Ubiquitous learning environment: An adaptive teaching system using ubiquitous technology

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Education has undergone major changes in recent years, with the development of digital information transfer, storage and communication methods having a significant effect. This development has allowed for access to global communications and the number of resources available to today's students at all levels of schooling. After the initial impact of computers and their applications in education, the introduction of e-learning and m-learning epitomised the constant transformations that were occurring in education. Now, the assimilation of ubiquitous computing in education marks another great step forward, with Ubiquitous Learning (u-learning) emerging through the concept of ubiquitous computing. It is reported to be both pervasive and persistent, allowing students to access education flexibly, calmly and seamlessly. U-learning has the potential to revolutionise education and remove many of the physical constraints of traditional learning. Furthermore, the integration of adaptive learning with ubiquitous computing and u-learning may offer great innovation in the delivery of education, allowing for personalisation and customisation to student needs.

Keywords: digital information, global communications, ubiquitous learning

Introduction

Ubiquitous computing

Educational technology is constantly evolving and growing, and it is inevitable that this progression will continually offer new and interesting advances in our world. The instigation of ubiquitous media for the delivery of education is another new approach now emerging.

> The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it. (Mark Weiser, 1991)

Mark Weiser, a researcher at Xerox PARC, coined the term 'Ubiquitous Computing' in the late 1980s. It refers to the process of seamlessly integrating computers into the physical world. As we move towards a more ubiquitous computing environment, the presence of computers is becoming less conspicuous and will eventually blend into our everyday lives. When using a PC the user's attention is, in general, focused on the screen. As computers become ubiquitous they will cease to be the focus of activity, allowing them to fade into the background. As well as personal computers (PCs), ubiquitous computing includes computer technology found in microprocessors, mobile phones, digital cameras and other devices.

Weiser's third wave in computing describes a many to one relationship between computer and human (Weiser, 1993). This relationship is common in the evolving ubiquitous computing era. This also correlates to the u-learning concept currently emerging. Each student interacts with many embedded devices. In the ubiquitous classroom, students move around Ubiquitous Space (u-space) and interact with the various devices.

Adaptive learning

Adaptive learning is based on the idea of adapting learning methodologies to students' learning styles. The concept is that an individualised method of teaching will help students learn at a faster pace, more effectively, and with greater understanding. Some of the elements of adaptive learning include: monitoring student activity, interpreting the results, understanding students' requirements and preferences, and using the newly gained information to facilitate the learning process (Paramythis and Loidl-Reisinger, 2004).

Adaptive learning can offer great advantages in providing students with specific and personalised knowledge as and when required. It has been haled as a 'promising alternative approach' and is believed to improve student learning outcomes by catering to the diverse learning needs of individual students. Adaptive strategies were implemented in education as early as the start of the 20th Century as educators began looking at alternative means to improve the outcomes of student learning and understanding (Talley & Martinez, 1998). The development and use of adaptive learning environments allow for the integration of the concepts and theories of education and information technology. Jones, *et.al.* (1992) believe that the development of such systems can, in due course, "provide or support effective learning experiences for a wide range of learners across a broad spectrum of knowledge domains".

The development of a ubiquitous learning environment combines the advantages of an adaptive learning environment with the benefits of ubiquitous computing and the flexibility of mobile devices. Students have the freedom to learn within a learning environment which offers adaptability to their individual needs and learning styles, as well as the flexibility of pervasive and unobtrusive computer systems.

CBE, e-Learning and m-learning

Over the last few decades information and communication technologies have improved greatly and computers have become more widespread. As a result, educators started to look at ways to use this technology. Computer Based Education (CBE) was one of the initial stages, leading to online education and e-learning in the mid-1990s. E-learning offered new ways for students to access many resources. This was a major breakthrough in education leading to better management of both in-house tertiary education and distance education.

M-learning is often thought of as a form of e-learning, but Georgiev et. al (2004) believe it would be more correctly defined as a part, or sub-level, of e-learning. They believe m-learning is a new stage in the progress of e-learning and that it resides within its boundaries. M-learning is not only wireless or Internet based e-learning but should include the anytime/any place concept without permanent connection to physical networks. The advantages of m-learning compared to e-learning include: flexibility, cost, size, ease of use and timely application. The devices used include PDAs, mobile phones, portable computers and Tablet PCs.

The ubiquitous learning environment

A ubiquitous learning environment is any setting in which students can become totally immersed in the learning process. To define:

> Ubiquitous = pervasive, omnipresent, ever present, everywhere
> Learning = educational, instructive, didactic, pedagogical
> Environment = surroundings, setting, situation, atmosphere

So, a ubiquitous learning environment (ULE) is a situation or setting of pervasive (or omnipresent) education (or learning). Education is happening all around the student but the student may not even be conscious of the learning process. Source data is present in the embedded objects and students do not have to DO anything in order to learn. They just have to be there.

In this paper we report on the adaptation of u-learning in an educational setting. The ULE resides within the physical environment. Microprocessors are embedded in objects, or devices. The use of wireless and mobile technology makes them easily accessible and contributes to educational functionality. The wireless and mobile devices include mobile phones and PDAs. A ULE can provide the props and stimuli needed to easily encourage student involvement but without needing the active attention of the student. The benefits of the many to one relationship found in u-learning include the potential for one ULE (of many devices) to service an unlimited number of individuals at once. Essentially, the many to one relationship exists for every one of the students within the environment.

Figure 1 shows an example of four students within a ULE in which there are five ubiquitous objects/devices. Each student is part of the many to one relationship within this u-space. It is immaterial which particular device the student is currently interacting with, as all devices are networked and communicating within the Ubiquitous Space (u-space) - see the purple dotted lines linking the objects in

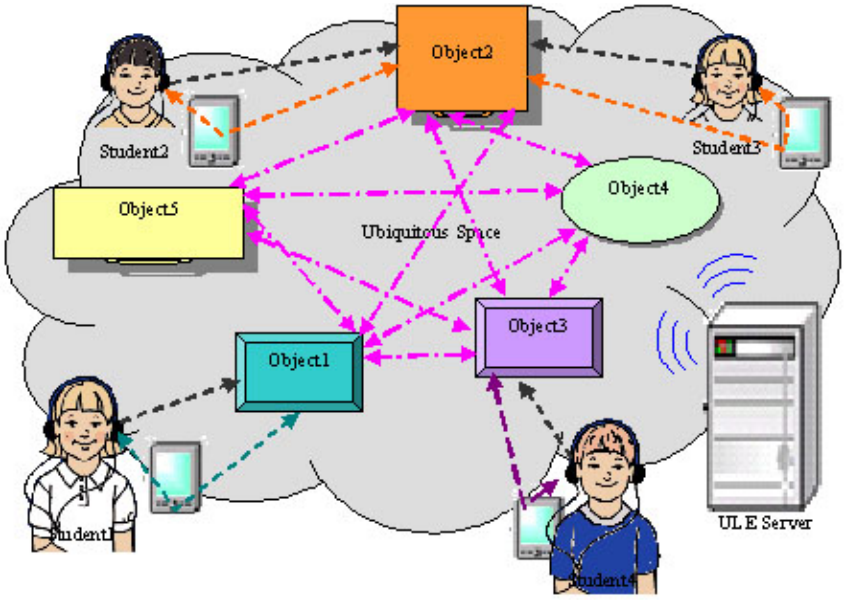

Figure 1: Students within u-space

Figure 1. So if **Student1** is interacting with **Object1**, all devices that are part of the network are aware of this interaction. However, for each student the relationship is unique and their interaction is uninterrupted by the interaction of others. This also allows each student to progress through the learning experience at their own pace.

In designing the ULE, the application of learning theories is an important consideration. Jacobs (1999) states that using learning theories in educational design helps to create a relationship between the information, the learner, and the environment. Gersten and Baker (1998) explain that when this relationship does occur there is a greater chance that the student will retain the information within their own knowledge base. For example, if a student can understand ***why and how*** something happens in nature, such as why and how a seed will sprout in soil and not in rocks, rather than just being told that it is true; the information has more relevance and therefore more meaning. Put simply, once an individual understands a concept they are more likely to remember it. A lack of understanding results in the opposite, as Jacobs (1999) explains:

> ... if learners learn facts of information that are isolated from a meaningful context, their understanding is often incomplete and meaningless.

There are, of course, a number of learning theories that have been presented over the years. However, for this ULE model the theory of constructivism is applied.

The ULE model

The two main factors in this design are the '*what*' and the '*how*'. The '*what*' is the model itself which resembles an interactive learning gallery and uses a wireless network with both Bluetooth and WiFi technologies. The '*how*' is the inclusion of pedagogical information which is based on constructivist theory, allowing students to create knowledge from what they see, hear, read and perceive. Students using the ULE will intuitively interpret their surroundings and construct their own knowledge.

The ULE model is not unlike the interactive guides currently being produced and implemented in large museums. Electronic museum guides provide an information service to aid museum culture and tend to mimic or replace human guides; however, this model is designed for use in the education sector rather than entertainment or enrichment. Also, the source information is meant to be both adaptable and flexible, allowing updates and amendments to be applied through the network's database. In this way curriculum changes can be easily achieved.

Components of the ULE include:

1. ***Microprocessors*** with memory will be embedded in every object/device. The information each microprocessor will hold will be about the object. When a student approaches, the sensor detects their presence and will start relaying information to the student's PDA.
2. ***ULE Server Module*** will include the Server, the Educational Strategies Unit and a Database:
   The *ULE server* manages the network resources;
   The *Educational Strategies Unit* allows for the application of strategies to reinforce and aid student understanding through interaction and feedback. It analyses student responses to short quiz questions and returns more information or information in a different form when needed;
   DataBase – stores all the data about the 'objects/devices', the users and the interactions that occur.
3. ***Wireless technology*** – this will be in the form of Bluetooth and WiFi:
   Bluetooth has weak signal strength, uses little power and covers a relatively short distance. Its low power consumption and ability to communicate with many devices is extremely beneficial when using handheld devices.
   WiFi, based on the IEEE 802.11 specification, has a range and speed which surpasses that of Bluetooth. It is compatible with any brand of Access Point and client hardware built to the WiFi standard (Brevard User's Group, 2002)
4. ***Sensors*** will be used to detect any changes in surroundings. These will be placed adjacent to the objects/devices and will be used to recognise the presence of students. The sensors used will include proximity, to detect movement, and light, to detect changes in light intensity.

The ubiquitous learning centre

In the Ubiquitous Learning Centre each student will carry a wireless device (PDA or mobile phone) fitted with headphones. The ULE Server Module tracks and locates each student within the u-space by the use of sensors. When a student approaches an object, sensors wirelessly access the intranet and ULE Server Module and transmit information about the object. The data is then transmitted from one of the objects in the Ubiquitous Learning Centre to the student's handheld device.

Seamless interaction between student and device

Figure 2 illustrates the seamless interaction between one student and the system. Here the student approaches and observes the object. Adjacent sensors detect the student's presence and send data about the object to the student's PDA (**a1**). This can be transferred to the student in the form of images, text, sound or other format (**a2**). At the same time, the object will access the ULE Server Module (**b1**) and request information about the student. However, being capable of both networked and independent operation, the object can function alone and transmit data. Information about the student, such as whether the student has accessed the data previously and what format is most suitable for this particular student is sent by the ULE Server Module. If the student has responded well to verbal or visual information in the past, this information will be transmitted.

A discreet quiz by way of a game or other entertaining method may be sent to the student's handheld device and then on to the student (**b2** and **b3**). The student's responses are transmitted to the ULE Server Module (**c1** and **c2**) and the results analysed by the Educational Strategies Unit. If the student requires some additional help in understanding the topic or some reinforcement, then this is sent back to the student via the PDA (**c3** and **c4**). Information about all students is held in the ULE Server Module, whereas information about an object is held by the object as well as the ULE Server Module.

Communication between objects/devices

Figure 3 illustrates communication between devices. Again, the student, **Student1,** approaches and observes **Object1**. A number of points relevant to **Object1** are conveyed, possibly in the form of text, images or sound delivered to the student's handheld device. When the system receives a response from **Student1**, it can review the information and unobtrusively 'test' the student's understanding. Once this is analysed, **Object1** relays this information to the other objects, in this case, **Object2** and **Object3**, within the u-space. This allows the ULE Server Module and the objects to download relevant information to the student. The sequence would be as below:

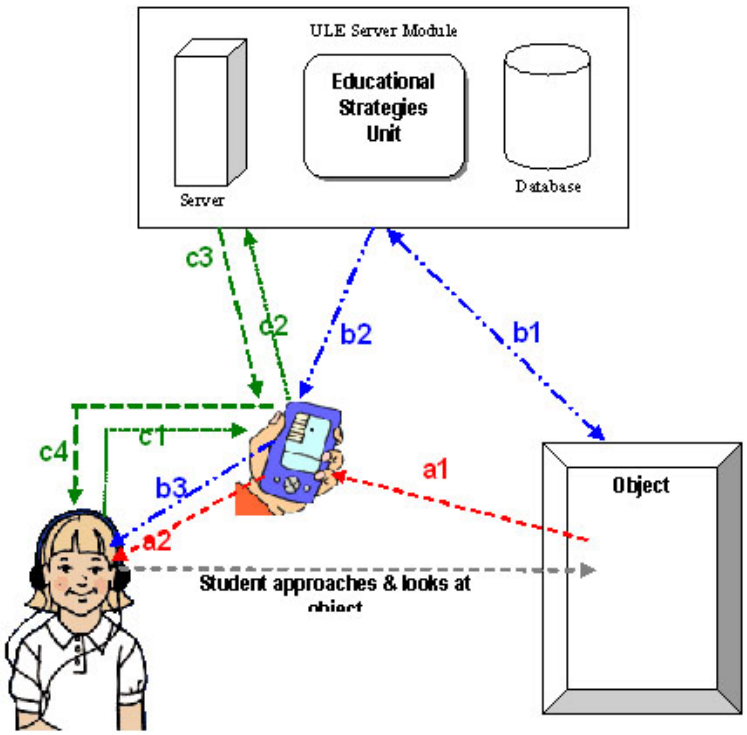

Figure 2: Student object interaction

1. **Object1** is approached by **Student1**
2. Information is sent to **Student1**
3. **Object1** analyses the student's responses and hence understanding of the topic (with help from the ULE Server Module)
4. This information is relayed to all other objects in the u-space e.g. '**Student1** understands 6/10 points on this topic'

When the student approaches the next object, that object is 'aware' of what the student already knows and will only attempt to explain some of the remaining four points of the original ten. Throughout this procedure the ULE Server Module is only accessed as required by the objects. A student's interaction with objects during the session can also be tracked and stored on the server. On the student's next visit, the ULE system is 'aware' of the student's accumulated knowledge and can assist learning constructively by building on this knowledge. In this way the student's learning experience can be enhanced and a deeper understanding may be attained.

The type of content suitable to be taught within the ULE includes knowledge based disciplines such as History, Geography and the Sciences, which require knowledge transfer, reflection and active (physical or mental) participation. This may also be referred to as museum, or gallery, style learning which caters for the primary learning styles of visual, aural, and kinesthetic/tactile learning. Students are encouraged to create their own knowledge from their surroundings as they move around in u-space and interact with various objects and devices. Constructivist theory is used to allow students to build knowledge from what they see, hear, read and perceive.

Conclusion

In this paper we describe the development of a ULE model that uses ubiquitous technology and the concept of adaptive learning. This is part of ongoing research and development being undertaken at the Robotics and Games (R&G) Laboratory at Griffith University, Gold Coast campus. The R&G research team is extensively involved in ubiquitous technology and robotics. The team is currently also developing a ubiquitous robot, which uses sensor technology, and have created prototypes of both biped and wheeled

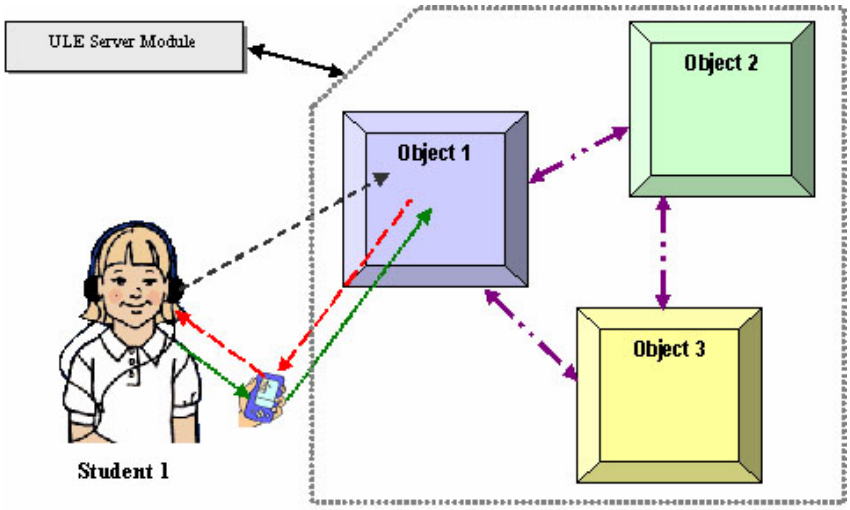

Figure 3: Communication between objects/devices

robots. Members of our team have recently developed a pair of small robots equipped with Bluetooth modules and are testing communication between the robots without the need for user interaction. So far we have had some success with this and are continuing with testing and development. Ubiquitous technology plays a major role in all aspects of R&G research.

The concept of ubiquitous computing and u-learning goes beyond portable computers. As new technologies evolve and more pervasive forms of technology emerge, computers will become 'invisible' and will be embedded in all aspects of our life. They will be seamlessly integrated into our world in a phenomenon referred to as calm technology. Wearable computers and embedded microchips are not as unbelievable or mind boggling as they were when first depicted in early science fiction novels and movies. Many technologies have become integrated into our lives over the years, for example: the telephone; television; PCs; the Internet and mobile phones. These innovations may have appeared strange and futuristic at first but, over time they blended into our everyday lives. In this age of progress and great change, we tend to easily adapt to the technologies and pedagogies that emerge. Ubiquitous technology and u-learning may be the new hope for the future of education.

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