Towards context-aware and mobile e-learning applications

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ABSTRACT
This papers introduces the Learning While Moving (LWM) project, discusses some mobile and ubiquitous learning applications, and propose to extend previous models and even create a new context model for the domain of u-learning applications.

KEYWORDS
Context-awareness, ubiquitous learning, mobile learning.

INTRODUCTION
In this decade, the progress of miniaturization of computational devices (e.g., sensors and mobile phones), and the increasing availability of wireless communication resources, seem to bring us towards a real ubiquitous computing world similar to the one described by Weiser et al. [1]. In Weiser's vision, the computational devices are embedded in a ubiquitous environment allowing users to access information naturally, anywhere, anytime, and with multiple types of interaction (e.g., vision, voice). Then, an important characteristic of such a ubiquitous environment is referred to as context-awareness. Dey and Abowd [2] define the notion of context as "any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant for the interaction between a user and an application, including the user and the applications themselves". In other words, a context-aware system captures and makes use of user's context information in order to adapt its behavior or to provide personalized content and services accordingly.

Not surprisingly, the progress made in mobile and ubiquitous technologies has also had an impact in the field of e-learning. Thus, research issues have progressed from web-based learning to mobile learning (m-learning) [3][4]. Real mobile learning case studies, such as those described by Crawford [5], have shown that the introduction of mobile computing in the classroom promotes the motivation to learn, the collaboration and the communication between students. The integration of context-awareness and sensor-based technologies into m-learning systems increases the possibilities of interaction between the students, the objects of the real world, content of the lecture itself. In this new e-learning sub-domain, called ubiquitous learning (u-learning), the learning system is able to capture the situational context of the students and to guide them in their learning activities with adapted digital support [6].

Although researchers have recognized the great potential of context-aware u-learning, only few practical applications have been implemented. This occurs mainly due the insufficient experience on the development of context-aware u-learning environments and the designing of learning digital lectures that can take benefits from context-awareness. In this project, we intend to assist the development of this kind of systems by proposing a ubiquitous learning environment and a reuse-oriented software process. Together, they should facilitate the developments of these systems.

The main goal of the Learning While Moving (LWM) project is to gather and merge expertise from all partners in order to construct a Ubiquitous Learning Environment (ULE) that makes easier the creation of u-learning lectures. Figure 1 shows an overview of this proposal. U-learning is an approach that places the student in a series of designed lessons that combine both real and virtual learning environments. Hence, the ULE system should be able to acquire precise contextual information about the student, specially, location and spatial relationships with real world objects. The acquired context will be used by a Lecture Adapter entity that will change the course according to the pedagogical workflow defined by the teacher combined with the gathered contextual information.

FROM M-LEARNING TO UBIQUITOUS LEARNING

A widely used way to motivate students is using new technologies and different types of media. In this scenario, mobile Learning (m-Learning) emerges as new technology that uses mobile devices (e.g., mobile phones, Smartphone, palmtops) during the learning process. The m-learning paradigm arose from the possibility of using the ready availability of mobile devices to tend to some specific education and training needs [3]. The ubiquity of mobile devices, its integration with wireless communications technologies, and the growing increase in memory and multimedia capabilities have made them a ideal platform for developing applications for providing content anywhere at any time to the users [7].

Mobile Learning Applications

The concept of m-Learning provides flexibility and the ability to organize, awakens a sense of responsibility, and supports and encourages teaching practices and learning from a pedagogical perspective [8]. Also, m-Learning is presented as support for educational processes of a mobile nature, which require high levels of interactivity during the learning process, the integration of content and the ubiquity of learning activities [9]. Thus, mobile learning tools are very attractive because they use novel technologies that can be harnessed to carry out educational activities. For example, currently devices such as MP4 and MP3 players, Smartphone or touch-screen phones are used. The great advantage of these devices is that students can take them wherever they go. Additionally, such tools can help to eliminate some of the formality involved in traditional learning methods, making it more convenient for students and especially those young people who are always seeking the opportunity to learn about technology. Mobile learning also allows for these devices to be used by adults, who are generally resistant to technological change, thus involving them in this new era of experience with mobile learning [10].

Several studies [8][11][12] show how these new mobile technologies can increase access to education. In particular, such studies propose the use of mobile phones and PDAs, as today such devices have the ability to deliver learning objects and provide access to the Internet. One limitation describe by Attewell [8] involves the cellular networks themselves, which do not have the stability and robustness needed to be online all day. Thus, he suggests a mix of online learning and downloaded learning materials. This study suggests that such learning tools should be flexible for users. Finally, such research proposes the need to train teachers and facilitators in order for the use of these technologies to elicit a good response from the community; in addition, such training should be motivating and enthusiastic.

A study conducted by the Stanford Research Institute came to the conclusion that mobile devices can offer students unique advantages [5]. Almost all the professors that participated in the research stated that the use of appropriate educational software and accessories was very important to improve learning activities, by complementing the basic resources with mobile device applications. In general, the majority of professors stated that the introduction of mobile computing into the classroom increases learning motivation, collaboration and communications among the students.

Lehner et al. [13] states that mobile devices, in particular, offer a natural extension to distance learning based on computers. It occurs because mobile devices contribute to easily access to knowledge by, for example, assisting students in obtaining some specific content about certain subject, regardless of pre-established times and places. Tarouco [14] state that m-learning can be used as a strategy for the training of adults, through learning systems able of setting up content on demand, to provide students with learning situations, and adequate support for their needs.

Ubiquitous Learning Applications

Context-aware and ubiquitous learning environments (i.e., u-learning environments) addressed on this project are a natural extension of a m-learning system. U-learning environments add to m-learning systems the support to context information of the students during the learning process assisted by the ubiquitous devices (sensors, mobile devices…). Some u-learning experiments have been conducted on science courses [6][15], or language training courses. They propose to guide students into the observation of real-world objects or the experimentation of real-world contexts. Other studies have attempted to apply this innovative approach to science experiments, such as computer hardware assembly and X-Ray experiments.

Some other experiences have been developed that have had a very positive impact on different learning contexts. Spikol & Milrad [16] integrated the traditional game of Geocaching with mobile technologies to develop a system of outdoor learning. The navigational system provides maps and interactive learning materials in order to promote student motivation in learning processes. Likewise, Bichard & Waern [17] developed outdoor learning experiences through the use of mobile technology, integrating augmented reality and GPS in order to provide for an immersive scenario so that students would enjoy their gaming experience.

Wang, Shen, Novak & Pan [18] present a mobile learning system that can be adapted for any class. The system is designed for the whole class to be online, in which students use their mobile phones to send text messages to the instructor and communicate with each other. These messages may include questions, suggestions, requests or any other of the students' needs. The teacher, in turn, replies to the messages sent through a screen, by either writing about it or providing an oral response. Along with this, through pre-created messages for quick access, students can notify the teacher that he or she is going too fast, that his or her handwriting is not comprehensible or to speak louder. Once the students are working, the teacher can monitor the work of each of his/her students, almost in real time, and can provide help if necessary.

Shih et al. [19] built a digital library for mobile and ubiquitous learning situation. Wang and Wu [20] applied context aware technology and recommended algorithms to develop a u-learning system to help lifelong learning learners realize personalized learning goals in a context aware manner and improve the learner's learning effectiveness. Ciruela et al. [21] presented a ubiquitous intelligent tutoring system for aiding electronic learning that interacts with educational books to customize your self-assessment tasks through tags. Zhao and Okamoto [22] proposed an adaptive multimedia content delivery for context-aware u-learning, which create the adaptive contents for learners to get a seamless access in learning according to learners' interest and contexts. Ogata et al. [23] proposed a personal learning assistant called LORAMS (Link of RFID and Movies System), which supports the learners with a system to share and reuse learning experience by linking movies and environmental objects.

Chen et al. [24] proposed a context-aware mobile learning (CAML) environment based on situated learning to process an outdoor learning activity and to evaluate the attitudes of learners. Yen et al. [25] proposed an adaptive service, as a resource discovery and search middleware, to assist learners in obtaining possible objects under ubiquitous environment, that can reorganize the search results in order of similarity degree based on the mixed information including the usage history, geographical information and query criteria.

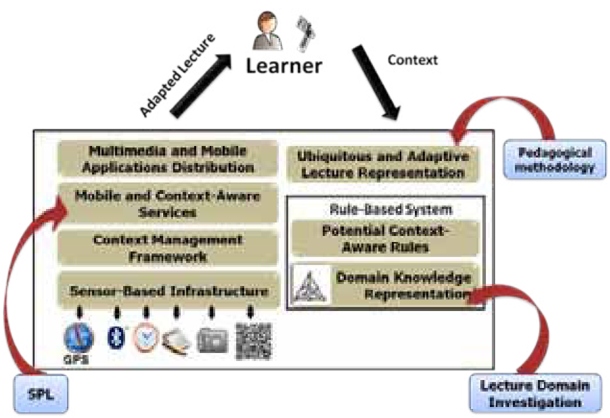
AmbientGPS [26][27], developed by the University of Chile, provides a hardware and software solution to help blind users in their daily outdoor navigational tasks. This audio-based software runs on a PocketPC device together with a Bluetooth GPS connection. The results of the usability evaluation showed that the system is quite easy to use. Blind users were able to navigate their way to the required destinations without any problems, even in unfamiliar surroundings. This experience led them to discover better ways of reaching their destinations.

These experiences and others presented in Sánchez et al. [28] show that mobile devices have generated a revolution in different areas of research and development. They have also generated an enormous opportunity to significantly affect different educational settings, by developing innovative and motivating learning environments.

LEARNING WHILE MOVING

We have to describe the LWM project consortium and the proposal that copes with the challenges and takes benefits from the technologic opportunities.

Take from introduction, the project work packages.



The research community of context-awareness has proposed a variety of context models and representation technique. For instance, the STEAMER Team (France partner) has proposed the ontology models ContextMultimedia and ContextTop for context-aware multimedia annotation [29] and Access Context and QoC ontologies for context-based access control solutions [30]. These works, together with numerous other context models proposed in the literature, symbolize the various viewpoints of the context notion and the diversity of context-aware applications where these models were used (e.g., ambient intelligence, mobile tourism systems).

One of the challenges in this project is to extend or even to propose a new context model for the domain of u-learning applications. This model should represent the most important dimensions of information that characterizes the learning situations and the existing relationships between context elements that could be used to improve the digital lecture or even help to its better comprehension.

Context Management Framework

A context management infrastructure should also be deployed in the ULE in charge of gathering, deriving, inferring, and providing learning context information for adapting u-learning application. For instance, the STEAMER team has proposed in [30] a component-based context management framework (see Figure 2) that was implemented to support context-aware applications and services. This infrastructure can be used as basis to design the context management framework for u-learning environments.

In the ubiquitous scenarios, we have considered for implementing this framework, various sensors distributed on the environment and/or on the mobile devices producing context information can be used. Let CxtObj be an object that represents a context information C and its value about a real world entity E (e.g., the student). CxtObj can be sensed from the environment and associated with some quality of context (QoC) information by sensors S. Context Providers (CP) and Context Information Service (CIS) are the principal services of our framework, as described below:

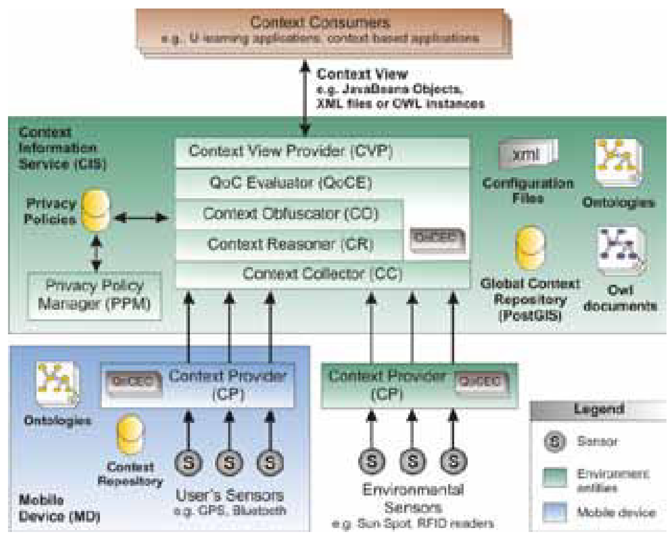


Figure 2 – An Overview of the Context Management Framework [30].

Context Provider (CP): CP are brokers on the environment or on the mobile devices capturing and sending CxtObj to the Context Information Service (CIS). Each CP keeps a dynamic list of registered sensors, controlling the synchronous and asynchronous notifications from them. This service is able to select sensors based on QoC thresholds defined by the context management administrator. CP deploys dynamically QoC evaluator Components (QoCEC) in order to evaluate the quality of raw context data. Each QoCEC is in charge of evaluating a well-defined QoC dimension (e.g., precision, up-to-dateness);

Context Information Service (CIS): Main component of our context management framework, which the sub-services (described below) should integrated to the ULE:

Context Reasoner (CR): CR runs inference and derivation process on context information described by OWL documents in order to obtain semantic high-level context information. The architecture supports the dynamic deployment of Context Reasoner Components (CRC) in order to derive new high-level context information;

Context-Collector (CC): it collects and aggregates context information sent by CP and sensors distributed on the environment, constructing the global context of users. It communicates directly with QoC Evaluator (QoCE) service in order to evaluate the QoC dimensions of raw context information. The global context of users are stored by the Global Context Repository (GCR) and it is generated an OWL document representing the context of the user. This document will be used by the Context Reasoner (CR) and Context Obfuscator (CO) services for inferring/deriving/modifying high-level context information from the raw sensed data;

Context View Provider (CVP): context information queries are answered by CVP providing Context Views of users. CVP are able to provide QoC-enriched Context Views to the context consumers as JavaBeans objects, XML files or OWL instances. They can yet receive and transfer context information of users to the others CIS of different domains with which they maintain trust relationships.

The main object of the architecture proposed in [30] was to provide QoC-enriched context information to context-aware applications and services, taking into account the privacy requirements of the users. Now, this architecture should be revised and extended in order to be integrated in the ULE we propose in this project. The addition of new sensors (RFID or 2D tags) for better identify objects on the field should also be contemplated.

Knowledge Representation and Rule-based System

Knowledge representation and reasoning are key factors when dealing with adaptation. In the LWM project, three entities are essential: the context of the user (her/his profile, preferences, activities, location, any other physical parameter considered as useful for the u-learning application, etc.), the lecture (in the shape of a multimedia presentation), and the domain of application targeted by the lecture. These three entities constitute three inter-connected models, which are instantiated during the design of the u-learning application and whose content evolves during the execution of the application:

1. The model of context of use will be built by capitalizing on the experience of the French research team (STEAMER) regarding context modeling for adaptation purpose since 2002. Context models have been proposed and implemented for web-based information systems [31], collaborative systems [32], web services [33], and ubiquitous systems [34][29]. Central entities of these models of context describe the user (her/his profile, preferences, activities, social network…), the software and hardware characteristics of the device used, and any other environmental and physical information (time, location, direction, temperature, speed, light, etc.) that can be captured through available (distant or embedded) sensors and which is considered as valuable. For the project LWM, those models will profitably be re-used and extended when needed. Some parts (instances) of this model are stable and kept unchanged most of the time, while others evolve continuously (especially at runtime) as the context changes frequently when moving, receiving data captured by information sources (like sensors, but also web services, etc.).

2. The model of lecture will be designed through the collaboration of LIG-STEAMER, UFRGS and UNESP partners. The model of lecture is in charge of describing the structure (composition) of the lecture, how its components (multimedia elements) are organized in space and time. In the past, LIG-STEAMER team has led research of the adaptation of multimedia presentations to both users' profiles and mobile devices, using XML, SMIL and XSLT technologies [35]. The targets of such adaptation process are both the content and the presentation (styles). Here, one of the challenges will be to also adapt the lecture to some environmental and physical parameters, such as the location and the orientation, for instance. One event, triggered by one change in the context, may change the instance corresponding to the current lecture.

3. The model of the domain of application describes the entities (notions to learned) that are addressed in the lecture and the relations that hold between them. For instance, in the case study dedicated to Geology, the entities of "Rock" or "Sediment" could be part of this model. It should be noticed that these entities might refer to multimedia documents that describe them and can, be used (unchanged or transformed), to form a multimedia lecture according to the model of lecture.

These three models will be described using the OWL knowledge representation language. They capture and describe pieces of knowledge that are used by adaptation rules. Adaptation rules are the very heart of the ubiquitous learning applications proposed by the LWM project. The challenge is to be able to describe when and how the lecture of the mobile learner has to be adapted to a new situation (a change in the context) and modified consequently. Clearly, the ECA (Event, Condition, Action) paradigm is well suited to describe such adaptation rules. The event represents the identification of changes in the context, the condition describes a set of valid context constraints, and the action describes the adaptation to be performed when the event occurred and the contextual constraints are satisfied [36]. For this purpose, the SWRL language, a Semantic Web Rule Language for OWL will be used.

Adaptable Multimedia Lectures

Adaptable Multimedia Lectures or Presentations, in this project, have to do with the perception of things or situations (that occur or change) in the user's context considering time, activities, location, and so on. This perception is achieved, in the present project, roughly by means of various sensors, but encompasses also some more evolved information analysis and data mining processes. The rational for this is that recurrent patterns usually correspond to situations that happen on specific cases, while certain cases differ from patterns known a priori.

The interaction between professors or students and the Learning Information System encompasses many activities, among which mobility is a relevant and key factor. In order to send users information adapted to their needs and taking in account their mobility, it is necessary to exploit information adaption techniques able to deal with different contexts. Context, here, has to do with: i) who is the user, ii) what is she/he doing, and iii) which device she/he is using (mobile phones, PDA's, etc.). We will focus on the study and development of algorithms and tools to support these activities (perception of situations and changes, information summarization and ability highlight relevant information using dashboards, and adaption of information to the user context).

DISCUSSION

This paper discuses mobile and ubiquitous learning, introduces an innovative learning while moving project including France and Latin-American researchers, and discusses about the extension and the elaboration of a new model for designing and implementing ubiquitous learning applications.

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