"Docs 'n Drugs – The Virtual Polyclinic "

An Intelligent Tutoring System for Web-Based and Case-Oriented Training in Medicine

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ABSTRACT

Since the beginning of the year 2000 medical students of the University of Ulm are working in their curriculum with the web-based and case-oriented tutoring system "Docs 'n Drugs – The Virtual Polyclinic".

The system consists of different subsystems and services. One subsystem is the Training System. It is based on three models: the Tutoring Process Model, the Case Knowledge Model and the Medical Knowledge Model. They describe the tutoring process as a series of nodes and steps, depict the structure of the medical cases, and provide the medical knowledge respectively. Case knowledge and medical knowledge form the expert knowledge of the medical domain. Together with the tutoring process, they build the basis for automatic intelligent tutoring.

After giving a deeper insight into the system architecture and the training case structure, an informal evaluation shows a first feedback of the learners.

INTRODUCTION

Computer supported learning has a tradition that can be traced back to the 50's [1]. However, there's again a growing interest and popularity in the use of computers in educational settings. The World Wide Web in combination with modern technologies and multimedia provides new possibilities for establishing up-to-date learning strategies. Time and location independent learning has become possible. Computer Supported Collaborative Work (CSCW) components or an Intelligent Tutoring (IT) component can support the learner and prevent him from feeling lost. In contrast to conventional systems for Computer Aided Instruction (CAI) [2, 3], Intelligent Tutoring Systems (ITS) [4] promise to provide more flexibility and adaptability to modern learning theories since they use pedagogical and domain knowledge for constructing adaptive learning strategies instead of operating with fixed, predesigned lessons [5, 6, 7]. An ITS usually comprises a module for expert knowledge about the teaching domain, a module for tutorial strategies and a user model.

The ITS described in this paper, "Docs 'n Drugs – The Virtual Polyclinic" (DND), is a web-based and case-oriented training system for medicine. Its structure reflects the requirements of an ITS: the expert knowledge is represented by the Medical Knowledge Model and the Case Knowledge Model. The tutorial strategies are described in the Tutoring Process Model. All three models are part of the Training System. Additionally, DND provides a user model which is part of the Administration System. Internally a user is represented as an agent.

The first part of the paper describes the project the system is developed in and the current state of the art. The second part gives insights into the systems architecture, particularly the Training System with the respective models, i.e. the Tutoring Process Model, the Case Knowledge Model and the Medical Knowledge Model. Finally, a first result of an informal evaluation is presented.

DOCS 'N DRUGS – THE VIRTUAL POLYCLINIC

Medical education is a combination of mediating systematic medical knowledge provided by textbooks and lectures, and practice relevant training with emphasis on patient contact. However, practice relevant training is highly time-consuming. Additionally, patients for certain medical problems are often not available, or patients are not willing to act as 'illustrative material'. Therefore, an extensive patient centered education is hardly realisable. Thus, a web-based case-oriented tutoring system like DND becomes a meaningful supplement to traditional lectures and courses [8]. Furthermore, intelligent tutoring systems promise to provide more flexibility and adaptability to the user and thus are useful for self-studies.

State of the art

DND is a web-based and case-oriented tutoring system. It is implemented in Java, works with a relational database and uses XML as an exchange format. The system makes use of modern approaches in reusable multimedia and realises adaptable learning strategies. Furthermore, it provides an intelligent tutoring component, interfaces for simulations [9, 10] and CSCW components.

Currently, the application domain is the clinical medicine. The program contains medical knowledge as well as interaction patterns of medical treatment [11]. Thus, it is a meaningful supplement to deepen and complete the traditional lectures and courses. Students of medicine at the University of Ulm work with the program since the beginning of the year 2000 as a part of their curriculum. Since early 2001 the system is open to public with some selected medical training cases in German language. The registration procedure and a demo of the system is accessible on the project's website at http://www.docs-n-drugs.de.

Since researchers of computer science and medicine participate in the joint project, the realisation of the system is permanently accompanied by the development of medical contents. Current medical project partners are nephrology, cardiology, paediatry, infectiology, psychology, neurology and gynaecology. So far about 80 cases are practicable for students. Some of them are available in supervised courses only and others are didactically elaborated and thus can be used for self-studies.

Medical contents are represented in a case structure. A case represents a certain patient, his history and his current diseases. The case structure reflects the medical treatment process. This process starts with the first contact between patient and physician, subsumes the medical treatment from anamnesis to therapy and might end with the result of the therapy.

The learner has to act as the physician. He has to make or order examinations, e.g. anamnesis, laboratory or x-ray, find the correct diagnosis and finally choose the right therapy. While the learner works with the medical case, he can use the intelligent tutor to get hints and tips. Furthermore, he can contact a human tutor that is currently online via CSCW features (e.g. video-chat), or ask other students via mail or chat.

THE SYSTEM ARCHITECTURE

The entire system, which is called Tutoring System, consists of six main software components, which can be divided into three subsystems and three services. The three system components are:

- the Training System to process cases,
- the Authoring System to create cases,
- the Administration System to administrate users and user roles.

The three main service components are:

- the Intelligent Tutoring Service, which supports both kinds of users, authors and learners,
- the Telecollaboration Service, which comprises possible CSCW features of the system, and provides users with a communication environment,
- the Evaluation Service to permanently evaluate the system.

Figure 1, The Tutoring System Architecture, shows the main systems, possible user roles and the relations between them.

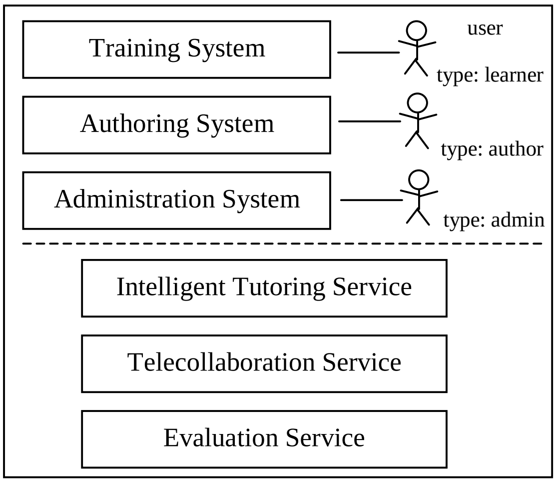

Figure 1: The Tutoring System Architecture

In the following, the Training System is focussed.

The Training System

The structure of the Training System is based on three main models [12]:

- the Tutoring Process Model,
- the Case Knowledge Model and
- the Medical Knowledge Model.

These three models are implemented in three linked databases:

- the Tutor Process Base,
- the Case Knowledge Base and
- the Medical Knowledge Base.

This structure is shown in Figure 2.

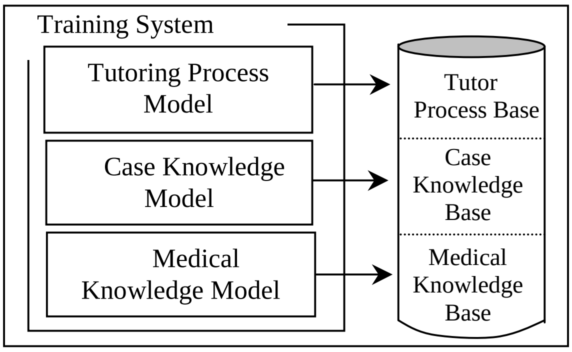

Figure 2: The Training System and the Databases

The Tutoring Process Model

The Tutoring Process Model specifies the parts necessary to construct a training case and describes the role of the user. The respective database, the Tutor Process Base, contains the data formally described by the Tutoring Process Model. Thus, it contains the didactically elaborated medical case, its knowledge level, and the process' structure.

Obviously, an aim in constructing medical training cases is to teach the medical background of a certain case. This should happen in an ordered and didactically elaborated way. Another aim is to teach students how to behave in the treatment process. Thus, the treatment process can be perceived as a set of nodes which contain the information, and directional edges between these nodes which reflect single steps in the process [13]. Steps can be refined by sub steps and this leads to a hierarchy of steps. Some steps are in classical order, which can be reflected in a sequence of steps. For example, a special question might be to ask the family situation of the patient, which is part of the anamnesis. Usually the anamnesis is a starting point in the treatment process. If the tutoring process is perceived as a set of interrelated steps, the student's behaviour is reflected in the steps that he chooses. For example, it might be assessed whether has he chosen the correct initial step in an emergency situation. Thus, the chosen sequence of steps in a tutoring process leads to knowledge about the learner's behaviour and can be used to reason about the learner's knowledge and progress.

Additionally, because of this network of interrelated steps, the tutoring process is flexible and adaptable to differently experienced learners. The flexibility of the tutoring process and its adaptation to the learner's profile and skills are realised in two different ways: the process adaptation itself and the adaptation of the pages' contents. This may take place just before the learner starts the process or during runtime. Two adaptation methods are described later in the paper.

As mentioned above, the training case is perceived as an hierarchical compositional process [13] whose elements are nodes and steps between these nodes. For the learner, these elements are respectively the shown pages and possible ways to navigate between these pages. The pages are divided into information pages and interaction pages. The latter contains exercises, e.g. answering questions or interacting with multimedia elements. Navigation between the pages can be realized in three different ways: guided, half-guided and unguided. The learner navigates to different pages by selection from a navigation menu.

Using only guided navigation within a training case, the learner has no freedom of choosing further steps – he can only follow the prescribed didactical path. Figure 3 shows a guided tutoring process. This kind of training case is particularly useful for beginners. From the pedagogical point of view, this process type lacks the important element of choosing the best next step, which is a training element itself.

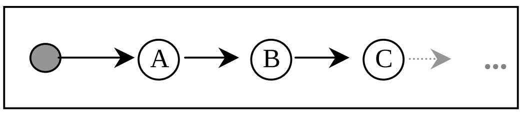

Figure 3: Guided Tutoring Process

The unguided process shown in Figure 4, provides no default steps at all. Here, the learner has the freedom of choosing further steps on his own. In the view of the learner, that means all possible elements of the navigation menu are available. The construction of an unguided training case needs a high grade of accurateness and thus a lot of time. Help and explanations are necessarily rather coarse from the pedagogical point of view. This kind of training case can be used by professional learners mastering consolidated knowledge about the domain and otherwise should be supported by a human tutor.

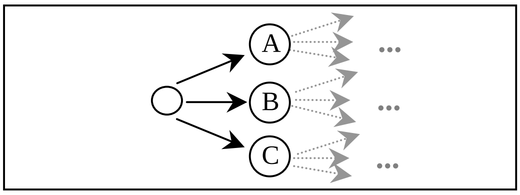

Figure 4: Unguided Tutoring Process

The half-guided process shown in Figure 5, realises an approach that lies in-between. The learner has the possibility to choose the next step from a variety of preselected possible steps. Sometimes he may be guided and may only choose a predefined next step, for example to an important information or a controlling question.

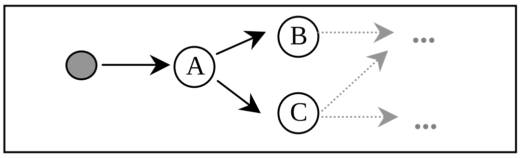

Figure 5: Half-guided Tutoring Process

The flexible tutoring process provides for an adaptable process generation during runtime. The process itself, as well as the contents of a single page, are constructed to be adaptable to the learner's behaviour. If the learner selects a training case for execution, the Intelligent Tutoring Service checks the learner's profile and starts the case with the detected knowledge level [14]. For example, if the learner is a beginner, the case can be started in a guided manner. According to the learner's actions (e.g. if he answers all questions correctly) the level of guidance can be eased. If the learner starts at an expert knowledge level and makes a lot of mistakes (e.g. in the choice of steps, in the differential diagnosis or in the interaction pages), the system can support him by restricting the amount of possible further steps.

So far, the process adaptation has been described. Furthermore, the contents of each page are adaptable. Pages consist of a set of content elements. The content elements, e.g. text elements, questions and pictures, are associated with a knowledge level. The page which appears on the learner's screen is constructed during runtime. According to the learner's profile, the system adapts the elements to be displayed. Figure 6 shows the scheme for the page adaptation.

In analogy to the process adaptation, the page adaptation is dependent on the learner's skills and behaviour within the current and former training cases. For that reason an expert can be confronted for example with few but difficult questions, whereas a beginner might need more but less difficult ones.

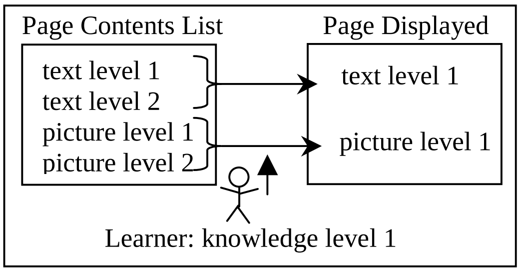

Figure 6: Page Adaptation

Both described possible adaptations, i.e. process adaptation and page adaptation, are fundamental for training case authors being able to construct reusable cases which can be used by different types of learners.

The Case Knowledge Model and The Medical Knowledge Model

To provide the Intelligent Tutoring Service with the necessary expert knowledge to reason about the knowledge a learner has gained and the progress he has made, the Case Knowledge Model and the Medical Knowledge Model have been developed [11, 12].

The Case Knowledge Model describes the part of the medical knowledge that is embedded in a particular medical case. The knowledge content of a medical training case is twofold, it contains correct and important steps and elements, as well as wrong and redundant ones. For example, it should provide a set of diagnoses, whereas some are correct, some are possible and some are incorrect. Furthermore, according to the insight that committing errors is an important aspect of learning, possible wrong and redundant paths in a treatment process of a training case should be added. In a medical case, a lot of medical rules and relations are embedded. Based on these rules and relations, the Intelligent Tutoring Service is able to reason about the progress of a learner. If an author identifies and specifies these rules, the Intelligent Tutoring Service can derive the knowledge gain of the learner. Additionally, the Intelligent Tutoring Service can generate automatic corrections authors did not specify in advance. For example the diagnosis "appendicitis" is possible in the context of "pain in lower abdomen". But if the learner has made the correct anamnesis and has learned that the patient has had an appendectomy several years ago, this diagnosis changes from possible to wrong.

The Medical Knowledge Model building the base of the Case Knowledge Model describes the general knowledge of the medical application domain and is not dependent on a certain medical case. Details about structuring the medical domain knowledge are covered in [11]. To use a unique and comprehensive medical language in all cases, the according knowledge base uses standard nomenclatures (e.g. ICD-10). The database is based upon the open world assumption and therefore incrementally expandable. Additionally, the Medical Knowledge Base contains all multimedia elements of the system. Therefore, multimedia element can be reused in different cases.

FIRST FEEDBACK

Currently, the evaluation is running in its last period and therefore no empirical evaluation data can be presented in this paper. Nevertheless, first interviews with the learners have shown the following results. Medical students who are obliged to work with the program have different experience in learning with computers. So it has been necessary to divide the students into two groups and to adapt some of the questions to the experience level of each group. The first group A contains learners with no computer experience, the second group B those with experience. In the current evaluation, it has been necessary to distinguish different knowledge levels according to the students' domain knowledge. This first interview did not take this into account. Also, the first questionnaire refers only to students, who have participated on a DND training course, supervised by an human tutor. Self–studies have no impact on the answers given. Nevertheless, most of the students enjoyed to work with DND and mentioned, that they intend to use it for their self-studies.

Students interviewed in group A stated that they have less fear now to learn with a computer or to use the Internet for their work. Admittedly, this group criticised the user-interface to be not very intuitive to handle, especially the huge navigation menu bar. The main problem there is that the states of the menu items depend on the tutor process structure, i.e. if the author of a medical case has constructed a half-guided training case, some items change from active to interactive during runtime. Students with little experience in working with computers were fairly irritated that they were not allowed to click a button, which has been active already at a previous step. Here, further reflections are necessary. Students of group B had less problems with the user-interface. This group criticized for example that a lot of mouse clicks are necessary to complement a body examination. The navigation handling problem played a minor role. In this group the criticism was focussed in the structure of the cases, which again reflected how difficult it is to construct a sophisticated medical training case which is well didactically elaborated.

Both groups reported that medical studies will significantly be enriched by online-learning of medical cases. Almost all students had the opinion that it is of great value to be tested and corrected in the context of the concrete medical case, because it trained to apply the knowledge learned in theoretical lectures. As one advantage of computer based training, some students mentioned the possibility to make and thus to learn from mistakes. This implies that it seems to be a good idea to embed redundant and wrong paths into the tutoring process and to show the student mistakes he has made during or after his work. Both groups valued the impact of multimedia elements on their learning progress. Some students stated that it helped to present results of certain technical examinations by showing an ultrasound movie instead of merely displaying a static picture . The movie can be re-played several times and gives a more realisitic impression. As a possible problem some mentioned that in a self-study scenario the quality of pictures and movies depend on the quality of the monitors– and not every student has a good one. Moreover, students using modems connections will have problems if they want to learn at home, e.g. because of large multimedia elements. In both cases, some think that a book with a good picture explaining this medical topic seems to be a better alternative than an online-learning system. Further evaluation and also further discussion will lead to new ideas in these contexts.

CONCLUSION AND ONGOING WORK

The web-based and case-oriented intelligent tutoring system "Docs 'n Drugs – The Virtual Polyclinic", which is still work in progress, has been a success in the last years. It is sucessfully implemented in the medical curriculum at the University of Ulm.

Since DND is part of the medical curriculum, nearly 300 students and about 20 authors work permanently with the training program. Currently, an evaluation is in progress. According to the results of this evaluation, the program will be reengineered, especially the user-interface.

Future work will include the expansion of CSCW components (e.g. a chatroom for the users) and to establish more multimedia components (e.g. a web-based 3-D hospital, realized in VRML , used to find patients and thereby training cases),. Moreover, the user model is currently in development because the first implementation has been on a rather coarse level. The extension of the user model will imensively increase the capabilities of the Intelligent Tutoring Service.

The flexible architecture of the system has proven to be good from a software-engineering point of view, because each of the components can be separately revised. The construction of the tutoring process, its flexibility and its adaptability has been approved. Admittedly, authors have criticised the large amount of work, which is the price for this adaptability. So, two main activities are necessary in the following period of the project. On one hand, a sufficient authoring system must be developed. At the moment, the authoring system is only an "ad-hoc" implementation and thus not very comfortable. On the other hand, it is under discussion to embed some kind of rewards and certifications for authors. This is under consideration in other projects developing WBT systems, too.

After all, to embed a web-based training system into the curriculum as well as working with the case-oriented approach are steps towards a modern education. The close coupling of computer science and medicine in this context has proven its value and has led to good results.

REFERENCES

1. Lelouche, R., Intelligent tutoring systems from birth to now, *KI 4/99*, 1999, pp. 5-11

2. Baehring T, Weichelt, U., et. al. ProMediWeb: Problem based case training in medicine via the World Wide Web. In: *Proc. of ED-MEDIA*, Freiburg, 1998.

3. PRIMAPRACTICE, Vol.2, No.3. Published by: IVI Publishing,Churchill Livingstone, 1996.

4. Reinhardt B. Generating Case Oriented Intelligent Tutoring Systems. *AAAI Fall Symposium, IST Authoring Systems*, 1997.

5. Wang, M.J., Contino, P.B., Ramirez, E.S., Implementing Cognitive Learning Strategies in Computer-based Educational Technology: A Proposed System. *Proc. AMIA Annual Fall Symposium* 1997, pp. 703-707.

6. Zaharakis, I.D., Kameas, A.D., et.al.. A Multi-Agent Architecture for Teaching Dermatology. *Journal of Medical Informatics*, 1998, vol. 23, No.4, pp. 289-307.

7. Adelsberger, H.H., Bick, M., Pawlowski, J.M., The Essen Learning Model. In*: Proc. of ED-MEDIA*, Montreal, Quebec, 2000.

8. Friedman, C.P., Dev, P., Education an Informatics: It's Time to Join Forces. In: *JAMIA* 1996, pp. 184-185.

9. Van Schaick Zillesen, P., Using Educational Computer Simulations, Van Hall Institute, 1998.

10. Downs, A.M., Marasigan, F., Abraham, V., et.al.. Scoring Performance on Computer-Based Patient Simulations: Beyond Value of Information. In: *Proc. of AMIA Symposium*, 1999, pp.520-524.

11. Seitz, A., Martens, A., Bernauer, J. et.al., An Architecture for Intelligent Support of Authoring and Tutoring in Multimedia Learning Environments. In: *Proc. of ED-MEDIA*, Seattle, June, 1999.

12. Illmann, T., Martens, A., Seitz, A., et.al., Structure of Training Cases in Web-Based and Case-Oriented Training Systems. To appear in*: Proc. of IEEE Int. Conf. on Advanced Learning Technologies, ICALT* 2001, Madison.

13. Martens, A., Uhrmacher, A.M., How to Execute a Tutoring Process. In: *Proc. AI, Simulation and Planning, AIS* 2000, Tucson, Arizona.

14. Seitz, A., A Case-Based Methodology for Planning Individualized Case Oriented Tutoring. In: *Proc. Int. Conf. on Case-Based Reasoning, IC-CBR*'99, Munich, 1999, Springer.