MEDINFO 98
B. Cesnik et al. (Eds)
Amsterdam: IOS Press

Vision of an 'automated' hospital information system

László Balkányi MD PhD, Géza Lakner MD

Dept. of Medical Informatics, HIETE University of Health Sciences, Hungary Budapest

Abstract

This paper tries to describe a coherent vision of a possible next generation of HIS that rethinks how and what for computing is used in hospitals. Current systems, organized mainly around the `database` and the `communication` paradigm help the data processing to a great extent. At the same time they cannot be accepted as 'automated' systems, as handling of information is done mostly by end- users, i e. by human actors. Emerging methods enabling automated information handling are the following: integrated handling of different media, seamless communication among different systems, alternative input-output devices, tools for pro-active information handling These technologies should be grouped to two main branches: technical advances in data handling and theoretical advances in knowledge handling. The advances in knowledge handling are really important: tools based on that can take over routine information handling tasks from human end users. To discuss automation in HIS it is useful to understand the process of information handling in general within the hospital. A suggested multidimensional information space, where information objects are gathered mainly along two axes, the 'patient axis' and the 'management' axis might be of help. Combinations of selected dimensions resulted in a space of an estimated 2294082 possible information handling situation types in an earlier publication. Automation of information handling tasks can be derived from this model. The authors suggest to automate certain tasks done usually by active actors of the information handling situation space. Software agents working 'on their own' are known entities in HIS systems. Two components are needed for automation:

- *an organized data base where its content can be 'understood' and interpreted by an algorithm, with other words a knowledge base*
- *an algorithm, that covers a certain routine information handling task.*

Data bases of HIS should be re-thought in a way that enables automated processing to a greater extent. The development of data base technologies clearly point to this direction. If most of the data bases of a HIS will be like that, new generation of applications might be launched to use them. E.g. a software agent called 'patient assistant' could collect data from different sources and build a coherent and updated patient file. The results of a knowledge based, agent operated HIS should be the following:

- *significantly less direct human involvement*
- *significantly less paper to be produced*
- *enhanced speed of data flow in general*
- *enhanced reliability by widespread watchdog functions*

Keywords

automation, HIS, software agents, knowledge base, information space

Introduction

Development of Hospital Information Systems (HIS) is usually a time consuming, tedious process. Further on, life cycles of HIS systems are unusually long compared to that of systems in the business world. Among the different reasons for this phenomenon might be mentioned the need for continuous operation and data security together with scarce financial resources in respect of worldwide cuts in health care budgets [1]. This situation results often in keeping old-fashioned but reliable hardware and software solutions in their well deserved positions. At the same time promising new technologies appear day by day on the market.

This paper will describe a coherent vision of a possible next generation of HIS that is logically-structurally different from the usual market-driven pull thus tries to rethink how and what for computing is used in hospitals.

Firms selling HIS systems usually try to sell more and more advanced hardware and networking technology and more and more functions realized by software modules that cover up the paper based documentation process of hospital work. Systems are organized mainly according the traditional `database` paradigm, collecting data from different sources and answering typified queries for processed batches of these data. The use of `communication` paradigm is also present, advanced HIS systems facilitate communication among health care actors in the hospital by workgroup-oriented messaging services. Although

these systems do help the data processing to a great extent, they cannot be accepted as 'automated' systems, as coordination of the information processing is done mostly by users, i e. "by hand".

Emerging new technologies allow the redesign of HIS systems, where routine information handling is in fact automated.

Methods

Which are the key methodologies in data handling that enable automated data processing?

Among the most important methods the following can be pointed out:

- integrated handling of different media (i.e., multimedia, hypermedia)
- seamless communication among different systems TCP/IP)
- alternative input - output devices, including virtual reality
- emerging medical knowledge representation methods (i.e. GALEN)
- tools for pro-active information handling (artificial intelligence tolls - logical programming, i.e. LISP, PROLOG, push technologies, know-bots, web-crawler type tools and others)

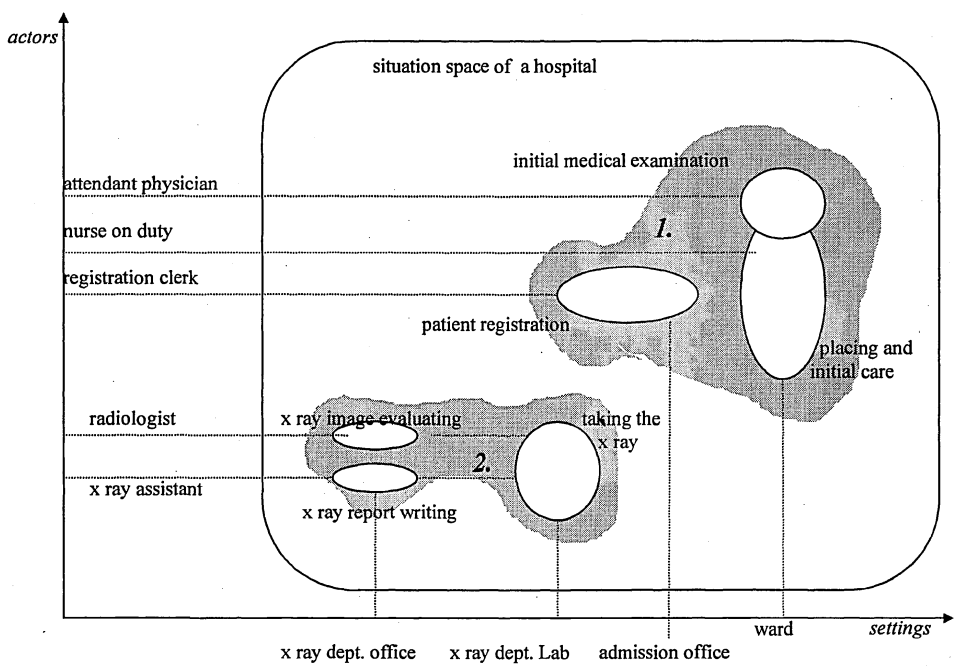
While realizing new level of automation, the technologies mentioned above should be grouped to two main branches: advances *in data handling* as multimedia and seamless communication and advances *in knowledge handling* as GALEN.

While advances in data handling are a condition for automated hospital information systems, the advances in knowledge handling are the real thing: such tools enable to take over routine information handling tasks from human end users. In the following influence of these technologies are discussed in detail.

Discussion

- discussing automation of HIS in general

To discuss possible automation in HIS at first it is useful to understand the process of information handling in general within the hospital. Authors in a previous publication [2] suggested a multidimensional information space (see fig.1.), where information objects are gathered mainly along two axes, the 'patient axis' and the 'management' axis. #The information space of a hospital in which different information handling events are happening is a vast area with a lot of objects. Authors in another publications [3] tried to measure the size of this space and the possible number objects in this space. The hospital information space was assessed as a multidimensional space of which different projections can be studied. The 'situation space' projection grabs the environmental factors of information handling actions in the general information space. Using the emerging standards [4] for health care information handling



grey area no. 1. shows the procedure of admission built from three situations
grey area no. 2. shows the procedure of an x ray examination built from three situations

Figure 1 - Information space of situations in a hospital

the following dimensions were defined and assessed quantitatively: *activity areas* (e.g.: patient data management or nursing), *actors* (e.g.: nurse, department clerk) and *settings* (e.g.: admission office, or x-ray laboratory). Other dimensions as *time*, *channels* and *containers* of information handling were also analyzed. Combinations of selected (actual hardware and software platform independent) dimensions resulted in a space of an estimated 2294082 possible information handling situation types. Of course most of this situation space is empty, but even if 1 % of these possible situations are realized, the HIS will have to deal with several tens of thousand information handling situations. .

Automation of information processing tasks can be derived form this model. The authors suggest to automate certain tasks done usually by active (human) actors of the information handling situation space. Software agent working 'on their own' are known entities in HIS systems. For example watchdog expert systems control the medication prescription in the HELP HIS in the LDS hospital in Salt Lake City. Let us analyze what enables such a quasi autonomous operation of a software agent. In case of medication most of the related data are easy to interpret. Names of drugs and their doses, side effects, interactions are relatively straightforward, easy to formalize part of medical knowledge. Because of the large number of possible ingredients and their combination indeed it is by far not a trivial task to build a software application that reliably controls prescription. This successful application shows the two components essential for successful automation:

- an organized data base of which the content can be 'understood' and interpreted by an algorithm, with other words a knowledge base
- an algorithm, that covers a certain routine information processing task.

These components are well known from expert system and decision support system research. Most of these systems however were and are aimed to support medical thinking and decision making with limited success. We suggest a different approach with an even more limited but pragmatic goal:

- data bases and knowledge bases for HIS automation

Data bases of HIS should be re-thought and rebuild in a way that enables automated processing to a greater extent. For example the medical record has to be build from parts that follow the logic of medical work and its content should be formalized. In a previous publication [5] authors described a prototype electronic medical record, that is built from SNOMED terms by PROLOG statements and is generated by an active query interface collecting medical history, signs and symptoms, creating 'problem lines' that are in fact working diagnoses. Rules of the knowledge base enable automatic generation of queries for laboratory tests, i.e. a patient with a recent history of diabetes mellitus type I will be offered a blood glucose test upon entering the hospital in case of any medical emergency.

The same type of data bases for managerial tasks i.e. different stocks or human resources allocation might be built. The core idea is to build these data bases according to the logic of their usage. The development of data base technologies clearly point to this direction: from simple, flat databases, complex relational databases to object oriented design more and more 'knowledge' is built into the data structure itself, facilitating the application of intelligent query technologies.

- agents for HIS automation

If most of the data bases of a HIS will be like that, new generation of applications might be launched to use them. A software agent called 'patient assistant' could collect data from different sources and build a coherent and updated patient file. Other agents for example 'radiology clerk assistant' could collect radiology investigation queries and build a working schedule for the radiology department, leaving only exceptional or emergency cases to the human interaction. The software agent 'physician's assistant' could actively screen the HIS database for its' master's patients for critical data and so on. The above mentioned agent ideas are just a few examples

Following the systematic approach of the information space idea mentioned in [2], it is possible to group these agents into the following scheme:

- input agents that seek data in the databases of the HIS
- processing agents that process or convert data from one of the databases of HIS to others without direct human interaction.
- output agents that present processed data for users, again in some cases (i.e. emergency) without specific request.

Different input agents are required for collecting data from machine and human 'interfaces'. More and more diagnostic equipment like laboratory automata, ultrasound and other imaging tools have their built-in data collecting and processing facilities. On-line data exchange is already widely practiced from these sources. This concept can be extended to organized collection and redistribution of data filtered through a knowledge base, that interprets them e.g. by checking inconsistencies. In the management area automated input is enabled by advanced logistic systems using different product identification techniques. Another type of input agents should collect medical or health care related data from unqualified sources e.g. from the patient or his/her relatives in form of the already mentioned intelligent queries. Input agents should be able to reach data beyond the limits of the hospital. E.g. a web-crawler type agent could collect data for the physician related to a specific case. Processing agents should collect related data defined by their own background knowledge base form different databases of the HIS. For example an agent could compare continuously the operating theater schedule with predicted availability of human resources. Watchdogs of several types can monitor data flow and give pre-emergency notes to HIS users. The amount of stocked materials can be reduced that way, as because of security reasons these stocks usually exceed that of the usual in the business world. Output agents scanning continuously the HIS databases can produce regular reports without much human interaction. Human users could configure their personal software agents for their specific goals i.e. in a teaching hospital for a scientific survey.

Further on agents of a HIS can interact not only with HIS data bases but with each other as well. Such interactions as e.g.

checking availability for consultations among specialists, or finding answers for a frequently asked question in Internet FAQ style might also reduce the direct involvement of human users.

Results

The results of a knowledge based, agent operated HIS should be the following:

- significantly less direct human involvement
- significantly less paper to be produced
- enhanced speed of data flow in general
- enhanced reliability by wide spread watchdog functions

The extent of this vision paper does not allow detailed analysis of a possible future HIS system. We hope that the ideas will trigger discussions leading to better systems.

References

[1] A. van der Werff, FM Ferrara, G. Mobilia: *European Distributed Information technology for Healthcare,* Technology and Informtics Vol. 34. MIE 96, Ed.: J brender, J.P. Christensen, J.-R. Scherrer, P. McNair, IOS press Amsterdam,1996

[2] Balkáyi, L., Lodder, H.: *Information Flow in the Hospital: A comparative Study of the Hungarian and the Dutch Situation Using a Two Axes Model of Hospital Information Flow,* Journal of Medical Systems Vol. 16. no. 4. pp 129-143, 1992.

[3] Balkáyi, L: *Explorations on the Nature of Medical Information.* Ed.:Printz Nyomdaipari Kft, 1966, Budapest

[4] *Settings the standards for Healthcare Informatics and Telematics* CEN TC 251 brochure, ed.:Georges De Moor, F-TWEE Editors Gent, Belgium, 1995.

[5] Balkáyi, L., Molnár, K., Farkas Zs, et al.: *Knowledge-based Electronic Medical Record,* Technology and Informtics Vol. 34. MIE 96, Ed.: J brender, J.P. Christensen, J.-R. Scherrer, P. McNair, IOS press Amsterdam,1996