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Towards a methodology for semantic and context-aware mobile learning

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INTRODUCTION

Internet and mobile devices open the way towards mobile learning (m-learning) offering new opportunities to extend learning beyond the traditional teacher-led classroom.
M-learning is not only any form of teaching or studying that takes place when the user interacts with a mobile device. M-learning is more than just using a mobile device to access resources and communicate with others. It should take account of the constant mobile situation of the learner.
To provide personalized training adapted to the learner's situation, an m-learning system should adapt its educational resources according to the context. However, it is often difficult to identify relevant resources and to organize them into a coherent training course, especially when the learner context is continually changing. M-learning needs a better organization of knowledge, to deliver better in a mobile situation.
A way to address this problem is to create a pedagogical repository of Learning Objects (LOs) and to model learner context. A semantic approach using ontologies provides a semantic organization of learning information and the personalized situation.
This paper presents ongoing research about an ontology based context-aware system for Mobile Learning. This work is partially funded by CrossKnowledge[1], the European leader in remote development of leadership and managerial skills using new technologies.

BACKGROUND

Before any discussion on m-learning, we need to look at the main steps of evolution in the learning domain.
As a first step, learning became distant and moves away from the traditional teacher-led classroom. Distant education and training result from the technological separation of teacher and learner, which frees the learner from the necessity of traveling to a fixed place, at a fixed time, to meet a fixed person, in order to be trained (Keegan, 1995). In the mid-to late 1800's, home study became a legitimate form of education with the development of inexpensive postal services in Europe and across the United States. In 1840 Isaac Pitman used the new postal services to provide a correspondence course, which was in fact the first distance education program. The University of London claims to be the first university to offer d-learning degrees, providing its external program in 1858. Since 1920, educational programs including academics, have been broadcasting in Europe.
Then with the emergence of computers and the World Wide Web, distance learning evolved and became a critical part of modern education. These new technologies have made d-learning distribution easier and faster, emerging a new dimension of learning, known as e-learning or electronic learning.
The first learning system assisted by computer appeared in the 1970s. Its objective was first learning as knowledge transfer. In 2001, the Commission of the European Communities defined e-learning as:

[1] http://www.crossknowledge.com

"*E-Learning, defined as the use of new multimedia technologies and the Internet to improve the quality of learning by facilitating access to resources and services as well as remote exchanges and collaboration*".

Early e-learning systems, based on computer-based learning, often tried to copy autocratic teaching styles whereby the role of the e-learning system was assumed to be for just transferring knowledge. This is opposed to systems developed later, based on CSCL (Computer Supported Collaborative Learning), which encouraged the shared development of knowledge and collaborative work.

With the emergence of Web 2.0, e-learning became e-learning 2.0. E-learning 2.0, by contrast to e-learning systems not based on CSCL, assumes that knowledge is socially constructed when learning is perceived as an interlinked social process in which Web 2.0 tools are used to develop learning through collaboration and communication.

We cannot separate e-learning from the technology that enables it, which is the Learning Management system (LMS). A LMS is a software application in which training programs are assembled and made available for the learner. Typically, an LMS provides the trainer with a way to create and deliver content, learner participation, and assess learner performance. A LMS may also provide learners the ability to use interactive features such as threaded discussions, video conferencing and forums. Hundreds of LMSs platforms have been developed, the most known are Moodle and Blackboard.

An LMS supports Learning Objects (LOs). A LO is any digital material breaking an educational content into small pieces which allows modularity and reusability of the content. These pieces of digital resources can be rearranged in modules, like training courses. To simplify this process LOs uses metadata as prescribed by standards like IEEE LTSC's Learning Object Metadata (LOM[2]) or ADL's Sharable Content Object Reference Model (SCORM[3]). These metadata form pedagogical repositories and can help to catalog LOs to make easy searching and reuse (Trifonova, 2004).

Furthermore, every LMS should support tools to help learners, and trainers to manage their learning resources. There are two types of tools: synchronous tools and asynchronous tools. The first one (chat, shared applications, whiteboard, webcast, video conference, games, simulations…) are interesting pedagogical tools because they promote interactivity. Trainers and learners are simultaneously in front of their respective computers and share live, orally or by script. Asynchronous tools (email, forums, wiki, blog…) are also interesting because they can often structure communities, besides, they do not need trainer presence at the moment of exchange.

With the development of e-learning, the concept of mobile computing also called ubiquitous computing emerged. (Sharples, 2006) writes: "*We are now entering the mobile age, where phones are carried everywhere, banks are accessed from holes-in-the-wall, cars are becoming travelling offices, airplane seats are entertainment centres, computer games are hand-held, and advertising is ubiquitous".* We can define mobile computing as the ability of moving physically a computer environment which is not connected to any static network. Since then, devices that have been developed for mobile computing have taken over the wireless industry.

Advances in mobile computing, intelligent user interfaces, context modeling applications and recent developments in wireless communications including Wi-Fi, Bluetooth, multi-hop wireless LAN and the global wireless technologies such as GPS, GSM, GPRS, 3G and satellite systems have created a wide array of new possibilities for technology users.

When these technologies started to be used with mobile computers, a new learning paradigm, called mobile learning, emerged. M-learning holds the promise of offering interesting new opportunities for learning as shared, ubiquitous, collaborative, fluid and with an integral access to applications that support learning, anywhere and at anytime (O'Malley, 2003).

[2] http://ltsc.ieee.org/wg12/

[3] http://scorm.com/scorm-explained/

E-learning	M-learning
Computer	Mobile
Multimedia	GPRS, G3, Bluetooth
Interactive	Spontaneous
Hyperlinked	Connected
Collaborative	Networked
Media-rich	Lightweight
Distance learning	Situated learning
More formal	Informal
Simulated situation	Realistic situation
Hyper learning	Constructivism, situationism, collaborative
Lecture in classroom or in internet labs	Learning takes place while mobile
More text- and graphics based instructions	More voice, graphics and animation based instructions

Table 1. Terminology comparisons between e-learning and m-learning

The transition from the e-learning to the m-learning revolution is characterized also by a change of terminology. For example, the dominant terms in e-learning are: multimedia, interactive, hyperlinked and media-rich environment. In m-learning terms like spontaneous, situated, connected, informal, private, personal… are used to characterize it. Table 1 contrasts the choice of these terminologies with underlying characteristics of the two types of learning environments.

Since the emergence of mobile learning concepts, its definition has not stopped evolving. For most of the 2000s, m-learning is the use of mobile technology. (Quinn, 2000) considers that m-learning refers to learn that occurs while using mobile ICTs (Information and Communication Technology): "*it's e-learning through mobile computational devices: palms, Windows CE machines, even your digital cell phone*".

The practice of mobile learning is impossible without the use of mobile devices. They vary significantly in their abilities, sizes and prices. The common abilities which merge are their mobility and the possibility to make wireless connections. The main types of mobile devices used in learning process are (Georgiev, 2004):

- NoteBook computers: From one hand they have such abilities as desktop personal computer; from the other hand they have small sizes and support wireless communications.
- Personal Digital Assistant (PDA): They have small sizes and significant processor power. New models support more than 65000 colors, recognize handwritten text and can play different types of multimedia files.
- Cellular phones: The low range devices can be used mainly for voice communication and exchanging text messages (SMS). Some of their disadvantages are low memory capacity and low data transfer rate. The cellular phones from the higher class can be used for Internet access via WAP or GPRS technologies. They also can be used to send and receive multimedia messages.
- Smartphones: They are hybrid devices which combine the abilities of cellular phones and PDA. They are smaller than PDA and bigger than cellular phones. Typically they haven't full sized keyboards and can recognize handwritten text. As they have internet browsers they have potentiality to be successfully used in the mobile multimedia learning.
- Tablets: These are one of the newest mobile devices. They also have a full range of abilities like personal computers. Some of them haven't keyboards but have software to recognize handwritten text.

To summarize, m-learning as shown in figure 1 proposed by (Georgiev, 2004) is considered as the follow-up of e-learning which, for its part, originates from d-learning.

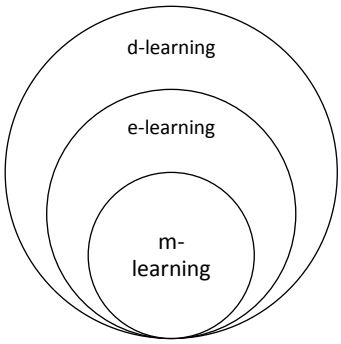

Figure 1. M-learning as part of d-learning and e-learning

From 2005 research and reflection on m-learning increased and no longer focus only on technologies and devices. When considering mobility from the learner's point of view, rather than the technology's, it is more important to say that m-learning is about people moving through environments, learning as they go, using electronic devices that enables connectivity to information sources and communication while they are able to change their physical location. In short, our new definition of mobile learning is "learning in context". Context is one of the key areas which distinguishes m-learning from e-learning. (Dey, 2000) defines 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 to the interaction between a user and an application, including the user and application themselves"*. In an intelligent space the context can be information including specific locations, capabilities and services looked for and proposed, the activities and tasks in which they are involved, and situational roles, beliefs, desires and intentions. It must also include information about the physical environment (e.g. lighting, noise levels) since this may change the way users interact with any device they may be using.

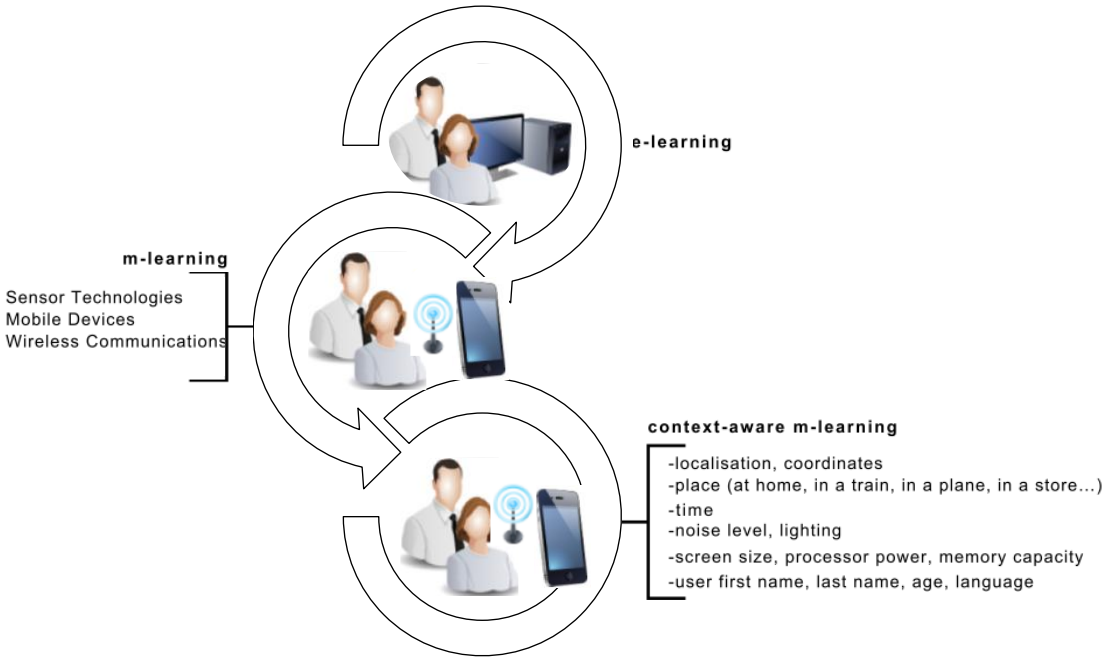

Figure 2. Shifts in e-learning

The context often refers to information localization, time, devices, network, user profile, but also other more specific information such as temperature, noise level, light level, user tasks... (figure 2).
The most manipulated context dimensions in research are: physical context (spatial, temporal, environment), device context, user context and specific context of the application domain (Dey, 2000). We briefly describe these different dimensions below:

- Spatial dimension: The simplest form refers to the position (coordinates), or place (at home, in a train, in a plane, in a store…). Today, there are many technologies for capturing and tracking these features such as GPS systems, wireless networks or proximity detection methods.
- Time dimension: Time is important in order to find out and manage the history of contexts to enrich the current context. Sequencing and scheduling activities, actions or events in time may also be important for decisions taken by the system. For example, the history and the behavior tracing of users enables access to past contextual information to infer future behavior of the latter, by analyzing past interactions to offer a share of better future resources.
- Environment dimension: In some systems, it is necessary to measure the characteristics of the environment around the user to regulate the system's operations. For example, the system may measure the noise level to adjust the sound of the mobile device.
- Device dimension: This dimension considers the characteristics of mobile devices: PDA, Smartphone, tablet, laptop... Different properties define these devices: screen size, screen resolution, processor power, memory capacity... They aim to provide an interaction interface between the system and the user on the move. Therefore, the system has to present the appropriate content depending on the characteristics of these devices.
- User dimension: It matches with the user model in the architecture of our recommender system for m-learning. Specifically, it is a set of data that characterizes a user or a group of users. In this model, the system collects different types of information. There are two types of information. The first type describes general information about the user such as first name, last name, age, birthdate, nationality, language. The second type varies according to the different application domains: preferences, knowledge, skills, role (learner, teacher, administrator...), centers of interest...

Context-aware computing in the m-learning domain offers many advantages. (Chen, 2002) lists them:

- Accessibility: Learners have access to their documents, data, or videos from anywhere.
- Interactivity: Learners can interact with experts, trainers, or peers in the form of synchronies or asynchronous communication. Hence, the experts are more reachable and knowledge is more available.
- Immediacy: Wherever learners are they can get any information immediately. Therefore, learners can solve problems quickly. Otherwise, the learner may record the questions and look for the answer later.
- Adaptability: Learners should get the right information at the right place, at the right time in the right way.
- Placing of instructional activities: The learning could be part of our daily life. The problems encountered, as well as the knowledge required, are all presented in the nature and authentic forms. It helps learners to notice the features of problem situations that make particular actions relevant.

Context-aware applications need acceptable context modeling and reasoning techniques. Modeling context knowledge is an important task to support the delivery of the right information at each moment, to adapt and to personalize the information, and to anticipate the results.
There are many methods for modeling context (Sielis, 2012). (Schilit, 1994) uses key-value models. (Strang, 2004) provides markup schema models like XML. Others like (Henricksen, 2003) use graphical models such as UML (Unified Modeling Language) or ORM (Object Role Extension), object oriented models, logic based models, and finally ontology-based models.
Ontology represents the knowledge on a specific domain using semantic relationships between concepts describing the domain. This set forms a semantic network. Ontologies provide many useful

features for intelligent systems (Gruber, 1991): first, ontologies provide the capacity to create a common data model for all applications in an organization. They can set up shared and centralized repositories. Also, ontologies provide information modeling independent from applications which use them. Besides its obvious contributions from classic approaches of comments by keywords, ontologies are used for sharing and reusing data, and for improving communication.
Therefore, ontologies are a promising instrument to model contextual information, because of their high and formal expressiveness, and the possibilities for applying ontology reasoning techniques (Chen, 2004).
At the same time, ontology can be used to model concepts of the learning domain by adding semantic description to LOs (figure 3). To build an approach of quality, in recent years international standards (IEEE and ISO) are developing standardization initiatives in educational technologies. They do not seek to standardize teaching methods or multimedia technologies used. They just aim to set up rules that will help in sharing and reusing educational modules. For example, ADL has recognized the need to have a model that aims to make learning platforms and their content interoperable. This model is the standard SCORM which has become a major asset for distance learning platform. To define a SCORM course, the author builds SCOs (Sharable Content Object). SCOs are the building blocks of a course, then explain how to link them (by analogy, we now replace the term "item" previously used, by the term "SCO"). A SCO is a learning unit that has a pedagogical meaning, which can be reused in another course and can be recognized by other SCORM platforms. A SCO may consist of web pages, animations, drawings, videos, etc. A set of SCOs forms a LO, and one or more LOs form a training course.
We can make parallels between the principles of SCORM and semantic Web, emphasizing that they both aim to enable better management of content, and they both adopt the incorporation of metadata on resources. However, the granularity level of knowledge is different: in semantic Web, the entire content of a document is associated to many metadata. In SCORM, the granularity of knowledge stops at the SCOs (the resource). However, a SCO can itself be composed of one or more Web pages, so the content of a SCO is a kind of box, inaccessible to semantic search mechanisms. In addition, SCORM isolates metadata describing a resource from the resource itself, to help access, search, sharing and reuse; each SCO must be described using metadata and semantic annotations. Indeed, a non-indexed or annotated SCO cannot be recovered and reused.
By exploiting ontologies in our research project, we may support a LO around small pieces of learning knowledge that are semantically annotated. Then, these pieces may easily be arranged in learning courses and delivered on demand to a user according to his profile needs and context.

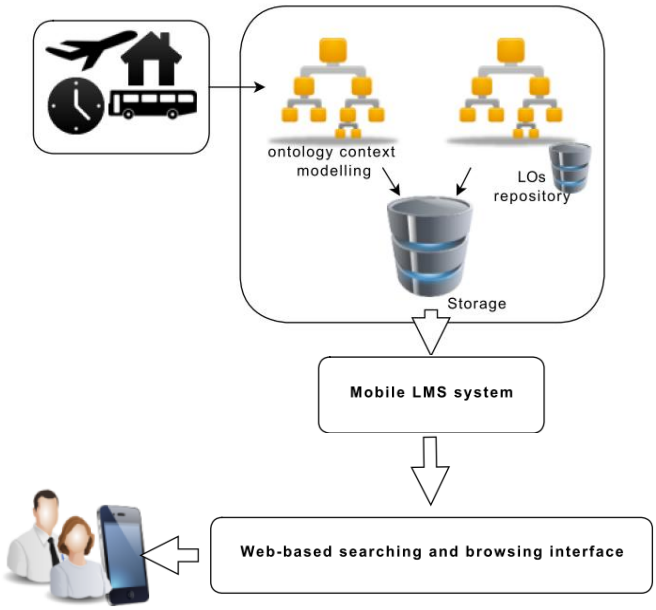

Figure 3. Ontology mapping for mobile learning

CONCLUSION

In recent years, there have been major advances and research done on opportunities to learn with mobile devices. These new devices provide the possibility of extending the learning environment far beyond the traditional classroom. M-learning aims at replacing predetermined methods of learning with a just-in-time, customized and on-demand process of learning. The key word on m-learning is the context. The context consists of the learner's state, the educational activity's state, the device's state, and the environment's state. Each one of these states is further described by its dimensions. Techniques for modeling the context are multiple. A better representation of context is necessary to fix dynamically which LO to propose to learner.
A way to reach this target is the use of a set of common ontologies that the devices, LMSs and users will use to describe their context. Ontologies are knowledge representation frameworks that enable us to express knowledge in a clear and expressive way with well-defined semantics. Ontologies will help to construct an adaptive, personalized m-learning system and add a semantic interpretation to learning resources. Also, modeling context by ontology will make the m-learning system more adaptive and intelligent.

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KEY TERMS

Blackboard: This is an enterprise software company with its corporate headquarters in Washington, and is primarily known as a developer of education software, in particular learning management systems. The company provides education, mobile, communication, and commerce software and related services to clients, including education providers, corporations and government organizations.

Computer Supported Collaborative Learning (CSCL): This is a pedagogical approach where learning takes place via social interaction using a computer or through internet. It is characterized by the sharing and construction of knowledge among participants, using technology as their primary means of communication or as a common resource.

Context-Awareness: This is the ability of a system to be aware of its context.

Learning Object (LO): This is the smallest element of meaningful instruction, independent of other pieces of instruction and correlated with a specific learning objective. The Institute of Electrical and Electronics Engineers (IEEE) defines a learning object as any entity, digital or non-digital, that may be used for learning, education or training.

Learning Object Metadata (LOM): This is a data model, usually encoded in XML, used to describe a learning object and similar digital resources used to support learning. The purpose of learning object metadata is to support the reusability of learning objects, to aid discoverability, and to facilitate their interoperability, usually in the context of online learning management systems.

Moodle: Abbreviation for Modular Object-Oriented Dynamic Learning Environment. It is a free source e-learning software platform, also known as Learning Management System. Moodle helps learners create online courses with a focus on interaction and collaborative construction of content, and is in continual evolution.

Ontology: An explicit formal specification of how to represent the objects, concepts, and entities existing in an area of interest, and the relationships among them.

Semantic Web: The term was coined by Tim Berners-Lee who defines the semantic Web as a web of data that can be processed directly and indirectly by machines. In other words, semantic Web is a mesh of information linked up in such a way so as to be easily processable by machines, on a global scale.

Sharable Content Object Reference Model (SCORM): This is a collection of standards and specifications for web-based e-learning. It defines communications between client side content and a host system called the run-time environment, which is commonly supported by a learning management system.

Web 2.0: This is a concept where internet is viewed as a medium in which interactive experience, in the form of blogs, wikis and forums, plays a more important role than simply accessing information.