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Adaptive Hypermedia Systems: A review of adaptivity variables

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ABSTRACT

Adaptive hypermedia systems (AHS) offer an alternative to the traditional "one-size-fits-all" hypermedia and Web systems by adapting to the goals, interests, and knowledge of individual users represented in the individual user models. This paper serves as a review of all different variables reported in the literature that have been used in AHS.

Keywords: *Adaptive Hypermedia Systems, user model, adaptivity variables*

INTRODUCTION

The phenomenal growth of the Internet and the Web over recent years has led to an increasing interest in creating Web-based learning tools and learning environments. Many researchers have been working to construct sophisticated hypermedia systems, which can identify the user's interests, preferences and needs and give some appropriate advice to the user throughout the learning process. Adaptive Hypermedia was introduced as one possible solution. Adaptive Hypermedia Systems (AHS) combine hypermedia systems with Intelligent Tutoring Systems to adapt web-based educational material to particular users.

Traditionally adaptation decision in AHS was based on taking into accounts various characteristics of their users represented in the user model. That was true for pre-1996 adaptive hypermedia systems (Brusilovsky, 1996). Currently the situation is different. A number of adaptive Web based systems are able to adapt to something else than user characteristics (Brusilovsky, 2001, Kobsa, 2001, Carver, Hill and Pooch, 1999). The objective of the research presented in this paper is to provide researchers, designers, and developers of Adaptive Educational Systems a review of all different variables that have been used in adaptive educational systems and reported in the literature the recent years.

ADAPTIVITY VARIABLES

Adaptive hypermedia systems (AHS) build a user model of the goals, preferences and knowledge of the individual user and use this model to adapt the content of pages and the links between them to the needs of that user. The variables that user models include can be classified to 'user dependent' that includes those directly related to the user and define him/her as an individual, and to 'user independent' that affect the user indirectly and are related mainly to the context of a user's work with a hypermedia application.

The user dependent variables are: (a) knowledge on the domain presented, (b) background - experience, (c) preferences, (d) interests, (e) individual traits, (f) personal data, (g) abilities/disabilities, (h) social-group. On the other hand, the user independent variables are: (a) current goal/task, (b) environment-work, and (c) situation variables. Next, the paper will proceed to examine what the above variables concern with and how they can be represented in the user model.

Dependent variables

<u>a) Knowledge on the domain presented</u>

In most of the existing adaptive hypermedia learning environments user's knowledge on the subject articulated appears to be the most used and the most important user characteristic. In reviewing adaptive hypermedia systems, Brusilovky (1996) argues that one third of the systems adapt their interface according to the perceived knowledge of the user. The use of user knowledge requires an understanding of the underlying structure of knowledge that can be defined as the structure of interrelationships between concepts and procedures in a particular domain, which is organized into a unified body of knowledge.

An overlay model or a stereotype user model usually represents user knowledge. Overlay model as a type of knowledge representation was initially developed in the area of intelligent tutoring systems and student modelling. According to overlay model that is based on the structural model of the subject domain, user's knowledge of a subject is represented as an "overlay" of the domain model. For each concept in the domain model, an individual overlay model stores estimation of the user's knowledge degree of that concept. This estimation is usually presented by twofold concept-values (i.e., known or not known), qualitative states (good - average - poor), or a quantitative value (e.g., the probability that the user knows the concept, one for each domain concept of the task). Stereotype model is a more straightforward approach to classify the users. This model distinguishes several "stereotype" classes of users, which have preset values for the domain overlay (e.g. novice, expert).

<u>b) Background - Experience</u>

Another variable related to users previous general knowledge state is that of background-experience. This twofold variable is not concerned with the user's knowledge on the subject presented in the hypermedia system but it describes all the information related to the user's previous relevant experience outside the subject of the hypermedia system such as his/her familiarity with the information space and the ease of navigation within it. Moreover, it concerns with the user's profession, experience of work in related areas, and the user's point of view and perspective. Usually modelled using stereotype model (e.g. experience stereotype, background stereotype for profession).

c) Preferences

Preferences are user features that relate to the user's likes and dislikes. This variable describes that a user can prefer some types of nodes and links to others or some parts of a page over others. Moreover, preferences can indicate interface elements such as preferred colours, fonts, navigation ways, etc. User preferences are not assumed by the system; instead the user has to notify the system, directly or indirectly by providing feedback. Usually, the user through checklists can select preferred interface elements. Once the preferences are determined the system generalise the user's preferences and apply them for adaptation in new contexts (Brusilovsky, 1996).

d) Interests

Interests are a new adaptive variable that recently becomes popular in web-based information retrieval systems. It concerns with the user's long-term interests, and use these in parallel with the user's short-term search goal in order to improve the information filtering and recommendations. Interests can be modelled through navigation monitoring, for example, by observing which links the user visits more often.

e) Individuals Traits

User's Individual traits is a group name for user features that together define a user as an individual. Examples are user personality factors (e.g. introvert/extravert), cognitive factors, and learning styles. Like user background, individual traits are stable features of a user that either cannot be changed at all, or can be changed only over a long period of time. Unlike user background however, individual traits are traditionally extracted not by a simple interview, but by specially designed psychological tests.

User Personality

Murray and Bevan (1985) argue that human-computer interaction would improve if computers were assigned personalities, as the best way for a human to interact with a computer should closely resemble the interaction between two humans. On that view, Richter and Salvendy (1995) compared the performance of introverted and extroverted users using "extroverted" and "introverted" interfaces. The extroverted interface they design had more words, more "fun" pictures, more sounds, bold fonts and exclamation marks than the introverted interface. The subjects used in their empirical study were classified as introverted or extroverted according to the Eysenck Personality Inventory score. The main findings from this study suggested that users perceive the computer software as having personality attributes similar to those of humans and also using software designed with introverted personality results in general fastest performance for both individuals with extroverted and introverted personalities (Rothrock et al., 2002).

Cognitive Style- Learning Style

Cognitive or learning styles refer to a user's information processing behaviour and have an effect on user's skills and abilities, such as preferred modes of perceiving and processing information, and problem solving. They can be used to personalise the presentation and organisation of the content, the navigation support, and search results (Magoulas and Dimakopoulos, 2005).

Cognitive style is the way individuals organize and structure information from their surroundings and its role is critically important. It is associated with student success in any learning situation. Cognitive style is usually described as a personality dimension, which influences attitudes, values, and social interaction. It also refers to the preferred way an individual processes information. There are many different definitions of cognitive styles as different researchers emphasize on different aspects. However, Witkin's definition of field dependent (FD) and field independent (FI) is the most well known division of cognitive styles and is more relevant to hypermedia research than others (Witkin, Moore, Goodenough, Cox, 1977). Many experimental studies have showed the impact of field dependence /independence on the learning process and academic achievement and identified a number of relationships between cognitive style and learning, including the ability to learn from social environments, types of educational reinforcement needed to enhance learning, amount of structure preferred in an educational environment (Summerville, 1999, Ford & Chen, 2000, Triantafillou, Demetriadis, Pombortsis, Georgiadou, 2004).

Learning style is an important issue that affects the learning process and therefore the outcome. Many definitions and interpretations of learning styles appeared in literature the past decades. However, in general terms, learning styles is the individual preferences for how to learn. When designing instructional material, it is imperative to accommodate elements that reflect individual differences in learning as every learner has a unique way of learning. Papanikolaou and Grigoriadou (2004) suggest that important decisions underlying the incorporation of learning style characteristics in educational adaptive hypermedia systems demand the synergy of computer science and instructional science, such as: (i) the selection of proper categorizations, which are suitable for the task of adaptation, (ii) the design of adaptation, including the selection of appropriate adaptation technologies for different learning style categorizations and of apposite techniques for their implementation, (iii) the design of the knowledge representation of such a system in terms of the domain and the learner model, (iv) the development of intelligent techniques for the dynamic adaptation of the system and the diagnosis process of learners' learning style including also the selection of specific measurements of learners' observable behaviour, which are considered indicative of learners' learning style and studying attitude.

f) Personal data

Personal data, such as gender, age, language, and culture should be taken into account when designing adaptive educational interfaces to optimise learner's potential to benefit from the system's design in terms of knowledge acquisition.

Research suggests that males significantly outperform females in navigating virtual environments. Special navigation techniques (Tan, Robertson, and Czerwinski, 2001) when combined with a large display and wide field of view, appeared to reduce that gender bias. That work has been extended with two navigation studies in order to understand the finding under carefully controlled conditions. The first study replicated the finding that a wide field of view coupled with a large display benefits both male and female users and reduces gender bias. The second study suggested that wide fields of view on a large display were useful to females despite a more densely populated virtual world.

g) Abilities / Disabilities

People with disabilities often find difficulty to use computer-based systems, as the vast majority of these systems have no design considerations for them. These different users have varying needs regarding content and presentation of the information. For example, information for the blind should be presented in audio mode and a Braille display and speech synthesiser is needed so as to interact with the learning material; information for the deaf should never be in audio format.

h) Social – group

Computer Supported Collaborative Learning (CSCL) and groupware applications are at the focus of educational research lately. Group models are important for collaborative work, since a standard group model should serve as a starting point for interaction for the new member that enters a group (Brusilovsky, 1996). While the new user starts to interact with the system, the user profile can be formed including those characteristics that are in common with, and are different from, the group profile.

To build the group profile, information from users can be acquired using similar techniques with those used for the individual user model: stereotypes, interviews, monitoring users' behaviour. However, these techniques take into account adaptivity variables such as mental models in order to select users for the group construction.

The group profile is quite important for web-based courses as web facilitates collaborative activities. The web browsing advisor called Broadway (Jaczinsky & Trousse, 1998) uses Case-Based Reasoning (CBR) to learn relevant cases from the navigation paths from a group of users in order to improve the recommendation process. CBR is based on the hypothesis that if two users went through a similar sequence of similar documents, they might have similar browsing objectives, and therefore enable us to recommend the same selection to both (Hinrichs and Kolodner, 1991).

Independent Variables

a) Current goal / task

The most changeable user feature that activates adaptation is the user's goal(s) or task(s). It is related to the context of a user's work with a hypermedia application rather than with the user as an individual. It informs what the user wants to accomplish by using the application. For example, in information retrieval systems, a user's goal is a search goal; in educational systems is a learning goal; in testing systems might be a problem-solving one.

User's goal or task is not firm but they constantly change from session to session and frequently change several times within a session. However, there can also be simultaneous goals i.e. simple, multiple, concurrent. In order to accommodate multiple user strategies, Rasmussen and Hurecon (2000) suggests that systems should be designed to adapt to the work contexts by supporting a set of possible user goals or tasks. A system for example can provide a set of possible user goals that users can recognise, and then the most suitable goal will be included in the user model. Vassileva (1996) argues, that the most advanced representation of possible user goals is a hierarchy of tasks. Alternatively, the user model may hold a probability value for each goal supported by the system, to determine the likelihood that a particular goal is the current user goal. This technique can be used also to refine the classification of a goal hierarchy.

b) Environment – Work

Adaptation to user's environment is a new kind of adaptation that was brought by web-based systems. Users of web-based systems can work irrespective of time and location using different equipment and as a result adaptation to the user's environment can result in better use of the system and yet better performance. Systems can adapt to the user platform, such as hardware, software and network bandwidth. Such adaptation usually involves selecting the type of material and media to present the content, for example, still image vs. movie, text vs. sound.

Current Information and Communication Technologies developments focus on mobile information technology that allow for mobility in the physical space. Given the user and the information is connected to a network this technology facilitates accessibility of information from any point in the physical space. For communication purposes the user employs different devices that have, however, specific characteristics and limitations in terms of bandwidth and information presentation. For mobile information technology the particular challenge for adaptivity is the support of users at different locations. To achieve this, mobile information technology can be combined with technologies to identify the users' working environment and his or her position in the physical space such as infrared or General Positioning Systems (GPS) (Oppermann and Specht, 1999).

c) Situation Variables

In different situations the same user may have different requirements, and therefore, a system might need to take into account activities that are not expected from the user (Francisco-Revilla and Shipman, 2000). Situation variables that influence user abilities as well as task requirements include: time pressure, location in space and presence and location of targets; situation in time; weather conditions; visibility; and vibration and noise.

An example of how situation variables are examined is the 'Mars Medical Assistant' where three different situations are classified under time pressure: emergency, consultation and educational (Francisco-Revilla and Shipman, 2000). Time pressure is also the main characteristic of the user's profile used in Ready, an experimental system that adapts the type and the duration of advice given to people requesting for services over the telephone (Jameson, Schafer, Weis, Berthold, Weyrath, 1999).

DISCUSSION

Modelling multiple variables is important, as users have complex characteristics that ultimate affect their performance. User models must incorporate multiple variables of the user; dependent and independent. A user model could be in general stable during the learning process as this usually lasts for a specific period of time. However, as complex AHS emerge that would not be tied in a specific time period developers should consider that a user model might vary over time as the student progresses through hyperpace and their goals and interests may change while they work with new concepts. In that case the user model must quickly adapt to these changes.

Adding additional variables will not always increase the accuracy of the user model but will always increase its complexity and the requirements to collect additional user information (Carver, Hill and Pooch, 1999). Moreover, multimedia adaptation adds additional complexity and requires a greater implementation effort. Media elements are difficult to generate and are not flexible to automatic recombination as text is. For example it is extremely difficult to automatically adapt video segments on the fly and present the results to users. There are many research questions related to multiple variables modelling with regards to the type and number of variables, variables' modelling and most important with maintenance of a balance between the number of variables, model complexity, and the accuracy of the model.

Besides research questions the key issue remains; taking into account individual characteristics in interface design result in better user performance. The essence of learning is to measure performance and consequently user modelling for AHS must be the way ahead. The type and number of variables that each AHS would comprise in the user model depend heavily on the subject matter and the way that the course is implemented.

REFERENCES

Brusilovsky, P. (1996). Methods and Techniques of Adaptive Hypermedia. *Journal of user modeling and user-adapted interaction*.6 (2-3), 87-129.

Brusilovsky, P. (2001) Adaptive hypermedia. *User Modeling and User Adapted Interaction*, Ten Year Anniversary Issue (Alfred Kobsa, ed.) 11 (1/2), 87-110.

Carver, C., Hill, M. & Pooch, U. (1999). Third Generation Adaptive Hypermedia Systems. WebNet 99, Honolulu, Hawaii, 1999.

Ekstrom, R.B., French , J.W., Harman, H.H., Dermen, D. (1976). *Manual for kit of factor-referenced cognitive tests*. Princeton, N.J.: Educational Testing Service.

Ford, N. & Chen, S. (2000). Individual Differences, Hypermedia Navigation, and Learning: An Empirical Study. *Journal of Educational Multimedia and Hypermedia*, 9 (4), 281-311.

Francisco-Revilla, L. and Shipman, F.M. (2000). Adaptive medical information delivery combining user, task, and situation model. *Proceedings of the International Conference on Intelligent User Interface 2000*, ACM Press.

Hinrichs, T.R. & Kolodner, J.L. (1991). The roles of adaptation in case-based design. *Proceedings of the Ninth National Conference on Artificial Intelligence*, Anaheim, CA, 28-33.

Jaczinsky, M. & Trousse, B. (1998). Broadway: a world wide web browsing advisor reusing past navigations from a group of users. *Proceedings of 3rd UK workshop on case-based reasoning*.

Jameson, A., Schafer, R., Weis, T., Berthold, A., Weyrath, T. (1999). Making systems sensitive to the user's time and working memory constraints. *Proceedings of the IUI 99*. ACM press.

Kobsa, A. (2001). Generic User Modeling Systems. *User Modeling and User-Adapted Interaction,* 11, 49-63. Netherlands: Kluwer Academic Publishers.

Magoulas G. D. & Dimakopoulos D. N. (2005). Designing Personalised Information Access to Structured Information Spaces. *Proceedings of the 1st International Workshop Workshop on New Technologies for Personalized Information Access.*

Murray, D. & Bevan, N. (1985). The social psychology of computer conversations. In B. Shackel (Ed.) *Human-Computer Interaction – INTERACT 84*. New York: Elsevier Science.

Oppermann, R. and Specht, M. (1999). Adaptive information for nomadic activity: a process oriented approach. *Proceedings of the Software-Ergonomie '99*, Stuttgart: Teubner, 255 –264.

Papanikolaou, K.A. & Grigoriadou, M. (2004). Accommodating learning style characteristics in Adaptive Educational Hypermedia Systems. *Proceedings of the AH 2004 Workshop "Individual Differences in Adaptive Hypermedia".*

Rasmussen, J. and Hurecon, S. (2000). Designing to support adaptation. In *Proceedings of the IEA 2000/HFES 2000 Congress*.

Richter, L.A. & Salvendy, G. (1995). Effects of Personality and Task Strength on Performance in Computerized Tasks. *Ergonomics,* 38(2), 281-291.

Rothrock L., Koubek R., Fuchs F., Haas M., Salvendy G. (2002). Review and Reappraisal of Adaptive Interfaces: Toward Biologically-Inspired Paradigms. *Theoretical Issues in Ergonomic Science*.

Summerville, J. (1999). Role of awareness of cognitive style in hypermedia. *International Journal of Educational Technology*, 1(1).

Tan, D.S., Robertson, G.G. & Czerwinski, M. (2001). Exploring 3D Navigation: Combining Speed-Coupled Flying with Orbiting. In *Proceedings of CHI 2001, Human Factors in Computing Systems*, (Seattle, WA April 1-6, 2001), ACM press, 418-424.

Triantafillou, E., Demetriadis S., Pombortsis, A. & Georgiadou, E. (2004). The value of adaptivity based on cognitive style: an empirical study. British Journal of Educational Technology, 35 (1), 95-106.

Vassileva, J. (1996). A task-centered approach for user modeling in a hypermedia – based information system. *In Proceedings of the 4th International Conference on User Modeling*, Hyannis, MA, 115-120.

Witkin, H.A, Moore, C.A., Goodenough, D.R., Cox, P.W.(1977). Field-dependent and field-independent cognitive styles and their educational implications. *Review of Educational Research*, 47(1), 1-64.