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Research at the Department of Medical Informatics, Statistics and Documentation of the University of Graz

Abstract: The Department of Medical Informatics, Statistics and Documentation of the University of Graz has a double responsibility: research in medical informatics, and implementation and operation of information systems in the hospital. Research is therefore application oriented with emphasis on departmental information systems, image management, and information integration. Other topics include analysis of the preconditions for the acceptance and successful use of information systems in medicine, and the ethics and professional responsibility of medical informatics.

Keywords: Medical Informatics, Information Systems, PACS, Ethics.

1. Introduction

The most significant feature of the Department of Medical Informatics, Statistics and Documentation (abbreviated as IMI, the Institut für Medizinische Informatik, Statistik und Dokumentation) is the strong orientation towards clinical applications in our research. This is due in part to historical reasons because IMI has its origins in a section for medical informatics within the Department of Radiology, and in part to its position within the faculty where it is a department of both the university and the university hospital. The IMI has a double role: as a department of the hospital it was and is responsible for the implementation and operation of information systems for routine patient care, and, as part of the university it is responsible for research and teaching. It is a logical step to combine these duties and to focus research on both the development and the analysis and evaluation of clinical applications of medical informatics. This analysis includes the conditions which must be fulfilled to introduce information systems successfully and safely into clinical practice, anticipating and preventing undesired side-effects. This paper concentrates on the research and systems in medical informatics, omitting our research in statistics. Our concept of medical informatics is defined in [1].

Our "mission" is the objective of medical informatics as defined by Hasman and Haux in [2]: " . . . to assure and to improve the quality of health care as well as the quality of research and education in medicine and in the health sciences". The focus on improving the quality of healthcare requires an effective and efficient use of our limited resources and a careful selection of topics to maximize the impact on patient care.

The boundary between scientific and applied medical informatics is fuzzy and changing with time. Thirty years ago, almost any application of electronic data processing in medicine was a scientific project whereas today many applications are commercial developments or developments by domain experts.

2. Historical Summary

Following the installation of a UNIVAC 490 mainframe at a computer center for the universities and the industry in Graz in 1965, and the installation of a PDP 15 computer in the Department of Radiology in 1970, several medical projects were initiated: notably, a project of the Department of Pathology to develop a system for the automatic indexing of natural text of histology reports with SNOP codes (Systematized Nomenclature of Pathology, the precursor of SNOMED), and many projects in radiology.

Radiology is a technology-oriented discipline within medicine and the importance of computer applications in this field grew rapidly. In consequence, medical informatics (although this name was to appear only later) became a recognized organizational entity within the Department of Radiology providing a range of services not only for radiology and pathology but also for other clinical departments. In 1989 the section became an independent Department of Medical Informatics where duties comprise research and education and, in cooperation with the informatics services of the hospital association, the planning of infrastructure and the planning and implementation of clinical IT projects. Our research projects and clinical developments include, amongst others: quantitative modeling in nuclear medicine [3], computer-assisted radiotherapy [3-8], clinical information systems [9-14], PACS [14-17], image processing [18], and computer-assisted diagnosis [19,20].

A constant feature of the steady evolution from a one-man workshop in radiology to a department of medical informatics was the interest in supporting clinical practice. The final measure for the success of a concept was support for and acceptance in clinical practice. This led to an interest in the conditions of acceptance, and success and failure of medical information systems. In the following some research topics of IMI are presented - they will also be used to discuss general conceptions of and developments in medical informatics.

3. Medical Informatics, Domain Experts, Industry: the Development of Computer-Assisted Radiotherapy

In 1970 the Department of Radiology had one cobalt unit for therapeutical irradiation. The set-up of radiation therapy with the positioning of irradiation fields was largely based on experience and only rarely checked by tedious manual calculations with the aid of published dose distributions. This was a clear case where computerization would improve the quality of healthcare and, consequently, a computer program for the calculation of dose distributions for individual patient contours and arbitrary beam positions was developed and introduced into clinical practice [3]. Despite its cumbersome nature the program was used for every patient, since the advantages were obvious. Knowing the exact dose distribution and being able to detect unexpected hot spots in sensitive tissues that could result in severe damage or underdosing in target areas, possibly leading to incomplete deletion of tumor cells, was considered of vital interest. The program was subsequently adapted to advances in computer technology, radiation therapy and diagnostic imaging. The system in Graz was one of the first (if not the first) to overlay CT cross-sections with dose distributions [6,7], to combine doses from endotherapy and teletherapy [4], to calculate three-dimensional dose distributions from beams at arbitrary positions in space (non-coplanar) [8] etc., thus advancing the scientific state of the art and considerably improving the quality of patient care in our hospital.

On the other hand, despite a well-designed modular structure, the program became increasingly complex and difficult to maintain while, at the same time, some effective planning systems were developed and marketed by industry. With the introduction of linear accelerators and the installation of a unit for radiation physics it was decided to purchase a commercial system and to transfer the responsibility to domain experts, i.e. the radiation physicists.

This development is typical: when new informatics technology appears, its application to medicine often requires in-depth informatics knowledge. Therefore, these applications are developed either by informaticians who are (or cooperate closely with) domain experts, or by domain experts (e.g. physicists, physicians) who also have to become informatics experts. When the technology becomes a viable tool, its application shifts to the domain experts in universities or in industry and away from the field of medical informatics.

4. Natural Language Based Documentation Systems

Pathology, histology and radiology are diagnostic disciplines with a high volume workload. For example, in a study on the detection of microcalcifications under conditions that simulate rapid interpretation of screening mammograms, radiologists were given 5 seconds (!) per case for film reading [21]. This is an extreme example, but clearly shows that the task of film reading (or interpretation of histologic slides), reporting and report typing must be streamlined and additional workload in any step needs excellent reasons to be accepted. In the late 1960s, a discussion started (continuing until today) on how to integrate documentation into routine operation such that no additional work is needed, or such that additional work is compensated for by other advantages. There are two main approaches:

- Radiologists/pathologists code during diagnostic interpretation and the reports are generated automatically, avoiding dictation and typing and providing an unambiguous, computer process-able documentation.
- Radiologists/pathologists dictate reports in natural language, the typing is done on computers and the texts are used for retrieval or automatic indexing.

Our reasons to choose the second approach are twofold:

- We could not conceive any means to enter codes in a way that did not disturb the workflow of conventional reporting, where during dictation, the pathologist looks into the microscope and the radiologist at the X-ray images.

- Codes or any kind of fully standardized description of findings and diagnoses with a systematic but shallow structure are adapted for computer processing while the deep and complex structure of natural language is adapted to human communication and human understanding. Codes reduce the possibility of expressing the state of a patient to a finite and (usually) small set, compared with the flexibility of natural language; codes may even restrict the way a clinician thinks about patients. Coding means classification, i.e. putting similar things in one class regardless of individual differences. This classification process is necessary for scientific work, but is inadequate as a basis for individual patient care. Therefore, we felt that coding (i.e. standardized input) is potentially harmful if it serves as the basis for human communication and, according to the old principle "primum non nocere" we did not try to replace natural language dictation of findings and diagnoses by more standardized means.

This does not preclude, of course, the use of codes, where a set of discrete states actually exists, e.g. the type of examination, the referring ward etc. that are standardized.

We therefore started a project to implement automatic indexing from free text to SNOP (Systematic Nomenclature of Pathology) and to a local radiology code. In pathology for example, a comprehensive thesaurus with over 60,000 entries was constructed for the indexing of histology findings [9]. Despite some success, the approach towards automatic indexing was eventually abandoned in favor of a simple search for words in the reports, where the handling of synonyms, homonyms, negations, etc. was the responsibility of the user. The reasons for this still apply:

- Automatic indexing did not reach the desired quality, because natural language has such a rich structure (far from being unstructured) that a complete, automatic semantic and syntactic analysis by computer was impossible (and, we suspect, is still so).
- A medical indexing system is never finished; new words and constructs constantly generated from reports and have to be classified and inserted into the system. This work requires medical experts and created a sense of dissatisfaction that led to a rejection of the whole system. When we decided to discontinue the thesaurus and chose for simple text search, acceptance was immediate.

These and other experiences led to a principle: if an informatics application is to be accepted by users (and cannot be enforced) it must serve (or at least not hinder) the primary goal of those users. Radiologists do not accept additional work for coding while dictating reports, because data retrieval is not the primary goal of reporting.

The development efforts were redirected to build a system (called AURA) to support each user in attaining their primary goals. Medical routine documentation is not a primary goal (unless one employs medical documentalists) and was therefore implemented as a byproduct of the normal reporting and typing process, where typewriters were replaced by computer terminals. Details of this system that eventually evolved into a complete RIS are described below. Here, we are concerned with the use of natural language for scientific retrieval and routine documentation of findings and diagnoses.

What is the value of simple free text retrieval as a tool for scientific work? We are addressing "retrospective" research, not prospective studies where the hypotheses and data are known in advance and therefore should be standardized. Both pathology and radiology rely on the interpretation of visual input and almost all studies in these disciplines are based on a reinterpretation of the primary data (e.g. histological slides, X-ray films or CT/MR cross-sections, etc.) in the light of a new hypothesis. The same applies to other clinical disciplines: research is usually based on human (re)interpretation of the original data in the patient record. The support of an information system consists in the selection of relevant cases and availability of the images. In the search for relevant cases, the main priority is usually high sensitivity, because the user does not want to miss any interesting case. Low specificity is less of an issue because the effort to discard unspecific cases is small compared with the time needed for data interpretation. In our experience, free text search is well suited to attain high sensitivity at the expense of specificity, if the user carefully formulates the retrieval terms and refines the formulation based on retrieval results, taking into account synonyms, dictating habits, etc. When the user undertakes a study, the primary goal in formulating a retrieval request is an appropriate selection of cases. We have shown, that retrieval results were as good or even better than retrieval using codes, when codes were produced in an additional step after dictation [11]. The system has since become the basis for case finding beyond radiology and pathology and is used daily for scientific retrievals.

We still hope that, eventually, viable systems for automatic indexing of natural language texts will appear. However, our experiences and the literature have convinced us that developing such a system for routine clinical use is an enormous task that must be tackled in large, cooperative and coordinated projects.

5. AURA Departmental Systems (RIS/PIS/PACS): Tools for Medicine

Our main efforts were shifted to the development of a comprehensive information system that supports all aspects of departmental operation. There were two main causes for this shift:

- Complete medical data for scientific research can only be acquired as a byproduct of an information system that serves routine operation
- Improvement of patient care was served most efficiently and effectively by optimizing routine operation providing the necessary information for patient care (rather than by putting resources into one particular aspect of information systems, e.g., automatic indexing).

In our RIS and PIS (Pathology Information System) almost every step of the workflow is computer assisted: scheduling, patient admission (with linkage to the HIS), examination, worklist, documentation, exchange of data with modalities, routing of patients, reporting, transcription, billing, workload statistics, e-mailing of reports, etc.

The guiding principle for the introduction of each module was to serve the overall goals of improving patient care and to provide a positive cost/benefit balance for each user, providing the tools to perform work more efficiently and minimizing boring tasks. An important feature is adaptation to the workflow, in particular to "microworkflow". If a user interacts with the system to perform a task or a series of tasks, the system should anticipate the most likely course, the most likely data, etc. and enable the user to complete the task with a minimum of interactions. However, the user must always be able to select a different course, if an exception occurs.

With the increasing importance of digital images (e.g.,CT, MR, US) in radiology, the addition of images to our radiological information system became a logical extension. In 1985 we started a cooperation with Siemens to develop a PACS (Picture Archiving and Communication System) pilot [15]. During this cooperation many new concepts have been developed and implemented, including the folder structure of images, features of user interfaces, the coupling of RIS and PACS, etc.

The impact of PACS reaches beyond radiology. Images are distributed hospital wide for viewing by clinicians and as a basis for secondary applications, e.g. surgical navigation, 3D-models for maxillofacial surgery, virtual endoscopy, radiotherapy planning and others. The existence of an infrastructure for image communication has initiated a multitude of clinical applications and research projects .

The RIS and the PACS are now in operation in all state-owned hospitals in Styria with a department of radiology or pathology. All physicians can access (in seconds) the results of previous radiological or histological examinations (wherever performed). Data are available for research and for administrative and managerial tasks such as the planning of new resources, etc.

6. Integration of Decentralized Information Systems

Although successful, our developments in the PIS/RIS/PACS domain were more or less standalone systems. In the late 1980s there was an emerging demand to interface these applications with newly installed administrative and departmental information systems. At the same time the problem of integrating decentralized information systems had been recognized in the field of medical informatics and motivated the development of standardized protocols for the electronic exchange of medical data. However, it quickly became clear that the "integrative force" of these specifications was not sufficient to provide for "plug and play" interoperability and functional extensions were necessary to fulfil our requirements for flexibility and adaptability to local constraints. In this context the introduction of message engines (an HL7-based middleware, also called communication server) was important [22,23]; this allows the separation of the application functionality from the respective message flow, thereby generating a loosely coupled overall system.

The World Wide Web and Internet technologies raised interesting points regarding the integration of medical information systems. Specifically, the document-oriented architecture of the Web, its intuitive user interface, and the availability of browsers on all major platforms are features which support the cost-efficient development of distributed medical records. The Web simplifies access to individual information systems; however, the integration achieved is mainly at the presentational level with no essential advantages for inter-application data exchange. To achieve application level integration we decided to use distributed object technologies (e.g. CORBA, DCOM) to develop a document-based framework. The framework, which utilizes a Web browser for presentation purposes, subsequently was used to implement an experimental reporting system for the pathology and radiology department. As a spinoff, a statistical reporting tool for the analysis of operational data (utilization of individual modalities, types of examinations, used materials, etc.) has been in routine use since 1997. Our recent work in this area covers the application of CORBAmed compliant components and XML for semistructured medical documents.

7. Professional Responsibility in Medical Informatics

Our interest in the field of professional responsibility had been triggered by concrete experiences:

A program that was used to determine renal function by replacing one-to-one a manual method to characterize measurement data was in successful operation for years, when it turned out that results had become unreliable and possibly harmful. On analysis it was found that new physicians in nuclear medicine were unaware of the underlying algorithms; they were no longer able to check the plausibility of results from simple visual inspection of the measurement data. Further, a feature intended to allow radiographers to manually correct artefacts resulting from the unreliable data transmission had been used to "correct" incorrect examinations, where target organs had been moved out of the viewing regions of the collimators, yielding wrong and possibly dangerous values. From the point of view of traditional engineering, there was no fault on the side of medical informatics: a correct program had been delivered and tested according to specifications - its later misuse was not our responsibility. Nonetheless, we felt some responsibility for the negative side-effects and thus, ethical questions became a matter of concern and analysis [24].

We try to check all our own developments for negative side-effects and there are successful programs that were never put into clinical operation because we could not exclude the possibility of harmful results (e.g. predicting lethal outcome after severe head injury [25]). To counter negative side-effects we also engage in policy setting, normative work and education for data protection, telemedicine etc. on the local, national, and international level.

We summarize our views on professional responsibility as follows [2]:

- Any data processing system or application in medicine must aim to contribute, directly or indirectly, to the quality of patient care or, at least, must not decrease the quality of patient care.
- The system must conform to the state of the art concerning security, reliability, etc.
- Before introducing a system possible negative effects must be analyzed. They may be caused by intentional or accidental misuse or by systemic effects where, finally, the system has a negative influence on patient care
- The clinical use of data processing systems must be monitored to evaluate the results, not only the intended outcome but also unexpected effects.

Examples of possible systemic effects are changes in human communication caused by standardized data as discussed above, or changes in clinical practice due to indiscriminate distribution of radiological images without a radiologist's interpretation.

8. Outlook

Informatics and medical informatics are changing constantly and institutions have to change accordingly. Our responsibilities within the hospital will change; systems with a strong research aspect will become products for routine operation and maintenance and therefore move into the responsibility of the hospital IT, and new challenges will appear. Our mission remains to improve the quality of healthcare and to use our resources efficiently to this end. Medium-term goals are to evaluate the effects of the introduction of a new HIS, the development of concepts to integrate the HIS with the inevitable specialized and legacy systems, the implementation of tools - when needed - to put the data within the HIS to the best use for patient care, research and teaching. The teaching of medical informatics and statistics will have a greater impact with new curricula, that we are active in shaping. And, last but not least, we need to asses the impact, positive or negative, of IT systems on the medical field.

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