responsible for identifying appropriate learning objects (LOs) to the student's context, according to both the information provided by SAgs and the learning objects available in the repository. Once identified these information, the RAgs inform both the IAg and the instructor.

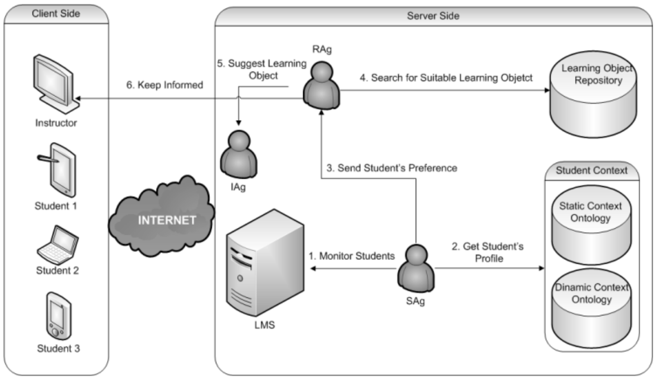

Fig. 1. Agent-based approach for recommending learning objects

6.1 Agents Model

This section describes how the agents in the proposed agent-approach were modeled and implemented. For a better understanding, it was chosen to detail this approach using the MAS - CommonKADS+ [18], a methodology for modeling multiagent system, which consists in an extension to the traditional methodology MAS-CommonKADS.

This methodology describes the agents through diagrams and CRC (Class-Responsibility-Collaborators) cards, referring to the tasks of the system. These artifacts describe features that the system should perform. The roles model shows the roles which each agent can play in the system. These roles are responsible for meeting the existing tasks in the task model. The diagram in Figure 2 shows the system roles model.

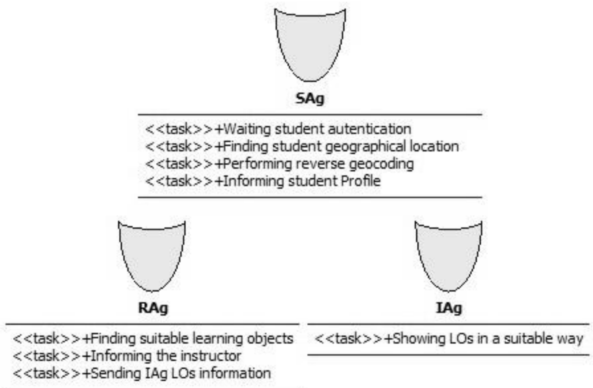

Fig. 2. Roles model

CRC cards, on the other hand, show the details of the agents and their goals. Each CRC card is built to specify a particular agent. The agent goals are listed and the plans

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(actions that should be performed to achieve the goals) are described. It also identifies the knowledge that the agents own to perform their actions and the agents that collaborate in the execution of plans and services through which the interaction takes place among agents [19]. The CRC cards will be shown in the next sections.

Another model used in this methodology is the agent model. This one is responsible for defining which agents will be responsible for each presented role, by defining the agent architecture, their goals and characteristics, such as data entry, activation conditions of the agent and available information types. Figure 3 shows this diagram for the Recommender Agent (see Section 6.3).

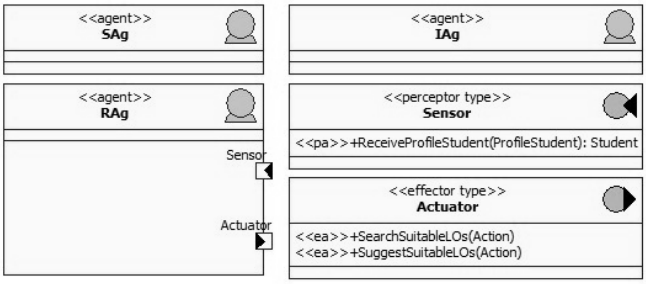

Fig. 3. Agent Model

The MAS-CommonKADS+ methodology, in its turn, proposes the integration of AML (Agent Modeling Language) to the MAS-CommonKADS methodology. Finally, it also suggests, among other things, the use of an interaction model to describe all the interactions among agents through the AML. This model is represented by interaction diagrams, like sequence and communication diagrams, using AML diagrams [18]. It was chosen to use the sequence diagram in this work. This diagram will be shown in the next sections.

6.2 Student Agent (SAg)

SAgs are intended to search, in both the static and the dynamic context ontologies of the students, the learning preferences that make up their profiles and dynamic information of the student context. To facilitate the comprehension of the behaviour of SAg, Table 3 shows the CRC card of the SAg.

TABLE 3
CRC CARD OF THE SAG

Agent: Student Agent (Sag)	Class: mod_StudentAgent
Goals	Verifying student profile.
Plans	Searching for a specified profile.
Knowledge	Student authentication.
Collaboration	Rag.
Service	Informing student profile.

The SAg has a one shot behaviour, in charge of perceive the authentication of a student at LMS. While not finding any student, the agent remains in a locked state. If a new student has logged into the LMS, the agent loads the student profile ontology model, and it looks for the preferences of this student. Then, the preferences information, in conjunction with information about the student geographical location, are sent to the RAg, so that it can identify LOs tailored to the needs of this student.

The following Java code shows the SAg's behaviour whose aim is to read both the static and the dynamic student information.

```
1. public class StudentAgent extends Agent{
2. [...]
3.   private class SearchForStudent extends OneShotBehaviour{
4.   @Override
5.     public void action(){
6.       int id = (int) getArguments()[0];
7.       Location location = (Location) getArguments()[1];
8.       Student student = new OntologyParser(ONTOLOGY_PATH).
9.         getStudent(id);
10.      student.setLocation(location);
11.      send(student);
12.    } // End of action() method
13.  } // End of SearchForStudent Behaviour
14. [...]
15. } // End of StudentAgent
```

In the line 6 of the presented code, the SAg discovers the current location of the student. In the line 8, it maps information from the student's preferences in the ontology through a Java class, according to the specified student ID. Finally, in the line 11, it sends the student profile to RAg. Figure 4 shows the messages exchange flow between the SAg and the RAg through the interaction model.

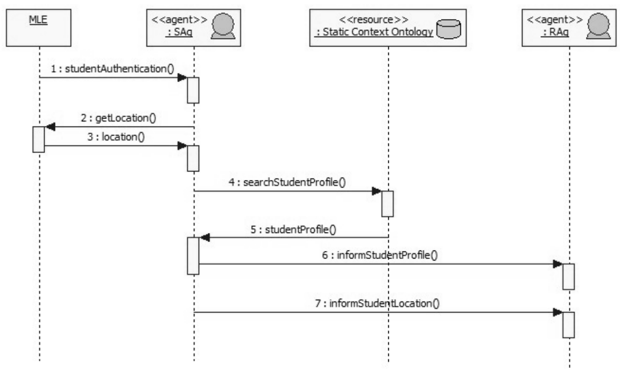

Fig. 4. Interaction model between the SAg and the RAg.

6.3 Recommender Agent (RAg)

The RAg is responsible for detecting LOs appropriated to the context in which the student is inserted, according to information provided by the SAgs and the metadata information of the available LOs in the repository. Once the student context characteristics have been identified, it communicates to the instructor and passes information

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from the LO to the Interface Agent (IAg). To facilitate the comprehension of the behaviour of the RAg, Table 4 shows the CRC card of the RAg. The personalization mechanism used by the RAg is presented in Subsection 6.3.1.

TABLE 4
CRC CARD OF THE RAG

Agent: Recommender Agent (RAg)	Class: mod_RecommenderAgent
Goals	Finding suitable learning objects.
Plans	Searching for learning objects in the repository related to the student's profile.
Knowledge	Student profile and learning objects repository.
Collaboration	IAg
Service	Informing suitable learning objects.

The following code shows the Java code of the RAg cyclic behaviour, which goal is to wait the student profiles sent by SAg.

```
1. private class WaitStudent extends CyclicBehaviour{
2. @Override
3.   public void action() {
4.     try{
5.       ACLMessage msg = myAgent.receive();
6.       if(msg!=null){
7.         student = (Student) msg.getContentObject();
8.         addBehaviour(new FindLearningObjects());
9.       }else{
10.        block();
11.      }
12.    }catch(Exception e){
13.      System.out.println("Exception in
RecommenderAgent[WaitStudent]:
14.      " +e.getMessage());
15.    }
16. } // End of action() method
17. } // End of FindLearningObjects Behaviour
```

In the line 6 of the presented code, the RAg verifies if there is any message in its messages' queue. If there is any message, the RAg makes an instance of the student according to this content (line 7). Following, in the line 8, it executes the FindLearningObjetcs behaviour to find the suitable LOs. If there is no message, the RAg keeps itself blocked until a new message shows up (line 10).

The next code shows the FindLearningObjects behaviour, which is a kind of one shot behaviour. It is responsible for finding and recommending suitable LOs, according to both the student profile and the dynamic context information of the student.

```
18. private class FindLearningObjects extends OneShotBehaviour{
19. @Override
20.   public void action() {
21.     for(LearningObject recommendedOA:new RBC(student).
22.       getrecommendedOA()){
23.     new MessageDAO().sendMessage(2, "Current location:
24.     City: "+student.getLocation().getCity()+"
25.     State: "+student.getLocation().getState()+"
26.     Country: "+student.getLocation().getCountry()+"
27.     <br/>LearningObject:"
28.      "+recommendedOA.getTitleTagValue()[0]);
29.   } // End of for loop
30.  } // End of action() method
31. } // End of FindLearningObjects Behaviour
```

How can be viewed in the presented code, for each suitable LO found, the RAg sends a message to the student through the mobile application interface (lines 21 - 29). Figure 5 shows the messages exchange flow between the RAg and the IAg through the interaction model.

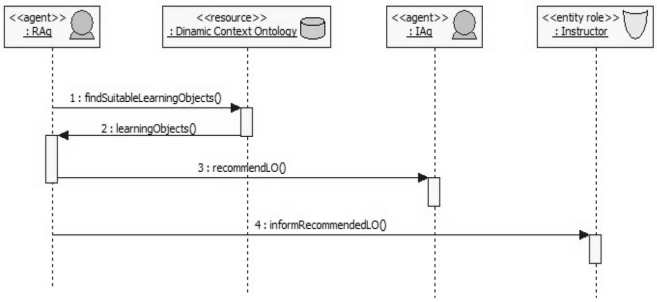

Fig. 5 Interaction model between the RAg and the IAg.

The Figure 6 shows the recommendation performed by this behaviour. The Subsection 6.3.1 shows how the personalization mechanism is performed.

Fig. 6. Main mobile application interface to recommend LO.

6.3.1 Personalization Mechanism

The personalization mechanism considers the preferred location and time for studying and preferred interest area of student, which can be found in the static context ontology. These information are weighted according to the influence level that each one implies in the student learning model. The strategy to identify the suitable LOs according to the student context is performed in accordance with the Equation 1.

$$RF = ((IA * 5) + (PL * 3) + (PT * 2))/10 - AF \quad (1)$$

The Recommendation Factor (RF), which is determined by the RAg, is mainly influenced by the Interest Area (IA) of the student, having therefore weight 5. The Preferred Location (PL) of study receives weight 3, since it has enough influence in the student's concentration capability. Finally, the Preferred Time (PT) of study is also of interesting, because it has influence in the concentration level and, thereafter, it can influence in a positive or negative way on the LO recommendation. The Adjustment Factor (AF) regards to a factor that can be established by the instructor in order to increase (when AF is smaller) or decrease (when AF is greater) the impact that the user's context implies in the LO recommendation. The numeric values of IA, PL and PT represent a comparison between the dynamically found values and the ones which have been defined in the student static context ontology.

To dynamically define the value which represents how suitable is the LO regarding to interest area of a student, the LO characteristics have three considerations: description, title and keywords. The RAg, on the other hand, verifies the frequency of student's interest words, which are present in the static context ontology, in these three LO characteristics. On following, these values are weighted by the RAg according to the Equation 2.

$$IA = ((KW * 3) + (D * 2) + (T * 1))/6 \quad (2)$$

The Equation 2 shows that the Keywords (KW) have the greatest weight, whereas they represent the issues treated in the LO in a better way. The Description (D) of the LO gives us an overview of how its several issues are integrated. Finally, the Title (T) represents a smaller influence among the three characteristics, due to the fact it does not contain a range of related words as extensive as the KW.

To dynamically define the PL factor, it has been made an extension in the application development framework MLE (Mobile Learning Engine) [20]. It has been added to this framework a class which is in charge of finding the student geographical location from an API (Application Programming Interface) integrated to the GPS (Global Positioning System) of the mobile device. Thus, it is possible to acquire the latitude and longitude of the mobile device. Then, this information is sent by the application client of the mobile device to SAg. On the other hand, the SAg performs the reverse geocoding3 of information before sending them to RAg.

Finally, the SAg dynamically finds the current time at the moment of system student authentication. This information will be used by the RAg to define the numerical value which will be assigned to the PT.

6.4 Interface Agent (IAg)

The Interface Agent (IAg) aims to provide students with information as they progress in the distance learning course in which they are participating. This agent adjusts the type of message according to the device capabilities of the student. To facilitate the comprehension of the IAg's behaviour, Table 5 shows the CRC card of the IAg.

TABLE 5
CRC CARD OF THE IAG

Agent: Interface Agent (IAg)	Class: mod_InterfaceAgent
Goals	Showing learning objects in a suitable way.
Plans	Checking the available resources for the student.
Knowledge	Suitable learning objects.
Collaboration	Student
Service	Showing learning objects in a suitable way

7 FINAL REMARKS

In this paper, it was described the implementation of an agent-based approach for recommending learning objects in ubiquitous learning environments. The proposed solution aims to make the learning environment suitable to the student's needs, considering their contexts. The presented agent-based approach can be used together with any learning management system, once it has been developed as an software layer independent of the application.

As further work, we can consider other user information, like the courses which the student has already participated in the past. This way, system could suggest LOs according to these preferences.

Another issue that can be implemented is the collaborative recommendation. This kind of recommendation considers suitable LOs according to similar preferences of students. First of all, the system identifies students with similar preferences. Then, it considers LOs chosen by the students in the past. According to these choices, the system suggests suitable LOs to the present student.

We also intend to do a case study with undergraduate students of the computer science course to evaluate the impact of the proposed agent-based approach in the learning content suitability.

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