Integrating Adaptive Techniques into Virtual University Learning Environment

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Abstract

We describe the design and integration of adaptive techniques into a virtual university environment. It comprises a series of techniques that customizes the educational process to the learning curve of the user and pro-vides personalization features to the exchanging information flow. Its distinctive functionality is that it encompasses combined adaptation between educational material and well-known communication facilities. In fact the environment is personalized towards two directions. Firstly adaptation is performed separately per user activity and subsequently knowledge of the different levels is shared to provide further personalization globally to the environment. Time obsolescence of personalization is also used to prohibit outdated adaptation to keep loading the user profile. Finally the object-oriented methodology followed is discussed as it was considered fundamental for incremental scaling, reusability and maintenance of the environment.

1. Introduction

In the past years, numerous virtual universities have become available on the Web [16]. A virtual university is an infrastructure that does not have a traditional campus, classes or a library; instead there are hypermedia facilities that provide richer functionality and features than their physical analogs [13]. 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 hypermedia document for all the users with diverse needs and knowledge backgrounds gaining access to the system [14]. A virtual university environment that adopted intelligence in content providing is the Electronic Education Environment [2]. 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 integration of combined and synchronized adaptation between educational material and well-known communication facilities into a virtual university learning environment (from this point mentioned as Virtual University). The Virtual University is implemented to support the postgraduate curriculum in the School of Fine Arts in Greece. The designed hypermedia aims to cover the fundamental needs of a student in a virtual university, 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.

At the moment Virtual University provides training on Internet Technologies and Fine Arts Science coupled with a range of supportive tools like communication tools and shared workspaces. 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 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.

The questionnaire in particular is filled in two steps. Firstly during the very first login the user has to answer questions about the experience that he/she has got in using computers and the Web. In the sequel the user may choose the courses to attend. There are different sets of

questions for each one of the courses. All courses' questionnaires consist of nine (9) questions grouped in three levels determining this way a corresponding stereotype for each user (per course).

Key features are the curriculum adaptation [4] and the communicational information filtering [12]. The first feature adapts the educational topics' presentation and inter-connection according to user's knowledge state and interests and the second one categorizes the exchanging streams of communicational items creating this way a corresponding archive for each topic.

Additionally in order to support scalability and to ease maintenance, object oriented design approach has been followed [11]. Standardized representation was used for the user modeling profile, the courses and the communicational services making use of XML (see W3 Consortium for specifications). Virtual University has been built in a step-by-step process supporting an incremental process and focusing on a particular design concern each time.

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. The methodology elaborated covers section 6. Concluding results are summarized and future work is presented in section 7.

2. Virtual University Framework Overview

The Virtual University has been designed as a hyper-media 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. It is optimized to include any web-based course that might be available. 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 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. 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).

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.

On the other hand intelligent cognitive filtering is performed, in conjunction with the collaborative filtering for the educational material, to unify the popular communicational (email) and workspace (share space) support within the Virtual University, 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. Multi-layered User Profile

A profile records information concerning the activities and the knowledge state of a user [3]. This information is vital for the system's operation according to the user's needs and preferences. Implicit collection of user actions is used to form the profile, as it requires minimum user involvement. 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 history of educational achievements.

In our profile multiple layers represent each activity and a common layer interconnects the behavior of the user within all the activities together. There is a need for differentiation in the profile itself, due to the variety and diversity of the possible activities of a single user in the Virtual University. As a result the profile of each user is both a learning model depiction for the educational

procedure and activity representation for the rest services. In particular 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 re-corded (e.g. topics in emails exchange, titles in file ex-change 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.

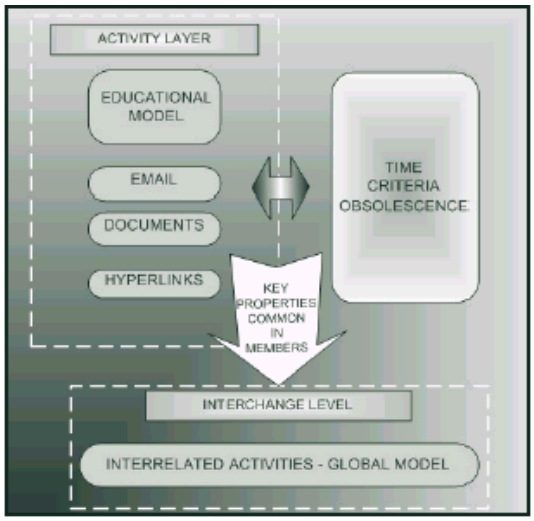

Figure 1. Multi-layered User Profile.

Subsequently 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 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 a course to attend. As a result communication activities have to be performed for the course. The environment captures the educational activity and, after the profile's levels exchange knowledge, the filtering properties for all communication activities adapt to the new keywords. Specifically it redirects the information flow into a course-specific email folder and respectively transforms the environment for all activities. Moreover it represents this adaptation within the course environment by activating appropriate link for each course-specific archive.

3.1. Time-based Personalization Obsolescence

In order to prevent forgotten and obsolete notions to be maintained in the 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 [1]. Although this approach has been neither proved nor disproved, the mere influence of time is a subject of high effect.

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. Before describing the adaptation used for the educational material we have to mention that we have based the courses on the overlay model [5] for a start. It is a learning model that was used quite often in the past by other educational systems. 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.

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 [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 layer of the profile according to interests deriving from their topic accesses. Once 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 [8]. In our case we address the collaborative filtering method, which is the filtering of information based on the advice of others. 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 (for the mathematical details of the approach see [7, 9]). 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 objects and users accessing them. The precise notion of "access" refers to frequency of access.

5. Filtering of Communication Data Streams

Content of incoming data streams is characterized using cognitive filtering. Moreover the same technique is used to track the information needs of potential topic specific pools of knowledge recording user browsing activity. Then using these representations intelligently matches data streams to pools of knowledge. Our approach is a combined content-based and property-based filtering [10] taking place under the 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 proper-ties that include more than areas of interest of the user. As a result the environment automatically transforms according to the user needs transparently to the user.

One such transformation for example is caused every time the user chooses to attend a new subject. At that moment the profile of the user acquires a new set of key-words. A filter is initialized that checks all incoming communicational data (announces, hyperlinks, emails and files) and categorizes them into a common pool of knowledge. Together appropriate links are introduced so that the user may access all relative hypermedia documents while taking the course.

The Virtual University performs categorization through filtering in a broad sense by delivering relative information of data streams together in just one most suitable place per different activity.

In this way each educational or interest topic can be accessed from all topic-relevant places within the environment. Adaptive presentation of hyperlinks intelligently

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 hyper-links from all operational sections of the Virtual University. We imagined this as the best way to access an email from the mailbox or to peak a look in a book from the course's library, while attending a course but without having to search for it anywhere else.

6. Optimizing Reusability & Maintenance

Web application development is a multi-facet activity involving different players with different skills and goals [6]. The design and development process was addressed with the object-oriented hypermedia design method (OOHDM). The method uses abstraction and composition mechanisms in an object-oriented framework to describe complex information items and specify navigation patterns and interface transformations. Classification, aggregation and generalization/specialization are used throughout the process to enhance abstraction and reuse. A summary of the methodology used includes 1) requirements gathering (interviews and questionnaires), 2) conceptual design (conceptual model is built using object-oriented modeling principles), 3) navigational design (the structure of the application in terms of navigational contexts), 4) abstract interface design (the abstract interface model is built by defining perceptible objects - e.g. a picture) and 5) implementation (mapping interface objects to implementation objects and involves elaborated architectures). The fundamental elements are entities, which are containers of data elements, and relationships, which enable the semantic connection of entities.

In order to support personalization, all hypermedia elements and their presentation styles were defined so to take personalized data into account. This can be done in

two complementary ways [6] through the declarative and the procedural personalization. In the first case derived concepts are defined (e.g., entities, attributes, multi-valued components) whose definition depends on user-specific data. In this way, customization is specified declaratively; the system fills in the information relative to each user when computing the content of units. In the latter, procedural personalization XML syntax is used for writing modeling conditions that compute and store user-specific information. This personalized content is used both in the composition of the multi-layer profile and in the definition of presentation specifications for each modeled case. Typical tasks performed by modeling conditions are the assignment of keywords to the user profile appropriate level and activity, based on dynamically collected information (e.g., the path traversal history), the collaborative filtered information notification to users upon the update of the modeling profile (elaborating push technology) and custom usage logging of user actions.

As an example of declarative personalization, the computations for categorizing the communicational data stream to keywords and proper storage location according to the user model personalization. Procedural personalization is the modeling condition that assigns a user to the "advanced researcher" group based on the educational topic attendance and questionnaire information.

7. Conclusions and Future work

In this paper a Virtual university is presented, designed and implemented as an adaptive hypermedia environment. It provides 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.

This environment provides an adaptive virtual desk for the user to study on. It transforms according to the needs and choices of the user in order to cover in a single view all his/her needs. Just like on a desk, using the environment the users may find the main course material and all additional info and tools together without browsing around in the library, their mailbox or the web catalogues. An additional core advantage, we paid particular attention to, is the methodology followed for the design and implementation. It has been considered fundamental in order to support incremental scaling, reusability and maintenance of both in users' terms and educational volume.

The environment has been used by post-graduate students- artists with basic experience of internet tools. At the end of the semester they were asked to provide feed-back. The result has been quite encouraging. They have found useful the fact that they could find course-related material categorized in one single place without browsing around the system. They liked that they could use information from email and documents while studying a subject. On the other hand some of them have found tiresome the extensive categorization of their emails into different folders. That is why we may add different types of categorization providing one simple and a more extensive one. It seems that we shall provide some differentiation of the categorization provided among communication tools.

Our future work aims to develop a dynamic object oriented hypermedia methodology that will incorporate our synthesized adaptive user model. The model will be re-fined 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.

8. References

[1] Arampatzis, A.T., van der Weide, T.P., Koster, C.H.A. and van Bommel, P. (2000): *Term selection for filtering based distribution of terms over time, RIAO' 2000 Conference Proceedings, Vol.* 2, 12-14/4, Paris, France, 1221-1237

[2] Barua, A., Chellappa, R. and Whinston, B.,A. (1997): An electronic infrastructure for a virtual university, *Communications of the AC*M, September 1997/Vol. 40, No 9.

[3] Beck, J., Stern, M., and Haugsjaa, E. (1996) Applications of AI in Education, *ACM Crossroad*s.

[4] Brusilovsky, P. (1998): Adaptive educational systems on the world-wide-web: A review of available technologies. In *4 th International Conference in Intelligent Tutoring Sys-tems,* San Antonio, TX.

[5] Carr, B. and Goldstein, I. (1977): Overlays: a Theory of Modeling for Computer-aided *Instruction. Technical Re-por*t, AI Lab Memo 406, MIT.

[6] Ceri, S., Fraternali, P. and Bognio A. (2000): Web Modeling Language: A modeling language for designing Web sites. WWW9, Amsterdam.

[7] Chakrabarti, S., Dom, B., Gibson, D., Kleinberg, J., Kumar, S., R., Raghavan, P., Rajagopalan, S. and

Tomkins, A. (1999): Mining the Web's link structure. *IEEE Computer* 32 (8) pp.60-68.

[8] Hanani, U., Shapira, B. and Shoval, P. (1999): Information Filtering: Overview of Issues, Research and Systems. User *Modeling and User-Adapted Interactio*n, Kluwer Academic Publishers, Netherlands.

[9] Kleinberg, J. (1998): Authoritative sources in a hyperlinked environment. *Proc. ACM-SIAM Symposium on Discrete Algorithm*s.

[10] Morita, M. and Shinoda, Y. (1994): Information filtering based on user behavior analysis and best match retrieval. *Proceedings of the 17 th NNUAL Intl. AACM SIGIR Conference on Research and Development, 272-281.*

[11] Schwabe D. and Rossi G. (1995): The Object Oriented Hypermedia Design Model, *Communication of the AC*M, Vol. 38, #8, Aug. 1995.

[12] Shapira, B., Shoval, P. and Hannani, U. (1997): Stereo-types in information filtering systems, *Information Processing and Management* 33(3), 273-287.

[13] Shih, K.,T. (2001): Software Systems for Virtual University Operations, *ACM Multimedia Conferenc*e.

[14] Stern, M., Woolf, B. and Kurose, J. (1997). Intelligence on the Web?. Proceedings of the *8th World Conference of the AIED Societ*y, Kobe, Japan.

[15] Stern M. and Woolf B. (1998): Curriculum sequencing in a Web-based tutor. In B. P. Goettl, H. M. Halff, C.L. Red-field, and V.J. Shute, editors, *Intelligence Tutoring Sys-tem (Proc. 4th Int'l Conf. ITS'98*), p. 584-593. Springer.

[16] The VU gazette URL:
http://www.geteducated.com/vugaz.htm