m-AdaptWeb®: AN ADAPTIVE E-LEARNING ENVIRONMENT FACING MOBILITY
Adaptation and Recomendation Processes based on Context

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Abstract: This work presents a case-study focused in practical learning scenarios of m-AdaptWeb, an adaptive e-learning environment envisioning the exploration of mobile functionalities in the web-based learning environment AdaptWeb®. The main objective of our research is to provide content adapted to different students facing different learning problems when using their mobile devices. In this paper we present an infrastructure to allow mobile-aware behaviour to an e-learning system and a case-study that emphasizes the enrichment needed to be applied to learning objects metadata, in order to be effective in specific mobile conditions. Also, we show how m-AdaptWeb provides support for the adaptations presented to the students and for the recommendations depending on their progress in a specific learning activity.

1 INTRODUCTION

The growing adoption of distance learning (or e-learning) brought new focuses and resulted in fundamental changes in teaching and learning. In particular, as e-learning environments become widely used, more sophisticated personalized features have to be investigated.

An efficient solution for distance learning are the Adaptive Hypermedia Systems (AHS), which build a model of goals, preferences and knowledge of each individual user, and use this model throughout the interactions with the user, in order to adapt to his or her needs. Nowadays, with the multiplication of mobile devices, people are connected all the time and should be enabled to develop their learning activities wherever they are and what device they are using to.

Mobile learning (m-learning) is an emerging concept as educators had initiated exploring mobile technologies in teaching and learning environments, and they cover from the ability to transmit learning modules and administrative data wirelessly, to enabling students to communicate with tutors and peers "on-the-go" (Yuen and Yuen 2009). M-learning refers to learning opportunities through the use of mobile solutions and handhelds devices (i.e., PDA, mobile phones, smartphones and tablets) and it is engaged to deliver right information and resources – anytime and anywhere – to a specified user, in a rich interaction, with powerful support for effective learning, performance-based assessment and strong search capabilities (Yuen and Yuen 2009). Presently, these mobile devices have become cheaper and thus their usage by the students of our universities is more common. In addition, in many countries there is a government incentive for lowering taxes for these devices for educational use, offering a real possibility of use in high schools.

Our research in this paper goes further on the functionalities and requirements of these systems in order to be effective when learners develop their learning activities using mobile devices. We are not focusing just on mobile versions of e-learning environment, which must be previously downloaded and installed or specially developed for some group of mobile devices. Indeed, we are focusing on the real adoption of the m-learning environment *transparently* by the student, adapted to student´s context and needs.

To become this proposal a reality, is necessary to enrich the learning objects (LOs) available to each

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activity in the e-learning environment, providing different versions to be chosen in running time, according to student’s location, device, interests, behavior, learning activity, knowledge and performance as being presented in the m-learning environment. Also, we present our integration of two fields of study, recommender systems and adaptive systems - in a synergistic way. Our approach deals with creating context-aware recommendations of different LO and filtering and adapting the user interface, the navigation and the LOs taking in account the user´s context and situation as well.

This work is structured as follows. Section 2 presents a background on e-learning environments (ELEs). Section 3 present general concepts of adaptation and recommendation and theirs connection with ELEs. In section 4 we show the infrastructure of m-AdaptWeb. A case study focused on the internal operation of m-AdaptWeb is presented in section 5, with our proposal for adapt the student’s interface and recommend learning content. The work finishes in section 6, with our conclusions and future works.

2 E-LEARNING ENVIROMENTS

Many are the ELE projected to manage distance learning. They are constantly improved in order to better fit the exigencies of real persons facing real learning problems. Some examples of these systems are: Moodle (Moodle, 2011), BlackBoard (BlackBoard, 2011) e SAKAI (Sakai, 2011).

The main objective of those environments is to structure and manage content, not necessarily enabling: content adaptation; student-teacher interaction facilities; and authoring tools. These facilities are not found in traditional e-learning environments, but they have been required as much as these systems are more intensively used and easily accessible via Web.

AHS have the ability to adapt and personalize the systems content, navigation and presentation, and can incorporate some recommendations to each student. This means that the systems must be able to anticipate the needs to users and provide them with recommendations of items that they might appreciate based on their interaction with the system and with other user. Focusing on e-learning environments, this implies in personalize the interface and navigation to student’s, helping them facilitating their learning, and recommending the best LO, adapted by the student´s needs, tasks, profile and context.

There are many AHS works described in the literature, like for example De Bra (2008) and Canales et al. (2007). In our research the experiments are developed into the AHS AdaptWeb®, which consists on an adaptive web-based learning environment developed by the efforts of different Brazilian academic institutions. AdaptWeb® is an e-learning environment able to adapt hypermedia courseware contents and navigation to student’s characteristics and preferences. It was developed in PHP language and handles a MySQL data base to store the students and learning data. The software is free and available at the sourceforge website (AdaptWeb, 2003).

The adaptive character of AdaptWeb® is mainly supported by the structuring phase of a discipline (e.g. Introduction to Programming, Artificial Intelligence or Calculus). To develop the discipline content, the author registers all concepts and materials related to each topic. After that, AdaptWeb® generates XML that represent the domain content of each discipline in particular, and is used by adaptation module to filter the different learning objects that are linked to a student profile.

Storing files in XML format makes possible to structure data in a hierarchical way, making possible to filter the content of a discipline to determine which content have to be present to each learner and how. In this sense, discipline content may be applied to different courses (e.g. Computer Science, Mathematics, Physics), adapting which concepts and their related documents have to be presented.

2.1 Managing Learning Objects

A learning object (LO) is defined as any entity, digital or non-digital, that may be used for learning, education or training (IEEE, 2002). The LOs have several characteristics which justify their use. Ferlin et al. (2010) describe the characteristics differentiating them in technical and pedagogical.

The technical characteristics are related to the standardization, storage, transmission and reuse of LOs. Among these features, stand out: reusability, interoperability, granularity, classification and adaptability. The pedagogical features focus on the construction of knowledge from the use of LOs and on the concern in their construction. These features are: interaction, autonomy, cooperation, cognition and affect (Kemczinski et al., 2011).

Seeking to provide solutions for storing, managing and searching LOs, a lot of repositories were developed like: MERLOT (2008), LabVirt (2010), BIOE (2010), OE^3/e-tools (2010) and

Interred (2010). In this work, we adopted the repository ROAI (Learning Object Repository for Computer Science and Informatics) (Kemczinski et al., 2011) to store the LOs. The set of metadata adopted in this work are presented in subsection 4.1.

3 RECOMMENDING PROCESS AND ADAPTABILITY

Recommender system describes any system that produces individualized recommendations as output or has the effect of guiding the user to interesting or useful objects in a large space of possible options (Burke, 2002). Recommender systems can apply the following kinds of techniques in recommendation (Jannach et al., 2011): i) *Collaborative recommendation*, implies implicit or explicit collaboration among users; ii) *Content-based recommendation*, based on the availability of item descriptions and a profile that assigns importance to these characteristics; iii) *Knowledge-based recommendation*, when historical information is not available, this technique makes use of additional information (like technical feature of products) for recommendation; and iv) *Hybrid approaches*, this approach combines different techniques to generate better or more precise recommendations.

In the special case of e-learning environments, the recommendation process has to take into account student’s relevant information, like student’s interests, goals and problems. In our research, beyond the user modelling and the learning objects information, we propose the use of student´s context and the experienced mobile situation in order to guide the recommendation. To us, the student´s context is considered as a 'broad notion' of relevant data that can be used for recommendation.

The areas of recommender systems and AHS can cooperate and actually one can benefits from the other. However, we recognize that one significant distinction relies in what is the final objective of each one. Normally recommender systems provide a set of resources that can be (or not) choose by each user/student. By the other hand, AHS - besides preparing different recommendations - also prepare and execute different adaptations and personalization for each user/student. Our work integrates both approaches in a synergistic way: our system is able not only to 1) creating context-aware recommendations of different LO and the students could choose accept or not, but also to 2) filtering and adapting the user interface, the navigation and the LOs taking in account the user´s context and situation as well. In the next section we describe the main characteristics of our system.

4 INFRASTRUCTURE OF m-AdaptWeb

In this section we present our infrastructure for modelling the user context in order to support recommendations and a richer adaptability focused on mobile devices. As presented in Figure 1, the m-AdaptWeb infrastructure has to deal with data stored in database repositories, related to: the LOs; technological and location data; the student profile, preferences and culture; learning domain data, which represents the taxonomy of terms being.

First, in the LO repository, we have the different LOs defined by the teachers and available to the students. Each LO is defined according to a specific set of metadata content, aiming at describing its different characteristics in order to be adapted to different mobile situations experienced by the students. Details about the metadata that describe the LOs are presented in the subsection 4.1.

The infrastructure also contains the description of the mobile devices, used by learners when navigating into the environment, and the location of this device. This data consist on sensor data, which describes: the kind of device student´s is using; the screen resolution; kind of navigation browser; the IP address and the network speed. These features are very important for the recommendation because the environment cannot recommend some LO that is not the most adequate for the used device.

The Learning domain provides a taxonomy of terms related to the learning domain being taught to the student. The “subject” element from the LOs metadata is related with some specific item from the learning domain. We need information about the student profile, preferences and culture to adapt/recommend some specific material. Thus, the Student personal data storages all needed information about the students including their profiles and contexts. These data are request by different ontologies in the semantic layer.

Our semantic layer includes two ontologies: the Technological ontology and the Learning ontology, which are described in details in (Pernas et al., 2011a), and an Student ontology, that, extended typical characteristics of the students, to include new dimensions (e.g. personal, educational and cultural context dimensions) and each dimension is

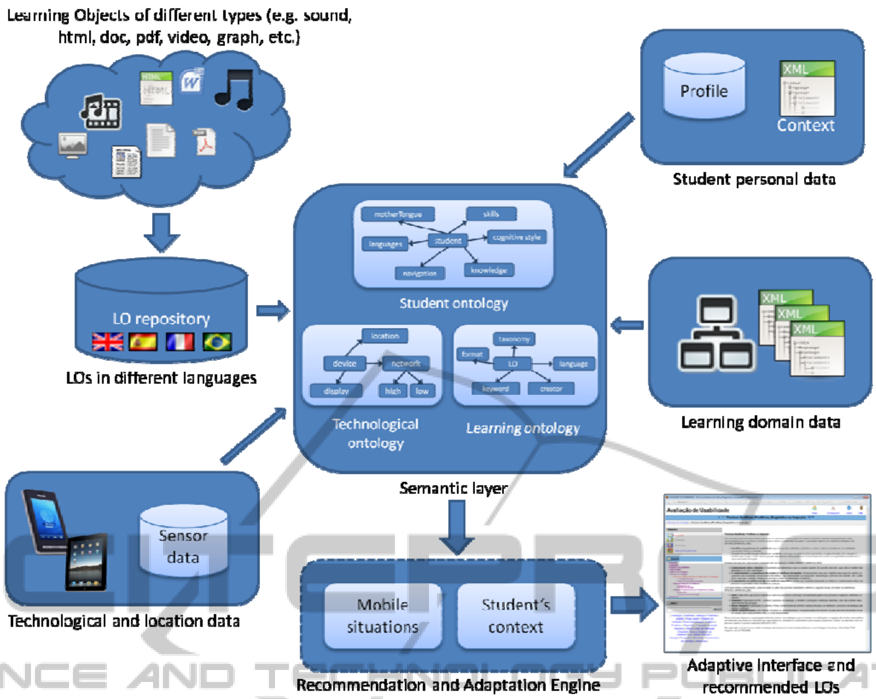

Figure 1: Infrastructure of m-AdaptWeb.

represented by a specific ontology that can be used jointly or separated, depending on the information that we have available. More information about each dimension can be found in Gasparini et al. (2011) and about the structure see Gasparini et al (2012).

The infrastructure presented in Figure 1 collects all relevant information from the repositories and merge it in order to define the current mobile situation of the student, depending on the LO being accessed; the technological requirements of the mobile device and the student's profile and context. To this merge, we are using the ontology network and situation ontology defined in (Pernas et al., 2011a) from which is possible to represent the relationships among the individuals, obtained from the data repositories, and infer the mobile situation. A practical application of the ontology network is presented in (Pernas et al., 2011b), with the relevant events and the learning situations detected.

The Recommendation and Adaptation engine is responsible to filter the content and present the right LO to the right situation detected. Details about the engine are presented in our Case Study, in section 5.

4.1 Structure of the Learning Objects

As we are working with an already existent and functional e-learning environment, but not designed to provide adaptations required by mobile users, the structure of the learning content had to be revised.

The diversity of LOs present in the web today, and their relationship with the current e-learning environment had led our group thought of how to store and organize these different materials. In this way we have been integrating the "*Learning Object Repository for Computer Science and Informatics (ROAI)*", an online repository, available to students in our university (Kemczinski et al., 2011) to AdaptWeb® environment. As ROIA uses the *Dublin Core* metadata standard, either adopted by us in our Domain model, the communication with ROIA repository was facilitated. The element properties defined by Dublin Core and applied in the ROIA repository are: *Contributor, Coverage, Creator, Date, Format, Identifier, Language, Publisher, Relation, Rights, Source, Subject, Title and Type*. More details about them in (Dublin Core, 2011).

AdaptWeb® requests the LOs to the ROAI repository, which returns the specified LOs. Diverse elements of the Dublin Core standard (Dublin Core, 2011) are needed, for example, the *Creator* element is important to AdaptWeb® to be able to check if the professor is responsible to the LO. The *Date* helps AdaptWeb® checks the date to the learning situation. With the *Format*, AdaptWeb® searches this element to compare to the learning style and culture-awareness of the student. The *Language* helps in discovering this element to recommend or not based on student´s skill in any language. The *Relation* is used to recommend a different LO. The *Subject* and *Title* are used to compare with the AdaptWeb®' subject and title materials.

5 CASE STUDY

In the case study we describe two different learning scenarios, where two distinct students, from different regions of Brazil, are developing the same learning activity. These two scenarios are focused on students from the 8th grade of the middle school.

General scenario – learning activity*: the students of the middle school (8th grade) have to develop a research work about the Liberal Revolutions occurred in Brazil in the beginning of the XX century. They have to choose one Revolution to explain and also relate the chosen revolution with other revolutions that were occurring in Europe at the same period.*

Profile of student_1*: José lives in Rio Grande do Sul, a state in the south of Brazil. He is developing the discipline of History, in the modality of distance learning. As he is visually impaired, he needs special functionalities when using a web-based learning system. Also, his learning style is active (learn by trying things out, enjoy working in groups) and verbal (prefer written and spoken explanation).*

José's current situation: *José is in the library, searching for some material about the Farroupilha Revolution. He is currently using his tablet to help him in this activity, connected in the Wi-Fi network from his school library.*

Profile of student_2*: Maria lives in Bahia, a state from Northeast of Brazil. She is also doing the discipline of History in the modality of distance learning. Her learning style is active, but she is visual (prefer visual representations of presented material, such as pictures, diagrams, flows and charts). As she had lived for 2 years in Canada, she has skill in English and French.*

Maria's current situation: *Maria is on the bus, going to her college, using her smartphone. She is searching for some material about the Sabinada Revolution, another Liberal Revolution occurred in Brazil. She is connected through a 3G data connection, which varies according to her location.*

Internal rules that represent the valid context of *José* and *Maria* in the infrastructure:

```
Context of João = {
  hasDevice (O_Student.João,O_Device.Tablet),
  hasNationality (O_Student.João,O_Nationality.BR),
  interac_pref (O_Student.João, O_Student.Style1),
  hasKnowledge(O_Student.João, O_Domain.History),
  hasCourse (O_Student.João, O_Course.8^th grade),
  hasTask(O_Student.João,O_Task.RW_01),
  hasRestriction(O_Student.João, O_Restrct.Visual),
  hasLocation(O_Student.João,O_Location.IPLibrary),
  style_1 (O_Student.João, O_Student.Verbal),
  style_2 (O_Student.João, O_Student.Active),
  hasConnection (O_Student.João,O_Netwk.High)}

Context of Maria = {
  hasDevice (O_Student.Maria,O_Device.SmarthPhone),
  hasNationality (O_Student. Maria,O_Nationality.BR),
  interac_pref(O_Student. Maria, O_Student.Style2),
  hasKnowledge(O_Student. Maria, O_Domain.History),
  hasCourse (O_Student. Maria, O_Course.8^th grade),
  hasTask(O_Student.Maria,O_Task.RW_01),
  hasLocation(O_Student.Maria, O_Location.Transit),
  style_1 (O_Student. Maria, O_Student.Visual),
  style_2 (O_Student. Maria, O_Student.Active),
  hasConnection (O_Student. Maria,O_Netwk.Medium),
  langSkill (O_Student.Maria, O_Student.English),
  langSkill (O_Student.Maria, O_Student.French)}
```

5.1 Recommendation and Adaptive Interface generation

AdaptWeb® already allows a certain level of adaptive navigation. However, with the architecture improvements', it is possible to provide another ways of adaptation, being aware of a broad number of student's context and, consequently, adopt other ways of adaptation and recommendation.

As presented in Figure 1, our infra-structure has a recommendation and adaptation engine. In this engine we have been using different adaptive techniques. First, in the adaptation of interaction, we use the two categories of adaptation: *content adaptation* (De Bra, 2008) and *link adaptation* (De Bra, 2008). In the content adaptation category we use the *removing fragments* technique to eliminate all elements in the interface that do not correspond to the student´s device, nationality and interaction preferences.

In the link adaptation category we combine two techniques: *adaptive link annotation* is used to shows students their current state in the learning process, by differing links already known, in study, available to learn but not yet clicked. Also in the menu, could be links that students' do not have sufficient knowledge yet and for that we used the *adaptive link hiding* technique (by disabling the link and present only the name of the topic.

In order to make recommendations, we evaluate the metadata of the LOs stored in the ROAI to filter the list of LOs that suite the student´s context and situation properties in the mobile situation detect in the last process step. In the first filter we evaluate the metadata related to the *Subject* of the LO (and the student' knowledge and course); the *Format* of LO (if it is appropriated to the student´s restriction) and the *Coverage* and *Description* of LOs to analyze if this LOs fit the students' task. The second filter is responsible to evaluate the metadata related to *Relation* and *Type* to rate which of them cover the student´s learning styles; evaluate the *Language* metadata; and finally we re-evaluate the metadata related to *Format* of the LOs with respect to network connection restrictions.

6 CONCLUSIONS AND FUTURE WORKS

This work presented a practical view of the m-AdaptWeb. m-AdaptWeb is a module developed to provide situation and context-aware behaviour to mobile students in courses of the e-learning AdaptWeb®, an adaptive e-learning environment. A detailed description of how this context-awareness is put in practice is provided, including the infrastructure, the extended student´s model and its representation in complementary ontologies.

A simple but actual contribution of this work is the description of one feasible infrastructure – particularly containing a recommendation and adaptation engine - for adapting the content and navigation taking in account properties of student´s context in a specific mobile situation. We think that our work has also a potential contribution, trying to provide some directions of how to apply mobile-oriented contextual aspects in e-learning environment design. Our intention is to provide a basis to discuss practices that address mobility dimensions and cultural-aware issues for helping designers incorporating such aspects in their e-learning design process.

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