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Dynamically Generated Tables of Contents as Guided Tours in Adaptive Hypermedia Systems

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Abstract: The Multibook project of the Darmstadt University of Technology builds a webbased adaptive hypermedia teaching and learning environment for multimedia and communication technology. Hereby, the demands of diverse user groups, user levels and especially of diverse learning strategies are taken into account. Besides information gained from the interaction with the user, the system uses standardized content relations and meta-information to adaptively compile a selection from the set of available information units. A subset of the meta-information represents the compiled lesson on a high level and is presented to the learner as a dynamically generated table of contents.

1. Motivation

"Imagine everything is available and tied together. Grand visions come to mind of what things will be like when ?it's all there and linked'. The thought of that great body of material calls to us, calls to us like an ocean. ...? But that ocean of universal hypertext is not enough: we want free sailing on it."[10]

So why should we restrict this demanded freedom of navigation? There are many applications where it makes sense to guide the user to a certain amount. One of these are learning environments. If the use of such a system is supposed to lead to an intersubjectively measurable learning effect, it must be guaranteed that the user has seen/learnt certain parts of information, and doesn't get completely lost on his/her way. Hence the decision where to go cannot be entirely up to the user.

The solution we are going for is to offer a special form of guided tours comparable to those of a classical hypermedia system. It's our concern to build a system, in which we can generate tours dynamically. We offer these guided tours to the user in form of tables of contents, that structures a relevant subset of the material. We see this as a suitable way to overcome the gap between a linear ordered text and free navigation.

2. Related Work

Recently, ideas from intelligent tutoring systems (ITS) and from hypermedia have been brought together opening the field of adaptive hypermedia. This synthesis responds to the specific strengths and weaknesses of both approaches. ITS [1],[4],[15] provide a high level of guidance in learning, they model and control the entire learning process in great detail. A domain model representing all facts of the field that are to be learnt, usually forms the background for a model of the learner's knowledge and knowledge acquisition. Free exploration by the learner does not play an important role in ITS, the navigation decisions are very much up to the system. As discussed in [6], most of the existing ITS systems are environments for coding and testing a specific programming language. Furthermore, users often need considerable time for learning how to use an ITS, because the development of an intuitive user interface for ITS systems seems to be a very difficult task. Hypertext and hypermedia systems exploit the nature of different media such as text, pictures, audio, video or simulations as a medium for making differentiated statements and communicating less structured knowledge. In addition, a hypermedia system offers more than predefined learning paths - by selecting different nodes in different order, the individual learners produce a multitude of paths through the material. The drawback of these systems is that the learning process cannot be controlled in a well defined way. This results in insufficient guidance. In particular when used for educational purposes, hypermedia systems are striving for a higher degree of control [7],[3]. We regard as decisive the step of adding conceptual information on top of the hypermedia chunks, being the basis for their intelligent selection and sequencing. Connecting the concepts with semantic rather than didactic relations that would already imply sequences or dependencies among the concepts [2] provides yet a higher degree of flexibility - this way, the concept space lends itself to realizing different learning strategies and goals but also to tasks like information retrieval.

The Interbook project is a well known adaptive hypermedia system, which also makes use of a concept space, called domain model [8]. Interbook supports navigation through the lesson with adaptive annotation, showing the type and the educational state ("ready to be learnt", "recommended", "not ready to be learnt") of each offered link. Interbook is based on the domain modelling approach of ELM-ART, a WWW version of ELM-PE, that is currently one of the most advanced intelligent learning environments for programming. In the online description of Interbook the term "I3-textbooks" (integrated + interactive + intelligent textbook) is suggested for approaches which integrate on-line representation of learning material with the interactivity of problem solving environments and intelligence of ITS. In this sense, the Multibook project can be seen as a specific type of an I3-textbook, although our application domain brings along some different problems which requires slightly different approaches and techniques, which we will describe in the remainder of this article.

3. Multibook

3.1 Constraints and Requirements

The content of the Multibook system, currently being developed at the TU Darmstadt, is the printed book "Multimedia: Computing, Communications & Applications" by Ralf Steinmetz and Klara Nahrstedt consisting of about 1200 pages, and a selection of Java applets [13]. The aim of Multibook is to have individual views on this material according to the needs and preferences of the individual users. A linear, printed book does not satisfy these requirements: It does not adapt flexibly to the level of difficulty, the learning aim, the learning strategy and the media preferences of the specific user. Apart from that, many aspects of multimedia technology can be explained better using motion and interactivity. A pure hypertext or hypermedia system does not satisfy these requirements either. A hypertext is static, in that the text is either heavily linked and there is a suitable path through it for every user - then the user might be confused by the number of possibilities and not be able to find this path. Or there are only a few links, then it will probably not satisfy the demands of each individual user. An ITS system does satisfy these requirements, but these systems only work in areas which are highly structured, such as Mathematics and especially programming languages. The level of control and the detailed knowledge of the state of the user can't be achieved in our subject domain. To formally model everything that can be said about multimedia in texts or images would not be a feasible approach. Also the extent and the extensibility of our material and the amount of text describing it are constraints which make it impossible to guide the user in such a controlled way.

3.2 Approach

The Multibook system has multiple facets: it provides an intelligent testing environment for the user, offers search facilities for a direct access, etc. In this article, however, we will focus on the main task: To find and to propose a suitable path, hence a suitable composed lesson. To be able to acomplish this, the content and meta information concerning the content must be represented in a formal way, that enables the system to operate on it. As a result the system can play the role of a guide for the user. In order to find a suitable path, the system makes use of a user profile and of the meta information. In the beginning, the profile is filled with the demands and preferences of the learner. There are two spaces in which the knowledge base is modelled: a domain model, which we call the ConceptSpace, and the MediaBrickSpace, where knowledge is represented in small modular pieces of text, in images etc. The concepts and the actual content are therefore separated. The ConceptSpace represents the domain, the MediaBrickSpace is a set of possible explanations of this domain. The concepts are comparable to possible chapter headings and are interconnected by semantic relations. There are different possibilities to choose a set of relations. The granularity of the model relates to the fact that we are interested in roughly structuring the domain rather than completely representing all facts. In the vocabulary of Knowledge Engineering, this makes our ConceptSpace a terminological rather than a axiomatic ontology [12]. We are aware of the benefits that the extended use of verb concepts, and the expression of a greater variety of facts they allow, could have for our domain. However, the current model is, for simplicity reasons, mainly built around noun concepts [5]. Semantic relations strongly guide the composition of lessons but do not predetermine a unique set of topics and the order of these, to make application of different learning strategies possible

In the following we will describe in an exemplary way the rules that operate on the different categories of the profile and on the relations in the ConceptSpace to compile a adequate outline for a lesson.

The rules which are responsible for choosing the global structure of the lesson use the semantic relations corresponding to the learning aim. Note that these rules are not a hardwired part of the system. At this stage, we modeled some rather straightforward didactic rules ourselves, later we want to give the domain experts working with the system the possibility to specifiy their own rules. Examples for rules using the semantic relations: In his/her profile, the user is characterized as a student learning for exams. In this case the system will search for concepts which are related to the chosen topic by the relations "uses", "part_of" and "is_a".The selection of the topics has to be coordinated with their order arising from the chosen learning strategy, e.g., hicrachical: Definition - broader term- component - application. In other cases the selection of the topics uses, on a small scale, inferences on the ConceptSpace. Example: The topic is related to another by the relation "problem". Then the system would most probably find a concept representing a solution for this problem among the more specific concepts (i.e. one that is connected by a "is_a" relation). The lessons are finally put together by combining a set of media bricks. They can be in form of text or other multimedia elements such as images, graphics, video and audio streams and - with the main focus - animations realized as Java applets. Also these multimedia elements satisfy the requirements of modularity. This requires that the format of the media bricks enables the system to describe the content, grade of detail, and the underlying pedagogical concept of the media brick. Thus it is possible to integrate a media brick in a lesson, independent of the kind of media. Particular emphasis of our work lies on the issue of coherence [14]. When a user of a hypertext does not have the possibility to choose the pages, i.e. he/she cannot establish the relation between the parts of the lesson by himself/herself, he/she is more likely to expect a coherent lesson, a lesson where the relations between the parts are obvious, although they are put together by someone else. For this purpose the media bricks are not only linked to the corresponding concept but also interconnected in the MediaBrickSpace by rhetorical relations based on the Rhetorical Structure Theory [9] [11]. Examples for such rhetorical relations are "deepen" or "explain". It is a major task of the system, to make this relations explicit.

In general, the rules for building the lesson out of the relevant media bricks, have to use the rhetorical relations and the characteristic of the media bricks, in order to match the users level of difficulty, media preferences and coherence expectations. Simultaneously, they have to work off the structure of the lesson compiled earlier and to fulfil the demands of the user's learning strategy. Note that the learning strategy requires rules working on both spaces. These goals are not always easily harmonized: The system will, for instance tend to select as the next media brick one that is connected to the current one but also one that is connected to the next topic in the planned structure.

4. A Table of Contents for each User!

As an example how we overcome the gap between free navigation and static guidance by using the meta-information described above, we suggest a dynamically generated table of contents. Dynamically generated tables of contents combine the best of both worlds: The interests of the user are made manifest by the outline, the structure, of the lesson. This task can be achieved by applying the user profile instead of constraining the user to choose the media bricks by himself/herself. As with a guided tour the lessons are coherent, and more security is given to a sensible course of text/media. Rules working on the ConceptSpace are responsible for creating the outline according to the user profile; rules working on the MediaBrickSpace are responsible for the coherence of the lesson.

4.1 Tables of Contents

Tables of contents, what are they and what function do they have? Generally, a table of contents is the rough structure of lessons. Any kind of table of contents is motivated by semantic relations. A table of contents gives the reader an overview of the lessons and shows the view the author has of the subject.Therefore we can consider the table of contents as a path through a net of concepts. We observe that not every path can serve as a table of contents, nor does every structure of a topic make sense. Obviously some proven patterns occur quite often. These characterize a sensible structure for texts. We give three examples:

A structure based on *part_of* relations:

1. Media Server
    1. Disc Controller
    2. Storage Management
    3. File System
        1. Allocation Table
        2. Access Control
    4. Memory Management

The subchapters describe the components of a media server, the sections of "File System" represent the components of a file system.

A structure based on *is_a* relations:

1. Image Compression
    1. JPEG
    2. PNG
    3. TIFF

Here the subchapters are examples of the topic of the chapter.

A structure based on *proceeds* relations:

1. JPEG
    1. Picture Preparation
    2. Picture Processing
    3. Quantization
    4. Entropy Encoding

The structure of these view follows the order of the process itself.

The structure in each of these three examples is a paths, that is a tree, even leading to multiple trees or forests. It is not necessary that the structure is based only on one kind of relation, hybrid composition can also be observed quite often. There are several reasons why it makes sense to provide explicit guiding for the user in the form of a table of contents:

- A user in a learning environment has to learn certain topics, if he/she wants it or not.
- The user may not have the necessary overview of the area to choose the relevant concepts.
- The user is not able to compose a lesson according to a learning strategy by himself/herself.
- The knowledge base is too broad to be managed effectively without help from the system. The system can select and combine the media bricks faster and more efficiently than the user.
- A table of contents offers the user some sort of orientation. He/She can see exactly where he/she is and to which context the current topic belongs.

In the Multibook system there are also situations where "classical" free navigation is the appropriate strategy: The user selects the topics being relevant for him/her from a net of content objects, which is a simplified version of the ConceptSpace where the relations are omitted. The net offers the user an overview of the area with connections between the topics beyond the linear order of a table of contents in a printed book and many hypertext systems. The user can choose the topics without working on the media bricks, thus simplifying the complexity of the knowledge bases.

4.2 Dynamic Table of Contents

Since the aim of the Multibook system is to be adaptive to the needs and preferences of the specific user we need more than just one table of contents: We need a table of contents for each single user. This cannot be obtained by having several static tables of contents. If the set of media bricks would be static we could precompute every possible way through the material. This means, every possible learning strategy etc., could be realized and presented to the user. But since our system is open for extensions of both ConceptSpace and MediaBrickSpace including media bricks from external sources, we must be able to generate the tours through the material dynamically for every user.

Our system is able to fulfil this task because of the partition into ConceptSpace and MediaBrick Space. The concepts/topics are modelled separately from the descriptions, therefore every concept can be picked up to be the main topic. The semantic relations which allow the diverse structuring of the topics make it possible to tell the difference between sensible and senseless structures, i.e. table of contents. The ConceptSpace with its manifold semantic relations is a starting point for different and meaningful ways to construct tables of contents. Topics which are chapter headings in one lesson can be subchapters in another.

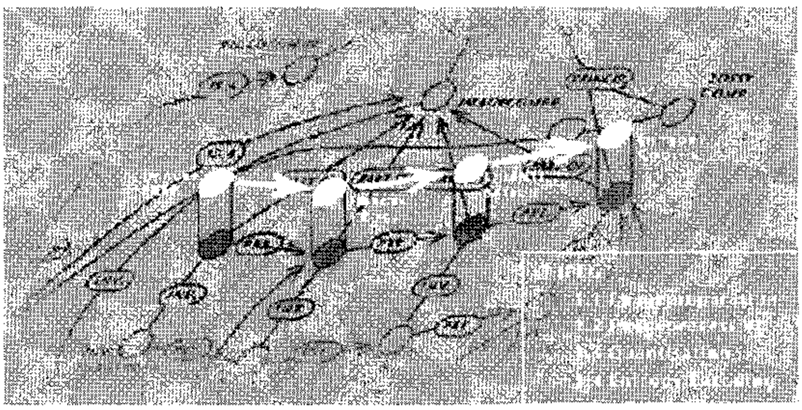

Figure 1.1 JPEG as main chapter described by its components

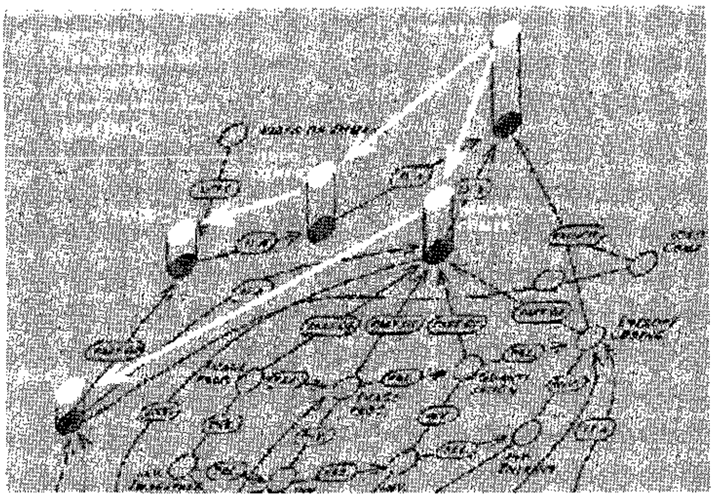

Figure 1.1 JPEG as a subchapter of compression

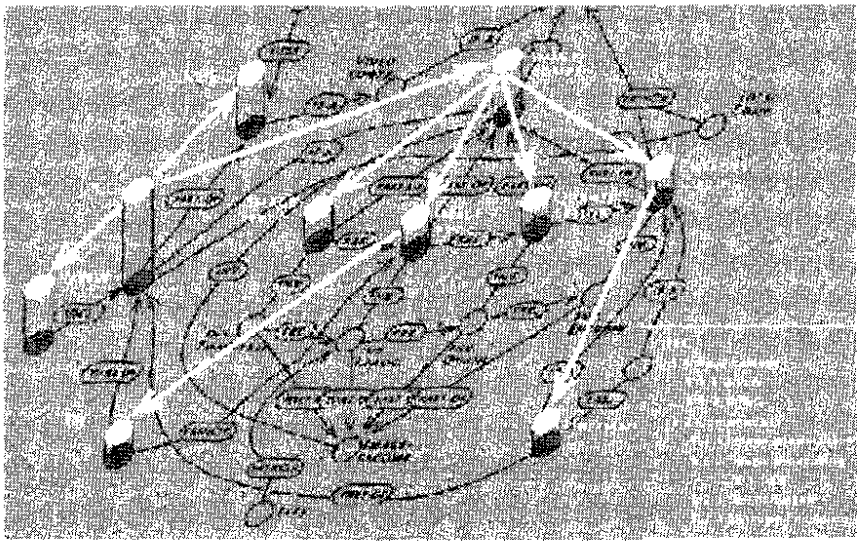

Figure 1.3 JPEG as main chapter described by its applications

In Figure 1 different views of the complex JPEG are shown. The topics selected for the outline are highlighted in the figures. In Figure 1.1 JPEG is defined by its componenents, in Figure 1.2 JPEG is a subchapter of Compression and is explained in the context of MPEG. In Figure 1.3 JPEG is the main topic of the chapter and is described first by its applications where MPEG is mentioned, then in detail by its components

5. Conclusions and Outlook

The learning strategies we have implemented so far (problem oriented vs. hierachical) are exemplary. Our aim is not to prove whether a certain strategy is under certain circumstances better than another. We rather want to provide a tool for educationalists to conduct these kind of experiments. They can test their theories about learning strategies by applying their research results to our system. The system is flexible for changing the rules in both spaces which are responsible for composing the lessons. As we only recently finished a prototype of our system, an empirical evaluation is now on its way: In a broad field trial at the end of this year with the students of our institute, we will investigate to what extent the individual tables of contents help to navigate on a hypermedia system. A major problem which needs further investigation is how to produce the media bricks. To write a text in a modular way is quite unaccustomed, also a deeper understanding of the relations is necessary to bind new media bricks in the MediaBrickSpace.

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