International Journal Of

Recent Scientific Research

ISSN: 0976-3031

Volume: 7(4) April -2016

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THE OFFICIAL PUBLICATION OF
INTERNATIONAL JOURNAL OF RECENT SCIENTIFIC RESEARCH (IJRSR)
http://www.recentscientific.com/ recentscientific@gmail.com

Available Online at http://www.recentscientific.com

International Journal of Recent Scientific Research
Vol. 7, Issue, 4, pp. 9875-9879, April, 2016

ISSN: 0976-3031

International Journal of Recent Scientific Research

Research Article

A STUDY ON THE COMPATIBILITY OF UBIQUITOUS LEARNING (U-LEARNING) SYSTEMS

Shazia Farheen[1]., Indira B[2] and Ramana Murthy M.V[3]

[1]Computer Science Department, Madina Degree College for Women, Shahalibanda, Hyd, (Ap) India
[2]Kasturba Gandhi Degree & PG College for women, Marredpally, Secunderabad, AP, India
[3]Department of Computer Science & Mathematics, Osmania University, Hyderabad, AP, India

ARTICLE INFO

Article History:

Received 05th January, 2015
Received in revised form 08th February, 2016
Accepted 10th March, 2016
Published online 28st April, 2016

Keywords:

Ubiquitous learning, context awareness, science education, wireless networks, ubiquitous computing.

ABSTRACT

Recent progress in wireless and sensor technologies has lead to a new development of learning environments, called context-aware ubiquitous learning environment, which is able to sense the situation of learners and provide adaptive supports. Many researchers have been investigating the development of such new learning environments; nevertheless, the criteria of establishing a context-aware ubiquitous learning environment have not yet been clearly defined. To resolve these problems, this paper presents the basic criteria, technology, infrastructure, strategies, and research issues of context-aware ubiquitous learning. Illustrative examples of conducting context-aware ubiquitous learning activities and the requirements of setting up such learning environment are also presented at the end of this paper.

INTRODUCTION

The current emphasis and availability on mobile technologies produces a need to reconsider mobile design principles and mobile usability testing. New interaction paradigms, e.g. on the iPhone, new mobile system platforms e.g. Android and the increased availability of free wireless network access points, affect the way that end users interact with ubiquitous devices, extending traditional e-Learning into a new phenomenon named: Ubiquitous Learning (u-Learning)[1]. Zhan & Jin defined u-Learning as a function of different parameters: u-Learning = {u-Environment, u-Contents, u-Behavior, u-Interface, u-Service} This definition illustrates that the application of u-Learning requires different usability aspects as well as different aspects of education Usability evaluations traditionally investigate whether and to what extent the user interface is suited to the work context of the user and whether it is easy to learn and efficient to handle. In the last years experts increasingly discuss different aspects, including joy of use, aesthetics and emotions [2]. Such terms and other related design aspects are generally described as user experience, which is evidently set apart from traditional usability goals such as efficiency, effectiveness and learnability.

In recent years, the progress of wireless communication and sensor technologies have evolved the research issues of e-learning to mobile learning (m-learning), and now is evolving from m-learning to ubiquitous learning (u-learning). In an ideal u-learning environment, computing, communication, and sensor devices are embedded and integrated into learners' daily life to make learning immersive. Based on this concept, [3] proposed a learning environment facilitated with context-aware peer to peer search to empower learning resource finding and sharing. Ubiquitous learning environments raise the issue of context –awareness; that is, the capability to sense the status and situation of the learners and provide them with adaptive contents and supports.

Characteristics of a Ubiquitous Computing Environment

To develop context-aware and seamlessly integrated Internet environments, a variety of new techniques and products concerning ubiquitous computing have been developed in recent years, such as sensors and actuators, RFID tags and cards, wireless communication, mobile phones, PDA (Personal

*Corresponding author: *Shazia Farheen*
Computer Science Department, Madina Degree College For Women, Shahalibanda, Hyd, (Ap)I ndia

Digital Assistant) and wearable computers. From the system designer's point of view, physical integration and spontaneous interoperation are the two main characteristics of ubiquitous computing systems [4]. Physical integration means that a ubiquitous computing system involves some integration between computing nodes and the physical world. For example, a smart coffee cup, such as a Media-Cup (Beigl *et al*.,, 2001), serves as a coffee cup in the usual way, but also contains sensing, processing and networking elements that let it communicate its state (full or empty, held or put down), enabling the cup to give hints about the state of the cup, as well as its owner. Moreover, consider a smart meeting room that senses the presence of users in meetings, records their actions [5], and provides services as they sit at a table or talk in front of a whiteboard [6]. The room contains digital furniture such as chairs with sensors, whiteboards that record what is written on them, and projectors that can be activated from anywhere in the room, using a PDA. In the meantime, a ubiquitous system must spontaneously interoperate in changing environments. A component interoperates spontaneously if it interacts with a set of communicating components that can change both identity and functionality over time as its circumstances change.

A spontaneously interacting component changes partners during its normal operation, as it moves or as other components enter its environment; it changes partners without needing new software or parameters [4]. For example, to seamlessly hold a video conference, the system needs to immediately locate the nearest functional objects, such as a CCD camera and display equipment, for each attendee. If the attendee moves toward another room, the system will change devices according to the user's context, so that the video conference can be seamlessly continued. If the attendee switches his or her device from a notebook with a 100 Mbps local area network to a PDA with a lower-speed wireless network, the system will locate additional translation coders or drivers accordingly. From the user's point of view, in a ubiquitous computing environment, anyone can make use of computers that are embedded everywhere in a public environment, at any time.

A user equipped with a mobile device can connect to any of them, and access the network by using wireless communication technologies [7]. Moreover, not only can a user access the network actively, but computers around the user can recognize the user's behavior and offer various services according to the user's situation, the mobile terminal's facility, the network bandwidth, and so on [8]. User assistance via ubiquitous computing technologies is realized by providing users with proper decisions or decision alternatives. That is, a ubiquitous computing technology-equipped system supplies users with timely information and relevant services by automatically sensing users' various context data, and smartly generating proper results [9]. Therefore, by employing this new technology in education, the learning system is not only adapted to the individual's needs, but is also actively involved in his or her learning activity. Hence, the ideas of using u-computing technology for learning concur with the pedagogical theory of constructivism. In the frame of constructivism, educators need to provide student-centered learning environments to facilitate the active construction of each individual learner [10]. It also highlights the student's prior knowledge and cognitive apprenticeship [11]. Clearly, well-developed learning systems that employ u-computing technologies can be highly adaptive, based on the student's prior knowledge and existing performance to provide proper guidance or apprenticeship for each learner.

Technologies and infrastructure

Ubiquitous learning relies on a very wide spectrum of portable, mobile, wireless, wearable and embedded computers and transmitters. The information processing devices and the communication network remains to be the two main ingredients of technological infrastructure of u-learning, but they will turn up in somewhat different forms.

Ubiquitous information processing will be integrated not only into portable and hand held electronic devices, but also into home and office appliances, garments, and personal accessories. In addition to processing information in various media forms, they can also directly communicate with each other, concurrently forming the units of a local network and of a global network. We can anticipate a large heterogeneity of the ubiquities devices and communicators at least in the coming decade. The variety of them will be even higher that that of mobile devices. This arsenal of devices will involve all sort of portable computers, networked mobile phones, PDAs, PalmPilots, smart digital cameras, media players, and even handheld gaming tools, such as NGage.

With respect to communication networks, the major difference will be heterogeneity and ad hoc formation. The first means that the network will not be based on a single technology, but on a combination of complementary technologies. Obviously, this heterogeneity will be invisible for the users of learning services. From the aspect of the technology, it requires seamless integration and synergic operation. As an infrastructure, the network is supposed to have some sort of intelligence to select the most suitable technology and the best way of operation. The second means that the network is not predefined, but formed according to the demands and opportunities. Various concepts of ad-hoc networks will be implemented in a dynamically changing network topology. In these ad-hoc networks fixed and mobile nodes and network segments will be interconnected. The nodes act as a router and repeater for other nodes, forming a wireless mesh network. Likewise, emerging wireless sensor networks, whose nodes will be devices with sensing and processing capabilities. It is expected that these networks will merge in so called hybrid adhoc networks in the near future. They may also incorporate other types of mobile networks such as vehicular, personal and ambient networks.[12]

Criteria of Context-Aware Ubiquitous Learning

Although u-learning has attracted much attention from the academia, the criteria of developing a u-learning environment have not been clearly defined. Till now, researchers have different views of the term "u-learning". One view is "anywhere and anytime learning", which is a very broad-sense definition of u-learning. With this definition, any learning environment that allows students to access learning content in any location at any time can be called a u-learning environment, no matter whether wireless communications or mobile devices are employed or not. From this viewpoint, the mobile learning environment which allows students to access learning content via mobile devices with wireless communications is a special case of the broad-sense definition of u-learning.

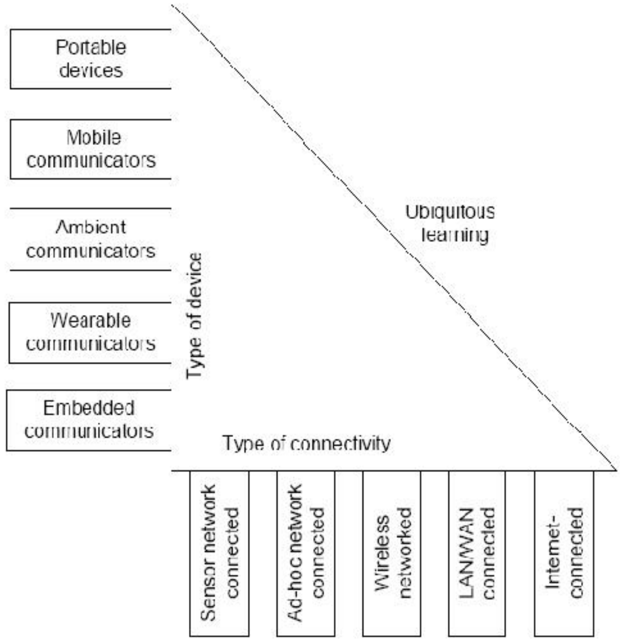

Figure 7 Types of devices and connectivity for ubiquitous learning

[13]

It is clearly identified through the above discussion that u-learning is not equal to "learning with u-computing technology", which emphasizes not only the usage of wireless communications, but also the sensor technology [13]. More precisely speaking, "learning with u-computing technology" is a special case of mobile learning. In the following discussion, we shall focus on such a special definition of u-learning that employs mobile devices, wireless communications and sensor technologies in learning activities, called "context-aware u-learning", to distinguish it from the broad-sense definition of u-learning, and the concept of mobile learning. Figure 1 shows the relationships amongst u-learning, mobile learning, u-computing in learning and the newly defined "context-aware ulearning".

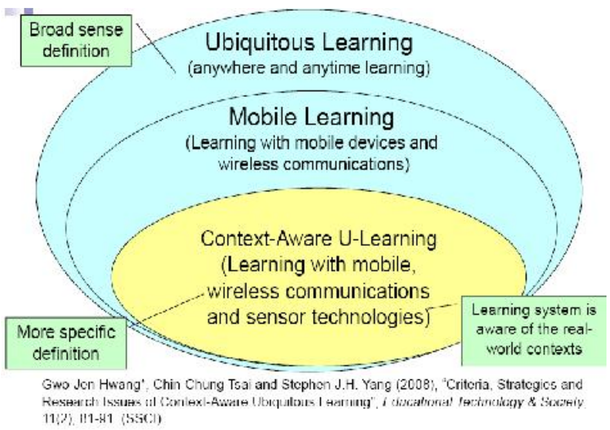

Figure 1 Relationships amongst u-learning, mobile learning, u-computing in learning and "context-aware ulearning" [3]

The context-aware feature of u-computing environments allows the learning system to better understand the learner's behavior and the timely environmental parameters in the real world, such as the locations and behavior of the learner, and the temperature and humidity of the learning environment [14]. Such contexts could be brief or detailed; for example, the location of the user could be described by a zip code or a physical address. Among various contexts that can be sensed, researchers have indicated that "time" and "location" may be the most important and fundamental parameters for recognizing and describing a learner's context [15].

For example, [16] presented a u-learning system which has been used to help students to learn Japanese in real-world situations. The systems can provide learners with appropriate expressions according to different contexts (e.g., occasions or locations) via mobile devices (e.g., PDA) [17] integrated the learning experiences of indoor and outdoor activities by observation in the working scene.

Learners are not only capable of getting data, voice and images from the scene by observation, but also of gathering related information from learning activities via wireless networks. Recently, Joiner [18] presented their studies of applying context-aware devices to education by providing students with timely vocal statements related to specific activities in real conditions. Meanwhile, researchers have attempted to identify principles and methods for designing u-learning activities [19]. For example, Cheng *et al*. (2005) demonstrated how a u-learning system provides adaptive services via four steps: (1) Setting instructional requirements for each of the learner's learning actions. (2) Detecting the learner's behaviors. (3) Comparing the requirements with the corresponding learning behaviors. (4) Providing personal support to the learner.

Accordingly, the potential criteria of a context-aware u-learning environment are given as follows:

1. A context-aware u-learning environment is context-aware; that is, the learner's situation or the situation of the real-world environment in which the learner is located can be sensed, implying that the system is able to conduct the learning activities in the real world.
2. A context-aware u-learning environment is able to offer more adaptive supports to the learners by taking into account their learning behaviors and contexts in both the cyber world and the real world.
3. A context-aware u-learning environment can actively provide personalized supports or hints to the learners in the right way, in the right place, and at the right time, based on the personal and environmental contexts in the real world, as well as the profile and learning portfolio of the learner.
4. A context-aware ubiquitous learning environment enables seamless learning from place to place within the predefined area.
5. A context-aware ubiquitous learning environment is able to adapt the subject content to meet the functions of various mobile devices. Such a learning environment basically consists of the following components:

1. A set of sensors that is used to detect personal contexts (e.g., the location and body temperature of the learners)

and environmental contexts (e.g., the temperature and humidity of the learning environment).

2. A server that records the contexts, and provides active and passive supports to the learners.
3. A mobile learning device for each learner with which the learner can receive support or guidance from the server, as well as being able to access information on the Internet.
4. Wireless networks that enable communication among the mobile learning devices, the sensors and the server.

Strategies of Learning Activity Design for Context-Aware U-Learning

To conduct learning activities in a context-aware u-learning environment, it is necessary to define the situation parameters taken into account [19]. For a learning activity conducted in the real world, there are five types of situation parameters, as shown in the following:

1. Personal contexts sensed by the system: includes the learner's location and time of arrival, temperature, level of perspiration, heartbeat, blood pressure, etc
2. Environmental contexts sensed by the system: includes the sensor's ID and location, the temperature, humidity, air ingredients, and other parameters of the environment around the sensor, and the objects that are approaching the sensor.
3. Feedback from the learner via the mobile learning device: includes the observed or sensed data of the target items (such as environmental temperature and acid value of water, air pollution, shape and color of a tree, machine status after performing an operation), acquired photos or interactions with the learning system (e.g., the answers to the test items or the log for operating the system).
4. Personal data retrieved from databases: includes the learner's profile and learning portfolio, such as the predefined schedule of the learner, expected starting time of a learning activity, the longest and shortest acceptable time period of a learning activity, the learning place, the learning paths or sequences of a course, the constraints or prohibitions of a course of learning activity, etc.
5. Environmental data retrieved from databases: includes the detailed information of the learning site, such as the schedule of learning activities arranged at the site, the constraints or management rules of the site, notes for using the site, the equipment located at the site, the persons who use or manage the site, etc.

Illustrative Example of Context-Aware U-Learning

To address the context-aware u-learning activities in more detail, a learning environment with several illustrative examples of learning activities is given in this section. Consider the "Identification of Plants" unit in the Natural Science course of an elementary school. Figure 2 shows the context-aware u-learning environment with RFID sensors and wireless networks. Each target plant has an RFID tag attached to it which records the identification data of the plant, and each student is equipped with a PDA with an RFID reader which can read the data from the tag if the student is close enough. Once the u-learning system identifies the plant, relevant information can be read from the plant database in the server via wireless communications.

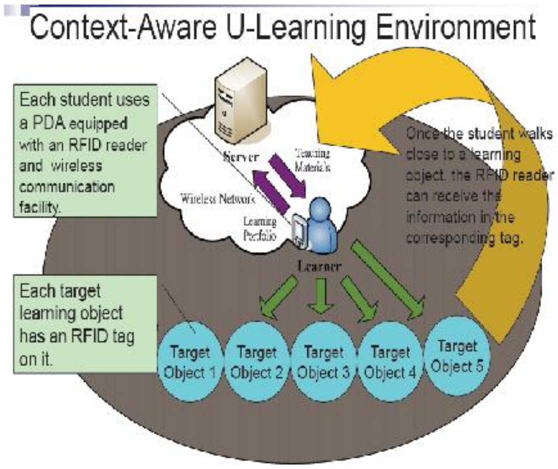

Figure 2 Illustrative example of a context-aware u-learning environment [20]

CONCLUSIONS

Although u-learning or context-aware learning environments have attracted the attention of researchers in the fields of computer science and education, the criteria for establishing a fully functional u-learning environment is still unclear. In this paper, we have attempted to define the basic criteria, technology and infrastructure of a u-learning environment, and propose various models of conducting u-learning activities. It can be recognized that a variety of personal and environmental parameters are available in a u-learning environment, such that more adaptive support can be provided by the system. In addition, the real-world observation and problem-solving abilities of the learner can be trained and evaluated in such a context-aware environment. Basically, there are several levels of individualized guidance which can be provided in a context-aware u-learning environment: for naive learners, adaptive supports and guidance for real-world operations or observations can be provided; however, for experienced learners with different backgrounds and experiences, only hints or necessary warnings are given.

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How to cite this article:

Shazia Farheen., Indira B and Ramana Murthy M.V.2016, A Study on the Compatibility of Ubiquitous Learning (U-Learning) Systems. *Int J Recent Sci Res.* 7(4), pp. 9875-9879.

ISSN 0976-3031
9 770976 303009 >