Interactive Computer Assisted Formulation of Retrieval Requests for a Medical Information System using an Intelligent Tutoring System

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Abstract: A medical information system at Graz University contains three millions of diagnostic reports, which form the basis of patient care and of scientific work. Complex retrieval systems are prepared in a time consuming dialogue between clinical researchers and IS-experts. In this paper we describe the development and questions of evaluation of an intranet Web-based query/answer system with reference to aspects of human-computer interaction. The system formulates a well structured and, ideally, machine interpretable retrieval request in interaction with the user (i. e. medical professionals, bio-statistical researchers, ...) and stores it in an existing request-management-application. The user learns, incidentally, how to use the hospital information system for his needs. For optimal interpretation of the gathered information exact formulation of the questions is essential. An intelligent guidance during the dialogue is obligatory since we cannot assume any technical skill on the part of the medical users. In the near future this service will be extended to the countrywide hospital information system. By using this system, the quality of the retrieval and therefore the quality of scientific research and medical studies is raised. Less iterations mean a lower system-workload. Last but not least, we expect to lower the response time without increasing the need of human resources.

“When we write programs that "learn", it turns out that we do and they don't.”
(Alan J. Perlis, Yale University)

1. Introduction

The information systems at the departments of radiology and pathology at the 2.300 bed University Hospital in Graz support activities in patient care and serve as a basis for scientific research, not only for radiology and pathology but also for all other clinical departments which refer to these systems in connection with their own patient data. Since the data are partly in standardized form (codes for examination types, organizational entities) and partly in natural language, scientific retrievals require complex strategies to yield optimal results. As will be shown below, the scope of the retrieval request is defined in an interactive discussion between a clinical researcher and an IS-expert. This procedure will be replaced as far as possible by the proposed system. The system will primarily be used by medical doctors or assistants. To improve the quality of data preparation it is necessary to provide precisely formulated questions. Since the typical user does not have detailed technical knowledge, intelligent guidance is required during the dialogue.
The user starts the dialogue with the System by stating his question in medical terminology for administrative and future purpose only. During the subsequent dialog, unconsciously he will adopt the dialogue’s behavior in formulating further questions. Succeeding dialogues must always be based on information already ascertained, thus avoiding ‘silly questions’. Following the indicated evaluation of criteria and features, only useful selections of data-reports should be offered. In this project the main emphasis is on ‘the dialogue’. The dialogue will help the user understand and benefit from the functional possibilities of the information system. Furthermore it will help them to accept limitations and guide them to provide structured information. The high level of the system’s operating

comfort aims at persuading the user not to make complicated and time consuming telephone discussions or use written inquiries to collect required information. This system provides a remarkable potential of savings in administrative expenditures by means of good integration into existing administration facilities and adding to the quality of data evaluation.
The system itself has to adapt to the user's formulation of a question not only per session but also in the long term, thus adapting to the importance and priority of knowledge objects in general.

2. Background

The Information-System used for research and patient care was originally developed by the Institute of Medical Informatics, Statistics and Documentation (IMI) at Graz University for use in Radiology, Pathology, Neurosurgery and Pediatrics, and has been steadily refined ever since the early seventies. The IS Data Base contains approximately three million (!) medical documents, which have been gathered since 1971. Patient information, technical parameters and performance data are saved in a thoroughly structured form, anamnese, examination descriptions and diagnoses are available in free-text. Besides hundreds of simple routine retrievals for patient care, there are, on average, about one or two highly complex retrieval requests per day for scientific purposes, which requires the knowledge of an IS expert. Quite often the huge possibilities and potentialities of filtering, structuring and representing are not familiar or even known to the medical researcher. High competence by the IS expert in medical and technological fields is needed to assess the real scope of the information required by the clinical researcher for his work. The formulation of the retrieval needs are elaborated in a personal discussion between the clinician and the IS expert, a time consuming process, requiring patience and perseverance. Due to the personnel shortage and the increasing demands based on increasing standards in quality management, output documentation, health reports, etc. we consider an automation of this process is necessary to enable continued functioning in the future. The following excerpt of a conversation between an IS-expert and a client shows that several areas of knowledge are necessary to lead an intelligent dialogue:

Client: I would like to have all reports of the angiography with interventional cases from 1998 up to the present.
IS-Expert: You mean all types of examinations concerning the angiography ?
Client: Yes, because the examinations are all entered with different coding abbreviations.
IS-Expert: That is clear to me. How can I identify interventions ? What does the examination report say?
Client: ... well, the criteria of the contexts are ... (speaks slowly and pause for a moment) ... A.carotis, A.vertebralis, A.basilaris, embolisation, neuroembolisation, stent, baloon dilatation, PTA, ...
IS-Expert: ... hmm, that appears to be a lot to me ... if I ... for instance only look for A.carotis or A.vertebralis ... then I will find a vast amount of data-sets ... should these criteria really all combined by 'OR' ?
Client: ... no, no ... I only mean neuroembolisation OR embolisation etc. with A.carotis OR A.vertebralis, ...
IS-Expert: ... ah, I see, ... well that is O.K., ... I am looking for interventions in the examination reports such as embolistion, neuroembolisation, stent, balloon dilatation and PTA and within the diagnosis for A.carotis OR A. vertebralis, OR A. basilaris
Client: yes exactly ...
IS-Expert: ... would you like to read all the documents of the interventions ... or are you primarily interested in the patience convalescence ...
Client: No, we are looking for eventual complications which might have occured later ...
IS-Expert: Ah, yes ...

It would be extremely difficult and exhaustive to put the whole special medical knowledge into the system. For instance the fact, that a balloon dilatation is already an intervention, on the other hand A. basilaris is an organ, where the intervention actually has been made. Also the knowledge about the structure of the IS (types of examinations are divided into coding abbreviations, these depict the radiological technology, but not an interventional operation) and meta-knowledge would be extremely difficult to put into the system. With the strategy mentioned above, one can find the initial intervention, but to find more about complications requires other strategies.

These problems are solved by using a combinatorial approach. Every fact, which can be appear as a filter, a classification item or as representation feature in the resulting request, is represented as an object. One method, implemented in this objects enables the dialogue with the user (e. g. a question about an examination type within a meaningful subset represented as HTML Structure). The reactions which alter the factual knowledge basis of a particular session and that modifies the persistent user depended state of learning are important methods which are also implemented in these objects. By extending a good Meta-Data-Strategy with actions that represent semantic rules in medical context, we implement a small, dedicated part of global behavior. These actions are 'triggering questions' and 'generating answer-like facts'.

3. The system assembled as an Intelligent Tutoring System

3.1. What is an ITS ?

Intelligent Tutoring Systems (ITS) are remarkable with regard to their methods and the fundamental theories used. Their origin comes from the field of Computer Assisted Learning. Generally the “Intelligence” in ITS is traced back to Carbonell in 1970. Carbonells prototyp SCHOLAR, which was actually an interactive program for computer-aided instruction based on semantic networks as the representation of knowledge, was primarily designed for learning geography. He implemented a socratic dialogue in an artificial tutor.
ITS generally provides a high level of guidance and control interactive processes in great detail. Possible navigation decisions by the users are controlled by the system. There is no clear border between adaptive systems and those generally called ITS (cf. Sleeman & Brown (1982)).
Recently, ideas from both intelligent tutoring systems and from hypermedia have been brought together. This has lead to interactive and adaptive hypermedia, which we use in our system. This synthesis responds to the specific strengths and weaknesses of both approaches. A domain model representing all facts of the field to be learnt usually forms the background for a model of the learner's knowledge and knowledge acquisition.

3.2 The problematic of intelligence

Constant misuse and misinterpretation of the term “Intelligence” and in particular “Artificial Intelligence” has made it increasingly undesirable to label systems with this designation.
It is generally accepted to refer to an “Intelligent Tutoring System” if the system is able to

a) build a more or less sophisticated model of cognitive processes,
b) adapt these processes consecutively and
c) is based on these fundamentals to control an question-answer-interaction.

The basics of Intelligent Tutoring Systems are most suitable for our special purpose.

3.3 Interface and Interaction

Initially, an ITS should be able to analyze the current process of knowledge acquisition. Based on this information the ITS should be able to build instructions for the user. An ITS is generally considered to be “intelligent” if it is able to react to the process of communication in a flexible and adaptive manner. Kearsley (1987) distinguishes basically between five different types of interfaces for IT-Systems: 1) socratic dialogue, 2) coaching, 3) debugging, 4) microworlds, 5) explainable expert-systems. In our system we use the principles of the “socratic dialogue”:
The system questions the user and, on the basis of the questions and answers, guides the user through a controlled interaction. A specific answer of the user is a starting point for the next question. The interaction happens close to a natural-language dialogue (cf. Kearsley (1993)).

4. The System, its features and its implementation

4.1. Prerequisites

Concerning the implementation of this system, there were several preconditions to be taken into consideration.
Firstly, the system is supposed to work in cooperation with the Meta-Data strategy of existing department information systems that currently work on proprietary databases. As mentioned the information systems are about to be replaced with a countrywide information system within the next year. That means that our solution needs to provide an interface that can be easily extended or replaced.

Secondly, we had to keep in mind that we needed to find a way of implementing the system so that the result would provide as open an architecture as possible with regard to interfaces and interoperability with other systems and platforms.
Thirdly, the system should also be capable of easy expansion, e.g. additional functionality in future at very low expense.
Fourthly, in the event of migration to other hardware and/or software platforms in future, it should be easily possible to port the system without endangering the stability and/or functionality. Only minor changes or adaptations should be necessary by that time. This means that portability also had to be taken as a prerequisite.

4.2. Implementation Framework: The Java 2 Enterprise Edition

We ran across Java and the Java 2 Enterprise Edition (J2EE) pretty quickly. The J2EE provides all the functionality and tools that fulfill the preconditions of the project listed above and impresses the developer with its "write once - run anywhere" functionality. In addition, the Java Enterprise Components give us the advantage of minimum possible implementation time and low costs combined with a maximum outcome. Networking, multithreading, security and even database connectivity are available via standard APIs and do not have to be written again from scratch. Since the release of Java in 1996, a very large community of Java developers (Java Developer Connection, about 1 Mio. members) has evolved, who provide a wide variety of Servlets and Beans (reusable components) almost for free which can easily be integrated in any project without having to “reinvent the wheel”.
When considering an open system that is expected to provide as much interoperability and expandability as possible, the choice for a Multi-Tier architecture approach is obvious. Using a Multi-Tier architecture also ensures that the whole system is built to work in a distributed scalable environment, which was another prerequisite of the project.

4.3. Multi-Tier Architecture

Taking into consideration a Multi-Tiered architecture relating to the general condition explained before, we expect the following framework to meet our needs.

Presentation Layer

The user communicates with the system through an HTML - Browser that is driven by a Thin - Client Servlet. The dialogue phases should be fast and simple. In addition to the claim that the dialogue should usually be similar to a natural language dialogue, (Spada and Opwis (1985)), the possibilities of graphical user interfaces should improve the performance of the human computer interaction.

Business Layer

Here we implement all application specific components and the session management using state-full Session Beans. It is necessary to convert the stateless http-communication into a persistent, re-activateable dialogue by means of the user context. So, if the user looses the dialogue with the system for what ever reason, next time he authenticates himself to the system, he has the opportunity to continue, without loss of previous dialogue.

Technical Layer

The association of the fact-, semantic- and knowledge objects builds the didactic components in this layer. The dependency of classes from the database layer and the over all didactic strategy builds the classes.

Database Layer

Here we find the object representation of the Meta-Data in the Data-Dictionaries and their semantic meanings, as well as the user specific model, his habits, behavior, last session status and previous accesses. Also the knowledge model is represented as a class of this layer.

With respect to the manageability of all growing information components, all permanent data will be stored on database servers. Flexibility is acquired by means of using only JDBC-interfaces to the servers.

5. Research

A hospital information system provider looks ahead, hoping to gain experience in covering the complexity of huge information archives under retrieval aspects. For the cognitive scientist, the greatest advantage of that approach will consist of the feedback, that will be provided by the quality improvement for retrieval requests. During our talk at ED-MEDIA 2000 we will present some answers to questions asked in the following paragraphs.

5.1. Aspects of Informatics

5.1.1 Meta Data Dictionary (for details see http://www-ang.kfunigraz.ac.at/~holzinge/its/mdd)

The main goals during design of the Meta Data Dictionary were simplicity and extendibility, but focusing on an intelligent way of storing knowledge (actual legacy database and future SAP R/3). How can the IS-Meta-Knowledge be stored and accessed in a intelligent way to get an optimum out? What has to be prepared to be able to change the database engine itself whenever the MDD has to be moved to another platform (what about XML)?

5.1.2 Distributed System Design (for details see http://www-ang.kfunigraz.ac.at/~holzinge/its/dsd)

Thinking about a distributed application framework, it is obvious that one has to be prepared for different platforms and will result in a multi-tier architecture. The main questions in this context are: How can the system be kept portable for future platforms (JAVA Enterprise Edition)? What will happen when one component in the network cannot be reached and will not deliver an answer? What can be done to ensure good performance of the system so that the user will be satisfied?

5.1.3 Intelligent Engine (for details see http://www-ang.kfunigraz.ac.at/~holzinge/its/ite)

How should the engine decide in case of equal weighted questions (aspects of fuzzy logic)? How can the user profile be integrated as a decision criteria (adaptive behavior)?

5.2. Aspects of Human-Computer-Interaction

The knowledge representation, as a framework of objects that cover facts, semantic information and parts of common knowledge is especially important, as are the methods used to keep the users' interest, motivation and attention on the actions to keep the dialogue process alive. As an experimental design we have chosen a pre-test/post-test control-group design, assisted by qualitative analysis via interviews. The experimental sample to be examined includes 24 people: 12 experts (including MD's) and 12 novices (students of medicine). The research questions are divided into Dialogue, Usability and Learning.

5.2.1 Questions concerning the evaluation of the System (Dialogue)

How do users (experts versus novices) handle the machine-dialogue, in contrast to the human-dialogue provided by an IS-expert ? How extensively do the users proceed within the dialogue ? At which time do they quit the dialogue ? Why do the users break off the dialogue ? How often do we get useless or irrelevant information ?

5.2.2 Questions concerning the evaluation of the Graphical User Interface (Usability)

How does the GUI influence the user behavior ? What is the difference in handling between experts and novices ? What screen contents and hints are useful for novices and experts ?

5.2.3 Questions concerning the evaluation of the Intelligent Behaviour (Learning)

How big is the learning achievement by using this system ? How does incidental learning (cf. Holzinger & Maurer 1999) increase the efforts of the users ? How do motivation, attention and arousal directly influence the necessary actions to keep the dialogue process alive ?

6. Practical Aspects

Eventually, when the IS is extended to the countrywide hospital information system, it will no longer be possible to include the whole system information in one human to human consultation call. The findings and experiences of this project will lead to a suitable knowledge representation, which provides an interactive dialogue suitable for a more complex system. Finally the quality of requests for scientific medical research can be increased by reducing the response-time and lowering the system work load through minimizing iteration cycles.

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