Maximizing educational opportunity for every type of learner: adaptive hypermedia for Web-based education

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The paper discusses the problems of applying adaptive hypermedia techniques, namely adaptive navigation support in Web-based educational courseware. Adaptive navigation support techniques provide support mechanisms, which are tailored to accommodate the current knowledge, background and learning goal of an individual user. Web-based education with adaptive guidance is a way to maximize educational opportunity for every type of learner.

1. INTRODUCTION

Web-based education is still far from achieving its main goal - reaching wide distance audience and, in particular, students from underrepresented groups. The experience shows that Web-based courses work relatively well only for well-prepared and well-organized students who know what to learn and can manage their learning. We think that one of the bottlenecks of Web-based education is the course material, which currently comes in various forms - lectures, tutorials, examples, quizzes, and assignments. In all current Web-based courses, the course material is in most cases still implicitly oriented for a traditional on-campus audience - reasonably homogeneous, reasonably well-prepared and well-motivated students. However, Web-based courses are to be used by a much wider variety of users than any campus-based courses. These users may have very different goals, backgrounds, knowledge levels, and learning capabilities. A Web-based course, which is designed with a particular class of users in mind (as it is usually done for on-campus courses) may not suit other users. The only way to proceed is to make the course material richer and more flexible so that different students can get the personalized content and the personalized order of its presentation. Current Web-based courses are not flexible. In the best case the course material is a network of static hypertext pages with some media enhancement. Neither the teacher nor the delivery system can adapt the course presentation to different students. As a result, some students waste their time learning non-relevant or known material and some students fail to understand (or just misunderstand) the material and overload a distance teacher with multiple questions and requests for additional information.

The solution is to develop Web-based courses, which can adapt to the users with very different backgrounds, starting knowledge on the subject and learning goals. Currently, several research groups are investigating various ways to approach this solution (Brusilovsky, 1999). At the moment, the most promising set of relevant techniques can be found the area of adaptive hypermedia (Brusilovsky, 1996). Our own work in this direction is centered around applying various adaptive navigation support techniques to develop adaptive guidance mechanisms which are specially tailored to accommodate the current knowledge, learning goals, and information seeking tasks of that individual user. Guidance in this context addresses the problem of a user's unproductive wandering, refocusing them on their learning objectives, suggesting logical next steps to inform them about the knowledge structure of the hyperspace, or re-sequencing materials according to their demonstrated knowledge of content. Adaptive guidance is especially important for Web-based courses because in many cases the user is "alone" working with it (probably from home). That is why "external" guidance that a colleague or a teacher typically provides adaptively in a normal classroom situation, is not available.

To explore the problems of adaptive guidance in educational context we have developed *InterBook* (Brusilovsky, Eklund, & Schwarz, 1998) - a system for authoring and delivering adaptive electronic textbooks (AET) on the WWW . InterBook uses a content metadata (prerequisite concepts and outcome concepts) about every courseware object and a overlay model of student knowledge to provide every student with several kinds of adaptive navigation support and guidance - adaptive page sequencing, adaptive help, and adaptive link annotation.

The paper reviews adaptive navigation support functionality provided by InterBook, provides a brief review of similar works in this area, and advocates the use of this technology in large-scale Web-based education.

2. KNOWLEDGE REPRESENTATION AND CONTENT STRUCTURING

The key to adaptivity in an adaptive textbook is knowledge about its domain represented in the form of domain model and knowledge about individual students represented in the form of individual student models. The domain model serves as a basis for structuring the content of an adaptive ET. We distinguish two content parts in each AET: a glossary and a textbook . This section provides some minimal information about knowledge representation and content structuring. Some more information can be found in (Brusilovsky, et al., 1998).

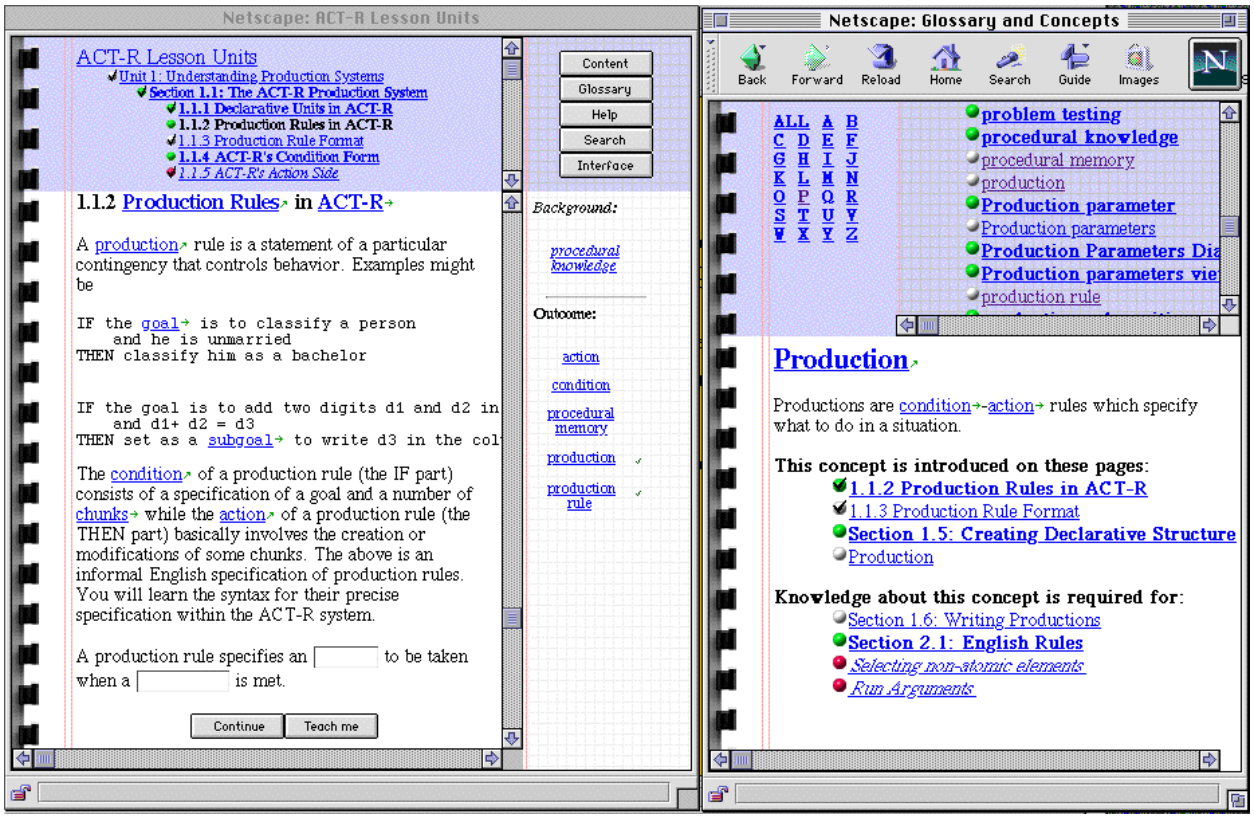

Figure 1. A section of an electronic textbook (left) and a glossary page (right) as presented by InterBook. Links to all book pages are annotated with colored bullets. Links to glossary concept pages on the right panel of the textbook window are annotated with checkmarks.

AET uses the simplest form of domain model: a set of domain concepts. By concepts we mean elementary pieces of knowledge for the given domain identified by a domain expert. The domain model provides a structure for an overlay student model which is a 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 knowledge level of this concept (for example, "unknown", "learned" and "well-learned").

In InterBook, each AET is hierarchically structured into units of different level: chapters, sections, and subsections. To make AET "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. Several books on the same subject form a bookshelf. All books from the same bookshelf are indexed with the same set of domain model concepts. Each terminal unit has an attached list of related concepts (we call this list spectrum of the unit). For each involved concept, the spectrum represents the name and the role of the concept in the unit (each concept can be either a outcome concept or a prerequisite concept). The system has an option to show all outcome and background concepts for the current section on a page border to the right of the section content (Figure 1)

The Glossary is, in fact, a visualized 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 links between domain model concepts constitute navigation paths between glossary entries. Thus, the structure of the glossary resembles the pedagogic 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 or require the concept. This means that the glossary integrates traditional features of an index and a glossary.

3. STUDENT MODELING AND ADAPTIVE GUIDANCE

To support the student navigating through the course, the system uses adaptive annotation, adaptive sorting, and direct guidance technologies. Adaptive annotation means that the system uses visual cues (icons, fonts, colors) to show the type and the educational state of each link. Direct guidance means that the system can suggest to the student the next part of the material to be learned.

The key to all adaptive functionality is student modeling. The system maintains an up-to-date model of individual student knowledge on the subject. The student modeling mechanism accepts two kinds of evidence of student knowledge of a concept:

- a student has visited a page which presents some information about a concept (i.e., the page has this concept among outcome concepts)
- a student correctly answers a question which checks the knowledge of this concept

The latter evidence is stronger, so no "well-learned" grade can be given to a concept unless the student confirms his or her knowledge by answering a test.

Using the student model, it is possible to distinguish several educational states for each unit of an electronic book: the content of a unit can be known to the student (all outcome concepts have been already learned), ready to be learned, or not ready to be learned (the latter example means that some prerequisite knowledge is 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, red means not ready to be learned, green means ready and recommended, and white means no new information. A checkmark is added for already visited units (Figure 1). The same mechanism can be used to distinguish and show several levels of student knowledge of the concepts shown on the concept bar. In InterBook, no annotation means "unknown", a small checkmark means "known" (learning started), a medium checkmark means "learned" and a big checkmark means "well-learned" (Figure 1). For many students, adaptive guidance provides enough support to make a navigation decision. Those who hesitate to make a choice could push the button "Teach me" and the system will apply several heuristics to select the most suitable node among those ready to be learned.

Another type of guidance that the system can provide is goal-based learning. 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 (Figure 2). Here "helpful" means how 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.

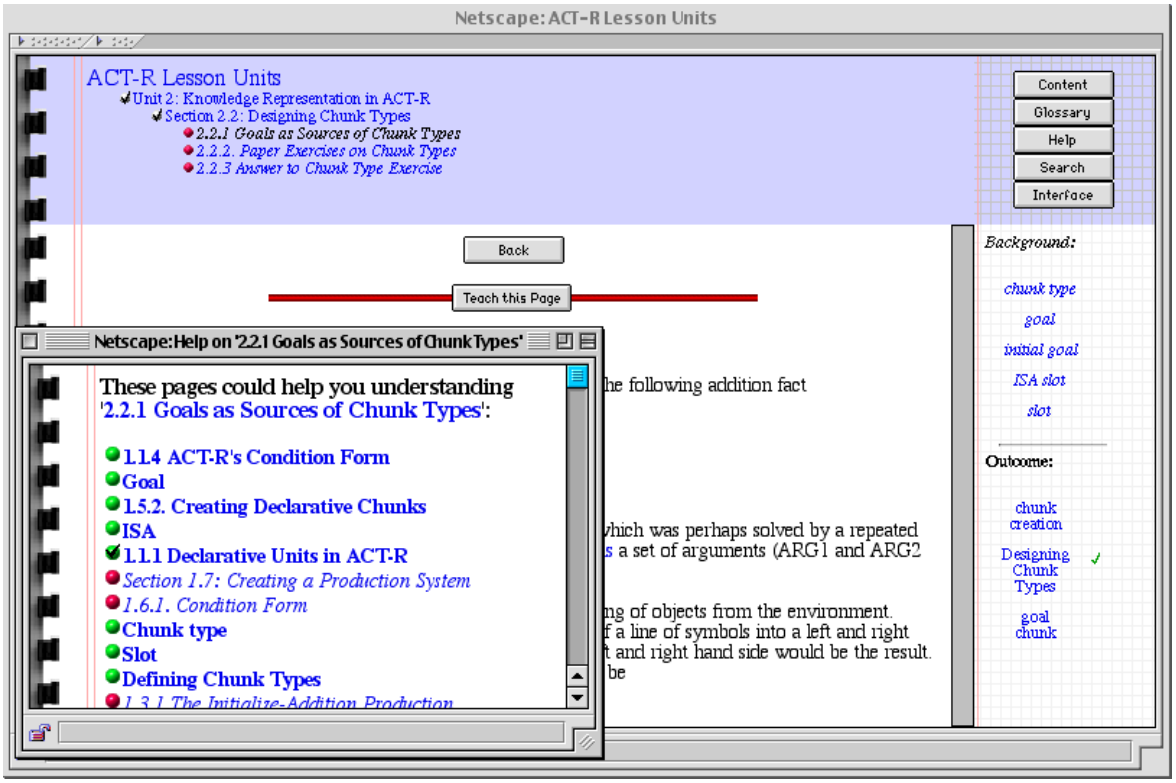

Figure 2. Prerequisite-based help is provided using adaptive link sorting technology

4. SIMILAR WORKS AND PROSPECTS

A number of works suggest the use of adaptive navigation support technologies for educational applications. Adaptive link annotation is currently the most popular technology. Most often these annotations are provided in the form of visual cues, i.e. different icons, font colors, or font types. In Web context It was used first in ELM-ART and since that applied in all descendants of ELM-ART such as InterBook and many other systems (Brusilovsky, Schwarz, & Weber, 1996; De Bra, & Calvi, 1998; Henze, Naceur, Nejdl, & Wolpers, 1999). ELM-ART and InterBook also use adaptive navigation support by sorting. Another popular technology is hiding and disabling. The options here are either to remove the link, make the link completely non-functional, or mask it. This technology was explored in several systems such as AHA (De Bra, et al., 1998).

We think that adaptive navigation support technologies can be successfully used to provide adaptive guidance in the hyperspace of learning material in the context of Web-based education thus maximizing

educational opportunity for every type of learner. Our own work and the work of other researchers brought promising results. In particular, empirical studies have shown that adaptive navigation support can significantly reduce navigation overhead, encourage students to use non-linear navigation and spend more time working with the system, and improve quality of learning (Brusilovsky, 1998). Our own approach based on prerequisite-outcome indexing of learning material looks particularly attractive. It is relatively simple, scalable, yet powerful enough to guide the students. We have already used it for implementing AET for Web-based courses. Currently we are extending the approach to handle large-scale Web-based courses. At the moment the price of indexing a course may look too big for a benefit of being able to provide an adaptive guidance. However, we think that in the future concept-based guidance will be an important part of any courseware engineering system. The emerging standards on Learning Objects Metadata (IEEE LTCS WG12, 2000) are quite compatible with our prerequisite-outcome approach to course indexing. As soon as larger and larger amounts of indexed course material will become available, the use of use of concept-based adaptive guidance will become cost-efficient.

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