Using Dynamic Hypertext to Create Multi-Purpose Textbooks

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Abstract: In textbooks the different topics are introduced in an order which is (supposedly) the best way for learning the subject at hand. Once the student masters the subject, most textbooks are not well suited for use as reference material, because related topics are not located near each other. This paper presents a framework for self-modifying hyperdocuments. A textbook, delivered as on-line hypertext, transforms itself into a reference book during the learning process. This is accomplished by modifying the link structure and the node contents each time a hypertext link is followed. This framework is illustrated by means of the courseware for an on-line course on "Hypermedia structures and systems", developed at the Eindhoven University of Technology, and currently offered at six different universities in the Netherlands and Belgium, by means of World Wide Web technology.

1. Introduction

Hypertext is being used more and more often in distance education, as a replacement for paper course texts. A textbook usually suggests only one (linear) reading order. The student can of course elect to read the pages in a different order, but it will always be obvious to her that she is deviating from the intended reading order, and in many cases such alternative order does not make sense. A hypertext offers many (supposedly) intended different reading orders. Every page (or node) contains links to a number of different pages which can be read next. Despite this flexibility, the link structure in a (hyper)textbook cannot offer complete navigational freedom because concepts must be introduced or defined before being used, and storylines must be preserved. This implies that detailed or advanced pages must only be accessible after reading introductory pages. Such a link structure makes a hypertext version of a textbook unsuitable as a reference book, because the advanced information, which is used most in such a book, is not directly accessible from the starting page(s) of the course text.

The most important factor rendering course texts unusable as reference material is the inability to change the terminology or wording depending on the student's progress through the course, or to change the link structure during the learning process, to enable links to advanced pages from the starting page when the student is ready to read and understand them. As an example, in a course text on the subject of hypertext, the word *page* can be used to indicate what is normally called a *node* (in hypertext terminology), until the student has read an explanation of the concept of *nodes*. Almost everywhere the word *node* is needed in the course text the word *page* can be substituted automatically, until the definition of *node* is read. Such minor variations in textual content are unobtrusive. The student will probably still recognize the text when visiting it again, so she will not be tempted to read it all again as if the node were completely new. Larger variations in a text can of course also be introduced, but may confuse the reader because a page she thought she read before would suddenly look completely different.

Variations in the link structure are not only needed for modifying the access path to advanced reading material. In a textbook it is common to first define a concept or term, and then move on to the applications of that concept.

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In reference books, the opposite order is sometimes also used: throughout the text some concepts or terms are used, which the user may or may not know; links (or references) to the definition of these concepts or terms provide access to these definitions, so the reader who isn't aware of an exact definition can easily get to it. Such cross-references are also used in textbooks, but in most cases for backward references (pointing to information to review if needed), and seldom for forward references (pointing to previously unread information). Hence, the modifications to the link structure that are needed to transform a textbook into a reference book are more intricate than simple "unveiling" of links when the reader is ready to follow them.

This paper describes research and experimentation with dynamic hypertext structure and content, in order to guide the student through the learning process, thereby slowly transforming the course text from a textbook into a reference book. Prototype software has been written to enable teachers to create and deliver such dynamic course texts through World Wide Web. A successful course on "Hypermedia structures and systems", organized by the Eindhoven University of Technology, and offered (through the Web) to students at six different universities in The Netherlands and Belgium, is now being used as a test case for evaluating the use of this dynamic hypertext courseware. This course was chosen because hypertext is not only the medium through which the course is taught, but is also the subject matter of the course.

This paper is organized as follows: Section 2 gives a brief review of previous research on adaptive hypermedia. Section 3 describes the possibilities and dangers of using dynamic link structures, and shows how they are used in the hypermedia course. Section 4 shows how the addition of dynamic node contents can improve usability of hypertext courseware even more, but also how it can confuse readers if used carelessly.

2. Quick Review of Adaptive Hypermedia Research

Since the early seventies computer-assisted instruction (or computer-aided instruction, or CAI for short) researchers have been trying to develop adaptive systems by mimicking human-to-human interaction [Wenger 1987] [Self 1988]. However, the first attempts at putting documentation on-line closely followed the existing book model. Hypertext links were only being used for linking from a table of content or an index to the appropriate pages, and for explicit ("see also") cross references. This did not remove the essentially linear style of the presentation, thereby making it difficult to convey non-linearly structured information.

A primary concern when using hypertext for the creation of a course text is the structure to be given to the knowledge it conveys so that students can easily and naturally find the most appropriate information depending on their needs [Bareiss et al. 1993]. To make information presentation in a hypermedia environment effective and its management efficient, it is necessary that text, graphics, and images are properly coordinated [Hekmatpour 1995]. Some researchers, e.g. [Feiner et al. 1991], [Maybury 1991] have investigated the automatic generation of coordinated multimedia; [Carver et al. 1996] for instance have proposed (and implemented) a system for generating personalized hypermedia course presentations depending on the student's learning style, rather than based on the student's (fore)knowledge. From the learning style they generate a selection of prefered media types, but then go on to generate a linear presentation of multimedia information objects. [Merlet 1993] has focused on how to control and manage the diverse elements that concur in the composition of a multimedia document. What has emerged from all these (and other) studies, and what they all share, is the fact that they have shown and proved the inefficiency of the classical book model for on-line systems. This does not yet address the specific requirements and limitations of the on-line presentation of information through hypermedia systems.

Reading paper documents demands that the reader adapts to the level at which information is presented. Often too few details are provided to avoid the need to consult other sources of information. (A bibliography at the end of the book refers the reader to more information.) But also, often too many details, background or other information are given which the reader wishes to skip. When a book is presented on-line it becomes much more difficult to skip unwanted parts than with a paper document. Turning pages and very quickly skimming the text is something most, if not all, people can still do more easily with a (paper) book than with an on-line document. (We can, for instance, often find a certain illustration in a 200 page book in under 2 seconds by flipping the pages very rapidly, but we cannot yet do this with an on-line system.) In a hypermedia system it is possible to adapt to the reader by applying technology from intelligent tutoring systems or artificial intelligence, but even the simple technique of putting introductory information or summaries in separate nodes that provide links to nodes with detailed information can significantly improve the usability of a hyperdocument for a varied audience.

Most previous studies on adaptive systems have only focused on dynamically assembling information and presenting it according to the user's class and/or knowledge state without including the user's learning procedure in identifying which information to present to students. [Carver et al. 1996] are an exception to this, since they do apply learning styles to select media types, but then use them to generate a linear multimedia presentation, not really a hypermedia presentation. In the framework we propose we adapt the selection of links and the content of nodes without switching between media types. In fact, in the hypermedia course at the Eindhoven University of Technology almost all information is offered as text only. Furthermore, we propose not to assemble information nodes, but to limit textual modifications to otherwise static nodes. Slight modifications are enough to avoid the use of technical terms or concepts for which the user has not yet read the definition.

3. Using Dynamic Link Structures

The organization given to on-line documentation mostly depends on the kind of information that has to be delivered. However, whatever the structure may be, the underlying purpose in outlining the subject matter is to make it as simple and as useful as possible [Rojas-Fernandez 1991]. An unstructured information space topology can indeed give rise to problems similar to the GoTo statements in computer programming [Tomek et al. 1993]: difficulties on the side of the user in understanding the application domain and a consequent navigation breakdown due to uncontrolled linking.

Graph-theoretical methods have been used [Botafogo et al. 1992], [Begoray 1990], [DeYoung 1990] for analyzing link structures. These methods identify link structures that are unusable no matter what the content of the nodes is and regardless of the visual aids that may be provided to help the user in understanding this structure. To quote DeYoung [DeYoung 1990]:

> "(...) if a hypertext is a densely connected unstructured graph, no presentation of the mess is going to clean it up or make it conceptually easier to understand."

However, while these methods are able to find link structures which are likely to be unusable, they cannot guarantee that link structures having all suggested values for different metrics will actually belong to highly usable hyperdocuments. Empirical findings have demonstrated that links are often introduced without a deep consideration of their actual use and usefulness [Campagnoni et al. 1989]. Because of the lack of a clear methodology for linking as well as of a common understanding of what the notion of link eventually means, users often happen to be unable to understand why some piece of information is at the end of a certain link and they may also fail to understand why they are sometimes unable to find what they are looking for [Landow 1987]. So, linking one piece of information to another can not only fail to provide the expected benefits, but, in some cases, it even frustrates users. Since the mere presence of links in a hyperdocument seems to suggest that the relationship between the interconnected materials is a significant one, it becomes very difficult for users to ignore them.

Instead of searching for the "ideal" link structure for a hyperdocument, we opt for a system that adapts the link structure during the browsing process. A static link structure, possibly displayed graphically to provide a better overview, uses a "spatial metaphor" for guiding the user. Our approach, with links that are created and removed at different points during the browsing process, uses in some way a "temporal metaphor" [Calvi 1996]. However, because as soon as temporal relationships are mentioned in a hypermedia context this concept is often interpreted as involving real-time aspects, we will not use the term "temporal" to describe our approach, but rather use the terms "dynamic" or "adaptive".

A common problem with static hypertext is the abundance of links, many of which may not be appropriate at all times. As part of the course 2L690, "Hypermedia structures and systems", at the Eindhoven University of Technology, students have to convert a (linear) review of hypermedia research (by V. Balasubramanian from Rutgers University) into a hyperdocument by splitting the document into reasonably sized nodes and by adding links. Some pages offer an explanation of concepts that are used throughout the text. A typical example is the page describing what *nodes and links* are. Both the course text and the hypertext review used for the assignment contain a page describing what *nodes and links* are. In the (dynamic) course text the student is carefully guided to the definition page early in the reading process. In the hypertext review used for the assignment this is difficult to achieve because the table of contents invites the reader to go off in any desired direction. Almost all students create a large number of links from pages throughout the review to the *nodes and links* page (and to some other descriptive pages). The navigational possibilities of each student's version of the hypertext review are so overwhelming that it is difficult to predict where the reader will meet the concept of *nodes and links* first. Consequently the students create links to the *nodes and links* page from every possible source. Because in this assignment work the students can only create a static link structure, their only solution would be to select interesting places for linking to the *nodes and links* page very carefully. The students have neither the time nor the skill to perform this task.

The software for the hypermedia course keeps track of all nodes read by each individual student. With each node three “knowledge identifications” can be associated:

- **Required knowledge** is knowledge that is needed in order to view this node. The system will automatically hide (conditional) links to nodes for which the user has not yet acquired this knowledge.
- **Forbidden knowledge** is knowledge that makes viewing this node uninteresting. The system will automatically hide (conditional) links to nodes for which the user has acquired this knowledge.
- **Generated knowledge** is knowledge the user gains after reading this node. (By “after” we mean that a node which generates its own forbidden knowledge can be viewed once, because the forbidden knowledge is only gained after visiting the node.)

Whether certain links appear or not depends on the combined knowledge id’s a student has acquired. But regardless of the student’s knowledge, there are also **unconditional links** which are always shown.

Using knowledge id’s we can make links accessible when the reader is ready for them, and make them inaccessible again after the reader has no need for them anymore. The link structure of the course text changes each time the student follows a link. This technique is used in the courseware for the hypermedia course in the following way:

1. When the student first visits the course, the starting page gives some kind of table of contents, but provides no other links than one to a node containing instructions about the use of this courseware.
2. When the student returns from the instructions page, the first three “chapters” of the course text become accessible. These chapters are an introduction, a set of definitions, and a historic overview of hypermedia research and development. The student may follow different paths through these chapters, and depending on the path taken, the link structure within these chapters may also differ.
3. After reading some of the nodes of these chapters, and completing a small (multiple-choice) test at the end of each chapter, links to the more advance chapters appear in the table of contents.
4. While reading, some links will disappear. Links to definitions of terms will disappear after reading these definitions. Links to nodes containing unimportant background information will also disappear after looking at that information (in the hypermedia course there are nodes that briefly describe the IBM PC, the Macintosh, etc. which we do not expect the student to wish to read multiple times).
5. After reading (some of each of) the advanced chapters, a link to the final assignment appears in the table of contents.

Figure 1 gives an impression of what the table of contents page looks like, when only the first three chapters are available.

Hypermedia structures and systems

Welcome to course 2L690 at the Eindhoven University of Technology.

If you are just beginning to browse through this course, you should first read the instructions. . .

This course contains the following (not necessarily disjoint) parts:

- Introduction (it is advised to read this before the other items)
- Definition of hypertext and hypermedia
- The history of hypertext and hypermedia
- The architecture of hypertext systems
- Navigation (and browsing semantics) in hypertext
- . . .

Figure 1: Possible table of contents of the hypermedia course.

From the example of the hypermedia courseware it is clear that a dynamic link structure can be used to eliminate confusion that could be caused by providing links to information the student is not yet ready for, or that the student has already read and may not wish to find other links to. However, seeing a different selection of outgoing links each time a node is visited can also be confusing. Therefore, the pages with a varying link structure must be limited and well chosen. The table of contents is an excellent candidate for a node with a varying link structure. Through the links in this node large parts of the course text can be enabled at once. In the hypermedia course, most other use of dynamic link structure is in the elimination of links to definition nodes and to unimportant background information.

From figure 1 we may observe that apart from the presence of links, the presentation of the path leading to different chapters is identical. No reason for the absence of links to the advanced chapters is given. Similarly, pointers to the definition of *nodes and links* are given in the introduction, while the use of these terms could be easily circumvented, thereby eliminating the need for guiding the reader to that definition. A solution for these problems is presented in the next section on dynamic content.

4. Dynamic Content, or How to say something in Other Words

A student at the Eindhoven University of Technology developed a first hypertext courseware on environmental law back in 1990. In order to circumvent the need for learning lots of definitions and terms right at the start of the course two versions of each node were produced: one using common English vocabulary and one using the proper technical terms. Depending on the knowledge of the student (which was measured in a way somewhat similar to our current approach), the introductory or the advanced version of a node was presented. As a result of offering different versions of the content of a node the link structure could also vary, because some links that were present in one version of a node might not be present in the other version.

Having two (or more) completely different versions of a node can be confusing:

- After reading the introductory version of a node a student may continue browsing, thereby gaining the necessary knowledge, and then revisit the node without knowing so and reading the advanced version without realizing it is actually the same as the introductory version, up to some rewording.
- Because students may not revisit a node after reading the introductory version, the author must make sure that that introductory version contains the same information as the advanced version. Authors may be tempted to leave out important parts because they are difficult to describe without using technical terms.
- Different parts of a node may depend on different definitions or terms. One would like to have more than two versions of the entire node. Maybe two versions of every paragraph or sentence would satisfy this need. However, nodes which contain some paragraphs using concise technical vocabulary, and other paragraphs with plain English vocabulary may be very awkward to read.

In the software for the hypermedia course, the Unix C preprocessor is used to select between arbitrary pieces of text (using #if constructs). Although this offers the possibility for large modifications, we use dynamic content only for small variations in content:

- In the table of content (and other places), additional text is added to explain why certain chapters are still unavailable.
- In the text, some technical terms, like *node* and *link* are carefully replaced by the non-technical terms *page* and *reference* or *cross-reference*.

Figure 2 shows the table of contents for the hypermedia course, after applying dynamic content modification.

Hypermedia structures and systems

Welcome to course 2L690 at the Eindhoven University of Technology.

If you are just beginning to browse through this course, you should first read the instructions. . .

This course contains the following (not necessarily disjoint) parts:

- Introduction (it is advised to read this before the other items)
- Definition of hypertext and hypermedia
- The history of hypertext and hypermedia

After reading the three introductory parts the following topics will become available:

- The architecture of hypertext systems
- Navigation (and browsing semantics) in hypertext
- . . .

Figure 2: Table of contents with dynamic content modification.

5. Conclusions

Using hypertext for course texts is non-trivial because the navigational freedom, typically associated with hypertext, may conflict with the need to study concepts and definitions before moving on to applications or advanced topics. Dynamic link structures and content can be used to guide the student throughout the learning process, while preserving as much nagivational freedom as desired. Hypertext textbooks can be transformed into reference books by gradually changing the structure during the browsing process.

However, the use of a technical framework for supporting dynamic link structures and dynamic content does not guarantee a usable result. Dynamic link structures must be used with care because unexpected changes in the link structure may confuse the student, and excessive content changes may cause students to read the same (but rephrased) information several times, not realizing that, or wondering whether two such versions represent the same information or not.

In the course "Hypermedia structures and systems", taught (only) through World Wide Web at the Eindhoven University of Technology (and taken by students at six universities) we are using dynamic link structures and dynamic content sparingly, in order to benefit from this framework, without causing more confusion with the students. All browsing actions of all students are currently being logged for later evaluation and for comparison with previous logs of students who have used a version that had no dynamic link structure and no dynamic content.

6. References

[Bareiss et al. 1993] Bareiss, R., Osgood, R. (1993). Applying AI Models to the Design of Exploratory Hypermedia Systems. Proceedings of the ACM Conference of Hypertext, pp. 94–105.

[Begoray 1990] Begoray, J.A. (1990) An Introduction to Hypermedia Issues, Systems and Application Areas. International Journal of Man-Machine Studies, 33, pp. 34–45.

[Botafogo et al. 1992] Botafogo, A.R., Shneiderman, B. (1992)., Identifying Aggregates in Hypertext Structure. Proceedings of the Third ACM Conference on Hypertext, pp. 63–74.

[Calvi 1996] Calvi, L. (1996). Beyond the Space Frontier. In Vouros, G., Klas, W., Sellis, T., Vazirgiannis, M. (Eds.), KRIMS '96, John Wiley & Sons.

[Campagnoni et al. 1989] Campagnoni, F.R., Ehrlich, K. (1989). Information Retrieval Using a Hypertext-Based Help System. ACM Transactions on Information Systems, 7(3), pp. 271–291.

[Carver et al. 1996] Carver, C.A., Howard, R.A, Lavelle, E. (1996). Enhancing student learning by incorporating learning styles into adaptive hypermedia. In Educational Multimedia and Hypermedia, Proc of ED-MEDIA'96, pp. 118–123.

[DeYoung 1990] DeYoung, L. (1990). Linking Considered Harmful. Designing and Reading Hyperdocuments. In Streitz, N., Rizk, A., Andre, J. (Eds.), Hypertext: Concepts, Systems and Applications. Proceedings of the First European Conference on Hypertext, Cambridge University Press, pp. 238–249.

[Feiner et al. 1991] Feiner, S., McKeown, K. (1991) Automating the Generation of Co-ordinated Multimedia Explanation. IEEE Computer, 24(10), pp. 33–41.

[Hekmatpour 1995] Hekmatpour, A. (1995). An Adaptive Presentation Model for Hypermedia Information System. Journal of Educational Multimedia and Hypermedia, 4(2/3), pp. 211–238.

[Landow 1987] Landow, G.P. (1987) Relationally Encoded Links and the Rhetoric of Hypertext. Proceedings of the ACM Conference on Hypertext, pp. 331–343.

[Maybury 1991] Maybury, M.T. (1991). Planning Multimedia Explanation Using Communicative Acts. Proceedings of AAAI-91, pp. 61–66.

[Merlet 1993] Merlet, J.F. (1993). Human-Computer Interactions Through an Intelligent Hypermedia. Proceedings of IEEE Int. Conference on Systems, Man and Cybernetics Part 4, pp. 268–271.

[Rojas-Fernandez 1991] Rojas-Fernandez, H. (1991). "Online and Hypermedia Information Design." Proceedings of IPCC'91, Engineered Communication, IEEE Cat. No. 92CH3087-4, pp. 28–32.

[Self 1988] Self, J. (ed.) (1988). Artificial Intelligence and Human Learning: Intelligent Computer-Aided Instruction. Chapman and Hall, London.

[Tomek et al. 1993] Tomek, I., Maurer, H., Nasser, M. (1993). Optimal Presentation of Links in Large Hypermedia Systems. Proceedings of ED-MEDIA'93, pp. 511–518.

[Wenger 1987] Wenger, E. (1987). Artificial Intelligence and Tutoring Systems: Computational and Cognitive Approaches to the Communication of Knowledge. Morgan-Kaufman, Los Altos, CA.