Adaptive User Model for Web-Based Learning Environment

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Abstract. We present the design and implementation of an adaptive user model in a web-based virtual university learning environment. It includes techniques that provide personalization features to the educational topic and the exchanging information. In this way it customizes the educational process, served by any virtual university to the personal characteristics of the user. Its distinctive functionality is that encompasses combined adaptation between educational material and well-known communication facilities. In fact the user model consists of different layers that make the environment personalized in two axes. Firstly adaptation is performed separately per activity (member of the profile's higher level) and subsequently knowledge of the different levels is shared through the common lower level and provides further personalization in a more global sense. Personalization obsolescence is also included in the user model in order to prohibit outdated adaptation or intelligence to keep loading the user interface. Furthermore curriculum sequencing provides guidance to the user's learning procedure. Most interesting educational pages for the users –based on their profile- are selectively delivered to them, according to the collaborative filtering method. Finally special care has been taken for the categorization of incoming data streams handled by content and property based filtering.

1. Introduction

A number of virtual educational environments have become available over internet in the past years [24], [22], [23]. Such an infrastructure is also known as "virtual university". It does not have traditional facilities such as campus, classes or library; instead there are web-based services that provide richer functionality and features than their physical analogs [18]. 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 of a hypermedia document to the users with diverse needs and knowledge backgrounds gaining access to the system [19], [22]. A virtual university environment that adopted intelligence in content providing is the Electronic Education Environment [3]. However, 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 design of an adaptive user model and its implementation in an advanced web-based Virtual University environment that encompasses combined and synchronized adaptation between educational material and well-known communication facilities The Virtual University environment has been implemented to support a postgraduate course. It aims to cover the fundamental needs of a student, which 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.

The environment at the moment provides training on Internet and Multimedia technologies coupled with a range of supportive tools like communication facilities and common shared workspace. The environment 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 first developed for each student based on a questionnaire and continuously evolves according to the student's choices and activities within the virtual university framework.

Key features are the curriculum adaptation [6] and the communicational information filtering [17]. According to the user's knowledge state and interests the former adapts the educational topics' presentation and interconnection, while the latter categorizes the exchanging streams of communicational data items creating this way a corresponding archive for each topic mostly interesting the user.

This paper is organized as follows; section 2 presents an overview of the virtual university framework. The user model is described in section 3. The adaptation mechanisms are the theme of section 4. Section 5 outlines intelligent filtering in data. Results are summarized and future work is presented in section 6

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2. Overview of the Virtual University Framework

The Virtual University Environment has been designed as a hypermedia environment addressing users with a vast variety of knowledge backgrounds and targets. Educational material at the moment comprises a variety of courses on the Science of Fine Arts and on Internet technologies. The environment is optimized to include any web-based course that might be available. The courses on all directions are available for every student. In fact it is possible to take any of the courses at every possible combination. 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. Introductory topics address to novice students and will cover introduction of the Internet, introduction in computer assisted multimedia design etc. Advanced topics cover areas such as advanced web application development, advanced 3-dimensional modeling, etc.

Due to the diversity of the students 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 his/her first course to attend. The stereotype of the user evolves while the student performs activities in the Virtual University environment (such activities are the specific course flow that is followed and the students' achievements in tests and projects).

As a sequel the stereotype of the student is used in order to support the system's curriculum adaptation model [6]. In this case adaptation is used in order 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.

On the other hand an intelligent cognitive filtering is performed, in conjunction with the web based educational material collaborative filtering, to unify the popular communicational (email) and workspace (share space) support within the Virtual University framework, in full parallelism with the fact that every university gives its students an email and some electronic space to utilize with the classes. The communication services in our framework take into consideration the activities of the user in its educational journey within the courses, by deriving some key notions, in order to make a categorization of the information flowing into his/her mailbox. As a result it makes use of the students profile to selectively filter out and categorize its incoming data stream delivering them to proper activity-based topics together with older relative information creating in this way a personal archive.

3. User Profile Model

The user profile records information concerning the user and his knowledge state [4], [1]. This information is vital for the system's operation according to the user's needs and preferences. The method used is an implicit collection of user's actions and it requires minimum user involvement [10]. However, such data is quite difficult to gather because it is not easy to represent the user's knowledge abilities. Moreover, the nature of the Web imposes certain constraints on the system's perception of the user. For the time being, it is difficult and time-consuming to record every user action. In the environment at hand it has been chosen to keep track of the users' traversal path for every visit, the courses', topics' and subjects' keywords and analytical scores in tests, projects and all given grades in general (every user- student has a personal history list of achievements and grades just like all students).

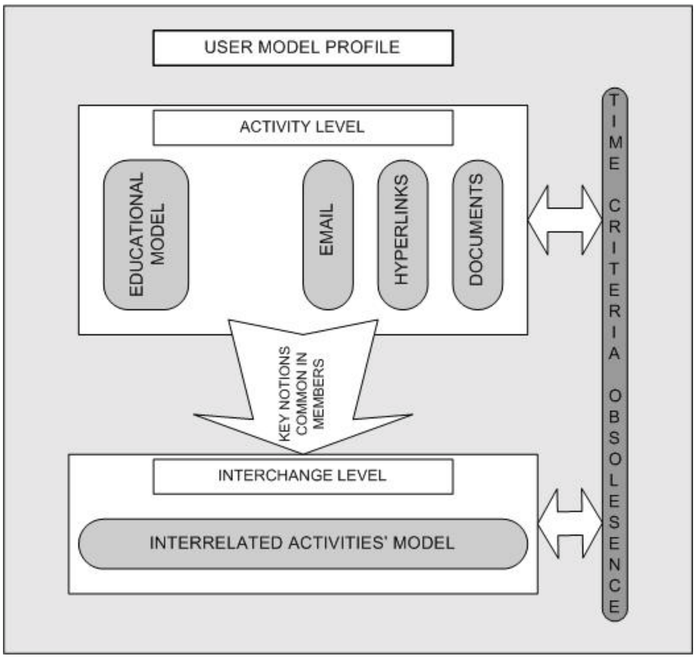

Figure 1: User Model

3.1. Different Levels in the User Model

Due to the variety and diversity of the possible activities of a single user in the Virtual University there is a need for differentiation in the profile itself. In this model the profile contains different levels that represent each activity and a common layer that interconnects the behavior of the user within all the activities together. As a result the profile of each user is both a learning model for the educational procedure and activity representation for the rest services. Specifically the educational procedure is being monitored for the choices (e.g. courses, topics and key notions selection) and the progress (e.g. tests, questions and project achievements). To the other end information exchange within the whole set of communication tools is also recorded (e.g. topics in emails exchange, titles in file exchange and hyperlink exchange). In this way the method creates a set of characteristics (e.g. keywords) that best describe and therefore represent each user’s activity.

In the sequel the profile’s higher level members are examined for similarity in the characteristics. Each member of the activity level delivers to the interchange level the properties that describe it. In this common pool best-matched properties are considered interconnected and therefore of common interest. These notions that are found common in more than one profile member in the activity level are stored in the interconnection member of the profile in the lower layer. They are used to improve the usability of the environment by interconnecting the activities that they describe in a dynamic sense personalized per user.

The different levels in the profile of the user model make the environment personalized in two axes. Firstly specialized adaptation is performed per activity member of the profile’s higher level and subsequently knowledge of the different levels is shared through the common lower level and provides further personalization in a more global sense. The multi-layered profile covers the gap between interrelated adaptive services transforming them to services that associate adaptive techniques towards usability and learning improvement.

Such a case of inner profile information exchange happens whenever a student chooses to attend a course. As a result of this he/she has to perform communication activities for this course. The environment captures the user’s educational activity and, after the profile’s levels exchange knowledge, it adapts to the new keywords the filtering properties for all communication activities, as email, file and hyperlink exchange. Specifically it redirects the information flow into a new “course” email folder and accordingly makes changes for all activities. Moreover it represents this adaptation within the course environment by activating appropriate link for each course-specific archive.

3.2. Additional Time-based Criteria in the User Model

In order to prevent forgotten and obsolete notions to be maintained in the multileveled profile, it is designed to support short and long-term distinction in users’ reactions. The properties that have not been used for a period of time longer than two academic seasons become disabled (though kept in the users profile) indicating that perhaps the user has nothing more to do with this keyword. In the third subsequent season these keywords are being deleted as out-dated for the user. The property obsolescence can be easily transformed so as to be based on the hypothesis that a uniform distribution of property appearance over time is more valuable than others [2]. Although this approach has been neither proved nor disproved, the mere influence of time is a subject of high effect.

3.3. Educational User Model

A learning model that used quite often in the past by other educational systems and which is used in our frame is the overlay model [7]. 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 to the user so that in the end his/her knowledge will match the expert's knowledge. Another way of modeling the user's knowledge is to use Bayesian networks [14], [21]. These networks probabilistically reason about the student's knowledge state concerning the various knowledge concepts.

4. Curriculum & Course Adaptation

The Virtual University environment consists of an educational framework that uses a curricula adaptation based firstly on the stereotypes, created with the registration’s questionnaire, and subsequently mixed with personalization features for each user.

4.1 Curriculum Sequencing

It is recommended that a Web-based educational environment should offer some sort of guidance to the user by presenting the next best course units to be learned [20], [15]. The used type of curriculum sequencing involves the selection of the most appropriate section or topic to be presented next. This selection is made according to the concepts learned by the user indicated in his/her profile. If the user has not learned yet all the outcome concepts of the current subsection (section) then the system will select the topic (subsection) with the least unknown prerequisite concepts. This goes on until the user learns the outcome concepts of all sections of the specific course.

4.2 Collaborative Filtering

The users receive key characterization in the educational profile level according to their interests deriving from their topic accesses. Once a topic (typically a web page) is updated with new material concerning a specific topic, the users who had with certain frequency expressed interest on it in the past are informed about the changes. Thus instead of making the users go after recently updated web pages, it is desirable to have information selectively flowed to them. This is called information filtering [10]. In our case we address the collaborative filtering method, which is the filtering of information based on the advice of others [12]. The users are not only informed of the recently updated topics that they have visited quite often in the past, but also for those topics that have been accessed with certain frequency by other users belonging in the same group of interest with the first ones. In particular, the profile of the users’ information needs is captured through their classification in groups of interest.

The classification of the users into subsets according to their path traversal and page accesses will be achieved by using the spectral filtering method developed in [5], [8], [9], [11]. The initial motivation for the development of the method was the discovery of high-quality topical resources in hyperlinked corpora. The full power of the approach is visible when being applied on entities other than hyperlinked documents. In our paradigm we have two kinds of entities: web pages and users accessing them. The precise notion of “access” refers to frequency of access.

Following, we will only outline the method of spectral filtering, as it is applied in our virtual university environment (further details concerning the mathematical details of the approach see [5], [8], [9], [11]). 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 S1 and S2, 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 AAT and ATA 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 AAT and ATA are both real and symmetric and their eigenvectors have only real components. Moreover they have the same set multiset of eigenvalues. Let xs1, xs2 be two eigenvectors of AAT and ATA 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. From the above discussion it follows that the eigenvectors xs1, xs2 provides us with two pairs of interrelated clusters (c1,c′1), (c2,c′2) where ci 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 ci 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.

5. Intelligent Filtering in Communication Data

Cognitive filtering characterizes the contents of an incoming stream data and the information needs of potential topic specific pools of knowledge, and then using these representations to intelligently match data streams to pools [13]. Our approach is more a combined content-based and property-based filtering under [16] the common umbrella of the lower profile layer. Cognitive filtering in this environment lies in between filtering based on the content of the incoming streams of the communication data and filtering based on the properties that include more than areas of interest of the user. In this way the environment automatically transforms according to the user needs transparently to the user. The Virtual University performs categorization through filtering in a common sense manner by delivering relative information of data streams together in just one most suitable place per different activity.

In this way each educational course and topic is intelligently possible to be accessed from all topic relevant places within the environment. Adaptive presentation of hyperlinks interconnect all relevant resources such as emails (e.g. exchanged among student partners), files (e.g. shared or distributed by course responsible) and all sorts of hyperlinks from all sections of the Virtual University. It is possible to access all sorts of topic-specific knowledge pools from any of them. We imagined this like the best way to access an email from our own mailbox or have a look in a book from the course’s library just while we attend a course (without having to look in all the email list or the library’s citations).

6. Conclusions and Future work

In this paper an adaptive user model is presented, designed and implemented within a web-based Virtual University environment, n order to cover the real needs of the learning community. It covers the fundamental needs of a student in a virtual university environment; that is to provide a 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. Its distinctive functionality is the interrelation of adaptation techniques used in different activities of the user within the environment, in order to create a picture of the users’ behavior as a whole. In this way, it produces a unified characterization of the user. By utilizing this characterization the model extends the adaptivity methods that were used in each activity separately. The user model profile comprises multiple layers of personalization features that interconnect. Moreover time constraints prohibit the profile to become outdated.

Following the above, curriculum sequencing provides guidance to the user’s learning procedure. Furthermore most interesting educational pages for the users –based on their profile- are selectively delivered to them, according to the collaborative filtering method. Special care has been taken for the categorization of incoming data streams handled by content and property based filtering.

Our future work aims to develop a dynamic object oriented hypermedia methodology that will incorporate our synthesized adaptive user model. The model will be refined and extended to handle more intelligent and adaptation techniques. A next step for is to be able to personalize more services for the virtual university user in order to attract different academic community members such as researchers. Finally we believe that an extension of our adaptive user model will try to cover the needs of alumni in a virtual university.

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