Adaptive multimedia content delivery for context-aware u-learning

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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 cannot be displayed correctly) during ubiquitous learning (u-learning) environment. This paper proposes an adaptive contents delivery model for context-aware u-learning according to three-level service models proposed, which create the adaptive contents for learners to get a seamless access in learning according to learners' interest and contexts. The evaluation on a mobile virtual community system shows that the learners may not only study in rich media on mobile device at anytime and at anyplace, also get a better learning experience, e.g. learners may get instant help from other participates by ubiquitous device and access the rich contents: PowerPoint files.

Keywords: adaptive content; u-learning; ubiquitous learning; context-aware learning; mobile learning context.

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1 Introduction

Much of what has been written about teachers conducting field trips has been anecdotal (Michie, 1998). Some similar quantitative studies of the attitudes of teachers towards field trips were also undertaken by Falk and Balling (1979), Fido and Gayford (1982) and Muse et al. (1982).

Sorrentino and Bell (1970) reviewed texts and research articles by science educators, summarising their reasons for taking field trips into five 'attributed values': providing first-hand experience, stimulating interest and motivation in science, giving meaning to learning and interrelationships, observation and perception skills and personal (social) development.

Of course, negative attitudes of teachers revealed by the research are interrelated to lack of support from school administrations for field trips (Falk and Balling, 1979; Muse et al., 1982; Orion, 1993; Price and Hein, 1991) and inadequacy of resources and choice of venue (Orion, 1993; Price and Hein, 1991).

Another, one of the main characteristics of our life is constantly changing and moving, lately also integrated with an increasing desire for mobile usage of computing and communications (Tumasch, 2003), which leads to the fast-growing working and learning on the move, not just at the office or school (Keegan, 2004; May, 2001).

Also, since ubiquitous computing technology was firstly proposed by Weiser (1993), the capabilities of ubiquitous devices, such as personal digital devices (PDAs), cell phone, portable computers and smart phone, are increasing at a steady rate (Ortiz, 2008). 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 (Esra et al., 2008; Ortiz, 2008). Cell phones can take pictures, record sounds, reveal location and even measure the population density and moving speed of users.

Now people can learn/work anytime and anywhere using laptops, phones and palm devices with wireless connectivity, an enabled hotspot or wireless network. 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 and tax amount in India (Sylvers, 2008).

The ubiquitous devices have become increasingly integrated into many facets of our daily activities, including education (Esra et al., 2008; Ortiz, 2008). Ubiquitous device seems an ideal tool for participating in field trips at anyplace and anytime to access learning contents/resources during field trips.

In school or university, learners may access e-learning contents by their portable devices at anytime and at anyplace or receive information about class or school news in real time, which is called ubiquitous learning or u-learning (Jones and Jo, 2004). Over the past 10 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 (Sharples, 2007; Song, 2008; Stanescunew, 2008).

Today the unified u-learning system evolved from a singular SMS m-learning system is shown in Figure 1. U-learning, which provides a seamless learning access for learners, can bridge the gap of mobile and desktop computing (Farooq et al., 2002). In other words, the learning process can be continuously conducted at anytime and place with ubiquitous device (PDA, cell phone, smart phone, iPhone, etc.), not just with personal computer at home or office.

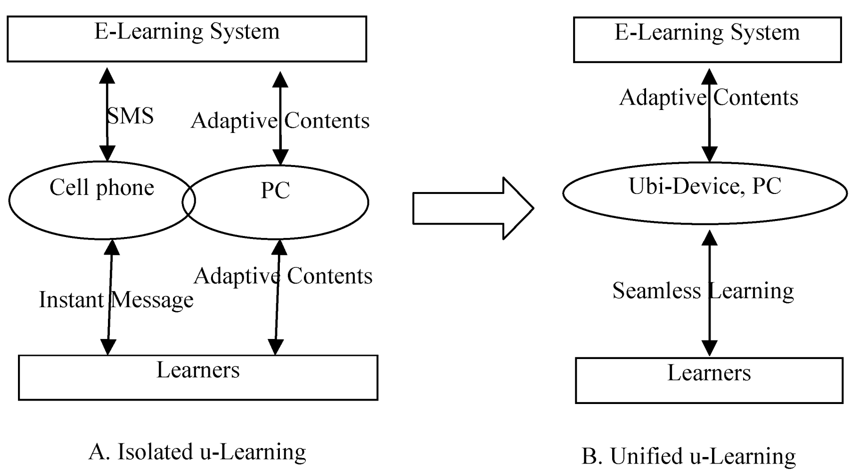
By the use of wireless technology, anyone can access information and learning materials at anytime and anyplace by ubiquitous device. As a result, learners have a complete control of when they want to study and from which location they want to study. With u-learning, learners will be empowered since they can learn from anywhere and at anytime (Mohamed, 2009).

Information visualisation is a well-established discipline (Card et al., 1999). 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 information retrieval and exploration in an attempt to overcome search and access problems on conventional, large-screen displays (Matt and Gary, 2006).

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 visualisation 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 (Matt and Gary, 2006). For example, rich contents cannot be correctly displayed on mobile device (Kojiri et al., 2007; Yang, et al., 2007); different needs under different learning location and time (Esra et al., 2008; Hsiao et al., 2008).

Figure 1 Evolution of u-learning



Unified u-learning easily makes learners drop out from e-learning system on mobile device for much diversity in u-learning environment (ULE). 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 (Chang et al., 2008; Kojiri et al., 2007; Yang et al., 2007).

This paper proposes one adaptive content delivery framework for ULE, which delivers learning contents adapted to learning context (e.g. device feature, learners' preferred media type and learning location) and provides a seamless accessing service for learners at anytime and anyplace with any device. In this study, the three-level service models are proposed for adaptive content delivery: content service, transcoding service and presentation service. Within each service, the suggestion for adaptive content is created. Meanwhile, the adaptive contents are dynamically created, not by LMS managers previously, which reduces the burden of LMS managers.

2 Adaptive learning

The adaptive system is in the present a common and trendy concept with the field of computer science (Vitor and Maria, 2009), 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 behaviour of a person or group in response to new or modified surroundings. Every adaptive system converges to a state in which all kind of stimulation ceases (José et al., 2009).

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 (Vitor and Maria, 2009). Within learner-centric adaptation system, Conlan et al. (2002) 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.

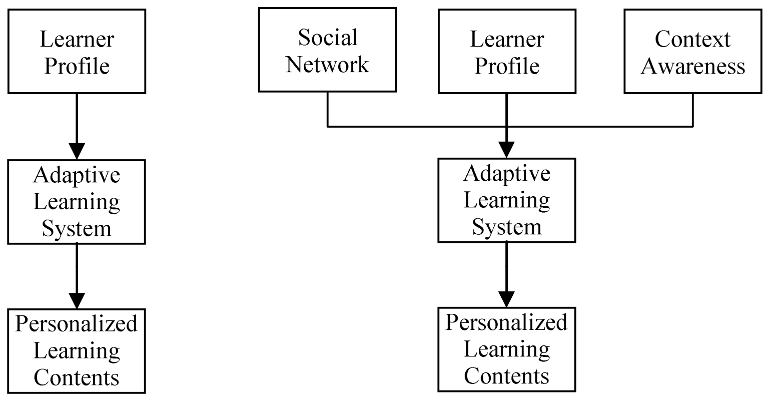
Thus, the adaptivity and adaptability in e-learning systems are essential in order to adjust the changing of learners' situations dynamically. A formal definition of the Law of Adaptation is as follows.

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 $P(S \to S' \mid E)$ 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:

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

Figure 2 gives different domains between adaptive e-learning and u-learning. The learning history or learners' profiles are used for adaptive contents in traditional e-learning. In ULE , more context data (e.g. device capabilities, network feature, learning environment, etc.) are used to recommend adaptive contents besides learners' profile.

Figure 2 Different domains in e-learning and u-learning



The context data in ULE are usually followed into four categories: device capabilities (DC, codec capabilities; input–output capabilities; device features), network characteristics (NC, static network features and dynamical network conditions), learning environment (LE, learner information and learning process; presentation preferences) and learner characteristics (LC, location; time; social awareness).

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 personalisation techniques.

Thus, from the technological point of view, the main challenge of these personalisation techniques depends on correctly identifying characteristics of a particular learner (Shute and Towle, 2003). The characteristics may be knowledge, skills, cognitive abilities, learning process/history and styles, learning preference, etc.

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 and learning: right learning contents at right learner at right time in the appropriate way – anytime, anyplace, any path and 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 (Shute and Towle, 2003).

2.3 *Adaptive u-learning*

The dynamical and continuous change of learning setting in ULE 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 (Conlan et al., 2002). 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 behaviour according to learning context awareness (Zhao and Okamoto, 2009). The works are completed by an adaptation engine in general.

The adaptation engine uses context data of u-learning as input data to produce the adaptation results.

The main purpose of the adaptivity is to provide context awareness-based learning under learners' different skill and motivations. In general, the context data may be from learner, learning environment or educational strategy and so on.

One of the challenges 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 ubiquitous device, which has constrained capabilities.

So the system should consider more learning contexts than e-learning system, such as connectivity, communication expense, device capabilities, learning locations, etc. 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

With the development of communications, the 3G is approaching and used in the world. Many applications on personal computer, e.g. the successful e-learning application, have been altered to ubiquitous device too. 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 that are summarised in Table 1. There are still research difficulties today how to reason or infer the context data for application.

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 et al. (2008) and Hsiao et al. (2008) show that the small display sizes and limited input capabilities for user interaction are likely to remain the major bottlenecks for many mobile applications. Although Japan has most advanced communications technology in the world, Goda et al. (2008) stated that more 13% mobile phones still do not support mobile browser. In addition, even if the phone supports mobile browsers, their capabilities are still different.

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, screen sizes, etc.

Table 1 Different diversity in ULE

Type	*Features*
Devices	*Hardware*: memory, screen size, resolution, colour depth, etc.
	Software: supported media formats, mobile browser
Contents	*Text*: TEXT, PPT, DOC, PDF, etc.
	Image: SVG, JPEG, GIF, PNG, WBMP, etc.
	Animation: FLASH, GIF, etc.
	Audio/video: AMR, 3GP, EVRC, etc.
Contexts	*Personal context*: users' preferences, calm behaviour, etc.
	Social networks: personal history, friends, blogs, etc.
	Other context: location, time, etc.

3.3 Diversity of mobile context

AMF Ventures from Tenla (2008) 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, which may include personal context (users' preferences, calm behaviour, etc.), social networks (personal history, friends, blogs, etc.) 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 ULE is by no means a trivial task (Sharples, 2007). The learners get a bad learning experience during ULE for the reason of the much diversity as discussed above.

Firstly, 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 Three-level service models for adaptive content delivery

The ULE 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 characterised 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) 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. $U_i(t)$ is used to define the u-learning state at time *t* for learner *i* (shown in Figure 3):

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

where $L_i(t)$ is the learners' preference at time *t*; $O_i(t)$ is the items state in learning object (*O*) at time *t* and $E_i(t)$ is the context awareness at time *t*.

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

The Mars Medical Assistant (Luis and Frank, 2000) uses a combination of user model, task model and situational model to resolve the conflict according to the semantic content and cognitive characteristics of component's media type. Finally, the virtual hypertext structures as adaptive contents are created based on rule mechanisms.

The adaptive process in this research is completed through the following three steps: adaptive to context, content adaptation and content delivery. The adaptive process to context creates suitable content for learners according to contextual data and situational data. Secondly, content adaptation process recodes original content into adapted contents according to the adaptive suggestion, from adaptive process.

Adaptive process is made of three steps: adaptive to learning context, content adaptation and adaptive content delivery. The three steps complete adaptive process together. The adaptive learning model recommends the adaptive contents according learners' preference and context. Then content adaptation model creates adaptive content based on learning environment. At last, the content delivery model delivers adapted content embedded with suitable markup.

During each step, there are many existing conflictions. In general, the confliction will be resolved by rule base. When learners learn with his ubiquitous device, the system will distribute suitable content for learners.

The content service suggests what information is recommended, specially learning contents under current contextual (dynamical and static) environment. Here, the recommended contents are the place or link of real contents in general. These are computed by adaptive learning model in Figure 4.

The transcoding service recodes or reconstructs the suggested contents into adapted contents according to transcoding suggestion, which is generally produced based on learning context (device, network, etc.). Transcoding services use many transcoding agents to complete the transcoding tasks by one or more steps, e.g. when learners study in courseware on cell phone, standard document transcoders transform courseware file into text, then audio transcoders transform text into speech or other transcoders transform them into other media.

Figure 3 Adaptive content delivery model

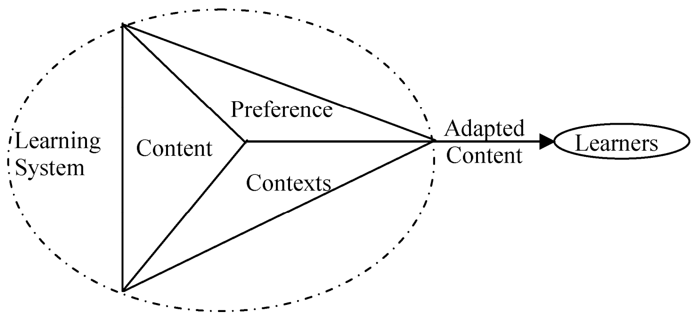
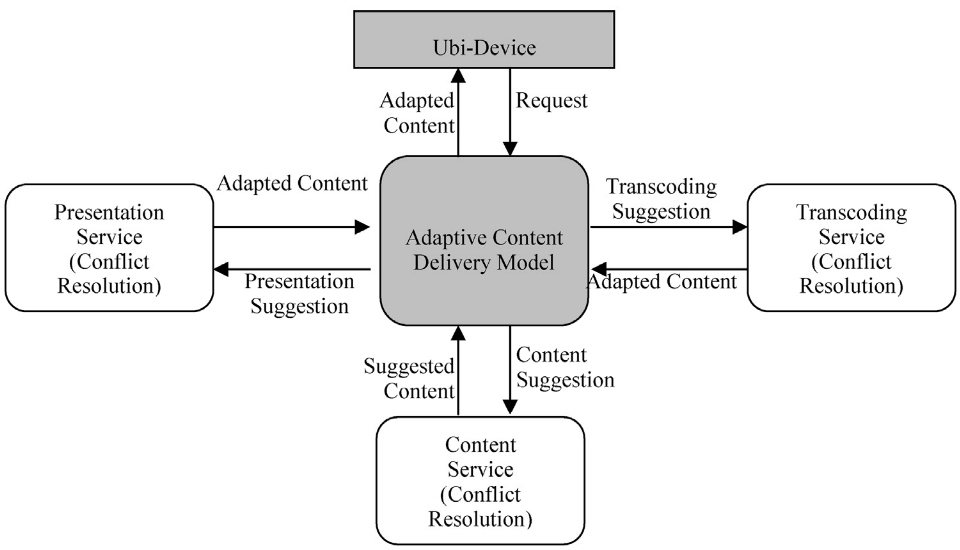


Figure 4 Three-level service models for adaptive content delivery



The presentation service determines the final adaptive content format according to presentation suggestion, which is determined according to learning environment. At last, the adaptive contents are distributed to learners.

The conflicts among three services are resolved by negotiation algorithms. The suggestion references and conflict resolutions are rule-based mechanisms. Within each service, the conflicts can occur due to differences in suggestions from adaptive content delivery model. For example, the learner is accessing a learning object based on text while riding his bicycle. The adaptive content delivery model suggests audio as media type for learning. At last, the presentation service determines what pattern of learning content is provided for learners.

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 (Motiwalla, 2007). 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 as follows:

Sam will attend a test at 9:30 today. While going to school,

- he wants to check some latest information, which is learning materials uploaded for test on e-learning system may include portable document format (PDF) files besides plain text information
- he wants to review some courseware, which is power point (PPT) files
- he wants to review parts of teaching video
- he wants to discuss some questions with classmates.

These e-learning contents (PPT or PDF files), 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 above questions, the learners may get the following poor experience during accessing the e-learning contents:

When Sam accesses such a web page from e-learning system on a mobile device, he may get a poor or unusable experience, which maybe

- he cannot 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 cannot review the courseware
- he cannot 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

To realise the learning scene above according to the three-level service models proposed, adaptive ubiquitous learning (AubiLearn) system for a seamless learning accessing has been developed, which also 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 identify the contents sender before the system publishes mail contents on adaptive discussion system. For example, the system assigns mail address: sam@ourglocal.org to Sam. When the server receives a mail sent to sam@ourglocal.org, the system takes Sam as the sender. Of course, learners may also access adaptive contents from AubiLearn. Please refer Zhao et al. (2009) for the technical details of AubiLearn.

The AubiLearn provides two ways for learners to attend discussion by mobile device. Firstly, 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 are integrated in a mobile device. So a 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. One example for discussion based on mail is shown in Figure 5.

To create adaptive contents according to learning context, the system should consider the following issues (Lum and Lau, 2002):

- The image size < device memory buffer size. W3C-MWBP (2008) recommends that the content size is smaller than 30 kB, because today memory of most mobile devices is up to 30 kB. In general, size of per page (S) = markup size + text size + image size < device memory buffer size (M).
- The response time C should be smaller than the t_{threhold}. Totally, the transcoding time T, we can compute the learner-perceived response time (C) will be

$$C = 2 \times \text{RTT} + \frac{S}{B} + T + m \leq t_{\text{threhold}}$$

where RTT is the network round-trip time latency between the client and the e-learning system; S / B is the transmission time of contents on the fly; m is means waste time for contents (e.g. creation XML, negotiation, etc.); $t_{\text{threshold}}$ is the maximum transmission time that the learner can put up with.

Figure 6 shows the transcoding ratio, transcoding time of an image contents (size: 18,580 and dimensions: 600 × 390) with different device features and network speed. The AubiLearn system could create different size and dimensions according to learning context.

Figure 5 Mail discussion systems on AubiLearn (see online version for colours)

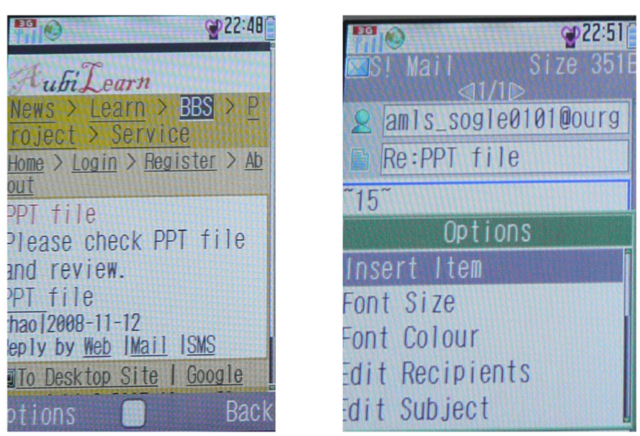
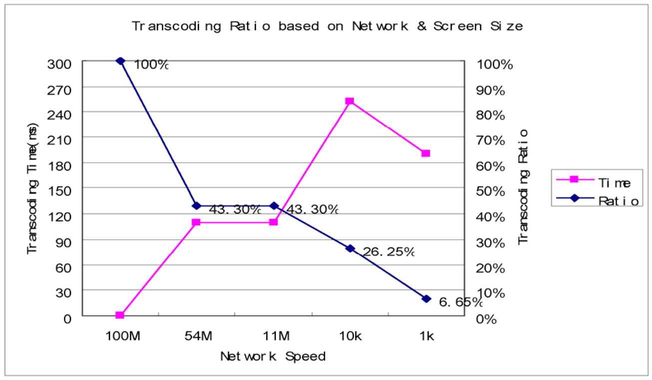


Figure 6 Transcoding ratio based on network and screen size (see online version for colours)



For poor wireless signal strength, the contents size will be compressed to 6.6% of original contents. Of course, the format of image learning contents is recoded into suitable contents. It really consumes more time during the transcoding dynamically. On the contrary, for strong signal strength (PC learner), the AubiLearn system will send original contents for learners.

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 personalised contents from a sub-page (one slide) based on learners preference and context awareness, such as deleting image (may not be favourable 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, voice XML, MMS, etc. Here, the authors only discuss web pages and mail/MMS/SMS.

5.2.1 *Adaptive contents based on mail/MMS/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). Figure 7 shows the transcoding time for each request to standard contents, PPT files (size: 2,125 kB).

From Figure 7, we can know that it takes more time to response the learners' 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.

5.2.2 Adaptive contents based on mobile pages

If a mobile browser is embedded in handheld device, adaptation engine negotiates items of personalised 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 learners, which are shown in Figure 8.

Figure 9 shows the response time for request from learners at first 150 requests. During each request, a dynamically transcoded content is added into feature finite state machine (FFSM) (Zhao and Okamoto, 2009), 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 sec. 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 learners' devices.

From Figure 9, 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.

Figure 7 Response time for mail/MMS/SMS (see online version for colours)

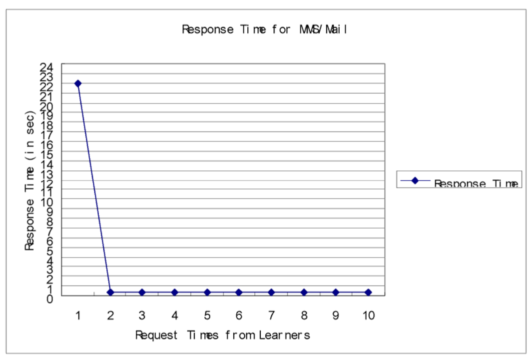


Figure 8 Snapshots of AubiLearn based on PPT file contents (see online version for colours)

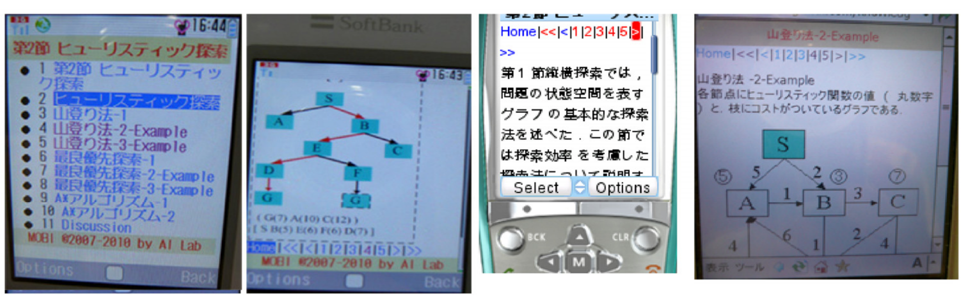
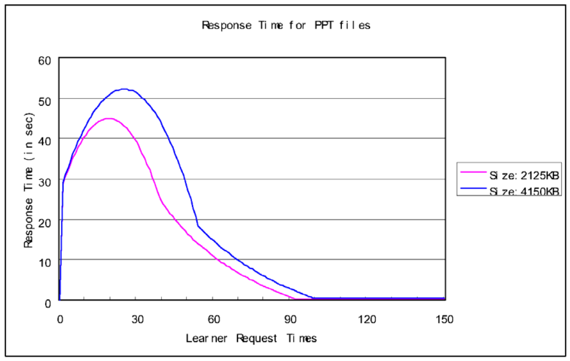


Figure 9 Response time for request from learners (see online version for colours)



5.3 *Adaptation on rich media resources*

Table 2 shows times for transformation of a specific media into another final media (video with MPEG file 800 × 600, size of 4.12 MB; text: 0.3 kB). As reported in the table, times of transcoding vary from 0.7 to 2.2 sec. As to text, instead time to convert text into WAV format, it takes more time to transcode at first time. But next time, to audio, time will need less time to transcode from WAV to other audio format (e.g. AMR only 706 ms). The results show that transcoding strategies can be applied on e-learning in real time.

5.4 *Evaluation on learners*

To evaluate learners' satisfaction degrees for the proposed adaptation contents, a questionnaire which involves 13 questions divided into 2 types questions were designed to measure whether the adapted contents satisfy the real requirements of most learners. The two types of questions contain learners' information using mobile device and operation on AubiLearn, which is shown in Table 3.

The results in Table 4 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 of 20 attendees (Table 5) responds that learners can view standard documents on mobile device. On the contrary, 100% agree that documents can be displayed on mobile device after test.

Around 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 summarisation, the authors find that the personalised recommendation model need to be improved in future according to context awareness. Also, for adapted contents, we have to improve the quality about them (positive and negative: 50–50), e.g. the caption of adapted video becomes unclear.

Table 2 Adaptation time on rich video, text and audio

	Original LO		Adapted LO		
Media	*Dimensions*	*Format*	*Dimensions*	*Format*	*Time (ms)*
Video	800 × 600	.mpg	240 × 320	.mpg	1,723
Video	800 × 600	.mpg	240 × 320	.3gp	2,200
Text	NA	.txt	NA	.wav	2,045
Audio	NA	.wav	NA	.amr	706

Table 3 The descriptions of question type

Question type	*No. of questions*	*Description*
Learners' information using mobile device	4	To know about learners' information
Operation on AubiLearn	9	To know about learners' operation and quality of adaptive learning contents

Table 4 Investigation results on AubiLearn

Question	*Strongly agreed*	*Agreed*	*No opinion*	*Disagreed*	*Strongly disagreed*
I can attend discussion at anytime and anyplace 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

Table 4 Investigation results on AubiLearn (continued)

Question	*Strongly agreed*	*Agreed*	*No opinion*	*Disagreed*	*Strongly disagreed*
The AubiLearn can improve learning experience	8	9	3	0	0
Average	41%	39%	9%	7%	4%

Table 5 Results of learners' 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

6 Conclusion

This paper discusses the issues on application of ULE. Based on these questions, this research proposes an adaptive content delivery service model for ULE, which may get original contents from e-learning system and recommend adaptive contents according to learning context awareness. 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 ULE 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 and resources context) and describe the learning environment (capabilities of ubiquitous device, characteristics network and learner) during mobility.

Secondly, interactions among participants during ULE 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 realise more complicated interoperation on constrained devices today.

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