A Service-Oriented Architecture for Context-Aware Ubiquitous Learning Delivery

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Abstract—With the continued increase in the use of ubiquitous devices, learners’ expectations of learning services have also increased. Most of the learning services being provided today are not designed or delivered for ubiquitous learning environments because these learning services have not been taken into account rich learning contexts. This paper proposes a service-oriented architecture for context-aware adaptive learning services, which contains adaptation service, transforming service, and presentation service. Within each service, the conflicts are resolved by different learning rule base. The results show that the system may improve the learning experience under ubiquitous learning environments, and the learners are more interested in adapted learning service than those from general learning service.

Keywords—learning service; mobile learning; pervasive computing; context-aware service; content adaptation

I. INTRODUCTION

People use their portable devices not only for speech communication, but also as a powerful data communication tool today. The use of wireless, mobile portable and handheld devices is gradually increasing, which consequently diversifies every sector of education in the world [1]. Now portable devices have been used in teaching and/or learning activities to enhance learning efficiency.

One important nature of ubiquitous learning in contrast to traditional learning or e-learning is mobility, which means that the learner has a variety of contexts during learning. Learning that used to be delivered “just-in-case” can now be delivered “just-in-time, just-enough, and just-for-me” [2]. But the heterogeneous nature of these learning situations puts constraints on adaptive learning service to maximize the end learner experience now [3]. Ubiquitous learning using handheld computers is obviously immature in terms of both its technologies and pedagogies [1].

Mobile devices and techniques are pervasive and ubiquitous. It is possible to integrate the digital information with the physical environment. Context and context-awareness have begun to be investigated in distributed computing with the emergence of mobile computing components in the beginning of 90’s, led by the desire to support computer usage adequately in varying physical environments [4]. The contextual approach supports several learning methodologies ranging from those instructional in nature to more constructivist ones [5].

By the use of sensors and positioning data collected, these applications attempt to allow learners to engage with, and be engaged by, their context. Dey, et al [6] defined context as

*Any information that can be used to characterize the situation of an entity, where an entity is a person, place, or object that is considered relevant to the interaction between a user and its application, including the user and the application themselves. Context is typically the location, identity and state of people, groups and computational and physical objects.*

Although the e-learning has evolved from one-size-fits-all system to adaptive learning system, the adaptive contents from an e-learning system are not suitable to learning in ubiquitous environments because the e-learning system does not take into account their various contexts in the heterogeneous learning situation, e.g., the learning terminal specifications. The learner produces different needs under various contexts although he/she is accessing the same learning object/service in ubiquitous learning environments [6].

Therefore, besides learning characteristics, learning adaptation to contextual environment is a new kind of adaptation methodologies that were brought into e-learning system. The combination of location-aware technologies and contextual learning approaches facilitates learners to construct meaningful contextualization of concepts during field trips [5]. Based on features of device, learning state (such as goal, interest, location, etc.), educational state (such as requirements, purpose, results, etc.), and learning environment (such as weather, place, neighbor, device, etc.) [7], the system may provide an adaptive learning service in a seamless way.

In this study, we have proposed a service-oriented architecture for ubiquitous learning system, which tries to resolve the different adaptation issues (content redesigning, reconstructing, recoding, etc.) for context-aware ubiquitous learning delivery.
The remainder of the sections in this paper is organized as follows. Section II presents state of arts of related works in providing ubiquitous learning delivery service and service-oriented architecture. Section III proposes the service-oriented architecture for adaptive services based on learning contextual data. Section IV discusses the evaluation on learning experience on the proposed architecture. Finally, Section V summarizes our present work and points to future research works.

II. RELATED WORKS

A. Adaptation Service in a Learning System

Besides the actual service delivery in ubiquitous learning environments, it needs a high degree of service adaptation in contrast to the learning situation given by content preferences, transforming constraints, and device capabilities [8-9], which are necessary to maximize the quality of learning experience given the service constraints [3, 23].

In general, various learning services existing are provided on different domains. The rule base approaches have been adopted to realize extensible service on different application environments, such as parsing the HTML contents for mobile users [10-11]. Rules are used to match available services with diverse hardware and software capabilities and learning preferences. It is easily extensible for supporting new contents types. Rich media may be transformed among different media, such as standard document to text, html, image, multimedia clips [12-14], text to speech [15], text, image to video [14].

When a learning management system (LMS) server employs user’s experience with the context awareness, it can send an optimized service to the requesting device. In order to realize these adaptive services, contexts are categorized into different domains, learning state, education state, learning environment, learning situation [7, 16].

Different contexts are used in the adaptation service, such as learning/teaching educational activity, network, learning state for identifying the interest and preference of learners [5] or network speed [13], location, identity, time, and activity [17], physical and social environment, device state, cognition, behavior and task [4] for realizing content adaptation. The adaptation mechanism may be divided into different levels, such as content service, the presentation service, or transcoding service [9, 16].

B. Service-Oriented Architecture (SOA)

Service-oriented architecture generally defines a way for web application services, such as e-learning applications for learners, to integrate heterogeneous applications into one unified platform, which may be reliable, secure, scalable, flexible, manageable, expandable, reusable and interoperable [18].

Based on the SOA, the system can deliver durable learning contents to learners, regardless of evolutions in technology, such as the learning terminal from personal computer to ubiquitous device.

Today, many learning metadata standards have been proposed to provide scalable and robust learning services on the web. But in fact, these heterogeneous standards are lack of interoperability of controlled metadata sets that could replace the indefinite structured information for describing learning objects [19].

In order to resolve integration issues among heterogeneous systems, linked data have been proposed to share educational resources [19], reconstruct a learning system [20], or implement distributed repositories of learning objects [21] between service-oriented architecture and web services.

In general, students' learning needs are changing in different learning situations. The learning system should capture the contexts of both formal and informal learning environments [22] and deliver learning services according to learning needs, and learning task [8, 23].

In addition, in order to provide a seamless integration and provision of diverse services, a new model of flowable service has been proposed, which can be applied to deliver learning services to achieve maximum satisfaction of both service providers and consumers (e.g. learners) for service assurance [23], and another one to maintain the flow-service quality under a unified engineering for large-scale, adaptive systems [24].

III. SERVICE-ORIENTED ARCHITECTURE FOR LEARNING

For the provision of learning service with a transparent and seamless way, learning system should be scalable, manageable, and interoperable among heterogeneous applications platforms. The service in this research is implemented through the following flow data model: adaptive service, service adaptation and service delivery, which is shown in Fig. 1.

![Figure. 1 Data flow of service](image)

The adaptive service facilitates suitable service for learners according to various educational strategies, different contextual and situational data, which may come from the learner, learning system, or other third parties. In other words, this process recommends the most personalized service under available service and learning situation.

With adaptation suggestion from adaptive service, service adaptation module recodes/reconstruct original service (information, contents, etc.) into adapted service. In general, we call it content adaptation, which is the action of transforming original contents to adapt to learning situation, especially to device capabilities [3, 9-12]. It determines
where the service adaptation takes place, when the adaptation is transformed, and what content is adapted.

Finally, service delivery module maximizes the learning experience with presentation capabilities of devices, which should be consistent with original service semantics.

While learners study with their ubiquitous devices, the learning system recommends a learning service with available learning services that fit under current contextual environment. Based on the proposed data flow model in Fig. 1, a service-oriented architecture for ubiquitous learning delivery is proposed, as shown in Fig. 2, which includes three services: adaptation service, transforming service, and presentation service.

The transforming service bridges the gap between the learning service and ubiquitous learning situation, which recodes or reconstructs the suggested service into adapted services according to transforming suggestion. Since the learning semantic and needs are changing, the interaction (e.g. access feedback) between learners and learning system are also used in service provision.

The presentation service realizes the final presentation media of the learning service with suitable markup or multimedia according to the presentation suggestion.

In order to provide the adaptive learning service, conflict-resolution method is adopted in this research [16]. In general, the confliction will be resolved by a rule base (decision logic) system. In this research, a negotiation algorithm is used based on the credibility rank of learning context. Here, the conflict exists between the service provision and learning context. The resolution is the different rules. Simple decision logic to judge whether the learning service can be implemented is shown in Table 1.

The adaptation service is similar with a general learning system based on learning profile, learning situation, learning characteristics, etc. But more context-aware data are used in this research than others. In other words, the credibility of learning service is more suitable for learning situation, which recommends a suitable learning service, specially learning contents access under current learning situation, from the learning system.

![Figure 2](image-url)  
Figure 2 Service-oriented architecture for learning delivery

Context recognition module provides the context aware information, which is refined from raw data from various context detection terminals, such as sensors, cameras, GPS, etc. The functionality of different context data is changing with mobility. The credibility rank of each learning context produced by context impact module is recommended to each service for adaptive service, e.g. the relationship among participants for cooperative learning is changing under different learning situation.

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**TABLE 1 DECISION LOGIC BASED ON RULE BASE**

<table>
<thead>
<tr>
<th>IF (Logic Decision)</th>
<th>THEN</th>
<th>ELSE</th>
<th>return False</th>
</tr>
</thead>
<tbody>
<tr>
<td>return True</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

The transforming service bridges the gap between the learning service and ubiquitous learning situation, which recodes or reconstructs the suggested service into adapted services according to transforming suggestion. Since the learning semantic and needs are changing, the interaction (e.g. access feedback) between learners and learning system are also used in service provision.

The presentation service realizes the final presentation media of the learning service with suitable markup or multimedia according to the presentation suggestion.

Fig. 3 shows one example for the presentation service of PowerPoint Content, which delivers suitable multimedia according to different rule base in Table 2. For example, the learner wants to review this learning object while going to train station from home by riding a bicycle. The ubiquitous learning delivery system suggests audio as media type for study media based on learning feedback and learning situation. Finally, the presentation service determines what representation way for learning service should be delivered to learners according to device specifications.

**TABLE 2 PRESENTATION RULE BASE FOR POWERPOINT SERVICE**

```
<rule name="appliation">
  <r source="vnd.ms-powerpoint" target="image/gif" format="gif"/>
  <r source="vnd.ms-powerpoint" target="text/html" format="html"/>
  <r source="vnd.ms-powerpoint" target="application/xml" format="xml"/>
  <r source="xml" target="text/html" format="html"/>
  <r source="xml" target="text/vnd.wap.wml" format="wml"/>
  <r source="xml" target="audio/x-wav" format="wav"/>
</rule>

<rule name="text">
  <r source="html" target="audio/x-wav" format="wav"/>
  <r source="html" target="image/jpg" format="image"/>
  <r source="vnd.wap.wml" target="audio/x-wav" format="wav"/>
  <r source="vnd.wap.wml" target="text/html" format="html"/>
</rule>
```

.. note::
The questionnaire was designed to evaluate learners' satisfaction degrees for the proposed adaptive learning service on AubiLearn system [16], which is an engine for adaptive ubiquitous learning content delivery system.

The six questions shown in Fig. 4 are designed to know about the learning experience on ubiquitous devices. Another ten questions shown in Table 3 are conceived to know about learning experience on the AubiLearn system.

Fig. 4 shows that none of them knew that they could study on mobile devices. Especially, they thought that it was impossible to study based on rich media (e.g., pdf, doc format contents) on mobile devices.

Table 3 shows that learning experiences of learners on AubiLearn are rated very highly. The weighted average values (WAV) are larger than 3.00. Especially, “I can access e-learning contents by AubiLearn anyplace and anytime” is rated the highest among them with 3.65 point, “I may fully read document on device” with 3.7. The mean value of all items is 3.2, which shows that our proposed service-oriented architecture is very important for ubiquitous learning environments.

On the other hand, we found that one of the existing problems is the Quality of Service (QoS) of adapted contents (WAV: 2.7) because of the limited features of mobile devices. For example, the caption of video is not clear after the high resolution video is re-encoded. At this situation, the learner studies by listening.

Another issue is the communication fees (WAV: 2). From Q.3, half of them pay more to access the learning contents for study, especially for video contents. Fortunately, this situation has greatly improved in Japan now, since mobile companies allow users to choose a cheaper plan for Internet use. We think that it must be cheap for learners to study on mobile devices in near future.

<table>
<thead>
<tr>
<th>Questionnaires</th>
<th>WAV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q.1 I can get e-learning contents at tolerate time</td>
<td>3.15</td>
</tr>
<tr>
<td>Q.2 I can get instant help from others</td>
<td>3.15</td>
</tr>
<tr>
<td>Q.3 I may pay less during discussion on the system than others</td>
<td>2</td>
</tr>
<tr>
<td>Q.4 I can get best quality of adapted contents</td>
<td>2.7</td>
</tr>
<tr>
<td>Q.5 I may get right format for my accessing</td>
<td>3.35</td>
</tr>
<tr>
<td>Q.6 I may fully read document on device</td>
<td>3.7</td>
</tr>
<tr>
<td>Q.7 I may fully view video on device</td>
<td>3.4</td>
</tr>
<tr>
<td>Q.8 I can access e-learning service at anyplace and anytime</td>
<td>3.65</td>
</tr>
<tr>
<td>Q.9 The AubiLearn can promote my learning interest</td>
<td>3.4</td>
</tr>
<tr>
<td>Q.10 Do you think that AubiLearn can help you study totally?</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Weight Average Value (WAV) = (P + 2Q + 3R + 4S)/20, where P, Q, R, S are the number of responses for the Likert Scale 1,2,3,4 respectively and 20 is the total number of responses.

V. CONCLUSION

In this study, a service-oriented architecture has been proposed for adaptive learning content delivery based on learning contextual data in ubiquitous learning environments. The original learning service semantics can be preserved according to the proposed service-oriented architecture. The proposed architecture has been evaluated on the AubiLearn system. The results show that the system may improve the learning experience under ubiquitous learning environments.
In other words, it implies that the learners are more interested in the recommended learning service.

As for future work, we will tackle the specific research question concerning “social relationship” for learning collaborators that match the learning preferences. It is a challenging work to define and reason different contexts (physical context, time context, learner context, resources context) for reasoning the learning relationship during moving. We pursue more intelligent approaches for ranking the learning social relation among learners to maximize quality of experience and learning resource utilization.

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REFERENCES