medical information system, agent, interoperability, ontology, standard

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A MULTI-AGENT ARCHITECTURE FOR INTEROPERABLE MEDICAL INFORMATION SYSTEMS

The Medical information systems evolve constantly. The quality of the medical information system relies on competences, qualifications, and the organization of the participating partners. Those last ones belong to heterogeneous and autonomous information systems. So, it is necessary to assure a permanent cooperation. This paper shows a coherent architectural framework that allows the development of interoperable medical information systems in measure or these systems evolve. The essential idea is to use concepts of multi-agent systems to perform the different activities of medical information system and thus, to adapt the solutions provided by the agent paradigm to solve the different problems encountered while establishing a medical information system.

1. INTRODUCTION

Information Systems (ISs) applied to the health sector, especially health care institutions today as a matter of fact, Radiology Information Systems (RIS), Laboratory Information Systems (LIS), Hospital Information Systems (HIS), etc. that support modern organizations, do not operate any more only in their own localization, but participate in dynamic environments to form cooperative Medical Information Systems (MIS) [7]. Indeed, the cooperation accords became desirable strategic options, rather inescapable. Some fundamental properties such as the scalability, interoperability [1, 9] and re-usability are required in MIS. However, these properties are difficult to implement when using traditional architectures based on centralized control. To satisfy these properties, the agent paradigm has received much interest. Doubtless, the Multi-Agent Systems (MAS) seem to be the most promising candidates for the development of MIS [4, 5]. The scalability property of MAS [6] seems appropriate to support the MIS in which, dynamic different levels of cooperation with different sets of partners could be established in the various phases of care. On the other hand, each IS can be seen as a network of autonomous entities. A state of the art concerning this work was published recently in [8]. 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). This paper shows a coherent architectural framework that allows the development of interoperable MIS in extent that these systems evolve. First we give a general description of the architecture and then we present its components and their functionality. We conclude by giving an overview of the implementation of our first prototype.

2. THE PROPOSED ARCHITECTURE

The main quality of MIS is to interoperate physical entities (ISs, people, etc.) while respecting their autonomy. These entities are autonomous in the sense that they operate without the intervention of other entities. These entities are not necessarily designed to work together. Each entity is implemented to satisfy local objectives. However, it may not satisfy some objectives if they exceed their know-how. In this perspective, the multi-agent paradigm provides concepts particularly interesting for the development of MIS: dynamic organization, self-control, decentralization, negotiation, collaboration, reuse, etc. Indeed, the paradigm of multi-agent can be used to support the reflection for the design and establishment of MIS. MAS are currently widely used, particularly for applications requiring complex interaction between multiple entities and human-machine interfaces. Indeed, MAS became a dominant paradigm in the field of development of complex distributed medical systems.

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Despite its simplicity, the proposed architecture presented on Fig.1 is called DAMIS (Distributed Agents for Medical Information Systems) arrives to take over the necessary concepts for cooperation and thus to solve a rational real problems from the complexity of modern medical applications. Indeed, it allows connect components ISs in the distributed and coordinated activities to satisfy organizational purposes. It is capable also of returning services belonging to each of agents available to the other agents. So, it is a new way of answering requirements, adapted of advantage to the current reality due to the simplicity of its structure.

The generic architecture DAMIS allows to support a heterogeneous environment in which several systems are ready to cooperate. This architecture is generic in the sense that it is independent of applications and medical application domain. The knowledge and control are distributed among all participating agents supported by heterogeneous and autonomous information systems. Each agent has the capacity to help other agents and humans during problem solving, sometimes in decision support. The aim is to permit loosely coupled information systems to interoperate (i.e. exchange data and information) in a diversity of healthcare delivery contexts.

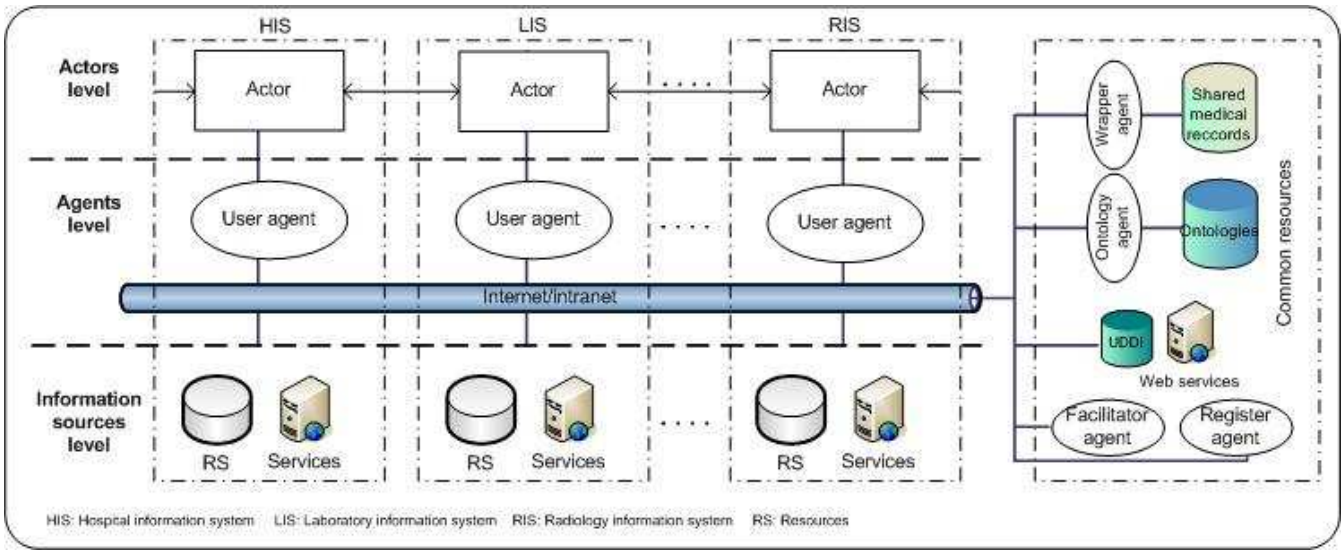

Fig.1. DAMIS: an agent based architecture for the MIS.

2.1. INFORMATION SOURCES LEVEL

This level includes in particular the existing ISs and other automated systems. These systems are developed using conventional technologies such as databases management systems, workflow and programming languages that run on the distributed software / hardware platforms. Originally, these systems are designed to meet local needs and not necessarily to work together. Each IS provides services that may be exploited by other IS. The publication of services available to user agents is made in the agent registry by a human or software agent. Each service must be independent of others to ensure its re-usability and interoperability. As there are common resources shared among all partners:

The shared medical records. This record plays a key role supporting the coordination, continuity and quality of healthcare systems. The shared medical records is an essential tool for sharing information, planning, tracking procedures and efficiency of taking care system, for decision making, research and continuity of care. It facilitates communication and the fluidity of information between agents within the system. That assures the circulation and sharing information throughout the patient's route of taking charge.

The ontologies. The MIS requires a cooperation of several actors. These last ones share a large number of medical information. The diversity of actors involved in managing care and their specialties (doctors, nurses, etc.) can result in semantic conflicts during the interpretation of transmitted medical information. The problem is that there is no established consensus on the definition of various terms used.

These terms denoting concepts risk ending in the multiple interpretations. This kind of semantic ambiguity may result in misunderstanding. For that, the goal of ontologies is to have a common vocabulary between agents to share collaboratively an understanding common structure of information, easily communicate reason or solve problems and make decisions. This avoids any ambiguity in the communication or information exchange, through the formal syntactic and semantic representation of knowledge specific to the domain of MIS.

The web services. The aim is to expose services in such an environment, regardless of software and hardware platforms. The web services make interoperable remote and heterogeneous information systems for rapprochement of partners. For example, the terminology is the most requested service on the web. In addition, statistics are updated continually through the health information system.

2.2. THE ACTOR LEVEL

In the proposed architecture, actors of MAS are represented by software agents that communicate and cooperate to meet their objectives. Each actor belongs to IS. This last one has its own local source of information and its own services.

2.3. THE AGENT LEVEL

Agents involved in our architecture are diverse in their specific functions and domain of special activities. It's a real collaborative multidisciplinary team, they participate in the development and implementation of decisions by combining their efforts, and constantly adapting to evolutions of the system. We distinguish the user agents, the facilitator agent, the register agent, the wrapper agent and the ontology agent. The user agents involved at certain moment to accomplish specific tasks that correspond their competence (knowledge) and their capabilities during the process of MIS (know-how). Our architecture is fully distributed in the sense that each agent communicates with any agent of system without a mediator (a total distribution of knowledge, competence and tasks on user agents).

The model of proposed agents is adapted to the context and specifics of our system. It allows in particular realizing processes of search, selection, negotiation, coordination and cooperation that we do not treat in this paper. As it allows agents to accomplish their tasks, to meet needs of services from an agent to another i.e. to cooperate. Indeed, the choice of agent's model is essentially based on needs that are expressed to the agent.

2.3.1. THE USER AGENT

The user agent represents an actor of an IS that participates in the taking care of patient. It cooperates with other agents of the system to achieve its goals. Its components are (see Fig.2):

The user interface. It allows interaction between user agent and human agent (this latter plays the role of partner or expert). This is an interface of assistance for the human agent, this last one has decision-maker's role, whether to be a part of the MIS by accepting terms of the contract with the facilitator agent, Either for decisions concerning the exchange of the confidential information.

The coordination module. This module takes into consideration all of the overall process of coordination. It takes as input parameters a set of goals (the interpretation results of messages by the user interface and the communication module) and produces a plan which satisfies these purposes. The coordination module consists of sub module of planning for the orientation and the organization of the local tasks and a sub module of negotiation for tasks allocation, the resolution of conflicts and the convergence towards accords with partners.

The individual knowledge module. An agent must have the ability to represent knowledge i.e. to remember and reason above. Thus, the individual knowledge base represents all information and knowledge about the agent himself: its abilities and competences, the state and the charge of the current task. Accordingly, each user agent of MIS keeps any information relative to its interventions, activities, etc.

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

The communication module. This module manages the interaction between an agent and the outside world such as other agents (acquaintances). It contains all processes of taking charge of messages from either the facilitator agent or another user agent. This module is responsible for all functionalities of sending and receiving messages.

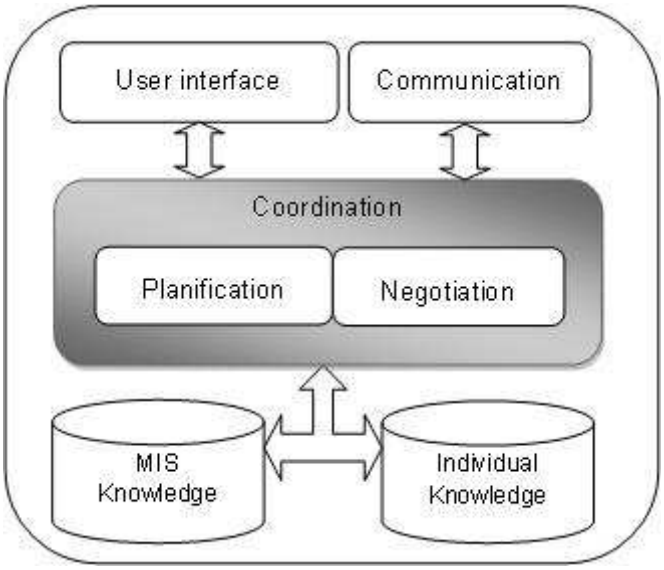

Fig. 2. The structure of a user agent.

2.3.2. THE FACILITATOR AGENT

It is able to establish a conversation with the different agents (see Fig.3 for its components). Through the facilitator pass any research of pertinent user agents (partners) to cooperation. As it can act as an expert for any health care system: (i) Research and intelligent selection, dynamic and optimal user agents (partners) (ii) The ease of negotiation mechanism (exploitation's Knowledge of the choice criteria of the user agents to interrogate) (iii) Transmit knowledge to the user agents and\or the human actors via *the expert interface* and *the user interface* (iv) Knowledge on the user agents that can realize very specific tasks. The search and the partners' selection and the negotiation adapt themselves perfectly to specifications of the facilitator agent.

The coordination module. It allows to the facilitator agent to negotiate with the partner agents, searched and selected before using the sub modules of *research* and *selection*. For the *knowledge* base, it contains all the information for the MIS in which it operates. On the other hand, the facilitator acquires new knowledge from past experiences.

The communication module. This module is responsible for the process of sending and receiving messages, exchange of information, communication with the user agent via a communication language. It contains all processes of management messages, including: receiving, filtering and translating incoming messages and the formulation and sending of outgoing messages.

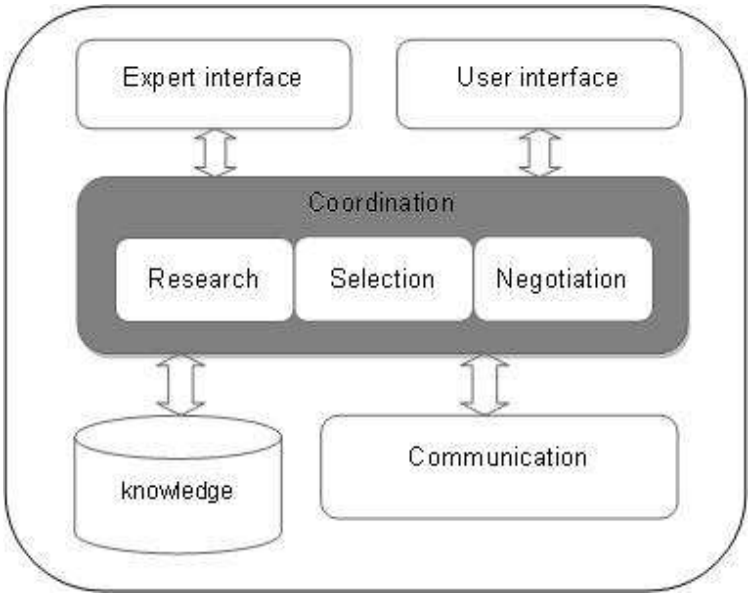

Fig. 3. The structure of the facilitator agent.

2.3.3. THE REGISTER AGENT

It plays the role of directory. It collects names and addresses of participating agents in the system. This agent allows finding agents of the system capable to assure a certain activities. It maintains for this a list of system agents and their competences.

The register (yellow pages and white pages). The white pages include a list of all user agents that announce their services and their activities domains through the yellow pages. These last ones record profiles of agents (competence, specialty, experience, etc.). These two pages are continually updates by the register agent. These pages allow a user agent (software or human) to select the profile of appropriate user agents (partners), through interaction with the register agent.

The user interface. It allows direct interaction between the register agent and the human agent. This allows to human agent to create or modify its profile, or to consult the profile of other interesting agents for a partnership.

The communication module. This module manages the interaction with user agents and facilitator agent. This module is responsible for all functionalities of sending and receiving messages.

The processing module. This module manages all operations concerning the registration of the profile and competences of a user agent.

2.3.4. THE WRAPPER AGENT

He answered questions from the user agents and through *the user interface* for human actors. In particular, it must manage all associated databases (medical record) to make their manipulation uniform, regardless of languages and data structures they support via *the module of control and managemen*t. It also manages data security and protection of privacy of patients and partners (confidentiality). Thus, it uses authentication and encryption mechanisms. Indeed, it controls all the formulated queries. The solution of the wrapper agent allows a full control for the partner agents the voluntary or involuntary access to shared medical records, which may contain sensitive data. The authentication system allows to partner agents to prove easily their identities and get access to shared medical records without threatening the security of the MIS. The wrapper agent has the advantage of supporting the scalability, adaptability, reusability, independence and interoperability.

The user interface. It allows direct interaction between the wrapper agent and human agent. What allows this last one to formulate queries. Interoperability of MIS also includes two important aspects that are data security and privacy of patient and partner agents. These latter can be neutralized by using

authentication and encryption. These two techniques seem to us the adequate solution to both cited problems, what assures the cooperation of agents.

2.3.5. THE ONTOLOGY AGENT

This agent manages all access to ontologies. It answers queries of software agents through *the communication module*. It answers queries formulated by human agents via *the user interface*. The purpose of the use of ontology agent is to increase the flexibility of the system.

3. A PROTOTYPE IMPLEMENTATION

In order to show how DAMIS can be used and the feasibility of using it, we give a prototype implementation. We implemented a prototype using standards. We used XML technology to represent the information exchanged between agents (the possibility of using standards like HL7 v3 message, CDA, DICOM, etc. encoded in XML) via the standard communication language ACL-FIPA [3] (syntactical interoperability). The communication is based on a generic model of domain ontology called OntoMIS (Ontology Medical Information System). We focus on its interest. We determined an explicit and formal specification of the MIS structure, roles, activities and relations between involved partner agents (semantic interoperability). For the development we opted for Java. This language is chosen for its portability and its considerable contribution in the application development. JADE [2] 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 behaviors via the multithreading solution offered directly by Java. JADE supports P2P application (technical interoperability). The Fig.4 represents agents' implementation in JADE, where every user agent is launched in a separate host and in an appropriate container. More particularly, Fig.6 represents messages exchanged between agents to cooperate.

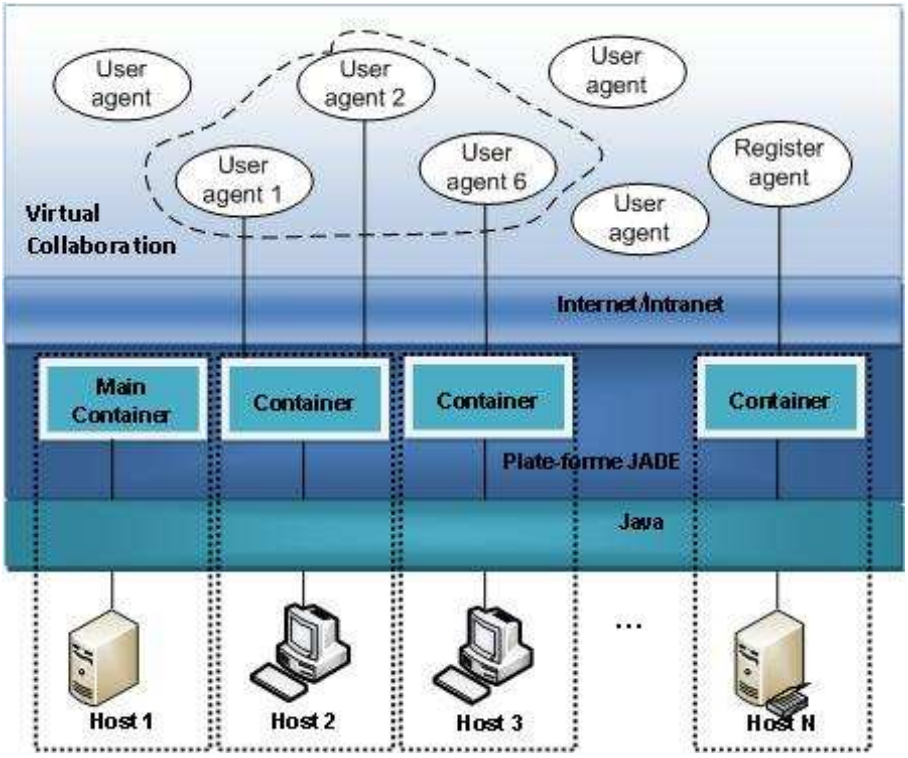

Fig. 4. Implementation of architecture using JADE.

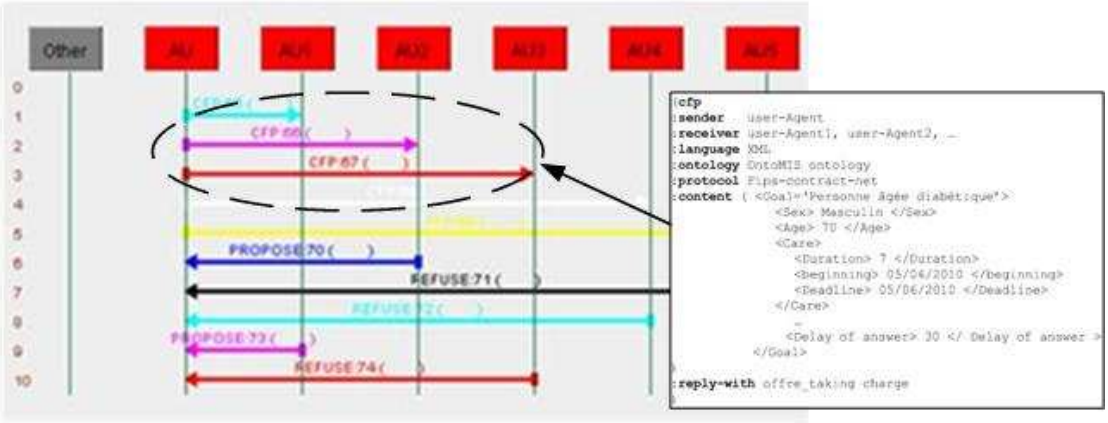

Fig. 5. Simulation protocol of Interaction between user agents.

4. CONCLUSION

In this paper, we proposed an agent based architecture in the aim of increasing the MIS interoperability (open dynamic multi-agent environment). The use of agents in the medical domain is motivated by the multitude of aspects that the agents can cooperate, analyze during the elaboration of diagnostics and the realization of different tasks in healthcare. 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 technical, syntactical and semantic conflicts of the shared information to be able to cooperate. In the future, we intend to combine advantages of the other technologies to give more synergy to the interoperability to allow the re-use (e.g. Service Oriented Architecture based Peer to Peer). Certainly, it is a question of meeting new challenges, towards open and evolutionary healthcare information system.

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