Adaptive Hypermedia: From Systems to Framework

Paul De Bra
Eindhoven University of Technology
and
Peter Brusilovsky
Carnegie Mellon University
and
Geert-Jan Houben
Eindhoven University of Technology

The navigational freedom in conventional hypermedia applications leads to comprehension and orientation problems [Nielsen and Lyngbæk 1990]. Adaptive hypermedia attempts to overcome these problems by adapting the presentation of information and the overall link structure, based on a user model. This paper introduces a framework for adaptive hypermedia systems (AHS). It briefly describes some popular methods and techniques for adaptation. Examples and evaluations of existing AHS are used to illustrate the potential benefits of using adaptation in hypermedia applications.

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1. INTRODUCTION

Adaptive hypermedia is a direction of research on the crossroads of hypertext (hypermedia) and user modeling. The goal of this research is to improve the usability

Name: Paul De Bra, Geert-Jan Houben
Affiliation: Eindhoven University of Technology
Address: P.O. Box 513, Eindhoven, The Netherlands
Name: Peter Brusilovsky
Affiliation: Carnegie Mellon University
Address: 4615 Forbes Avenue, Pittsburgh, PA 15213, USA

of hypermedia. Adaptive hypermedia systems build a model of the goals, preferences and knowledge of the individual user and use this throughout the interaction for adaptation of the hypertext to the needs of that user.

A "classic" hypermedia application serves the same pages and the same set of links to all users. This is true even for most applications that are built on top of systems that are capable of presenting different views to different users. Adaptive Hypermedia Systems (AHS) make it possible to deliver "personalized" views or versions of a hypermedia document (or *hyperdocument* for short) without requiring any kind of programming by the author(s). Also, although it is possible to offer users a way to initialize the user model through a questionnaire, an AHS can do all the adaptation automatically, simply by observing the browsing behavior of the user. (There are many *adaptable* systems that allow "personalized" views based on user-selected stereotypes like "beginner" and "expert", or based on interface and style preferences. Another paper in this issue [Quentin-Baxter 2000] deals with this issue in an educational context. The crucial differences with AHS are that in an AHS the adaptation uses a much more fine-grained user model and that the adaptation is done automatically instead of being "selected" by the user.)

A number of adaptive hypermedia systems (AHS) have been developed. The application areas for these systems range from educational hypermedia to information retrieval systems with a hypertext interface. Various research groups have developed different original techniques to adapt aspects of hypermedia systems to individual characteristics of a user. A comprehensive review of adaptive hypermedia techniques and systems can be found in [Brusilovsky 1996]. In Section 2 we briefly review some popular methods and techniques for AHS. Some adaptive hypermedia applications have been empirically evaluated. Experiments have been conducted to test whether information can be found faster or can be better comprehended when adaptive techniques are used. Section 3 reports on such evaluations.

2. FRAMEWORK, METHODS AND TECHNIQUES FOR ADAPTIVE HYPERMEDIA

2.1 A Framework for Adaptive Hypermedia

The authors independently developed a similar framework to describe adaptive hypermedia applications. In this framework the "knowledge" contained in a hyperdocument is described by a *domain model*:

—There are three kinds of *concepts*: *atomic* concepts or *fragments* (the smallest information units), *pages* (composed of fragments) and *abstract* concepts (representing larger units of information).

—Concepts are connected through *concept relationships*. Apart from *link* relationships an AHS may support other types of relationships; *prerequisite* relationships are a good example.

An AHS typically performs three functions:

—While a user is "browsing" through an adaptive hyperdocument all user actions are registered. (In Web-based AHS this means that requests for pages are logged.) Based on these observations the AHS maintains a model of the user's knowledge about each domain model concept. Typical attributes a user model keeps for each concept are *knowledge-value* (how much does the user know about this concept) and *read* (has the user read something about this concept).

—The user model is applied to classify all nodes (pages) into several groups according to the user's current knowledge and interests or goals. The AHS manipulates link anchors within nodes (and link destinations) to guide users towards interesting, relevant information. Brusilovsky [Brusilovsky 1996] calls this *adaptive navigation support*. Depending on the class of the node a link leads to, the link anchor could be specially annotated, disabled, or removed.

—In order to ensure that the content of a page contains the appropriate information (at the appropriate level of difficulty or detail) the AHS will conditionally show, hide, highlight or dim conditional fragments on a page when presenting it. This is done in order to ensure that the content of a page contains the appropriate information for the given user at the given time. Brusilovsky [Brusilovsky 1996] calls this *adaptive presentation*.

A detailed description of a proposed "reference" model for adaptive hypermedia applications can be found in [De Bra et al. 1999].

2.2 Adaptive Presentation

Adapting the presentation of information within a page is most often performed as a manipulation of (canned) text fragments. The aim of these manipulations can be:

—*Providing prerequisite, additional or comparative explanations*: Additional information can be shown for users with a specific state of knowledge or interest to provide missing prerequisite knowledge, additional details, or a comparison with a previously known concept. Two techniques that are used to provide such explanations are:

  —*Conditional inclusion of fragments*: This technique is used in the AHA system [De Bra and Calvi. 1997; De Bra and Calvi. 1998] which is used in the course "2L670: Hypermedia Structures and Systems" at the Eindhoven University of Technology. From the user model and the concept relationships in the domain model the AHS determines which fragments should be displayed.

  —*Stretchtext*: This technique is used (for instance) in MetaDoc [Boyle and Encarnacion 1994]. For each information fragment there is a (short) visible place holder. The AHS determines which fragments should be "stretched" (i. e. shown) and which fragments should be "shrunk" (i. e. only the place holder is shown). This decision only determines the *initial* presentation of the fragment. The user may stretch or shrink fragments through mouse clicks. The AHS uses these user actions to better predict which fragments to stretch or shrink in subsequent page requests. An evaluation of MetaDoc is described in subsection 3.1.

  Recently [Hothi and Hall 1998] a new technique was introduced, evaluated and found useful, where fragments that are not recommended for a user are grayed out instead of removed or shrunk.

—*Providing explanation variants*: Essentially the same information can be presented in different ways. Depending on values in the user model the level of difficulty, the related concepts a page refers to, the length of the presentation, the media type (text, images, audio, video) or other aspects may be changed. This can be done within a page or through guidance towards different page variants. (In the latter case the method becomes adaptive navigation support rather than adaptive presentation). Explanation variants are used in Anatom-Tutor [Beaumont 1994], Hypadapter [Hohl et al. 1996] and other systems.

—*Reordering information*: Depending on user model values the order in which information items are presented may have to be altered. For instance, some users may prefer to see an example before a definition, while others prefer it the other way around. Sorting is used in Hypadapter [Hohl et al. 1996] for instance. On a page fragments of information are typically sorted from most to least relevant, a method which is best known from information retrieval systems.

There are some AHS and also *dynamic hypertext systems* that use frame based techniques and/or natural language generation techniques in order to provide individualized (and naturally sounding) presentations. We do not elaborate on these systems in this paper. Another kind of applications which are also called *dynamic hypertext* are systems that combine querying and linking in order to provide "personalized" link structures. Such systems are discussed in another article in this issue[Bodner and Chignell 2000].

2.3 Adaptive Navigation Support

The manipulation of links that are presented within nodes (pages) is typically done in one or more of the following ways:

—*Direct guidance*: A "next" or "continue" (link) button is shown. The destination of this link is the node which the AHS determines to be most appropriate.

—*Sorting of links*: A list of links is sorted and presented from most relevant to least relevant. This technique is useful in information retrieval systems and in goal oriented educational systems. Link sorting is used in Hypadapter [Hohl et al. 1996].

—*Link annotation*: Link anchors are presented differently depending on the relevance of the destination. ELM-ART [Brusilovsky et al. 1996] and Interbook [Brusilovsky et al. 1998] use colored dots and arrows as annotations. (Green means interesting and red means inappropriate.) ISIS-Tutor [Brusilovsky and Pesin 1998] and AHA [De Bra and Calvi. 1997; De Bra and Calvi. 1998] color the anchor text itself. AHA also lets the user configure the color scheme.

—*Link hiding*: Links leading to inappropriate or non-relevant information are hidden. This can be done by presenting the link as "normal text". The default color scheme used by the AHA system uses black for undesirable links, and thus corresponds to link hiding.

—*Link disabling*: Inappropriate links are disabled. Whether the link anchor is visible depends on the combination of this technique with link annotation or link hiding.

—*Link removal*: Inappropriate links (and anchors) are simply removed. This works well in lists, but removing the anchor text does not work for anchors that appear in running text. ISIS-Tutor [Brusilovsky and Pesin 1998] uses link removal.

—*Map adaptation*: Some hypermedia systems provide a graphical presentation of (part of) the link structure [Mukherjea 2000; Benford et al. 2000]. Such maps can also be subject to adaptation. (We do not consider this adaptive navigation support further in this paper.)

3. EVALUATION OF ADAPTIVE HYPERMEDIA APPLICATIONS

Whether the use of adaptive hypermedia (presentation and/or navigation) is beneficial, for comfort or performance, is always a combination of the adaptive methods and techniques that are used and of the way in which the adaptation is used. (One could use adaptive techniques to guide users in the wrong direction and turn navigation through a hyperdocument into an adventure game.) Below we describe some evaluations of adaptive hypermedia applications. We do not (and cannot) imply that these results would carry over to all applications that use the same adaptive techniques.

3.1 Evaluation of adaptive presentation

The most comprehensive evaluation of adaptive presentation in hypermedia was performed by Boyle and Encarnacion [Boyle and Encarnacion 1994] with their adaptive stretchtext system MetaDoc. (See subsection 2.2 for a description of stretchtext.) The three systems that were compared are the original MetaDoc with all functionality and two "disabled" versions of MetaDoc: the stretchtext version which had all stretchtext functionality, but no user modeling and adaptation and the hypertext-only version which had no stretchtext functionality at all. Two kinds of tasks were used to compare these kinds of hypertext: eight reading comprehension tasks and five search and navigation tasks.

The experiment shows that the users of the adaptive stretchtext version have found answers to comprehension questions significantly faster than users of the traditional hypertext version while showing significantly better comprehension. No significant difference was found regarding the performance in solving search and navigation questions (search correctness, number of visited nodes, and number of operations).

3.2 Evaluation of adaptive navigation support

Brusilovsky and Pesin conducted one of the earliest studies of adaptive link annotation and link removal mechanisms using their system ISIS-Tutor [Brusilovsky and Pesin 1998]. ISIS-Tutor uses the dynamic state of user knowledge represented in the user model to classify all concept and task nodes into several classes such as *not ready to be learned*, *ready to be learned*, *well-learnt* and *in work*. Adaptive link annotation (color fonts and special symbols) was used to show classes of pages behind links. The study compared three versions of ISIS-Tutor: a non-adaptive version, a version with adaptive annotation, and a version with both adaptive annotation and adaptive link removal (link anchors for *not ready to be learned* pages were removed.) The study (performed with 26 first year computer science students) showed that the overall number of navigation steps, as well as the number of unforced repetitions of concept and task pages were significantly lower with both adaptive versions of the system. No difference was found between the link annotation with or without the additional link removal technique. No difference was also found between all three groups for the quality of mental maps of the hyperspace developed by students.

A similar study involving 25 undergraduate "teacher education" students was performed with the InterBook system [Brusilovsky et al. 1998], a Web-based descendant of ISIS-Tutor. The study compared two versions of the system: with and without adaptive link annotation. The trial had some clear limitations. Since the non-annotated "continue" link (which takes the user to the next page) was used in over 90% of transactions, the effect of link annotation on student paths was relatively small. However, the study showed that link annotation encourages the novices to use non-sequential links more often. The study also showed that the students who follow the system's guidance are able to achieve better post-test scores.

4. CONCLUSIONS AND FUTURE TRENDS

In this paper we presented a framework for adaptive hypermedia systems. We considered domain modeling and user modeling and showed methods and techniques for adaptation of hypertext, notably adaptive presentation and adaptive navigation support. Examples of adaptive hypermedia systems are described, including evaluations of the adaptation in those applications.

Future developments include a generalization to adaptation in nodes other than text nodes and the creation of standards for adaptive hypermedia systems to communicate with each other (in order to exchange information on users between different applications). More experiments need to be done to evaluate the benefits of adaptive hypermedia in different application areas.

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