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Adaptive hypermedia: the state of the art

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The goal of this paper is to provide a brief overview of recent works on the development of adaptive hypermedia systems. Adaptive hypermedia systems apply user models to support adaptive presentation and adaptive navigation. We tried to answer the most important questions: why and where do we need adaptive hypermedia systems, what and how can be adapted in these systems.

Introduction

Hypermedia systems and user-model-based adaptive systems (i.e. intelligent tutoring systems, information retrieval systems) are most often considered as two different approaches to browsing information spaces and interface organization. Adaptive hypertext and hypermedia systems (AHS) attempt to bridge the gap between the two extfmes. AHS enhance classic hypermedia with an intelligent agent which supports a user in her work with hypermedia. The intelligent agent can adapt the content of a hypermedia page to the user's knowledge and goals or suggest the most relevant links to follow. AHS avoid the `unrelevant adaptation' problem of classic adaptive systems by providing space for user-driven adaptation. AHS also avoid the lost in hyperspace' problem of classic hypermedia systems by providing intelligent guidance.

The goal of this paper is to provide a brief overview of recent works on the development of adaptive hypermedia systems. We hope that this overview will be useful for several categories of researchers and will stimulate further work in this area. We start the review with answering three most important questions: why do we need adaptive hypermedia, where it can be useful, and what can be adapted in AHS. We give several answers to each of these questions, thus forming simple classification. The answers are supported by references to real systems. Then we provide more technical details. We uncover underlying structures of domain knowledge representation and user models and describe several methods of adaptation applied in various AHS.

Why adaptise hyperwedia?

Hypermedia systems become increasingly popular for the last five years as a tool for user-driven 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. Unlike other kinds of application systems, any hypermedia system is adaptive in some sense: using free browsing different users can adapt the system to their information needs. Many researchers hold that it is the user who should bring the adaptivity to the man-machine hypermedia system. Why do we need any other kind of adaptation? Why do we need that the hypermedia system adapts itself to the particular user? People working on adaptive hypermedia gives two main arguments for that.

At 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 on the subject covered by

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the hypermedia system. Regular hypermedia system provides the same hypermedia pages. and the same set of links to all users, while different users really need different information. Users with different goals and knowledge may be interested in different pieces of information presented on a regular page and may use differenr links for navigation. Information and links which are unrelevant to these users just overload their working memories and screen. 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 links being presented to the given user. We call it adaptive presentation. Adaptive presentation can also solve the problem of educational hypermedia systems, where the same user can have different knowledge on the same topic (and thus need different information on this topic) on different stages of learning.

Second, adaptation can protect the user from being lost in hyperspace, what 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, providing adaptive comments to visible links or just suggesting most relevant links to follow. We call it adaptive navigation.

Where adaptive hypermedia can be helpful

According to the above considerations adaptive hypermedia can be useful in any situation where the hyperspace is reasonably big or/and when the system is expected to be used by people with different goals and knowledge. Potentially it gives us a variety of application areas. Analysis of existing systems gives us only three areas which are used at present in most of research projects on adaptive hypermedia.

First application area is on-line documentation systems. Adaptive hypermedia technologies are used here for both the above reasons: to provide different information for different users [2, 3) and to provide individualized navigation support in a big space of information [2, 10].

Second area is application systems with advanced help and explanation facilities. Examples of such application systems are a statistical package [8], a design critic [9], a CAD system [fly or a decision support system [15]. The role of hypermedia here is to provide explanation of application-specific and system-specific details and concepts. The reason to use hypermedia, (and adaptive hypermedia in particular) for explanation is the need to adapt explanations to different classes of users. Navigation support doesn't play significant role here, because the hyperspace is usually compact enough.

Third application area is educational systems. Hypermedia components are used in educational systems to provide student-driven exploration of educational material. Adaptive hypermedia is required here for both the above reasons: to adapt the presented information to the current knowledge level of the student [5,1], and to provide navigation support on various levels from commenting existing links [7,4,6] to suggesting the best link to follow [5,13].

Very few of existing adaptive hypermedia systems are applied in the areas different from the above three. Progress in this direction is probably related with application-independent adaptive hypermedia shells [11], which can be used in a number of different application areas.

What can be adapted is adaptive hypermedia?

On 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. What can be adapted here are the content of a hypermedia page and the links to related pages. Adaptation of the page content is the main example of adaptive presentation. It is also the most popular way of hypermedia adaptation [2,5,9,8,1,3,11]. Adaptation of links can be .used for both adaptive presentation (changing the set of visible links) 141 and adaptive navigation (changing the layout of links to provide guidance). We distinguish two essentially different ways for supporting adaptive navigation: re-ordering the list of links (the more close to the top, the more relevant the link is) 12,10,141 and augmenting links with personal dynamic comments in any form 17, 4,61. Both ways can be combined with adaptive hiding of some links. It gives us three main directions of adaptation: adapting the content, re-ordering the links and augmenting the links. Next sections will describe some known techniques of adaptation along these three direction.

How hypermedia can be adapted: internal structure

To present existing methods of adaptation in hypermedia we need first to describe typical internal structure of adaptive hypermedia. Interesting, but internal structures of different adaptive hypermedia systems are quite similar, though the adaptation techniques can differ significantly. The heart of an adaptive hypermedia system is a set of topics or concepts. Topics represent elementary pieces of knowledge for the given domain and the size of a topic depends from the domain. Topics are usually linked to each other thus forming a kind of semantic network. This network is actually the structure model of the domain covered by the hypermedia. Most of existing adaptive hypermedia systems are based on such domain models, more or less complex. Simplest models, we call it level one models, do not provide typization of topics and links 110,41. More advanced systems distinguish several kinds of topics and several kinds of links in the domain model [5,6,8,2,11,12,9,11. Here the domain model is real semantic network, we call it level two model. Finally, some systems use frames to represent internal structure of topics by a set of attributes (different kind of topics can have different sets of attributes) (5,6,8,2,9,151. We call such network of frames as level three model. The more advanced is the underlying model, the more advanced techniques of adaptation can be used in the system.

The relations between domain model topics and hypermedia pages can be also different. Almost all existing systems use the rule "each topic has a page as external representation (or several pages if the amount of information about topic is big)". However the inverted relation is not always true. In many systems each hypermedia page really corresponds to exactly one topic. Advanced systems often have multi-topic pages, like "example" pages 15,81 where each example can correspond to several topics. To provide internal structure for multi-topic pages, different parts of such pages can be related to different topics 111,31 or sets of topics 151.

User models in adaptive hypermedia systems are usually based on its domain models. The kind of user model most often used in existing system to model user knowledge is the overlay model 15,6,4,8,9,2,111. For each domain model topic the overlay model keeps some estimation of how well the user is familiar with this topic. This estimation can have discrete 15,21 or probabilities 18,111 values. I7te model of user knowledge thus can be represented as a set of pairs "topic - value'. Similar representation can be used to model user's goals, traits, background and other personal details. Overlay model is powerful and flexible, it can measure independently user knowledge on different topics.

Sometimes more simple stereotype user model is used 13, 101. Here the model of user knowledge is also represented as a set of pairs 'topic - value', but the values are not completely independent. In a

stereotype model the user can be assigned to one or more stereotypes (for example, novice - intermediate expert). Each stereotype is characterized by a fixed set of pairs "topic-value", and the user assigned to a strereotype inherits all these properties. Stereotype modeling is reliable enough and works nice for the systems which need to adapt to different classes of users (as on-line documentation systems It is more simple then overlay modeling, but less flexible and powerful. In particular, stereotype models are too week for educational systems. Good results can be achieved by combining stereotype and overlay modeling [2, 8,1,111. One possible way to combine it [8k stereotype modeling is used to determine the class of the user and to assign initial values for overlay model. Then overlay modeling is used to keep the model updated.

Pow hypermedia can be adapted: techaignes

To support adaptive navigation by re-ordering of links some simple techniques can be used. Level one domain model and stereotype user model are enough for that purpose (but overlay model can provide some improvement). Good example is provided by HYPERFLEX system (10]. HYPERFLEX use a kind of overlay user model to represent individual strengths of association between pairs of byperspace nodes and between user goals and nodes. This model can be-updated by both the user and the system. If the user set current goal and/or node, HYPERFLEX can present him a list of related nodes ordered by the strengths of association.

Adaptive augmenting of links can be more or less elaborated, depending from the models used. The most simple technique which is used in many regular hypermedia systems and some adaptive bypermedia systems [131 is just to mark all links which are connected to already visited pages. It provides minimal navigation support and play the same role as bookmark in a book. If overlay user model is used, the system can distinguish more then two states for the links. For example, the system (71 mark all links with three different colours (black, gray, white) according to educational state of related nodes (well-learned, partly lea: ned, not learned). If level one or level two domain model with prerequisite links is used, the system can also mark specially the links to not-ready-to-be-learned topics. For example, ITEM/PG [61 use domain and student model to distinguish four states for hyper-nodes: not-ready-to-be-learned, ready-to-be-learned, known and well-known. Thus at any moment the hyperspace is divided implicitly into several "zones". Our idea was that different zones have different meanings for the student and marking these zones visually would help the student in navigation. To mark the zones the hypermedia component just marks the hyper-links from index and from each node by four different ways. For example, the links to the nodes which are not ready to be learned are dimmed so as not to distract the student. The links to ready to be learned nodes are colored green inviting the student to visit it.

Adaptive presentation usually requires level three domain model and overlay user model. We can mention three interesting adaptive presentation techniques. "More explanations - more details' tecbaique is used in [3, li]. This technique is suitable for multi-topic hypermedia pages, where each page can `refer or mention several topics. Each topic can have two kinds of information associated with it: ntwre explanations and more details. It's expected, that the user who is not familiar with the topic week yore explanations for it, but yet can't appreciate more details. Vise versa, the user who is wcfl familiar with the topic does not need any explanations, but needs all details about k. Using the user model, the system, if required, can insert (or collapse) more explanations or/and more details after the reference to a **topic.** Thus the content of a hypermedia page can be different for users with different knowledga:

Another technique is used in ITEM/IP system [5] for adaptive presentation of programming concepts and constructs. In ITEM-IP the student who is well-familiar with a concept gets more concise and complete explanation than a novice. This become clear from the following example. The textual information which is stored for the given concept can be divided into a sequence of text fragments. Each fragment has a condition which addresses the knowledge level of the given and related concepts. While producing a description of the concept, the system presents only the fragments with true condition. The more the concept is learned, more concise descriptions are presented. Textual description of the concept is usually followed by a generated list of related concepts, giving the names of related concepts for each possible kind of relationships. To avoid confusion only the are known, more complete information is presented. are known, more complete information is presented.

The most advanced adaptive presentation techniques are used in systems Hypadapter [2) and EPIALM [8]. These systems use level three domain model (each topic is represented by a frame with several slots) and different combinations of overlay and stereotype user models. Flexible rule-based formalism is used to represent the strategy of adaptation. Hypadapter system has a set of independent "slot" rules based on the student model. These rules are used to decide, should a particular slot be presented, and to calculate slot importance. Selected slots of the frame are ordered by importance and presented to the user. EPIAIM system provide an intermediate level for decision making: the presentation schemas. Each schema is just as ordered subset of attributes to present. A set of user model based rules is used to select the most relevant schema, which is used then to control the concept presentation. Both systems contain in different slots of its frames two or more versions of topic description oriented for users with different knowledge. Thus each user can get the most relevant version of concept description during the presentation. At the end of this section we should note that different techniques of adaptation do not contradict each other. Moreover, they are complimentary and based on the similar domain model and user model. Interesting direction of research is integration of several different adaptation techniques in one system on the base of the same domain and user models. At present we know only one system - Hypadapter [2] which use two different ways of adaptation, namely adaptive navigation support and adaptive presentation.

Conclusions

In this short overview we concerns only a part of problems related with adaptive hypermedia. Our goal was to present this area of research to people who never hear about it, as well as to provide some systematization of the work done up to date. We tried to answer the most important questions: why and where do we need adaptive hypermedia systems, what and how can be adapted in these systems. More information about real projects, experimental results and typical problems of adaptive hypermedia systems can be found tin he papers listed bellow.

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