Improving the Quality of Health Service with Smart Communication

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Abstract. This article presents the Hippocrates of Cos Multi-Agent System 1.0 (HC-MAS 1.0) a multi-agent system (MAS) based on PAINALLI, an open MAS architecture based on virtual organizations. PAINALLI utilizes an agent-based model to facilitate the development of MAS and optimize the communication process in business organizations. The architecture and the system can access information and services ubiquitously from either land or mobile devices connected to wired or wireless networks. HC-MAS 1.0 supports the communication process for the healthcare services of a hospital. This paper presents the results obtained from the implementation of the system and demonstrates the advantages produced by the use of this new technology.

Keywords: Quality, medical informatics, HCE, HL7, DICOM, ISO 9000 y 15489, organizational communication, open MAS and virtual organizations.

1 Introduction

Communication is one of the fundamental processes in which individuals engage throughout their lifetime. It is the tool that society uses to advance towards the compliance of the demands and needs of its members. As with specific societies, business organizations require the tools, systems and models that allow them to

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adapt to the new knowledge-based society on a daily basis. They need to adapt their strategies in order to become the type of business organization that learns and focuses on teamwork, the optimal use of human resources, flexibility, and the involvement of professionals in an innovative corporate culture that is fully integrated within a society. Such organizations emphasize just-in-time objectives, quality, efficiency and the continual improvement of processes [1].

Among the most prominent MAS objectives is the ability to build systems capable of autonomous and flexible decision-making, and to cooperate with other systems within a ¨society¨ that meets the following requirements: distribution, continual evolution, flexibility to allow members (agents) to enter and exit, the appropriate management of an organizational structural, and the ability to execute agents in both multi devices and other devices with limited resources. It is possible to meet these requirements with the use of an open system and virtual organization paradigm [3].

Open MAS [4] can be thought of as distributed systems in which the agent population interacts and exhibits various behaviors. Unlike distributed systems, the cooperation between agents is not determined during the design process, rather it emerges upon execution.

The objective of this paper is to present the HC-MAS 1.0 system, an open MAS that can manage the communication process within healthcare environments. The system is based on the PAINALLI architecture, which is used for developing open MAS for virtual organizations. This makes it easier to develop open MAS systems that can optimize the communication process in business organizations by using an agent platform, which can be accessed via fixed and mobile devices such as PDAs (Personal Digital Assistant), smart phones and personal computers connected to wired and wireless networks.

The majority of the methodologies used in the development of MAS are an extension of existing methodologies from other fields [5] . Some are based on specific agents and architectures [6], while others are geared towards organizations, Agent-Group-Role [7], Tropos [8] , MOSEInst [9], OMNI [10], and E-institutions. There does not currently exist a methodology for developing MAS that is based on organizational structures and that would allow direct communication between the various communicative aspects within an organization. Nor is there a methodology that allows a complete specification of the system´s social structure. PAINALLI is based on THOMAS (MeTHods, Techniques and Tools for Open Multi-Agent Systems) [12], a system that strengthens the definition for the organizational model and the specific methods for the development of open MAS focused on the concept of organization.

Poor internal communication is one of the weaknesses that most affects the development of an organization. For this reason, it is necessary to create a new business model in which communication assumes a critical role [14].

The following section describes the components of the architecture. Section 3 presents the HC-MAS 1.0 system, and section 4 offers the results and conclusions.

2 Painalli Architecture

PAINALLI is an architecture that is used for developing open MAS based on virtual organizations. It focuses specifically on the communication process in business organizations. The communication process in PAINALLI is based on the use of templates and metadata that are associated with attached files. The input methods are based on international standards: ISO 15489 e ISO 9000:2000.

The goals for the architecture were rooted in the exchange of messages and attached files as a support mechanism for an organization´s communication process. The primary objectives are to manage personal and business related messages, documents, user accounts, user groups, and agendas. All of the information is stored and transferred with encryption algorithms.

Users are able to manage their own messages, which are created from templates: scheduling, information, question and request. The sender is notified once the message has been read. A conversation is a set of messages with a common theme, which is ¨owned¨ by the original sender. Only the original sender can eliminate messages and conversations.

The architecture administrator is responsible for managing the templates and the input methods, both of which can be tailored to the specific needs of the organization. The administrator manages the users, who can be grouped according to the organizational structure.

2.1 Architecture Components

PAINALLI is composed of: applications and services, communication protocol, and an agent platform

✓ **Applications and Services**
The combined set of applications and services proposed in PAINALLI constitute the foundation that support the functionalities given to the users and developers who can now benefit from web services such as: web interoperability, offering services through an open exchange of applications and data, offering remote procedure services, and requesting procedure services through the web.

The programs required for accessing the system functionalities are the applications. They must be dynamic and able to adapt to their context, and capable of reacting differently to particular situations and the type of service requested. The applications make it possible for the services to be executed locally or remotely, through computers or mobile devices. The low processing capability of the applications is irrelevant since computing tasks are carried out by the agents and services located in the devices specifically intended for these activities.

Services constitute a set of activities that are meant to respond to the needs of the requester. They are programs that provide methods for accessing databases, manage connections, analyze data, obtain information from external devices, publish information, or even use other services to carry out a particular task.

PAINALLI uses service directories that can be managed dynamically according to the needs of the developers and the demands of the users. Both services and applications in PAINALLI are reusable and function independently from the system to which they are offering their functionalities and from the programming language used by the platform agents.

✓ **Communication Protocol**

Messages are transmitted in PAINALLI through a communication protocol that allows applications and services to communicate directly with the agent platform. The SOAP (*Service Oriented Architecture Protocol*) [15] specification serves as a reference for establishing the communication protocol in PAINALLI and allows the programming language to function independently. Agents use the ACL (*Agent Communication Language*) specification in FIPA [16] to communicate. ACL messages are objects and require protocols to allow their transport, which is provided by RMI (*Remote Method Invocation*). This specification is very useful in the event that the applications are executed from mobile devices, which have limited processing capabilities.

✓ **Agent Platform**

The set of roles that comprise the agent platform in PAINALLI can control and manage all of the architecture´s functionalities: applications, services, communication, output, reasoning capability and decision-making. Any modifications on agent behavior are carried out according to user preferences, knowledge obtained from previous interactions, and the available options for responding to a particular situation.

Figure 1 shows the elements that comprise PAINALLI.

Fig. 1 PAINALLI architecture

In PAINALLI, the agents take on the following roles, which will subsequently help the external agents in the case study: **IA**: Interface agent, **ACA**: application communication agent, **CSA**: communication services agent, **DAA**: document administrator agent, **MAA**: message administrator agent, **DiA**: service directory manager agent, **SeA**; security manager agent, SuA: supervisor agent, **KEA**: knowledge extraction agent, **MA**: manager agent.

With both PAINALLI and web services, security has to control the users and the access given to each of the operations exposed through WSDL (*Web Services Description Language*) to all other users. It is also necessary for security to provide a set of bookstores that make it easy to work with security APIs for both the client and the server. When using SOAP protocol, one way of dealing with security is through WS-Security (*Web Service Security*), which allows the exchange of security Tokens between client and server (End-to-End security). This exchange of Tokens, as well as the mechanisms associated with encryption and signature, makes it possible to ensure the authentification, integrity and confidentiality of the operations that are carried out.

3   HC-MAS 1.0 System

The HC-MAS 1.0 system supports the administrative and medical communication process in a hospital. A hospital is an organization in which a great deal of information is generated and used, and where the key players in the process can be grouped into three categories: sources, recipients and intermediaries.

The information system in a healthcare environment, particularly that of a hospital, must be able to adopt the messages, formats, code and structure of medical histories in order to allow interoperability within the system.

The use of standards permits an increase in security, lowers costs and encourages market development. The implementation of standards and norms for all users, manufacturers and service providers, promotes the creation of more economical and stable solutions.

A document is one type of standard that is established by consensus, approved by a recognized entity, provides rules, guides or characteristics needed to carry out activities [19] . The use of standards makes it possible to achieve interoperability within the system and its components.

Interoperability is the ability of two or more systems or components to exchange information and use the information that has been exchanged. Syntactic interoperability (operative or functional) is the structure of communication, the equivalent of spelling and grammar rules. H7 (Health Level Seven) is one type of method that can be used to exchange messages or data within a health environment. Semantic interoperability contains the meaning of the communication, the equivalent of a dictionary or thesaurus. The CDA (Clinical Document Architecture) within HL7 is a structural and semantic. It is based on XML language, and SNOMED (Systematized Nomenclature of Medicine) terminologies and LOINC (Logical Observation Identifiers Names and Codes), both of which are examples of semantic standards.

For messaging and data exchange, HC-MAS 1.0 uses one of the HL7 standards, while for image exchange it uses DICOM. In order to best integrate the data and the HCE structure, the CDA standard proposed by HL7 is followed.

The following section presents the various roles that HC-MAS 1.0 needs to execute all the actions described in PAINALLI, in addition to the communication process for a hospital.

3.1   Agent Platform

After analyzing the communication process, the information, and user requests made by hospital personnel, it is possible to see how these elements can form an adaptive virtual organization whose administration depends on the variability of its products, users, etc. [20]. In order to completely satisfy the demands of the users in the communication process of a hospital, as well as those of the agent roles presented in PAINALLI, new roles can be added using the system´s open architecture. The new roles allow the system to conform to HCE by managing patient data, appointments, lab analyses, clinical tests, diet and patient care.

Figure 2 shows the PAINALLI architecture and the health agents that together manage and formalize the communication process in a hospital.
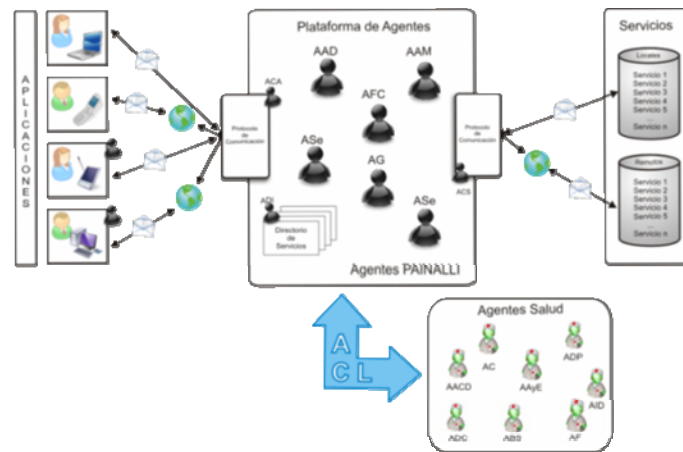

Fig. 2 Scenario of the communication process in a hospital

Health agents take on the following roles: **PDA (*Patient Data Agent*)**: manages the administrative and personal data of the patients; **SA (*Scheduling Agent*)**: manages appointments; **ALA (*Analysis and lab tests agent*)**: handles order forms for analyses and clinical studies; **IDA: (*Image diagnostic agent*)**: keeps track of messages for managing hemoderivative transfusion devices; **PA (*Pharmaceutical agent*)**: controls the templates for medical prescriptions; **CDAA (*Clinical document architecture agent*)**: assumes the same responsibility as the AG in PAINALLI, but with the roles corresponding to health agents.

4   Results and Conclusions

HC-MAS was installed in a hospital in Salamanca, Spain. Several interviews were carried out in early 2008. During the same period a number of hospital activities were timed. The goal of both activities was to have reference data to compare against the results obtained after installing the system.

Because the purpose of this paper is not to provide a full description of the various quality indicators, only a few descriptions will be identified. The results presented in this section are divided into 3 indicator groups. For each group there will be 2 variables described in detail, which makes it possible to gain an insight on: doctors, nurses, managers, patients and caregivers.

➢ **Assistance Indicators**

This information allows us to understand how much time doctors and nurses invest in writing reports and connected to the system.

Medical histories are the most important documents in a health system since they contain all of the information related to each of the patients. The indicator shows a 20% decrease in preparing these documents, which is due to the fact that HC-MAS can ¨write¨ the information directly in an electronic document. The indicator that most significantly demonstrates the effectiveness of using HC-MAS 1.0 is the interconnectivity that doctors can have with other doctors or clinical services in the hospital. What previously took on average 5 days to complete can now be done immediately.

➢ **Management Indicators**

Some of the different management indicators include: confirming patient eligibility and managing the costs involved in image diagnostics.

Confirming patient eligibility is an important step towards ensuring that services are rendered as quickly as possible, and that whoever receives treatment is eligible. A decrease of 32.44% in the waiting period involved in confirming eligibility makes it easier to grant services and more importantly ensures that 100% of the patients receiving services are in fact eligible. The indicator for managing the costs involved in image diagnostics is reduced significantly (90%) because with HC-MAS 1.0 it is no longer necessary to print images.

➢ **Patient and Caregiver Satisfaction Indicators**

Because the patients and healcare providers receive the services directly, their input carries more weight in the evaluation of system quality. Some of the indicators that demonstrate the level of satisfaction are: (i) the waiting time between appointments, which fell by almost 28% making patients feel that they are being better attended; (ii) the number of complaints, which fell from 84 to 35, resulting in 49 fewer complaints. To support this indicator, we analyzed the complaints. Of the 35 that were brought forth, 20 were related with variables from HC-MAS and 15 were related to aspects, such as administration and billing, that will be addressed in version 2.0.

The indicators reflect a significant decrease in time, which can now be spent on activities related to the professional and personal development of the employees.

One of the advantages of PAINALLI is the flexibility for adapting to different systems. HC-MAS 1.0 takes the agent platform architecture and adds new agents to solve the problem of communications in public or private healthcare environments.

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