Context Awareness and Adaptation in Mobile Learning

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Abstract

This study investigates the importance of context-awareness and adaptation in mobile learning. Context-aware mobile learning that senses mobile environment and reacts to changing context during learning process has four interaction modes with three mobile entities of different mobility. Contexts in mobile learning are categorized into six dimensions that form a context space. Several mobile learning systems are examined according to the definition of context-aware mobile learning. Challenging issues of context awareness and adaptation are explored.

1. Introduction

As mobile technologies become widespread, teachers and students will be increasingly mobile, using more portable devices and interacting with computationally-enhanced learning environment. There has been a tremendous increase of research and experiments in the use of mobile technologies for learning. The proliferation of numerous mobile learning systems, such as [1,2,3,4], illustrates the importance of developing wireless and mobile learning applications.

High dynamics is brought on a new challenge due to so many combinations of mobilities in mobile learning. The challenge is to exploit the changing environment with a new class of learning applications that can adapt to dynamic learning situations accordingly. The mobile computing devices available for usage, the capacity and cost of networks accessible for connection, and so on, may all change over time and place. In short, the learning setting is continually changing. An instantiation of dynamic learning setting is called a learning context.

[1]The awareness of learning context is important. A learning system that examines the learning context shall adapt learning process with respect to context change. Although it is not a new idea, context awareness is increasingly vital in mobile learning because learning context is more dynamic and complex.

However, context awareness is not easy to achieve. The diversity of mobile and wireless technologies and the nature of dynamics in mobile environments complicate context awareness. Therefore, contextual information, such as display capabilities of mobile devices, is usually predetermined and coded within the system. There have been a few prototype systems utilizing context-awareness to support learning [5,6,7,8,9]. Most contextual information, such as learning place and live learning activities, has to be gathered, abstracted and transmitted by teachers, or even students.

Context-aware computing has become an endeavor to the research of intelligent human-machine interface in mobile computing [10]. Mobile devices and sensing technologies are combined to provide physical and environmental contexts in mobile applications. Although location context and location-dependent applications currently dominate this research field, many enlightened works [11,12] extend the meaning of context from location and other physical sensor data into abstract context. A few architecture frameworks [12,13,14,15] are also proposed for context-aware computing. They provide a ground foundation for system development of context-aware applications.

Context-aware computing, concerning physical context sensed from embodied sensors, provides enhanced and situated interactions. Mobile learning, as an emerging research field on the application of mobile technology in learning, currently concerns less in context awareness and adaptation. There is no way for this paper to give a broad and detail portrait to clarify the vital position of context in mobile learning. Here I make an attempt only to give a flavor of the marriage. Some characteristic facets of context-aware mobile learning are discussed and elucidated in the following of this paper.

2. Context-Aware Mobile Learning

Context-aware mobile learning (CAML for brevity) puts emphasis on mobile learners who are carrying portable devices, such as Personal Digital Assistant (PDA), that has been augmented with hardware sensors, such as GPS receivers, wireless LAN, camera, etc, and software sensors, such as network congestion

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manager, web log analyzer, student behavior analyzer, etc. These sensors could detect location, activity, network connectivity, learner state, and so on. A CAML system examines the sensed learning contexts and reacts to changes to the learning environment. Course materials presented to learners properly reflect learning context, and provide more relevant information to meet their dynamically changing contextual requirements.

The adoption of context awareness in learning is not a new idea, but rather has been at the center of one branch of computer-supported learning. Several classical researches, like portfolio [16] and student modeling [17], are kinds of context awareness approaches. Although the detection and use of context has been explored for learning in related literatures, this paper claims that context can be more richly used in mobile learning.

Context awareness, of course, is not the goal of CAML. Context adaptation strategy is crucial in order to engage learners with their context and a willingness to construct new knowledge while learning. Appropriate context adaptation strategy could be integrated with pedagogic approaches, such as active social learning, problem-based learning, situated learning, alternative schedules, and so on.

To elaborate CAML, three fundamental elements, context and interaction, are described in the following subsections.

2.1. Context

Context happens due to interactions between students and teachers, or students and computers. Context is dynamic, interactive, and situated, but context can enable richer forms of interaction. Learner naturally provides context in the form of signs of frustration or confusion, for example, and the teacher can perceive it and make changes to teaching. But currently computers may not sense or use it. In addition to the emotional context which is difficult, there are many other contexts that computer can sense and use.

There are many proposed definitions and taxonomies of context. Shilit [13] divided context into three categories: computing context, user context, and physical context. Chen and Kotz [10] extended it by adding a time context. Dey, Abowd, and Salber [12] gave four categories: identity, location, status, and time.

Since none of them came for education, a definition of *learning context* can be given as "any information that can be used to characterize the situation of learning entities that are considered relevant to the interactions between a learner and an application." More specifically, context in CAML is defined in this paper by six dimensions: identity, spatio-temporal, facility, activity, learner, and community dimensions. The six dimensions form a *context space*. Identity dimension is commonly adopted in computer-supported learning. Spatio-temporal and facility dimensions are specific in CAML. Activity dimension, although having been appeared in various kinds of computer-supported learning, contains more characteristics in mobile learning.

(a) Identity dimension

Identity of learner is a necessary context in CAML. The identifier of each learner has to be unique in the namespace that is used by the applications. Identity is typically recognized via a logon system, or through special devices like smart cards or fingerprint readers.

(b) Spatio-temporal dimension

This dimension spans two elements, time and location, that are useful in a wide array of applications. Time context enables us to utilize temporal information. It is used as a timestamp indicating an instant or period during which some contextual information is known or relevant. Knowledge of time is easily obtained through mobile device.

Spatial location has been demonstrated as an effective context in many applications. Possible locations in CAML include classroom, home, and outdoor. Some learning applications may need more accurate resolution for the three location categories. Location was provided through a locating sensor, such as GPS (Global Positioning System) receiver that could locate the learner to within 10 meters anywhere outdoor.

(c) Facility dimension

The situation of numerous facilities are inevitable in CAML, such as different kinds of mobile devices, stationary workstations affording high-power computing capability, various standards of wired and wireless network connectivity, and versatile sensors providing context awareness. The context of facility is necessary for the support of intelligent interface. For example, different kinds of mobile devices, such as cellular phone, PDA, tablet PC, notebook, and so on, have diverse capabilities of CPU power, display size and color resolution, and input method. A CAML system that is conscious of the facility context can adapt learning material to fit the mobile device.

(d) Activity dimension

Learning activities provide important contexts. Common activities include learner's attendance, status of assignments, peer support, participation of discussion, and group collaboration. Activity contexts can be acquired by web actions [16] that are portfolios of student's access log and discussion records on web, or live actions occurred in classroom [3,6]. Both actions could be extended to mobile situation. Some examples of mobile activities are assignments that could be done or should be done in a mobile place (museum, zoo, and so on), and group collaboration in a mobile place.

Student modeling is sometimes adopted to help detect activities. Activity is application-dependent and not easy to detect. Determining an appropriate set of activity context in a learning process may be difficult.

(e) Learner dimension

A learner has many intrinsic and psychological properties that are important for the success of learning. These properties include learner's emotional state, focus of attention, and background. The intrinsic and psychological properties are not easy to detect automatically, but shall be useful in CAML.

(f) Community dimension

A learning process takes place within a community. Status and interactions among members of the community constitute complex social contexts. In the social context, various learning activities could be interlaced across time, place, school, home, and expertise. Learning roles are dynamic among participants. Instantaneous and emergent behavior of the social context is the most challenging issue.

Among the six dimensions, identity and spatio-temporal dimensions are the bases of formalisms and mechanisms for dealing with context-aware learning. Identity, spatio-temporal, and facility dimensions are considered as low-level contexts, which can be acquired from simple sensor data (hardware or software sensors). Activity and learner dimensions correlate information from multiple low level sensors in order to deduce some higher level states. Activity dimension takes account of dynamic behaviour, and community dimension stretch to highly dynamic behaviour within large population.

2.2. Interaction through Context Adaptation

Interaction through situated or reactive adaptation can improve learning processes. There are four key modes of interactions in CAML: spatio-temporal dependent interface, contextual event notification, context-aware communication, and navigation and retrieval of course material.

(a) Spatio-temporal dependent interface

It is situated used 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, homeworks 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. Course calendar reminder is an application that falls into this category. Notification is dynamically scaled and adapted by inferring interruptibility based on the user's recent activity and context of the mobile environment. They wish to remain aware of significant events or be notified for urgent course requirements. 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. In addition to reminding learners of certain dates and times of activities, anticipatory course materials for coming activities in accordance with the course calendar can be automatically transmitted to their mobile devices.

(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, BBS, and discussion board, are desired when the recipient is unavailable or if either is not currently near a computer. Synchronous messaging, such as online chat and ICQ, 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. When outdoor learning in the field, e.g., bird watching, bird retrieval interface with higher retrieval priority of birds around the location is more appreciated.

3. Some Mobile Learning Systems with Context

There are a few pilot researches in mobile learning that considers context. Since providing a thorough review of these pilot systems is not my intension, here I will take only four representative works for discussions.

In the ad hoc classroom [1], Chang and Sheu designed an e-schoolbag system compatible with a lot of facilities, such as PDA and notebook, and WLAN and GPRS. Facility context was not automatically sensed, but hard-coded in system and switched by human. An e-scheduler module provided temporal context and contextual event notification that reminds students of some learning activities. Although the ad hoc classroom was experimented in zoo, spatial context was not utilized.

Chen et. al. [2] proposed an outdoor learning system with a scaffolding approach. Leaner with higher learning efficiency will gain less support of the system. Support-fading in the scaffolding is achieved by an ongoing assessment module. The system automatically detects activity context in mobile learning environment. No other context is adopted for the help in mobile learning.

The kidsroom project [6] in MIT Media laboratory provided a room that guides children through an interactive storytelling game. Children could freely move in the room. Their actions and voices were captured through sensors like camera and microphone, and captured actions were analyzed to verify that these children act exactly as what the story wants. If it was verified, then the story could continue to next part of the story. The kidsroom utilized a lot of invisible computer and ubiquitous sensors to free children from acting. Activity context was automatically detected and the system can adapt well to the context. Navigation of learning materials is adapted according to the activity context.

An interesting robot educator [9] in CMU was developed for educating visitors in museum. In this study, the mobile device, the robot, could navigate autonomously and avoid obstacles. The job of the robot was to attract and lead visitors to several places in the museum, and taught them something about the demonstration in the place. To effectively attract visitors, the robot detected activity context of listeners: pranking or listening. Multimedia presentation was adapted according to the sensed activity context. Also, the lead of visiting route could be stopped if the robot sensed that audiences are disappearing. Since it is a learning in public place, no identification and learner contexts are needed. Spatial context and spatial interface are needed in order to present different multimedia learning information at different demonstration places.

4. Challenging Issues

As mobile learning continuously emerges, CAML will also become more important. However, presently, there is little support for building CAML systems in a robust and reliable manner. As result, developers must deal with a wide range of system issues. These issues include specifying context needs, discovering available sensors that can address these context needs, acquiring data from these sensors, applying fusion algorithms to improve the reliability of sensor data, employing recognition algorithms to transform low-level sensor data into higher-level context data, and routing the context data to the learning application. Four critical issues: context sensing, context denotation, inference, and framework, are discussed.

4.1. Context Sensing

Context is obtained via sensors that can measure a variety of information. These sensors provide situational information about the state of the world. Location sensor is the most significant and promising one among all context sensors. Most developed location sensing technologies are wireless, including GPS, WLAN(IEEE 802.11a/b/g), Cellular network (GSM, CDMA), infrared, microwave, and RFID (Radio Frequency IDentification). Every kind of sensors has its own properties. For example, GPS can be used only outdoor. Cellular network can locate mobile phones globally, but not very accurate.

Sensing activity context is also difficult, especially situated reaction of learner. For example, frustration expressed in learner's face expression must be detected by machine vision algorithms. Inattentive learning and focus of learning can be detected by eye gaze shift, which also needs complex analysis by machine vision.

There are a number of sensor-level issues, such as ad hoc networking, routing, addressing, naming, binding, security, power consumption, and so forth. These topics, which are issues of sensor networks, are far away from the focus on the application level in CAML. In an ideal setting, contexts would be sensed automatically. However, in the real world, most contexts cannot be sensed automatically and applications must rely on the user to manually provide it.

4.2. Context Denotation

Every context dimension needs a denotation system. For example, location is more than two-dimensional or three-dimensional position information. Spatial relations between entities, such as co-location, proximity, or containment are also important. Suppose students wish to refer to a classroom. Should they simply use the room number? If so, we will have to devise a way to indicate whether we mean the classroom S301 near S302. We could use latitude and longitude, but what point on the earth, exactly, should we choose to represent S301? Thus, we see that the ability to unambiguously reference place and feature names remains an intricate problem. Instead of location, other contexts also need appropriate denotation systems for specific applications.

4.3. Inference

The state of a context in the context space can infer additional information, lead to a more extensive situation, and issue an action. The process is called an inference or context adaptation. Appropriate context adaptation strategy could be integrated with pedagogical approaches, such as active social learning, problem-based learning, situated learning, alternative schedules, individualized learning, and so on. Therefore, CAML can be learner-centered, constructive, and/or situated learning by incorporating appropriate context adaptation strategy. Context-triggered actions may be evoked by simple IF-THEN rules, or complex mechanisms like Bayesian networks. However, effectiveness of the combination of context adaptation with pedagogical approaches needs more research efforts.

5. Conclusions and Future Works

Learning contains highly context-sensitive activities. Mobile learning shall also support context-sensitive learning activities. With new computer technologies teachers and students should be able to explore much more knowledge. Through the help of context awareness of computer, course participants can learn more about learning than they do about computers. In order to qualify these differences, several characteristics peculiar to the context-aware mobile learning have been identified in this paper.

Although several important ideas about what is needed to get into context-aware mobile learning are presented, we are still coming to work deeper with what we mean by context, and it will take some time before we have good design principles for context-aware mobile learning. We intend to create some prototypes, in particular a university learning system and a wireless learning pet. With these applications we will explore the use of a variety of different context elements and evaluate which context elements are effective for some applications.

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