FROM AN E-LEARNING TO AN U-LEARNING ENVIRONMENT

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Abstract: AdaptWeb® is an e-learning environment designed to offer personalized content to different groups of students according to student's models that are mainly based on personal information. This paper shows how the platform is modified to support ubiquitous learning, managing mobility, social interaction, device independence, and context awareness in a broader and richer notion of the student's context. The paper presents the architecture and its implementation by three different kinds of data servers, working together for modeling the situations experienced by the students, storing their profiles and contexts, and maintaining corresponding learning objects.

1 INTRODUCTION

Learning in the traditional class model has been viewed as "one size fits all" approach; all students receive the same content without regard with the student's different background, preferences, skills and learning styles. Such diversity has brought new opportunities and challenges; one of the most desired challenges is to present an adaptive and personalized behavior (Brusilovsky and Peylo, 2003). Personalization may be characterized as the process of adapting a computer application to the needs of specific users, taking advantage of users' behavior analysis. An ELE, however, may be dynamically adjusted not only according to the student's model but also depending on a richer notion of **context** (Eyharabide et al., 2009). In our approach, 'context' is related to all resources that influence and are influenced by the student during a particular situation. That situation may be any learning activity like solving a list of exercises, answering an evaluation or attending to a class. Context is related to the different resources that surround the student performing a task, e.g., location (rooms, buildings, and laboratories), available devices, people, and available learning objects. A contextualized ELE provides the student with exactly the needed material, appropriate to his/her knowledge level and suited for a special learning situation called **scenario** (Eyharabide et al., 2009). We assume that the inclusion of the situation experienced by each student can improve the learning process (Bouzeghoub et al. (2007) and Ogata and Yano (2004)).

This paper presents an extension to an e-learning environment – AdaptWeb® (Adaptive Web-based Learning Environment), focusing on how its structure and contents could be modified to support ubiquitous learning (u-learning). In this new approach, three servers are responsible for modelling the situations experienced by the students, storing their profiles and contexts, and maintaining corresponding learning objects. To support this approach, a context-aware architecture was defined, in which ontology-based and scenario-oriented aspects are combined to explicitly represent rich context, supporting the context and scenario concepts as an extension to traditional user-student modelling. This paper is structured as follows: next section gives an overview of the main concepts. Section 3 summarizes relevant related works. Section 4 briefly describes the AdaptWeb® environment. Section 5 explains our extension, illustrating its behaviour by the means of some context-aware scenarios. Finally, Section 6 presents concluding remarks.

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2 FUNDAMENTALS

The research and practice in Computer Science and Education has evolved with the introduction of the Internet and Web-based courses. However, some educational applications are usually developed without taking into account the dynamic capabilities and personalization that the Web environment can provide. This limitation raises serious usability issues (Kalbach, 2007) such as (i) **guidance problems**, i.e., pages always presenting the same fixed content, and (ii) **navigation problems**, with are the consequence of a totally opened linking schema. A ubiquitous learning environment (ULE) combines the advantages of adaptive learning, the benefits of ubiquitous computing and the flexibility of mobile computing (Jones and Jo, 2004). U-learning enables the enhanced possibilities of accessing learning content (typically learning objects) and computer-supported collaborative learning environments at the right time, at the right place, and in the right form (Bomsdorf, 2005).

Like most of ELEs, AdaptWeb® employs student modelling as a basis for the personalization process, and the most common student's models for e-learning include knowledge about the student, his/her background, learning styles and so on. In order to provide such adaptation an ULE may be dynamically adjusted not only according to the student's model but also depending on a richer notion of **context**. In the present approach, we consider as contextual information the student location, connectivity, device, time, schedule, objectives, profile (e.g. learning styles, interaction preferences), and learning objects from the application domain, thus characterizing a situation-aware environment.

In a situation-aware environment, a **situation** is defined as the set of contextual characteristics that are invariable in a defined time interval (Weißenberg et al., 2006). Like Bouzeghoub et al. (2007) and Yang et al. (2006), we also consider a situation as consisting of a set of contexts over a period of time that affects the future system behaviour. Different types of **events** (Bouzeghoub et al., 2007) can be defined in a situation-aware environment, and depending on them a new situation may exist.

3 RELATED WORK

Although u-learning is a recent area, there are yet many efforts focused on the development of ULEs. An example is the UBI-Learn project (Laroussi and Derycke, 2004) aiming to design a complex learning dispositive, taking into account ubiquity and mobility. That project is mainly focused in the student mobility, allowing them to interact in an augmented class. Another ULE-related work is the CLUE project (Ogata and Yano, 2004), which is a computer-supported collaborative learning (CSCL) in a ubiquitous environment. Their focus is a knowledge awareness map that retrieves past interactions and experiences based on the current learning context of the student, providing the right information at the right place.

In Sieg et al. (2007) is presented a framework to integrate critical elements that make up the user context, namely the user short-term behaviour, semantic knowledge from ontologies that provide explicit representations of the domain of interest, and long-term user profiles revealing interests and trends. They present an interesting approach for building ontological user profiles by assigning interest scores to existing concepts in the domain ontology. They also present a framework for contextual information access using ontologies and demonstrate that this knowledge (combined with long-term user profiles) can be used to tailor search results based on users' interests and preferences. The AdaptWeb® also aims to provide adaptation related to the user location (Laroussi and Derycke, 2004), necessities (Ogata and Yano, 2004) or behaviour (Sieg et al., 2007), but combining the three forms of adaptation in an integrated way.

4 ADAPTWEB® ENVIRONMENT

AdaptWeb® is an adaptive learning system whose purpose was to adapt content, presentation and navigation in an educational web course. Currently, it is an open source environment fully operational and actually being used on different universities. It is available at SourceForge.

AdaptWeb® is composed by an authoring environment where the teacher (author) organizes and creates the content structure of their disciplines, and by a students' environment that shows personalized views of the content, interface and navigation to the student. The educational content of AdaptWeb® is modelled through a hierarchical structure of concepts where the criteria of prerequisites are established. This structure is defined during the authorship's phase and then stored in XML. The XML documents go then through a filtering process, which happens dynamically as the student interacts with the environment.

The student's model describes users in terms of theirs characteristics as knowledge, interactions preferences, background, technological resource, navigational history and cognitive learning styles. The user's background analyzes the student occupation. For instance, a Computer Science student and a Mathematic student need distinct content of the logic discipline. The teacher, through his experience, determines which content will be provided for each group of students (knowledge depth), thus enabling the content to be adapted for each student.

User's interaction preference environment sets two navigational conducts for a discipline: guided tour or free mode. Guided tour takes into account the prerequisites set by the author at the stage of authorship, and the student can only access a concept if its prerequisites are already known. In a free mode, the student can navigate throughout the contents of a discipline without restrictions. The student's knowledge is supposed to improve during the navigation in a course and then the environment monitors the student's navigation, making constant updates in the user profile. Finally, we assume that the learning process will be improved if the content is accessible in several media formats, including video, adapted to different formats and resolutions. While addressing these variation possibilities, the system allows the delivery of videos with variable resolution and quality, according to the network bandwidth available.

5 TOWARDS U-LEARNING

In this section, we present how the AdaptWeb® architecture was extended to support mobility, social interaction, device independence and context awareness, being adapted to specific scenarios. First, we have restructured the existing AdaptWeb® architecture to be Service-Oriented (SOA), having different data and context modules that are individually adapted and orchestrated by a set of high level services, allowing our environment to communicate with other ones in a flexible manner.

In this approach, the new architecture is based on three servers that operate together to provide and manage contextualized data according to the student's scenarios. Each server manages specific data related to the user context, being respectively responsible for the storage and adaptation of (i) information about students (personal data, preferences, objectives, knowledge background, behavior, learning styles, cultural context, etc.), (ii) environmental context (information related to the user environment, tasks, activities, time interval, devices, location), and (iii) learning object's information (documents provided by the educational environment to its users for their learning).

However, since this information is managed and stored separately and the context needed to the adaptation environment is diverse, it is orchestrated by an internal component called **Context Management Service** (Figure 1). This service is responsible for analyzing the context managed by the servers, generating different scenarios that can be experienced by the students in a specific period. These scenarios are used to guide the adaptation (in the Adaptation Engine), and materialized in the interface rendered to the user.

The main goals of the architecture are: (i) easily reuse of educational resources, since they will be adapted to the user scenario while the stored content remains the same, (ii) integration into the existing architecture, since the new architecture is supposed to take advantage of the existing functionalities and (iii) extensibility to other educational systems, using standard technologies. The personalization is possible with the combination of contextual data related to whom and where the user is, what he/she is doing and what does he/she needs to achieve his/her educational targets.

5.1 Extended Architecture

The AdaptWeb® architecture (Figure 1) works as follows. The **User Interface Component** module interacts directly with the user (represented by data flows 'a' and 'b'), identified after a login procedure. User id data, in conjunction with the current user location and time, is sent to the **Context Detector/Collector** ('c'), who sends this new information to the servers ('d') and informs the Context Management Service that new scenarios must be constructed ('e'), since new data is available in the servers ('e'). The communication between the Context Management Service and the servers is performed through Web Services that are responsible for transporting XML's files in/outside the environment ('g' and 'f').

After obtaining student's data, each server internally updates their models, i.e., the **situation model server** uses information about tasks, activities, time, location, and device to (re)structure generic adaptation situations in the environment; the **user model server** manages the student profile (containing information like background, interaction preferences, learning style, cultural context, and other aspects related to the students learning); the **learning objects' model server** uses data related to user disciplines and didactic meetings to (re)organize the learning objects according to his/her needs, adapted to the context.

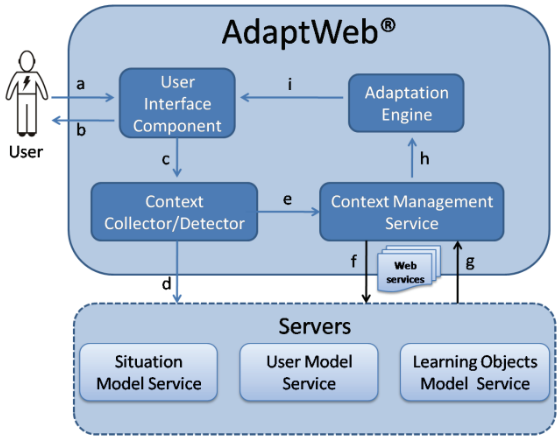

Figure 1: ULE-oriented architecture.

Therefore, the **Context Management Service** communicates with the servers ('f' and 'g') to dynamically build student adaptation scenarios, which are described by the tuple {situation, user profile, learning objects}. This module communicates with the Context Collector/Detector to identify when new important data is included in the servers and when a new scenario must be constructed. The **Adaptation Engine** is responsible for the acquisition of the diverse scenarios provided by the Context Management Service ('h') and for the ordering of these scenarios to be adapted to the student. In other words, it has to organize the user's scenarios, to give priority to some actions and perform changes in the User Interface Component, personalizing the navigation scheme and context view of the student ('i'). During the user interaction with the system, actions and events are collected by the Context Collector/Detector, which passes these data back to the servers ('d'). The servers update their models based on these events. Thus, the environment keeps track of the student actions, while being adapted to the student's needs. In the next subsections, the internal functioning of each server is described.

5.1.1 Situation Model

The goal of the situation model is to define generic clauses of situations, which can be combined, using specific operators, to derive new generic situations. Generic situations are those that could be applied to different users or group of users. Accordingly to activities, devices, time, and other variables valid for a student in a specific time interval, different clauses may be chosen to represent his/her situation.

The Situation Model comprises four ontologies: activity; device; time and location. The activity ontology contains information about the user's activities, including classes, meetings, and their respective time interval (day, month, year, beginning and ending times). This information helps the system to identify which user's activities are available in a given period of time. The device ontology contains information (display resolution, network bandwidth, etc.) about the current user device, in order to allow filtering information according to its technological constrains. The time ontology is an abstract ontology of time (Bouzeghoub, et al., 2009), like OWL-Time (W3C, 2003). Finally, the location ontology contains information about locations and places, which allow the system to filter information according to its distance or proximity to the user. Beyond these ontologies, the Situation Model has some simple defined situations, which can be addressed to specific students, helping the user detection that is performed by the Context Management Service. When the Context Collector/Detector receives basic information related to the tasks and activities selected by the user during his/her first access in AdaptWeb®, it can send this data to the situation server, which can define simple situations that identify that user in the Situation Model. For instance, if we want to state that "A student is using a mobile device", "He is taking a specific course" and "He is studying for three hours", we could use the following expression involving the user (student), device, activity and time ontologies (Bouzeghoub, et al., 2009).

LearningSituation = {
  use(O_{User}.Student,O_{Device}.MobDevice),
  do(O_{User}.Student,$O_{Activity}$.Std),
  haveSubject($O_{activity}$.Std, O_{domain}.@Domain)
  setDuration($O_{activity}$.Std,O_{time}.@3h)}.

5.1.2 Student Model

An example of Student model is shown in Figure 2.

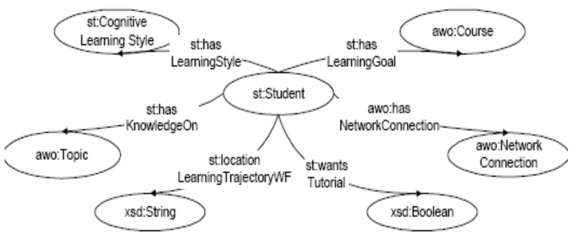

Figure 2: Student Ontology (Musa et al., 2004).

In Figure 2, the central class *st:Student* has properties that characterize the student profile. The property *st:has LearningStyle* indicates the student's cognitive learning style (Souto et al., 2002). The property *st:hasLearningGoal* refers to an element of *awo:Course*, containing customized discipline content for goals of a specific group of students. The Boolean property *st:wantsTutorial* indicates if the student prefers to work in a tutored mode (guided tour) or not. Using an overlay model, the student's knowledge on each topic of the Knowledge Model is indicated by the relation *st:hasKnowledgeOn*, i.e., if an instance of the relation *st:hasKnowledgeOn* exists relating the student to an instance of the class *awo:Topic*, then the system believes the student has knowledge about this topic. The property *awo:hasNetworkConnection* indicates the kind of Network Connection detected in the current session. The property *st:locationLearningTrajectoryWF* indicates the URL where the current learning trajectory for the student is. The remaining classes in the model represent the range of the properties defined in the Knowledge Space Model (Musa et al., 2004).

We can also take into account the cultural context, represented in practice by features that distinguish between the preferences of students from different regions, like languages, skills, values, etc. (more details see Eyharabide et al. (2009)).

5.1.3 Learning Objects Model

The Domain Knowledge Ontology, located in the learning object's server, contains the knowledge describing the pieces of content in the hyperspace. It also contains the rules to assemble them correctly in order to compute complex learning objects adequate to the profile of each student. More details can be found in Muñoz and Palazzo (2004).

5.2 Examples of Context Adaptation

To illustrate our approach, here we describe a few examples (scenarios) of the improvements in personalization's capabilities of AdaptWeb®. The illustrated scenarios are composed by different context types. For each scenario, we present how the environment should be personalized to the student.

In the first scenario, Smith is connected to a ULE through a desktop computer inside located in his university's research laboratory. He is a Computer Science student, and now he is considering to solve a list of exercises given by his Calculus teacher. He is not going well in the subject and, consequently, is not obtaining satisfactory results. The user model analyzes his number of mistakes and identifies that he needs help resolving the exercises. At the same time, the situation model can detect via the teacher's agenda that a chat with the students was previously scheduled by the teacher to happen in 10 minutes. These events detected by the situation model and user model will start a service of notification in the Context Management Service, informing that a change of the current scenarios that are related with these events may change. After a new orchestration by the Context Management Service, the User Interface Component can send a message to the student, notifying him of this possibility to solve his doubts.

In a second scenario**,** Maria, a Portuguese-speaking PhD student of Chemistry, has very good skills in three different foreign languages (English, Spanish and French). She is going to France, to study for a short period of time – to work in a different research group. When she gets there, the system detects her location change and adapts her learning objects and interface for the new linguistic environment where she is now inserted, selecting their French version.

Finally, in third scenario, Smith (the same student from the first scenario), will follow an exam in a few days. The system detects this activity in his agenda and organizes the learning objects in a priority order, indicating the most important ones for the moment. The system also presents some exercises to the student and indicates some complementary material to complement the acquired knowledge about the exam content.

These three examples show how our approach can personalize the system to different scenarios (user's context, situation and learning objects). A richer adaptation for a specific student generates a better learning process, since all features are personalized. We are developing experimental work not only to get overall feedback (mainly subjective) from users but to statistically validate the approach.

6 CONCLUSIONS

The use of e-learning brought new focuses and resulted in fundamental changes in teaching and learning. The ubiquitous computing defines a new paradigm in the computing field, where the computing capability is provided to users anytime, anywhere. This approach offers new possibilities and new challenges! It is necessary to deal with context awareness and its relationship with users. Context-aware modeling extends traditional user modeling techniques, by explicitly dealing with aspects that have a significant influence on the learning process. It is orchestrated by an internal component called Context Management Service responsible for analyzing the context managed by the servers, generating different scenarios that can be experienced by the students in a specific time interval. This new adaptation model is a must in providing a real application of the semantic Web as proposed by Berners-Lee et al. (2001). This approach is a real challenge to all Web systems' developers; eight years after the scenarios proposed in the Berners-Lee paper very few real customizing agents are in operation. We put this technology working in a real-life e-learning system. In this paper, we have presented an extended approach to provide a richer personalization in the AdaptWeb® environment, describing an extension of its architecture, which is based on Web services technologies and context-awareness, allowing the adaptation of course content to the user's context and situation. As the learning environment is operational in some Universities the next research stage is centered in gathering navigational and pedagogical data from real classes to fine-tune the context-scenarios modeling concept.

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