

Learning Resource Adaptation and Delivery Framework for Mobile Learning

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Abstract - With the rapid development of wireless networks and mobile devices, mobile learning has got more and more attention. However, most of current learning resources (LR) were designed with desktop computers and high-speed network connections. Moreover, for different user preferences in mobile learning environment, not all of the data are relevant and critical to the learning process. It is a challenge to deliver such learning resources to various devices with limited capability over low-speed wireless network while ensuring higher synthetically quality of learning resource.

To solve above problem, in this paper we proposed a Learning Resource Adaptation and Delivery Framework to adapt learning resources to various learning environments. It consists of two layers: multimedia adaptation layer and learning object adaptation layer. In the multimedia adaptation layer, MPEG-21 Digital Item Adaptation (DIA) mechanism is incorporated to handle the adaptation of low-level multimedia contents contained in learning resources. In the learning object layer, the appropriate selection of learning objects is based on an extended Learning Object Model for mobile learning.

With the introduction of an integrated quality mechanism filling the quality metrics gap between high-level learning objects and low-level multimedia objects, an adaptation decision algorithm is presented to ensure higher final adaptation quality of learning resources.

Index Terms:

Learning Resource, Mobile Learning, MPEG-21 Digital Item Adaptation

I. INTRODUCTION

In recent years, there has been a dramatic increase in the use of computer embedded devices, such as intelligent mobile phones, PDAs. Furthermore, emerging standards and technologies in wireless communication and wireless network are developed to enable all kinds of devices to ubiquitously access multimedia information. With such rapid development of wireless networks and mobile devices, mobile learning has got more and more attention. However, most of current learning resources (LR) were designed with desktop computers and high-speed network connections. They usually contain rich media data such as image, audio, and video.

These contents may not be suitable for the presentation on the devices with limited capability and the transmission with limited network bandwidth. Moreover, for different user preferences in mobile learning environment, not all of the data are relevant to the learning process. It is not effective to develop new learning resources for mobile learning environment by discarding large amounts of existing ones. It is a challenge to deliver existing learning resources to various devices with limited capability over low-speed wireless network.

To meet the constraints of network bandwidth, user preference, and devices limitation, adaptation technology is used to dynamically adjust content presentation. There has been intensive research both in e-learning area and multimedia processing area. In the first area several adaptive learning content management systems have been proposed [1-2]. These systems usually use XML and XSL instead of HTML to describe learning contents and their presentation respectively. XSLT is used to dynamically adjust web-based learning content to various devices. However, they can only handle the adaptation for content presentation but not the adaptation of the multimedia contents. In multimedia processing area transcoding technology is widely used for the adaptation of multimedia contents. Lots of transcoding algorithms and system architectures have been proposed [3-5] for coding format conversion, image size reduction, and video frame dropping and so on. In addition, to enable transparent and augmented use of multimedia resources across a wide range of networks and devices used by different communities, MPEG-21 multimedia framework is developed [6].

The technologies in above two approaches are separately used, especially in e-learning area no integrated work has been investigated to ensure the final adaptation quality of learning resources consisting of various multimedia contents. In this paper, we integrated these two approaches and proposed a Learning Resource Adaptation and Delivery Framework to adapt learning resources to various learning environments. Because learning resource may consist of two levels of learning contents: high-level learning objects and low-level multimedia objects or documents, the adaptation is defined in two layers: multimedia adaptation layer and learning object adaptation layer. In the multimedia adaptation layer, the adaptation refers to media adaptation operations such as image size changing, frame dropping of encoded videos or cross-media conversion. MPEG-21 Digital Item Adaptation (DIA) is

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incorporated to our framework to handle the adaptation of low-level multimedia contents within learning resources. In the learning object layer, the adaptation is the appropriate selection of learning objects based on an extended version of Learning Object Model for mobile learning.

The remainder of this paper is organized as follows. Section II is the description of our proposed Learning Resource Adaptation and Delivery Framework. Then the adaptation decision algorithm is presented in Section III. A prototype system based on our proposed framework is introduced in Section IV. Finally conclusion and future work is given in Section V.

II. LEARNING RESOURCE ADAPTATION AND DELIVERY FRAMEWORK

A. System Architecture

The system architecture of Learning Resource Adaptation and Delivery Framework is illustrated in Fig. 1. It is logically

divided into two layers: multimedia adaptation layer and learning object adaptation layer. The major components of the framework include Context Description Manager, Learning Resource Adaptation Engine and Learning Resource Database.

a) Context Description Manager:

The function of this component is to exchange and manage two types of context information between the learner client and learning content server: learner context description and MPEG-21 DIA context description. The former is the metadata information about the learner including learner profile, learner model and learning settings. The other type is more about the conditions and constraints of the learning environment such as learner's terminal capability, network characteristic and session mobility. Learner Description Manager and DIA Description Manager store corresponding type of description information to Learner Metadata Database and DIA Description Database respectively.

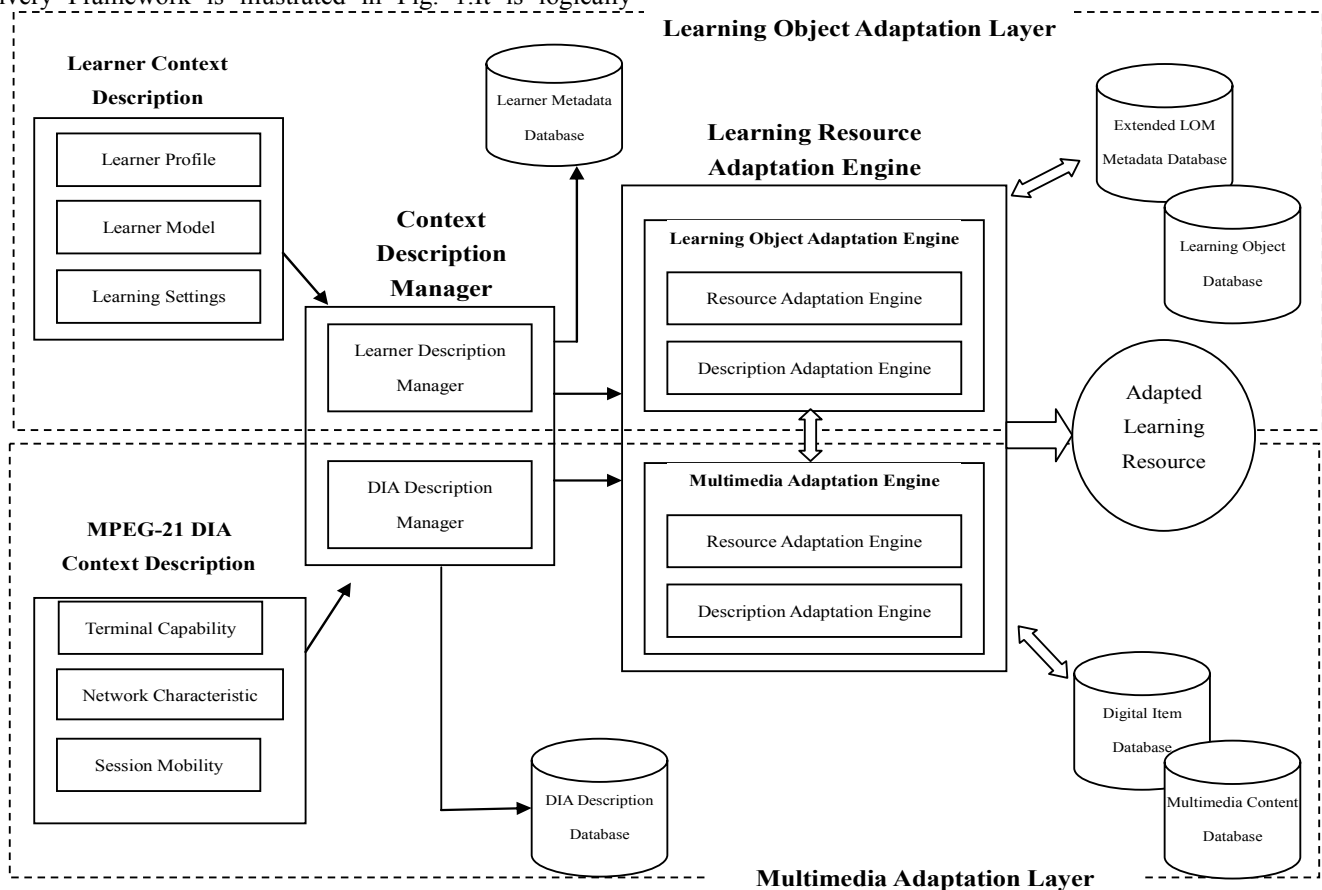


FIGURE.1
SYSTEM ARCHITECTURE OF LEARNING RESOURCE ADAPTATION AND DELIVERY FRAMEWORK

b) Learning Resource Adaptation Engine:

It consists of two adaptation sub-engines for the adaptation in every layer: Learning Object Adaptation Engine and Multimedia Adaptation Engine. The structures of the sub-engines are very similar. Every sub-engine comprises two

logical modules, Resource Adaptation Engine and Description Adaptation Engine. Resource Adaptation refers to the adaptation of learning object or multimedia content itself, while Description Adaptation refers to the adaptation of metadata information regarding learning objects or multimedia

contents. The reason for the definition of Description Adaptation module is that metadata information should be appropriately modified after certain adaptations have been applied to the real contents of learning objects or multimedia objects.

c) Learning Resource Database:

There are four databases in our framework to store learning resource and related information. Learning Object Database and Multimedia Object Database are used to store the real contents in the two adaptation layers, while Extended LOM Metadata Database and Digital Item Database are used to store corresponding metadata information of the contents in every layer.

Context Description Manager receives context descriptions containing environment constraints and learner preferences from learner client and sends them to Learning Resource Adaptation Engine. Then the adaptation engine determines the optimal adaptation operations according to the given context description and metadata information regarding learning resources. After appropriate adaptations are applied, the contents of the adapted learning resources are delivered to the learner and the adapted metadata information is stored back into related databases.

B. Extended Learning Object Model

Although there are several metadata standards and specifications such as LTSC Learning Object Metadata (LOM) and IMS Learning Resource Metadata, they are towards traditional E-Learning on desktop computers and formal training or teaching environment, not suitable for mobile and informal learning environment. Certain extensions of existing metadata standards should be made to adapt to the rapid change of learning context. By considering the fact that learning objects created by the learner may be shared and validated by other learners, restrictedly used with regard to the location where it can be taken or used, some elements have been proposed to extend LOM within the “Rights” category [7]. However, there is still lack of elements to assist the adaptation process of learning resources. Thus we add “AdaptationQuality” element and other related ones to LOM standard within the “Technical” category. They are listed in Table I.

TABLE I.
EXTENSIONS TO LOM STANDARD FOR LEARNING RESOURCE ADAPTATION

Element Name	Explanation
AdaptationQuality	This category describes the quality related information for the adaptation process
AdaptationQuality.QualityParameter	Specify what types of quality is concerned such as color, size, frame rate.
QualityParameter.QualityValue	Specify the value of Quality Parameter
QualityValue.min	Specify minimum Quality Value
QualityValue.max	Specify maximum Quality Value
QualityValue.Model	Specify the model for quality parameter such as first-order model, second-order model
QualityParameter.Priority	Specify the priority of this Quality Parameter.

For the elements in Table 1, it should be mentioned that the authors of learning objects can specified several “QualityParameter” elements. The author or the learner can also redefine the priority of every “QualityParameter” during the learning process. With this extended LOM, we can integrate the adaptation quality of learning object with the adaptation quality of multimedia object. Such integrated quality definition will be discussed in detail in Section III.

C. MPEG-21 DIA Description for Multimedia Content Adaptation

Digital Item Adaptation (DIA) is one important part of the new MPEG-21 standard. It enables the provision of network and terminal resources on demand to form user communities where multimedia content can be created and shared, always with the agreed/contracted quality, reliability and flexibility, allowing the multimedia applications to connect diverse sets of users [8]. Because learning resources always contain much of multimedia contents, in this paper we incorporate MPEG-21 DIA to our proposed framework. Two categories of description tools specified in MPEG-21 DIA are used.

The first category is Usage Environment Description tools to express the information regarding terminal capabilities, network characteristics and natural environment characteristics. They cover various dimensions of the learning environment.

The other one is the resource description tool for multimedia contents such as audio, image, and video. In our framework we utilize BSD/gBSD description tools to make a flexible description based on XML language for the multimedia contents within learning resources. Instead of describing the actual symbol syntax of the multimedia bitstream, BSD/gBSD gives emphasis on the high level structures in most cases. In the multimedia adaptation engine description transformation based on XSLT technology can be applied to the original BSD/gBSD description according to the optimal adaptation decision. Using the new transformed description created by the transformation, an adapted digital item (multimedia content) can be easily generated. With the incorporation of BSD/gBSD tools, a lightweight and flexible adaptation mechanism for multimedia learning resources is realized.

D. Adaptation Process

The workflow of the learning resource adaptation process is illustrated in Fig.1 by the arrows from the left side to the right side. When the learner sends a request of learning resource to the learning resource management system, the augmented client used by the learner firstly collects necessary context information regarding the learning environment and the learner. Then the context information is sent to the Context Description Manager deployed in the learning resource provider side. Context Description Manager may store received description in the description database or just update the old stored description.

Context description and learner requirements are then delivered to the Learning Resource Adaptation Engine. If the

requested learning resources are not suitable for current learning context, the adaptation processes in the two adaptation layers are invoked in sequence.

➤ Learning Object Adaptation Layer

The adaptation in this layer is more concentrated on the selection of appropriate learning objects towards learner preferences and requirements but not the learning environment. The adaptation engine determines the relevant learning objects for the learner according to the context description and LOM Metadata information. For example, a person is attending an aircraft exhibition. He is standing near a combat plane produced in 1940s and is interested to know more about other combat plane produced in the same period. The learning object adaptation engine will update the metadata information such as the location and the capability of the equipment used by the learner. The engine can infer that the learner likely wants to know more about the combat planes produced in 1940s (via the proximity to the combat plane). Then the engine will further filter the learning objects according to this learner preference and other learner's abilities expressed by the learner context description. However, the restrictions on the learning environment and resource delivery network are not taken into account in this layer because some learning objects dissatisfy these restrictions can be adjusted and adapted in the lower layer- multimedia adaptation layer.

➤ Multimedia Adaptation Layer

The objective of this adaptation layer is to correctly present the learning objects and multimedia contents that meet technical requirements of learning environment. The technical requirements include terminal capability like screen size, color depth, network characteristic such as network bandwidth, packet loss rate and so on. If the original version of learning object or multimedia content doesn't meet such constraints, some multimedia transcoding methods that change the format or technical properties of multimedia contents should be used. Available transcoding methods include image size reduction, video frame rate reduction, color depth reduction, bit rate reduction and so on. However, the transcoding procedure inevitably causes quality degradation effect. The adaptation engine should make the trade-off between applying transcoding and the selection of learning objects to ensure higher adaptation quality. Additionally the adaptation engine will also take all multimedia contents within learning objects into account for a global optimal adaptation decision. The decision algorithm is discussed in detail in Section III.

After the execution of above adaptation processes in the two layers, an adapted version of the original learning resource is generated and delivered to the learner. This adapted one meets both the requirements of the learner and the constraints of the learning environment.

III. ADAPTATION DECISION ALGORITHM

A. Integrated Adaptation Quality Mechanism

Because the final adaptation quality of learning resources depends on not only the adaptation quality of low-level multimedia objects but also the appropriate selection of

learning objects. It is obvious that the quality metrics of these two level contents are very different. For example the adaptation quality of learning object selection is the learning objects' relevance to the learner preference and learning states, while the adaptation quality of image/video objects may be PSNR (Peak Signal-Noise Ratio), image size, color and so on. Thus we defined an integrated quality mechanism to fill the quality metrics gap between high-level learning objects and low-level multimedia objects.

At first the adapted quality metrics for the low-level multimedia objects are introduced. As stated in Section II.B, an extension has been made to traditional LOM standard. By this extension, the author of learning objects can specify various quality parameters for one learning object. By assuming that low-level multimedia object can be regarded as an atom learning object, the quality parameter can also be specified to multimedia object within high-level learning objects. Let $QV_{\min}(i)$ and $QV_{\max}(i)$ are the minimum and maximum quality value for i th quality parameter. Then we define the evaluated adaptation quality metric $QV_e(i)$ for the adapted version of the multimedia content, in this case $QV(i)$ is the adaptation quality value for i th quality parameter. Here $QV_e(i)$ is an abstract metric to give the learner a meaningful quality measure because learners are not very sensitive to the real values of quality parameter but the change of the values. By assuming a quality model such as first-order model or second-order model, we can get the expression $QV_e(i)$ as below:

First Order Model:

$$QV_e(i) = \frac{QV(i) - QV_{\min}(i)}{QV_{\max}(i) - QV_{\min}(i)} \quad (1)$$

Second Order Model:

$$QV_e(i) = \frac{QV(i)^2 - 2QV_{\max}(i)QV(i) - QV_{\min}(i)^2 + 2QV_{\max}(i)QV_{\min}(i)}{2QV_{\max}(i)QV_{\min}(i) - QV_{\min}(i)^2 - QV_{\max}(i)^2} \quad (2)$$

If several quality parameters are specified to the multimedia object, a general evaluated quality metric QV_{ge} for all the quality parameters should be formulized by taking account of the priorities or the weights W_i of every quality parameter.

$$QV_{ge} = \sum W_i QV_e(i) \quad (3)$$

Here the general evaluated quality QV_{ge} is the evaluation metric for the adaptation quality after certain transcoding operation has been applied to the multimedia object. It should be mentioned that QV_{ge} is a normalized variable. Thus for every possible adaptation operation O_j , we can evaluated the adaptation quality $QV_{ge}(j)$.

In another aspect it is straightforward to define a normalized relevance factor $R(k)$ for k th learning object related to current learner requirements and learning states.

Finally the integrated adaptation quality of the learning object by applied adaptation operation O_j is defined as:

$$QV_{ge}(j, k) = R(k) \cdot QV_{ge}(j) \quad (4)$$

Equation (4) reflects both the adaptation quality of learning object selection process and the one of multimedia transcoding operation.

B. Adaptation decision algorithm

With the help of the integrated adaptation quality mechanism, we model the adaptation decision process as the following optimization problem.

$$Max\{\sum_{k=1}^m QV_{ge}(j, k) / m\}$$

Such that $C(i) < C_{context}(i)$ for all possible i (5)

Where m is the total number of relevant learning objects to be delivered. $C(i)$ is the value of the i th constraint parameter after the j th available adaptation operation is applied and $C_{context}(i)$ is the value of the i th constraint parameter indicated by the context description.

In our framework we simply define a greedy algorithm to get the decision as following:

- 1) With regarding to the constraints indicated by the context description, all adaptation operations available for learning objects in the relevant list and multimedia objects can be found. Although excluding of a learning object from the final delivery list will release constraint resources and enable more available adaptation operations for reserved learning objects, the number of available operations is still limited. So a greedy algorithm is reasonable.
- 2) For every candidate adaptation operation O_j , the

average integrated adaptation quality $\sum_{k=1}^n QV_{ge}(j, k) / n$

for all delivered learning objects are computed and stored in decreasing order. Here n is variable because some learning objects may be excluded in the candidate adaptation operation.

- 3) The result of the adaptation decision is that the adaptation operation with the highest average integrated adaptation quality value is selected.

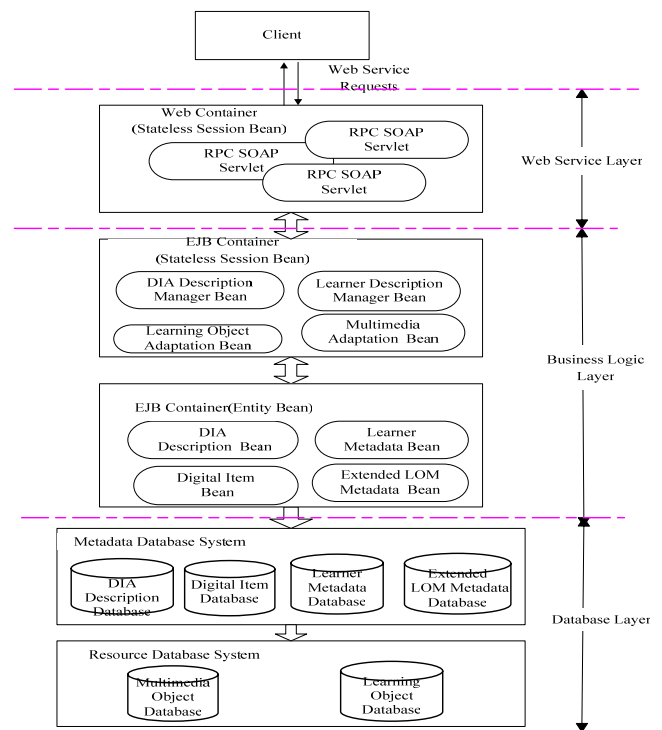
In above decision algorithm, the average integrated adaptation quality is ensured as high as possible while the requirements of the learner and the technical requirements of the learning environment are both satisfied.

IV. PROTOTYPE SYSTEM

Based on the proposed framework, we use J2EE technology to implement an adaptive Learning Content Management System. This prototype system can provide adapted learning resources such as web-based courseware to various learner devices and delivery networks. To improve the flexibility of system deployment, we wrap most of the interfaces between framework components into Web Services. For example, the

interfaces between Context Description Manager and Learning Resource Adaptation Engine act as Web Services. This is for the case that several Learning Resource Adaptation Engines can cooperate with each other and a general Context Description Manager serves them in the same time.

The prototype system consists of four layers: Presentation Layers, Web Service Layer, Business Logic Layer, and Database Layer. The layered system architecture is shown in Fig. 2. The presentation layer is not shown in Fig.2, it includes some components like JSP pages or servlets. In business logic layer, several Enterprise JavaBeans including session EJBs and Entity EJBs are developed. The Session Beans implement function modules such as context description manager and adaptation engine, they also act as Web Services accomplished by RPC-SOAP servlets in the Web Services Layer. Clients may send Web Service requests to these servlets, which will parse SOAP message and invoke target Stateless Session Beans. The use of Web Service in the system also provides another type of adaptation ability that is the software adaptation.



The instances of Entity bean represent the actual data records in the databases that belong to the database layer. Because the LOM description and MPEG-21 DIA description are both in XML format, we use a native XML database, Tamino 3.1 database to store and process description information. Tamino 3.1 database provides a consolidated representation of data in XML format [9], it is very useful to store and retrieve XML data in our system.

The creation of the extended LOM description can be realized by using the extended version of the authoring tool stated in [10]. And we use the methods stated in [11][12] to

generate MPEG-21 DIA description for multimedia resources. For example, a learning object such as one HTML page of a traditional web-based courseware may include JPEG2000 images and H.264 videos. Then we can generate corresponding gBSD/BSID description for these multimedia contents. The fragments of these MPEG-21 DIA descriptions are illustrated in Fig. 3 and Fig.4 respectively.

FIGURE 2. LAYERED IMPLEMENTATION OF THE PROTOTYPE SYSTEM

```
<?xml version="1.0" encoding="UTF-8"?>
<Codestream xmlns="JP2" xml:base="image/1.jp2 instance "
xsi:schemaLocation=" JP2 JP2.xsd">
  <MainHeader>
    <SOC>
      <Marker>FF4F</Marker>
    </SOC>
    <SIZ>
      <Marker>FF51</Marker>
      <LMarker>47</LMarker>
      <Rsiz>0</Rsiz>
      <Xsiz>384</Xsiz>
      <Ysiz>256</Ysiz>
      <XOsiz>0</XOsiz>
      <YOsiz>0</YOsiz>
      <XTsiz>384</XTsiz>
      <YTtiz>256</YTtiz>
      .....
    </Codestream>
```

FIGURE 3.

A FRAGMENT OF BSD DESCRIPTION FOR JPEG2000 IMAGE

```
<dia:Description xsi:type="gBSDType" id="gBSD1">
  .....
  <gBSDUnit start="53" length="2997" syntacticalLabel="H264:I_FRAME"/>
  <gBSDUnit start="3050" length="705" syntacticalLabel="H264:P_FRAME"/>
  <gBSDUnit start="3755" length="187" marker="QualityLayer-1"
  syntacticalLabel="H264:B_FRAME"/>
  <gBSDUnit start="3942" length="208" marker="QualityLayer-2"
  syntacticalLabel="H264:B_FRAME"/>
  <gBSDUnit start="4873" length="244" marker="QualityLayer-6"
  syntacticalLabel="H264:B_FRAME"/>
  <!--... and so on ...-->
</dia:Description>
```

FIGURE 4.

A FRAGMENT OF GBSD DESCRIPTION FOR H.264 VIDEO

In above case available adaptation operations for JPEG2000 image include image size reduction and color component changing by modifying the header information in the BSD description. And feasible adaptation operations for H.264 video include bit-rate reduction and frame rate reduction by removing “gBSDUnit” elements (corresponding to video frames). Based on the adaptation decision algorithm stated in Section III, the prototype system delivers best suitable learning resources to different devices. Fig.5 shows an example that different presentations of learning resources are created for different clients.

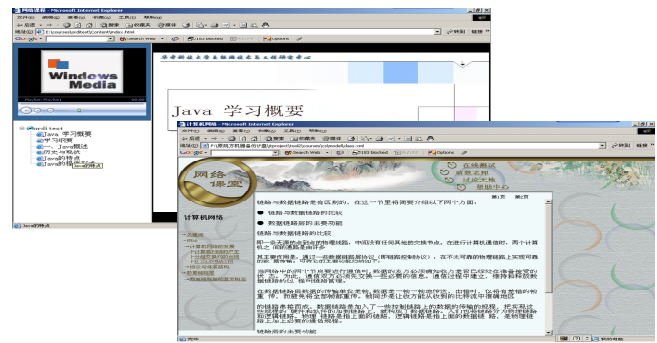


FIGURE 5.

DIFFERENT PRESENTATIONS FOR DIFFERENT CLIENTS

V. CONCLUSION AND FUTURE WORK

Towards the adaptive delivery of learning resources in mobile learning environment, this paper presents a Learning Resource Adaptation and Delivery Framework to adapt learning resources to various learning contexts. The layered adaptation architecture and adaptation decision based on the integrated adaptation quality mechanism ensure both the adaptation quality of learning objects and the one of multimedia objects as high as possible.

Future work includes more study on metadata model for learning resources and multimedia resources to meet new requirements of mobile learning. The relationship between the adaptation quality of learning objects and the adaptation quality of multimedia objects still need to be carefully investigated.

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