Enhancing Domain Model with Performance Oriented Metadata for Adaptive E-learning Systems

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Abstract

Due to the increasing complexity of web site navigation, but also as a response to the "one size fits all" approach, adaptation mechanisms have emerged and have started to be used by a large number of on-line educational systems. As educational content may be delivered though various types of networks that differ in characteristics and vary with the time, the quality of the transmitted information is affected. PAMAH (Performance-Aware Multimedia-based Adaptive Hypermedia) proposes to overcome this barrier by taking into consideration in the personalisation process not only the classic learner profile but also the performance of the network connection used by the learner, when rich media content is delivered. This paper focuses on presenting performance oriented metadata required for modelling the educational content and for enhancing the adaptation process. The goal is to provide a personalised media rich content suitable for the learner network connection.

1. Introduction

E-learning systems are plagued by the same problems that all rich content and link structured hypermedia systems exhibit: the learner suffers from the "lost in the hyperspace" syndrome and when s/he finally arrives to the targeted information, s/he realizes that the information is either too complex and further explanations are required, or too many details are presented and it is difficult to follow it. This happens when the provided information does not suit learner goal and knowledge. Adaptive Educational Hypermedia (AEH) comes as a solution for these problems by providing adaptive navigation support (link adaptation) and adaptive presentation support (content adaptation) based on a learner profile.

The typical components of a traditional Adaptive Educational Hypermedia System (AEHS) are: the User Model (UM), the Domain Model (DM) and the Adaptation Model (AM) [1]. The UM maintains information about the user which is relevant during the adaptation process. This information is collected directly from the learner, or by monitoring s/he behaviour while interacting with the e-learning system. DM consists of a collection of learning resources and their attributes. AM consists of rules used during both content and navigation support adaptation process. These rules combine information from the DM and UM in order to provide a personalized educational content. For example, a user who has knowledge about a certain subject would need maybe just a brief review, whereas a novice learner will need more explanation, in order to understand the same concept.

Different AEHS have been developed and they consider different aspects related to the learner such as: knowledge [2], goal [3], learning style [4], learner device [5], prerequisite and experience [6], etc. A number of research projects [7, 8, 9, 10] have also focused on innovative techniques for modelling the learning resources (Domain Model). While most of AEHS are based on the learner knowledge, interests or learning styles there are very few who have considered learner connectivity conditions when it comes to transmitting the education content [11]. It had been shown that the combination of the network QoS with the personalised delivery of educational content containing text and images, improved the learning outcome [12, 11]. Since video files are more and more used for providing educational content, their quality as perceived by the learner when delivered over a given connectivity should be analysed and considered in the content selection process. These files, having a large size, are difficult to be transmitted over the network and delay and loss of information are unavoidable. The delay affects the learner that has to have patience until the video is downloaded. Loss affects the integrity of the delivered information.

Considering all these aspects we believe that adaptive e-learning systems should consider learner connectivity aspects in the personalisation process as well as the suitability of a given media clip to the current network delivery conditions. Metadata on the characteristics of the multimedia content such as bit rate, resolution, file format should be added to the domain model and later on to be used by the adaptation model. This paper focuses on presenting how this metadata can be authored in the Domain Model and used by the Adaptation Model in the content selection process

2. Framework for Assessing Network Performance in AEHS

The goal of the PAMAH framework is to offer, besides the adaptation based on the classical learner profile, also an adaptation based on the learner network conditions. The idea is that there is no use in providing the user with the best quality multimedia files if (because of the network conditions) the files will arrive at the learner having a poor quality. The system also evaluates what is the acceptable quality of the multimedia files for the learner. The PAMAH (Figure 1) components are modularized in order to increase reusability. It extends the QoE-aware AHS [10] in order to allow for the delivery of multimedia content.

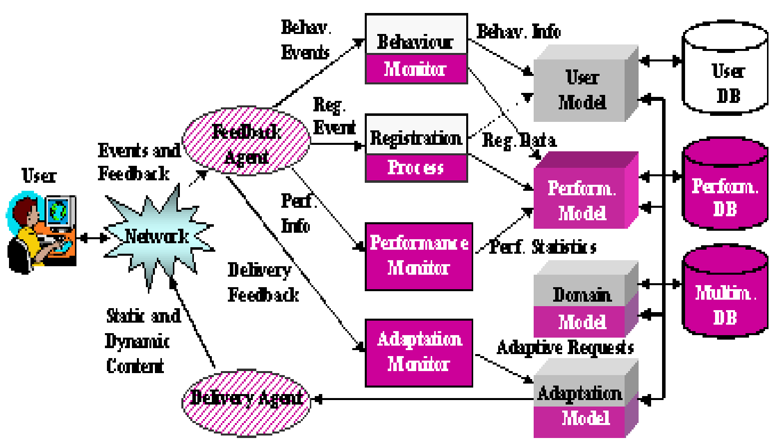

Figure 1 PAMAH framework

The PAMAH framework adds to the traditional AEHS (that consists of DM, UM and AM) a new layer: Performance Model (PM) in order to perform an optimised multimedia selection and adaptation. It models information about the network performance and media stream processing.

The AM (Adaptation Model) performs both the personalization based on the learner profile and the adaptation of the content to the network conditions. It takes into account both the information contained in the UM and PM.

3. Domain Model enhanced with performance oriented metadata

The Domain Model (DM) contains fragments of educational content (e.g. multimedia clips) between which logical relationships exist. Fragments may be grouped based on the relationship between them in order to form concepts. The concepts are grouped again in order to form a more complex concept, or even educational units.

In order to provide the separation between the DM and AM, a concept must be uniquely identified. Therefore every concept within DM has an attribute, *conceptId*, which will uniquely identify the concept. In this way, the adaptation rules are created for a class of concepts, instead of having rules for every individual concept, which would be unrealistically for large courses or courses on which the concepts change quickly (e.g. a course for the fields where the information becomes quickly outdated).

Every fragment has associated specific attributes (metadata). In order to allow multimedia manipulation, the domain model is enhanced with specific attributes based on the resource type. Text, image and video fragment types are considered.. The following metadata is added:

- *Text* files metadata*: size* (kilobytes)*, length* (number of words)*, format* (e.g. plain text).
- *Image* files metadata: *size* (kilobytes), format (e.g. jpg), resolution (pixels).
- *Video* files metadata: *bitrate* (megabits per second), *framerate* (frames per second), *resolution* (pixels), *colours* (number of colours represented in bits required for encoding), *encoding* (e.g. MPEG4).

DM allows multiple versions of the same content to be associated with the same fragment. Different versions of video with different qualities are associated to each fragment. Based on the attached metadata (which describes their performance characteristics) and taking into account the network performance, the version which best suit to the learner is delivered.

4. Exemplification

In order to develop a prototype version of PAMAH we extend AHA! [6]. AHA!-an Open Source AESH, developed at the Eindhoven University of Technology. In order to allow for multimedia content manipulation, we integrated with the DM different variants of the same multimedia type learning objects (LO) and we added performance oriented metadata. The AHA! Application Management Tool (Figure 2) is used in order to add performance oriented metadata to each multimedia file.

For exemplification, a simple rule on how the DM performance oriented metadata is used in the adaptation process is presented in Figure 3. The rule determines the most suitable multimedia version for the learner based on the network conditions. Information about the network performance is kept in the PM. PM provides information on the minimum size (*PM.size.minValue*) and the maximum size (*PM.size.maxValue*) of the suitable file.

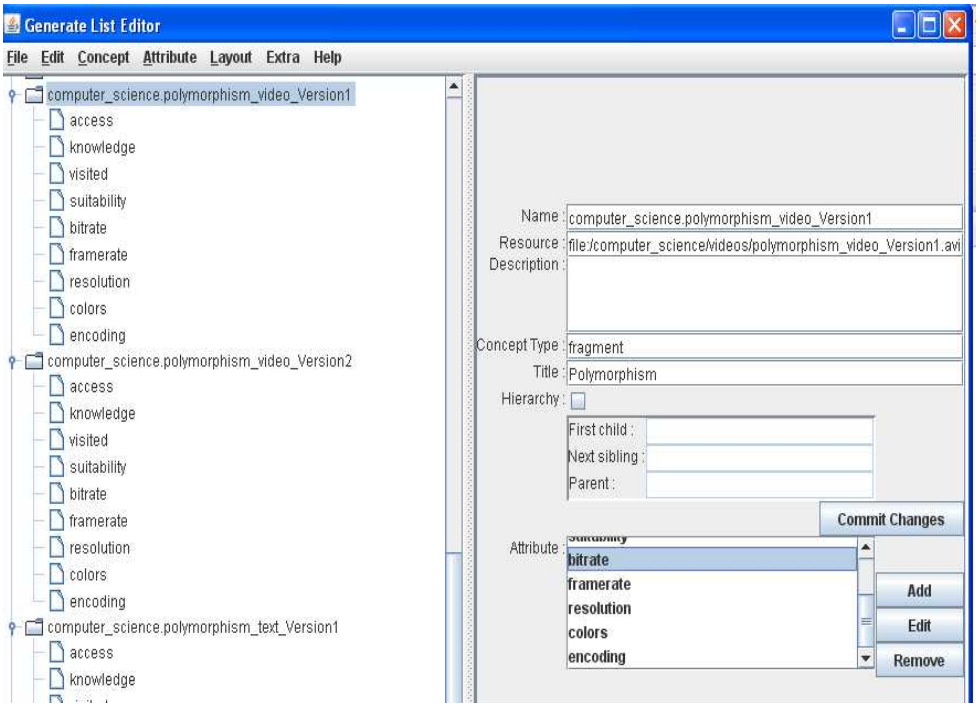

Figure 2 Multimedia files metadata

```
<concept>
  <name>computer_science:polymorphism</name>
  ...
  <generateListItem isPropagating="true">
      <requirement></requirement>
      <trueActions>
          <action>
              <conceptName>computer_science.polymorphism_video_Version2.size &gt; PM.size.minValue &amp;&amp;
                  computer_science.polymorphism_video_Version2.size &lt; PM.size.minValue</conceptName>
              <attributeName>showability</attributeName>
              <expression>1</expression>
          </action>
      </trueActions>
   </generateListItem>
```

Figure 3 DM metadata used during the adaptation process

If the condition between the *requirement* tag is satisfied (*computer_science.polymorphism_video_Version2.size* > *PM.size.minValue* && *computer_science.polymorphism_video_Version2.size* < *PM.size.maxValue*), then the value of the *showability* attribute is set to one(Figure 3).

Showability (Figure 4) is the attribute used in the selection of the conditionally included multimedia clip. We choose for exemplification, two versions of the same video, with different performance oriented metadata:

- *computer_science.polymorphism_video_Version2*
- *computer_science.polymorphism_video_Version1*.

The LO resources are organised in a *casegrou.* Based on the *showability* attribute value, a resource is chosen. In this case, if the condition from the *requirement* tag (Figure 3) was fulfilled, the *showability* attribute is set to one and the second version of the video (*computer_science.polymorphism_video_Version2*) is delivered to the learner; otherwise the first version (*computer_science.polymorphism_video_Version1*) is delivered.

```
 <attribute name="showability" type="int" isPersistent="true" isSystem="false" isChangeable="false">
   <description></description>
   <default>0</default>
   <casegroup>
     <defaultfragment>file:/computer_science/xhtml/polymorphism_video_Version1.xhtml</defaultfragment>
     <casevalue>
         <value>1</value>
         <returnfragment>file:/computer_science/xhtml/polymorphism_video_Version2.xhtml</returnfragment>
     </casevalue>
   </casegroup>
 </attribute>
</concept>
```

Figure 4 Showability attribute exemplification

5. Conclusions and Future Work

This paper presented how performance-oriented metadata that enhances the classic DM in order to model the educational content. The goal is to improve the adaptation process in such way that the delivered content is suitable to the learner network environment. The rich multimedia content was considered delivered through AEHS because is the one most affected by the network conditions. An exemplification on how the proposed metadata can be applied on an adaptive e-learning system (e.g. AHA!) was presented. How this information is used by the AM for content personalisation was illustrated.

The proposed domain modelling technique needs to be further tested. Simulations should be done in order to investigate the performance improvements brought by the proposed solution when transmitting the multimedia content over the network. Subjective testing should also be performed in order to assess the learner perception of quality of the educational content, the learner satisfaction and also the learning outcome.

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