Learning Scenarios with Wireless and Networked Sensors

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ABSTRACT

In this paper we present a survey and scenarios using sensors and sensor networks in learning. A sensor is typically a device that measures its environment and sends the measurements to the data gathering system. Such a system can be for example a mobile phone. The paper initiates a discussion on can we create new kinds of learning applications using mobile sensor networks. Also we ask should mobile sensors and sensor networks be used in developing 21st century learning applications and do they contribute to 21st century skills.

Keywords: sensor, network, mobile, learning, gps, location, accelerometer, gaming, games

1. INTRODUCTION

There has been a lot of discussion and research of mobile learning or m-learning, and learning theories for eLearning, web-based learning, and mobile learning [25, 26, 27, 29, 35, 38]. The first research pilots on mobile learning were based on transferring the electronic content to mobile phones. Soon, it was realized that mobile learning should not just copy the "old" practices of eLearning but the strengths of the mobile device should be harnessed in some other way for learning purposes. With the technology developing in a rapid phase we soon got mobile phones with digital cameras. The mobile phone appeared as a tool for creating digital recordings of learning activities for example on field trips [41].

The next innovations in mobile devices are sensors [10]. Many mobile phones already have a GPS (Global Positioning System) feature that can be used to add location information for mobile applications. Some devices have motion sensors that monitor the acceleration and movements of the device in the 3D space. It is also possible to use a heart rate monitor with a mobile phone for monitoring the physical exercises. In addition, mobile phones can observe the ambient light or sound level from the surroundings of the device. In general, a sensor is a small device that observes its environment and reports back to a remote base station [3]. Bose [3] calls sensor platforms as motes. A mobile phone can act as a sensor platform so in this sense mobile phone is also a mote.

By the nature, mobile phones have a good connectivity, and in addition to voice, there can be Internet data traffic between the phone and a remote service. In such, mobile phones with sensors form ad-hoc sensor networks [10]. In this article, sensor network is defined to be a group of sensors that observe its environment and send the data to a server. It should be noted that the definition differs from what is commonly defined as Wireless Sensor Networks, which means fully autonomous self-configuring ad-hoc networks [42].

The data collected from the surroundings of the device can be used to determine something about the context where the device (and the user is). The context can then be used in personalizing mobile services we use with our mobile devices. There already are applications that can suggest a nice restaurant or a store nearby based on our location. Could the context and sensor data be used in creating new kinds of (mobile) learning applications?

Sharples [36] argues that "the main barriers to developing these new modes of mobile learning are not technical but social" (p. 4). According to Sharples [36] we should have more understanding of context, learning outside the classroom, and the role of new mobile technologies in the new learning process. In this paper we present several ideas on how to use mobile sensors and sensor networks in learning applications. The paper tries also to initiate a discussion on can we create a new kinds of learning applications using mobile sensor networks and could this be the way we should progress in developing 21st century learning applications. The 21st century skills and learning applications can be defined in terms of knowledge, skills, attitudes, values and ethics, and they describe the skills that are needed in understanding information in the information society [43].

2. CONTEXT IN MOBILE LEARNING

Lonsdale, Baber, Sharples, and Arvantis [20] suggested that contextual information should be used in mobile learning to deliver right content and services to the user. This could help to overcome user interface (UI) and bandwidth related limitations of mobile devices. A context in Lonsdale et al. [20] is understood as a combination of an awareness of current technical capabilities and limitations and the needs of learners in the learning situation.

The concept of context is also related to concepts of adaptive, pervasive and ubiquitous. For example, Syvänen, Beale, Sharples, Ahonen, and Lonsdale [37] presented experiences of developing an adaptive and context aware mobile learning system that they also describe as a pervasive learning environment. They define pervasive learning environment to be a single entity formed by overlapping of "mental (e.g., needs, preferences, prior knowledge), physical (e.g., objects, other learners close by) and virtual (e.g., content accessible with mobile devices, artefacts) contexts" (p. 2).

Sharples et al. [35] explains that computer technology and learning are both ubiquitous. The concept of mobile learning is closely related to ubiquitous learning and context-aware ubiquitous learning. Context-aware ubiquitous learning system integrates authentic learning environments and digital (virtual) learning environments, hence, as a result, enables the learning system to more actively interact with the learners. This is possible because of current mobile devices and sensors, such as radio-frequency identification (RFID). [5] It can be said that learning in a workplace or outside the classroom on a field trip can be ubiquitous.

Yau and Joy [40] presented three different types of context-aware mobile learning applications: location-dependent, location-independent and situated learning. They also present a theoretical framework for mobile and context-aware adaptive learning. In the framework they use contexts such as the learner's schedule, learning styles, knowledge level, concentration level and frequency of interruption.

3. Applications and learning scenarios

In this chapter we present scenarios on how to use different types of sensors, sensor networks and sensor data in learning applications. Especially, we discuss of location, heart rate, ambient sound, orientation, camera, and humans as sensors. In these examples sensors provide information that can be used to construct a context for learning (such as location) or the learning topic is itself based on the sensor data (measuring sound levels in an environment).

Location

Brown [4] states that "if learning becomes mobile, location becomes an important context, both in terms of the physical whereabouts of the learner and also the opportunities for learning to become location-sensitive" (p. 7).

Many mobile phones already have a capability to locate the device based on satellite navigation system, and present the location of the device on a map. The location data can also be send to a service, and for example a suggestion of a nice restaurant could be enquired based on the location data. In any case, all mobile devices can be located based on cell tower location, but this method may not be so accurate as GPS positioning. The drawback in GPS is that it cannot be done inside a building.

In mobile devices it is also possible to use other location methods that do not require GPS [12]. W3C has a standard API for web applications to use different kinds of location technologies. The Geolocation API defines a high-level interface to location information associated with the user's device. In addition to GPS data the API can use location data based on from network signals such as IP address, RFID, WiFi and Bluetooth MAC addresses, and GSM/CDMA cell IDs [32]. Google has been scanning WLAN networks in several countries and has a database of locations of WLAN networks from the areas they have the street view images [28]. Although this has raised privacy and security issues, the database enables Geolocation API based applications to locate quite accurately even inside buildings.

GPS positioning has been used in outdoor games to generate location based game plots. The players have GPS enabled devices and the game has been designed in a way that the location affects to the game logic. For example, in order to get to the next level in the game, the player has to go to a certain building or find another player based on her location information.

Researchers from the University of Zurich have developed a mobile game for a university studies introductory course [33]. The game contained collaborative elements and it was based location based technology. Based on this study the players considered the game to be motivating. Game world was a mixed reality experience for game players where both the real world game space integrated with virtual game world and virtual and real social spaces integrated to an interactive experience. Falk, Ljungstrand, Björk and Hansson [7] have similar research results. Mobile mixed reality games developed so far does not utilize mobile video very well. This can be considered as an important future research topic [8].

Location based social networking applications Gowalla (www.gowalla.com) and Foursquare (www.foursquare.com) adds gaming aspects to social networking for mobile devices [6]. The idea behind these applications is simply to log-in to places where the user is. The application locates the user and displays a map showing places where the user can check-in. The user can typically also see where her friends have checked in, and who have checked in to the same place as she is. By checking in the users collect badges or pins that are displayed on the users profile. The user can also send images from the place to the service and collect new stamps from this activity.

Location-based social media applications could be used also for learning purposes. For example, a university could create a gaming environment where new students have to check-in to certain locations on the campus using their mobile devices. Each check-in would earn them points. There could also be certain tasks that the student has to do while visiting a place. For example, while checking-in to the library the student should get the access to the library resources and take an image with a mobile phone as a proof of the activity. This kind of gaming environment would replace tutoring tours around campus, because while playing the game the students learn how to navigate around campus.

Geocaching (www.geocaching.com) is another example of using GPS positioning in a game-like application. In geocaching, users try to find geocaches other users have hidden. The geocaches can be in historically important places and it can tell also facts about the place.

Geocashing is actually not using sensor networks as such. It can be played by one player only and it is not necessary a social activity. However, geocachers use websites to share their experiences of finding a geocache and this adds a social dimension to geocaching.

An example of a social activity and the use of the GPS data is the pilot done with high school students in Pori, Finland [11]. The students were studying about different forest types and for that they did a field trip to the forest near the city. The students were divided to groups that were sent to different parts of the forest. The groups reported from their areas about the forest types they observed using their mobile phones. The data included the location, the height and thickness of the trees. The students could visualize the collective data on a map using their mobile phones while they were still in the trip.

Based on the location information the current weather information can be fetched from a free weather service on the Internet. This could be used to enhance content production. For example, MoViE mobile social media platform for mobile video sharing creates automatic geotags and weather tags when the user uploads a video file to the service [22, 23, 24, 39]. The weather could be search criteria: all the videos that were recorded in a certain location on a sunny day could be searched.

MoViE supports the tag creation by collecting automatically as much context data as possible. A custom-made mobile client application is a video capturing, tagging and uploading tool. It uses GPS and GSM cell information as automatic context to videos. This information is used to find the most appropriate words for tag suggestions. GPS and GSM cell information are stored as a background process during the video capturing. With this information the database can perform queries to the server and determine where the video was captured. Also, MoViE server tries to suggest some tags that could be appropriate with particular video. [23, 24]

MoViE were used as a part of teaching biology and geography with 8th and 9th grades in Finland [39]. According to Tuomi and Multisilta [39], MoViE service and mobile social media in general were as a useful tool for school projects. The making of mobile videos using social media services and thus telling stories is an example of 21st century skills needed for society in the future.

Heart rate

Heart rate monitors have been used several years in monitoring the suitable heart rate during and after an exercise. The devices have typically been a watch with a heart rate belt. The heart rate has been monitored from the wristwatch in real time. Optionally, the belt or the watch saved the data that can later be transferred to a computer and analyzed there. Nokia SportsTracker and Nokia N79 mobile phone enabled users to upload the heart rate and GPS data online to SportsTracker service [1]. In the service the exercise can be studied by plotting the data to a map and using several graphical summaries.

Heart rate monitors can surely be used in physical education (PE) class as such. In addition, using services such as SportsTracker the students could compare their exercises with others and learn from the analysis.

This kind of data is important not only in running or bicycling exercises but also on team sports such as soccer and football. During the games, the coach could monitor in real time for example who has been running the longest distance. This information could then be used to select the best players and planning changes on the field.

Monitoring collective heart rate enables to create new types of educational games. In this paper, collective heart rate is defined to be a mathematical mean of measured heart rates in a group at a certain time. For example, a group of students wear a heart rate monitors that send the data in real time to the game server. The group have a goal that they have to keep the collective heart rate at a certain level, for example on 120 beats/min for a certain period, for example one minute. After that they have to raise the collective heart rate to the level of 130 beats/min and sustain it a minute. The group can then decide how they gain the target heart rate and how they sustain it (ie. running, jumping etc). Groups compete against each other on how well they succeed on the mission.

Sound

Sound can easily be observed thru the microphone on every phone. It could be used to create a world wide sound sensor network for observing on what kind of sound environments we live. For example, classrooms could compare their sound environments against other schools in other countries. The ambient noise may also be an important issue when we think about the neighborhood we would like to live. Sound pollution is an environmental issue and it could be visualized using data from mobile phone sound system. For example, student teams could go around a selected area or city and measure sound levels with their phones. The data is uploaded to the server and a colored layer will be overlaid on a map based on the measurements. One of the existing systems is WideNoise mobile application and webpage (www.widetag.com/widenoise).

Another application could be automatic recognition of different sounds. Selin, Turunen and Tanttu [34] have studied how inharmonic and transient bird sounds can be recognized efficiently. The results indicate that it is possible to recognize bird sounds of the test species using neural networks with only four features calculated from the wavelet packet decomposition coefficients. A modified version of this kind of automatic sound recognition system could be also used in learning environments.

Furthermore, voice can be used even to control learning applications. For example Uplause Ltd. (www.uplause.com) has developed social games for big crowds. Games are designed for large events, where the audience can collectively participate in playing the interactive mini-games, real time, on location. Game controllers for the game are the audience's voice – clap sounds from hands and shouts.

Orientation

Some phones have orientation sensors or accelerometers that can monitor the movements of the phone. This is similar known from Nintendo Wii remote controllers. For example, Apple's iPhone has accelerometers that are used in gaming applications for controlling a game object. iPhone could be a steering wheel for a car in a game environment and by turning the phone the player controls the movements of the car in the game.

Apple iPad has demonstrated the use of compass data in GoSkyWatch Planetarium application. The application itself is a simple planetarium and astronomy star guide software for educational purposes. It utilizes the date, time, location and compass in the iPad for displaying the sky view in correct orientation when the device is pointed to the sky. The use of the applications helps in the identification of objects in the sky and thus supports learning. In addition, the application includes a lot of detailed information of the selected object and it can be displayed on the screen with the sky image.

This kind of user interface is very natural for us and it raises the usability and learnability of a game or application to a new level. The orientation sensors could be used also for monitoring the movement of a person. In a simple application, a device with an accelerometer can be used as a pedometer. In more complex applications the device could record for example movements in a dance practice. The data could be used to analyze the dancing figures and it could be compared to the data available from the teacher doing the same figure. To fully use this kind of motion detection requires the use of several motion sensors in the legs, arms and body. However, using current technology the usefulness of this concept could already be validated.

For the deaf people the phone with a rhythm counter that converts tapping rhythms for example to colors could be used in teaching musical rhythms. Another solution to bring out rhythms is mobile device's vibration feature. This kind of feedback and guidance can be seen as a contrary to dance movements recording. Phone provides directions instead of data storing.

Novel interaction solutions provide new possibilities to design appealing game experiences for wider demographics. The development of motion-based controllers has facilitated the new coming of exercise game genre that involve physical activity as a means of interacting with the game. Furthermore, the major reason for increased interest in exergaming is the concern over the high levels of obesity in Western society. One of the biggest challenges is the need to make a game attractive collective experience to players, and at the same time effective as an exercise. [14, 15, 16]

Camera

Obviously the camera in the mobile device is a sensor. Belhumeur et al. [2] have presented an interesting application that aids the identification of plant species using computer vision system. The system is in use by botanists at the Smithsonian Institution National Museum of Natural History. NatureGate by Lehmuskallio, E., Lehmuskallio, J., Kaasinen, and Åhlberg [17] is another tool that can be used as a tool for identifying plants, but currently without computer recognition. The use of the camera in the mobile phone has already been reported to be used to identify a poisonous plant [21]. In this case, an image taken with mobile phone of the suspected plant was emailed to specialist who identified the plant.

Collaboration between the Department of Botany at the Smithsonian's National Museum of Natural History and the computer science departments of Columbia University and the University of Maryland has produced the Image Identification System (IIS) for this purpose [19]. IIS matches a silhouette of the leaf against a database of leaf shapes and returns species names and detailed botanical information to the screen of users phone. It would be easy to add an automatic collection of other sensor data to this kind of applications, for example date, time, location, and amount of light. Again, students could use the application on field trips as an interactive encyclopedia with plant recognition system.

Other sensors

Some phones have an ambient light sensor. The sensor observes the lightning conditions of the environment and the phone adjusts its screen brightness accordingly. Ambient light sensor could provide a meaningful data for example in situations where students take images with their phone. The ambient light data could be added as a metadata for the image. With other metadata (such as date and time) the information could be used to decide if the image has been taken for example during a night, or if it has been taken inside or outside. In biology experiment the amount of light could be measured during intervals. The device could take an image of a plant by every hour and record the light condition among other data. The data could then be viewed with the images and the results compared with other class doing the same experiment (but on the other side the country).

Humans as sensors

So far we have discussed about sensors that are a part of a device itself i.e. piece of technology. However, we can consider the user itself as a sensor. For example, when the users are sending tweets using Twitter, they could write something they have observed in their surroundings. The users can also express their feelings in the tweets. The students could use Twitter for creating a school-wide or nation-wide emotion channel. Students could be tweeting their emotions to a certain Twitter channel by marking their tweets with a handle, for example #emotionPori. The tweets can automatically be monitored and a "heat-map" could be generated based on collective emotional experiences.

Nokia Internet Pulse (pulse.nokiaresearch.com) is a web service for monitoring public opinion by tracking social network status updates and grouping the results based on positive or negative sentiment. Nokia Internet Pulse presents the aggregated status updates in a timeline format as an interactive graph that allows users to drill down into the various search terms that demonstrate the hot topics in Twitter feeds on selected time period.

Perttula et al. [30] presented a pilot study on using collective heart rate visualized in the indoor ice rink to bring intensiveness into the audience experience. The aim of the study was to explore the usefulness and affect of the developed collective heart rate and to evaluate it as one of the new features that could enhance the user experience among the audiences in wide public events. In particular, the study focuses on studying the significance of the technological equipment in creating a sense of collectiveness and togetherness of the audience. Results indicate that it is possible to enrich user experience in public events from user-generated data.

In Koivisto's and Perttula's [17] study the audience is seen as an active part of the large scale public events and one of the intentions of their study is to increase and enhance the interaction between the audience and the happenings on the event area. Audience members are sensors, not just consumers but producers and content creators as well. With the concept of collective emotion tracker, it is possible to invite the audience to participate the event and give advice to other participants. In this study, every participant can send a location-based mood to the server by using a custom-made mobile application or mobile web page. Moods form a heat map of emotions. Furthermore, participants are able to select interesting ones from different venues by observing the mood heat map.

Navigating an unfamiliar, eventful environment such as a festival or conference can be challenging. It can be hard to decide what to see, and when you have decided where to go, it can be difficult to know how to get there. While several research projects have investigated the mobile navigation of physical environments, past work has focused on extracting general landmarks from relatively static sources, such as structured maps. Perttula, Carter and Denoue [31] presented a system that derives points-of-interest and associated landmarks from user generated content captured onsite. With this approach, it helps users navigate standard environments as well as temporary events, such as festivals and fairs. Using social network and preference information, the system also reflects a more personalized set of points-of-interest. This kind of system could enhance learning events for example in large camps or campus wide events.

CONCLUSIONS

Can we create new kinds of learning applications using mobile sensor networks and could this be the way we should progress in developing 21st century learning applications? According to the present study, sensors and sensor networks provide new possibilities for a variety of learning applications. Some of these applications promote 21st century learning skills as such. In addition, the understanding of sensors based contextual data and the skill to apply this data to everyday activities in learning and life could also be considered as a new kind of 21st century skill.

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