A Middleware for Adapting Context to Mobile and Collaborative Learning

Jihen Malek[1/2], Mona Laroussi[1/3], Alain Derycke[1]

1 Laboratoire Trigone - CUEEP - Bât B6 Université des Sciences et Technologies de Lille
59655 Villeneuve d'Ascq cedex – France
http://noce.univ-lille1.fr/cms/index.php
Mona.laroussi@univ-lille1.fr; Alain.derycke@univ-lille1.fr
2 RIADI ENSI campus de la manouba 2010 Tunisia
mjihene@yahoo.fr
3 INSAT Centre Urbain Tunis Nord BP 676 CEDEX 1080 Tunis TUNISIA

ABSTRACT
The rapid and accelerating move toward the adoption and use of mobile and wireless technologies creates opportunity for new research field-'mobile learning' that includes a variety of applications and new learning techniques. An efficient mobile learning system has to be sensitive to the context that characterizes the interactions between humans, applications and the surrounding environment.
Researches in context aware mobile learning have concentrated on how to adapt applications to context. In this paper, we describe the design of a context aware middleware (with an emphasis on controlling the environment) with the aim of supporting M-learning. First, we identify contextual elements and their features relevant for mobile and collaborative learning. Then, we propose a middleware architecture for managing and adapting context which supports tasks including: acquiring, interpreting, modeling, storing, reasoning, updating and adapting context.

KEY WORDS

Mobile learning, context, adaptation, middleware.

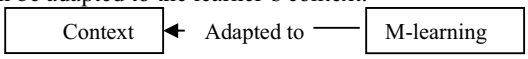
1 INTRODUCTION

The evolution in education and training at a distance can be characterized as a move from d-Learning (distance learning) to e-Learning (electronic learning) to M-Learning (mobile learning). M-learning, or mobile learning involves delivery of digitized e-content through wireless phones hooked into laptops or personal digital assistants (PDAs) [SUS 04].

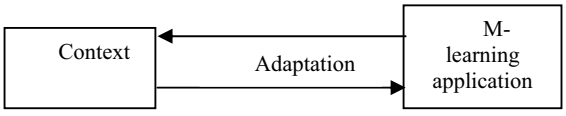
There are two familiar approaches to the issue of mobile learning. The first approach points out that since the dominant mode of access to the Internet will soon be through wireless devices, e-learning simply becomes m-learning, without any particular changes in content. The new approach stresses that M-learning is a new paradigm that creates a new learning environment and that provides content dynamically depending on a learner's context [SUS 04].
Mobile learning allows learners to access learning material related applications any time and anywhere through several devices. Through the notion of context-awareness, researchers have tried to improve the learner's interaction within M-learning session by exploiting information related to learners, devices and the environment.
From our point of view, context aware mobile learning applications must achieve two goals:

- Mobile learning must become an extension to our natural senses, thus enriching and facilitating our life. Then, We can talk about man-machine integration instead of man-machine interaction [ALA 01].
- Context-aware learning must be able to extract, interpret and use contextual information and adapt functionalities to the current context of use [ENS O2].

Context-aware mobile learning is a very active area of research and development but a review of past research shows that there is a great interest into how applications can be adapted to the learner's context.



But to achieve man-machine Integration, M-learning applications must interact with the learner's environment. This interaction requires that M-learning applications control the context parameters in order to adapt that context to the learner's needs. Such a communication aims to facilitate the learner's life and to create an adequate learning environment which helps him/her to concentrate better on his/her learning task.



We will use a case study to explain our motivations to conduct this study on how to guarantee context-adaptation.
Imagine learning in an indoor place (e.g., in your office). If the contextual elements are to be considered "adapted" to the learner's needs, from our point of view, one or more of the wide range of possible events should occur:

- The lamps will be switched on, and dimmed to the learner's personal preferences.

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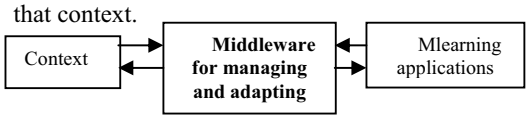
- The air cooler or the central heating of the room will be adjusted to the learner's personal preferences.
- The user's favorite radio channel will be switched on and the volume will be adjusted automatically according to the type of the task performed by the learner and the degree of concentration needed.
- The window store will be closed or opened automatically.

According to the mentioned examples, the purpose of this study is to focus on how to manage context and adapt it to the learner's and M-learning needs.
In this paper, we present our work on context adaptation for mobile context-aware learning. The major steps of this work are:

- Identifying the contextual elements relevant to mobile learning in order to define which of them can be adapted.
- Building a middleware level support between M-learning and the context for managing and adapting that context.



Our middleware provides supports for most of the tasks involved in dealing with context: Acquiring context from various sources; Interpreting context; Modeling context; Storing context in knowledge base; Reasoning context in order to extract new implicit contextual elements; Updating context; Adapting contextual elements by commanding them automatically.

This paper is organized as follows. Section 2 overviews our definition of context and identifies contextual elements relevant to the field of mobile learning. Section 3 presents our approach for adapting mobile context aware learning and discusses the middleware architecture of the system.

2 CONTEXTUAL ELEMENTS OF A MOBILE AND COLLABORATIVE LEARNING ENVIRONMENT

Most of previous and current works on adaptive e-learning focus on user model [IKS 02] [LAR 01]. Location context and location dependent applications currently dominate the research field of context aware mobile computing [LAR 04], so we try to give a marriage of these contexts and attempt to extend the meaning into more abstract context that gathers all characteristics facets of the context of mobile and collaborative learning (cf. Figure1).

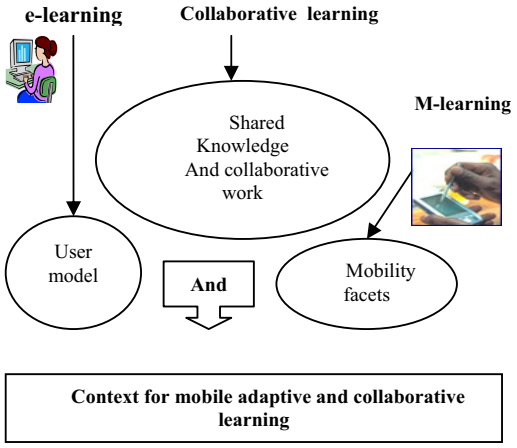


Fig. 1. Context for mobile adaptive and collaborative learning

Based on previous definitions [ENS 02] [KEA 04][GUA 00][SAL 01][ANI 04][MAA 05], we provide our definition of context for mobile and collaborative learning. Given the diversity of context information, it is useful to attempt to categorize it to make it easier to apprehend in a systematic manner. To this aim, we introduce a simple classification of context information, based on categories of contextual information.
We introduce two essential categories of contextual information —individual context and shared context.
Individual context includes information relevant to the interaction between the learner and M-learning applications.
Shared context includes information relevant to collaborative group work or learners sharing common interests.
The context categories we have identified can be used in a number of ways by context-aware mobile learning applications.

2.1 Description of Individual Context

According to Table 1, Individual Context includes:

- *Internal environment* which includes information about the learner itself: his/her user model and his/her current state during interaction with M-learning application.
- *External environment* which includes information about the learner's surrounding environment (social environment, physical environment, temporal environment and software and hardware environment).

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Table 1 Individual Context

Category	Sub category	Contextual element
Internal environment	**User model**	Personal information Knowledge Experience and practices Competences Preferences Interest center Goals Health state Previous activities Agenda
	Current state of learner during interaction	Concentration degree Physiological state Psychological state Type of Mobility Current activity
External Environment	**Physical environment**	Location and orientation Noise level Weather temperature Light
	Temporal environment	Date Hour Season
	Hardware environment	Device capabilities bandwidth processor speed storage capacity resolution sound quality sound power battery network capacity connectivity
	software environment	Plug in OS
	Social environment	Connected people People around the learner

2.2 Description of Shared Context

According to Table 2, Shared Context includes:

- Shared individual contexts of teamwork's members (practices, common errors, experiences).
- Collaborative work environment (production environment, communication environment and coordination environment.

Table 2 Shared context

Shared individual contexts of teamwork's members	practices common errors experiences knowledge	Obtained from individual contexts of teamwork's members
collaborative group work environment	communication environment	Available tools that help learners to accomplish their tasks Resources needed to help learners in specific fields.
	coordination environment	Synchronous Communication (chat, visioconference) Asynchronous Communication (FAQ, forum, mail)
	production environment	Tools making coordination between teamwork members (e.g., schedule tools)

2.3 Contextual Element Features

In order to manage Contextual elements, we must differentiate between them by giving them different features. Table 3 illustrates these features: nature, acquisition type, acquisition mode, relevance, evolution, adaptation and frequency of updating.

Table 3 Description of Contextual Element Features

Contextual element features	Possible values
Nature	*Natural : temperature* *Artificial* : the sound of the stereo channel
Acquisition type	*Explicit acquisition*: contextual element is directly acquired. Automatic acquisition: contextual element is sensed automatically (e.g., by sensors) Manual acquisition: contextual elements are given by learner. *Implicit acquisition*: contextual elements are inferred from others stored contextual element.
Acquisition mode	*Instantaneous*: contextual element is acquired only once at the beginning of the interaction (e.g., date) *Continuous*: contextual element is acquired continuously during an M-learning session (e.g., noise level).
Relevance	*Active* : contextual element relevant to the interaction between learner and the system (e.g., if learning type is a Visio-conference, noise level is an active element) *Passive*: isn't relevant to a given interaction between learner and the system (e.g., if the learner's task consists of reading a text, the name of learner is a passive element).
Evolution	*Dynamic* : contextual element change during the interaction (e.g., noise level) *Static* : contextual element does not change during interaction (e.g., season)
Adaptation	*Adaptable* *Not adaptable*
Frequency of updating	This feature ensures the newness of contextual elements

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3 MIDDLEWARE ARCHITECTURE

Based on contextual elements. We are able to design a middleware level support between M-learning and context.

3.1 Specification of the Middleware Functionalities

According to figure 2, our middleware includes three levels: Context adaptation, Context Storage and Context manager.

Each of these levels includes modules which must ensure functionalities as shown in table 4:

Table 4: Middleware Functionalities

Level	Modules	Functionalities
Context adaptation	Context adapter system	**Context updating:** the middleware updates contextual elements to ensure freshness. Different contextual elements require different update frequency. For example, some contextual elements may require updating every month or year whereas sensed contextual elements may need to be updated more frequently due to the dynamic nature of the sensed data.
		Context adaptation: the middleware adapts some active contextual elements to meet the learner's and the M-Learning application needs. This adaptation consists in controlling and commanding contextual elements of the learner's environment.
	Context filter	**Context filtering:** first, the middleware distinguishes between passive contextual elements and active ones. Second, it retains only those which can be adapted.
	Context Reasoner	**Context reasoning:** the middleware provides deduced contextual elements or implicit contextual elements based on explicit context.
Context Storage	a Contextual knowledge base (CBK) stores context values	**Context storing**: the middleware stores contextual elements in a contextual knowledge base in order to build a contextual history.
Context manager	Context modeler	**Context modeling:** the middleware models the contextual elements by representing them in the form of high level description. The basic concept of our context model is based on ontology which provides a vocabulary for representing and sharing context knowledge in a pervasive computing domain, including machine-interpretable definitions of basic concepts in the domain and relations among them. An ontology-based model for context information allows us to describe contexts semantically in a way which is independent of programming language, underlying operating system or middleware; enables formal analysis of domain knowledge (context modeling is out of the scope of this paper but it concerns another related work).
	Context interpreter	**Context interpreting:** the middleware interprets the acquired contextual elements in order to obtain high level contextual elements. For example, it's possible to transform GPS coordinates to a complete address because it's more significant than GPS coordinates.
	Context provider	**Context acquisition**: the middleware acquire contextual elements from different sources: Sensors: light sensors, Gps, bio-sensor, audio sensor, temperature sensor, camera... Knowledge base of the learner (User model) M-learning application (contextual element about the activity which would be made by the learner) Mobile devices and network (contextual elements are about Mobile devices and network characteristics)

3.2 Middleware Architecture

This middleware Architecture aims to manage contextual elements and adapt them to the learner's needs. This context adaptation will facilitate the learner's life and create an adequate learning environment which helps him/her to concentrate better on his/her learning task (cf. Figure 2).

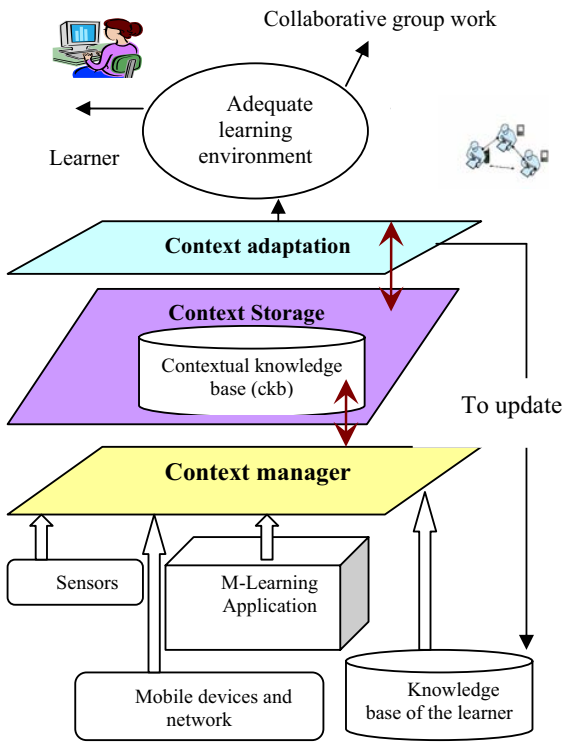

Fig 2. Overview of the middleware architecture

CONCLUSION AND FUTURE WORK

In this paper, we proposed a new definition and classification of context for mobile and collaborative learning. First, we have classified contextual elements into two categories: individual context and shared context. Individual context gathers information relevant to the interaction between a learner and M-learning application. Shared context gathers information relevant to collaborative group work or learners sharing common interests. Then, we have identified contextual elements features: nature, acquisition type, acquisition mode, relevance, evolution, adaptation and frequency of updating.

This proposition helped us to present our approach for adapting context to learner's and M-Learning application requirements.

The fulfillment of that context adaptation has required the proposition of a middleware architecture that supports tasks including: acquiring, interpreting, modeling, storing, reasoning, updating and adapting context.

The proposal is complete from the conceptual and methodological point of views, but needs to be evaluated in a set of experiments. Then we shall develop a prototype following the middleware architecture and including an ontological based model for modeling context.

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