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A Coherent Architectural Framework for the Development of Hospital Information Systems

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Abstract
The mission of the hospital is to take measures in order to enhance the efficiency, shorten patient waiting time and improve quality of treatments. Among those measures is enhancing the accuracy and efficiency of Hospital Information Systems (HIS). This enhancement is currently an attractive option that draws the attention of an increasing number of hospitals. In this paper, we propose a global architecture for the development of a HIS. This paper shows a coherent architecture that allows the development of interoperable HIS in case they evolve.

Keywords: Hospital information system; Agent; Peer to Peer (P2P); Ontology; Access control.

Introduction

Over the last years, healthcare information systems have been developed having a major drawback. It is the gap between the speed of technological change and the relative slowness of decision making and execution in the world of health institutions. Since its inception, the hospital places the patient at the heart of its organization. It provides patients the best professional competences and resources necessary that it has for a comprehensive and effective care.

The hospital is a whole that has the patient in its core for which different services cooperate. The objective is to create a patient-centered process information system. The group work is in the nature of the health care that improves cooperation and coordination, facilitates and accelerates communication and information sharing among teams.

HIS are evolving constantly during their existence. We point out that according to the literature available architectures for HIS are often closed and not extensible [1-3]. We faced several difficulties and problems, such as: the information diversity, the huge quantity of data provided by very different stakeholders, the distribution and traffic of the information, and as well the tasks complexity [4]. Also the important number and wide variety of stakeholders' activities, the complexity that arise from the growth of the system. The HIS are found not to be suited for some of the needs expected from them: they are not patient-centered, weakly secured, and the applications they are made from are not communicating well [5]. These problems are a major obstacle to improving care and taking care of patients.

The main objective of this study is enhancing the access control, communication and to facilitate sharing and exchange of medical information among healthcare actors of HIS. Another objective is to reduce the difficulty of HIS construction, maintenance and cost.

Hospital Information System

Hospitals need information technology to help them ensure that medical information is accurate and to improve communications among doctors, nurses and patients [6]. According to the literature, several definitions are attributed to the HIS:

According to Pietka and Chang [7,8], HIS refers to the computer system which is used in medical information management and online operations. It covers all the hospital services and business. General HIS also contains Laboratory Information System (LIS), Radiology Information System (RIS), Ultrasound Information System (UIS), etc. [9].

HIS is a comprehensive, integrated information system designed to manage the administrative, financial and clinical aspects of a hospital. As an area of medical informatics, the aim of a HIS is to achieve the best possible support of patient care and administration by electronic data processing. It can be composed of one or a few software components with specialty-specific extensions as well as of a large variety of sub-systems in medical specialties (e.g. LIS, RIS) [10].

For Lea [11], Hospital electronic information comprises three parts: Electronic Medical Records (EMR), Picture Archiving and Communication Systems (PACS), and Order Chart Systems (OCS). EMR is the main hospital database to store all in- and out-patients medical records. HIS incorporates an integrated computerized clinical information system for improved hospital administration and patient health care. It also provides an accurate, electronically stored medical record of the patient. HIS is based on the exemplar of a centralized information system designed for quick delivery of operational and administrative information.

Other authors described HIS as a subsystem [12]. HIS is that sociotechnical subsystem of a hospital, which comprises all information processing actions as well as the associated human or technical actors in their respective information processing role.

HIS and Types of Information

HIS are characterized by their ability to record and transmit information and medical knowledge. The objectives of this information are various; in particular they include patient care, quality assessment, research, epidemiology, planning, management and training.

Information flows are manifold. They concern health functions, logistical and administrative management function. The nature of the information exchanged is wide; they depend on the actor and their field of activity and the action taken. We classify it into three categories:

- Medical: related medical information.
- Organizational: activities of all actors
- Common: hierarchical roles and functions among all actors.

HIS can be characterized by their functions, their types of processed information and their types of services offered [12]. In order to support patient care and the associated administration, the tasks of hospital information systems are to provide:

- Information, primarily about patients, in a way that it is correct, pertinent and up to date, accessible to the right persons at the right location in a usable format. It must be correctly collected, stored, processed, and documented;
- Knowledge, primarily about diseases but also for example about drug actions and adverse effects-to support diagnosis and therapy;
- Information about the quality of patient care and about hospital performance and costs.

Problems of traditional HIS

HIS is supposed to organize the coordination of all actors in the system. We are stating that the majority of nowadays used HIS are not fulfilling the needs they suppose to fulfil. They show some

chronic anomalies which are:

- Professional disagreements exist and translate into communication problems among different actors.
- The limiting factor for the evaluation of the treatment of patients is the quality of the information system.

Authors of [9] mentioned the following problems:

- Lack of uniform standards for data-sharing: Unified format and content of data storage are the basis for communication between systems. Information classification and data standards are not strictly uniform.
- High cost for independent construction: hospitals with not abundant capital prefer to continue using film and paper materials to record the clinic information.
- Difficult to manage, upgrade and maintain: the management and maintenance of HIS requires continuous investment, which is an important cost to hospitals.

In HIS, protecting the confidentiality of health information, whilst at the same time allowing authorized doctors to access it conveniently, is a crucial requirement. The need to deliver health information at the point-of-care is a primary factor to increase healthcare quality and cost efficiency. However, current systems require considerable coordination effort of hospital professionals to locate relevant documents to support a specific activity [11].

The Global Architecture

The global architecture proposed for the development of a HIS is generic and based on the notion of agent, Peer to Peer (P2P) and ontology. It is an architecture-independent platform. The principal motivation that confirms the need for the use of the agent in medical field is the possibility to combine other technologies with the agent (Ontology, P2P, etc.) and in the architecture itself of the agent. The main idea is to establish a more efficient HIS and meeting requirements of a modern healthcare that combines quality patient care, cost control and collaboration among health professionals as part of the health care organization. In the proposed architecture, the considered agent is cognitive. It is capable of foreseeing and anticipating actions. Its key characteristics include autonomy and flexibility (sociability and pro-activity). Besides, our agent has to allow the addition, the access, the diffusion, the propagation, and traceability of the information. Consequently, our agent must be also informative. Every agent in the system can communicate with another one without passing by an intermediary (a total distribution of the knowledge, the competence and tasks on agents). In the following, we give components of the architecture presented in Figure 1.

Hospital Authorities

They act on behalf of the hospital. These authorities have a number of powers (recommendation, decision, regulation, sanction). Also, they ensure some form of control over the different actors.

User's PDA

Actors of the HIS are different in terms of forming, competence or task to be carried out. This variability is translated by a perception mechanism of knowledge and various access modes to information. Then, it is necessary to take into account this variety, to offer to the actors the adapted and efficient interaction modes, a better diffusion, and a data acquisition to interoperate. Mobile tools such as PDAs (Personal Digital Assistant) and the mobile phones constitute a real condition for the HIS success. Their uses on behalf of all the participating agents appear to be: the power to share information, knowledge and taking decisions through cooperation. As a consequence, it is a question of guaranteeing the quality of service (QoS).

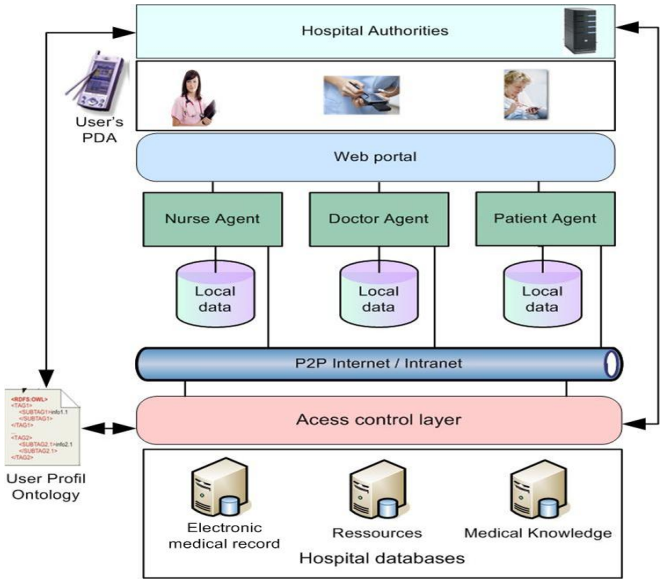

Figure 1. Architecture overview

Web Portal

The portal helps guiding health actors in their browsing the Internet and Intranet. It provides a gateway to a set of common services and resources. Thus, this portal will redirect the user to pages that best correspond to their expectations according to their profile.

Adopted Agents

An agent represents an actor of a HIS that takes care of the patient. It cooperates with other agents of the system to achieve its goals. They are linked among them by an inter-professional collaboration. Every agent consults only the information that concerns them according to the access rights (example: only the doctor agent can write a prescription and that the patient agent can have access, the nurse agent can make reports, etc.). Every agent (doctor or nurse) has to up to date on all new information, and a part of their function is to inform on every new situation and pathological state of the patient agent. Accordingly, each agent of HIS keeps all information relative to its interventions, activities.

Local Data

Each database is designed to satisfy local needs and not necessarily to interact with other local databases. Indeed, actors of HIS are very attached to their personal notes for their own use.

P2P Network

On the cost and performance side, P2P decentralized networks have several advantages over traditional client-server platforms. P2P networks have advantages on redundancy, robustness, performance and scalability. In our system each agent belonging to the HIS is a peer of the P2P network. Each peer controls and maintains its own data. This data can be solicited by other peers. On the other hand, Electronic Medical Record (EMR) represents a common model of sharing data and information. We know that the strong point of P2P technology is that it allows the addition or deletion of a peer without degrading the whole system. This is a facility of our system too, during operation agents can be added or removed. This P2P structure allows: (1) Communication (2) File Sharing and (3) Distributed Processing. Furthermore, the agents do more than file sharing, but rather they interact with each other. Another essential point is to facilitate collaborative work, the

use of these tools (groupware, calendaring, etc.) i.e. allows actors geographically distant to work as a team.

Shared Hospital Databases

The medical actors will be able to access the hospital's databases through two different ways: Via the Hospital network (Intranet) which will be used by the medical actors during their working days and via Internet with any mobile device (e.g. PDA). The patient will access his medical records using credentials from these devices. So, hospital databases are composed of:

Medical Knowledge. Relating to disease and medicine.

Resources. Relating to web services, ontologies, etc.

Electronic Medical Record. The medical record is an essential tool to share information for cooperation. It consists in an important amount of information. The EMR is stored and capable to be consulted even from distance. The sharing of medical information is vital in medicine concerning at the same time: diagnosis, prognosis, analysis and care continuance. It is a progress factor for better medical care, faster and adapted, and so, systematically transmits information to other participants (agent). To improve information traffic and functioning of our approach, the medical record is primordial, It helps to: (i) Minimize medical errors (ii) Accelerate knowledge diffusion (iii) Help decision making.

EMR is brought to evolve and to be updated more frequently. It allows a permanent communication between agents in an interprofessional context in order to cooperate, and to inquire mutually their conclusions' result and actions. Every agent has to find any indication and any information which is useful for understanding situations: to keep information traceability, to orchestrate, to organize interventions, to share and to exchange information to assure the coherence interventions, the continuance and the care quality. EMR guarantees the interoperability among agents in the sense of coordination to collect, enrich and exchange structured medical data. Furthermore, a virtual collaborative working space reserved for all user agents allows them to work while being geographically distant and by keeping a permanent assistance around the patient.

User Profile Ontology

The purpose of any health institution is to increase health quality and to decrease the access errors to medical information. Our approach is to build a specific ontology. This ontology allows presenting necessary knowledge which guarantees the coherence of integrity of the health actors' profile. The purpose of User Profile Ontology (UPO) is to improve safety of medical data by reducing and controlling the access to the EMR. UPO groups the terms relative to profile of the different actors of HIS in a formal way. This ontology allows the hospital authorities according to the profile of the appropriate actors control access to databases of the hospital. Their profiles are saved and continually updated by the hospital authorities.

Access Control Layer

Each actor has his own credential key automatically generated and delivered by the hospital authorities to access the web portal. On the other hand, they supply a username and password to different actors from the hospital to access data. EMR must be associated with access control for designated agents (actors) or groups of agents having the right to read the contents of the folder and to add information in a systematic way or using some conditions. Here we mean by group of actors the team that will take care of a patient. Any other agent that doesn't have these rights must not have access. It should be noted that direct access to medical records is simple in principle, but sometimes complex when it is applied in real life.

The safety methods means proposed in the previous section are not sufficient. A Better protection is possible when we consider the profiles of health actors defined in UPO. This ontology plays the role of an access control model based on profiles. For each profile, we associate permissions represented by access rights.

Standardization

The development of HIS is also based on standards. They have a significant contribution to interoperability in the HIS. Among our contribution's objectives, are to encourage and push the evolution of normalized standards, to support the reusability and the interoperability in the field of distributed medical information. The need to transmit data in a structured form allowing automatic processing has resulted in the development of standard messages. Therefore, it is relatively easy to interconnect systems. Making them interoperable requires an agreement on the structure of exchanged data. But it is not always easy to interconnect systems. For this purpose the international standardization in the field of health plays a vital role to ensure some interoperability in HIS. There are many organizations developing standards for health informatics across the world, namely: HPRIM, HL7, CEN TC251, DICOM, IHE, LOINC, SNOMED and UMLS.

It should also be noted the predominant place occupied by the XML standard. XML is the standard of data description. This standard promotes the convergence of all standards and norms above. In our proposition, all exchanges of messages and information are based on XML.

Inter-Agent Communication

The success of our approach also depends on an effective communication throughout its progress. To analyze data, identify information, maintain knowledge, communicate syntheses, recommendations and decisions-making of agents that are different in their functions and activities, require an unfailing communication. So, it is necessary to assure a permanent communication. Several mechanisms of communication are possible: message exchange, methods invocation and the use of the "blackboard" mechanism. Consequently, standardized inter-agent communication languages should be supplied. In our approach, we use the ACL to formulate messages and the XML to describe the contents of messages. The use of ACL-XML in inter-agent communication permits to achieve a first level of interoperability by surpassing the problem of heterogeneous exchanges among the different actors in the HIS. The success of the information diffusion among actors resides certainly in the communication protocols standardization. We have used the language ACL FIPA [13] which is the most useful for HIS.

Prototype Implementation

In order to study the feasibility of the proposed architecture, we implemented a prototype using standards. We used XML technology to represent the information exchanged among agents (the possibility of using standards like HL7 v3 message, CDA, DICOM, etc. encoded in XML) via the standard communication language ACL-FIPA. We developed UPO with Protégé [14]. We give in figure 2 a preview of UPO published under Protégé tool. We opted for OWL ontology possessing the following advantages: (1) capacity to be distributed through large systems (2) scalability for the needs of Web (3) compatible with the Web standards (4) open and extendable.

JADE [15] is the platform which gets closer most our criteria. It is a platform of agents' creation that takes into account FIPA specifications for the Multi-Agent Systems (MAS) interoperability. JADE supports P2P application. It allows each agent to dynamically discover other agents and communicate with them according to the P2P paradigm. Figure 3 shows the connectivity of doctor

with PDA to system. The following example represents the profile of this doctor (Urologist) described in XML:

```
<Act_Profil Name= Dr. Chaouche Ahmed >
      <Act_speciality> Urologist </Act_ speciality>
      <Competence Comp_id='ultrasound scan'>
            <Designation> ultrasound scan vesico-prostatic </Designation>
      </competence>
      <Competence Comp_id='endoscopy'>
           <Designation> endoscopy diagnostic </Designation>
      </competence>
</Act_profil>
```

Key benefits of using this architecture:

- Health actors and in particular doctors can easily access test results previously made, and information about hospitalised patients.
- Avoid unnecessary interactions between health actors.
- Efficiency side, health actors spend much less time and effort to search information, which allows to organize activities and to avoid delays in care.
- Patients undergo fewer redundant tests.
- It is not for an agent to simply respond to a message but be able to analyze any eventual possible response before reacting.

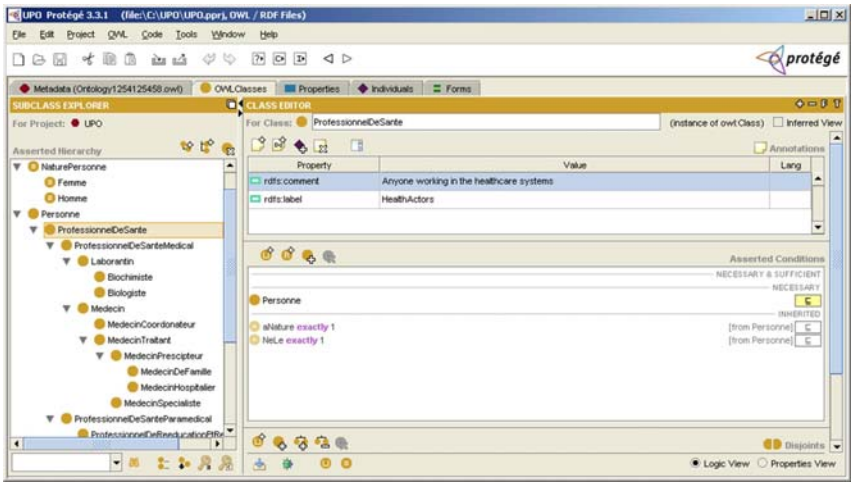

Figure 2. UPO published under Protégé tool

Figure 3. Doctor interface

Conclusion and future work

In this paper we have presented a new architecture for development of HIS based on agent, P2P and ontology. This architecture facilitates communication, access and sharing medical information. Every agent represents an autonomous actor. UPO allows enhancing of access control to the hospital databases. We implemented our system with the JADE platform. This approach reduces significantly the time spent by health actors to communicate among them in hospitals, allows being updated medical information from patients and facilitates flexible interaction between patient and doctor or patient and nurse through the Internet.

However, this study is subject to a future extension concerning other aspects such as the coordination among different health actors for taking care of patients.

Conflict of Interest

The authors declare that they have no conflict of interest.

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