HyperMed: A Hypermedia System for Anatomical Education

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Abstract: Multimedia and hypertext had and still have great impact on the evolution of educational software. On the other hand there has been a spate of interest in employing both multimedia and hypertext in health care, but unfortunately systems for education in central fields of medicine are not available or have not been satisfactorily dealt with. Basing upon this observation two institutes at the University of Dortmund and the Essen School of Medicine started a conjoint project in the area of educational software in anatomy. The resulting hypermedia system, called HyperMed, is presented in this paper. In our opinion both students and teachers will benefit from such a system. The paper briefly focuses on the traditional way of teaching gross anatomy, introduces the current version of HyperMed, summarizes the evaluation of the system and closes with an outlook on future developments.

1. Introduction

In this paper HyperMed, a hypermedia system for anatomical education, is presented. HyperMed was developed at the Department of Computer Science at the University of Dortmund in cooperation with the Department of Anatomy at the Essen School of Medicine and it is based upon a formal model for hypermedia published in [Tochtermann & Dittrich 95] and [Tochtermann & Dittrich 96].
The aim of the project is to improve education in cross-sectional anatomy which is a special field of gross anatomy. The courses in gross anatomy are a traditional central and indispensable part of the curriculum of medical students which introduces them into human anatomy. Recently, these courses are increasingly supplemented by classes on sectional anatomy which are needed to prepare students better than before for the interpretation of MR- or CT-images (magnetic resonance images and computer tomography images). In cross-sectional anatomy undergraduates have to understand and identify very complex structures in horizontal sections of the human body. In addition they have to locate the same structures in corresponding MR- and CT-images. The task is difficult because of the similarity and complexity of some tissues.
During courses in cross-sectional anatomy at the Essen School of Medicine participants study slices of a human body and they have to identify the organs and structures therein with the support of books, collections of photos, and tables [Hohn et al. 95]. This is quite time consuming and poses problems since only a small number of students can study a section at a time so that many groups of students have to be taught at the same sections consecutively. Thus, a major drawback is given by the fact that usually institutional budgets do not allow extensive supervision by departmental personnel or student tutors as would be necessary. We therefore decided to develop a hypermedia-based courseware for the undergraduate course in cross-sectional anatomy at the Essen School of Medicine which is designed to supplement this type of teaching program effectively.

The article is structured as follows: Section 2 gives a brief overview of hypermedia and education and introduces terms used in the paper. Section 3 stresses the functionality of HyperMed and section 4 explains some technical details of the system. In section 5 our work is related to existing literature. The students' experiences with the system are summarized in section 6. Finally, section 7 concludes the paper with a brief outlook on future developments.

2. Hypermedia and Education

First attempts to combine computers for educational purposes go back to the early sixties and terms like courseware, computer assisted instruction, computer based learning, or computer based teaching, to mention only a few, were coined. In this paper we only use the term courseware as an embracing term for any kind of educational software.

Due to expensive hardware and lack of graphical interfaces most of the early approaches, e.g. PLATO from the University of Illinois, were not very successful. This situation changed dramatically in the late eighties, when workstations with graphical user interfaces appeared on the market. In addition, multimedia and hypertext became more and more popular, so that lots of educational software have been developed using these new technologies and concepts.

Hypertext is a concept of information management in which data is stored in a network of nodes connected by links. The origin and destination of a link is referred to as an anchor. The navigational interface and a very simple structure allow users to easily handle the information in a hypertext. Multimedia may generally mean any mixture of different media, e.g. video and sound, and from a user-centred perspective it offers possibilities for manipulating richer information using natural sensory abilities. Hypermedia combines hypertext and multimedia, namely synchronized media that additionally have links between their components.

Apart from others, hypermedia-based educational software offers the following benefits:

- Animation can be used to illustrate complicated facts.
- Users can freely navigate through the courseware. Hence, students can learn by exploring the material.
- Hypermedia-based courseware can be interactive, and can respond to the students with evaluations of decisions taken,
- Using appropriate view concepts [Tochtermann & Dittrich 95] different levels of the hypermedia-based courseware can be offered to students with different experience.
- Simulation models are one of the most effective applications of computer-based instruction [Corvetta et al. 91]. They can easily be integrated in hypermedia systems.

However, to create good courseware it is not sufficient to dominate the technology. In addition, experts from various fields are indispensable, e.g. pedagogues, experts in the application domain of the courseware, experts for evaluation purposes of the courseware.

Therefore the consortium being involved in the development of HyperMed consists of computer scientists from the University of Dortmund. In addition, our partners from the Essen School of Medicine provide knowledge for advising and designing the courseware, physicians (anatomists) for providing anatomical information for the courses, and experts in statistics for the evaluation.

3. Description of HyperMed

HyperMed differentiates between authors, i.e. physicians, and readers, i.e. students, of hypertexts and offers functionality adapted to the personal needs of both groups.

3.1 Authoring with HyperMed

Authors (physicians, anatomical teachers) must be able to insert and expand existing data without knowing details of the overall program structure. Thus, HyperMed consists of an environment of ”small” applications rather than integrating the entire functionality within one application.

For creating the material for a course, authors are provided with different editors which do not depend on the hypermedia functionality of HyperMed. Text files can be created by using standard editors or text processing systems, e.g. MS Word. Similar to HTML, we use a simple markup language to define the text layout, link anchors etc. The idea is that authoring tools must be easy to use for the teaching staff. Another advantage is that for further extensions of HyperMed these markup languages can easily be converted into HTML so that HyperMed documents might be distributed via WWW.

Although any graphic editor can be used, we developed a special JPEG editor. It meets some requirements that are important for courseware in gross anatomy. Not only does the graphic editor allow the author to integrate new graphics or a photography of a cross-section, but the author can also identify structures in such a photography by outlining the structure's shape. The editor provides standard 2D-operations like freehand drawing, circles, rectangles, polygons etc. to define the shape of an object. Such a shape may serve as an anchor for a link.

The idea of defining links bases upon a simplification of the Frame-axis Model [Masuda et al. 94]. Within each node (frame in [Masuda et al. 94]) authors define anchors. An index (axis in [Masuda et al. 94]) is used to map nodes with defined anchors onto other nodes. The index is created as follows: For images the authors must define important structures within the image. These structures are described by index terms and the index terms are added automatically to the index. For texts, authors have to add intellectually index terms to the index. To give two examples: When the author defines an origin for a link within a text, e.g. the word “liver”, the program looks for corresponding entry in the index and connects this origin with all documents or all structures within images which are indexed by this word. When the author defines the origin of a link within an image, he has to outline the shape of a structure and he has to add an index term for this shape (if not already done). On the basis of this index term, the system then defines one or several links to appropriate textual explanations or other images.

In contrast to the Frame-axis Model, our approach only allows 1-to-1 links and 1-to-many links but no n-to-m links (N-ary relations in [Masuda et al. 94]).

3.2 Reading documents with HyperMed

At the moment HyperMed provides about 70 MB of compressed data for the course in cross-sectional anatomy. The data consists of about 30 cross-sections of a human body, corresponding MR- and CT-images (one uncompressed JPEG image requires about 7MB), texts, graphics and links. The data is densely interconnected by a rich variety of links (≥1000). One great challenge is to make this information comfortably accessible to the participants of the course. To meet this requirement HyperMed offers different navigational support to the students:

1. Index-based Retrieval

Students can enter index terms, e.g. the name of an organ, and the system returns all texts containing the term or a highlighted structure, e.g. the liver, within a cross-section that has been chosen previously. This requires that an author has attached the entered index term to the structure.

2. Navigational Retrieval

HyperMed provides two levels for retrieving information by navigation. At the macro-level HyperMed provides an image of a human body. Using a horizontal bar, students can select one of about 30 possible cross-sectional planes within this image. The selection corresponds to following a link to a cross-section of this part of the body. As a result, the cross-section including explanations appears on the screen. This feature is often used to start a session with HyperMed. At the micro-level students can freely navigate through the document by following links. With this navigational feature students can learn by exploring the material. Using links students can jump from a structure within a cross-section to its textual explanation. In addition, it is also possible to highlight a structure in a cross-section when a link is followed from an explanation to the cross-section. When a student selects an anchor of a 1-to-many link, a menu appears listing possible destinations. He then selects the desired destination, and the link is followed. For example, the benefit of 1-to-many links is, that students can choose the type of an image they want for a given explanation. Hence, time-consuming searching of MR-images, CT-images, illustrations etc. in different books, tables or collections of photos is not necessary.

3. History List

During each session, HyperMed records all visited nodes in a history list. Once a student is lost in hyperspace a known node of the history list can be selected to continue navigation. The history list is also important for the teacher because it gives him an overview of all nodes visited by a student. Basing upon this information he can advise students what other nodes are important for the current session and should therefore be visited. This part of the program also performs statistics anonymously for each user to what extent different components of HyperMed are used.

The following figure shows a screen shot of the user interface of HyperMed. On the right, HyperMed provides readers with the possibility for macro-navigation as described above. The buttons on the left can be used to select the type of image, e.g. cross-section, CT-image, or MR-image, which is displayed in the upper middle of the user interface. Finally, textual explanations for the displayed images are given in the lower part of the user interface. The history list can be found on the left-hand side of the textual explanation. In this example, a pop-up menu offers the different destinations of a 1-to-many link to the user. The user can select an entry and the corresponding destination will be displayed on the screen.

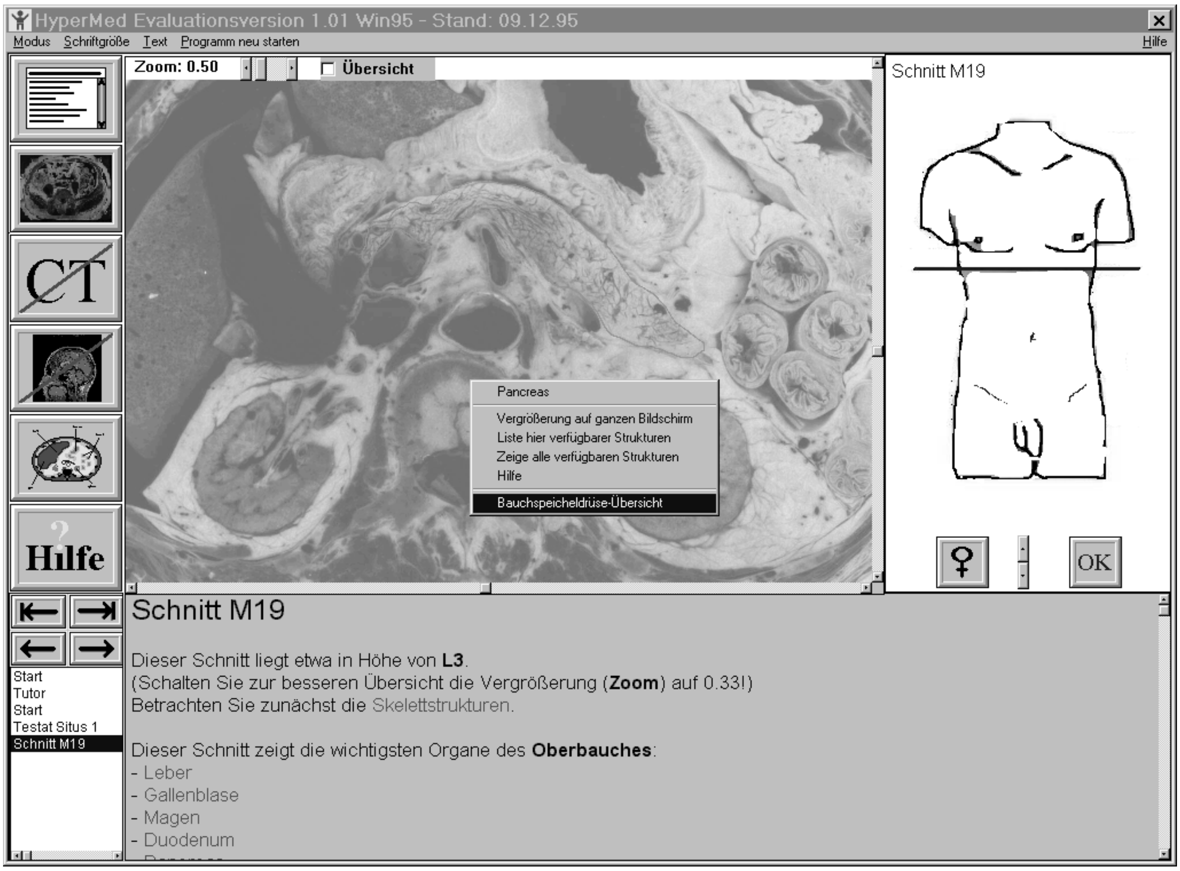

Figure 1: User Interface of HyperMed

4. Platform and Technology

HyperMed was developed by using the C++-language (Microsoft Visual C++ 2.0) under the operating system Windows 95. Windows 95 is well accepted and will be (or even is already) in widespread use so that students can install and try out HyperMed even at home.

The underlying formal model [Tochtermann & Dittrich 95], [Tochtermann & Dittrich 96] favours the use of a concept of independent components, i.e. text, graphic, video etc. The idea of this concept is to use special applications for creating these components rather than integrating the entire different editors within the hypermedia system. To follow this line, we decided to use the OPENDOC-standard for compound documents. For instance, this allows us to employ any JPEG editor for editing our JPEG images. Another advantage is that the created software and object library can easily be extended for further improvements and reused for other projects. Finally, we used the class library MFC 3.0 for the administration of graphical I/O. All other objects were created platform-independently.

5. Related Work

Since a lot of papers on hypermedia and medical education exist, e.g. [Corvetta et al. 91], [Cleynenbrengel et al. 95], we only focus on three systems that influenced our work.

Hyper-G is a second generation hypermedia system and has been developed at Graz University of Technology [Maurer 96]. The Hyper-G clients, Harmony and Amadeus, provide image viewers for common formats, including JPEG. Similar to HyperMed, both clients also allow overlapping anchors in JPEG images. Furthermore, link anchors in image documents may be rectangular, circular, elliptical, or polygonal in shape. In addition, HyperMed also allows free-hand drawn anchors, a feature that is helpful for outlining an uneven structure in an enlarged cross-section. However, Hyper-G is a hypermedia system especially designed for applications consisting of tens of thousands of documents (nodes) and links. Compared to typical Hyper-G servers, HyperMed only provides a small amount of nodes and links. Finally, most of the students working with HyperMed are computer novices so that our colleagues at the University of Essen, preferred a easy to handle frame-based user interface to the multiple window interface of the Hyper-G clients.

The WALT system developed at Washington University [Frisse et al. 91] provides a research environment for medical hypertext. In contrast to HyperMed the emphasis is placed on hypertext and information retrieval in clinical and basic medical research but medical education is not supported. However, we plan to integrate ideas, e.g. metaphors from the WALT interface or path clipboard, from the WALT system in later extensions of HyperMed.

At Cornell School of Medicine a system called PathMac was used to make the learning process more efficient [Diaz 91]. Students taking the course in Introductory Pathology can enrol in an electronic version of the course. Selected material for other courses, like biochemistry, anatomy radiology is available. Similar to HyperMed, students can study anatomy or compare images of normal organs against abnormal tissue cells. Unlike HyperMed, PathMac provides sophisticated simulation tools, i.e. a patient simulation tool and a tool to perform simulated laboratory experiments. However, to our knowledge, PathMac does not allow to define arbitrary regions in an image, in our case a cross-section, as an anchor for a link. In addition, PathMac includes applications written in HyperCard, Guide and other tools developed in-house. Furthermore, HyperCard and Guide are not appropriate for our requirements: both systems do not support compound documents (c.f. section 4) and the performance of these systems is too low for our needs, e.g. uncompressing of a compressed JPEG cross-section (about 300 Kbytes) which results in a high resolution cross-section (about 7MB).

6. Evaluation: Practical experience made with HyperMed version 1

In the winter term 1995/1996, the first version of HyperMed was used for three months as a tutorial for the course in cross-sectional anatomy which is a part of the dissecting course. During these classes about 200 undergraduate medical students were, on one hand, taught cross-sectional anatomy the traditional way (as described in the introduction) by student tutors for a defined time. In addition, however, they had free access to five workstations for using HyperMed.

HyperMed was very well accepted by the students. All students stated that the program is easy to handle. This was even confirmed by people who had never used a computer before. Such users usually got acquainted with HyperMed in about 15 to 20 minutes. As a rule the students expressed that working with HyperMed was much more convenient than using textbooks and anatomical atlases or waiting for the (only temporarily available) help of tutors in order to identify structures in cross-sections. It has been found a great advantage to have free access to HyperMed as a computerized tutor than being restricted to the very limited classhours when help form student tutors was offered (as in the traditional course for cross-sectional anatomy).

Although the majority of feedback from the students was positive they also made some suggestions for improvement: Most of the users asked for a mode for selfexamination in order to control their success in learning and understanding. Others were also missing statistics telling how much of the available information had been seen by an individual user so far.

Indeed, this type of information can and will be offered by HyperMed: Any user of HyperMed gets access to the program by an individual password. Based on this, the computer creates an anonymous record for each user and performs statistics to what extent any component of HyperMed is used. This information will be made available to students in the future. The records will enable us to define whether different groups of users use the program differently and whether certain components of HyperMed are used more frequently than others. All these statistics will direct our attention to parts of the program that ought to be improved or extended. Unfortunately, these records could not be evaluated so far because the courses had not been finished at the time this paper had to be submitted. Furthermore, at the end of the classes students will also be requested to fill out a questionnaire asking for their opinion concerning different aspects of HyperMed.

7. Outlook

After HyperMed has been used successfully as a tutorial in cross-sectional anatomy we are planning to extend it as follows:

1. HyperMed was developed originally in order to create a computer-based tutorial for teaching cross-sectional anatomy preparing undergraduate medical students to understand radiological images. In a collaboration with

radiologists HyperMed is now being extended so that radiologists can use the system in their clinical day-to-day work. Similar to the WALT system [Frisse et al. 91] HyperMed should serve as a research environment and should allow clinicians to retrieve medical information in a way that satisfies their personal needs. This extension can be regarded as a step towards an anatomical and radiological digital library.
2. As a response to the feedback from the students we will integrate functionality for selfexamination.
3. At the moment HyperMed does not provide real multimedia. The program provides the possibility, however, to integrate MPEG videos, audios and 3D-scenes, which are of great value for physicians, and this is in preparation. Like in Hyper-G, it should also be allowed to define link anchors in these types of media.
4. Novel ideas of the RIME system [Berrut et al. 95] for indexing of medical images could be integrated. Given an existing image, such an approach may help to find similar images. For example, this may be of great value in diagnosis.
5. Finally, HyperMed is a hypermedia system without any “intelligence”. We are planning to incorporate intelligence to the system to get an expertmedia system [Rada & Tochtermann 95]. For example, defining an anchor, e.g. the cerebellum, in an MR-image can be done automatically if the system is able to find this region in the MR-image. Our first results of finding structures in MR-images base on techniques of computational intelligence, i.e. fuzzy logic, genetic and evolutionary algorithms [Fathi et al. 94]. Knowledge bases can also be used to define links automatically.

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