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EDUCATIONAL APPLICATIONS OF ADAPTIVE HYPERMEDIA

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ABSTRACT: Adaptive hypermedia is a new direction of research within the area of adaptive and user model-based interfaces. The goal of this paper is to present the ideas and the state of the art of adaptive hypermedia, and to discuss the application of this ideas into education. Basing on their own experience, the authors talk about current state and prospects of adaptive educational hypermedia.

1. INTRODUCTION

Hypermedia systems have become increasingly popular in the last five years as tools for user-driven learning and access to information. Browsing along the hyperlinks, users can explore the hyperspace of information and find pieces of information which they actually need but never can request by a formal query. Adaptive hypermedia is a new direction of research within the area of adaptive and user model-based interfaces. The goal of this research is to increase the functionality of hypermedia. Adaptive hypermedia systems (AHS) build a model of the goals, preferences and knowledge of the individual user and use this throughout the interaction for adaptation to the needs of that user.

There are several reasons for using AHS. First, adaptation can solve the problem of hypermedia systems which are used by different classes of users. Users can seriously differ in their goals, background, and knowledge of the subject covered by the hypermedia system. A regular hypermedia system provides the same hypermedia pages and the same set of links to all users, while users with different goals and knowledge may be interested in different pieces of information presented on a regular page and may use different links for navigation. A way to overcome this problem is to use the information about a particular user, represented in the user model, to adapt the information and the set of links being presented to the given user.

Second, adaptation can prevent the user from getting lost in hyperspace, which is a problem for any big hypermedia system. Knowing user goals and knowledge, an adaptive hypermedia system can support users in their navigation by limiting browsing space (i.e. hiding non-relevant links), augmenting the links with some kind of comments (visual cues), or just re-ordering the links.

Third, adaptive hypermedia provide a convenient way for the system to guide the users unobtrusively in their work with the system. By adaptively creating dynamic links or just by highlighting some existing links the system can suggest to the user a way to proceed, while leaving him the freedom to make his own choices.

According to the above considerations adaptive hypermedia can be useful in any situation when the system is expected to be used by people with different goals and knowledge, where the hyperspace is reasonably big, or where the system can successfully guide the user in his or her work. We claim that education is one of the most promising areas for adaptive hypermedia. The goal of this paper is to present the ideas of adaptive hypermedia, and to discuss the application of these ideas in education.

Based on their own experience, the authors talk about current state and prospects of adaptive educational hypermedia.

2. ADAPTIVE HYPERMEDIA: THE STATE OF THE ART

This section provide a brief review of current research on adaptive hypermedia. We center the discussion around the question what can be adapted in adaptive hypermedia. At some level of generalization hypermedia consists of a set of "pages" connected by links. Each page contains some local information and a number of links to related pages. These links can appear within the content of a page, in a separate (sometimes pop-up) menu, on a separate local map, etc. Hypermedia systems often also include an index or global map which graphically shows all accessible pages. What can be adapted in adaptive hypermedia are the content of a hypermedia page and the links from a page (including index pages and maps) to related pages. We distinguish these two techniques of adaptation and call the first technique adaptive presentation (or content-level adaptation) and the second technique adaptive navigation support (or link-level adaptation).

Adaptive presentation is the most popular and the most studied way of hypermedia adaptation. The work on adaptive hypermedia presentation was influenced by the works on adaptive user interfaces, namely, the works of adaptive explanations [Paris 89]. With adaptive presentation the content of a hypermedia page is generated or assembled from pieces according to the user's class and knowledge state. Generally, qualified users receive more detailed and deep information, while novices receive more additional explanation. We can distinquish three techniques for adaptive presentation in hypermedia systems. In 'conditional presentation' technique [Fischer 90] each possible piece of information has a presentation condition, related with the user model. Only the pieces with currently true conditions are included into presentation. In 'frame-based' technique [Boecker 90, De Rosis 93] all information is presented in frames. The current presentation stategy (the order and the subset of slots to be presented) is determined by a set of rules which address the user model. In stretchtext technique [Boyle 94, Kobsa 94] each hypermedia page can contain special 'stretchtext' areas which can be hidden or opened by both the user and the system. When moving to a new page the system decides (using the user model) which stretchtext areas should be opened to the user and the expository style of this area (more details or more explanations). Two popular application areas for adaptive presentation are adaptive hypermedia-based help in knowledge-based systems [Fischer 90, De Rosis 93] and on-line documentation systems [Boecker 90, Boyle 94]. The experiments, reported in [Boyle 94] shows that adaptive presentation increases user performance.

By adaptive navigation support we mean all the ways to play with visible links which can support hyperspace navigation. Non-educational AHS rely on the user's current task, preferences and previous experience to adapt the set of visible links. Two techniques were suggested for that. 'Adaptive ordering' employs the user model and some user-valuable criteria to adapt the order of presentation for all possible links thus giving the user a hint which link to follow (the closer to the top, the more relevant the link is). This technique was suggested in [Boecker 90, Kaplan 93], and the latter paper reports positive experimental results. 'Hiding' technology [Vassileva 94] tries to protect the user from cognitive overload by hiding a part of possible links and showing only those links which are relevant according to the user model. At present, adaptive navigation support is used mainly in on-line documentation and similar information-retrieval system with huge hyperspaces.

3. ADAPTIVE EDUCATIONAL HYPERMEDIA

At present very few educational systems use adaptive hypermedia. Adaptive presentation was implemented in [Brusilovsky 92, Beaumont 94]. The system ITEM/IP [Brusilovsky 92] uses a simple 'conditional presentation' technique. The system Anatom-Tutor [Beaumont 94] uses more advanced techniques.

3.1 Modelling the User

Useful adaptation requires that the system have access to a relatively large amount of reasonably accurate information about the user. Adaptive presentation, especially, requires information about the user's knowledge of the domain. While pure hypertext systems often try to deduce such information solely by observing his behaviour in requesting further information, educational systems can include questions related to the material being covered. ANATOM-TUTOR, for example, uses both a questionnaire at the start of a session (for general information, such as a self-estimation of the user's general level of knowledge, which lectures he has heard, why he is using the system, etc.) and questions integrated into the lessons (i.e. questions about the domain) for deducing a "default closure" of what the user knows - i.e. the system extrapolates on information which the user certainly has and deduces a body of information which he very probably has. Discrepancies between the user model thus obtained and later answers given by the user are used for formulating explanations, generating additional questions, revising certain types of deduction mechanisms used in constructing the model, and updating the model itself. The deduction mechanisms fall into two categories:

1) those which predict the learner's use of domain laws for inferring new declarative information.
2) those which make use of a structure on the domain knowledge. (this is determined by the system

designers using their knowledge of the domain and statistical surveys of users learning the material).

The mechanisms in the second category, often referred to as "stereotypes", are those which can be revised in the course of a session (see [Rich 89] for more on stereotypes in user modelling, and [Beaumont 94] for a short overview of user modelling techniques).

3.2 Adaptation

Adaptative presentation can involve both the style and the content of the text. People at different levels of proficiency talk about their subject material in different ways, as anyone who has compared the conversations of experts on a subject with that of laypersons will readily admit, and texts prepared for a specific reader group orientate their presentation style on that group. ANATOM-TUTOR's hypertext component first chooses a default presentation style depending on the user's global classification, and can adapt this locally according to the user's (local) level of proficiency. The user's level of experience, the lessons and lectures he has already worked through, etc., are taken into consideration for choosing the default expository style. Two basic categories of user are distinguished, beginner and advanced, and two expository styles correspond to these two user categories. Most users will fall somewhere between beginner and advanced, and the view taken by Paris [Paris 89] and ourselves is that a presentation adequate for the needs of the individual user can be obtained by combining these styles in accordance with the user's local knowledge of the concepts involved. The effect produced is that of a continuous range of user levels. In addition to this presentation style, Anatom-Tutor also locally determines the content of the presented text, i. e. known material can be left out and additional material included. The content and actual local (i.e. for one or several sentences) expository style is chosen by comparing the user's (fine-grained) knowledge with the material covered in that part of the lesson. For example, if something is being taught about the area striata and the user has little or no pre-knowledge of this brain structure, then the system will use the morphologically biased descriptive style, while better knowledge can result in the functionally biased style being chosen (or in the material being left out altogether, in keeping with our philosophy of non-redundancy of content).

Adaptive navigation support was implemented in the following educational systems [De la Passardiere 92, Brusilovsky 93, Brusilovsky 94]. However these systems use neither 'hiding' nor 'adaptive ordering' techniques (though earlier versions of the two latter system used 'hiding' technology). Educational hypermedia is specific in two senses: each page hase reasonable number of links to related pages, and the links are often embedded (context) links. 'Hiding' and 'adaptive ordering' techniques provide a good way to support user navigation in the pages with dozens of possible links, are less useful when the number of links is smaller and can hardly be applied for embedded (context) links. Some research also shows that the stable order of options in menus is important for novices [Kaptelinin 94]. A more promising and flexible technology for adaptive navigation support in educational hypermedia is adaptive annotation of visible links (augmenting links with personal dynamic comments in any form) [de La Passardiere 92, Brusilovsky 93,94]. Recent research shows that even static annotation which tells the user more about the nodes designated by annotated links can increase students performance [Zhao 93]. Adaptive annotation can use icons [de La Passardiere 92], colours [Brusilovsky 93,94] or other visual cues to reflect the state of the related nodes according to user knowledge and goals. The most simple adaptive annotation technique is just outlining the links to previously visited nodes, giving two states for visible links (links to visited/not visited nodes). This can be found in many hypermedia systems including NCSA Mosaic. The systems [de La Passardiere 92,Brusilovsky 93,94] can distinguish and use four and more states on the base of the student model. For example, ISIS-Tutor uses colours to annotate the set of links leading from the current node to related nodes (and from index page to all nodes) according to the current user knowledge and educational goals. The system uses the student model to distinguish three knowledge states for each concept which is represented by a hypermedia page: not-ready-to-be-learned (i.e. has unlearned prerequisites), ready-to-be-learned, and learned. Thus, at any moment the hyperspace is divided implicitly into three zones with different educational status. The idea is that marking these zones visually would help the student in hyperspace navigation. To do it the system just marks the hyper-links of each node in three different colours. For example, the links to the nodes which are not-ready-to-be-learned are gray so as not to distract the student.

4. DISCUSSION

In this section we want discuss the prospects for adaptive educational hypermedia.

First, we think that adaptive hypermedia is an important technology for educational computing. Currently, most educational systems belong either to the class of 'tutors' providing 'guided', 'adaptive', machine-driven education (CAI, ITS), or to the class of environments providing 'free' student-driven learning (hypermedia, microworlds). Adaptive hypermedia can bridge the gap between these two poles. Adaptive hypermedia systems still leave the initiative to the student, however the system can adapt to the student and guide the student implicitly but significantly by changing the content and the links of hypermedia pages.

From another viewpoint education is a very promising area of adaptive hypermedia application because educational systems can provide more feedback which is a key for more precise and reliable adaptation. In the domain of online information systems the main feedback which the adaptive hypermedia component gets is the request for more information, which is usually done by clicking menu buttons or active fields in the body of the text. Boyle and Encarnacion [Boyle 94], recognise that the mouse click allows only a "narrow bandwidth of information" but make the most of it by using stretchtext technology, which enables the user to remove superfluous information (i.e. information which the user does not understand or which is too basic) from the screen, thus providing another feedback dimension. Unlike on-line documentation systems, tutoring systems such as ANATOM-TUTOR or ISIS-Tutor can use test questions and problems to increase the bandwidth of information available from the user without leaving the teaching paradigm. Adding questions relating to the material is obviously superior to trying to accurately update the model solely from the user's requests for more or less material.

Thus the educational application of adaptive hypermedia is a promising area from both sides. First, better adaptive hypermedia can lead to a breakthrough in educational computing by bridging the gap between traditional user-driven exploratory environments and machine-driven tutoring systems, resulting in better educational systems. Second, an educational setting can produce better and more reliable student models than most other areas in which adaptive systems are used. This means more possibilities for hypermedia adaptation.

In both the above senses the most promising kind of educational systems to be extended with adaptive hypermedia are intelligent tutoring systems (ITS). A specific feature of ITS is the use of well-structured domain models and student models to guide and to help the student in the process of learning. Thus, ITS can regularly and unobtrusively provide updated, fine grained user models, which are essential for effective adaptive hypermedia. At the same time, adaptive hypermedia can augment ITS with a component for user-driven exploration of teaching material, the lack of which is a weak point of many ITS. It's not by chance that the first work on adaptive educational hypermedia was made in the context of ITS. In its early days adaptive systems use a number of good ideas from the domain of ITS. It's the time now for ITS to use some ideas from the domain of adaptive systems. We think that for the next several years adaptive hypermedia systems will be going side-by-side with ITS. We conclude by saying that many existing ITS can be easily extended with adaptive hypermedia features and it's probably a nice way to go.

REFERENCES:

Beaumont I. (1994) User modelling in the interactive anatomy tutoring system Anatom-Tutor. In *User modeling and user adapted interaction*, 4: 1994, (p.21-45).

Boecker H.-D., Hohl H. and Schwab T. (1990) Hypadapter - Individualizing Hypertext. In Diaper D. et al (ed.) INTERACT'90. *Proceedings of the the IFIP TC13 Third International Conference on Human-Computer Interaction.* North-Holland, Amsterdam. 931-936.

Boyle C. and Encarnacion A.O. (1994) MetaDoc: an adaptive hypertext reading system. In *User modeling and user adapted interaction*, 4: 1994 .

Brusilovsky P.L. (1992) Intelligent Tutor, Environment and Manual for Introductory Programming. Educational and Training Technology International, 29(1), 26-34

Brusilovsky P., Pesin L., and Zyryanov M. (1993) Towards an adaptive hypermedia component for an intelligent learning environment. In Bass L.J., Gornostaev J. and Unger C. (eds.) *Human-Computer Interaction.* Lecture Notes in Computer Science #753, Springer-Verlag, Berlin, (p. 348-358).

Brusilovsky P. and Pesin L. (1994) ISIS-Tutor: An adaptive hypertext learning environment. *Proc. of JCKBSE'94, Japanese-CIS Symposium on knowledge-based software engineering*. Pereslavl-Zalesski, May 10-13, 1994. Tokyo. (p. 83-87).

de La Passardiere B. and Dufresne A. (1992) Adaptive navigational tools for educational hypermedia. In Tomek I. (ed.) *Computer Assisted Learning. Proceedings of the 4th International Conference, ICCAL'92.* Springer-Verlag, Berlin. (p. 555-567).

De Rosis F., De Carolis N. and Pizzutilo S. (1993) User tailored hypermedia explanations. In INTERCHI'93 Adjunct Proceedings, Amsterdam, 24-29 April, 1993. (p. 169-170).

Fischer G., Mastaglio T., Reeves B. and Rieman J. (1990) Minimalist explanations in knowledge-based systems. *Proceedings of the 23rd annual Hawaii international conference on system sciences*, Kailua-Kona, 2-5 January, 1990, (p. 309-317).

Kaplan C., Fenwick J. and Chen J. (1993) Adaptive hypertext navigation based on user

goals and context. User modeling and user adapted interaction,
3(2).

Kobsa A., Mueller D. and Nill A. (1994) KN-AHS: An adaptive hypertext client of the user modeling system BGP-MS. *Proceedings of the Fourth International Conference on User Modeling,*

Paris, C. (1989) 'The Use of Explicit User Models in a Generation System for Tailoring Answers to the User's Level of Expertise'. In: A. Kobsa and W. Wahlster: 1989, *User Models in Dialog Systems*, Heidelberg: Springer Verlag.

Rich, E. (1989) 'Stereotypes and User Modeling'. In: A. Kobsa and W. Wahlster: 1989, *User Models in Dialog Systems*, Heidelberg: Springer Verlag.

Vassileva, J. (1994) A practical Architecture for User modeling in a Hypertext-Based Information System. *Proceedings of the Fourth International Conference on User Modeling*, (p. 115-120).

Zhao Z., O'Shea T., Fung P. (1993) Visualization of semantic relations in hypertext systems. ED-MEDIA'93, (p. 556-564).