

A WEB-BASED SYSTEM TO REDUCE THE NOSOCOMIAL INFECTION IMPACT IN HEALTHCARE UNITS

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Abstract: The nosocomial infection has a critical impact on the mortality and morbidity of the patients in healthcare units, especially in intensive care units, and has been studied in order to be mitigated. The registration of information about this phenomenon in databases is, more and more, a reality, turning viable the representation of this information through mathematical formalisms that, conjugated with the application of Artificial Intelligence techniques, will allow the discovery of knowledge related with the critical factors, processes and infectious agents. The ultimate goal has been to construct a web-based computational tool to automate the registration process to support the clinical body work, monitoring the performance and identifying the procedures that can be implemented in order to reduce the impact of the infections.

1 INTRODUCTION

Medicine has been for some years a very attractive domain for Computer Science (CS) researchers, in general. There is a great potential for information automation, and a lot remains to be done. Medical Informatics (MI) is indeed an issue of study in which Medicine and Computing overlap. Another reason for this increasing interest was costs. Today's strained health-care economics makes it necessary for expensive resources to be efficiently managed. CS researchers have long used Medicine to elaborate on their own work. The field is probably one of the most knowledge intensive ones, loaded with human reasoning, with most of the procedure relying exclusively on the clinical experts. This makes health-care a perfect target for CS, since conventional systems are naturally bounded by their lack of rich knowledge representation and proof schemes. On the other hand, MI Systems have to be addressed in terms of a wide variety of heterogeneous distributed systems speaking different languages, integrating medical equipment and customized by several companies, which in turn were developed by people aiming at different goals. This lead us to consider the solution to a particular problem, to be part of an integration process of

different sources of information, using different protocols, in terms of an Agency for the Integration, Diffusion and Archive (AIDA) (Figure 1) of medical information, and the Electronic Medical Record (EMR) software (in Portuguese referred as PCE - Processo Clínico Electrónico), bringing to the healthcare arena new methodologies for problem solving, computational models, technologies and tools, using ambient intelligence (Removed for blind review). The homogeneity of clinical, medical and administrative systems is not possible due to financial and technical restrictions, as well as functional needs. The solution is to integrate, diffuse and archive this information under a dynamic framework, in order to share this knowledge with every information system that needs it. Indeed, to build systems for real health care environments, the infrastructure must meet a range of basic requirements with respect to security, reliability and scaling. With access granted to Clinical and Historical Databases, agent technology may provide answers to those who give assistance to patients with a maximum of quality and medical evidence (Maes, 1995).



Figure 1: AIDA.

2 AGENT ORIENTED PROGRAMMING

The traditional programming languages do not support the description of certain types of behaviour which usually involves computational agents (Weiss, 1999). In genesis, systems that incorporate those functionalities have a multi-layer architecture, evolve from esoteric software sub-systems, network protocols, and the like. An agent must be able to manage its knowledge, beliefs, desires, intentions, goals and values ((Analide et al., 2006)). It may be able also to plan, receive information or instructions, or react to environment stimulus. It may communicate with others agents, share knowledge and beliefs, and respond to other agents upon request. It may cooperate for diagnosing errors or information faults in its knowledge bases, sharing resources, avoiding undesirable interferences or joining efforts in order to revisit the knowledge bases of its own and of its peers, in order to reach common goals (Machado et al. 2006). Agents exchange messages which are well-formed formulae of the communication language, performing acts or communicative actions ((Bradshaw, 1997)). Agents in a healthcare facility configure applications or utilities that collect information about the assets in the organization ((Alves et al., 2005)). Once that information has been collected it can be posted directly to other entities (e.g. a physician), a server, saved to a file, emailed to someone to be handled at a later date or sent using HL7 (Health Level 7) (<http://www.hl7.org>). Indeed, in a hospital, the collection of vast amounts of medical data will not only support the requirements of archiving, but also provide a platform for the application of data mining and knowledge discovery techniques to determine possible medical trends and the real data to support educational training. Knowledge discovery techniques can be applied to identify pathologies and disease trends. The data can also be used for educational and training purposes; unique cases can be identified and used to advise practitioners. This may lead to one's goal of Ambient Intelligence at Health Care

Units at our doorstep (Costa et al., 2007) (Abelha et al., 2007). HL7 plays an essential role in extending the interoperability for the development of health information exchange, in the standardization of XML medical document structures and in the specification of robust vocabulary definitions for use in clinical messages and documents (e.g. SNOMED CT) (<http://www.ihtsdo.org/>) enabling functional specifications for the EMR.

3 THE ELECTRONIC MEDICAL RECORD

The Electronic Medical Record (EMR) is a core application which covers horizontally the health care unit and makes possible a transverse analysis of medical records along the services, units or treated pathologies, bringing to the healthcare arena new methodologies for problem solving, computational models, technologies and tools. One aims to develop a comprehensive, structured approach to EMR development and analysis. Indeed, this paper will thrash out the inner features of intelligent agents to be used in the EMR, in the context of the Telemedical Information Society, a step in the direction of Intelligent Health Care Units ((Hendler, 1996)). The process to collect data comes from Problem Oriented Medical Record (POMR) method ((Weed, 1969)). This is a format for clinical recording consisting of a problem list, a database including the patient history with physical examination and clinical findings, diagnostic, therapeutic and educational plans ((Machado and Alves, 2005) and a daily SOAP (Subjective, Objective, Assessment and Plan) progress note ((of Medicine, 1991)). The problem list serves as an index for the reader, each problem being followed through until resolution. This system widely influences note keeping by recognizing the five different phases of the decision making process, i.e. data collection, problem specification, devising a management plan, reviewing the situation and revising the plan if necessary. One's goal is to replace hard documents by electronic ones, increasing data processing and reducing time and costs. The patient assistance will be more effective, faster and the quality of service will be improved ((Machado et al., 2006)). The system uses freeware tools or software database packages which licenses belong to the Portuguese Health Ministry (e.g. Oracle software). Messages are sent by agents using XML or HL7. According to the ontology, messages are processed, integrated and archived in large databases. The ontology is defined by the administrators and can be managed using web tools. The "intelli-

gence” of the system as a whole arises from the interactions among all the system’s components. The interfaces are based on Web-related front-ends, querying or managing the data warehouse. Such an approach can provide decision support. A context dependent formalism has been used to specify the AIDA system incorporating facilities such as abstraction, encapsulation and hierarchy, in order to define the system components or agents; the socialization process, at the agent level and the multi-agent level, following other possible way of aggregation and cooperation; the coordination procedure at the agent level; and the global system behaviour. The data can also be used for educational and training purposes because maybe one of the unique cases can be identified and used in expert system like applications to advise practitioners ((Analide et al., 2006)). An screen view is shown in Figure 2.



Figure 2: Procedure Registration in the EMR.

4 A WEB-BASED SYSTEM FOR THE NOSOCOMIAL INFECTION REGISTRATION

Despite the advancements in the area of the health care, every year around one hundred thousand patients contract an infection at the hospital environment and more than ten thousand die in consequence of these infections. Beyond the morbidity and considerable mortality, the hospital infection provokes a considerable increase of costs with trials of diagnosis, of therapy and with the increase of the time of hospital admission.

The hospital or nosocomial infection is an infection that is not present at the moment of patient admission to the hospital. It can be provoked by internal or external agents to the patient. Some of the factors that prepare a patient to the development of a nosocomial infection are directly related with the age, the state of his immunity, the use of antibiotherapy, the time of hospitalization, the techniques of diagnosis, among

others. The dynamics and the hospital environment provide, on the other hand, diverse potential foci of infection as the patients, the visits, the personnels, the equipment, the installations, the environment, the invasive devices, etc. All these factors are potentiated when the patients are at Intensive Care Units, where the problem of the nosocomial infection has the greatest impact inside the Hospital environment.

The existence of scientific studies and guidelines, such as norms to control the infection and consensus for the diagnosis and handling of the infection, contribute for a deeper understanding and diffusion of the phenomena associated with the infections, in terms of its prevention, diagnosis and handling. However, despite such advancements, an efficient diagnosis on time, as well as the decision about the handling or therapeutic, is in itself based on the empirical knowledge of each professional of health. Frequently, the inherent information concerned with the process is not analyzed, and the results are not registered in systematized and adequate formats to a future processing. The monitorization assumes, therefore, an important role in the course of this trial, once it would permit to collect helpful and valid information for the creation of models to support the diagnosis and the medical decision process.

In the area of the Clinical Information Systems, we must highlight the EMR and the Laboratory Information System, as part of the platform AIDA that is today a reality within the Hospital Geral de Santo António (HGSA), that has acted in collaboration with the University of the Minho. It makes possible to collect in real time data from laboratory trials, patient and clinical information (e.g., medical images).

The making of data or knowledge bases with laboratory and clinical information, enabled with AIDA, complemented with information about the diagnosis and the trial decisions, allow for the Knowledge Discovery and Data Mining techniques in use, leading to the induction of formal models more adjusted to the patient profiles, and to the admission context.

5 THE IMPLEMENTATION

5.1 Preamble

The implementation plan of the registration system for infection control in HGSA’s Intensive Care Unit (ICU), emerged from the necessity of such unit of monitoring and accessing quality of health care provided. In order to accomplish the proposed task, it was fundamental to acquire specific knowledge related with epidemiologic vigilance. Since there was

no institutionalized pattern for structuring the registry form, operational parameters selection was performed in three separate ways:

- Discussion sessions with the ICU clinical team;
- Bibliographic research;
- Operational "catch up" with similar initiatives in other clinical facilities.

Since HGSA is also engaged in taking part in Helics III project (see <http://helics.univ-lyon1.fr/aboutHELICSIII.htm>), it was of major importance to maintain the compatibility between the selected terminologies. The unique symbiosis provided by the conceptual approach behind the EMR at HGSA, granted enormous easiness in implementing the referred system. It utilizes XML as an integration media, built on top of a relational database. This way, realization itself was not the hardest task. It uses a simple xml skeleton which contains specific formatting parameters to be interpreted by an external application or viewer. Different combinations of GUI Widgets can be used like combo and check boxes, labels, text fields, etc. This provided unique flexibility to the structure, while still maintaining a familiar user interface for the clinician. Such approach has also allowed restricting possible choice values, enabling data uniformity and, consequently, the accurate storage methodology in order to offer useful or meaningful information for comparative and statistical studies.

Due to the extent of the covered clinical parameters, it was decided to divide the main structure into two separate systems:

- The General Record;
- The MRB (Multiresistant bacteria) Individual Record.

5.2 General Record for the NI Control

As the system was planned in order to follow patient's ICU internment, record field line up and arrangement were chosen following clinician's own registry order. The first part of the registry contains information related with patient's internment like origin, possibility of infection's presence already at admission, previous hospitalization, antibiotic therapy, etc. All data already registered and available through EMR is automatically retrieved as a mean to avoid information redundancy.

As described above, there was constantly the concern to reduce record subjectivity to a minimum, restraining, when feasible, the clinical registry to a defined set of possible values.

The second part of the form covers clinical arguments that are registered during the first days of internment like the SAPS II ((Gall et al., 1993)) and Glasgow indexes, immunodepression subsistence, trauma, etc. Lastly, the rest of the structure accounts for controlling the use of invasive devices (intubation, central venous catheter, urinary catheter) and incidence of infection. In addition to the usual recording of first device application, the structure can store sequent similar procedures for future data mining analysis. It also previews simple colonization recording. In terms of infection, the main sites have been covered (urinary infections, surgical site infections, nosocomial pneumonia and nosocomial bacteraemia). All intermediary registries for each infection were parameterized under Helics III specifications so that maximum compatibility could be provided, foreseeing data sharing with European common database initiative (Helics III) (Figure 3).

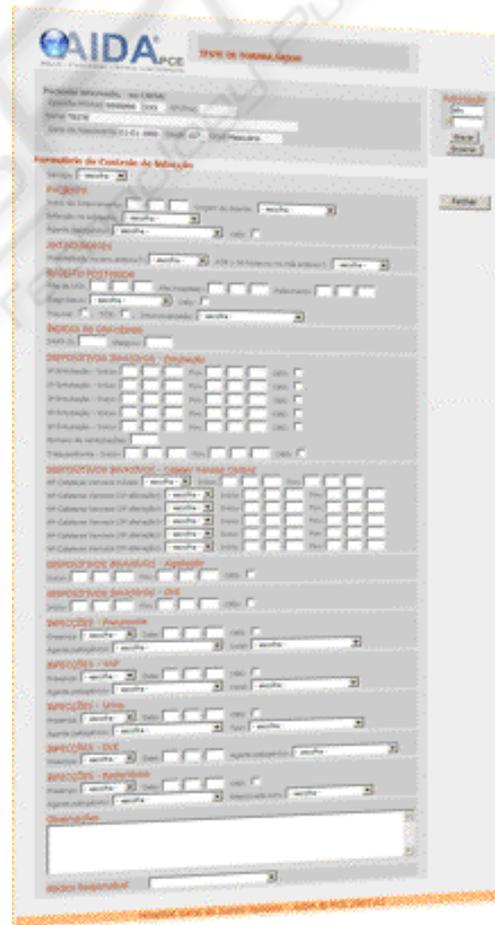


Figure 3: General Record for the NI control.

5.3 The Registry for MRB Control

Antibiotic resistance stands for the ability of a microorganism to withstand the effects of an antibiotic. This is recurrently accomplished via natural selection through random mutation and can be hastened by a deficient politic for antibiotic usage. In order to minimize this serious issue, an electronic record form was created so that antibiotic resistance of similar pathogens could be compared through time. This way, specific data can be compared in order to rethink antibiotic application actions. A scale of four possible values was chosen for antibiotic resistance categorization (Sensible, Intermediary, Resistant and unknown), embedded into a XML format.

The structure also permits recording of some specific recognition methods like Screening or CMI (E-test), used in VRSA (Vancomycin-resistant Staphylococcus aureus) detection.

6 CONCLUSIONS

Future work will consider the knowledge discovery about the nosocomial infections, on the basis of guidelines, consensus, refereed articles, and information registered on the EMR, crossing these data with the complementary means of diagnosis - analytic and, when applicable, imagiological; inducing patient models for the early detection of nosocomial infections, with high acuteness and more adjusted to the patients and to the environment of the healthcare unit; prompting models for the process of decision making, and to a better selection of handlings. On the other hand, we also intend to specify, to develop and to implement a data processing computational system starting from an online structured and systematized recording of information about the nosocomial infection, enabling the recording of the diagnosis that were effectively done, the register of the flat therapeutic being prescribe, the interoperation between the laboratory systems and the clinical information ones and the implementation of prevention systems and, accordingly, of programs to improve and to measure the quality of service.

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