Journal of Universal Excellence, Appendix
March 2015, year 4, number 1, pp. A39–A51.

WEARABLE COMPUTING IN E-EDUCATION

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Abstract
Emerging technologies such as mobile computing, sensors and sensor networks, and augmented reality have led to innovations in the field of wearable computing. Devices such as smart watches and smart glasses allow users to interact with devices worn under, with, or on top of clothing. This paper analyzes the possibilities of application of wearable computing in e-education. The focus is on integration of wearables into e-learning systems, in order to support ubiquitous learning, interaction and collaborative work. We present a model for integration of wearable technology in an e-education system and discuss technical, pedagogical and social aspects.

Keywords: computing, e-education, e-learning, cloud computing, learning management system

1 Introduction

Computer technologies are consistently getting more powerful and encroaching into all areas of human activity. Wearable computing is only the last example of technology getting

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Received: 18 November; revised: 11 March; accepted: 30 March.

smaller, more powerful, and more integrated. As such, it is only starting to make its impact on communication, human perception and socialization, and its potential is still mostly undiscovered. It can be very important for application in business and education.

Currently, most educational institutions use Learning Management Systems (LMS) to facilitate learning processes (Graf & Kinshuk, 2008). These solutions provide various features that enable management of online courses, e-learning activities and resources, collaboration, etc. Learning services constantly evolve, following the more general trends of technology (Anderson, 2004).

Wearable computing considers the use of miniature computing devices in order to support various human activities. Such devices can be utilized similarly to a more established application of mobile learning in order to enable learning independently of temporal and spatial constrains (Holzinger, Nischelwitzer, Friedl, & Hu, 2010). Although some learning management systems can support mobile learning through the use of adaptive themes or custom learning activities, wearable computing introduces many new variables into the mix, and learning management systems are not equipped to support such devices.

The main aim of this paper is to analyze the possibilities for improving the existing e-education systems and processes using modern wearable computing devices and approaches. Existing technologies and applications of wearable computing in general are overviewed, followed by examples of application in education. A model for integration of wearable gadgets and e-learning services of a higher educational institution is given. Some ethical and social aspects of using wearable technologies are also considered, especially for students with disabilities.

2 Wearable computing

The second half of the 20th century introduces a new way of thinking about computer technologies, supported by miniaturization and increasing prevalence in the everyday environment. Computers are becoming ubiquitous, and a natural term "ubiquitous computing" describes "computers everywhere", apparatus which is in wide set of locations, flexible and mobile, small in size and available for communication with other similar devices (Weiser, 1991). Eventually, this has led to the concept of placing computer devices directly on a human body, and allowing them to communicate between themselves and with other systems that exist in the environment.

The wearable paradigm generally assumes the existence of a device that interacts with the human in some way. The wearable computer can, therefore, be described as a device that is always connected to its user, while the user using it and wearing it in a comfortable way (Toh, 2013). Wearable computing can also be understood as having devices worn in the same way as clothing, that are always available for usage and able to perform various kinds of computing (Mann, 1997b).

The idea of wearable computing has existed in some form since the creation of the first analogue watch; however, the first electrical wearable device based upon the digital signal transmission is Edward Thorp's and Claude Shannon's roulette result simulator (Thorp, 1998). One of the main developments in this area was the development of a wearable battery-operated personal imaging system by Steve Mann in 1981 (Mann, 1997b). Evolution from analog, through digital, single function, multi-function, to always connected smart or analog wearables are shown in figure 1.

*Figure 1.*The evolution of wearables

Wearable computing in general covers broad range of devices and possible usages. It is necessarily that wearable computing architecture fulfils the requirements of persistence and constancy in order to be accepted as such (Witt, 2008). Furthermore, wearable devices should be stable in sense of power supply (Mann, 1997a) and context sensitivity (Billinghurst & Starner, 1999). Nowadays, implementations of wearable computing are limited and depend on developers' creativity and contribution.

There are three basic operational modes defined by Mann (Mann, 1998): constancy of wearable computer, augmentation of senses and mediation with physical reality. These three defined modes in cohesion make basic view of wearable computing paradigm which is nowadays widely accepted.

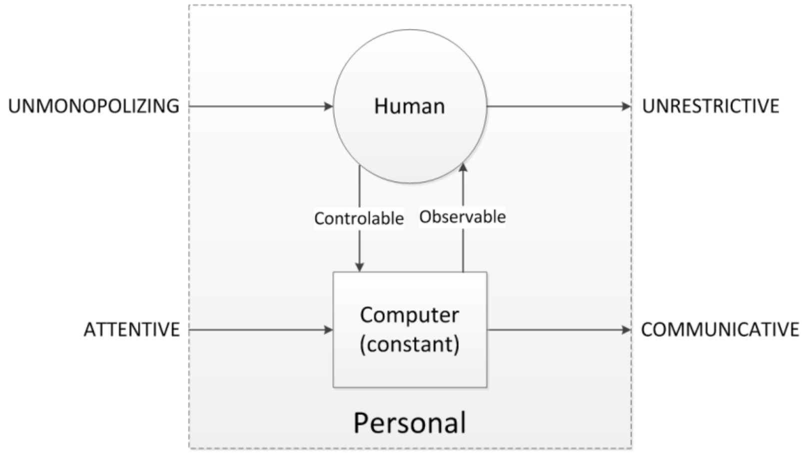

Figure 2. Comprehensive view of wearable computing (Mann, 1998)

3 Wearable computing in e-education

Unlike traditional education, e-education is an area where new technological possibilities are quickly explored and adopted. E-education is significantly improved by new learning theories and ideas. Modern visualization techniques help the students in exploring available educational resources and discovering new information (Dadzie & Rowe, 2011). Innovative methods of presenting information, imaginative interaction patterns and edutainment concept make the learning material more accessible to less motivated learners (Arnone, Small, Chauncey, & McKenna, 2011).

It is difficult to restrict which of the widespread technologies and devices are involved in e-learning, but it is certain that Internet is the basis of the modern educational framework. A number of technologies like learning management systems, multimedia technologies, wireless technologies, etc. are used for implementation of e-learning (Anderson, 2004). Technology concepts that are becoming dominant in e-education include Web 2.0, social media and mobile technologies (Labus, Simić, Vulić, Despotović-Zrakić, & Bogdanović, 2012).

With the increase of smart mobile devices in use among the student populations, learning management systems need to be flexible enough to provide appropriate services to appropriate devices types. A number of works deal with the use of mobile devices in e-learning and their integration with other modern technologies. An example of an environment for language learning where the formal classroom learning is combined with informal learning is given in (Wong & Looi, 2010). Mobile learning is often performed on the move, and mobile devices offer unique opportunities for delivering learning content in authentic learning situations. Modern devices and platforms have built-in GPS, cameras, sensors, accelerometers, and compasses that are valuable sources of context information (Godwin-Jones, 2011). Context information can be used in advanced adaptation scenarios, where content is organized according to some learner context parameter like location (Jong, Specht, & Koper, 2009).

Wearable computing shares many constraints and features with mobile learning, and even completely overlaps with it in some areas. Most conclusions given for mobile learning are applicable for use of wearable computing in education. However, wearable computing assumes a wider range of devices, with some of them being substantially different from the main staple of mobile learning - mobile telephones. Some devices might not even possess any type of visual display, while others can be specialized for performing a single task or function. This implies that the range of their capabilities is wider, in total, but individually the devices might be more limited. It is important for any learning system to properly recognize these capabilities in order to be capable of producing adequate learning materials.

A general overview of a learning management system that can support mobile/wearable devices is shown in figure 3. The learning management system needs to support inputs from various devices (mainly user activity and learning context), and deliver appropriate learning materials from a local database or an external source. Learning materials need to be prepared in some way in order to allow automated selection and delivery, and this can be performed in several ways, all of them relying on metadata. The educational content can be distributed into learning objects - small, context-free, metadata-annotated units containing learning materials (McGreal, 2004). If the institution possesses a large amount of materials, some form of automated analysis and annotation of resources might be more suitable (Bogdanović, Despotović-Zrakić, Milutinović, Anđelic, & Milinović, 2013). Finally (and not exclusive with other two approaches), an ontology can be used to describe all educational resources, their relations and characteristics (Milutinović, Stojiljković, & Lazarević, 2014). Social networks can additionally be utilized as sources of information about the learners, further enriching the learning context, as well as a platform for delivery of learning materials.

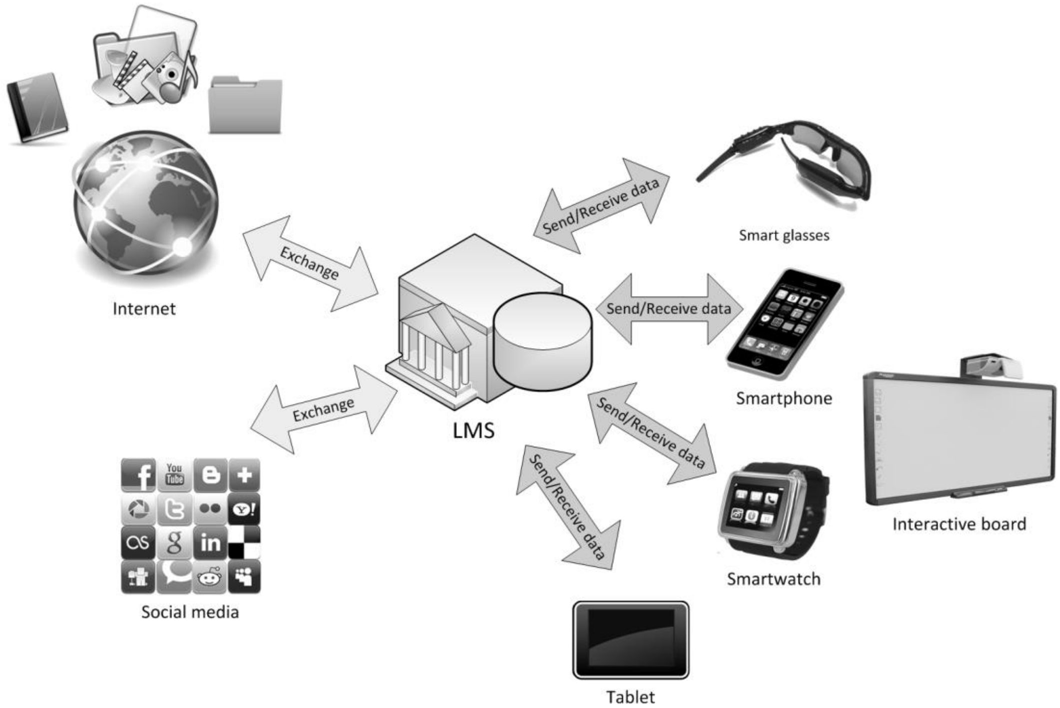

Figure 3. Wearable computing in e-education

Currently, there is a lack of research papers dealing with the topic of wearable computing in e-education, and there are even less examples of implementation. In order for such systems to become useful to students, interesting and effective applications need to be developed. A relevant approach to advancing the use of wearable computing in e-education is by developing engineering courses for development of wearable computing applications. One such example is given by (Ngai, Chan, Cheung, & Lau, 2010), where a special t-shirt was used as a “breadboard” for development, and where development tools were selected in such a way to allow students less proficient with electrical engineering and programming to still be able to design and implement their ideas. By introducing the students to wearable technologies in such a way, a gradual move forward can be made - each generation of students can develop applications that the next generation will improve on, and the students can suggest ideas that will actually be of help to them in the process of education.

A topic that is important for wearable computing in general, and especially important for educational applications, is the interface for use of wearable devices. If wearable devices are utilized directly in the process of learning, the methods of interaction with them need to be simple and intuitive, in order to lessen the cognitive load on learners and allow them to concentrate on the task at hand. In the context of wearable computing, visual interfaces (such as those on smart glasses) can be environment dependent and independent, and can be based around the concept of augmented reality, where the interface overlaps/augments actual, tangible objects from the environment (Zhou, Xu, David, & Chalon, 2013).

Besides of use in a institutional setting, wearable technologies are especially valuable as tools that enable lifelong learning (Sharples, 2000). Similarly to more traditional mobile learning, wearable devices allow learners to bridge formal learning sessions or learn completely independently, at any place or any time they wish. A review of characteristics, advantages and challenges of new forms of learning, including the wearable computing, is given in (Yordanova, 2007).

4 Model for applying wearable computing in e-education

The model for applying wearable computing in e-education was developed within the Laboratory for E-business (Elab), at the Faculty of Organizational Sciences, University of Belgrade. Components of the model are described, and some actual wearable devices are suggested for use. Some implementation remarks considering the integration with existing educational infrastructure are given.

The proposed model consists of cloud computing infrastructure, wearable computing devices and software (Figure 4). Wearables and software are different for the students and for the professors.

Cloud infrastructure is a mediator between students and professor in the classroom. The infrastructure consists out of web services, storage/ontologies, a learning management system, and management interfaces. The main purpose of this part of the model is to gather data from the students and teachers, and to deliver specialized learning materials to individual devices. It also authenticates the users and authorizes them to access a learning session/course. This allows the teachers to directly control the experience of students taking their lectures.

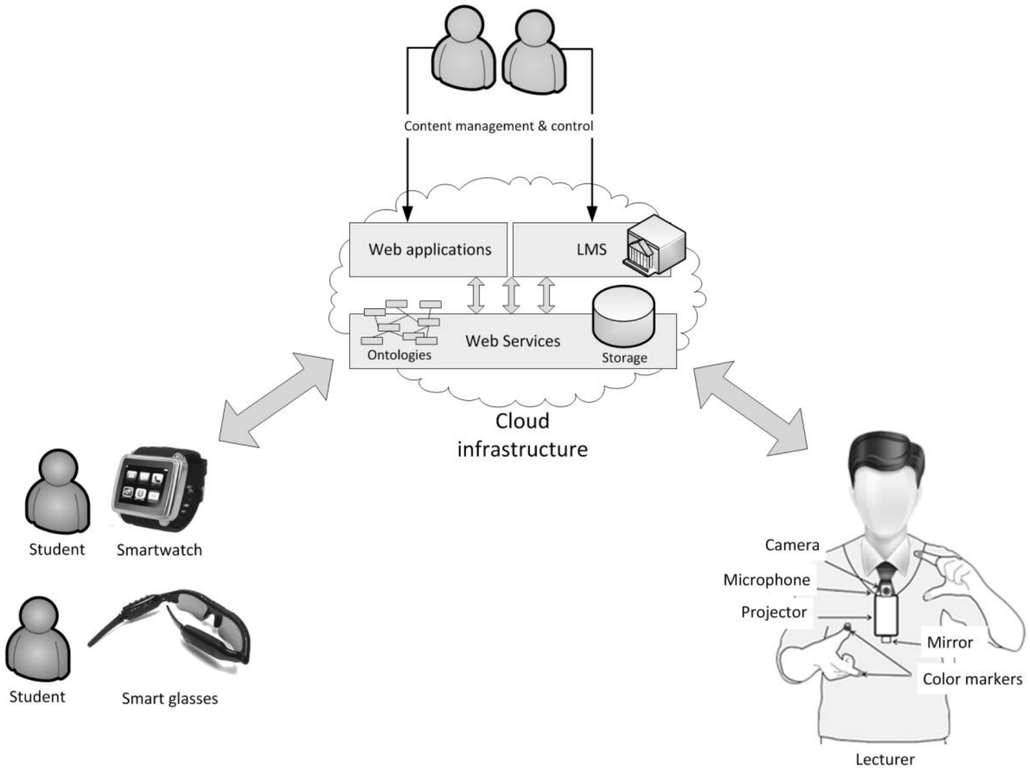

Figure 4. Model for applying wearable computing in e-education

In order to support various types of devices produced by different manufacturers and programmed using different languages and software components, the communication is performed using web services with standardized interfaces. If possible, the applications can be developed to use such interfaces, and several web services can be developed, if some devices are not flexible enough to allow the use of a single universal interface.

The educational content is stored within the cloud infrastructure. In the proposed model, this content takes the form of learning objects. Several standards exist for learning objects, but the most supported standard among learning management systems is SCORM (McKinney, 2003). SCORM is, however, tightly tied to the use of web technologies (HTML, CSS, JavaScript), which makes any adaptation to nonstandard user interfaces difficult. For this reason, we recommend a more clean separation, with learning objects carrying only the core educational content in textual form, with links to multimedia components, and the actual devices making a decision which form of presentation will they adopt. Such objects can also be described using an ontology, and an example of this can be found in our earlier work (Milutinović et al., 2014).

This removal of presentation concern from learning objects, however, does not eliminate the need for selection of appropriate content and the amount of content that will be served to a device. A device based reasoning approach can be used for this purpose, combined with a standard user model, a technically and educationally appropriate selection of learning objects can be served to learners (Chorfi, Sevkli, & Bousbahi, 2012). In order to facilitate device-based reasoning, device features need to be known for every device using the learning system. Projects like WURFL, OpenDDR, and Apache DeviceMap attempt to maintain databases of all device features for purposes of capability detection (Power, 2012).

Web services and accompanying educational content and ontologies represent the core of the system. These services can be used internally, in order to provide interaction between student/teacher devices, as well as externally, by other applications and systems. In this case, the learning management system (Moodle, used at the laboratory) and various interfaces for management of users, devices, and learning materials are considered as "external".

All these components are set up on a cloud computing infrastructure, providing scalability and easy management of a multitude of educational and other services needed for supporting the learning processes. An overview of benefits stemming from cloud computing application in educational institutions is given in (Ercan, 2010). Cloud infrastructures are also well-suited for supporting a large number of devices with less processing power, as means of offloading and speeding up the processing of data.

Students' devices can interact among themselves and with the professor's device, through the supporting cloud infrastructure. Since the core infrastructure is web service-based, users' devices can connect through Wi-Fi, mobile network, or any other past, present or future technology that provides internet connectivity.

The use of several types of devices was envisioned with the presented model. For instance, smart watches can allow students to sign in into the class with their digital signature, and this information can be submitted over the cloud infrastructure to professor so he can access information about list of present and absentee students. Some applications can be used to read textual documents and convert them to speech and make classes and lectures easy to follow. The core functionality of smart watches - time, can be used to notify students about the time that they have left to complete their tests or other class-defined chores.

Smart glasses also have an important role in the model. They provide visual contact and communication with available resources that are provided by professor and the learning management system. They can communicate with other devices in the classroom, like smart watches or professor's Sixth Sense technology wearable computing device, described below. Currently, various types of glasses can be found on the market, such as Vuzix Smart Glasses which can run both on Android and iOS, Google Glasses (Android OS), or Golden-i headsets which are intended for Windows CE OS.

A device based on Sixth Sense technology enables professor to take photographs, recognize objects, and bring the information from real to virtual world. Furthermore, the professor can easily use resources from cloud and communicate with students. In this way they are able to participate in classroom activities, get access to their work and have full control of the lecture course. In this way, activities can be made and conducted more interactively, and student performance can be constantly monitored.

Pranav Mistry, author and pioneer in this technology, defines Sixth Sense as: “wearable gestural interface that augments the physical world around us with digital information and lets us use natural hand gestures to interact with that information” (Mistry, 2010). The main components of this device (shown in figure 4) are the projector, used to project light on objects (paper, wall, table, hand, etc.), and a camera that detects and recognizes user’s movements, especially those of color markers worn on user’s fingers. These movements are later interpreted as actions or commands on mobile computing device, while the both projector and camera are connected to it.

The use of wearable computing can improve the learning process in many ways. The wearable devices can present relevant information quickly, dependant on the context, and personalized according to the user. The educational content can be adapted and a multimodal presentation utilizing sound, pictures, video, text, and possibly some other forms can be used. Wearable devices can also be of help to students with disabilities, allowing the students with bad sight to display the information on their glasses in size and form that is comfortable to them, allowing blind students to use audio-playing devices to read them the content of a lesson, or deaf students to have all of the teacher’s words displayed on their glasses.

The implementation of the presented model needs to be cheap and as simple as possible in order not to disrupt existing learning processes. An institution can utilize its existing cloud infrastructure, or lease cloud resources from another institution. Regular computer infrastructure can also be utilized, if cloud infrastructure is not present, however, sufficient computing resources need to be provided, or such implementation can potentially slow down other systems used to support learning processes. Some wearable devices can be expensive, but with the increase of manufacturers and models, cheaper alternatives can be found. Most modern devices are capable of connecting to the internet, and the institution only needs to be covered with wireless networks in order to support them, which is a commonality in this day and age. The development of applications for wearable devices is often done using similar methods to those of mobile programming, and comparable SDK’s, API’s and libraries can be utilized even by students. Smart environments to complement the wearable devices can also be set up cheaply, using simple sensors and devices like Arduino microcontrollers and Raspberry Pi microcomputers.

5 Conclusion

Wearable computing is only starting to get accepted in various areas of human activity, and applying it in education can provide long-term benefits. By introducing the students to wearable computing, the quality of the learning process can be improved, and even future development of wearable systems can be performed by students.

For the students with disabilities, implementation of wearable computing in e-education can bring many advantages and make learning process easier. By using wearables students with disabilities are able to compensate their handicap. For examples, students with vision or attention issues are able to participate in class undisturbed, or using bone conduction together with smart glass device could help students with hearing loss.

Model for applying wearable computing in e-education described in this paper represents one of potential implementations of wearable computing in existing e-education process and environment based on different software solutions and platforms.

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