Personalized Digital Item Adaptation in Service-Oriented Environments

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Abstract

The delivery of multimedia content often needs the adaptation of the content in order to satisfy user constraints. With the Digital Item Adaptation part, the MPEG-21 standard already defines a useful framework to handle this task. However, when the functionality of adaptation is split over several services the central instantiation of a suitable service chain needs to tackle a complex multi-objective optimization problem. In this problem between content choice and possible adaptations the current preference model in the MPEG-7/21 standard still lacks expressiveness. In the course of this paper we demonstrate this shortcoming and how the integration of more powerful models can ease the instantiation problem. As a running example we use a typical media streaming application with Web services as basic modules. We will let a central coordinator instantiate a service composition by integrating all needed Web services to adapt the multimedia content in the best possible fashion.

1. Introduction

Delivering multimedia content over a plethora of devices in a personalized fashion puts great demands on the selection and adaptation of content [12]. For every individual user a specific workflow has to be created respecting the user's content preferences, content semantics and network constraints, as well as terminal capabilities. Today, instead of building complex monolithic systems the flexible composition of services into suitable workflows for media handling is an important goal for system integration and reusability of components (for an overview see [9]). Such workflows have to be planned and their execution closely monitored, sometimes needing the seamless integration of replacements for failed services. Moreover, the instantiation of the service chain needs to solve a multi-objective optimization problem considering possible services (as have been discovered, cf. [1]), the content currently available and the author's, user's and client device's constraints on the adaptation.

In this paper we address the problem of adapting content in a personalized fashion by integrating MPEG-7/21 metadata with a complex preference framework, namely a model on qualitative partial order preferences (cf. [2], [5]). The benefit is twofold: on one hand integrating a more powerful model enables higher expressiveness of preferences; on the other hand services along the workflow chain can use the augmented metadata for choosing adaptation strategies more intelligently. Every service adapts the metadata according to the transformation of the content it performed and removes obsolete preference information. This also enables a more efficient matching of constraints for those services later in the service composition chain.

As a running example application throughout this paper we will use media streaming that flexibly adapts the multimedia content to the terminal capabilities of the user. Thus, users get the best possible quality with respect to their terminal capabilities. Our implementation uses Web services as basic modules for building multimedia applications. The description of the complex data types is provided by an MPEG-7/21 description attached to the media data. Each individual Web service evaluates the MPEG-7/21 description and adapts the multimedia material to the special needs of the user and the client device.

To coordinate the composition we currently use a central Web service that takes over responsibility for selecting the best available content and a suitable workflow by means of the technical profile and user preferences [1]. This *service instantiation and monitoring service (SIAM)* does also monitor the workflow, but it does not in detail decide in what way each Web service should adapt the multimedia content. Every individual Web service (e.g., merging or transcoding services) can use its own heuristics about how to adapt the selected multimedia content best with respect to the terminal capabilities of the end-user. In addition to the purely technical information, the services also use important description schemes from the MPEG-7/21 standard like e.g., transcoding hints [11].

Whereas our focus is on the integration of complex preference frameworks, the basic usefulness of the user preferences description scheme for automatic content adaptation has already been shown by a variety of approaches. [13] provides an useful overview of current digital item adaptation techniques in MPEG-21 and how they can be used in multimedia applications. The work in [10] goes beyond mere adaptation and provides concrete methodologies to open up the MPEG-7/21 usage environment for expressing more complex semantic user preferences. For eliciting and maintaining preferences [6] build a usecase of an advanced electronic program guide, where the user's interactive behavior with programs is monitored, and the user preferences are updated accordingly. Here, the relative importance of different preferences can be generated automatically.

In terms of the service-oriented processing of multimedia data the MPEG-21 standard also introduces network quality of service (QoS) tools. For choosing adequate network paths the usefulness of integrating more complex user preferences has already been recognized, e.g. for telephony [4]. However, the actual measurement of adequate information to decide for the best service paths is still difficult and beyond the scope of this paper (see e.g., [3] and [8]).

2. Metadata Descriptions in MPEG-7/21

The MPEG-7/21 *Usage Environment* is part of the MPEG-21 Digital Item Adaptation (DIA) architecture (Part 7, ISO/IEC 21000-7) and offers several opportunities to define user specific information. It includes the *User Interaction Tools* from MPEG-7 [11] and also the description elements for the device capabilities of the user (in the *Terminal Capabilities* description scheme). Figure 1 shows the typical interaction of a content adaptation engine with a media database and the end user, respectively his/her client device.

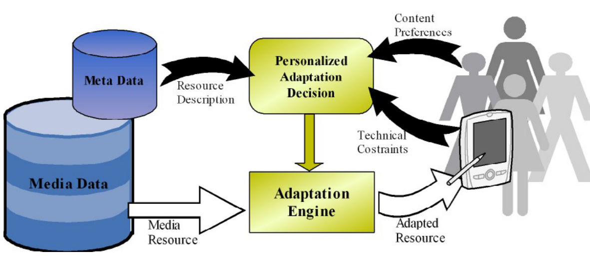

Figure 1: Digital Item Adaptation

Media data generally is retrieved by matching metadata descriptions. To perform a content selection the personalized adaptation decision engine matches the resource descriptions from a metadata directory and the user-provided information. This document contains content preferences of the user, the actual user query and technical constraints that include information about the technical device of the user. After determining the optimal adaptation, the decision is handed on to the adaptation engine. The adaptation engine retrieves the media resource from the media data database, adapts it and sends the adapted resource to the user. Basically an adaptation works as follows:

1. *The decision engine gets a request with content preferences and technical constraints*
2 *If the requested media is available and all constraints are satisfied the respective multimedia data is directly delivered*
3 *If the requested media is available, but the constraints are not satisfied*
   3.1 *If the multimedia data is adaptable, adapt media accordingly and deliver*
   3.2 *If not choose highest ranked preference to adapt to other formats or resolutions or to choose new content*

However, this adaptation scheme cannot work with more complex trade-offs, and decide intelligently when to choose alternative adaptation options that would make more sense than simply the highest rated preference. We now take a closer look on what MPEG-7/21 can actually express in user preferences.

The *User Interaction Tools* (UIT) offer possibilities to describe content preferences of the user. In contrast to the other description schemes defined in MPEG-7 the UIT are bound to the user and not to the multimedia material: the *User Preferences* are used to express specific preferences of the user in the selection of multimedia material and consist of several description schemes:

- A set of *Filtering and Search Preferences* describes individual user wishes with respect to the filtering and searching of multimedia data. Each element is decomposed into:
  - *Filtering and Search Preference* elements on a lower level to allow for preference hierarchies.
  - *Classification Preference* elements to describe preferences regarding to attributes, such as language, production format or country of origin.
  - *Creation Preference* elements to describe the preferred creation of content, such as title, creator or creation date.
  - *Source Preference* elements where preferred repositories to retrieve multimedia

material from (e.g., media servers or digital libraries) can be defined.
  - *Preference Condition* elements where the user can constrain the applicability of specific filtering and search preferences (for example time and date).
- A set of *Browsing Preferences* elements describe the user's wishes regarding multimedia content navigation and browsing. A typical example is a *Summary Preference* describing the preferred type of content summaries.

If the user got more than one preference, a weighting factor, the *Preference Value*, can be specified to express the relative importance of a preference. The preference value is a numerical value ranging from -100 to 100. With a negative weighting the user can express negative preferences. The following example shows a complex preference for user 'Kim', who prefers 'Action' movies with 'Matt Damon' and movies that are in German language.

```
<UserPreference>
 <UserIdentifier userName="Kim"/>
 <UsagePreference>
  <FilteringAndSearchPreferences>
   <FilteringAndSearchPreferences preferenceValue="63">
    <ClassificationPreference>
     <Genre>Action</Genre>
    </ClassificationPreference>
    <CreationPreference>
     <Actor>Matt Damon</Actor>
    </CreationPreference>
   </FilteringAndSearchPreference>
   <FilteringAndSearchPreference preferenceValue="50">
    <ClassificationPreference>
     <Language>german</Language>
    </ClassificationPreference>
   </FilteringAndSearchPreference>
  </FilteringAndSearchPreference>
 </UsagePreference>
</UserPreference>
```

To decide between preferences the preference values are compared: the higher the value, the more important the preference. However, the MPEG-7/21 standard just defines the syntax and semantics of the user preference description scheme, but not the extraction method of the preference value, cf. [6]. That means all users have assign preference values *manually*. But can semantically incomparable preferences (like actors and language settings) be compared in a quantitative way? It hardly makes sense to state something like: 'I prefer Matt Damon movies to movies in German'. Moreover, for the user it is entirely unintuitive, what an individual preference value (like 63) actually means. Other authors, e.g. [14], have proposed to use even more complex utility functions, but after all still rely on an unintuitive quantitative preference framework.

A simple matching of preference values does often not lead to effective trade-off management. This is because preferences generally distinguish between hard and soft constraints. Hard constraints have to be adhered to, no matter how (un-)important the respective preference is. Consider transcoding hints, where the original author of the multimedia material can define how the properties of the multimedia content can be changed without compromising the content's semantics. For example it can be established that the resolution of a movie can only be reduced up to 50% of the original resolution. A further reduction simply does not make sense; even if it is exactly the content a user requested by expressing content preferences with high preference values. On the other hand a user might express a preference for best possible resolution. Such a preference can be considered a soft constraint that can be relaxed, if necessary.

Generally speaking two hard boundaries always constrain service compositions (cf. figure 2): the device capabilities form upper boundaries for the capabilities of the terminal, like for example the maximum possible resolution. The transcoding hints form lower boundaries for the quality of multimedia material, like for example the minimum possible resolution. If the device capabilities and transcoding hints do not overlap a sensible media adaptation without changing the modality is not possible (cf. figure 2).

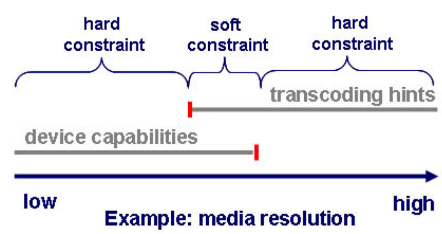

Figure 2: Boundaries for Media Adaptation

Whereas basically for adaptation of the multimedia material our SIAM service uses the InfoPyramid approach [7] to offer multimedia content in alternative fidelities and/or modalities, in case of impossible adaptations the user's content preferences are used to choose alternative media and thus realize a cooperative retrieval behavior.

3. A More Expressive Preference Model

The need of such an effective trade-off management with complex user preferences has already been considered in other communities like e.g., in database systems. Here, recent work in [2] and [5] considers preferences in a qualitative way as partial orders of preferred values that can be relaxed up to a certain point. To combine multiple preferences usually the notion of Pareto optimality is used resulting in all possible solutions that are not dominated with respect to all predicates in the media request. That means all preferences on different predicates are considered to be equally important, the sub-optimal solutions are removed and out of the remaining pool of possible solutions our SIAM service can pick a suitable instantiation. Of course also other combination methods (e.g. an ordering on the predicates similar to the current preference values in MPEG-7/21) can be used.

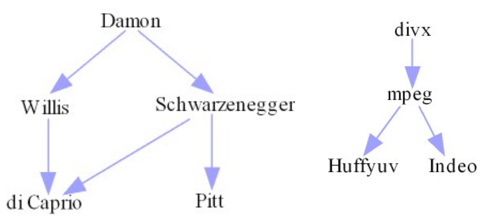

Figure 3: Explicit Preference Graphs

Example: Consider a user with a PDA who requests media and explicitly expresses two preferences, one about preferred movie actors and one about preferred codecs available of his/her client device (as defined by the terminal capabilities): The corresponding preference graphs might look as shown in figure 3. We extended the MPEG-21 notation to express these preferences in XML, e.g., the first preference:

```
<UserPreference>
 <UserIdentifier userName="Kim"/>
 <UsagePreference>
    <Preference>
      <EXP att="actor">
        <EXPSet>
          <Value val1="Damon" val2="Willis">
          <Value val1="Damon" val2="Schwarzenegger">
          <Value val1="Willis" val2="di Caprio">
          <Value val1="Schwarzenegger" val2="di Caprio">
          <Value val1="Schwarzenegger" val2="Pitt">
        </EXPSet>
      </EXP>
    </Preference>
 </UsagePreference>
</UserPreference>
```

To combine several preferences the combination semantics has to be stated. Figure 4 shows the first layers of a Pareto preference graph, which is already quite complex for combining only the two preferences from figure 3. Please note that due to the qualitative nature of the preferences some combinations are incomparable: if the best choice (a Matt Damon movie in divx format) should not be available or adaptable (e.g., missing a suitable transcoding service), the adaptation decision can explore several other options that are all equally preferable such as a Matt Damon movie in mpeg format or a Bruce Willis movie in divx format.

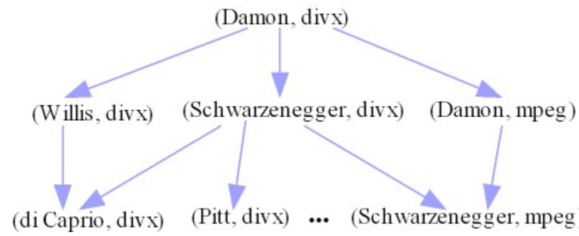

Figure 4: Pareto Preference Graph

To express such Pareto preferences in XML we allow to qualify the combination of explicit preferences following the respective preference algebra (see [5] for details on the evaluation of complex constraints):

```
<UserPreference>
 <UserIdentifier userName="Kim"/>
 <UsagePreference>
    <Preference>
     <Pareto>
      <EXP att="actor">
        <EXPSet>
          <Value val1="Damon" val2="Willis">
          <Value val1="Damon" val2="Schwarzenegger">
          <Value val1="Willis" val2="di Caprio">
          <Value val1="Schwarzenegger" val2="di Caprio">
          <Value val1="Schwarzenegger" val2="Pitt">
        </EXPSet>
      </EXP>
      <EXP att="codec">
        <EXPSet>
          <Value val1="divx" val2="mpeg">
          <Value val1="mpeg" val2="Huffyuv">
          <Value val1="mpeg" val2="Indeo">
        </EXPSet>
      </EXP>
     </Pareto>
    </Preference>
 </UsagePreference>
</UserPreference>
```

Figure 5 shows the basic approach of our preference trade-off management. The user requests media from our central SIAM service and provides constraints and preferences in the form of content preferences (UP) and technical capabilities (TC). The decision engine negotiates the content by retrieving all necessary metadata including the respective transcoding hints (TH).

The decision engine part of the SIAM service decides by means of the given constraints which Web services are needed to perform the media delivery. Possible Web services (which are discovered by the service instantiation part) have to respect the preferences to choose an optimal adaptation of the multimedia data for each individual user.

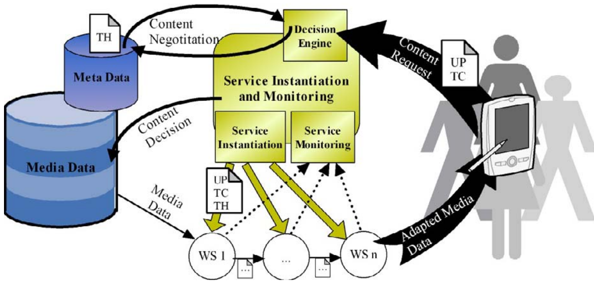

Figure 5: Service-oriented Adaptation

Example (cont.): Assume our user requests a movie to be delivered to a PDA in low resolution and additionally states the preferences in figure 3. Further assume there is only a Matt Damon movie in mpeg format available. This combination is definitely not optimal. Now we have different possibilities:

- Retrieve the movie with Matt Damon in mpeg format and transcode it into divx format.
- Retrieve a movie with Bruce Willis in divx format.
- Retrieve a movie with Arnold Schwarzenegger in divx format.
- Deliver the movie with Matt Damon in mpeg format.
- …

According to Pareto optimality the first option is the best possible solution, the next three options are equally preferable alternatives in case the first option fails, and so on. The service instantiation thus first tries the transcoding of the movie into divx format: to do this it has to integrate a suitable transcoding service into the delivery workflow and hand over all preference constraints. The transcoding service is now enabled to check, if it is sensible to transcode the movie into divx, e.g. matching service specific constraints (like the time needed for transcoding, etc.) against the user-provided constraints. If not, an alarm is raised to the monitoring service as described in detail in [1] and the SIAM service checks all possible alternatives. It will settle on the best possible solution with respect to the adaptation possibilities and initiate the workflow needed to adapt this movie. Please note that current MPEG-7/21 preferences encounter the same situation, if two choices feature the same preference value.

If the transcoding succeeds a scaling service is still needed, to adapt the current resolution of the movie to the highest possible display resolution of the PDA. This service again gets all preference data and decides locally if it is sensible to scale down the resolution. To make a decision about that, the Web service for example compares the information from the transcoding hints to the terminal capabilities. If a mismatch occurs, again an alarm has to be raised. Please note, that though some checks can already be performed by the adaptation decision engine, the services always may have to integrate local parameters into the decision whether and how to perform a task.

In addition the user might need the possibility to declare some preferences as hard constraints. Maybe our user only wants the movie with Matt Damon in divx, though other codecs would be available on the client device. To express such a preference the user needs the possibility to declare an explicit preference as hard constraint, thus overwriting respective preferences as given by other parts of the profile. We realized this by preference tags containing an additional attribute ‘*constraint="hard"*’, which signalize the SIAM service (and all subsequent Web services) that this preference must not be violated.

4. A Media Streaming Test Case

To proof our concepts we implemented the key features in a small testbed. Since we were interested in deriving suitable adaptations our implementation focused specifically on the changes in the metadata documents and what could be derived as adaptation decision. We did not perform the actual adaptation of the video files. All Web services have been developed in Microsoft Visual Studio .NET in C#. For interaction the SIAM service is addressed by a PHP interface, where users can place requests.

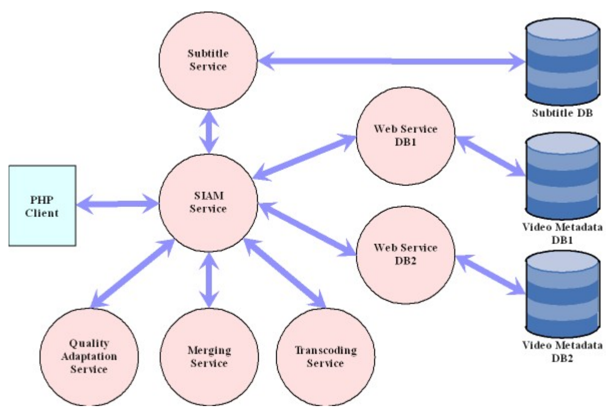

Figure 6: Experimental Scenario

Figure 6 shows our basic testbed. The experimental scenario focussed on the retrieval of videos from alternative databases, the merging with subtitles in different languages, as well as transcoding and quality adaptation. The initial query parameters, the user preferences and terminal capabilities are written into a MPEG-21 document, which is sent to the SIAM service for further processing. A typical workflow may request subtitles for a certain movie and the SIAM service will choose an adequate workflow from a set of patterns. Such subtitles are also saved into the MPEG-21 metadata document and handed on to the merging service together with the original media from the database. After the merging process the service removes the now obsolete subtitles and the language preferences from the metadata document of the adapted movie. If necessary it can then be handed on to a transcoder or quality adaptation service.

Throughout our experiments it proved possible to create a dynamic service composition based on the metadata with the SIAM service as central coordinator.

5. Conclusions and Future Work

With the increasing need of service oriented concepts in complex multimedia applications also the adaptation of content is split into several tasks. Depending on the available media, the discovered services and all semantic, user-specific and technical constraints, the selection of the best possible workflow needs to solve a complex preference problem. The current preference model in the MPEG-7/21 standard, however, is limited to the simple matching of numerical values representing the importance of each constraint. Hence for complex instantiations of workflows in a service-oriented adaptation engine a more sophisticated preference model is needed.

By integrating a model of partial order preferences and evaluating complex preference constraints using the respective algebra, we are able to handle trade-offs in a more meaningful way. We have shown on the example of a typical media streaming scenario that an automatic adaptation of the multimedia content is possible by means of structured metadata information. This information is augmented by all Web services in the workflow and allows an intelligent adaptation process. Every single Web service can decide how to adapt multimedia material the best.

After implementing the key components as a proof of concept we are currently implementing the entire framework including the actual adaptation of video streams to get further insights on the scalability of our approach. The MPEG-21 standard already provides description schemes to contain network QoS parameters, which will have a strong influence on the scalability of service-oriented adaptation processes. We want to explore in how far these parameters can be measured or estimated accurately enough to guarantee stable service compositions. Another open question is, if the routing path should also be determined by preferences. Generally speaking, routing media can be performed in a custom-made overlay allowing the distribution of services along the routing path. Here, the effective management of trade-offs for all services involved can lead to a better overall service for end users.

6. References

[1] W.-T. Balke, J. Diederich: A Quality- and Cost-based Selection Model for Multimedia Service Composition in Mobile Environments. In *IEEE Int. Conf. on Web Services (ICWS),* Chicago, IL, USA, 2006.

[2] J. Chomicki: Preference Formulas in Relational Queries. In *ACM Transactions on Database Systems (TODS), Vol. 28 (4),* 2003.

[3] X. Gu, K. Nahrstedt, R. Chang, C. Ward: QoS-assured Service Composition in Managed Service Overlay Networks, In *IEEE ICDCS 2003,* Providence, RI, USA, 2003.

[4] W. Kellerer, M. Wagner, W.-T. Balke, H. Schulzrinne: Preference-based Session Management for IP-based Mobile Multimedia Signaling. In *European Transactions on Telecommunications, Vol. 15 (4),* Wiley, 2004.

[5] W. Kießling: Foundations of Preferences in Database Systems. In *Int. Conf. on Very Large Databases (VLDB),* Hong Kong, China, 2002.

[6] H.-K. Lee, J. Nam, B. Bae, M. Kim, K. Kang, J. Kim: Personalized Contents Guide and Browsing based on User Preference. In *AH2002 Workshop on Personalization in Future TV,* Malaga, Spain, 2002.

[7] C.-S. Li, R. Mohan, J. R. Smith: Multimedia Content Description in the InfoPyramid. In *IEEE Int. Conf. on Acoustics, Speech and Signal Processing,* Seattle, WA, USA, 1998.

[8] K. Nahrstedt, D. Xu: Finding Service Paths in a Media Service Proxy Network. In *SPIE/ACM Multimedia Computing and Networking Conference (MMCN),* San Jose, CA, USA, 2002.

[9] K. Nahrstedt, W.-T. Balke: Towards Building Large Scale Multimedia Systems and Applications: Challenges and Status. In *ACM Workshop on Multimedia Service Composition (MSC),* Singapore, 2005.

[10] C. Tsinaraki, S. Christodoulakis: Semantic User Preference Descriptions in MPEG-7/21. In *Hellenistic Data Management Symposium (HDMS),* Athens, Greece, 2005

[11] P. van Beek, A. B. Benitez, J. Heuer, J. Martinez, P. Salembier, J. Smith, T. Walker: MPEG-7 Multimedia Description Schemes (Version 3.1, Working Draft), *ISO/IEC,* 2000.

[12] A. Vetro: MPEG-21 Digital Item Adaptation: Enabling Universal Multimedia Access. In *IEEE Multimedia, Vol. 11 (1),* 2004.

[13] A. Vetro, C. Timmerer: Digital Item Adaptation: Overview of Standardization and Research Activities. In *IEEE Transactions on Multimedia, Vol. 7 (3),* 2005.

[14] M. Zhou, V. Aggarwal: An Optimization-based Approach to Dynamic Data Content Selection in Intelligent Multimedia Interfaces. In *ACM Symposium on User Interface Software and Technology,* Santa Fe, NM, USA, 2004.