Information, Knowledge and Interoperability for Healthcare Domain

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Abstract

New technologies have improved the ability of electronically storing, transferring and sharing medical data; they also create serious questions about who has access to this cross-media content and how it is protected and distributed.

Our aim is to support healthcare professionals in this changing environment, by providing a set of software tools that help reducing the time and associated costs to collect the information and knowledge required, and in making the best use of it for a more informed decision making (diagnoses, therapies, protocols).

An appropriate and consistent level of information security consists of protecting information both in written, spoken, electronically recorded, or printed form from accidental or malicious modification, destruction, or disclosure by applying the strictest requirements for data security and privacy and complying with ethical standards.

By Doc@Hand project we experiment the distribution of computer-based patient record, natural language queries and the contained knowledge in a secured way.

1. Introduction

In health care the use of different types of Information Technology (IT) has progressed considerably since the beginning of electronic patient registration, leading to improvements in the interfacing and fusion capabilities of a large variety of computer and telecommunication technologies. Such evolution can be attributed partly to the need for facilities for information storage and management, improvements in quality of care, and expenditure control, in both the public and private sectors.

The healthcare systems had to cope with the computerization of medical records in hospitals and health clinics; the use of the Internet for communication and information exchange; the development of magnetic cards for user identification; electronic scheduling systems for appointments, examinations and hospital admissions; and computerized protocols for diagnosis and treatment support.

Health IT has facilitated access to health literature, both to online journals, books and databases, and offline to informational CD-ROMs, that support practising professionals [14].

In this scenario where Healthcare organizations tend to rapid decentralize, with multiple actors involved in the care delivery processes, the importance for professionals to collaborate, access and share data and knowledge becomes more and more stringent.

The development and/or implementation of health IT regarded information systems at health facilities, including hospitals, clinics, physician's offices and diagnosis and treatment at support centres. These information systems are used for data storage, processing, recovery or diffusion purposes and included systems designed for the management of clinical and administrative information [14].

New technologies have so improved the ability of electronically storing, transferring and sharing medical data; at the same time, they also create serious questions about who has access to this information and how it is protected.

We provide a set of tools that help healthcare professionals in reducing time and associated costs to collect the infomation and knowledge required, optimizing the decision making processes.

Information security and availability is the main requisite; Healthcare systems and networks protecting information both in written, spoken, electronically recorded, or printed form from accidental or malicious modification, destruction or disclosure is a preliminary system requirements. Security and authorization guarantee that information are accessible and distributed to all interested actors, at the same time meeting the strictest requirements for data security and privacy.

Health care is an information-intensive activity producing large quantities of data from laboratories, wards, operating theatres, primary care organizations and, in the future, from wearable, and wireless devices. Wireless networks are expanding the range of data availability and needs increasing the complexity of health delivery environments giving to caregivers the capability to access data from everywhere and at anytime. Thus, information management in healthcare requires considerable collaboration, mobility, and data integration [4]. In addition, the standard doctor-patient 1-to-1 relationship is being replaced by an n-to-m relationship in which the patient is one of the actors, the others being a team of health care professionals each specializing in a single aspect of care. The need for collaboration also derives from the rapid evolution of research in many sectors providing stress and difficulty for caregivers to take greater control of their own professional development and continuing education, especially when the daily routine leaves few resources and time to dedicate to this activity. Sharing of information means also to deal with a widening spectrum of diseases (e.g. infectious diseases) that a doctor may need to treat, as a consequence of people mobility around the world. In the latter case, diseases that are well understood and successfully treated in a country, could be not completely known or even ignored in another, originating delays in the diagnosis that could be fatal to a patient, or even to a wide segment of the population. Indeed it is the present inability to share information across systems and care organizations that represents one of the major impediments to progress toward shared care [4].

2. State of the art

The integration of health information systems is currently something of a truism, a taken form granted ambition.

Information in healthcare is complex, unstructured and frequently distributed among heterogeneous information systems. Integration of heterogeneous information is important to retrieve the patient history, to knowledge sharing and to formulate complex queries.

Strategies and approaches to integration vary [6] and includes technical solutions like federated database system, World Wide Web and EDI [7] as well as ERP-systems [4].

CEN, the European Committee for Standardization, is consisted today of a number of different technical committees. The Technical Committee 251 was formed to address the area of health informatics. The scope of activities of TC 251 is the standardization in the field of health information and communications technology (ICT) to achieve compatibility and interoperability of independent systems and to enable modularity.

HL7 is one of several ANSI-accredited Standards Developing Organizations (SDOs) focusing on the health care area. The term “Level 7” refers to the highest level of the Open System Interconnection (OSI) model of the International Organization for Standardization (ISO). HL7 correspond to the conceptual definition of an application-to-application interface placed in the seventh layer of the OSI model.

Increasingly, middleware is providing itself just the type of innovation healthcare is looking for. Two of the most promising types of middleware for healthcare IT are the interface engine and the Enterprise Master Person Index (EMPI).

More recently, the open EHR specifications incorporate a two-model approach that allows the separation of generic features of any EHR from the domain-specific (usually clinical) features needed for specific EHR instances.

Interface engines replace costly, individual point-to-point interfaces with a hub-and-spoke architecture that is easier to configure and manage. Unlike the interface engine, the EMPI is a middleware solution unique to healthcare.

Work in information system integration focuses to a great extent on three issues: autonomy, heterogeneity and distribution:

- Autonomy: the extent to which the components are self-sufficient. The systems are autonomous in their design and meaning. Integration in under such circumstances normally require organizational change.
- Heterogeneity: hiding differences in platforms, programming languages and data models,
- Distribution: hiding the geographical distribution of information systems.

Some hospital are already taking advantage of the knowledge sharing and decision support. Prototype

systems have been already in use, mostly developed in collaboration with computer manufacturer industries.

IT available products are in the fields of decision-support systems that facilitate clinical and administrative decision-making by means of interactive dialogues; clinical diagnosis, individual monitoring applications, facility and institution management applications and "virtual health libraries"; electronic data exchange, including general infrastructure designed to allow interaction and information exchange between the users and services and between systems themselves, by means of the Internet and electronic mail; support systems for educational activity, directed towards distance-learning and improvement of teaching ability in the education and training of health-care professionals; electronic patient registries systems that integrate and promote access (from a single site to multiple locations) to collections of clinical and administrative data concerning the patient, based on a distributed database and including different means of support, such as intelligent optical card technology; telemedicine such as support systems for diagnosis teleconferences, transmission of high-resolution images and vital signs for long-distance diagnosis and robotic telesurgery [14].

From a review of the specialised literature the main advantage reported by means of IT use in health care are the following.

Electronic patient registries: their main advantages are greater accuracy [15] and a higher proportion of correct information [16], [17]; time saved in locating information [18]; more economical use of financial resources; and greater ease and speed of recovery of patient data [19].

Process and programmatic action evaluation and management systems: their main advantages are reliability [17], speed [18] and the optimization of available resources [17].

The advantages reported included reductions in registration errors, identification of absentees, integration of prevention and control activities, and detection of risk factors and complications [18], [20], [21], [22]. These system could assist with evaluations of morbidity and patterns of drug prescription [23], allow managers to monitor compliance with conduct and norms regulated between different levels of care [24], and optimize the prevention and early detection of risk factors [25].

Clinical decision-support systems: positive experiences have been reported to result from implementation of these systems [26], including increases in physician adherence to standardized therapeutic plans [27], [28], [29], cost reduction [28], and easier standardization and regulation of requests for secondary and tertiary health care and for examinations [30], thus reducing variability between services.

3. Project objectives

Our main objective is the development of a distributed intelligent system aimed at supporting health professionals in their day-by-day activities, which allow to use all information anytime and anywhere, completely hiding to user the physical data location. Thus, we intend to develop, to test and to validate an advanced software application that:

- allows transparent access to heterogeneous and geographically dispersed databases owned by separate, but cooperating organizations;
- offers a proactively search, primarily using push technologies as opposed to traditional “pull” approach, for relevant information without the need for the user to perform an explicit query, based on domain ontology as well as static and dynamic information about the user profile and current activities;
- provides the user with representation tools and intuitive interfaces to easily filter and navigate through the information;
- integrates existing decision support systems, and is also able to extract knowledge from unstructured and semi-structured documents;
- incorporates all the above in a cooperative environment that allows virtual communities to be created for exchanging opinions around patients or scientific issues;
- design the system in way to protect patient’s sensible data from possible unauthorized accesses, both involuntary and fraudulent.

The integrated environment developed will be accessible from portable platforms such as tablet PCs to support the increasing mobility of Healthcare professionals, and will be validated by major clinical institutions for full adherence to standards and regulations for security and sensitive data handling.

4. Project organization

The vision behind Doc@Hand is a tool that assists a healthcare professional in his day-by-day activity, supporting his mobility needs, exploiting mobile computing and wireless connectivity (such as UMTS) coupled with autonomous capabilities when offline,

providing a comprehensive view of documents and knowledge, relevant to the activity that the Healthcare professional is currently performing, that are located in different and heterogeneous repositories, and "anticipating" his information needs and making it available at hand without the need for an explicit search/retrieve request. This intelligent system takes into account the user profile, the context of work, his preferences to adapt to different conditions, and modifies accordingly the search and pushing criteria. The project is developing a highly customizable system that allows user profiling in several dimensions: his role (specialist, GP, etc.), his work plan (hospital, visits at his office or at patient's home, etc.), his user interface preferences, that will be validated through an extensive set of trials at two major hospital sites, Corporaciò Sanitaria Clinic in Barcelona and Guy's and St. Thomas Hospital in London, acting as centers of two information providers networks.

Finally, the system will be designed to protect patient's sensible data from possible unauthorized accesses, both involuntary and fraudulent, by commercial subjects (e.g. employers, insurances) and to preserve a needed interoperability level.

The successful implementation of the system will be measured by the following quantified objectives:

- Reduced time needed to search for information and knowledge and organize results by 60% in at least 80% of the working situations
- Relevance of the search results of at least 80% (meaning that only once in five times the doctor will have to manually search for additional data)
- Reduction of noise (results not relevant to the current context) by 50%
- Reduction of costs associated to duplication of activities (i.e. laboratory tests) due to the lack of available information by 80%.

5. Privacy vs. interoperability

In the medical field nowadays there are an increasing need and opportunity of integration and communication of large amount of data referring to patients and diseases: that determines an incommensurable phenomenon of data sharing among multiple actors and multiple organizations.

This reality requires suitable software, hardware and networking to make possible the data transferring plus suitable tools for privacy protection. The risk of exposure is indeed for patient's sensitive and personal data but also for staff know how, for scientific property and even patents.

The Health National Services have to cope with limited financial resources but we have to remember that the priority of ethical principles cannot be ignored and the principles of professional secrecy and patient data privacy have to be protected.

Protection of privacy depends mainly in having a secure system. Security first of all requires that persons accessing the system are properly identified, or authenticated. Once they are authenticated, they can be authorized to read or manipulate specific data/information. It is also crucial to properly define the boundary of protection. In networked computing, as in common now, the boundary of protection is not simply the physical perimeter of a computer system, it extends to all the computer systems that share a common protection system.

Proposed system is able to manage a large amount of sensible data in a secure way, respecting privacy and security. We can say that privacy is the goal and security is the tool and it could be useful to consider both the definition.

- Privacy is the right of individuals to keep information about themselves from being disclosed and to define who is authorized to access information and for which purpose;
- Security is the ability of controlling the access to information and of protecting information from accidental or intentional disclosure to unauthorized people and from alteration, destruction or loss.

Figure 1 -Interoperability

Patients private personal information (EHR, Electronic Health Record) are treated by respecting privacy policy [Fig. 1]; no data are stored locally, all EHR content is managed entirely on memory as received from external heterogeneous data sources (typically, Healthcare structures Informative System). EHR is composed mainly by two distinct sections, personal data and clinical data; such EHR are stored locally on medical structures Informative System, protected by firewall and other security policies. On the other hand, such data need to be collected from request, retrieved by Doc@Hand Infrastructure Layer

in a very transparent manner and then submitted to system processing (authentication is required in order to access to patients' list).

Then, it is clear that the transmission from medical structure Informative System to our one could be unsafe; our solution supply this problem both by using https protocol (scrambling information before transmission) and by splitting EHR into two distinct packages, one containing personal data and one clinical data.

This way, EHR becomes completely anonymous; it is recomposed once received thanks to the packageID previously assigned to EHR.

From above it derives that the designed goals has to cope are:

- to convert the general security recommendations into specific implementation guidelines for healthcare products,
- to ensure consistent interpretation of the high-level security requirements,
- to ensure safe collaboration among different actors of the healthcare process,
- to design a modular architecture that creates a scalable framework for security implementation.

We have identified some tools to achieve the mentioned goals that are:

- Actors identification:
  - Unique user identification
  - User authentication / authorization
  - Role based access on services and resources
  - Automatic logoff
- Encryption:
  - Secure connection and data exchange with external sources
- Auditing/Logging:
  - Record and track of any interaction/access to clinical sensitive data

6. System architecture

Healthcare professionals have a complex and heterogeneous job, which includes several and different contexts and activities. For instance, a doctor may visit his patients at the hospital in the morning, meet with colleagues and share ideas in the afternoon, prepare slides for the university lectures late at night. The same doctor may work at both a public hospital and at a private study, co-operate with other doctors on other clinical organizations over a special-disease treatment, or even visit patients at home.

A hospital doctor, using his personal computer at his office wants to access his active patient list, thus control their electronic health records (EHR) stored in the hospital's system, view the patients' test data and clinical trial results, and browse referral protocols and guidelines. The same doctor wants to be informed about the clinical status of two patients who have been discharged from the hospital one week before. One of them has moved to another clinical organization and the other has gone home where he keeps receiving periodic treatment and being visited by his doctor.

Simultaneously, he wants to see the progress status of the patient currently hospitalized in another clinical organization, to have some access to the patient's clinical record and shared documents.

Leaving the hospital, doctor wants to continue working when offline, carrying his work on a tablet PC he owns. Part of the work done at the hospital is saved on his tablet PC, and at the same time he may use it to connect to a web information database searching for documents relevant to the article he is writing.

Late at night, he visits the other patient of his, reviews his status and keeps notes using his tablet PC about the status of the patient. This information will be used in case that the patient be hospitalized again and will update his clinical record.

From the above, we can assume that the information need of the doctor varies depending on:

- The environment he is working (hospital, primary care organization, other clinical organization, home-visit)
- The source he needs to access (local hospital information system, other clinical system, web database)
- His activity that is being performed (treatment, diagnosis, review of clinical trial results, home-visit treatment, referral material – protocol access, web information searching)
- The tools that he uses (share a document, search for documents, offline working, contact colleagues, and communicate with others).

Proposed solution, based on a server side and on a portable client side, will be a system that will support its users at their day-by-day activities, such as prescribing the best treatment action for their patients, access information and knowledge that are located in different repositories, setting up their daily schedule and co-operate with other healthcare professionals in a secure way.

An overall system architecture can be split in the following functional modules.

A. An Infrastructure module. This module deals with the data interoperability issue, and allows flexible and customizable data exchange policies between the participating organizations based on open standards (SOAP/UDDI services)

B. A Semantic Subsystem. Performs intelligent, context driven searches on the distributed databases. It will perform data/text mining and knowledge extraction, exploiting the domain ontologies that will be developed during the project.

C. A Profiling module, that performs the key functions of building and maintaining the static (role, preferences) and dynamic profile of the user. It is responsible for "pushing" the information to the user desktop. This way it tracks the user activity and feeds the Application Server with information on the current user activities.

D. An User Interaction module that performs all functions related to the user, on both the Application Server and the Client device. Includes the User interface and Knowledge representation and navigation.

E. A Services module, that includes:

- Security and Authorization
- Workgroup tools
- Data Synchronization tools to keep the user device data base up-to-date with relevant information for off-line operation
- Configuration tools

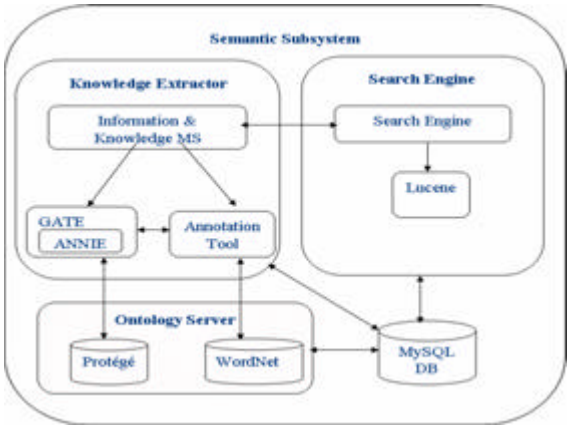

Figure 2 – Semantic subsystem

Proposed system's core features and main real innovations is provided by Semantic Subsystem [Fig. 2], which is a set of tools strictly interoperating each other such as:

1) Information and Knowledge retrieval (clinical records, guidelines, clinical cases, protocols, scientific publications, etc.); a Search Engine is responsible to analyze and perform queries on Information Repository and external data sources (via Infrastructure Web Services) and to return found results to the presentation layer.

2) Information Management entire process; document submission, content parsing, knowledge mark-up, concept extraction, document indexing are the basic features provided.

The Subsystem is composed by the following tools:

- An XML-based Search Engine able to analyze the user query submitted, to extract the main concepts, to expand the intended meanings leaded by semantic infrastructure.
- An Ontology Server in order to guarantee the access to Top Level (based on Dolce 3.5) and Domain Ontologies (both written in OWL); see figure 3.
- A Semantic Parser, responsible to analyze text documents performing concepts extraction (used to enrich a Virtual Knowledge space) and mark-up (used for document indexing).
- An Information Repository Management System where information and knowledge are stored and indexed.

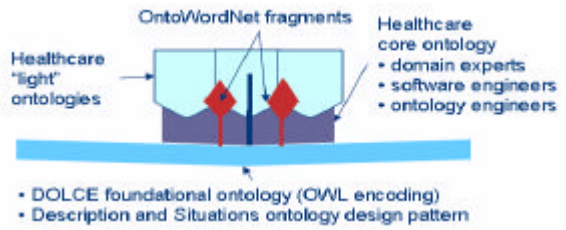

Figure 3 – Ontology composition

Knowledge extraction process is particularly interesting; document content is submitted to semantic parser that provides the following steps:

- Tokeniser - sentence tokenising process
- Gazetteer process – preconfigured rules are applied to tokens found in order to facilitate semantic parsing
- Relevant sentences finding
- POS tagging – sentences logical grammar analysis has been performed to detect contents (NN, NL, NNS substantives, etc.).

- XML/RDF annotated document creation
- Semantic tagging – concepts (substantives) found in previous steps are searched into Ontology [Fig. 3] in order to set the concept mark-up related to Ontology reference.
- Document indexing (domain relevant concepts marked by parser are used).

The process above described is completely asynchronous; the system then takes a generic unstructured document as input and creates an XML/RDF annotated document as output. Semantic interoperability is supported.

7. Conclusions

Nowadays, healthcare professional are involved in a huge amount of various activities; so, the need to concentrate his resources (very often they have to deal with a number of different systems where the information is dispersed) and to save his precious time is more and more rising.

The result of this situation is often that most of the huge quantity of available knowledge available is simply ignored just because it would take too long to dig into the different repositories, and the search is limited to the minimum set of documents that are vital to the task being undertaken. And, even in this case, the time spent is likely to be more than it would be required if there was a tool able to show a comprehensive view of the problem.

The available data and knowledge are very impressive, ranging from the clinical records of patients and collections of cases from different healthcare service providers, to online libraries of academic institutions, professional associations and specialized publishers. In all cases the access to information is regulated, either for privacy/confidentiality reasons, when patient's sensitive data is involved, or just because the information, as in the case of clinical literature, is provided as part of a paid service. Even when the formal accomplishments are fulfilled, inter-organization agreements signed or the service fee are paid, the practical problem of easily searching for data, filtering, merging and ranking the results is still there.

If this is, from one side, a waste of productivity, it has also impacts on the quality of work of the doctors, as they are forced to make decisions having only a partial view of the situation. And, of course, it reflects on the quality of the service perceived by patients.

Our approach puts healthcare professionals and the problems they have to deal "at the center of the world" thanks to an intelligent system able to support them in their day-by-day activities. The intelligence is distributed among the server and the portable client that has his own computing capability, an embedded workflow logic to gather, organize and manage their daily schedule.

With the proposed system, healthcare professionals can access to heterogeneous information distributed in geographically dispersed locations anytime, anywhere through a broad range of networking interfaces (Bluetooth, WLAN, cellular) and the logic to seamlessly switch from one to another to provide the highest degree of operation and synchronization regardless the location where it is being used; such information can support them in decision making for complex problem solving.

Moreover, we include a powerful Ontology-Based Search Engine, supported by other Case Based Repository (CBR) and NLP tools, able to dramatically improve the accuracy of the precision results, offering very specific information matching the request also saving their precious time. All that is possible under an accurate and effective IT system ideated in order to protect sensitive data and to assure the privacy of access, manage and transfer of data.

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