Developing Adaptive Electronic Textbooks on WWW

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Abstract
An Electronic textbook is a popular kind of educational applications on World Wide Web (WWW). We claim that adaptivity is especially important for WWW-based educational applications which are expected to be used by very different groups of users without assistance of a human teacher. In this paper we describe an approach for developing adaptive electronic textbooks and present InterBook - an authoring tool based on this approach which simplifies the development of adaptive electronic textbooks on WWW.

Introduction
World Wide Web opens new ways of learning for many people. Now, educational programs and learning materials installed and supported in one place can be used by thousands of students from all over the world. However, most of the existing educational WWW applications use the simplest solutions and are much more limited than existing 'on-site' educational systems and tools. For many designers, an ideal format of educational WWW material seems to be a static electronic copy of a regular textbook: chapter by chapter, page by page, picture by picture. Such electronic textbooks are non-adaptive, i.e., students with different abilities, knowledge, and background get the same educational material in the same form.

We claim that adaptivity is especially important for educational programs on WWW which are expected to be used by very different classes of users without assistance of a real teacher (who usually can provide adaptivity in a normal classroom). Currently, we can name very few adaptive educational applications on WWW (Brusilovsky, Schwarz, and Weber 1996a; Nakabayashi et al. 1997; Okazaki, Watanabe, and Kondo 1997; Stern, Wolf, and Kuroso 1997). All these applications keep a model of the user between sessions and use it to adapt the teaching sequence and the presentation of the material to a given user. The problem is that adaptive electronic textbooks are "knowledge-rich" applications and they are not very easy to design. There are some authoring tools for developing "static" electronic textbooks on WWW (Goldberg, Salari, and Swoboda 1996; Thimbleby 1996), but there are no tools available to support a designer in creating an adaptive textbook on WWW.

A possible approach for designing adaptive electronic textbooks on WWW was suggested recently in (Brusilovsky 1995). This approach was further elaborated by the ELM research group in the University of Trier which applied it for developing an adaptive WWW-based LISP textbook ELM-ART (Brusilovsky et al. 1996a). Now this approach is implemented in InterBook, a subject-independent shell which simplifies the process of creating adaptive electronic textbooks on WWW. In this paper we present the approach in its current form and describe the system InterBook.

The Approach
Our approach to developing adaptive electronic textbooks on WWW is based on the ideas from the areas of intelligent Tutoring Systems (Wenger 1987) and Adaptive Hypermedia (Brusilovsky 1996). Our adaptive textbooks use knowledge about its domain (represented in the form of domain model) and about its users (represented in the form of individual user models). The domain model serves as a basis for structuring the content of an adaptive ET. We distinguish two parts in an adaptive ET: a glossary and a textbook. Both these parts are based on the domain model. The student model is used by an adaptive ET to adapt its behavior to each particular user.

The Domain Model and the Student Model
According to our approach, the key to adaptivity in an adaptive ET are the domain model and the student model.
The simplest form of domain model is just a set of domain concepts. By concepts we mean elementary pieces of knowledge for the given domain. Depending on the domain and the application area, concepts can represent bigger or smaller pieces of domain knowledge. A more advanced form of the domain model is a network with nodes corresponding to domain concepts and with links reflecting several kinds of relationships between concepts. This network represents the structure of the domain covered by a hypermedia system. The domain model provides a structure for representation of the student's knowledge of the subject. For each domain model concept, an individual student's knowledge model stores some value which is an estimation of the student's knowledge level of this concept. This type of model (which is called an overlay model) is powerful and flexible: it can measure independently the student's knowledge of different topics.

The Glossary
The glossary is the central part of the ET. According to our approach, the glossary is considered as a visualized (and externalized) domain network. Each node of the domain network is represented by a node of the hyperspace, while the links between domain network nodes constitute main paths between hyperspace nodes. The structure of the glossary resembles the pedagogical structure of the domain knowledge and, vice versa, each glossary entry corresponds to one of the domain concepts. The links between domain model concepts constitute navigation paths between glossary entries. Thus, the structure of the manual resembles the pedagogical structure of the domain knowledge. In addition to providing a description of a concept, each glossary entry provides links to all book sections which introduce the concept. It means that the glossary integrates traditional features of an index and a glossary.

The Indexed Textbook
A human-written textbook represents human teaching expertise on how to introduce the domain concepts to the learners. It is usually a real textbook represented in hypermedia form. A textbook is hierarchically structured into units: chapters, sections, and subsections. To make the textbook "more intelligent" and to connect it to the glossary, we have to let the system know what each unit of the textbook is about. It is done by indexing of textbook units with domain model concepts. For each unit, a list of concepts related with this unit is provided (we call this list spectrum of the unit). For each involved concept, the spectrum of the unit can represent also the role of the concept in the unit. Currently, we support two roles: each concept can be either a outcome concept or a prerequisite concept. A concept is included in the spectrum as a prerequisite concept if a student has to know this concept to understand the content of the page. Indexing is a relatively simple but powerful mechanism, because it provides the system with knowledge about the content of its pages: the system knows which concepts are presented on each page and which concepts have to be learned before starting to learn each page. It opens the way for several adaptation techniques presented in the next subsection.

Functionality
Domain model-based indexing is a relatively simple but powerful mechanism, because it provides the system with knowledge about the content of its pages: the system knows which concepts are presented on each page and which concepts have to be learned before starting to learn each page. It opens the way for several adaptation techniques presented in this subsection. All of these techniques were implemented and tested in InterBook system (Brusilovsky, Schwarz, and Weber 1996b).

Advanced Navigation
The knowledge about the domain and about the textbook content is used to serve a well-structured hyperspace. The system supports sequential and hierarchical links between section. It generates the table of contents where all entries are clickable links. In addition, it generates links between the glossary and the textbook. The concept bar provides links from each textbook unit to corresponding glossary pages for each involved concept (Figure 1). On the other hand, from each glossary page describing a concept the system provides links to all textbook units which can be used to learn this concept (Figure 2). These links are not stored in an external format but generated on-the-fly by a special module which takes into account the student's current state of knowledge represented by the student model. This approach is not only reducing page design time but also provides room for adaptation. In particular, our approach supports two adaptation techniques: adaptive navigation support and prerequisite-based help.

Adaptive Navigation Support
Our approach provides many more opportunities for browsing the course materials than traditional on-line textbooks. The negative side of it is that there is a higher risk for the student to get lost in this complex hyperspace. To support the student navigating through the course, the system uses two adaptive hypermedia techniques (Brusilovsky 1996): adaptive annotation and direct guidance. Direct guidance means that the system can suggest to the student the next unit to be learned. A possible way to provide direct guidance with our approach is presented in (Brusilovsky and Schwarz 1997). Adaptive annotation means that the system uses visual cues (icons, fonts, colors) to show the type and the educational state of each link.
To make the textbook "more intelligent" and to connect it to the glossary, we have to let the system know what each section of the textbook is. It is done by indexing the textbook sections by domain model concepts. For each unit, a list of concepts related with this unit is provided (we call this list spectrum of the unit). For each involved concept, the spectrum of the unit can represent also the role of the concept in the unit. Currently we support two roles: each concept can be either an outcome concept or a background concept. A concept is included in the spectrum as an outcome concept if some part of this page presents the piece of knowledge designated by the concept. A concept is included into the spectrum as a prerequisite concept if a student has to know this concept to understand the content of the page. Indexing is a relatively simple but powerful mechanism, because it provides the system with knowledge about the content of its pages: the system knows which concepts are presented on each page and which concepts have to be learned before starting to learn each page. It opens a way for several adaptation techniques.

Using the student model, it is possible to distinguish several educational states for each unit of ET: the content of the unit can be known to the student (all outcome concepts are learned or well-learned), ready to be learned (all prerequisites are learned or well-learned), or not ready to be learned (some prerequisite concepts are not yet learned). The icon and the font of each link presented to the student are computed dynamically from the individual student model. They always inform the student about the type and the educational state of the unit behind the link. In InterBook, a red ball and italic font mean not ready to be learned, a green ball and bold font mean ready and recommended, a white ball means learned, no new information. A checkmark is added for already visited units (Figure 1). The same way can be used to distinguish several levels of students knowledge of the concepts shown on the concept bar. In InterBook, no annotation means "unknown", small checkmark means "known" (learning started), medium checkmark means "learned" and big checkmark means "well-learned" (Figure 1).

Prerequisite-based Help

The system knowledge about the course material comprises knowledge about what the prerequisite concepts are for any unit of the textbook. Often, when students have problems with understanding some explanation or example or solving a problem, the reason is that some prerequisite material is not understood well. In that case they can request prerequisite-based help (using a special button) and, as an answer to help request, the system generate a list of links to all sections which present some information about background concepts of the current section. This list is adaptively sorted according to the student's knowledge represented in the student model: more "helpful" sections are listed first. Here "helpful" means show informative the section is to learn about the background concepts. For example, the section which presents information about an unknown background concept is more informative than a section presenting information about a known concept. The section which presents information about two unknown background concepts is more informative than a section presenting information about one concept.

Figure 1. A unit of an adaptive ET prepared and shown with InterBook system. Colored balls (up) and checkmarks (right, on the concept bar) provide adaptive annotation. Button "Teach me" (bottom) provides direct guidance.
interbook

interbook (with small I and B) is the name for InterBook-served ET.

This concept is introduced on these pages:
- Interbooks: InterBook-served electronic textbooks
- interbook

Knowledge about this concept is required for:
- The glossary
- Content window
- Glossary window
- Search window

InterBook Interface

InterBook uses advanced features of modern browsers such as multiple windows and frames to provide the student with useful and powerful interface. Main windows used by InterBook are the textbook window (Figure 1) and the glossary window (Figure 2).

The Glossary window is used to view the glossary. The upper part of the window is a list of glossary concepts. The lower part of this window is used to show the glossary entry for a concept. For each concept the system presents the concept description (if provided by the author), the list of section titles (selected from all available textbooks) which present the concept (i.e., which have it as an outcome concept) and the list of section titles which require this concept (i.e., which have it as a background concept).

Section titles are clickable links which make the corresponding section to be loaded to the Textbook window.

The Textbook window is the most important window in InterBook interface. This window is designed to view the main content of a textbook, section by section. It is divided into frames performing different functions. Mainframe of the Textbook window is the Text window. This window shows a particular section of the textbook which is called the current section. For a terminal section the Text window shows the title of the section and the section itself. For a high-level section the Text window shows the title, the section preface (if existing) and the full table of contents for the section (i.e., list of hierarchically structured titles of its subsections down to terminal level). A vertical bar to the right of the Text window is the Concept bar. It is used to show the concepts related with the current section. All names of concepts on the Concept bar are links to the
Glossary. The upper part of the Textbook window hosts the navigation center and the toolbox. The navigation center shows the position of the current section in the textbook: it lists the titles of all direct predecessors (father, grandfather, etc.) and all brothers of the current section. All names of the sections are clickable links. The navigation center serves for both orientation and navigation. The toolbox provides a set of buttons which are used to call additional windows (such as content window, search window, and prerequisite-based help window) which provides additional functionality.

**Authoring with InterBook**

Authoring an adaptive electronic textbook can be divided into 5 steps which are described in detail below (see Figure 3). In brief, an Electronic Textbook is prepared as a specially structured Word file and the task is to convert this file into InterBook format. The result of this process is a file with the Textbook in InterBook format which can be served on WWW by the InterBook system.

![Figure 3. Authoring adaptive ET with InterBook](image)

InterBook recognizes the structure of the document through the use of headers. It means that the titles of the highest level sections should have a pre-defined text style "Header 1", the titles of its subsections should have a pre-defined paragraph style "Header 2", and so forth. The title of the textbook should have paragraph style "Title". The result of this step will be a properly structured MS Word file.

The second step in the authoring process then involves concept-based annotation of the Electronic Textbook (ET) to let InterBook know which concepts stand behind each section. This knowledge allows InterBook to help the reader of the ET in several ways, and the result of this step is an annotated (and structured) MS Word file.

An annotation is a piece of text of special style and format inserted at the beginning of each section (between the section header and the first paragraph). Annotations have special character style (hidden + shadowed) which are not visible in the text window to the reader of the ET. For each unit, the author provides a set of outcome and background concepts. In this way, each section is annotated with a set of prerequisite concepts (or terms which exist in other sections which should be read before the current section), and a set of outcome concepts (terms which will be assumed known once the reader has visited the section).

The format for the outcome annotation is: (out: concept-name1, concept-name2, etc.) and the format for the background annotation is: (pre: concept-name1, concept-name2, etc.).

Once the annotations are complete, the file is saved in RTF format. The RTF to HTML program with some special settings is used to convert the ET into HTML format. Then the .html extension on the file is manually altered to .interso that it can be recognized by the InterBook system. Lastly, when the InterBook server starts, it parses all interbook files into "Texts" folder (i.e. all files with extension .inter) and translates it into the list of section frames. Each unit frame contains the name and type of the unit, its spectrum, and its position in the original HTML file. The obtained LISP structure is used by InterBook to serve all the available textbooks on WWW providing the advanced navigation and adaptation features. The content which is presented to the student is generated on-the-fly using the knowledge about the textbook, the student model, and HTML fragments extracted from the original HTML file. These features of InterBook are based on the functionality of the Common Lisp Hypermedia Server (Mallery 1994).

As we can see, our tool seriously simplifies the design of adaptive ET on WWW for the authors who use the approach presented in section 2. It provides full support in preparation and serving an ET for the authors who know only how to use the MS Word text processor. An advanced used who have some knowledge on HTML and LISP programming can use our tool more flexibly. For example, an author can bypass step 1 and 2 by preparing the textbook directly in HTML format with annotations provided as specially formatted comments. The author can also replace server response functions and HTML generating functions to implement different structure and different "look and feel" of the be requested by a unique URL. To enable the server to correspond to a
Discussion: Indexing for "More Intelligent" Authoring on WWW

The main idea behind our tool is using concept-based indexing to make conventional educational material more intelligent and flexible. The idea of indexing is to provide the information about the content of each unit of conventional educational material by indexing this unit with related domain concepts. Previously, indexing was applied in three authoring contexts: CAI context, hypermedia authoring context, and ITS authoring context. Indexing was originally suggested in CAI context by Osin (1976) who suggested a framework for indexing CAI frames by a set of topics which it covers. Such indexed sets of frames were not related to any pre-scribed order of presentation. They can be accumulated, stored in special libraries, and re-used by different authors to create their own courses. In the multimedia field, a similar idea of an re-usable database of multimedia learning material indexed by topics and keywords is elaborated by Olimpo et al. (1990).

Later indexing was applied in hypermedia and ITS authoring area. In the hypermedia authoring area, an idea of indexing was elaborated by Mayes, Kibby and Watson (1988) in the StrathTutor system. They stressed the additional preference of indexing the frames of learning material - the possibility to indicate related pairs of frames not by tedious glossary linking of pieces of learning material altogether, but dynamically, on the basis of similarity of corresponding sets of topics. In the ITS authoring area, indexing was applied to turn traditional CAI into a "slightly intelligent" ICAI (Elsom-Cook and O'Malley 1990; Grandbastien and Gavignet 1994; Vassileva 1992). "Slightly intelligent" ICAI are based on both the CAI and ITS paradigms. The teaching material is not generated as in 'orthodox' ITS, but stored in ICAI-like frames. However, these frames are indexed with the concepts from an explicit domain model network, so they can be selected intelligently. The most recent application of indexing on the crossroads of the above directions is hypermedia-based ITS which use indexing technology to connect the learning material represented in a hypermedia form with the domain knowledge base: SHIVA (Zeiliger 1993), ITEM/PG and ISIS-Tutor (Brusilovsky, Pesin, and Zyryanov 1993).

Indexing shows to be a relatively cheap and useful technology for authoring "more intelligent" hypermedia and CAI systems. We argue that it is the relevant technology for developing more adaptive and intelligent educational applications of WWW. Currently, we can name only ELMART (Brusilovsky et al. 1996a) and CALAT (Nakabayashi et al. 1997) as examples of WWW adaptive electronic textbooks based on indexing. We expect that the WWW will boost the research and development work on adaptive electronic textbooks.

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