TOWARDS ENHANCING INTEROPERABILITY IN MEDICAL INFORMATION SYSTEM

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Abstract

Medical information systems evolve constantly. This paper shows a coherent architectural framework that allows the development of interoperable medical information systems in measure or these systems evolve. This architecture is based on agent, ontology and Peer to Peer. The proposed architecture is meant to include all the concepts necessary to perform all activities related to medical information system. This work indicates how to attain the organizational interoperability.

Keywords: Medical information system, Interoperability, Agent, Ontology, Standards.

1 INTRODUCTION

The recent technological revolution and the fast development in the field of communication networks offer to Information Systems (IS) new perspectives and new challenges. In particular, they have made emerged new distributed applications. These last ones require the design and the development of large-scale interoperable systems. The Medical Information Systems (MIS) are part of these systems which are autonomous, heterogeneous and distributed [1]. The quality of MIS takes into account various aspects of interoperability .i.e. syntactic (common data exchange formats), semantic (the sense of data), etc. to establish a more efficient medicine. To be more effective and take the right decisions at the convenient moment, MIS need to have relevant information. Furthermore, these information must have a sense (syntactically and semantically interoperable) [2] [3] and must be put at the disposal of various actors of the system when it is necessary. It is evident that the agent paradigm is the most suitable one for modeling the MIS since it is capable of taking into account all its properties (heterogeneity, distribution, decision making, etc.).The objective of this paper is an architecture based on agent and ontology through a Peer to Peer (P2P) network to support interoperable MIS. In this paper, we are particularly interested to organizational interoperability. The paradigm of Multi-Agent System (MAS) proposes interesting concepts for the MIS development, such as the control autonomy, the decentralization, and the communication [4] [5].

The rest of the paper is organized as follows. The section 2 determines the development of the interoperability in MIS and its various levels and aspects. The section 3 presents a generic architecture based agent. The section 4 shows how we surmounted the problem of organizational interoperability followed by a case study and implementation in the section 5 and discussion in section 6. The Section 7 recapitulates the synthesis of this paper and indicates orientations for the future works.

2 THE DEVELOPMENT OF THE INTEROPERABILITY IN MIS

The application of architecture and\or an infrastructure to support the interoperability of MIS is dependent on a great number of technological components, paradigms and standards. It's clear that it will be more skillful to integrate paradigms and technologies developed in various disciplines (relative to this context), that to spend important efforts to define paradigms totally new. Table 1 shows which aspect of interoperability that can bring every used technology (according to our study on state of art and our point of view). It illustrates certain basic technological components contributory to MIS' interoperability. A synthesis work on these components can give a breach on to needs and requirements of an effective environment to support the establishment of interoperable MIS.

We studied the various technologies, standards and paradigms of development and their deployments in the context of the interoperability in MIS. We emphasized the most relevant points which reunite and differentiate various research works and projects. These research may be realized or under development, in relation with our study frame. We established a classification, according to the interest and concepts treat in every project and research work (i.e. according to the used technology and various aspects of the interoperability). A state of the art concerning this work was published recently in [6]. So, we noticed that all works do not reach the organizational interoperability.

Table 1: Interoperability aspects according to the used technology.

	interoperability			
Technology approaches and paradigms	Org.	Tech.	Syn.	Sém.
MDA		+	+	+
SOA	+	+	+	
Web Services		+	+	+
CSCW		+	+	
Security			+	
Agent	+	+		
MOM		+	+	
P2P		+		
Grid		+		
Ontology	+			+
Terminology			+	

Org. : Organizational, Tech. : Technical
Syn. : Syntactic, et Sém. : Semantic.

3 AGENT BASED ARCHITECTURE

Our works lean on agent based architecture and ontology an infrastructure of P2P communication to support interoperable MIS. This architecture is independent from any domain of medical application. The interoperability of the MIS is reached via unavoidable standards and technologies: XML for the syntactic interoperability, FIPA-ACL / XML [7] as common communication protocol and ontology for semantic interoperability. Indeed, the cooperation is a critical point for the success of MIS, these last ones base themselves particularly on the new technologies. It is the case of the agent based MIS, composed of several partners agents linked by commitments in order to accomplish their tasks and satisfy needs of a patient. These partners agents are autonomous nature and supported by a variety of heterogeneous information systems. This architecture facilitates the interoperability, the accessibility to information and offers to partners the same functionalities as if they belong all to a single structure (the same place). The nature of the MIS (a set of autonomous systems, geographically scattered, wishing to collaborate to achieve a common goal) is well adapted to the "Distributed Multi-Agent Systems" approach, and thus, mapping the MIS into a MAS comes naturally. While the multi-agent approach is frequently used for MIS projects in the medical sector, we do think that this powerful approach can suit more or less any type of MIS, with certain adaptation for the basic concepts (see figure 1).

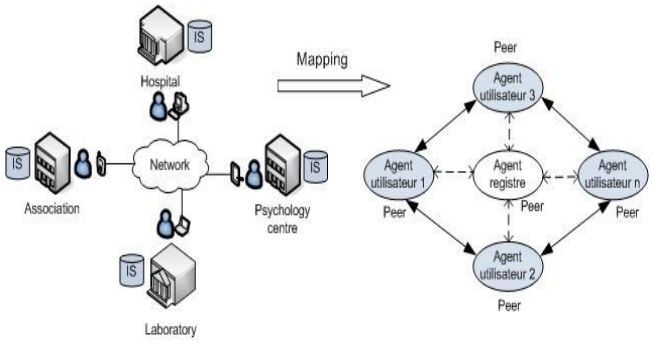

Figure 1: Actors of a MIS represented by agents.

Every actor is registered in the yellow pages and white pages registers maintained by the register agent according to the following profile:

```
<!ELEMENT Act_Profil (competence, speciality)>
<!ELEMENT Speciality (#PCDATA)>
<!ATTLIST Act_Profil Name CDATA #REQUIRED>
<!ELEMENT Competence (Designation)+>
<!ATTLIST Competence Comp_id CDATA #REQUIRED>
<!ELEMENT Designation (#PCDATA)>
```

Every actor is represented by a user agent. The following example represents the profile of a user agent (Urologist). Agents profile is critical for a specific partnership to reach a common purpose.

```
<Act_Profil Name='Prof. Sahli'>
    <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>
```

3.1 User agent

The user agent represents an actor of one IS which participates in the taking care of patients. It cooperates with the other agents of the system to reach its purposes. The components of user agent are represented in figure 2:

3.1.1 The user interface.

It allows the interaction between the user agent and the human agent (this last one plays the role of partner or expert). It is an interface of assistance for the human agent, this last one has decision-maker's role, whether it is to be a part of the SIM, either for decisions concerning the exchange of the confidential information.

3.1.2 The coordination module

This module considers the whole global process of the coordination. It takes as inputs parameters a set of purposes

(the interpretation results of messages by the user interface and the module communication) and produces a plan which satisfies these purposes. The coordination module consists of sub module of planning for the orientation and the scheduling of the local tasks and one sub module of negotiation for tasks allocation, conflicts resolution and the convergence towards agreements with partners.

3.1.3 The individual knowledge module

. An agent has to have the capacity to represent his knowledge that is to remember them and to reason above. So, the individual knowledge base represents all the information and the necessary knowledge on the agent it's self: its capacities and competence, the state and the load of the current task. As a consequence, every user agent of the MIS keeps any information relative to his interventions, his activities, etc.

3.1.4 The knowledge module of the MIS.

It contains the information concerning the organizational and operational rules defined in a MIS (ex: to which user agent of the MIS he has to put back the analysis results). What allows having an organizational interoperability between various agents partners involved in the system. It includes the list of all partners agents. It is knowledge which represents the know-how on the SIM, for the good progress of the reasoning process and a coherent behavior. Consequently, this knowledge base allows achieving the process of cooperation and the management of interactions with the other agents. This module also contains information on rights and commitments in the SIM.

3.1.5 The communication module.

This module manages the interaction between an agent and an outside world such as the other agents. It contains all processes of taking charge of the resulting messages of another user agent. This module is responsible for all features of expedition and for reception of messages.

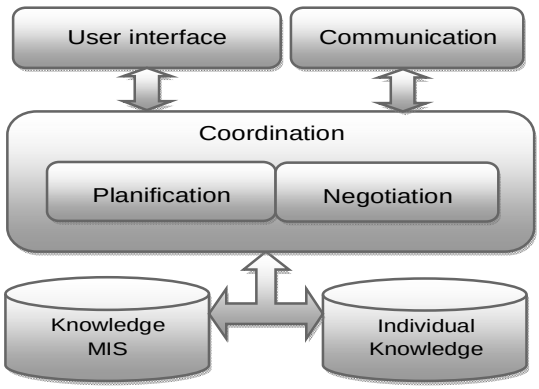

Figure 2. The structure of a user agent.

4 ORGANIZATIONAL INTEROPERABILITY OF MIS

The choice of the agent architecture and its modules are based on its functionality, its field of activity and its role in MIS. The MIS preferred agility, i.e. ability to answer in short-term to changes (e.g. patient's state, the abundance of a partner agent, etc.). It is therefore important to propose an agile organization of the MIS to allow quick and easy reconfigurations that led to investigate to the MIS interoperability at the organizational level. Indeed, the disposition of agents organization following some simple distribution i.e. responsibilities and roles of agents, depending on the type of service provided. The purpose of the organizational interoperability take care that organization maintain its coherence, and monitoring compliance with commitments undertaken by the various members of the organization to accomplish the overall task that is the full taking care of the patient. Through the example of figure 3, we show that each agent (Ai) plays a role in the organization in a hierarchical structure. This does not prevent agents A5 and A7 can cooperate directly under the supervision of their superior agents A5 and An respectively. No agent has the status of centralizer i.e. communication between agents is not through by it, this is a fully distributed architecture. Contrariwise, partners agents watch over the sequencing and scheduling of tasks and sub tasks of other partner agents, to accomplish a partial goal. In addition, an agent must wait for another agent performs its task so that it can run its own. Also, tasks can run in parallel. The consistency of the system is ensured through coordination mechanisms [4]. In our context, we adopt the coordination techniques at the heart of the MIS to provide an organizational interoperability. To recall briefly, however, partner members keep their autonomy certainly, which, the MIS is interoperable and flexible. Therefore, this organizational structure has certain advantages:

- Respect of the functional hierarchy.
- Cost and reduced number of messages between the various intervenient.
- Easy information exchange.
- Easier cooperative work.
- Allow (through simulation) to evaluate the performance of a distributed organization of agents.

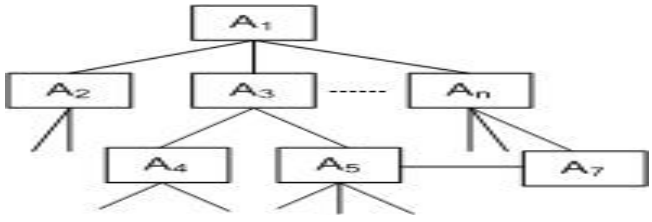

Figure 3: Organizational hierarchy in MIS

We recall that this organizational interoperability is reinforced by a generic model of domain ontology called OntoMIS (Ontology Medical Information System). We focus on its interest. Indeed, we determined an explicit and formal specification of the MIS structure, roles, activities

and relations between involved partners agents. By the ontology, we mean the development of concepts and relations allowing to structure a MIS to favor the organizational interoperability i.e. to organize MIS in a process logic of taking care of the patient supporting services offers of partners agents allowing to answer opportunities of collaboration (see figure 4). The essential contribution of the organizational interoperability is that allows to our P2P based system easy forwards of the information, by the respect for the hierarchy of the MIS.

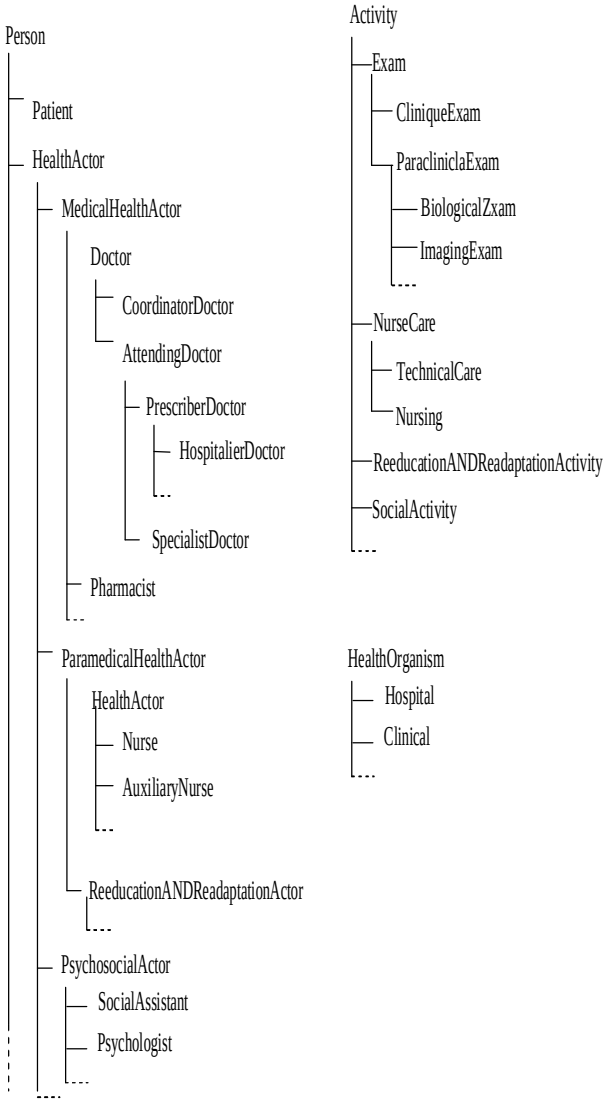

Figure 4: A partial view of concepts hierarchies of OntoMIS

5 OVERVIEW OF A CASE STUDY AND ITS IMPLEMENTATION

In this section, we use the agent technology as base of a case study in a real environment. This case study allows us to feign the MIS functioning modeled as being a multi-agent system. It is a question of taking care of a patient who suffers urinary pains. The MIS success leans on the distribution, the tasks coordination, the resolution of resources conflicts (which are not studied in this paper) of all the participating partners and their organization. The structure of global purpose is described in XML as follows (in the DTD):

```
<!ELEMENT Patient (Name, Surname, Address, Date_entry, Symptoms)>
<!ATTLIST Patient Patient_Nss CDATA #REQUIRED>
<!ELEMENT Name (#PCDATA)>
<!ELEMENT Surname (#PCDATA)>
<!ELEMENT Address (#PCDATA)>
<!ELEMENT Date_entry (#PCDATA)>
<!ELEMENT Symptoms (#PCDATA)>
```

The taking in charge of the patient (the global purpose) is the following one:

```
<?XML version='1.0' encoding='UTF-8'?>
<Patient Patient_Nss='1061008156'>
<Name> Boumali </Name>
<Surname> Ali </Surname>
<Address> 26, liberty street </Address>
<Date_entry> 05/04/2010 </Date_entry>
<Symptoms> urinary pains </Symptoms>
</Patient>
```

JADE [8] is the platform which gets closer most our criteria. It is a platform of agents' creation that takes into account FIPA specifications for the MAS interoperability. It supports the management of cooperative behaviours via the multithreading solution offered directly by Java. JADE supports P2P application (technical interoperability). The figure 5 represents agents' implementation in JADE, where every user agent is launched in a separate host and in an appropriate container. More particularly, figure 6 represents messages exchanged between agents.

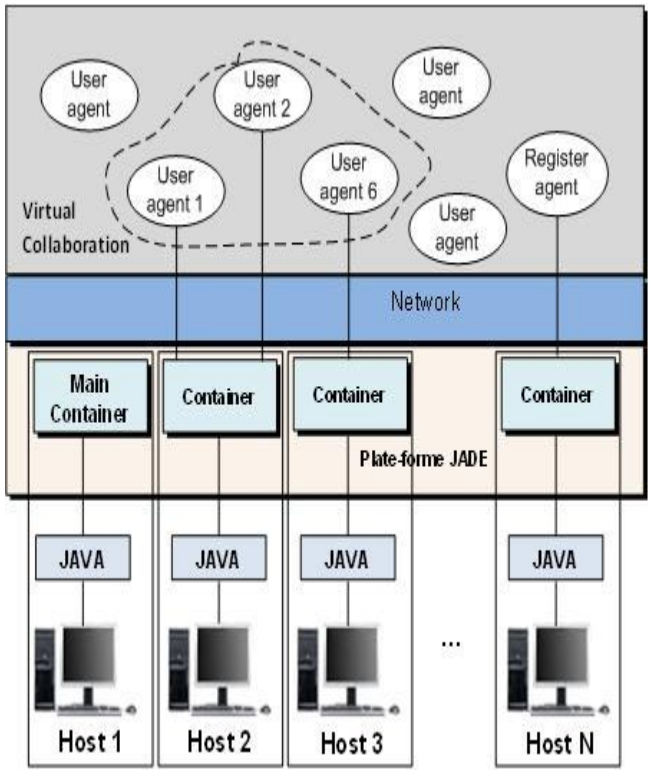

Figure 5: Implementation of architecture using JADE.

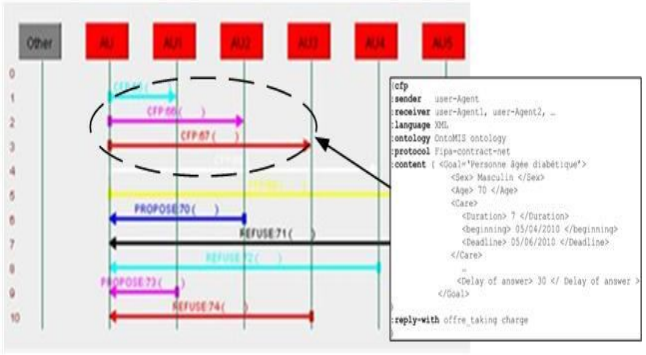

Figure 6: Simulation protocol of interaction between users agents.

6 DISCUSSION

We remarked in related works the lack of interoperable architecture based on unified concepts (standards and norms), that makes the appropriate functions for a medical system available on the other MIS (i.e. reuse) in a heterogeneous and distributed environment. Also, the architecture allows protecting the access, the sharing and the information treatment between various components of MIS. The proposed architectures remain local or regional what made the remark of certain authors. Needs in information and the manipulation functions of information are specific to each. Besides, we observed obstacles to produce valid information and to make appropriate decisions, considering the unsuitable, incomplete or ambiguous character of the available data (semantics). Indeed, there is no ontology universally accepted to represent roles and activities of actors in the medical information. Thus, the interoperability between various developed systems is really completely difficult. Indeed, difficulties met to develop and maintain MIS can be surpassed only: firstly by the choice of new models based on enough rich concepts and having mechanisms (such as the cooperation) which must be well adapted to MIS. The most emergent new concept for MIS cooperation is the approach of intelligent agent. Agents present very important characteristics, as the autonomy, the adaptability, the distribution, the intelligence and the mobility (for the mobile agents). So, they best agree to resolve certain problems in this context. Particularly, to resolve complex problems of a distributed way by intelligent autonomous agents which cooperate. This approach is very interesting and promising because it integrates profits of the intelligent agent. This search considered as very new and many points remain opened to the study and to the development. The second concerns the technological evolution which allows MIS' components to interoperate independently of their localization and of their software and material platform underlying. The third concerns the importance of the standardization stressed on the precise and sure transmission of any medical information through different systems. There are many organizations developing different standards at a national, regional and even international level. Nevertheless, there is no strategic vision which was developed to allow standards to collaborate. Therefore, it is necessary to consider the resolution of the following problems by taking into account the concept of MIS organization:

- The data heterogeneousness: it is a question of unifying structures and semantics of various sources' data.
- The processing and the sharing of information in a distributed environment: by taking into account the heterogeneity and the autonomy of systems.

The sharing of information is the keystone of any IS. Also, the security questions are extremely important in this domain, where the sensitive medical information is transmitted between actors. Appropriate measures must be taken to guarantee the confidentiality of medical information. So, it is necessary to emphasize in MIS stakes in terms of interoperability. Indeed, it is necessary to establish a methodology of development which takes in charge of the organizational, syntactic and semantic interoperability supported by architecture of interoperable MIS to assure the following objectives:

- Encourage the sharing of information, in the respect for the security and confidentiality regulations;
- Connect the professional interfering with its establishment and network of partners professionals;
- Connect the patient with services network (from a distance consultation, advanced telemonitoring, etc.);
- A regular revaluation of the situation;
- Improve the general organization of the work (e.g. coordination of interventions).

7 CONCLUSION

In this paper, we proposed agent, ontology and P2P based architecture, with the aim of increasing the MIS interoperability. We studied the organizational interoperability. We implemented our system with the JADE platform. Among objectives of our contribution, encourage the evolution of normalized standards to support the reuse and the interoperability in the field of the distributed medical information. Indeed, it is a question of resolving the organizational, technical, syntactical and semantic conflicts of the shared information to be able to cooperate. In the future, we intend to combine advantages of the used technologies to give more synergy to the interoperability to allow the re-use (e.g. Service Oriented Architecture). Certainly, it is a question of meeting new challenges, towards open and evolutionary care IS.

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