Adaptive Content Delivery in Ubiquitous Learning Environment

Xinyou ZHAO, Xin WAN, Toshio OKAMOTO
Graduate School of Information Systems, The University of Electro-Communications, Japan
E-mail : totoyou@ieee.org

Abstract

Empowered by mobile computing, teachers and students can benefit from computing in more scenarios beyond the traditional computer classroom. But because of the much diversity of device specification, learning contents, and mobile context existing today, the learners get a bad learning experience (e.g. rich contents can not be displayed correctly) during u-Learning environment. This paper proposes an adaptive contents delivery system for u-Learning environment, which creates the adaptive contents for learners according to learner's interest and learning contexts. The evaluation on a mobile virtual community system shows that the learners may not only study in rich media on mobile device at any time & place, also get a better learning experience, e.g. learners may get instant help from other participates by ubiquitous device .

1 Introduction

Since ubiquitous computing technology was firstly proposed by Weiser (1993)[1], the capabilities of ubiquitous devices such as personal digital devices (PDAs), cell phone, portable computers and smart phone are increasing at a steady rate[2]. People can now learn/work anytime and anywhere using laptops, phones, and palm devices with wireless connectivity, an enabled hotspot or wireless network. Over 60% people around the world accessed the internet or equivalent mobile internet services such as WAP and i-Mode at least occasionally using a mobile phone rather than a personal computer by the end of 2008[2,3]. For example, with text-messaging, government can go mobile, such as sending text message to pay parking tickets in Singapore, to pay income tax in Philippines, for suggestion to National People's Congress in China and receiving text message for examination results in Kenya, tax amount in India[4].

With the development of communications, the 3G is coming and used in the world. The ubiquitous devices have become increasingly integrated into many facets of our daily activities, including education[2,3]. Cell phones can take pictures, record sounds, reveal location, and even measure the population density and moving speed of users. Ubiquitous device seems an ideal tool for participating in virtual learning activities at any place and any time.

In school or university, learners may access e-learning contents by their portable devices at any time and at any place or receive information about class or school news in real time, which is called ubiquitous learning or u-Learning[5]. Over the past ten years, u-Learning has grown from a minor research interest to a set of significant projects in schools, workplaces, museums, cities and rural areas around the world[6]. Today the unified u-Learning system evolved from a singular SMS m-Learning system is shown in Fig.1. U-Learning, which provides a seamless learning for learners, can bridge the gap of mobile and desktop computing[7].

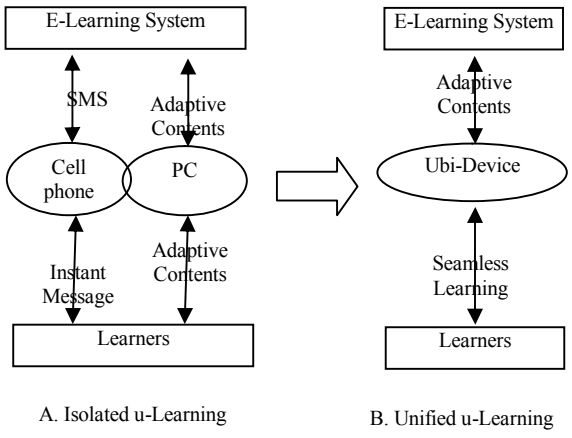

Fig.1 *Evolution of u-Learning*

Another, information visualization is a well-established discipline[8]. The highly graphical, sophisticated approaches have been proposed to provide vast sets of information for users. These graphical schemes have been applied to the fields of

978-0-7695-3992-8/10 $26.00 © 2010 IEEE
DOI 10.1109/WMUTE.2010.10

information retrieval and exploration in an attempt to overcome search and access problems on conventional, large-screen displays [9]. The users may conveniently access graphical information by personal computer.

Many applications on personal computer, e.g. the successful e-Learning application, have been altered to ubiquitous device too. But some visualization schemes may not be appropriate for small-screen devices: even if the display technology can deliver the high resolution required, the available screen space is not necessarily adequate for meaningful presentations and manipulation by the user[9]. For example, rich contents can not be correctly displayed on mobile device[11,12]; different needs under different learning location & time[3,17]. Unified u-Learning easily makes learners drop out from e-learning system on mobile device for much diversity in u-Learning environment.

Up to now, access to e-learning contents designed for desktop platform by mobile devices has not become as convenient as expected with mobile browser embedded in mobile devices[10,11,12]. The paper proposes one adaptive content delivery framework for u-Learning environment, which delivers contents adapted to learning context, e.g. device feature, learner's preferred media type, learning location. Meanwhile, the adaptive contents are dynamically created, not by LMS managers previously.

The rest of this paper is organized as follows. Adaptive learning is discussed in section 2. Section 3 describes the issues of u-Learning and research focus in this paper. Section 4 explains the adaptive content delivery model considered in this research. Section 5 discusses a learning scene on u-learning environment and the evaluation on the system model proposed. Finally, section 6 concludes the paper and sketches future research directions.

2 Adaptive Learning

The adaptive system is in the present a common and trendy concept with the field of computer science [13], e.g. artificial systems. Today there are distinct definitions in different academic subject.

In general, an adaptive system is a set of interacting or interdependent entities, real or abstract, forming an integrated whole that together are able to respond to environmental changes or changes in the interacting parts, which changes in behavior of a person or group in response to new or modified surroundings.

2.1 Adaptation Service in Learning

Arriving at the present and from the software engineering point of view, the user centric service is increasing more relevance within the research community[13]. Within learner-centric adaptation system, Conlan, Hockemeyer, Wade and Albert (2002) [14] state that adaptive services base their adaptivity on learner and context information, as well as on an encapsulation of the expertise that support the adaptation. Thus, the adaptivity and adaptability in e-learning systems is essential in order to adjust the changing of learner's situations dynamically. A formal definition of the Law of Adaptation is as follows:

Given an e-Learning system S, we say that a physical event E is a stimulus for the system S if and only if the probability $P(S \to S' | E)$ that the system suffers a change or be perturbed (in its elements or in its processes) when the event E occurs is strictly greater than the prior probability that S suffers a change independently of E:

$$P(S \to S' | E) > P(S \to S')$$

The Fig.2 gives different domains between adaptive e-Learning and u-Learning.

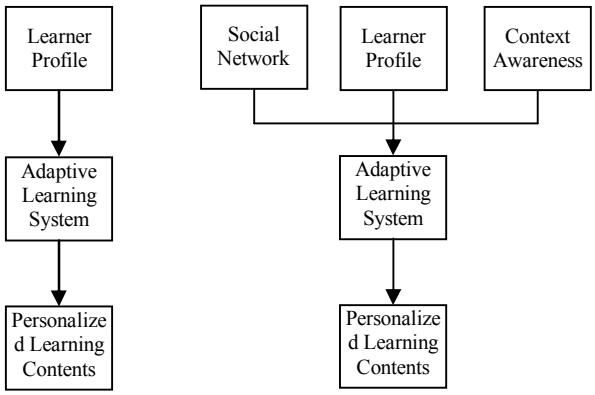

Fig.2 Different Domains in e-Learning and u-Learning

2.2 Adaptive e-Learning

Today, the success of adaptive e-Learning system is due to the efficient delivery of learning contents by means of advanced personalization techniques.

Thus, from the technological point of view, the main challenge of these personalization techniques depends on correctly identifying characteristics of a particular learner[15]. The characteristics may be knowledge, skills, cognitive abilities, learning process/history and styles, learning preference, and so on.

In short, enhancing learning and performance is a function of adapting instruction and content to suit the

learner, in other words, the aim of adaptive e-Learning system is coordinated with actual education & learning: right learning contents at right learner at right time in the appropriate way – any time, any place, any path, any pace. Usually, the adaptive e-Learning contents can be recommended by an adaptive engine given under learning content model, learner model, and instructional model[15].

2.3 Adaptive u-Learning

The dynamical and continual changing learning setting in u-Learning environment gives more different learning contexts than those in e-Learning. The task of context awareness in u-Learning is to detect the ubiquitous situation and adapt to the changing context during learning[14]. Context awareness is the key in the adaptive u-Learning system and must be integrated with learning system truly.

The system framework creates adaptive contents for u-Learning, which is implemented on an adaptive behavior according to learning context awareness[20]. The main purpose of the adaptivity is to provide context awareness-based learning under learner's different skill and motivations. The contexts may be learner's state, educational activity, environment state, or system infrastructure et al[20,21]. The works are completed by an adaptation engine in general. The adaptation engine uses context data of u-Learning as input data to produces the adaptation results. The one of challenge is to exploit the changing environment with a new class of learning applications that can adapt to dynamic learning situations accordingly.

Another challenge is to provide rich learning contents on mobile device, which has constrained capabilities. The system should consider more learning contexts than e-Learning system, such as connectivity, communication expense, device capabilities, learning locations et al. According to context awareness, the system should dynamically transcode adaptive contents to learners into adapted contents to learning contexts on the fly.

3 Issues in Adaptive u-Learning

According to more domains considered in adaptive u-learning than in adaptive e-learning, the system may provide more adaptive contents for learners. But it is difficult to provide adaptive contents because there is much diversity among these domains, which are summarized in Table 1.

3.1 Diversity of Mobile Device Specifications

The range and diversity of devices on the market today presents a challenge to provide contents on mobile device for users. Even though the memory and computational capabilities of these devices will continue to improve, Erol, Berkner and Joshi (2008)[16] and Hsiao, Hung and Chen (2008) [17] show that the small display sizes and limited input capabilities for user interaction are likely to remain the major bottlenecks for many mobile applications.

Table 1 Different Diversity in U-Learning Environment

Type	Features
Devices	**Hardware**: Memory, screen size, resolution, color depth…
	Software: supported media formats, Mobile Browser
Contents	**Text**: TEXT,PPT,DOC,PDF…
	Image: SVG, JPEG, GIF, PNG, WBMP…
	Animation: FLASH, GIF,…
	Audio/Video: AMR, 3GP, EVRC …
Contexts	**Personal Context**: User's preferences, calm behavior…
	Social Networks: personal history, friends, blogs …
	Other Context: location, time, …

3.2 Diversity of Learning Contents Media

Most of e-learning contents, designed for desktop computers and high-speed network connections, are not suitable for handheld devices, whose capabilities are usually limited in terms of network bandwidth, processing power, storage capability, markup language, and screen sizes, etc.

3.3 Diversity of Mobile Context

AMF Ventures find that on TV only 1% of audience data is captured; on the internet about 10% of audience data is collected; but on mobile 90% of audience information can be identified[18], which may include Personal Context (User's preferences, calm behavior…), Social Networks (personal history, friends, blogs, …), or other Context (educational strategy, location, time, presence and related status, handset status and capabilities.). Considering learning context means that for educational aim we know more exact composition of learners, individually and exactly.

3.4 Issues in Adaptive u-Learning

Delivering learning resources designed for tabletop computers to u-Learning environment is by no means

a trivial task[19]. The learners get a bad learning experience during u-Learning environment for the reason of the much diversity discussed above.

First, massive amount of contents, irrelevant to learners' preferences or contextual environment, will make learners feel frustrated and dissatisfied. Also, these make learners overload during learning. They also increase the learners' communication costs and channel burdens.

Secondly, most of learning contents, designed for desktop computers and high-speed network connections today, are not suitable for network features with low bandwidth and handheld devices with limited resources and computing capabilities.

4 U-Learning System Model

The u-Learning environment provides an interoperable, pervasive, and seamless learning architecture to connect, integrate, and share three major dimensions of learning resources: learning collaborators, learning contents, and learning services. U-Learning is characterized by providing intuitive ways for identifying right contents and right services in the right place at the right time based on learners surrounding context such as where and when the learners are (time and space), what the learning resources and services available for the learners, and who are the learning collaborators that match the learners' preferences.

As a result, the effectiveness and efficiency of u-Learning heavily relies on the surrounding context of learners. Economides (2006) [21] proposes adaptation engine in an adaptive mobile system that uses learning automata to implement the probabilistic adaptation decisions. The Learner's state, educational activity's state, infrastructure's state, and environment state are considered into context as input to adaptation learning system.

This research defines u-Learning context as two aspects, one is from client side, and the other is from the server side. From the client side, the learning time, place, network types, and device capabilities are considered as learning context. From server side, the teaching/learning strategy, learner's profile and preferences are taken as context. The $U_i(t)$ is used to define the u-Learning state at time t for learner i (shown in Fig.3):

$$U_i(t) = [L_i(t), O_i(t), E_i(t)]$$

where:

$L_i(t)$: the learner's preference at time t

$O_i(t)$: items state in learning object (O) at time t

$E_i(t)$: context awareness at time t.

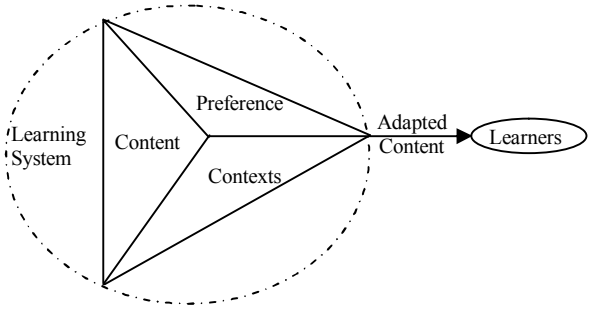

Fig.3 Adaptive Content System Model

For example, learner i accesses a learning object O (Text content) under context E (learning by cell phone while walking). The personalized content O' is ranked by $P(O \to O' | L, E)$. At last, the system may recommend adaptive contents O' (text→audio) according to learner preference, learning object, and learning context.

5 Learning Scene on u-Learning Model

The conversation theory suggests that learning to be successful requires continuous two-way conversations and interactions between the teacher/teacher and amongst the learners[22]. It is important for learners to share learning experience through online learning community or message boards. The teacher can guide the learning activities either through instant messaging or bulletin board system (BBS). Learner may response his/her feedback to teacher or other participants by BBS or instant messaging through his/her ubiquitous device.

According to the above, let us suppose a u-Learning scene:

Table 2 u-Learning Scene

Sam will attend a test at 9:30 today. During going to school,
➢ *he wants to check some latest information, which is learning materials uploaded for test on e-learning system may include pdf materials besides plain text information;*
➢ *he wants to review some courseware, which is ppt files;*
➢ *he wants to review parts of teaching video;*
➢ *he wants to discuss some questions with classmates.*

These e-learning contents (e.g. ppt contents, pdf), designed for desktop computers and high-speed network connections, are not suitable for handheld

devices. It is difficult to quickly input message or multimedia contents because of small keyboard embedded on ubiquitous device. According to the questions above, the learners may get the following poor experience during accessing the e-learning contents, which is described in Table 3.

Table 3 Poor Experience on U-Learning Scene

When Sam accesses such a web page from e-learning system on a mobile device, he may get a poor or unusable experience, which may be
➢ *he can not study while he is walking because more contents are displayed with text or something;*
➢ *he may only view the plain test information from the learning materials uploaded by instructor when he is taking train;*
➢ *he can not review the courseware;*
➢ *he can not access the teaching video;*
➢ *he would give up for cooperation discussion, especially for inputting some complex information such as mathematical formulas.*

5.1 Learning System on Ubiquitous Device

In order to realize the learning scene above, the system architecture is shown in Fig.4.

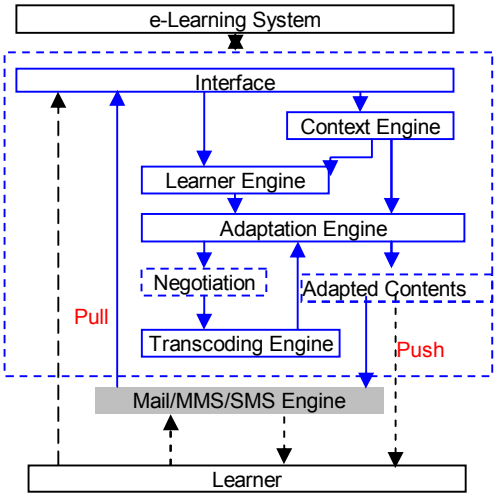

Fig.4 Virtual Community Systems on Adaptive Content Delivery

The core components of the architecture are learner engine, context engine, adaptation engine, and transcoding engine. Learner engine analyzes learner's profile and past learning experience and provides needs & preferences of learner according to learning contextual information of learning reasoned by context engine. Finally, the adaptation engine delivery the adapted contents, created by transcoding engine, to the learners. Please refer zhao[20] for the details.

The system developed is called Adaptive Ubiquitous Learning (AubiLearn) system, which allows learners to participate discussion by mobile mail/MMS/SMS engine. The Mail/MMS/SMS engine assigns a unique mail address for each learner, by which the server can indentify the contents sender before the system publishes mail contents on adaptive discussion system. For example, the system assigns mail address: sam@ourglocal.com to Sam. When the server receives a mail sent to sam@ourglocal.com, the system takes Sam as the sender. Of course, learners may also access adaptive contents from AubiLearn.

The AubiLearn provides two ways for learners to attend discussion by mobile device. First, learners attend the discussion in mobile web pages on mobile device, similar with BBS or learning community on personal computer. In general, the learner uses text information to participate BBS system.

Secondly, learners attend discussion in multimedia learning contents based on mail/MMS/SMS system. As we know, multimedia contents can be transmitted on the fly in mail/MMS/SMS. Also, a recorder and camera is integrated in a mobile device. So learner may send his question or comments in text inputted by small keyboard, speech recorded by recorder or a video/image captured from the pre-written question/comments on paper by camera through mail/MMS/SMS.

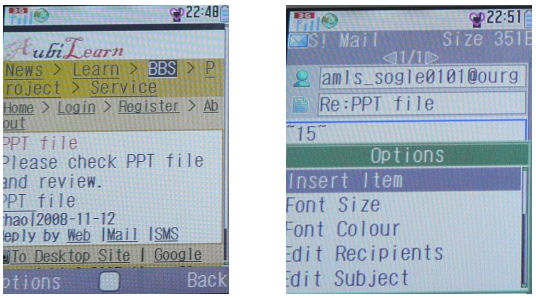

Fig.5 Mail Discussion Systems on AubiLearn

5.2 Adaptation on Document Contents

In general, standard documents contain plain text and images data. When learner accesses a standard document: PowerPoint files, which may contain text, image, audio, animation and video, Learner Engine recommends the personalized contents from a sub-page (one slide) based on learners preference and context awareness, such as deleting image (may not be

favorable to learner) or audio (may not be supported by device). At last, some items of pages are recommended to Adaptation Engine.

Adaptation Engine creates adaptive contents according to learning context. Lastly, the adaptive contents may be based on image, web pages, voiceXML, MMS and so on. Here, we only discuss web pages and MMS/Mail/SMS.

5.2.1 Adaptive contents based on MMS/Mail/SMS

If device does not support a web browser, Adaptation Engine only creates a transcoding request for text or limited media to Transcoding Engine by MMS/SMS. At last, Adaptation Engine pushes contents to learners in SMS (only text) or MMS/Mail (limited media contents). The Fig.6 shows the transcoding time for each request to standard contents, ppt files (size: 2125KB).

From the Fig.6, we can know that it takes more time to response the learner's request at first time because the system extract the plain text and image data from ppt files. But it takes a little time to transcode from second time because it is not necessary to transcode from the original contents, only from adapted contents cached previously. To different size and contents of ppt files, the response times are also increasing linearly. In general, the bigger, the more time and the more complex, the more time.

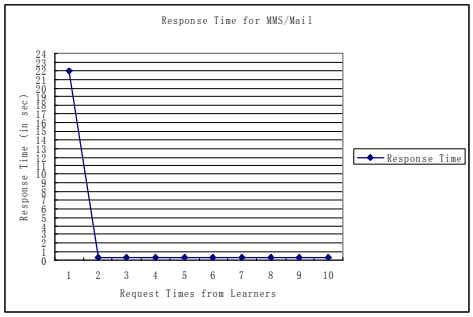

Fig.6 Response Time for MMS/SMS/MAIL

5.2.2 Adaptive Contents Based on Mobile Pages

If a mobile browser is embedded in handheld device, Adaptation Engine negotiates items of personalized contents (sub-page) and sends a transcoding request for unsuitable media. Then, Markup Language Module creates adaptive a mobile page by replacing the HTML tags with mobile tags (such as cHTML, WML). Lastly, mobile page, video or audio content is pushed to the learner.

Fig.7 shows the response time for request from learners at first 150 requests. During each request, a dynamically transcoded content is added into FFSM, whose process consumes the time. At first, the response time is closer to n^2, meaning that new adapted content is inserted into cache server. At peak value, the response time is over 50 seconds. But after some request, the response time begins to reduce quickly and arrive at a steady value at last, which means that the contents accessed have been transcoded for all adaptive to learner's devices.

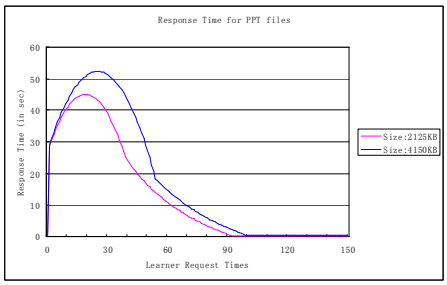

Fig.7 Snapshots of Adaptation Contents for PPT Files

From Fig.8, the spatial consumption is increasing fast during the initial request from learners. But along with the steady of transcoding, the spatial consumption is also tending towards stability.

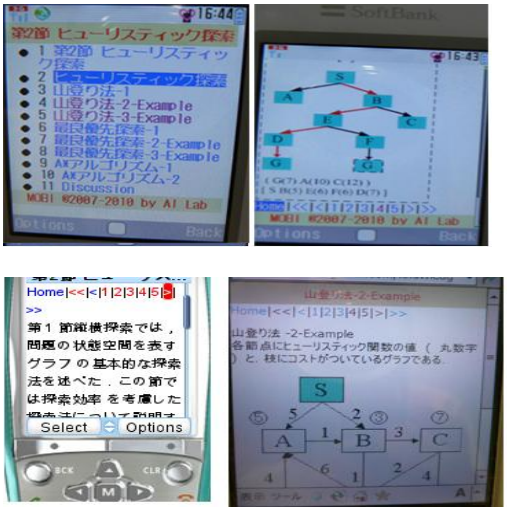

Fig.8 Response Time for Request from Learners

5.3 Evaluation on Learners

To evaluate learners' satisfaction degrees for the proposed adaptation contents, a questionnaire which involves thirteen questions divided into two types questions were designed to measure whether the

adapted contents satisfy the real requirements of most learners. The two types of questions contain learner's information using mobile device and operation on AubiLearn, which is shown in Table 4.

The results in Table 6 show that the learners feel convenient and easy to use (100%) when they participate in the discussion by their mobile device. Also, over 90% learners respond that discussion contents can be correctly displayed on their mobile devices.

Before the test on AubiLearn, only one out twenty attendees (Table 5) responds that learners can view standard documents on mobile device. 100% attendees agree that documents can be displayed on mobile device.

80% think that AubiLearn may improve learning experience by providing a seamless learning environment. Only 50% agree that right contents are for right needs. After summarization, we find that the personalized recommendation model need be improved in future according to context awareness.

Table 4 The descriptions of questions types

Question Type	Number of Questions	Description
Learner's information using mobile device	4	To know about learner's information
Operation on AubiLearn	9	To know about learner's operation and quality of adaptive learning contents

Table 5 Results of Learner's Information (Number: Count of Learners)

Question	Yes	No
Do you have mobile device?	20	0
Have you ever accessed learning contents by your device?	3	17
Have you ever used your device for discussion?	14	6
Do you think documents can be read on mobile device?	1	19

Table 6 Investigation Results on AubiLearn

Question	strongly agreed	agreed	no opinion	disagreed	strongly disagreed
I can attend discussion at any time & any place by mobile device	12	8	0	0	0
I can get instant help through the AubiLearn	6	12	1	1	0
All adapted contents can be displayed	5	13	0	2	0
I can get best quality of adapted contents	5	5	0	7	3
I may pay less during discussion on the system than others	10	5	3	2	0
I may get right contents for right needs	3	5	7	1	4
I may fully read document on device through AubiLearn	18	2	0	0	0
The AubiLearn can promote my learning interest	7	11	2	0	0
The AubiLearn can improve learning experience	8	9	3	0	0
Average	41%	39%	9%	7%	4%

6 Conclusion

This paper discusses the issues on application of u-Learning environment. Based on these questions, this research proposes an adaptive content delivery model for u-Learning environment, which may get original contents from e-learning system and recommend adaptive contents according to learning context awareness: device feature, learner's preferences. The adapted contents are created according to learning context awareness. The evaluation shows that the learners may get a better learning experience on the AubiLearn developed based on the adaptation content delivery model, e.g. contents can be correctly displayed.

Undoubtedly, the specific research question concerning "types of contextual information and sources" using in u-Learning environment represents the first and main open issue in future. It is still challenging works to define/reason different context (physical context, time context, learner context, resources context) and describe the learning

environment (capabilities of ubiquitous device, characteristics network and learner) during mobility.

Secondly, interactions among participants during u-Learning environment are another open issue now. Learning to be successful requires continuous two-way conversations and interactions between the teacher/learner and amongst the learners. It is still difficult to realize more complicated interoperation on constrained devices today.

Acknowledgments

We would like to thank for their useful suggestions and comments to Anonymous Reviews.

References

[1] Weiser, M. (1993). Hot Topic: Ubiquitous Computing. IEEE Computer, Vol.26(10): 71 – 72

[2] Ortiz, C. E. (2008). An Introduction to The Mobile Context and Mobile Social Software. http://cenriqueortiz.com/pubs/themobilecontext/themobilecontext-cenriqueortiz.pdf

[3] Esra, W., Niall, W. and Martin, O. (2008). Maintaining, Changing and Crossing Contexts: An Activity Theoretic Reinterpretation of Mobile Learning. Research In Learning Technology (ALT-J), Vol.16 (1): 41 – 57

[4] Sylvers, E. (2008). With Text-Messaging, Government Goes Mobile. Available: http://www.iht.com/articles/2008/12/21/technology/wireless22.php

[5] Jones, V. and Jo, J.H. (2004). Ubiquitous Learning Environment: An Adaptive Teaching System Using Ubiquitous Technology. Australasian Society for Computers In Learning In Tertiary Education: 468 – 474

[6] Stanescunew, I.A. (2008). Elearning Frontiers: Mlearning and Glearning. The 4th International Scientific Conference on E-Learning and Software for Education

[7] Farooq, U., Schafer, W., Rosson, M.B. and Carroll, J.M. (2002). M-Education: Bridging the Gap of Mobile and Desktop Computing. The IEEE International Workshop on Wireless and Mobile Technologies In Education (WMTE02): 91 – 94

[8] Card, S. K., Mackinlay, J. D. and Shneiderman, B. (1999). Readings in Information Visualization–Using Vision to Think. Morgan Kaufmann

[9] MATT, J. and GARY, M. (2006). Mobile Interaction Design. John Wiley & Sons Ltd. Press

[10] Chang, H.P., Hung, J.C., Wang, C.C., Weng, M.T., Shin, T.K. and Lee, C.Y. (2008). A Learning Content Adaptation Tool with Templates for Different Handhelds. 22nd International Conference on Advanced Information Networking and Applications (AINA 2008): 457 – 463

[11] Kojiri, T., Tanaka, Y. and Watanabe, T. (2007). Device-Independent Learning Contents Management in Ubiquitous Learning Environment. Proceeding of The World Conference on E-Learning In Corporate, Government, Healthcare, and Higher Education: 991 – 996

[12] Yang, S.J.H., Chen, I.Y.L. and Chen, R. (2007). Applying Content Adaptation Technique to Enhance Mobile Learning on Blackboard Learning System. Seventh IEEE International Conference on Advanced Learning Technologies (ICALT 2007): 247 – 251

[13] Vitor, B. and Maria, T.A. (2009). Context-Aware Content Adaptation: Standards and Research Trends. http://www.visnet-noe.org/pdf/v_barbosa-and-m_t_andrade.pdf

[14] Conlan, O., Hockemeyer, C., Wade, V. and Albert, D. (2002). Metadata Driven Approaches to Facilitate Adaptivity in Personalized Elearning Systems. The Journal of Information and Systems In Education, Vol.1: 38 – 44

[15] Shute, V. and Towle, B. (2003). Adaptive E-Learning. Educational Psychologist, Vol.38 (2): 105 – 114

[16] Erol, B., Berkner, K. and Joshi, S. (2008). Multimedia Clip Generation from Documents for Browsing on Mobile Devices. IEEE Transaction on Multimedia, Vol.10(5): 711 – 723

[17] Hsiao, J.L., Hung, H.P. and Chen, M.S. (2008). Versatile Transcoding Proxy for Internet Content Adaptation. IEEE Transaction on Multimedia, Vol.10 (4): 646 – 658

[18] Tenla (2008). Tenla Mobile Marketing and Advertising Guide (2008)

[19] Sharples, M. (2007). Big Issues in Mobile Learning. Report of a workshop by the Kaleidoscope Network of Excellence Mobile Learning Initiative: 1 – 37

[20] Zhao X.Y., Okamoto T. (2009). Scalable Learning Contents for Virtual Community in a Context-Aware Environment. IEEE Multidisciplinary Engineering Education Magazine. 4(1):37 – 45

[21] Economides, A.A. (2006). Adaptive Mobile Learning. Fourth IEEE International Workshop on Wireless, Mobile and Ubiquitous Technology In Education(WMTE'06): 26 – 28

[22] Motiwalla, L.F. (2007). Mobile Learning: A Framework and Evaluation. Computers & Education, Vol.49(3): 581 – 596