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Presentation Priority and Modality Conversion in MPEG-21 DIA

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Abstract

The part 7 of MPEG-21, called Digital Item Adaptation, aims at an interoperable transparent access of multimedia contents in heterogeneous environments. This standard facilitates the development of Universal Multimedia Access (UMA) systems, which adapt the rich multimedia contents to provide user the best possible presentation under the constraints of various terminals and network connections. Content adaptation has two major aspects: one is modality conversion that converts content from one modality (e.g. video) to different modalities (e.g. image), the other is content scaling that changes the bitrates (or qualities) of the contents without converting their modalities. At the output of adaptation process, the highly-subjective qualities of adapted contents may vary widely with respect to point-of-views of different providers and different users. So, user should have some control on the adaptation process. In this paper, we describe two description tools of user characteristics, the presentation priority preference and the modality conversion preference, which allow user to have flexible choices on the qualities and modalities of output contents. We also present a systematic approach to integrate these user preferences into the adaptation process. These description tools are developed in the process of MPEG-21 standardization.

I. Introduction

Universal Multimedia Access (UMA) is currently a new trend in multimedia communications. A UMA system adapts the rich multimedia contents to various constraints of terminals and network connections, providing the best possible presentation to user at anytime and anywhere. Meanwhile, the emergence of MPEG standards, especially the on-going MPEG-21[1], facilitates the realization of UMA systems in an interoperable manner.

Actually, the best presentation to user is a very subjective concept. So, there should be some means to let user to customize the adaptation process. These means are called user preferences and considered as components of the user profile, which is an important input of a UMA system. This paper presents two important user preferences, the presentation priority and modality conversion preferences, which we proposed and developed as description tools of user characteristics in MPEG-21 Digital Item Adaptation (DIA)[1][2].

In the content adaptation process, the quality of content presentation may be much degraded. Especially, when multiple content objects (or items) are adapted at the same time, the qualities of different content objects may be changed variously according to the point of view of provider. The presentation priority preference allows users to control the presentation qualities of different objects. For example, when user is interested in images, he will give high priority for image contents. The result is that images will be located more resource and then have higher quality, yet other contents will be degraded because the total resource constraint is fixed.

Moreover, content adaptation process may also convert the modalities of contents. Modality conversion is obviously needed when the terminal or network cannot

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support the consumption or the transmission of certain modalities. For each content object, there would be many conversion possibilities, whereas the user may prefer or even can hardly perceive (e.g. blind users) some modalities. The role of modality conversion preference is to let user specify his choices on modality conversion. Without these two description tools, user has to accept any adaptation solution provided by the provider.

So far, most researches on content adaptation have focused on transcoding of contents within a single modality[3][4], or on a single type of modality conversion, e.g. video to images[5]. Modality conversion may be supported in the approach of[6], yet this approach works with only one content item, resulting in little practical use. The approach in[7] is one of few adaptation approaches that can handle multiple modalities and multiple contents, however its resource allocation method is not quite suitable to find the output modality. Especially, user preferences on modality and quality of adapted contents have been examined just briefly in those researches. To the best of our knowledge, there have been no approaches that systematically address these QoS aspects of user profile.

Our paper is organized as follows. In section 2, we present an overview of digital item (content) adaptation and its relationship with the proposed description tools. In section 3 we discuss the important features of the two description tools. A systematic approach for integrating the user preferences into the adaptation process is described in section 4. Some experiment results are presented in section 5, and finally section 6 concludes the paper.

II. Overview of Digital Item Adaptation

MPEG-21 aims at an interoperable transparent access of multimedia contents in heterogeneous environments. The adaptation of Digital items is a key solution to achieve this goal. The conceptual architecture of Digital Item Adaptation is shown in Fig. 1.

We see that the metadata of digital items are adapted by the Description Adaptation Engine and the resources of digital items are adapted by the Resource Adaptation Engine. It should be noted that the adaptation engine is the non-normative part of DIA. It is the descriptions and format-independent mechanisms to support the Digital Item adaptation that are standardized within MPEG-21 DIA.

The Resource Adaptation Engine, which is the focus point in our work, can be further divided into three modules, a decision engine, a modality converter, and a content scaler as illustrated in Fig. 2.

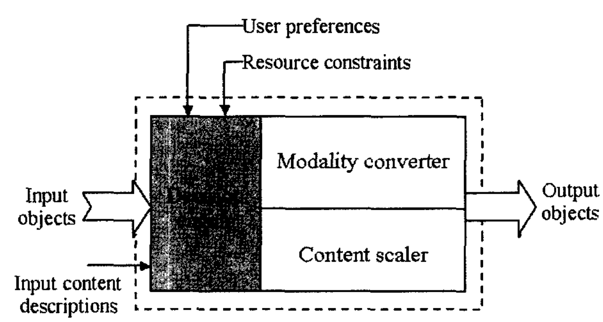


Fig. 2. Architecture of the Resource Adaptation Engine

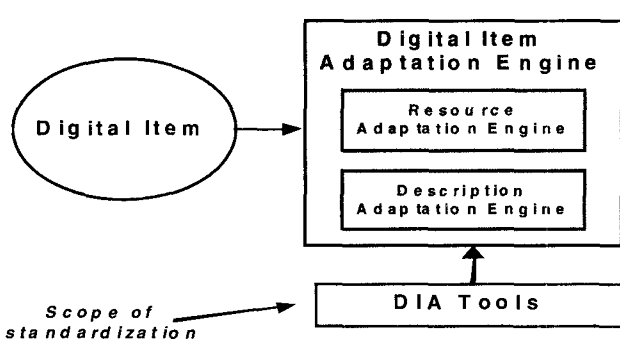


Fig. 1. The conceptual architecture of an Digital Item Adaptation Engine [1].

Decision engine is the kernel of the resource adaptation process. It has three important metadata inputs. The first input consists of the content descriptions, which shows the characteristics of input contents. The second input consists of the resource constraints from networks and terminals. These constraints show the characteristics of network connections and terminals. The third input consists of user preferences on the perceived contents. The decision engine analyzes these inputs and makes optimal decisions on modality conversion and content scaling.

The modality converter and the content scaler include the specific converting and scaling operations to adapt (or transcode) the content objects according to instructions from the decision engine. These two modules can be either offline or online. In the offline case, content objects are transcoded in advance into various versions of different modalities and qualities. In the online case, the needed versions are created on the fly. We can see that the functionality of the decision engine is essentially the same for both online and offline transcodings.

Suppose we have a multimedia document consisting of multiple objects. To adapt this document to some constraints, the QOS-related decisions of the decision engine have to answer two basic questions for every object:

1. Which is the modality of output object?
2. What is the quality (content value) of output object?

Without answers to these questions, we cannot apply the appropriate operations of modality conversion and content scaling to adapt the objects.

It is obvious that content scaling and modality conversion are two major aspects of content adaptation. The description tools presented in this paper address these two general aspects. They allow the user to customize the qualities and the modalities of the adapted contents, and in some way, help to answer the above questions.

Currently, there are still some other user preferences [1] such as audio, graphics, display presentation preferences. Our proposed preferences are different from the others in the way that they do not work only with a single content object, a single format or modality, but cover the QoS aspects of all content objects and modalities of a multimedia document. In some sense, we can say that the changes of modalities result in the changes of qualities.

Ⅲ. User preferences

1. Basic Requirements

Before going further, let us define some basic terms used in this paper. From the highest level, a multimedia document is a container of multiple content objects. A content object (or objectfor short) is an entity conveying some information, e.g. a football match. Each object may have many content versions of different modalities and qualities. A content version is a physical instance of the content object, e.g. a video file showing the information of a football match.

The user preferences help user to personalize the consumption of a multimedia document. For the decision engine, these are important inputs for it to answer the above basic questions. The tools should be flexible to support various practical cases and demands from user. We contend that these description tools need to support the following requirements:

1.1 Different ways to identify the contents:

Because a multimedia document may have multiple objects, the user would want to have preference on a group of objects or a specific object. We propose that the user can have two ways to identify the objects to apply the preference. The first is the general way where the user wants to apply the preferences to all content objects having some common features. The second is the specific way where the user wants to apply the preferences to some specific content objects having some known URIs, e.g. via a highlight of the document. It should be noted that, object can be actually of different levels. It can be a composite object, a whole video, a segment of video or a moving object in the video, etc.

1.2 Once-for-all preferences:

To give convenience to user, the preferences may be provided just one time and then stored in the user profile for all future sessions. The description tools should be flexible so that user does not have to provide preferences again every time a change of terminal/network occurs.

In the following, the presentation priority and the modality conversion preferences are described in detail.

2. Presentation Priority Preference

With this user preference tool, each object will be assigned a priority, showing user's evaluation on its relative importance compared with other objects in the document. Every object originally has a default priority of 1. The user can give any object a new priority of nonnegative real value, which can be as many times higher (or lower) than the default value as he wants. The higher the priority value is, the more important the object. An object will be discarded if its priority is 0.

When user does not have any information about the specific contents, he can make some general choices based on some common knowledge of content features. We propose the user identify the content by two most popular features: original modality and genre. The priority for a certain modality (genre) will be applied to all contents of that modality (genre). Various types of genres can be found in the content classification scheme of MPEG-7 standard.

On the other hand, when user is interested in some known contents, he just selects and gives some specific priorities for the contents. The user does not have to concern about other contents because they all have default priority.

The syntax of the description tool is illustrated in Fig. 3. We see that there are two kinds of priorities, one is for the general resources, and the other is for the specific resources. The priorities of general resources are then classified into the modality priorities and genre priorities. The priority for an object of some modality and some genre can be computed as the multiplication of its modality priority and genre priority.

3. Modality Conversion Preference

3.1 Preference on modality-to-modality conversions

First we see that the user preference should not allow only the fixed selections of modality conversion. For example, the user may request that all videos be converted to audios. However, if the terminal cannot support audio modality, the contents will be discarded. Second, the user preference should not allow only the

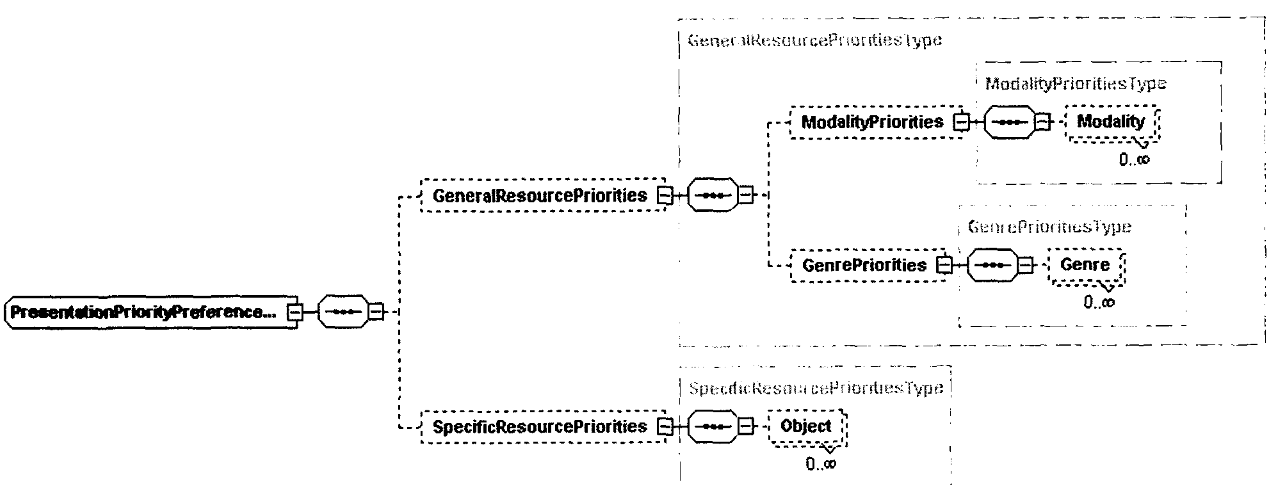


Fig. 3. Illustration of the Presentation Priority Preference

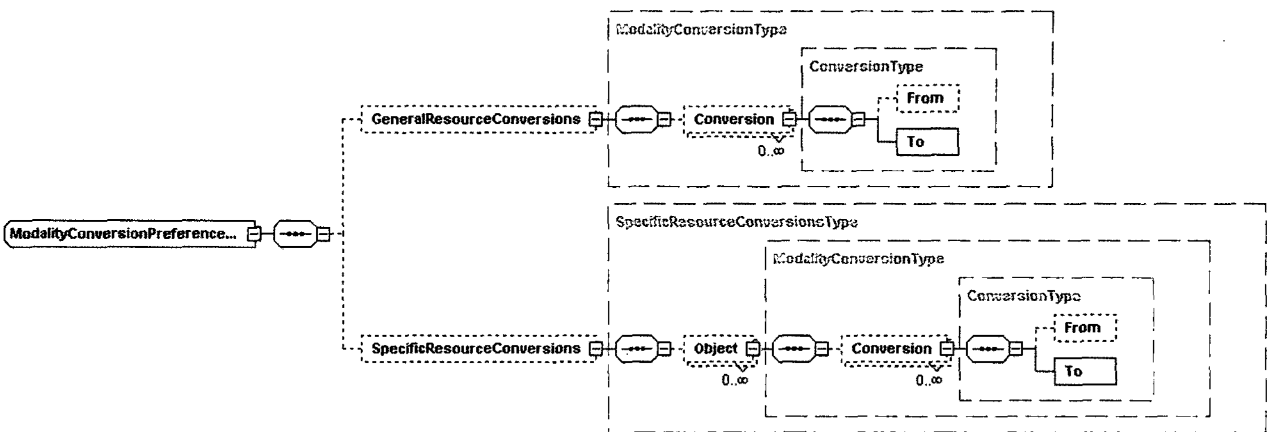


Fig. 4. Illustration of the Modality Conversion Preference

preferences on the destination modalities, because for example audio may be the best alternative for a concert video, whereas text may be the best alternative for a news image. So, we propose that, to flexibly support the various conditions of terminal/network, the user preference should support selections on the very conversions from modalities to modalities. In fact, the preference on modality-to-modality conversions can cover the cases of fixed selection and destination modalities.

3.2 Two levels of preference

Also, to help answer the two basic questions above, user preference for a conversion is divided into two levels. First, user will specify the relative order of each conversion of an original modality. Second, user can further specify the numeric weight of each conversion.

Given an original modality, the orders of conversions help the decision engine to determine which should be the destination modality if the original modality must be converted. For example, with the original video modality, the video-to-video conversion, that is "non-conversion"of video, has the first order; the video-to-image conversion has the second order; and so on.

As for the weights of conversions, they help the decision engine to determine when conversion should be made. This is based on the fact that conversion boundaries between modalities are determined by the perceptual qualities of different modalities. Meanwhile that quality is very subjective, so the user's weights can be used to scale the qualities of different modalities, resulting in the changes of conversion boundaries of a content object.

The syntax of modality conversion preference is shown in Fig. 4. Similar to Presentation Priority Preference, this preference is divided into General Resource Conversions and Specific Resource Conversion. With General Resource Conversion, the Conversion Type is applied directly regardless of the objects. Meanwhile, with the Specific Resource Conversion, we need to first specify the object, and then apply the Conversion Type.

The Conversion Type, as shown in Fig. 5, is the most important part of this description tool. It has elements From and To to indicate the original and destination modalities. The order and weight of each conversion are given as the attributes of Conversion Type. If the user

```
<xs:complexType name="ConversionType">
  <xs:complexContent>
    <xs:extension base="DIABaseType">
      <xs:sequence>
        <xs:element name="From" type="mpeg7:ControlledTermUseType" minOccurs="0"/>
        <xs:element name="To" type="mpeg7:ControlledTermUseType"/>
      </xs:sequence>
      <xs:attribute name="order" type="mpeg7:unsigned8" use="required"/>
      <xs:attribute name="weight" type="mpeg7:nonNegativeReal" use="optional" default="1.0"/>
    </xs:extension>
  </xs:complexContent>
</xs:complexType>
```

Fig. 5. Detailed syntax of the Conversion Type

uses the Modality Conversion Preference, he needs to specify at least the order of conversion (attribute order is "required"), which is the qualitative level of preference.

The detailed specifications of the two user preference tools can be found in[1]. In the next section we focus on the use of these user preferences in content adaptation process.

Ⅳ. Systematic approach for content adaptation

1. Problem Formulation

To tackle the above basic questions, the decision-making process of the decision engine will be first represented as the traditional resource allocation problem[7][8]. Let denote R_i and V_i the resource and content value of the content object i in the document. The content value V_i can be represented as a function of resource R_i, modality capability M_i, presentation priority preference P_i^p, and modality conversion preference P_i^m :

$$V_i = f_i(R_i, M_i, P_i^p, P_i^m). \quad (1)$$

Then the problem of content adaptation is that: given a resource constraint R_c, find the set of $\{R_i\}$ so as

$$\sum_i V_i \text{ is maximum, and } \sum_i R_i \le R_c \quad (2)$$

To solve this problem we first represent each content object with a content value model relating its content value with its resource. The content value models are then modified according to user preferences and terminal capability. After that, a resource allocation method is used to distribute the resource among multiple contents. Mapping the allocated resources back to content value models, we can find the appropriate qualities and modalities of adapted contents.

2. Content Value Model

Content value model is in fact a variation of the traditional rate-distortion model [7][8]. Content value model shows the relationship between the content value, i.e. the amount of information conveyed by the content, and its resource.

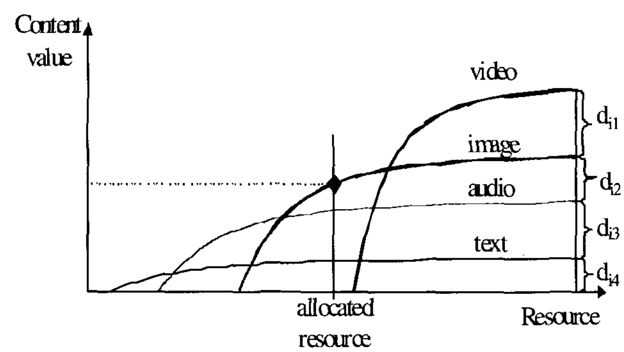


Fig. 6. Overlapped content value model of a content object

We have proposed a novel model, called the Overlapped Content Value (OCV) model[9]. Each content object will be given an overlapped content value model (Fig. 6) representing the content values of different modalities versus the resource. The number of curves in the model is the number of modalities the content object may have. Each point on a modality curve corresponds to a version of that modality. The final content value function will be the upper hull of the model, and the intersection points of the model represent the conversion boundaries between modalities.

Denote K_i as the number of modalities and VM_{ij} as the content value curve of modality j of the content object i, $j = 1...K_i$. The content value of a content object can be mathematically represented as follows:

$$V_i = max\{w_{ij} \cdot VM_{ij} \mid j = 1...K_i\} \quad (3)$$

where w_{ij} is the scale factor of modality j of object i and the value $j=1$ indicates the original modality of the object.

In essence, the OCV model helps clarify 1) the integrity and the trend of the content value of each modality, and 2) the relationship of multiple modalities within a model. This model plays a crucial part in content description. Moreover, it is the underlying basis to support user preferences and to make accurate decisions on modality conversion and content scaling.

3. The Use of User Preferences in Adaptation

The content value models are the important inputs of the adaptation process. In our approach, user preferences and are used to modify the content value models, resulting in appropriate changes at the output. For completeness purpose, the terminal capability is also considered.

3.1 Modifying according to modality capability

It is clear that when a terminal cannot support some modalities, the content values of those content versions at the terminal become zero. That means, the curves of the non-supported modalities need to be removed in the adaptation process. Then $V_i = max\{w_{ij} \cdot VM_{ij} \mid j \in \Im$, where $\Im$ is now the set of supported modalities.

3.2 Modifying according to user preferences

The presentation priority of a content object, showing the relative importance of the object with respect to other objects, can be combined into the content value model in various ways. One simple method is directly multiplying with the content value as follows:

$$V_i = max\{P_i^p \cdot w_{ij} \cdot VM_{ij} \mid j = 1...K_i \qquad (4)$$

If provider does not want to apply the presentation priority when the content object is not presented in its original modality, the content value can be represented by:

$$V_i = max\{P_i^p \cdot w_{i1} \cdot VM_{i1}, w_{ij} \cdot VM_{ij} \mid j = 2...K_i\} \qquad (5)$$

Based on the above formulation, which maximizes the total content value, the high-priority content object will tend to receive more resource, which results in a better quality.

Not only related to the amounts of resources, the presentation priorities can also be used to further control the transmission schemes of contents. For example, the high-priority content object may be sent early and with full available bandwidth, so the content object will be presented to user with the shortest download time.

Now consider the user preference on modality conversion. In fact, with a predefined content value model, there are already the orders of conversions. For example in Fig. 6, the video-to-video has the first order, video-to-image has the second order, and so on for the other conversions. These can be considered as the orders assigned by provider. User's orders of conversions may change the existing sequence of orders. In our approach all the curves that have violated orders (of user and provider) are removed. As mentioned above, the content values of modalities are very subjective. In our solution, the weights of conversions are used to scale the "distances" d_{ij} between the modality curves (as Fig. 6). The result of this scaling is the changes in the intersection points, or the boundaries between the modalities. If the weight of a curve increases, the operating range of the corresponding modality (delimited by the intersection points) will be broadened.

We can see that the presentation priority preference customizes the QoS tradeoff among different contents of a document in various ways. Further, the order and weight attributes of modality conversion preference customize the QoS tradeoff among the different modalities of each content object. The combination of these two preference tools effectively help to answer the basic QoS-related questions of the decision engine.

4. Resource Allocation

Given the content value models and resource constraint, we need a resource allocationmethod to find the optimal amount of resource for each content object. This problem is often solved by two basic methods, the Lagrangian method and the dynamic programming method[8]. The Lagrangian method is adopted in[7] to find the content versions having appropriate amounts of resource. However, the Lagrangian method is only suitable with the concave content value function, whereas the upper hull of our content value model is inherently non-concave. If it is replaced by the concave hull, the advantage of overlapped content value model in discriminating the modalities is degraded. So we decide to employ the dynamic programming method for resource allocation[8]. The advantage of the dynamic programming is its support for the non-concave functions, however its disadvantage is the high complexity. In order to speed up the allocation process, Viterbi algorithm[8] and some heuristic approximations are applied for dynamic programming.

V. Experiment results

We have deployed a trial system to test the usefulness and the efficiency of the user preferences and the above adaptation approach. The system includes a multimedia server and various types of clients such as PCs, Laptops, PDAs. The system is built based on some standardized parts of MPEG-21. The multimedia documents and user preferences are represented in XML format, namely the

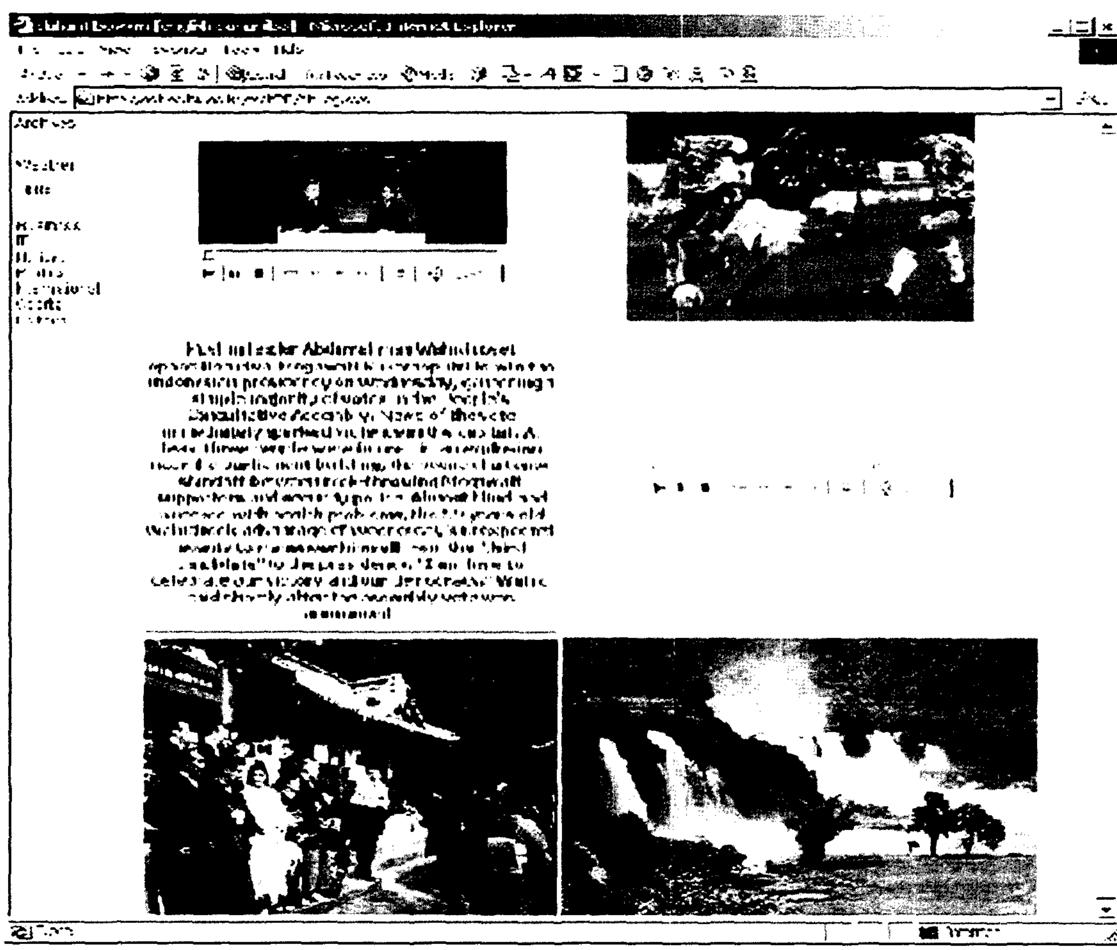
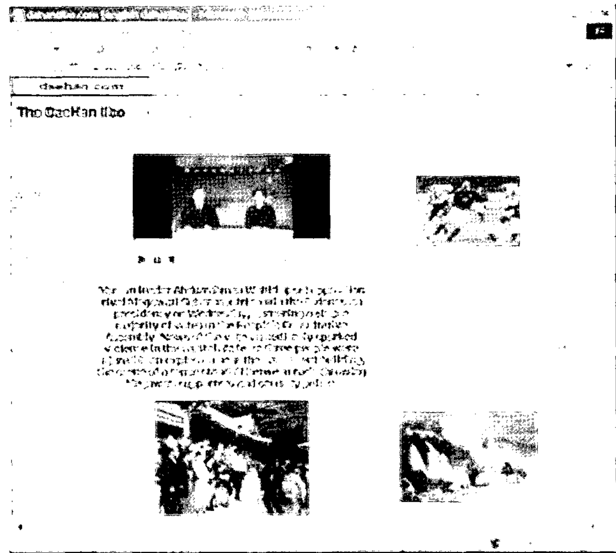


Fig. 7. Normally adapted document

```
<PresentationPreferences>
  <PresentationPriority>
    <SpecificResourcePriorities>
      <Object priorityLevel="2"
              target="http://myhost.org/CDI.xml#IT1"/>
    </SpecificResourcePriorities>
  </PresentationPriority>
</PresentationPreferences>
```



(a) (b)

Fig. 8. XML description (a) and the corresponding adapted document (b) when video priority is 2

CDI (content digital item) and XDI (context digital item). The OCV model is constituted from the utility functions of AdaptationQoS for different modalities. In the current experiments, resource constraint R_c is the total data size at client, measured in Kilobytes.

We have a multimedia document which has one MPEG-1 video object, one MP3 audio object, three JPEG image object, and one text object. Default values of priority and weight are 1. The maximum content values for the objects are manually assigned to 10, 3.0, 5.5, 6.0, 6.5, and 1.5 respectively. Due to the limited space, we just show some experiment examples here. Fig. 7 shows a normally adapted document when $R_c=1100$.

Now the user is interested in the video (at the left-top of document) and gives high priority value of 2 to video content. Fig. 8a shows the XML description of Presentation Priority Preference, having only the specific priority of video content. Fig. 8b shows the corresponding adapted document. We can see that the video quality is enhanced, however, the quality of images are degraded to make space for video.

In the above cases, there is no modality conversion. However, when R_c is reduced to 700, the newly adapted document is shown in Fig. 9. We can see that the video is now converted into a sequence of images, and the two bottom images are converted into audios.

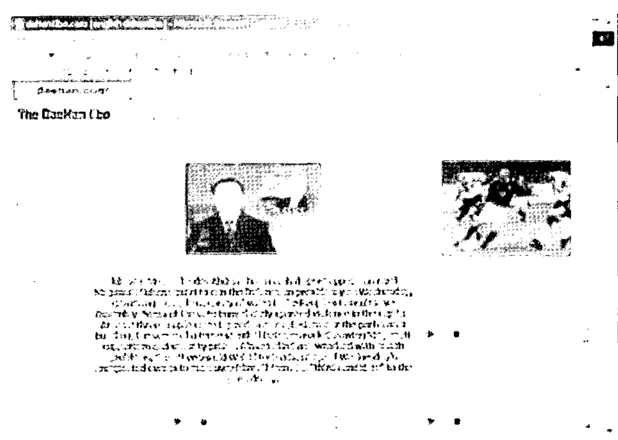
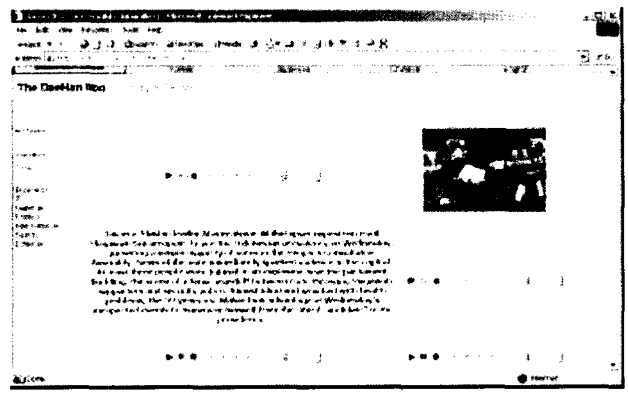


Fig. 9. Adapted document with $R_c=700$ and default orders

These conversions are carried out according to the default orders of Fig. 6. The user can request the video to be converted to audio by setting the order of video-to-audio higher than the order of video-to-image. The XML description specifying the new orders of

```xml
<PresentationPreferences>
  <ModalityConversionPreference>
    <GeneralResourceConversions>
      <Conversion order="1" weight="1.0">
        <From href="urn:mpeg:mpeg21:cs:ModalityCS:2003:1">
          <mpeg7:Name>Video</mpeg7:Name>
        </From>
        <To href="urn:mpeg:mpeg21:cs:ModalityCS:2003:1">
          <mpeg7:Name>Video</mpeg7:Name>
        </To>
      </Conversion>
      <Conversion order="3" weight="1.0">
        <From href="urn:mpeg:mpeg21:cs:ModalityCS:2003:1">
          <mpeg7:Name>Video</mpeg7:Name>
        </From>
        <To href="urn:mpeg:mpeg21:cs:ModalityCS:2003:2">
          <mpeg7:Name>Image</mpeg7:Name>
        </To>
      </Conversion>
      <Conversion order="2" weight="1.0">
        <From href="urn:mpeg:mpeg21:cs:ModalityCS:2003:1">
          <mpeg7:Name>Video</mpeg7:Name>
        </From>
        <To href="urn:mpeg:mpeg21:cs:ModalityCS:2003:3">
          <mpeg7:Name>Audio</mpeg7:Name>
        </To>
      </Conversion>
      <Conversion order="4" weight="1.0">
        <From href="urn:mpeg:mpeg21:cs:ModalityCS:2003:1">
          <mpeg7:Name>Video</mpeg7:Name>
        </From>
        <To href="urn:mpeg:mpeg21:cs:ModalityCS:2003:4">
          <mpeg7:Name>Text</mpeg7:Name>
        </To>
      </Conversion>
    </GeneralResourceConversions>
  </ModalityConversionPreference>
</PresentationPreferences>
```

(a)

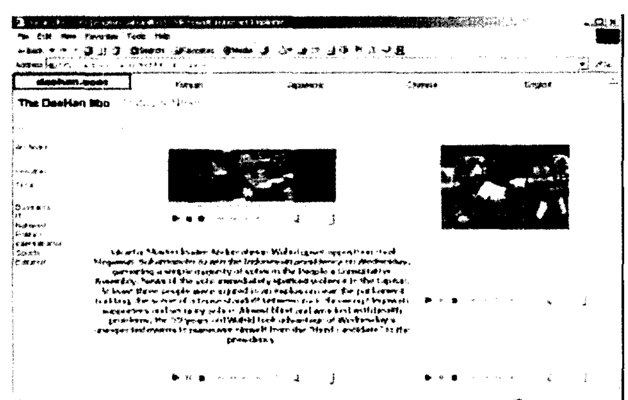


(b)

Fig. 10. XML description (a) and the adapted document (b) when $R_c = 700$ but video-to-audio is preferred

```xml
<PresentationPreferences>
  <ModalityConversionPreference>
    <SpecificResourceConversions>
      <Object target="http://myhost.org/adaptedCDI.xml#IT1">
        <Conversion order="1" weight="5">
          <From href="urn:mpeg:mpeg21:cs:ModalityCS:2003:1">
            <mpeg7:Name>Video</mpeg7:Name>
          </From>
          <To href="urn:mpeg:mpeg21:cs:ModalityCS:2003:1">
            <mpeg7:Name>Video</mpeg7:Name>
          </To>
        </Conversion>
        <Conversion order="2" weight="1.0">
          <From href="urn:mpeg:mpeg21:cs:ModalityCS:2003:1">
            <mpeg7:Name>Video</mpeg7:Name>
          </From>
          <To href="urn:mpeg:mpeg21:cs:ModalityCS:2003:2">
            <mpeg7:Name>Image</mpeg7:Name>
          </To>
        </Conversion>
        <Conversion order="3" weight="1.0">
          <From href="urn:mpeg:mpeg21:cs:ModalityCS:2003:1">
            <mpeg7:Name>Video</mpeg7:Name>
          </From>
          <To href="urn:mpeg:mpeg21:cs:ModalityCS:2003:3">
            <mpeg7:Name>Audio</mpeg7:Name>
          </To>
        </Conversion>
        <Conversion order="4" weight="1.0">
          <From href="urn:mpeg:mpeg21:cs:ModalityCS:2003:1">
            <mpeg7:Name>Video</mpeg7:Name>
          </From>
          <To href="urn:mpeg:mpeg21:cs:ModalityCS:2003:4">
            <mpeg7:Name>Text</mpeg7:Name>
          </To>
        </Conversion>
      </Object>
    </SpecificResourceConversions>
  </ModalityConversionPreference>
</PresentationPreferences>
```

(a)



(b)

Fig. 11. XML description (a) and the adapted document (b) when $R_c = 700$ and weight of video-to-video is increased to 5

conversions is shown in Fig. 10a. Now the order of video-to-image is 3 and order of video-to-audio is 2. And the corresponding adapted adaptation is shown in Fig. 10b. We can see that now video is converted to audio.

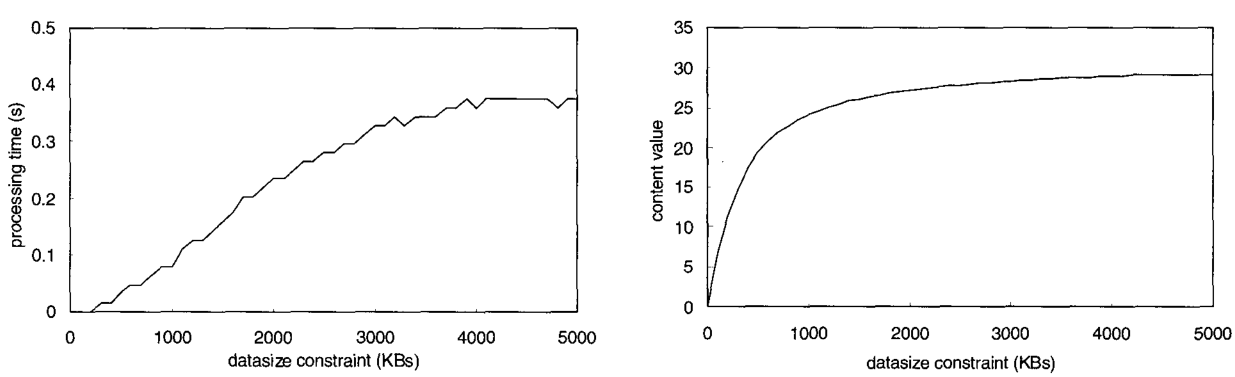
On the other hand, user may request to retain the video modality by increasing the weight of video-to-video conversion. Fig. 11a shows the XML description where Specific Resource Conversion is used to set weight of video-to-video conversion to be 5. The adapted document is shown in Fig. 11b. In this case the video quality is not quite good, but that is what the user prefers.

The performance of the decision engine is summarized in Fig. 12, which shows the total content value of the adapted document and the processing time of decision engine with respect to different values of datasize constraint. It shows that the total content value and the processing time decrease accordingly when the datasize constraint is reduced. And when the datasize constraint is high, the total content value and processing time become saturate. For the current document, the maximum processing time is below 0.4 second. One important feature of multimedia document is that the number of content objects in a document is not many, often not more than a few dozens. Our experiments also show that the processing time for such numbers of objects is just several seconds, which is acceptable for the practical Internet services.

These experiments show that the proposed adaptation approach and preference tools well service user's needs in various conditions in practice.

Ⅵ. Conclusion

In this paper, we have presented two important description tools of user characteristics in MPEG-21 DIA, the presentation priority and modality conversion preferences. These tools are crucial in providing customized content presentations to different users. They cover the QoS aspects related to quality and modality of all content objects in a multimedia document. We also described a systematic adaptation approach for integrating these user preferences. The combination of the overlapped content value model, user preferences, and the dynamic programming method, provides a comprehensive solution for content adaptation. UMA system based on this approach can handle multiple contents, support flexible user preferences and accommodate different situations of terminal and network. Our future works will be carried out in three main directions. The first is exploring more efficient ways to combine the user preferences into the content adaptation process. The second is further modeling the content value of contents within a single modality and across multiple modalities. And the third is



(a) (b)

Fig. 12. Performance comparison of the decision engines using Viterbi algorithm. Fig. 12a shows the total content value of adapted document and Fig. 12b shows processing time with respect to different values of datasize constraint.

extending the adaptation approach to support a combination of different resource constraints such as bandwidth, data size, computational complexity, etc.

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