The Design and Development of an Adaptive Web-Based Learning System

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Abstract. Currently, most web-based learning systems do not differentiate the content materials presented to the various types of learners. Content adaptation is a concept inspired by enabling dynamic presentation generation based on the learner's preferences, e.g. knowledge level, gender, age, language, or past visits. The goal of content adaption is to take the heterogeneous and changing needs of the learners into account and thus to provide the most appropriate contents and the best learning satisfaction. To handle content adaptation and dynamic presentation generation, an XML-based content description mechanism called ADAM is proposed in this paper. ADAM's goal is to enhance learning effectiveness through providing the most appropriate materials under changing learners' requirements and preferences while simplifying the process of presentation composition.

Keywords: content description, multimedia, web-based learning, XML.

1 Introduction

The rapid development of the Internet does not only create new types of information, but also changes how people access information. At the same time, many kinds of applications are inspired by the openness and the robustness of the Internet. Among them, web-based learning (WBL) systems have been one of the hottest research topics. The explosive growth of the Internet and the increasing amount of multimedia contents have made WBL systems an important information source for many people. The major benefit of these systems is that they allow learners from anywhere to learn with rich multimedia materials at any time. This kind of growth also comes with increasing diversity and heterogeneity in terms of the learners' capabilities, backgrounds, and preferences [1, 3]. However, the contents of most WBL systems are static and are designed for a single type of learners in mind only. That is, all the learners are provided with the same web pages and hyperlinks. In many cases, these systems are not suitable for the diverse types of learners coming from all over the world. Thus, they can not truly satisfy an individual learner's needs.

Given the huge amount of learners on the Internet, there are considerable interests in systems that are able to satisfy the diverse needs of different types of learners.

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Though more and more learning applications provide rich multimedia information, they do not differentiate content materials presented to the various types of learners. For example, learners with lower knowledge level or foreign learners may experience frustration due to improper content presentations or inability to understand certain materials. The multimedia-rich contents can definitely enhance learning results but may not be satisfactory for learners with specific requirements, such as dubbed audio and subtitles. As a result, most WBL systems are targeted at certain types of learners, and others usually experience frustration or feel lost when accessing these systems. The lack of content adaptation to accommodate this kind of variety or heterogeneity raises challenging research topics for enabling more effective learning over the Internet. Content adaptation is a concept inspired by the issue for enabling dynamic presentation generation based on the learner's preferences, e.g. knowledge level, gender, age, language, or past visits. The actual contents generated for a given learner is thus a combination of his own preferences and the adaptive criteria of the corresponding media objects. The goal of content adaptation is to provide the most suitable and personalized materials to each learner [2, 4]. To handle content adaptation and dynamic presentation generation, a content description mechanism called ADAM is proposed in this paper.

Adaptive content generation is a mechanism that can dynamically compose the corresponding media objects into a presentation according to the learner's preferences to enhance browsing results. The goal of content adaption is to take the heterogeneous and changing needs of the learners into account and thus to provide the most appropriate contents and the best learning satisfaction. Content adaption also has beneficial business implications beyond just providing a better browsing result. One of the main benefits is to increase the web site visit time of the users. This also means that the users are more likely to stay at the site, thus resulting in a greater profit for e-commerce sites.

Currently, HTML (Hyper Text Markup Language) has been the presentation platform for most web-based applications. HTML provides a simple and efficient way for content description. However, HTML lacks for some capabilities when used in certain applications. First, HTML can not handle adaptive presentations. Because with an HTML file, the browser can generate only one presentation. If the user wants to make minor changes to the presentation, e.g., changing the subtitles from English to Chinese, modifying the HTML file is required. This makes the development of adaptive learning systems very inefficient because the instructor must compose several versions of HTML files for different types of learners. Second, HTML can not describe the temporal relationships of the media objects in a presentation, e.g., playing an audio file when a specific video segment is over. With these shortcomings, HTML is not suitable for generating dynamic presentations. For an adaptive learning system, a more robust and dynamic content description mechanism is required. That is, the system should be able to dynamically generate presentation contents according to the learners' requirements and preferences. Also, it is preferred that the instructor can relieve the burden of composing presentations as much as possible. With ADAM, the instructor only needs to compose a base version of the content description file and specify the adaptive criteria in the file. After that, ADAM generates the adaptive presentations by including only the media objects with the conditions evaluated to be true. ADAM's goal is to enhance learning effectiveness through providing the most

appropriate materials under changing learners' requirements and preferences while simplifying the process of presentation composition.

With the popularity of WBL systems and the increasing diversity of learner backgrounds, there is a need to have adaptation of the learning presentations. Typical examples include the materials for learners with different knowledge levels and language preferences. For an instructor, it takes a lot of effort and time to compose suitable presentations for diverse types of learners to achieve adaptive learning. He/she must consider each individual's knowledge background, preferences, interests, and some other criteria when composing the presentations. ADAM's main feature is that it requires only one XML-based description file to specify the adaptive structures and to generate the corresponding presentations. That is, ADAM is a general framework for dynamic presentation generation and can handle the adaptation needs of web-based learning. XML is adopted because it (i) has been a W3C (the World Wide Web Consortium) standard, (ii) allows the specification of a document which is independent of its final presentation, and (iii) is platform independent. Though adaptive presentations can certainly enhance learning effectiveness, they also increase the complexity of presentation composition. ADAM can help the instructors to relief the burdens because they only need to edit a single content description file and ADAM will generate the adaptive presentations accordingly. That is, ADAM can help the instructors to compose the courseware that have different renderings to different types of learners. We propose ADAM to specify a presentation scenario through three dimensions: spatial, temporal, and adaptive.

In this paper, we also describe the development of a prototype WBL system to demonstrate the feasibility of ADAM. When a learner requests a presentation, ADAM handles the request by parsing the corresponding content description file and the learner's preferences and then makes adaptation decisions to generate the final presentation.

2 Design of ADAM

As suggested by the researchers, adaptive multimedia presentations are among the important factors in keeping students engaged in learning. This section describes the detailed design of ADAM. We start from how the adaptive presentations are generated.

2.1 Generation of Adaptive Presentations

To support adaptivity, ADAM aims to adapt the materials presented to a learner according to his/her preferences, knowledge level, and the adaptation criteria specified by the instructor. Conditional media objects are used to accomplish the generation of adaptive presentations. That is, each constituent media object of a presentation is associated with a condition indicating which type of learners should be presented with it. In this way, several variants of the presentations associated with a specific learning subject are prepared. Each variant presents the materials in a different style to satisfy the learner's needs. Fig. 1 depicts the flow of generating adaptive presentations.

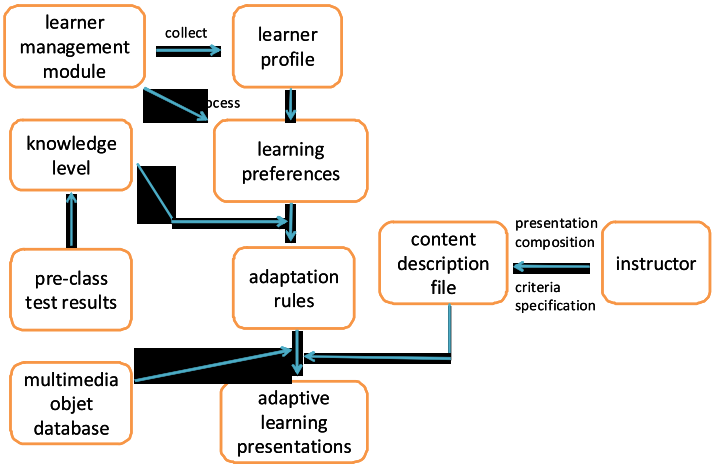

Fig. 1. Generation of adaptive presentations

In Fig. 1, the learner management module is responsible for collecting a learner's basic information such as gender, age, language, education, etc. This information can be obtained when the learner registers. Also, when the user logs in for the first time, he/she will be given some tests such that the system can know his/her knowledge level about the subject that he/she is going to learn. In addition, the learner can have some other options to accommodate his/her needs, e.g., the language of subtitles and audio, and video resolution. For the instructor, the system should provide a friendly user interface and some management functions to assist the composition of learning presentations and the specification of adaptive criteria. With the criteria, ADAM can dynamically change and adapt the presentation contents for various types of learners. Customization of the contents gives the learners some more opportunities for different learning styles. After that, an XML-based content description file is generated. When generating a presentation, ADAM takes both the learner's preferences and the adaptive criteria specified in the description file into account. Only the media objects with the corresponding adaptation rules evaluated true are included in the generated presentations. For example, if the learner prefers Chinese, then the Chinese version of subtitles and audio will be presented.

As revealed in Fig. 1, the instructor only needs to compose the content description file once. Also, a single content description file can be used to generate various types of presentations. Each type of presentations is specifically tailored to accommodate a variety of individual differences and requirements.

2.2 Overall System Architecture

As described previously, the literatures have revealed the importance of adaptation on students' learning performances. As a case study, an English learning system based on ADAM was developed to support the course "English Conversations" that is offered to the freshmen in the Department of Information Management at National Changhua University of Education, Taiwan. The main characteristic of the system is

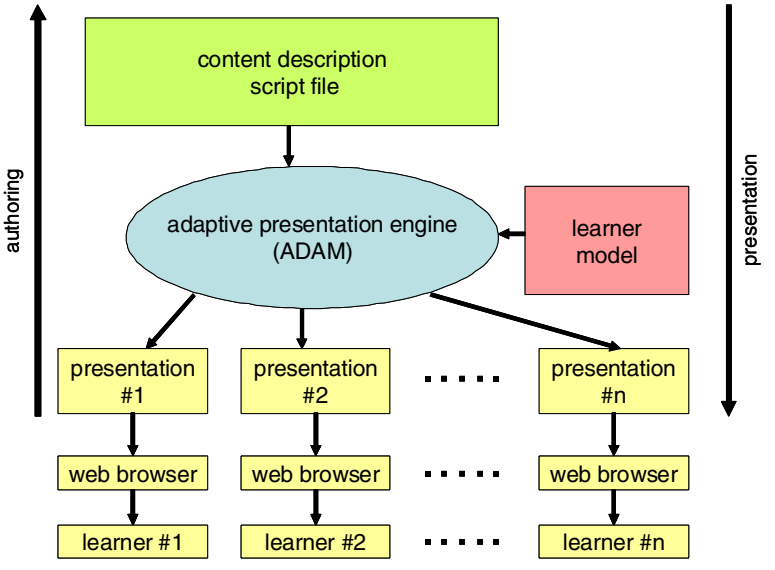

Fig. 2. System architecture

that the presented contents are adapted to the learner's preferences and knowledge level. Fig. 2 depicts the system architecture.

As depicted in Fig. 2, the system is developed in the form of three modules: the content description script file, the learner model, and the adaptive presentation engine, i.e., ADAM. The content description script file is XML-based and is composed by the instructor to specify how the presentations are generated. As to ADAM, its job is to adapt different aspects during the learning process, e.g., adapting the content according to the learner's prior knowledge, generating the presentations through the selection and combination of appropriate media objects, and modifying the corresponding hyperlinks, etc. The learner model is a simple data structure that can reflect the characteristics of different learners. Currently, the learner model contains two categories of information. (i) The personal profile includes static data such as account name, password, real name, student ID, gender, birth date, e-mail address, etc. (ii) The knowledge profile identifies the learner's knowledge level about a specific subject.

2.3 The Content Description Language

A multimedia presentation is composed of a set of media objects, e.g., video, audio, text, images, etc. With most application systems, it is preferred that the media objects can be reused to produce different presentations. Thus, a presentation's specification should be separated from its actual content. In this subsection, we introduce an XML-based content description language, called Adaptive Multimedia Markup Language (AMML). AMML's purpose is to facilitate the specification requirements of ADAM. Because AMML is based on XML, it also allows the specification of document structures independent of their final presentations, which is a basic requirement of

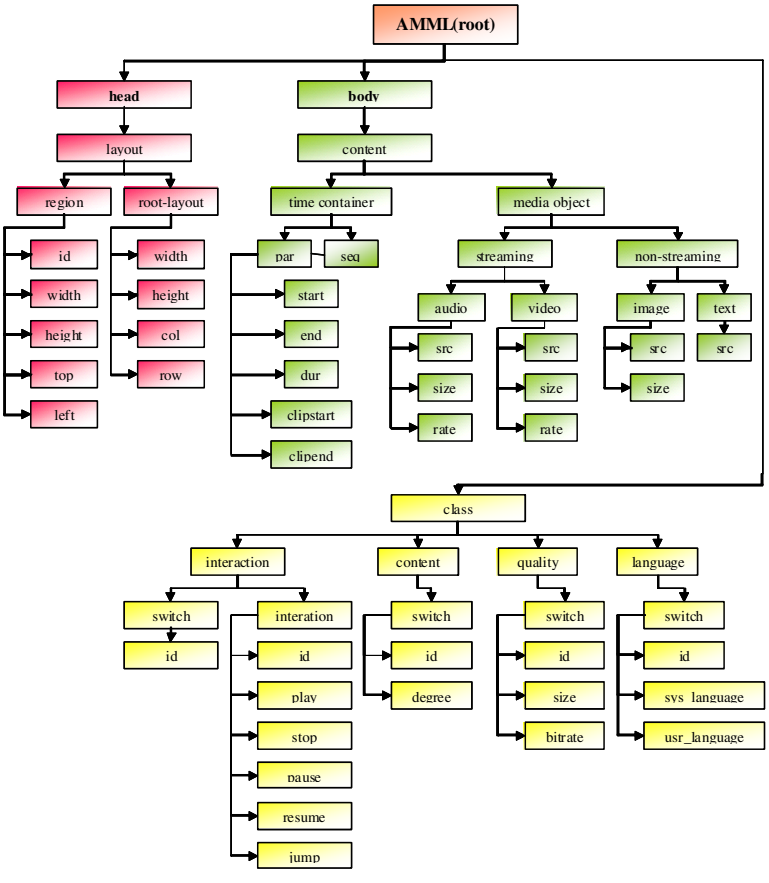

Fig. 3. The tree structure of AMML's tags

WBL systems. In order to fully benefit from XML's flexibility and expandability, AMML's syntax is formally described as an XML Document Type Definition (DTD) and therefore AMML can take full advantages of all the existing XML tools.

With AMML, the description of an adaptive multimedia presentation is organized around three dimensions: spatial, temporal, and adaptive. The tree structure of AMML tags is depicted in Fig. 3. In the remaining part of this section, we describe AMML from each of these three dimensions and explain their usages.

As shown in Fig. 3, an AMML description file is consisted of three major blocks.

1. The head block describes a presentation's properties of the spatial dimension, i.e., the layout of the media objects and how the presentation looks like.
2. The body block specifies a presentation's properties of the temporal dimension, i.e., the relative timing sequences of the media objects. This allows the organization of the media objects in a presentation over time.
3. The class block describes the adaptive requirements.

To simplify the specification of a multimedia presentation, the underlying model of AMML is interval-based. That is, the presentation is composed by a set of media objects that have some temporal relationships and each media object has a corresponding time interval characterized by a "start", a "duration", and an "end" attributes. In AMML, the synchronization among media objects is specified by both the composite objects and their temporal relationships. The composition of media objects is used to temporally group interval elements and is described by the "container" tag that is depicted in Fig. 3. Currently, two temporal relationship tags are provided by AMML: (i) The "seq" tag means that the media objects are presented sequentially. (ii) The "par" tag means that the media objects are presented in parallel.

As to the adaptive criteria, they are specified in the class block of an AMML document. Currently, four elements are supported: user interaction, content, video quality, and language.

1. The so-called user interactions are the control functions similar to those of VCRs, e.g., pause, fast forward, and rewind. With these user interactions, the learner can control the presentation flow and speed at any time during the presentations. However, in an adaptive WBL system, not all levels of learners should be provided with the same user interactions. In stead, the system should provide a proper set of user interactions to each level of learners. For example, for a higher level of learners, more use interactions can be provided. Because they have more background knowledge and should be able to control what they want to view. On the contrary, for the lowest level of learners, only the basic pause function is provided to restrict their browsing behaviors. In this way, the instructor can have control over the learners' learning states and behaviors.
2. Adaptation by content means that the system can generate the presentations about the same subject but with various difficulties. For example, when having a math course, higher-level students can have materials about 4-digit addition while lower-level students can have materials about 2-digit addition. When a learner selects a course, his/her information in the learner model is used to generate the most appropriate materials. In this way, the instructor can examine each learner's learning state more easily.
3. Because the learners' communication environments vary a lot, it is reasonable that the system delivers the media objects with an appropriate quality to the learners. That is, if there are several versions of a video object, the system will choose the one that has the adequate screen resolution and frame rate after detecting the network bandwidth to the learner. If the detection is not successful, a default version of the media object can be provided.
4. With WBL systems, learning becomes without any nationality and geographical limits. Because the learners are coming from all over the world, language becomes a major consideration of WBL systems. To improve efficiency, ADAM can dynamically adapt the language part, e.g., subtitles and speech, of a presentation, instead of generating the whole presentation from scratch.

3 System Development

As mentioned previously, we developed a real WBL system to demonstrate the feasibility of ADAM. This section describes its implementation. Our goal is that

ADAM and AMML can be integrated seamlessly to further improve learning effectiveness.

3.1 System Components

Fig. 4 depicts the components of our system. There are three major modules in Fig. 4: the XML parser, the synchronization processor, and the media content processor.

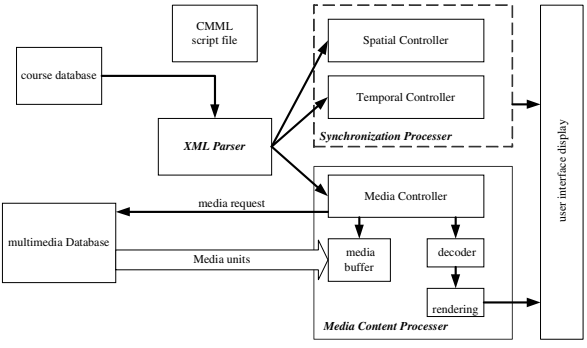

Fig. 4. System components

The operation flow of the system is as follows.

1. The instructor composes the course's content description files in AMML to specify the temporal, the spatial, and the adaptive properties of the presentations. These description files are stored in the course server's database.
2. When the learner wants to view a presentation, its content description file is retrieved from the server and passed to the XML parser for content generation.
3. The XML parser parses the AMML tags in the description file into a parse tree using the document object model (DOM) and keeps the corresponding attributes, including media type, start time, end time, and spatial location, of each media object in a parse table.
4. The synchronization processor contains the temporal controller and the spatial controller. They together allocate each media object in a presentation according to the object's temporal and spatial properties stored in the parse table.
5. Finally, the media controller of the media content processor retrieves the corresponding media objects from the multimedia database. At the client site, the media objects are first stored in the receiving buffer temporarily. When the media objects are about to be presented, they are passed to the decoder, then the renderer, and finally the user interface display, to be played out under the control of the temporal controller and the spatial controller.

3.2 An Illustrated Presentation

As mentioned previously, we developed an ADAM-based WBL system to support the "English Conversation" course. This subsection demonstrates some major results.

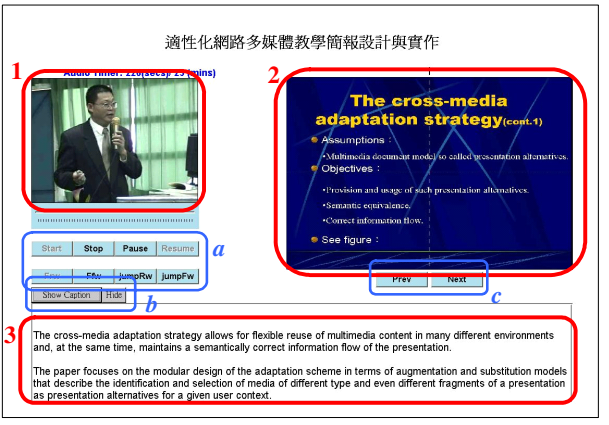

Fig. 5. An illustrated adaptive presentation

When a learner logs in for the first time, he/she is asked to fill in some personal information. After that, a pre-class test is given to determine his/her knowledge level about the course. The purpose of these steps is to gather the attributes of the student model for each learner. ADAM then utilizes the information stored in the student model to support adaptivity. To accomplish this goal, each media object is associated with a condition indicating which type of learners should be presented with it. Also, ADAM supports adaptive navigation that the selection and the color of hyperlinks are adapted to the individual learner by taking into account the information in the student model and the instructional strategy. Fig. 5 shows an illustrated presentation.

In Fig. 5, the presentation can be divided into three main areas. They are described as follows.

1. Video area: This area is used to place video and audio objects. The audio is associated with the video such that different versions of speech, e.g., Chinese or English, can be included.
2. Image area: This area is used to place image objects, e.g., JPEG files. ADAM also provides a slide-show feature to image objects. This is, the displayed image is automatically changed as the time goes by.
3. Text area: Text and audio objects can be placed in this area. The text can be the subtitles of the video or some annotations.

In addition to the three areas for placing media objects, Fig. 5 also shows three sets of control buttons, i.e. , a, b, and c. These buttons provide VCR-like user interactions. As mentioned previously, the web browser does not provide these user interactions. They are implemented in JavaScript. Also, some of the buttons may be disabled because the functions are not provided to this learner.

4 Conclusion and Future Work

In this paper, we proposed ADAM, an adaptive multimedia content description mechanism. The main feature of ADAM is that only a content description file in

AMML is required to generate various presentations. In order to demonstrate the feasibility of ADAM, an English-learning WBL system is developed. After developing ADAM and the WBL system, two evaluations, i.e., the expert review and the small group evaluation, are conducted to judge the values of our work. According to the results, the experts and the learners have positive attitude towards the perceived efficacy and enjoyment of the system. From the view point of instructors, with ADAM, it is easier to re-use the materials to compose adaptive presentations to accommodate the needs of various types of learners.

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