Comparative Study of the Mobile Learning Architectures

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Abstract. With the emergence of mobile devices (Smart Phone, PDA, UMPC, game consoles, etc.), and the growth of offers and needs of a company under formation in motion, multiply the work to identify relevant new learning platforms to improve and facilitate the process of distance learning. The next stage of distance learning is naturally the port of e-learning to new mobile systems. This is called m-learning (mobile learning). Because of the mobility feature, m-learning courses have to be adapted dynamically to the learner's context. Several researches addressed this issue and implemented a mobile learning environment. In this paper, we compare a list of mobile learning architectures with methods presented in the literature. The evaluation presents a set of criteria specifically identified to qualify m-learning architectures dedicated to the context-change management.

Keywords: Mobile technology · E-Learning · M-learning · Context-change management · Learning method

1 Introduction

The introduction of mobility in a learning process induces new practices and uses which change the conception paradigm of a learning courses. This paradigm was implicitly based on the unity of place. With a mobile learning systems, the learner can continue his education out of a classroom, move during the learning process and changed place using a mobile device whether a Smartphone or a tablet. This mobility led to the appearance of a new paradigm where the learning process has to be dynamically adapted according to the change of the learner's context.

M-learning objects can take many forms, such as text, audio or video documents organized into comprehensive training programs adapted to mobile devices. While there are a large number of courses available on mobile devices, this type of training is still at an early stage. In fact, it is sometimes difficult to adapt of the mobile devices to the available contents in e-Learning. For instance, the problems to migrate e-learning training course to mobile learning systems are not only limited to technical issue, such as the limitation of screen size and the bandwidth, but also to the management of

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change within the context and its impact on the training course. In addition, even if some contents, such as audio and video media course materials, are ideally suitable for mobile use, the existing systems are still unsatisfactory for the users' needs. Our goal is to identify how the existing mobile-learning methods resolve the technical heterogeneity and bridge the gap change management during the mobile learning process.

The remainder of this article is organized as follows: In Sect. 2, we give a brief definition of the mobile learning. The context and the opportunities of context-aware applications are described in more detail in Sect. 3. Then, in Sect. 4, some existing works in the literature are presented. Then, a comparison between the different architectures proposed in these works is made using a list of significant criteria. Finally, we end up our paper with a conclusion.

2 M-learning

M-learning is described by the use of mobile and wireless technologies allowing anyone to access information and learning materials at any time regardless of the place. Some approaches consider that mobile learning is simply an extension of the E-learning. However, they do not take into account the mobile device limitations, the particular circumstances of mobile learning and the added value of mobility, such as informal learning, learning on demand, in context, through contexts, etc. Mobile learning has been defined as the process of learning and teaching that occurs with the use of mobile devices providing flexible on-demand access (without time and device constraints) to educational resources, experts, peers and services from any place [1].

This evolution of learning can be characterized by the following changes: distance in e-learning and the consideration of mobility with m-learning and omnipresence with the ubiquity ubiquitous learning (ubiquitous learning, pervasive learning). These changes reflect the impact of computer technology, such as mobile and ubiquitous computing, on the learning process.

The shift from e-learning to mobile learning has given rise to much debate among researchers. For instance, Sharma noticed that the shift from e-learning to mobile learning is accompanied by a change in the terminology [2] as shown in Table 1.

Table 1. Comparison of e-learning terminology and m-learning (according to [3])

E-learning	M-learning
Computer	Mobile
Bandwidth	GPRS, 3G, Bluetooth
Multimedia	Objects
Interactive	Spontaneous
Hyperlinked	Connected
Distance learning	Situated learning
More formal	Informal
Simulated situation	Realistic situation
Hyper learning	Constructivism, situationism, collaborative

The main benefits of mobile learning for education and learning are reported as follows [4]: (a) it enables on-demand access to learning resources and services as well as instant delivery of notifications and reminders, (b) it offers new learning opportunities that extend beyond the traditional teacher-led activities and classroom-based ones, (c) it encourages learners to participate more actively in the learning process by engaging them to authentic and situated learning embedded in real-life context and (d) supports on-demand access, communication and exchange of knowledge with experts, peers and communities of practice.

The major difference between learning somewhere on a stationary desktop computer and learning with mobile devices is the context. In fact, mobile devices feature some functionality to capture some background information that can be helpful to personalize the learning experience. 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, their learning as they go, using electronic devices that enables connectivity to information sources and communicating while they are able to change their physical location. In short, our new definition of mobile learning is "context-aware in mobile learning" which discussed in more detail in the next sections.

3 Context-Aware in Mobile Learning

In a mobile learning experience, each learner has to be treated in a different way according to the current situation in which he is learning, e.g. his pre-knowledge or the specifications of the device he is using. Those different conditions are called the context in which the learner is situated.

As mobility is related to mobile learning, mobile devices, capacity, connectivity, user and the environment can all change over time and place. That is to say the set of learning exchange or the learning context can change all the time. A mobile learning's challenge is to exploit applications that can dynamically adapt to different learning situations. M-learning makes learning across contexts: "mobile learning is not just about learning using mobile devices, intended learning across contexts" [5]. Here the focus is on how learners are formed through places and transitions between different contexts.

It should not be a break in learning between the face-and outside. Learning is based on the business continuity through space and time interacting with mobile and fixed technologies. Learning should not be limited to certain environments, but should increase the mobility of the learner through these. With the emergence and evolution of new mobile technologies, adaptation to context has become an indispensable nature of new computer systems for mobile use. It is therefore necessary in the case of an adaptation to the context in learning, determined by the context of the learner what content to send, how, on what tool, etc. The whole learning process has to adapt to these changes in context. On the other hand, learning through contexts requires a series of organized activities, that is to say that learning takes place in a particular context depends on those who were before. This requires that the system takes into account the history of learning to provide the learner with meaningful learning activities and thus to monitor its activities through contexts.

4 Previous Works

In this section, we will review the work existing in the literature by introducing representative approaches and mobile learning platforms. We are interested in the adaptation management which is a very important parameter in managing and customizing the learning resources to the learners. We will focus, also, on the context, which is a central core of all the mobile learning systems.

MOBILearn is a European research and development project which aims at exploring the use of mobile environments to foster informal learning, learning through problem solving and learning at work. As part of this project, a new architecture for mobile learning was constructed. It can help generate contents and services to accompany a learner during his learning activities in a gallery or a museum [6]. In this context, Learning is backed by a set of activities at the museums. Being placed in front of a painting, the visitors can, then, use a PDA or Smartphone to get the relevant information while observing the painting in order to learn. A learner visiting a museum, for the second time, can acquire information related to his previous visit.

E-Bag (virtual bag) is part of the iSchool project for nomadic and mobile learning [7] for which mobility and context are two key elements. Briefly, the iSchool project vision is used to develop a software infrastructure, graphical interfaces and spatial concepts in an interactive environment. The idea behind eBag is the creation of a "virtual school bag" for each student to help him learn through contexts by moving to specific locations (classrooms, laboratories, workshops, libraries, museums, cities, clubs and home). Therefore, the objective of the system is to serve as a "personal and digital warehouse" in which all the resources (texts, photos, videos, etc.) can be stored for internal and external use of the school environment.

The MoULe project (Mobile and Ubiquitous Learning) aims at allowing pupils to use mobile devices in order to build up collaborative knowledge and incorporate learning activities in the classroom and laboratory for situation learning. The MoULe is an environment that helps the users edit and share documents and concept maps using desktop computers and smart phones equipped with GPS. These tools enable students to collect textual content, images, videos and audio recordings while visiting an outside site during their learning activities. Besides, the system allows them to comment on the media they collect and classify it, so that their research and the re-use of the information in collaborative activities will be easier [8].

The mCALS project (mobile Context-aware and Adaptive Learning Schedule) is a context-aware mobile learning system developed for supporting Java programming learning. The goal of the system is to select appropriate learning objects for learners based on their current context and preferences. User context attributes include their location, and user preference attributes include their knowledge level for the topic (in this case Java) and their available time. The system is made up of three layers: Learner Model Layer, Adaptation Layer and Learning Objects (LO) Layer. Learner model layer collects, organizes and manages the learner's context, which can characterize the learning situation for learning objects adaptation. Adaptation layer is in charge of selecting appropriate learning objects based on the learner's current context with a

series of adaptation mechanisms. Learning objects layer stores and manages learning objects in a learning object repository, with which learners are provided during their learning [9].

Nguyen Pham and Ho present CAMLES (Context-Aware Mobile Learning English System) to help students learn English as a foreign language to prepare them for TOEFL test by suggesting topics they need to learn on the basis of their test results. The test provides an adaptive content for different learners in context including location, time and the learner's knowledge. The system architecture of CAMLES includes three layers: Context Detection Layer, Database Layer and Adaptive Layer. The Context Detection Layer identifies the context factors such as location, time interval, manner of learning and learner's knowledge that impact selection of adapted learning contents for different learners. The Database Layer consists of context data, content data, the learner's profile and test. The Adaptive Layer includes an adaptive engine which selects learning contents according to the learner's learning context based on a set of if-then rules stored in the rules repository [10].

Chuantao YIN proposed the design for a contextual mobile learning system known as SAMCCO (French abbreviation for "contextual and collaborative mobile learning system for professional fields") [11]. It is based on EPSS (Electronic Performance Support System) whose goal is to group storage of technical, working and learning data in order to provide not only just-in-time and just enough training, but also information as well as tools and help mastering or repairing equipment, appliances or products disseminated in the smart city environment. This system is able to bring relevant information designed to maintain or ensure appropriate performance of smart city users whenever and wherever needed, thereby enhancing the performance of the industry and the company as a whole. EPSS is used to store and deliver plant reference materials including: training documents, operating procedures and historical maintenance information. SAMCCO edits and organizes learning contents stored in the EPSS information database, which is an essential professional learning resource offering abundant and well-structured learning contents.

In 2013, Soualah Alila et al. [12] proposed an approach for context-based adaptation for m-earning known as CAMLearn (Context-Aware Mobile Learning), making use of learning practices already deployed in e-learning systems and adopting them in m-learning. This system is built around an ontology that both defines the learning domain and supports context-awareness. The use of this ontology facilitates context acquisition and enables a standard-based learning object metadata annotation. It, also, uses a set of ontological rules to achieve personalized context-aware learning objects by exploiting knowledge embedded in the ontology. The future adaptive system will offer an optimized panel of learning objects matching with the learner's current context. CAMLearn consists of two parts: the first part consists of a knowledge server where data and business processes are modeled by evolutionary ontology and business rules, and the second part is based on metaheuristics algorithms allowing analyzing business rules and ontology to allow a good combination of learning content.

The UoLmP project (Units of Learning mobile Player) Project [13] is intended to present an adaptive, personalized and context sensitive mobile learning system which aims to support the semi-automatic adaptation of the learning activities. This is about the accommodations to: (a) the interconnection of the learning activities (i.e. the

learning flow) and (b) the educational resources, tools and services that support the learning activities. The initial results of the assessment of the UoLmP use provide evidence that UoLmP can successfully be adapted to the learning flow of a pedagogical scenario and the provision of educational resources, tools and service that support the learning activities. This project includes three parts: capture/retrieval part, adaptation process part, and delivery/adjustment part. The Capture/retrieval part captures or senses the current situation properties for filtering learning contents, and detects current device capabilities for presenting the filtered contents polymorphically. The Adaptation process part executes the adaptation mechanisms, including the filtering mechanism and the polymorphic presentation mechanism, based on the IMS Learning Design Specification (IMS-LD). The Delivery/adjustment part delivers the adapted learning contents and learning activities to learners.

Some of them will, then, be analyzed in the mobile learning systems that have been performed to show the mobile learning features mentioned in the previous section.

5 Comparative Study

In this section, we give a comparative study of the different approaches and architectures of mobile learning that we have presented in the previous section.

This comparison is based on some significant criteria and features. We are particularly interested in:

1. *Device mobile support*: this is due to the fact that all the mobile devices used in the previous architectures are of personal/portable type (PDA, Smartphone, PC, Tablet, etc.).
2. *Heterogeneity support*: the various hardware sensors, actuators, mobile devices with powerful servers, various network interfaces and different programming languages must be supported.
3. *Protection of privacy act:* flows of contextual information between system components must be controlled according to the needs and requirements of protection of users' privacy.
4. *Learning as a collaborative process.*
5. *The integration of formal and informal learning*.
6. *Learning as a set of activities in context*: it is to foster mobile technology in specific contexts to help carry out learning activities.
7. *Learning context-aware:* it is to help shift the monitoring of learning activities from one context to another in a mobile environment.
8. *Adaptability:* components that treated the context and communication protocols must adapt sufficiently in systems with a variable number of sensors, triggers and application components.
9. *Traceability and control*: the conditions of the system components and the flow of information between the components must be open to inspection so as to provide the users with adequate understanding and a control system.

10. *Tolerance at chess*: sensors or other components can possibly fail in the ordinary operation of a system. Disconnections may also arrive. The system should continue operations without demanding excessive resources, and detect failures.
11. *Deployment and configuration:* the hardware and software of the system must be easily deployed and configured to meet the requirements of users or environments, even for non-experts.

The result of this comparison is presented in Table 2. This table summarizes the capabilities of these architectures of context-aware systems. In fact, we find that none of the presented architectures fulfills all the criteria required for the implementation of a system sensitive to the context. The architectures layers (CAMLES and mCALS) and architecture of MoULe can be considered as models for system designers, but they still lack solutions to support privacy and tolerance failures. It is the same for architecture of eBag, which in addition does not support heterogeneity and traceability. The architecture of MOBIlearn has not context management. Learning as a set of activities in context is more important in the case of projects CMLearn and UoLmP in the other. Collaborative learning is most developed in the SAMCCO project in terms of participants' roles, pedagogical intention (collaborative missions) and supports. SAMCCO is based on the AM-LOM (Appliance Mastering LOM) metadata that is an extension of the LOM (Learning Object Metadata) metadata. AM-LOM the use of educational resources for indexing will allow several semantic ambiguity problems of some elements of the LOM and interpretation problems. For this, in our work we propose to use ontology for indexing educational resources based on LOM will allow a better understanding of the elements and securities offered and consequently facilitate their descriptions.

Table 2. Comparative Study of the mobile learning architectures

Criterion	Approaches							
	MOBILearn	E-Bag	MoULe	mCALS	CAMLES	SAMCCO	CAMLearn	UoLmP
(1)	√	√	√	√	√	√	√	√
(2)	√	–	√	–	–	√	√	√
(3)	–	–	–	–	–	√	√	√
(4)	–	–	√	–	√	√	–	–
(5)	–	–	–	–	–	–	–	–
(6)	–	–	–	–	√	–	√	–
(7)	√	–	–	–	–	√	√	√
(8)	√	√	√	√	√	√	√	√
(9)	–	–	√	√	√	√	√	√
(10)	–	–	–	–	–	√	√	√
(11)	√	√	√	√	√	√	√	√

Most approaches do not enable the adaptation of the content to the learner's profiles. Context-aware approaches have the advantage of providing the user with the appropriate learning resources depending on the context. It is, therefore, essential to determine, depending on the context, how, when, and on which interface the resources should be sent. However, Learning Through contextualization is not easy to achieve.

In fact, the development of mobile technologies and the dynamics in the mobile environments have complicated the process of contextualization.

Today, mobile computing (user mobility, terminal mobility, and network mobility) is characterized by a permanent change in context (connected or disconnected, low or high bandwidth, change of location, widescreen or small screen, varying input devices, etc.). Thus, it has become very complex to consider many and various aspects when designing such application.

It is worth-noting that mobile learning is very important, particularly in education, and the major utilization of mobile devices is in the field of medicine. In fact, medical students are placed in hospital/clinical environment require in their training an access to course information while on the move. In addition, the work of the postgraduates and the physicians involves a high degree of mobility between distributed sites and instant communications within work environments. Distributed sites, where physicians are working and in which students are placed, are often in remote and rural areas. The technological advances can be capitalized to promote and facilitate situated learning and collaborative.

In fact, because of the considerable growth of data, the heterogeneity of roles and needs as well as the rapid development of mobile systems, it becomes important to introduce a new system able to provide the users with a pertinent training adapted to their needs. We seek to develop an m-learning system of which the main issues are: (i) learning seen as "a collaborative process" that connects learners to communities of people through situations. Learners are not formed by a single teacher but by a learning community. (ii) Learning seen as "a process context-aware", the learning process must adapt to these changes in context: consideration of context aware and adaptation. This implies that the apprenticeship system is able to explore the environment to determine the current context and conduct learning activities in a particular context. Also, it is adapting learning resources (content, services, etc.) select the proper way to perform according to the current context activities.

In our work, a learning system named CCMLS (Context-aware and Collaborative Mobile Learning System) has been proposed. This system requires a context-aware architecture with mechanism that considers the change within the context. This architecture must take into account the users' different characteristics as well as all the contextual situations that influence their behavior when interacting with the mobile learning system. This system allows to share, to build, to collaborate with others remotely via collaborative tools (wiki, chat, forum, blog, etc.) or social networks of Universities, of Hospitals, etc.

The learner is only recipient of knowledge provided by the trainer but it becomes actor of the learning platform. He is involved in their own learning and working with the trainer and other learners. Finally, he shares his knowledge and expertise. We talk about learning community. Furthermore, the objectives of CCMLS can be specified as follows:

- To take not only learning objects, but also knowledgeable people as learning resources.
- The information about a role and individual role members should be used to help a learner to find appropriate knowledgeable people: such people may be a domain

expert, teacher and even a co-learner when the learner needs to learn how to perform an activity.
- To integrate necessary communication tools.
- To classify the learning contents into learning objects, and to describe learning objects with metadata.
- To enable a learner to get the right learning objects at the right time.
- To enable a learner to contact the right people at the right time with the proper communication tool.
- To assist the learner to access the extensive knowledge artifacts' with which the learner could better understand the just learned knowledge or skills and also extend his learning area.

Through analysis of the relative work stated in previous section, three essential elements of a context-aware mobile learning system are: the context model, the learning units, and the adaptation engine with designed learning strategies. According to this structure, we state the overall architecture of the CCMLS system. This architecture consists of three layers: Learning Context Layer, Learning Adaptation Layer and Learning Application Layer. The context layer contains various physical and visual sensors to sense the learning context values defined in the context model. The goal of the Learning Adaptation Layer is to provide appropriate learning supports, including learning objects, learning community and learning activities, in relation with the current learning context. The learning application layer is in charge of interacting with learners, such as: collecting their information and requirements, displaying to them the adaptive learning objects, building the appropriate communication platforms between them and the selected learning community, helping them to complete proper learning activities, etc.

To realize and validate our proposals, a prototype of the system has been developed to facilitate the management of reusability and discovery of resources and services to deal with a dynamic environment. This prototype implemented with the PHP, Java, Jena, OWL, XML and MySQL technologies, using the development and running tools Eclipse, JDK, Protégé.

6 Conclusions

In this article, we have presented and compared the list of mobile learning architectures according to a set of features. All the presented architectures are not able to detect the mobile learning environment or to get information about it. Therefore, they cannot be adapted. Our work is an extension of one of the presented m-learning approaches in which we propose the context management, the adaptation and the learning without a break through contexts. Our goal is to design a mobile learning architecture that supports the features of mobility and context in order to enhance the learning experience in the field of education, specifically in medical field.

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