Adaptive Approaches to Context Aware Mobile Learning Applications

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Abstract

Learning has gone through major changes from its inception in the human race. Among all such major changes mobile learning is the latest to happen with the advent of mobile learning technologies that have the potential to revolutionize distance education by bringing the concept of anytime and anywhere to reality. From the learner's perceptive, mobile learning is "any sort of leaning that happens when the learner is not at a fixed, pre-determined location or learning that happens when the learner takes advantage of learning opportunities offered by mobile technologies". Research in context aware mobile learning has concentrated on how to adapt applications to context. This paper reviews and discusses few mobile learning systems the approach in implementing context awareness and adaptation, and presents some others good work done in this line.

Keywords: adaptation, adaptive learning, context, learning activity, learner model, learning automata, mobile learning.

1. INTRODUCTION

Mobile learning has become widespread, and students nowadays are able to learn anywhere and at any time, enabled by mobile technologies and wireless internet connections. Mobile learning can be distinguished "by rapid and continual changes of context, as the learner moves between locations and encounters localized resources, services and co-learners" [1], and these different situations are described by different learning contexts [2]. The diversity of mobile and wireless technologies and the nature of dynamics in mobile environments complicate context awareness.

Context-aware mobile learning has become increasingly important because of the dynamic and continually changing learning settings in the learner's mobile learning environment giving rise to many different learning contexts. The challenge is to exploit the changing environment with a new class of learning applications that can adapt to dynamic learning situations accordingly. The task of a context-aware mobile learning application is to sense the mobile environment and react/adapt to the changing context during a student's learning process [1]. Context is a key in the design of more adaptive mobile learning systems [3] and context-awareness must be integrated within the systems in order for them to be truly effective [4]. Mobile devices and sensing technologies are combined to provide physical and environmental contexts in mobile applications.

Two characteristics of context have been described by Laerhoven [21] as activity and environment. The task that the user is performing at the moment is described by the activity, and focuses on the user of the device and his/her habits. The physical and social surroundings of the user are described by the environment, such as the current location and movements in the environment etc. The increasing use of mobile applications in varying contexts, locations and surrounding environments means that if these applications were made context-aware, then contextually relevant information from the devices can be transferred to the user [22].
In the mobile learning context, it is helpful to consider context awareness and adaptivity as two sides of the same coin [5]. The purpose of the adaptivity and context awareness is to provide better support for variety of learners, given that they may have very different skill and motivations to learn in varying contexts. Adaptivity can be one form of adaptation; or as a quality of a system to automatically and autonomically regulate and organize its functioning, the appearance of its User Interface and the order of information it offers [6].

In this paper, we present some of the different approaches and methods to context aware and adaptation/adaptivity that are already present in the literature. The remainder of this paper is organized as follows. In Section 2, we describe the Characteristics of an ideal learning system adaptive to the learner and to his/her context proposed by Telmo Zarraonandia, et al. In Section 3, we present three different (layered, modular, interaction) types of adaptive systems. In Section 4, we present different (Bayesian, Learning automata, Agent) type of methods for adaptivity implementation. In Section 5, we present Bijective adaptation between context and adaptivity in a mobile and collaborative learning. Finally, conclusions and future work is given in Section 6.

2. DESIRABLE CHARACTERISTICS OF AN IDEAL LEARNING SYSTEM ADAPTIVE TO THE LEARNER AND TO HIS/HER CONTEXT

Telmo Zarraonandia, Camino Fernandez, Paloma Diaz & Jorge Torres[7] have selected a group of desirable characteristics for an ideal learning system that is able to adapt the course to learner specific characteristics, knowledge, objectives and learning goals, also sensitive to the context in which the learning session is taking place and capable to adjust the appropriate parameters accordingly.

Different kinds of information has been separated and represented by means of different models like Domain Model, User Model and Adaptive Model, of which Adaptive Model is of our interest here.

“Adaptive Model: This model relates the two other models (Domain & User) defining which materials will be presented and how the presentation will take place in order to achieve the learning goal, optimizing the learning process. The characteristics that were considered for this model are:

- To use some kind of pedagogical approach for the adaptation.
- Pedagogical rules updateable: As the pedagogical approach may vary depending on the learning theory that is applied or on the knowledge domain, they wanted their system to be flexible enough to give the instructors the possibility of programming different pedagogical approaches for the same course.
- Levels of sequencing of learning material: to adapt the sequence of concepts presented to the user in order to achieve his/her learning goal (knowledge routes) and to adapt the sequence of learning materials presented to the user in order to achieve the knowledge of a particular concept (content sequencing)..
- Learner progress consideration: Capability to generate the knowledge routes of

materials dynamically by taking into consideration the learner progress during the course.

- Re-routing: Capability to re-plan the knowledge route if special difficulties are detected with a particular concept and even to change the current pedagogical method if the system detects it is not performing well for that particular learner.
- Use of standards to define the rules that govern the adaptation."

The above said characteristics are of most important when the learning system transforms into a mobile learning system taking into account all the dimensions of mobility.

3. ADAPTIVE SYSTEMS

3.1 Context Aware and Adaptive Learning

In architecture [8] of a context-aware and adaptive learning, Jane Yau and Mike Joy proposed two Adaptation Layers: The information has been considered for the survey purpose and presented here as taken from the cited reference.

"Learning Preferences Adaptation Layer: This layer consists of the Learning Preferences Adaptation Module, which contains sub-modules - Learning Styles Adaptation, Learning Priorities Adaptation and Knowledge Level Adaptation.

The learning preferences of a learner are retrieved from the Learner Profile database and incorporated into the relevant sub-module for the appropriate learning objects to be chosen at a later stage.

Matching the correct level of information according to the learner's most appropriate learning style can also create a more enjoyable and effective learning experience for the learner [9].

Contextual Features Adaptation Layer: This layer consists of the Contextual Features Adaptation Module, which contains sub-modules – Location-specific Adaptation and Time-specific Adaptation. Each of the contextual features are retrieved from the Learner Schedule database and incorporated into the relevant sub-module for the appropriate learning objects to be chosen at a later stage.

By placing a User Verification option, the problem of learner not conforming to his/her schedule is rectified; This prompts the user at the beginning of the learning session to indicate whether the location and the available time that the tool has retrieved is accurate. Another method which can also be used to detect discrepancies between the learner's stated location and his/her current location is to have an option for Software Verification.

The importance of obtaining the actual location of the user derives from the fact that the contextual features surrounding the location are different in various different places, and can affect the learner's ability to study such as their concentration level, which can be affected by the level of noise in the location or environment.

A number of methods for obtaining the noise level to determine the possible level of concentration that the learner has at a location have been considered. Firstly, a microphone sensor can be used to detect the noise level which can approximately indicate the level of concentration that the learner has in such an environment with that level of noise. Secondly, results obtained by Cui and Bull [10] can be used to map the concentration level of a learner to a certain type of location.

In the study conducted, student's location of study and their corresponding chosen level of concentration were recorded and discovered that the chosen concentration levels in various types of location by different students were found consistent even though noise levels may have been different. The results indicate that students shared similar levels of concentration in the same location despite the varying levels of noise. This also suggests that there are other elements in the environment which could affect a student's concentration level such a movement."

3.2 Context - based Adaptation in M-Learning

In architecture [11] for a Context-based Adaptation in M-Learning proposed by Estefania Martin, Nuria Andueza, Rosa M. Carro manages data about users and activities so that the most suitable activities to be accomplished at each time are suggested to each user are taken care of by Activity adaptation module.

"Activity adaptation module: This module is responsible for deciding about the availability of activities and of generating the list of available activities to be sent to the alert module which is responsible for alerting the learner about the same depending on the various contextual element values and by processing a set of rules that indicate in which cases the situation of the user is appropriate for alerting him/her about the availability of activity.
This module is structured into three sub-modules: Structure-based adaptation, Context-based General Adaptation and Individual Adaptation.

Firstly, the Structure-based Adaptation sub-module processes the structural rules, which establish, for each type of user accessing the system, the relationship between activities, as well as the order in which they must be performed, if any. Its main aim is to generate a list of activities to be suggested to the user. The first step is to select the activities according tot the most appropriate rules for a certain user. For the same activity, the list of sub-activities can be different depending on certain conditions related with the user's personal features, preferences, as well as his/her current situation, including the context(spare time, location, available devices), pending activities and actions during his/her interaction. Therefore, the rule activation conditions are checked and the corresponding rules are triggered.

Secondly, the Context-based General Adaptation sub-module consists of a filter that processes a set of general rules to choose the type of activities more suitable of being accomplished by the user. It adds/removes activities depending on their type (review, individual exercises, collaborative activities or messages, among others). This filter affects to all the activities to be performed.

Finally, the Individual Adaptation sub-module checks the conditions of atomic activities, if any. These conditions can be related to any user feature or action stored in the user model."

Rule-based adaptation techniques are used in the above discussed system.

3.3. Interaction through Context Adaptation

In the investigative study [12] by Yuan-Kai Wang shows importance of context-awareness and adaptation in mobile learning, proposes Context Aware Mobile Learning (CAML) that senses mobile environment and reacts or adapts to changing context during learning process has four interaction modes.

The challenge is to exploit the changing environment with a new class of learning applications that can adapt to dynamic learning situations accordingly. Interaction through situated or reactive adaptation can improve learning process. There are four key modes of interactions in Context

Aware Mobile Learning (CAML):

"(a) Spatio-temporal dependent interface: It is situated user interface adapted according to time and location contexts. For a mobile learner in classroom at course period, lecture slides and student notes are most important interfaces. However, homework and group discussions become primary when the learner changes place to home after course period. Located learning objects that are nearby or meaningful are emphasized or otherwise made easier to choose.

(b) Contextual event notification: Learning process is mostly planed as a calendar with a lot of scheduled activities, such as lecturing, test, examination, homework, and so forth. Timely execution of some course activities, such as the reminding of homework, can be implemented as context-triggered event. Notification is dynamically scaled and adapted by inferring interruptibility based on the user's recent activity and context of the mobile environment. The interruptibility of event notification could be spatio-temporal context dependent as a simple example. Facility and activity contexts are also helpful for contextual event notification.

(c) Context-aware communication: Communication can be divided into asynchronous and synchronous messaging between teachers and students, or among students. Asynchronous messaging, such as email, discussion board are desired when the recipient is unavailable or if either is not currently near a computer. Synchronous messaging, such as online chats are more appropriate after course for group discussion. Context of online status can be used to gauge whether the learner is in a course context or a social context where an interruption is less appropriate. Spatio-temporal, facility and activity contexts are important for the appropriate utilization of communication methods.

(d) Navigation and retrieval of learning materials: Learner can reactively or actively browse and search learning materials. In reactive learning, accurate learning materials are delivered to the learner if the activity context of personal learning progress is obtained. In active learning, effective browsing and searching of tremendous learning materials are important and can be achieved by context restriction. For example, proximate selection is one way of context restriction by spatial context."

4. IMPLEMENTING ADAPTIVITY IN MOBILE LEARNING

4.1. Using Learning automata as probabilistic adaptation engines

Economides A.A. proposed adaptation engine in an Adaptive Mobile System [13] that used Learning automata to implement the probabilistic adaptation decisions.

"Adaptation Engine: The inputs to the Adaptation engine are – learner's state, the educational activity's state, the infrastructure's state and the environment's state (Table1). The output consists of the adapted educational activity's state, and the adapted infrastructure's state (Table 1).

U(t)=[L(t),A(t),I(t),E(t)] is the input to the adaptation engine at time t.

O(t+1)=[A(t+1),I(t+1)] is the output from the adaptation engine at time t+1.

Input U(t)	Output O(t+1)
L(t): Learner's state A(t):Educational Activity's state I(t): Infrastructure's state E(t): Environment's state	A(t+1):Adapted educational Activity I(t+1):Adapted Infrastructure.

TABLE 1: Input and Output of the Adaptation Engine.

Learning Automata Adaptation: Here probabilistic algorithms to adaptively select the most appropriate state of the educational activity or/and the infrastructure are proposed. They employ learning automata that reinforce a good decision and penalize a bad one [14].

At time t, the adaptation engine selects the state for the educational activity to be A(t)=Am with probability PAm(t), and the state for the infrastructure to be I(t)=tn with probability PIn(t). Define PA(t)=[PA1(t),…,PAM(t)], and PI(t)=[PI1(t),…,PIN(t)].

Considering Learning Automata Adaptation decisions, following are given:

Assume that at time t, the A(t)= Am is selected probabilistically according to PA(t). If this results in “good” outcome (e.g., the learner is satisfied) then increase the probability of selecting again the Am and decrease the probabilities of selecting all other As. Otherwise, do the opposite.

Assume that at time t, the I(t)= In is selected probabilistically according to PI(t). If this results in “good” outcome (e.g., the learner is satisfied) then increase the probability of selecting again the In and decrease the probabilities of selecting all other Is. Otherwise, do the opposite.

For example, Let assume that there are two networks in the vicinity of the mobile learner. The problem is to select the network that will provide her the best communication performance and reliability in order to achieve her educational activity.

Therefore, let I1 be the Infrastructure including the first network, and I2 be the Infrastructure including the second network.

Let also, PI1 be the probability of selecting the I1, and PI2 be the probability of selecting the I2.

Let at time t, In(n=1 or 2) is selected with probability PIn(t).

If the communication performance and reliability delivered to the learner is “good”, then increase PIn(t+1), the probability of selecting again infrastructure In: PIn(t+1)=PIn(t)+a*(1-PIn(t)), 0<a<1,
Otherwise, decrease PIn(t+1): PIn(t+1)=PIn(t)-b*PIn(t), 0<b<1,

Of course, PI1(t+1) +PI2(t+1) =1.

In the above example, the Linear Reward-Penalty learning automation has been used. However, other learning automata algorithms [14] may also be used depending on the situation.”

4.2. Using Bayesian network to determine mobile learner’s style and adapt to it

Yu Dan and Chen XinMeng [15] used the Bayesian networks to determine mobile learner’s styles exploring the potential of individualization of learning process for the learners to implement adaptive mobile learning system architecture that provides a mechanism for adapting content presentation to the mobile learner model and device model, improving mobile learning process.

“Each individual has his/her unique way of learning. Learning style greatly affects the learning process, and therefore the outcome[16]. Mobile learners, who are typically distance learners, usually work individually without external support and have various learning backgrounds and levels. This work here uses Bayesian network to determine mobile learner’s styles, which is based on Felder-Silverman learning style theory.

Felder-Silverman learning style theory categorizes an individual's preferred learning style by five dimensions: active/reflective, sensory/intuitive, visual/auditory, sequential/global and inductive/deductive [17]. As inductive/deductive dimension has been deleted from the previous theory because of pedagogical reasons, here they modeled four dimensions of Felder-Silverman framework in their application domain. They built a Bayesian network representing the learning style with a knowledge engineering approach[18].

For each dimension they analyzed respective determining elements in mobile environment, and listed these elements and their values that can take in the following:

Active/reflective (Processing):
Wiki: participation, no participation.
Short message reply: many, few.
Forum: reply, browse, no use.

Sensory/intuitive(Perception):
Reading: facts, theory.
Example: before exposition, after exposition.

Visual/auditory(Input):
Learning material: audio, video.
Chat: audio, video.

Sequential/global(Understanding):
Information Processing: step by step, jump.
Answer: result after steps, only result.

According to the above analyses, they implemented by Bayesian network(Fig.1) encoding relations among three types of variables: learning styles, four dimensions of the learning styles, and different elements that determine learning styles.

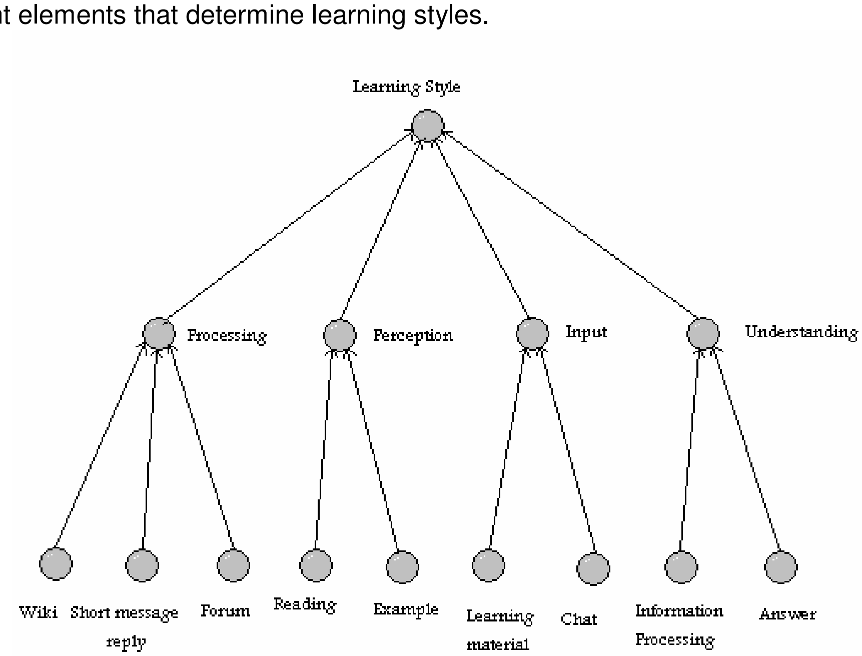


FIGURE.1 Bayesian network modeling mobile learner's styles

Once establishing the probability values associated with each node of the graph by expert knowledge and collected data, they made probabilistic inference of a learner's style. For example, suppose for a learner, we obtain the probability values from observation for the reading and example, and then with the conditional probability table of node Perception they compute the probability P (perception) to determine the student is a sensory learner or an intuitive learner."

4.3. Supporting Adaptivity in Agent-Based Learning Systems

Shanghua Sun, Mike Joy & Nathan Griffiths developed an agent-based learning system [19] that incorporates learning objects to facilitate personalization, and is based on a learning style theory as the pedagogic foundation for adaptivity, and evaluation indicates that the approach is able to provide personalized(or adapted) learning materials and improve the adaptivity in learning systems.

"Here the system locates the student's learning style preference into the learning style space, and also stores each student's current learning style, and the style attributes of each learning object, as coordinates in the four-dimensional space. The system will then search the repository of learning objects, to fetch appropriate learning object with similar dimensional descriptions. These are supported by agent technology to realize the algorithm and implement the process. The objects are then presented to the student, and the subsequent interactions between the student and these learning objects may be used to modify the learning style attributes recorded for a student.

Agent technology has been used to facilitate autonomy and adaptivity, decoupled from the pedagogic foundations of the system [20]. Their system consists of five agents as shown in the figure 2, namely Student Agent, Record Agent, Modelling Agent, Learning Object Agent and the Evaluation Agent. Each agent is designed to satisfy a certain functional requirement to actualize the service purpose of the education system, namely to provide dynamic and adaptive learning materials to individual users.

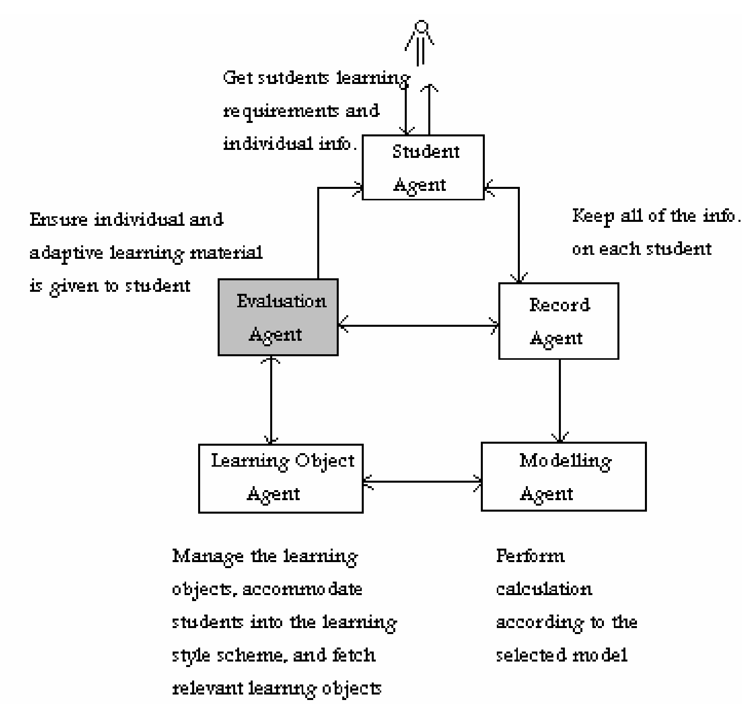


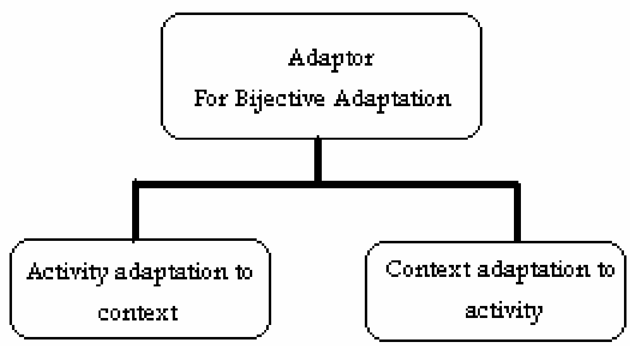
FIGURE 2. System Architecture

The Evaluation Agent ensures that learning objects are presented in individual and adaptive learning paths to each individual student. Here the use of learning objects and learning style in a agent-based learning system to enhance adaptivity has been introduced. At the conceptual level, personalization and adaptivity are achieved by the use of learning style schemes to tailor the presentation of learning objects to individual students. Conversely, at the practical level, this adaptivity is achieved by providing a set of agents that use a combination of prebuilt and acquired knowledge to determine the leaning styles and learning objects that are appropriate for individual students. Evaluation of the system effectiveness and efficiency is to be assessed."

5. Bijective Adaptation between context and activity

Jihen Malek, Mona Laroussi and Alain derycke [3] have presented an innovative approach for modeling a Bijective adaptation between context and learning activities within mobile and collaborative learning environments; in which is an adaptor that defines two classes of functionalities: the adaptation of learning activity to context and the adaptation of context to learning activity.

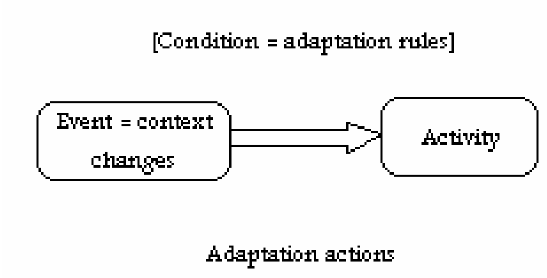
"Adaptor for Bijective Adaptation: This adaptor models all possible interactions between context and learning activity because context and learning activities influence each others in learning processes. This adaptor provides developers with all the possible adaptation actions that should be taken into account through a bijective adaptation process.



i. Activity Adaptation to Context

An activity is adapted or conducted with some variations depending on some values of contextual elements attributes. So, only relevant context changes are modeled and taken into account for the triggering of the activity adaptation process.

When event (or relevant context changes) occurs, conditions (or adaptation rules) are checked and then Activity adaptation process actions are triggered.



Three levels are differentiated within an activity adaptation process:

Presentation level: for example, if the physical environment is characterized by a high noise level and the learning activity includes a sound, then adaptation action compels the inhibition of this sound if it is not necessary for performing the activity.

Navigational level: to model the navigational schema of learning activity, they used UML activity diagrams as shown in figure 3 below. Adaptation actions at this level will consist of the selection of the appropriate learning sub-activity according to the current context.

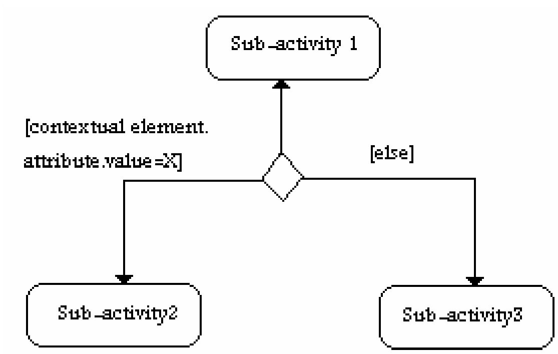


FIGURE 3. Navigational schema of learning activity

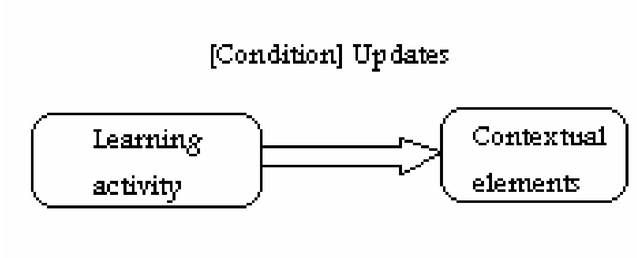
For example, the number of connected learners of the teamwork is used as selection criteria which outlay the nature of the adequate sub-activity.

Intentional level: The intentional level doesn't have the same role as the other levels of adaptation. This level guarantees that learning activity's objectives are preserved and not modified by the adaptation whatever the latter is; presentation or navigational level.

ii. Context Adaptation to Activity

a. Activity updates context

The values of some contextual element's attributes are updated when an activity is completed, but some conditions must be checked before the update (when activity's goals are achieved).



For example, passing an exam updates the user model in a way that extends the learner's knowledge in that relative area.

b. Activity adapts context

Some contextual elements can be adapted to the activity needs. So context adaptation process consists of controlling the context parameters in order to adapt them to the activity needs. This adaptation aims to create an adequate learning environment which helps learners concentrate better on their learning activity.

For example, the volume of the tape recorder stereo will be adjusted automatically according to the type of activity performed by the learner and the degree of needed concentration."

6. Conclusion and Future Work

This paper presents few mobile learning systems approach in implementing context awareness and adaptation. Adaptation is achieved in terms of the learner context, the learner's knowledge levels, the content that is to be presented, the learner's style which may vary from learner to learner and Adaptation to the device's context. Finally we identify that there is a need for explicitly modeling the entities in a mobile learning environment including learner and his behavior in dynamically varying contextual elements and representing inherently existing associations between all the above said approaches to be modeled for an effective mobile learning system which enhances the mobile learner experience, knowledge and usage of the device. We conclude that further research is needed in modeling the user interactions at application level, activity level and at user interface level to understand user intentions and acceptability levels for a given context(s) to make mobile learning more intelligent for adaptation and hence become learner friendly resulting in maximization of the mobile learning goals.

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