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AN ARCHITECTURE FOR AN ADAPTIVE WEB-BASED LEARNING ENVIRONMENT

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Abstract

Adaptive web based systems are believed to be a promising challenge for efficient curricula. In this paper we present the architecture of a system designed and implemented. A part of the paper presents the mining techniques that are used to extract students' preferences and the way their profile is created. The personalization processes used are briefly presented.

Key Words
Adaptive, personalization, architecture,

1. Introduction

In the past years, numerous web based learning systems have become available on the Web. A successful case study of web based educational system is the case of virtual universities. "*A virtual university is an infrastructure that does not need traditional campus, classes or a library; instead there are hypermedia facilities that provide richer functionality and features than their physical analogs*" [1]. A typical hypermedia application serves the same pages and the same set of link to all users. In order to improve usability, adaptive web-based applications make it possible to deliver personalized views or versions of a web document for all the users with diverse needs and knowledge backgrounds gaining access to the system [2]. These adaptation techniques are focused to a specific service (e.g. educational content delivery or presentation, document topic filtering) and therefore work completely independently in an environment that is supposed to cover a broad set of needs towards the common target of usability and learning improvement. The fruitful design and successful correlation of adaptation capabilities simultaneously for educational material and accompanying supportive services is a task not as simple as one may guess.

In this paper, we describe the integration of adaptation techniques in designing a web based educational system for use in the academic sector, combined and synchronized with communication facilities. This system can be used to support undergraduate curricula. The designed hypermedia aims to cover the fundamental needs of a student in a virtual university that is wide range of automatically renewable educational material, on any subject chosen, under the umbrella of a powerful set of supportive tools, homogenized with the user's topics of interest.

At the moment the system provides basic courses in computer skills for the new students, in order to help them work with computers in their early stages of university training. It supports personalization features to the educational topic and the exchanging information flow in order to customize the educational process to the learning curve of the student. This is accomplished by acquiring each user's learning model and activity choices. The educational profile is developed for each student based on a questionnaire and continuously evolves according to the student's choices and activities within the virtual university framework.

However in order to clarify the scale of difficulty for each course there is a short description and a grade (starting from one grading up to four for the most advanced topics) indicating the complexity and the demanding know-how of each one of them. Due to the diversity of the users all courses are personalized and delivered differently to groups of students with common characteristics. An educational profile is developed for each student based on a questionnaire that the student is asked to fulfill after choosing the first course to attend.

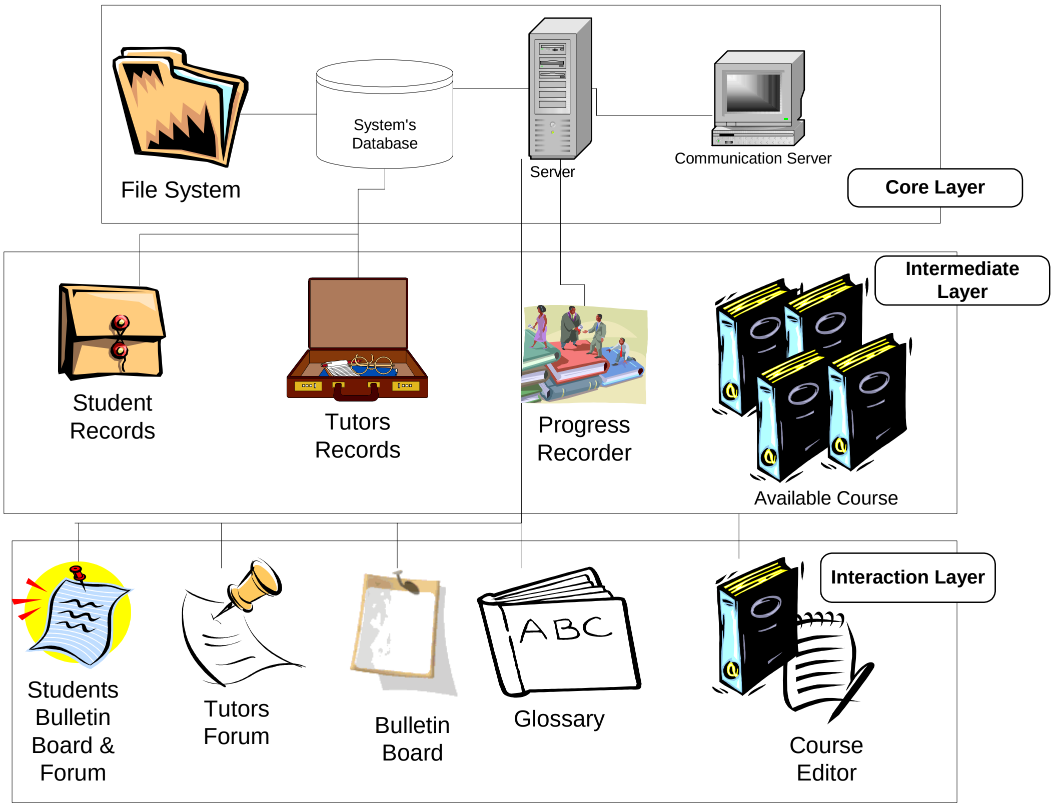

Figure 1. System Architecture

The stereotype of the user evolves while the student performs activities in the environment (such activities are the specific course flow that is followed and the students' achievements in tests and projects).

In the sequel the stereotype is used to support the system's curriculum adaptation model. In this case adaptation is adopted to perform at first a fundamental pedagogical curriculum sequencing (set by the curricula author), but, which is most, automatic information pushing of the most appropriate online resources for every student based on its profile. Complementary the technique of link deactivation is used in order to deliver specialized dictionary help for keywords throughout the corpus of a course.

This paper is organized as follows; section 2 presents the architecture of the system. Personalization techniques are the theme of section 3. The next section presents similar systems and the last section presents some thoughts from the experience of the use of the system.

2. System Architecture

The prime objective of the system is the creation, operation and the support of the learning process. The system should not be merely perceived as a distance learning application in the sense that people can remotely access information. The focus is rather placed on setting up a virtual electronic community of learners and tutors that are provided with the necessary IT tools for communicating with each other.

The system assumes three discrete profiles: students, tutors and administrators (the first two compile with the available training structure; the last one with the system's operation). Students are the main target group, as they are to use the system for learning and communicating. Tutors recreate and determine the structure of the learning modules and incorporate them in the system. They also provide feedback to students for their learning process. Administrators are responsible for system configuration and maintenance, as well as for managing user accounts.

The social requirement of the learning community concept is two-fold: synchronous and asynchronous, with each mode contributing to various scenarios of communication and collaboration. In order to facilitate asynchronous communication, the system provides the means for message exchange through the "Forums", the "Questions & Answers" or the "Submit a Question" facilities. On the other hand synchronous communication was also considered essential for creating a sense of directness, thus the Chat facility was incorporated.

System architecture (as depicted in Figure 1) is composed of three distinct layers. The core layer provides basic system functionality and in this framework it facilitates the file system, the database system, a web server and a chat server. The learning modules are divided into lessons and topics, which are stored as separate files, in order to achieve higher downloading speed. The database system is used to store a variety of data. It holds personal data on the user profile and user authentication. The records for the tutors and the students are also located there. It also contains the required information for describing the schema of the learning modules. Finally, it holds data relevant to both the design and the content of the Forum, the Questions & Answers and the Bulletin Board services. The chat server synchronizes the communication among users that takes place via the Chat mechanism. It manages the messages exchanged between the users, making sure that all messages are delivered to the appropriate recipients.

The web server accepts user requests returning the corresponding data back to the user. The returned data are not statically stored in web pages, but are constructed on demand by information maintained in both the file and the database system.

The intermediate layer interconnects the core layer components and provides all necessary information to the interface layer. The interaction layer is the system's front-end. The web interface is the part of the system that comes to direct contact with the end user providing access to system content and services. Users can interact with it using any commercial web browser.

The system focuses on students and for this reason it offers several capabilities related to the learning modules. It also offers diverse assistance methods, search facilities and a number of other services. The learning modules are divided into lessons and topics. A student can read and download these topics. The system provides a print-friendly version of all the topics comprising a lesson as a separate file, so that the student can download or print it. In addition, the student can mark topics already studied to his/her personal progress record. Topics marked as read, display an informative message to the student suggesting him to move on to a topic not completed yet. Students can also view their individual progress, in order to have a more general view of the progress of the learning process.

The system enables students to communicate and collaborate via the Chat and the Forum. Apart from the learning modules, students can watch lectures recorded during a face-to-face class session. Finally, students have access to announcements placed by tutors.

Tutors can manage the learning modules through the web interface. They can structure and the upload a module or a part of a module. Tutors can also update the on-line glossary of the system while there are completing all the learning modules. Recorded lectures (in any video format) can be posted to the system. Text announcements can be also posted by tutors.

3. Adapting to the Personalities of Students

The whole environment tries to record students' behavior and using advanced filtering techniques to adapt to the needs of each profile. The curricula are adapted on the stereotypes, creating during students' registration on the system. This is a first input for the system and subsequently is mixed with personalization features for each user. The courses are following the overlay model [3]. In this model, the user's knowledge is considered to be a subset of the knowledge perceived by an expert in the learning field. Using this representation, the system presents the educational material so that in the end the user's knowledge will match the expert's knowledge.

The primary issue for the curriculum adaptation is the starting point. Since it is very difficult to create a different starting point for any user, based on the limited first input, the tutor introduces, by his expert view to the subject, a starting point where a student starts navigating in the content.

Each curricula component is characterized by a difficulty factor by the tutor. The tutor also provides a list of complementary information for each component, such as the estimated time of completion and the components preceding the active one. In this way a directed graph is produced.

Every student is inspected through each navigational performance. Log files are used to mine the appropriate information. The methodology used has been presented in [4].

The students receive key characterization in the educational layer of the profile according to interests deriving from their topic accesses. The method used is the spectral filtering (further details concerning the mathematical details of the approach see ([5], [6], [7], [8]). A very short description of the method follows. Let S1 denote the set of users and S2 denote the set of web pages corresponding to a specific section. We associate with each ordered pair (i,j) of entities in S_1 and S_2, a non-negative real-valued affinity A[i,j]. Typically, we set A[i,j] to be a well-chosen function of the accesses user i performs on page j. The A[i,j]s constitute an n x m matrix A, each of whose rows corresponds to users and each of each column to web pages. The entries of the matrices AA^T and A^TA can be viewed as expressing the similarity between different users and web pages respectively (where the notion of similarity is deduced from similar patterns of accesses). The matrices AA^T and A^TA are both real and symmetric and their eigenvectors have only real components. Moreover they have the same set multiset of eigenvalues. Let xs_1, xs_2 be two eigenvectors of AA^T and A^TA respectively corresponding to the same eigenvalue. We can view the components of each eigenvector as assigning to each entity a position on the real line. We deem the entities with large positive values in an eigenvector to be a cluster, and the entities with large negative values to be a different cluster. Alternatively, we can examine the values in the eigenvector (in sorted increasing order). At the largest gap between successive values, we declare a partition into those entities corresponding to values above the gap, and those entities with values below.

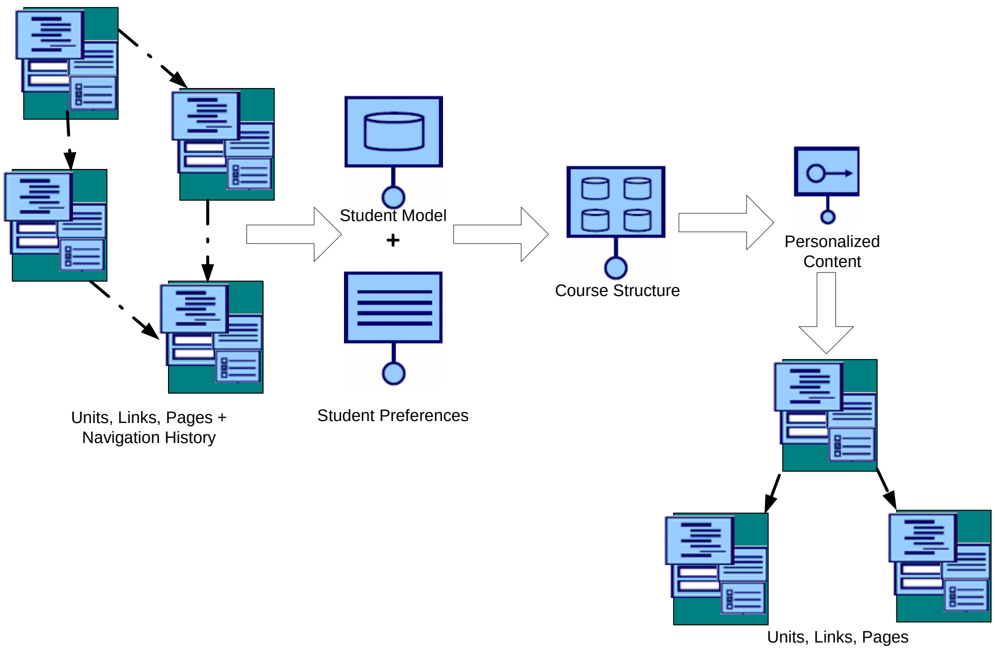

Figure 2. Composition and navigation

From the above discussion it follows that the eigenvectors xs_1, xs_2 provides us with two pairs of interrelated clusters (c_1,c'_1), (c_2,c'_2) where c_i corresponds to a group of users with similar web-access patterns and c'_i corresponds to the web pages that interest the users in the c_i group.

Following the above partitioning process for all the non-principal eigenvectors enables us to group the users into subsets with similar preferences and to map the entities of each subset to the web pages that are of interest to them.

In order to support personalization, the environment is explicitly modeled in the structure schema in the form of predefined entities called User, Group and Activity. Groups describe sets of users with common characteristics, whereas users denote individuals. Users always belong to at least one group, at first the default one (generic users). Each user or group is described by means of specific Activity properties that form the profile. Activity properties are modeled as special type of entities in the structure schema. As the normal entities, user and group profiles are internally sub-structured into attributes and components, which are used for writing derivation queries. Their features were used to store group-specific or individual content, like course selections, list of topics, and keywords derived from communicational streams of data.

Then, declarative expressions were added to the structure schema, which define derived content based on the profile data. This personalized content is used both in the composition of the multiplayer profile and in the definition of presentation specifications for each modeled case. The interaction between the users and the environment is proactive in two senses. First the users choose which educational material to see and what activities to perform by clicking on hyperlinks, in response to that the user model autonomously determines which content to render, by anticipating the effect of the user clicks. This feature was modeled, by expressing the filling semantics of pages. In the case that the user accessed a page, which contains an index over an entity pointing to data on that entity, the content of the pointed data is pending, i.e., it depends on the user's choice and the user's profile of one element in the preceding index unit. In order to cope with pending elements are filled using with a default value expressed by means of a declarative query (e.g., the object of a preceding index unit that satisfies a given predicate). Alternatively leaving the pending element empty, so that the user must explicitly perform a selection in one or more preceding units to display the content of the pending unit or filling the pending unit with a predefined default value (e.g., the first element chosen from a preceding index unit) was used in corresponding cases.

In Figure 2 show an excerpt specification of an environment using the WebML [9] graphical notation. The example shows the way mined data are used to extract knowledge and adapt the system to students' preferences.

3. Related Work

At a research level, certain systems have focused on specific aspects and theoretical issues deriving from the area of adaptive web applications and that of teaching and learning strategies; we indicatively refer to some of the most representative ones. On the topic of personalizing web-based learning InterBook [10] focuses on adaptive navigation support in e-learning systems and more specifically on link annotation techniques, while AHA! (Adaptive Hypermedia Architecture) uses link hiding [11]. NetCoach [12] derived from ELM-ART, which was one of the first adaptive web-based educational systems [13], and is a system designed to enable authors to develop adaptive learning courses without programming knowledge. WebPersonalizer [14] is a more general-purpose system used to provide a list of recommended hypertext links to a user while browsing through a website. OOHDM (Object-Oriented Hypermedia Design Method) is a methodology for designing personalized web applications and managing personalized views [15].

5. Conclusion

This paper presented the architecture of an adaptive web based learning environment. Although the whole process is based on efficient algorithms developed for the effectively adaptation to the learning curve of each student, there is a long way till the efficient use of such a system.

So far, the system is being used by 65 students for 5 courses presented by 3 tutors. The experience from the use of the system has shown that students are favorably accepted this online learning communities and the way it promotes online learning. A component is still missing due to the lack of an evaluation process for students' performance in exams. Exams are being handled by the traditional way of face to face presence in a room.

Although the use of this technology is promising enough, it needs to compile with the allocation of the training course to experienced distance learning tutors. The production of qualitative content for the curricula is the base for the efficient use of such a system at a more extended area.

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