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Synopsis

Recent Advances in Computer Technologies and Medical Education

Introduction

Over the last few years, exciting advances have been made in areas related to the use of computers in medical education. There has been a growing integration of work from fundamental research in areas such as knowledge representation, technical advances in the presentation of multimedia and the development of realistic computer-based simulations. The maturation of these technologies has allowed for unprecedented opportunities for medical education. For example, there is now the possibility for medical educational programs that can allow for previously difficult integration of pictorial and textual information in areas such as anatomy training.

The papers in this section can be grouped into several categories. The papers by Höhne et al. [1] and Rosse [2] deal with the use of semantic networks and representational structures which will allow for the organization of complex medical information within multimedia educational systems. Coherent knowledge-representation schemes will be essential for the development of effective educational systems in medicine. Details of specific systems for training in several domains are described in the papers by Hooper et al. [3] and Lee et al. [4]. The use of realistic computer simulations has not only advanced technically, but has become a practical type of application for medical education. An application is described by Sinclair et al. [5] that allows for teaching eye-surgery methods to residents and practitioners using computer simulations. Finally, the extension of expert-system technology, borrowing from research in applied artificial intelligence holds promise for medical education. Along these lines, Reider et al. [6] describe the possible extension of an expert system used in assessing severity of asthma for teaching purposes.

Knowledge Representation: Foundation for Multimedia Educational Systems

In the paper by Höhne et al. [1], the integration of computer graphics with artificial intelligence is discussed in the context of representing medical knowledge for educational purposes. Multimedia systems which allow for fast and random access to text and pictures are rapidly proliferating. However, according to Höhne, the underlying paradigm of such systems still requires greater consideration. Höhne highlights the unique possibilities for creating educational multimedia software based on conceptually sound knowledge representations, ranging from three-dimensional interactive atlases of the body to systems for surgery rehearsal.

At the basis of this work is the concept of semantic networks - representations that allow for the formalization of knowledge (such as anatomical information) and the modeling of complex domains. Such networks allow for the expression of links between objects in a domain via relations with a given semantics. The approach described in the paper is to combine in one coherent framework, based on a semantic network, a detailed spatial model of anatomy, allowing for realistic visualizations. This model is based on a large number of cross-sectional images of the human body. VOXEL-MAN, the system described in the paper, consists of several thousand objects and links in the domain of morphology, pathology, functional anatomy and the vascular system. The subdivision of the coarse components of the model (e.g., the volumes from cross-sectional images) into their constituent parts is facilitated by graphics editors, which allow the expert to modify and refine the system's knowledge base. From an educational perspective, such a coherent knowledge base allows the student to navigate and explore anatomy in a simple pictorial way (e.g., by clicking on parts of a displayed image) and ask questions regarding the relationship among anatomical components. However, as noted by Höhne, a number of cognitive issues related to how users can best access such information remain to be examined.

In a related paper dealing with knowledge representation in training, Rosse [2] argues that the purpose of anatomy education is to develop the cognitive skills necessary for anatomical reasoning. He further argues that computerized representations offer unprecedented possibilities for improving and promoting anatomical reasoning skills. Anatomical reasoning refers to the cognitive process that relates manifestations of normal and abnormal function to anatomic entities. Rosse argues that traditional methods for teaching anatomy have shortcomings for representing and integrating information from the spatial (i.e., images) and symbolic (i.e., verbal or textual descriptions) domains. With traditional methods of teaching anatomy, the symbolic descriptions are often taught separately in lecture mode, which is often quite disconnected from the dissection laboratory. Computer-based representations have the potential for promoting anatomical reasoning by overcoming such shortcomings, allowing for integration of both images and symbols. By going beyond merely replicating the traditional representations of anatomical information, technology can be applied to present students with 3-D spatial models, where anatomic entities are easily identifiable and symbolic anatomic information, showing relationships among the concepts, can be easily accessed by the student along with associated graphics. With these goals in mind, the Digital Anatomist Program at the University of Washington has been built to provide a client-server framework for anatomical information. Rosse goes on to argue that computer-graphics techniques, coupled with principled knowledge organizations, such as semantic networks (such as those described by Höhne [1]), can lead to a richer appreciation of anatomy than would otherwise be possible using traditional teaching methods. Such systems have the potential of bringing "basic science to the bedside".

Multimedia Approaches to Clinical Training

Hooper, O'Connor, Cheesmar and Price [3] describe work in the development of multimedia tutorial software to aid in teaching clinical biochemistry in a problem-based manner. The focus of this work is on student interaction with the case, and the modeling of decisions in diagnosis and treatment. The aim of the project is stated by the authors as a "move away from teaching towards learning", by allowing for student interaction with various forms of multimedia, including images of patients, animation of control mechanisms and video. Students work through cases, which are presented on the computer in a traditional format: (1) summary of patient history, (2) clinical history, (3) biochemical assessment, (4) diagnosis and treatment, and (5) summary/case resolution. Through these stages the student interacts with the system, requesting further tests, and making diagnoses. The system also poses questions to the student throughout the case. A critical aspect of such tutorial systems is the student-assessment component, with students obtaining a summary of key points at the end of the simulation, along with a cumulative score for their performance. According to Hooper, important advantages of this approach include the high level of engagement of student attention and the generalizability of such programs to other medical domains. However, as noted by Hooper, further evaluation of student learning using such systems is needed.

In another training application, Lee, Ault, Kirk and Comstock [4] describe the use of an interactive multimedia system for prenatal ultrasound training. Similar to Rosse's critique of anatomy training, Lee argues that the traditional ultrasound training paradigm has a number of weaknesses, including lack of integration between practical scanning experience and reading assignments, as well as inadequate exposure to fetal ultrasound abnormalities. The system Lee describes contains a collection of medical images and structured so as to integrate a 3-D heart model, with a laser-disc library of medical images (e.g., ultrasound video, X-rays and autopsy photographs) and multimedia tutorials. Like the tutorial program described by Hooper, Lee's system allows the student to interact with the simulation, request information and respond to questions posed by the system. An important component of the system is the underlying heart model that drives the simulation. Initial questionnaire data given to users has indicated that physicians felt that the system was a useful training tool. Consistent with the argument raised by Rosse's paper [2], Lee [3] also argues that the use of computer technology can lead to better learning than could be obtained using traditional methods. The combination of interactive multimedia with volume visualization models is a unique aspect of the system, and promises to assist physicians in learning not only how to recognize fetal anomalies, but at the same time understand how the presented images can represent such a complex biological structure as the human heart.

Computer-based Simulations

Sinclair et al. [5] describe the application of a realistic eye surgery simulator that engages the student's visual and tactile senses. The system consists of an integrated multimedia simulation environment that allows the surgeon to view computer-generated images of the eye, and to interact with this "virtual eye" by manipulating the position of a simulated surgical instrument (scalpel, forceps and scissors) using a stylus. Force-feedback is provided to add to the realism of the simulation. Sinclair argues that advances in computer simulation technology have now made such applications feasible, both technically and cost-wise. Like the work described by Lee [4], the simulation has an underlying computer model that provides features that are necessary for controlling the simulation. Thus, advances in the underlying model for educational systems constitute an important aspect of a number of new technologies in computer-based medical education. Sinclair states that further work will be needed in enhancing the features of the model. Planned developments include the analysis of the use of the system by both novice and trained surgeons in order to obtain feedback on the extent to which the simulation actually duplicates the surgical experience. The approach promises to assist physicians of all experience levels - for both training students and for allowing more experienced surgeons to practise new surgical techniques. In addition, Sinclair notes that the approach may offer not only a training methodology but also a way for obtaining objective assessment of technical skills. However, Sinclair also notes that although advanced simulation techniques are already well established in other domains, such as the airline industry, their introduction into medicine will still require careful consideration.

Expert Systems Extension to Training Systems

In the paper by Redier et al. [6], an applied artificial-intelligence application is described consisting of an expert system for the assessment of the severity of asthma. The paper places an emphasis on the knowledge base, again consistent with the consideration in the other papers of underlying knowledge structure. The system described assesses the severity of the disease, identifying trigger factors involved, suggests further investigations and offers a treatment strategy. The paper goes on to describe what becomes recognized as an important aspect of experts systems in medicine, namely evaluation of the system's performance and accuracy. The validation described involved clinical experts who were provided with case-report forms with their conclusions about the management of asthma. The same forms were then programmed into the expert system. The comparison of the human experts with the system indicated a good degree of agreement between the two, with the overall conclusions given by the system being as good or better than the experts. Given the results of the evaluation, Redier goes on to consider the use of the system not only for treating asthma, but also for training medical students and general practitioners.

Conclusions

The diverse set of papers in this section reflects a trend toward the increased use of computer technologies in medical education; in domains ranging from anatomy to surgery. Computer learning is increasingly seen as a critical component of medical curricula. This is partly in response to a pressing need to impart an ever-growing body of biomedical knowledge to medical students without increasing didactic lectures. New technologies are viewed as having the potential to introduce more effective learning approaches, as well as complex forms of performance assessment that are difficult via traditional methods. The work discussed in this section includes fundamental research which serves as a basis for the development of sound practical systems. The papers effectively build on the foundations of knowledge representation (Höhne et al.), human reasoning (Rosse), human computer-interaction (Sinclair et al.), and expert system's research (Redier et al.), and modeling (Hooper et al.; Lee et al.).

As has been recognized in several of the papers, there is a need for continuing educational and cognitive research to further explicate the conditions of learning, and the best possible means for successfully exploiting this technology. Multimedia and multiple modalities of representation, including three-dimensional graphics, sound, and moving images afford greatly advanced learning capabilities. However, instructional computing paradigms need to evolve to the extent that they can enhance knowledge and skill acquisition without increasing cognitive load. Multiple forms of representation can divide attentional resources and increase cognitive processing, thereby diminishing one's capacity to learn. There is a need for further research to determine how to effectively use rich representations in a multimedia system without promoting sensory overload.

Given the complexity of the domain of medicine and the variability of computer-based applications, there is a need for a comprehensive framework to guide the development and use of learning technologies in medicine. Most computer-based instructional tools build on idiosyncratic methodologies, and are driven by immediate interests and specific needs. There is a need to merge approaches into unifying paradigms towards different kinds of learning. Cognitive science has made significant progress towards characterizing different forms of learning, such as learning-by-doing and learning-via-analogy. In recent years, computer-assisted instructional (CAI) research has attempted to incorporate these different approaches to learning in their applications with considerable success. CAI development in medicine would do well to capitalize on this theoretical base. These papers provide us with considerable reasons for optimism concerning the state-of-the-art in medical informatics and education. However, they also highlight some of the challenges that will have to be dealt with in the near future.

References

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