The Design of Adaptive Engine in New Generation Ubiquitous e-Learning System

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Abstract—new generation ubiquitous e-Learning system is the key for merging ubiquitous learning into the mainstream of education. FekLoma is such a u-Learning system, which is specially designed according to the requirements of ubiquitous e-Learning environments by bottom-up approach. The system is developed with ULO technologies, and is realized with programmable and extensible programming facility. Based on these technologies, FekLoma can be used for learning resource delivering in ubiquitous environment with adaptive capability. In the system, adaptive engine is the key. In order to improve the usability and the ubiquity of the system, an special adaptive engine is designed, which synthesize adaptive features for mobile devices, networking communication, learning content according to media format and cognitive density, etc. The paper introduces the ongoing research efforts.

Keywords—ubiquitous learning; FekLoma; adaptive engine

I. INTRODUCTION

With the development of mobile learning and ubiquitous learning (u-Learning), adaptive features have been the keys of ubiquitous e-Learning system. The topics of adaptive features for u-Learning system include more broad requirements, such as adaptability for learning resource in mobile device, adaptive learning activities in varied learning context, and adaptability according to learner’s personal requirements, etc.

According to these varied adaptability requirements in u-Learning environment, there are many research works which focus on different aspects or adapt with different approaches. Among existing research efforts, some works focus on ubiquitous learning resource description with metadata schema, and accordingly, the resource described by the schema can be delivered adaptively, for example, the paper[1] propose an educational metadata schema for mobile learning. Some research works focus on technologies for realization of adaptability in u-Learning environment, such as works in the papers[1][3][4][5][6]. Some research works focus on how to develop u-Learning system, such as works in the papers[7][8]. Some other research works aim to provide more upper adaptive features, such as adaptability in context-aware situations, such as works in [9][10][11][12], and finally, some research works realize adaptability from the viewpoint of learner’s requirement, such as research efforts described in the paper[13].

Based on these aforementioned research activities, a more comprehensive prospect on adaptation has been discovered. In the paper[10], Yuan-Kai propose that contexts in mobile learning environment can be categorized into six dimensions, which are identity dimension, spatio-temporal dimension, facility dimension, activity dimension, learner dimension and community dimension. From the viewpoint of computer architecture, the focus of research on adaptability has been moved from bottom level to upper level, from learning devices, learning resources, networking communication to learning context, learners’ requirements. For example, in the paper[11], the author proposes the concept of learning context, which is used to describes the current situation of a learner related to a learning activity, and then the author introduce novel Contextaware and Adaptive Learning Schedule framework to support students’ daily routines, adapts learning activities to student’s learning styles and then selects appropriate activity for the learners based on their current learning context.

Furthermore, because learning quality is heavily effected by learners’ learning style and their cognitive level, many research efforts focus on provide adaptability according to these aspects, with which, more suitable learning activities can be delivered to learners. For example, in the paper[14], Hyosook Jung demonstrate the synergetic effects of mobility and adaptively that are contextualized in u-Learning environment, in which information about the cognitive load that a learner is experiencing and learning contents are adaptively presented based on cognitive and competency attributes of learners.

Above all, during the evolution of research on adaptability, there needs more steady and more advanced facility to support these demands, which can be used to provide adaptability to mobile learning device, learning content, and even to learner’s requirements, learning context, and more others. The stable and reliable facility is very important for high availability u-Learning system. This is objective of our research, which aims to create new generational u-Learning system by bottom-up approach with a integrated adaptive engine design, with the system, learning resource can be delivered to various learning terminals in u-Learning environment, and the system support different learning model, such as “mini-courseware”
learning or “mini-knowledge segment” learning based on learning object, therefore, more advanced adaptive u-Learning environment can be created.

The following is introduced with this sequence: In section 2, the system called FekLoma is introduced, which is a new generational ubiquitous e-Learning system, and the bottom mechanism for realizing adaptive features is introduced. In section 3, the details of the adaptive engine are introduced. In section 4, comparison to similar research activity is introduced. In section 5, further research plan of our work is introduced.

II. THE DESIGN OF ADAPTIVE ENGINE IN FekLoma

A. Brief introduction of FekLoma

Flexible Extensive Knowledge Learning Object Management Architecture (FekLoma) is a e-Learning system for ubiquitous learning, which is based on Ubiquitous Learning Object (ULO) technologies, with which learning resource can be delivered to various learning terminals adaptively. In FekLoma, all learning resource is organized into ULO, and every ULO is described by a special metadata schema. Besides, the behavior on a ULO can be extended with web services technologies. Based on these technologies, mini-courseware can be assembled and delivered to various learning terminals. Therefore, with FekLoma, learning resource can be assembled into ULO, be delivered from ULO, be re-purposed dynamically for creating mini-courseware, and furthermore, learning resource in different media format can be optimized for flexible u-Learning requirements. In a word, FekLoma is a new generational e-Learning system for ubiquitous learning.

B. Adaptability support by FekLoma by buttom-up approach

The adaptability of FekLoma is supported by a programming facility, which is developed with new technologies in e-Learning and ICT area, such as learning object technologies, web services technologies etc. With the facility, behavior on a ULO can be extended according to requirements, furthermore, a special behavior can be modified online according to real life requirement. The approach is explained in figure 1 and figure 2, and the figure 1 display the extensible behavior on a special ULO, while figure 2 explain the method for the realization of extensible behavior on a special ULO.

Brief introduction of the programable facility with web services technologies is described here. The Fedora service framework facilitates the integration of web services on ULO, and it takes a service-oriented architecture approach to adding new functionality around Fedora data object repository, allowing new services to be built around the core repository as stand-alone web applications that run independently in Fedora. The programable facility for flexible and extensible behaviors in FekLoma is described in figure 2. Hence, the behaviors on a ULO can be extended and reconfigured with web service, which is implemented with two kinds of Fedora data object, and they are Behavior Definition object and Behavior Mechanism Object, which both are special data objects in Fedora.

With the flexible and extensible programmable facility by web services technologies, the behaviors on a ULO can be extended and reconfigured in flexible way, which is important for the realization of adaptive features in FekLoma. All these services (new added ULO behaviors) can be easily integrated with Fedora framework which can be integrated with two kind methods: Firstly, Dynamic content delivery: any special web service can be associated with any data streams in a ULO object. Accordingly, a ULO object can deliver dynamic content: the output of a web service processing data in the object. Secondly, Management and Access APIs: ULO object repository runs as a service within a web server, and all of its functionality and features of its ULO object model are accessible through well-defined REST and SOAP interfaces.

C. The adaptvie features considered in current version FekLoma

Now, the following features have been considered in FekLoma:

- Dynamical mini-courseware assembling and creating. Adaptive engine in FekLoma must provide the capability for mini-courseware delivering to various learning terminals, and also, these mini-coursewares must be multi-model (different version mini-
courseware can be assembling dynamically). These different version mini-coursewares are created according to physical features of terminals and networking communication.

- Adaptive features based on media selection according knowledge points represented by special ULO. In u-learning environment, resource-based learning should cater for learner’s preference or learning style, therefore, u-Learning system should provide adaptability with knowledge representation selection. In the design of FekLoma, two learning model based on resource-based learning is provided. One learning model is based on mini-courseware for whole course learning, and the other is based on media selection for a special knowledge point described by different medias in a special ULO. Therefore, an adaptive learning resource delivering mechanism is realized in FekLoma.

- Adaptive feature realized based on knowledge density for cognition and knowledge point selection for in-depth learning. FekLoma is a u-Learning system, therefore, there need adaptive feature related to cognitive density of a knowledge points besides adaptive capability based on media selection. This is realized with remark and tagging on knowledge point carried by a ULO. The remark and tagging can be changed dynamically according to behavior statistic from learners’ feedback.

In a words, the current version FekLoma have considered adaptive features based on physical features of mobile terminals, status of networking communication, media selection of a ULO for a knowledge point, and cognition density computing with behavior statistic from learners.

III. THE DETAILS OF THE ADAPTIVE ENGINE IN FEKLOMA

A. the architecture of FekLoma

The architecture of FekLoma is designed according to research work aforementioned, which mainly includes two parts (refer to figure 3).

The first part of FekLoma is for ULO creating, publishing, managing, and re-using. Tools and facilities for ubiquitous learning object creating, publishing and managing have been designed. The function of creating and managing of ULO is the foundation of FekLoma, which is mainly realized through extended and customized Fedora. Initially, Fedora uses Dublin Core as metadata schema, and it has been expanded by our research team to the proposed metadata model in [17]. Now, the integrated functions for ULO object creating, ingesting, storing and managing have been realized, at the same time, the behaviors on a ULO can be reconfigured and extended according to adaptive features required by different u-Learning contexts. Till now, main sub-modules of this part include course structure management module, ULO module, etc. The course structure management module can be used to provide convenient access for teachers when they build their own course structure and create ULOs under the structure. ULO module is provided to enable resources providers to package learning resources in the way of ULO. The process for ubiquitous learning object creation can be found in the paper[17].

The second part of FekLoma is adaptive engine, which is composed by modules of Adaptive controller and information analysis. The design approach of the engine is introduced in the following section.

B. The design of adaptive engine

In our research, we consider adaptation about four dimensions: learner, device, networking communication and learning content. Learner dimension contains learner’s preference. Device dimension contains the type of terminal device, disposal capacity, screen size, memory size and supported multimedia formats etc. learning content is described by cognitive density, media selection, etc. Networking communication mainly considers the condition of network such as available bandwidth, delay and error ratio. With these considerations, the adaptive engine consists of two modules: information analysis module and adaptive controller module (refer to figure 3).

- Information analysis module.
  The module including user analyzer and property analyzer, which is used to analyze learner’s basic information. User analysis part is used to analyze the content of user requirements and user preferences such as preferences to media format of audio, video or text. Property analysis part is used to analyze the features about mobile devices used in learning (i.e. types, disposal capacity, screen size, memory size, and supported multimedia formats etc.), networking communication condition (i.e. available bandwidth, delay, and error rate, etc.) and learning content’s knowledge density. The information that the analyzer obtained will be sent to adaptive controller module as necessary parameters for the realization of system’s adaptation.

- Adaptive controller module.
  In the process of adaptation, adaptive controller module chooses learning resources for users through suitable behavior, which is dynamically binded through web.
service to meet specific performance and user preferences according to parameters obtained by information analysis module. This module consists of adaptive decision rules, learning resource adaptive conversion module and decision engine (refer to figure 4). **Adaptive decision rules.** A set of rules are developed to determine what kind of resources can be sent to user in certain circumstance. **Decision engine.** It is the core of the adaptive engine system which assembles resources dynamically. In the process of assembling, adaptive decision rules will be referred. The decision engine will match parameters obtained from information analysis with adaptive rules to decide which resources should be sent and whether the resources should be converted. **Adaptive learning resources conversion module.** With the command from adaptive engine, this module filters, chooses and converts resources. Finally, suitable learning resources are selected and delivered to user’s mobile devices.

The decision process of adaptation can be divided into three steps. **Firstly,** format matching. After picking up desired ubiquitous learning objects, the system matches original formats of resource with client supported media formats, and decides whether to convert resources on the basis of transformation rules in adaptive decision rules. **Secondly,** balancing the parameters. The resources, which will be downloaded into client, will be balanced with collected information, such as user preference, device’s property information, or downloading time according to computation. It aims to make the time and the resources balanced for user as a whole. **Thirdly,** identify priority of learning resource in different ULOs, and then chooses the final available resources. For example, the transmission time is prior than user preferences, text is prior than image and image is prior than audio.

The whole process of adaptive system is shown in figure 5. After establishing connection between client and server, network monitoring module checks network condition while client property module gets learner’s preference, device property etc, then, the system finds out whether existing resources in cache table fit into these parameters. If there are available resources, send their list to client. Otherwise, adaptive engine will filter, convert and select resources from FekLoma’s learning object repository according to these parameters, and finally learning resources are generated and delivered to client. Generally speaking, there are great deals of knowledge points and contents in a whole course, but the capacity of mobile device, such as storage capacity, screen size, supported media formats and so on, is limited. Therefore, the whole course learning resources will be much simpler in order to assure learners could get integrated content of a mini-courseware.

**Figure 4.** Decision-making structure of adaptive engine

**Figure 5.** The process of adaptation.

From the viewpoint of client, adaptive engine analyzes the requirement for whole learning mini-courseware firstly. If it is for whole course learning, the system will dispose resources according to the parameters of device, and then select them by learner’s preferences. In this way, the content of every knowledge points in a mini-courseware is sent to learner. However, in this model, it is hard to assure that every resource sent to learner is appropriate for learners. After the whole course learning, the learner may want to learn some knowledge points in the mini-courseware intensively, then, he could choose In-depth learning model. In this mode, adaptive engine will give learner the best resources which are totally fitting to learner’s preferences to satisfy learner’s requirement for detailed study. For In-depth learning, the system will filter resources according to learner’s preferences first, and then select or convert them according to supported formats of the device, the available memory space and network condition, etc..

IV. **COMPARATION WITH SIMILAR RESEARCH ACTIVITIES**

There are many research activities on adaptability for u-Learning system, and some similar research works include: the research in [1] focus on delivering contents tended to adapt to not only learner’s needs and preferences, but also to mobile device used. In literature [3], adaptive system is created based on learning object technology, and accordingly, the concept called self-adaptive learning object is proposed. PHAM.N.C carried out a series research work[4][5][6], in which web services technologies are used...
for creating adaptive ubiquitous e-Learning system. Comparing to these research efforts, the system of FekLoma adopt technologies of ULO, web services, and dynamic multimode mini-courseware creating. All these technologies are integrated together within a unified framework to provide foundation for more advanced adaptive engine. The architecture proposed in paper[14] is similar to FekLoma, in which multimedia adaptation layer and learning object adaptation layer are constructed, but in the architecture, the behaviors on a learning object could not be extended flexibility, which is different to FekLoma. There are also some other research works, such as research in the literature[7][9][10][11][12][19], although they also focus on the realization of adaptive features for u-Learning system, most of them just focus on upper adaptive features, while FekLoma focus on creating a more advanced adaptive u-Learning system with bottom-up approach.

V. THE FURTHER RESEARCH ACTIVITY

Now, the realization of adaptive features in FekLoma include learning device, learning content, knowledge density and networking communication, and they provide the foundation for high usability u-Learning system. with the further development of our research, the upper adaptive features are also required by the system, which include learner’s cognitive level, learning style, and learner’s profile, and they should be used for adaptive learning resource or activities delivering, and also, learning context is also needed for informal learning, which is more suitable for u-Learning. With these further researches, the system of FekLoma will provide more advanced and more comprehensive adaptability for u-Learning.

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