A FIRST APPROACH FOR A REGIONAL WIDE VEPR

Pedro Vieira-Marques
Informatics Department, Faculty of Medicine,University of Porto
CINTESIS, Faculty of Medicine, University of Porto, Portugal

Arthur Cunha, Luís Antunes
LIACC, Faculty of Science, University of Porto, Portugal

Ricardo Cruz-Correia, Altamiro Costa-Pereira
Department of Biostatistics and Medical Informatics, Faculty of Medicine University of Porto
CINTESIS, Faculty of Medicine, University of Porto, Portugal

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Abstract: Patients visit multiple health institutions and leave a trail of information scattered around hospitals, healthcare centres and laboratories. Information availability is of major importance in healthcare delivery. Most of the Electronic Patient Record systems are unarticulated and usually address only the specificities of a single medical specialty. Virtual Electronic Patient Records such as MAID (Multi Agent system for the Integration of Data) system provide for the necessary means for intra-institutions departmental information integration. In this paper is presented a mobile agent based extension to the agent based MAID system in order to enable inter-institution patient data integration. This system was designed as a MAID extension with additional patient data integration features. In order to accomplish this, modules for external data discovery and collection where developed using mobile agents. Data collection activities are trigged by scheduled clinical events. The system is intended to enhance an existing institutional system taking it beyond the institutional barrier providing health professionals with a more complete patient clinical history.

1 INTRODUCTION

Through the years Electronic Patient Record (EPR) systems have been developed in order to provide physicians with structured and helpful information. However most of these systems are unarticulated and usually address only the specificities of a single medical specialty. Integration of healthcare Information Systems (IS) is essential to support shared care in hospitals, to provide proper care to mobile individuals and to make regional healthcare systems more efficient.

Healthcare is recognised as one of the most important areas for applications and services integration.

However, to integrate clinical IS in a way that will improve communication and data use for healthcare delivery, research and management, many different issues must be addressed (Berg 2001; Littlejohns, Wyatt et al. 2003). Consistently combining data from heterogeneous sources takes a great deal of effort because the individual feeder systems usually differ in several aspects, such as functionality, presentation, terminology, data representation and semantics (Lenz and Kuhn 2002).

Successful integration seeks ubiquity – data stored at one place should be available elsewhere; consistency and integrity – different data items stored within the system should not be contradictory and integrity constraints should be maintained; synchronization – in particular, concurrent data access should not result in inconsistent data; single system image – the user should be able to interact with the system via a singe standard user interface; and finally transparency – the user should not be aware of heterogeneous system components.

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Multiagent systems can successfully solve problems where the required knowledge is physically distributed in several places (for example, they can gather patient data from different medical institutions or discover distributed e-health services) (Moreno 2006). Previously, we have developed MAID (Multiagent System for Integration of Data) (Cruz-Correia, Vieira-Marques et al. 2005), an agent-based system that provides access to patient data that's scattered between different units of major Portuguese hospital. It has been running for two years, having integrated (searched, verified, collected and stored) over 2 millions clinical records.

In (Vieira-Marques, Robles et al. 2006) we proposed a model for a medical-information-gathering system that addresses issues such as inter-institutional patient health data integration, the retrieval of momentarily unavailable online remote data, and secure data access and transport. In this model, clinical events scheduling trigger agents to gather information for a particular patient clinical history, making that history as complete as possible when those events occur. Integration efforts are directed at clinical documents and not at the data themselves.

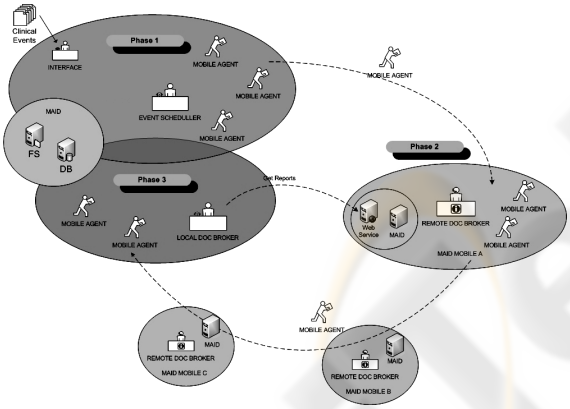

Figure 1: MAID Mobile model description.

In this paper, we describe a pilot implementation of the model which is focused in gathering information from multiple institutions, aiming at creating a first approach to a national wide Virtual Electronic Patient Record (VEPR).

2 METHODS

The system design was divided in three phases. To each phase corresponds one functional moment of the system (Fig. 1).

2.1 Events Management Phase

This is the first phase and corresponds to the management and scheduling of new events like consultations or surgeries. These events trigger actions for information search and retrieval. The Scheduler Agent (*SA*) manages the events and a set of information search and retrieval Mobile Agents (*MA*). To each patient a set of remote places where it is known to exist clinical information is stored. This list will grow has new places with information are discovered.

2.2 Information Search Phase

The second phase consists on a search performed by *MA* that will move between remote systems looking for information (exams, lab reports, etc) of a designated patient. If any documents are discovered references are collected and stored.

Besides clinical information, *MA* will ask for additional platforms where it is known for the patient data to exist. If other platforms are provided then they are added to the agent itinerary.

2.3 Document Retrieval Phase

At this stage, the process of searching for information references has ended and the collected references have been stored locally for retrieval. This retrieval will make use of basic remote transfer services using ftp or http urls or trough interfacing web services. After collection actions all the information is made available to the end user.

3 RESULTS

A set of agents was implemented using JADE platform and are described in the following sections along with their interactions while pursuing the designated objectives for each stage.

3.1 Scheduler Agent

This agent (*SA*) is in charge of scheduled events and *MA* management.

When some event is scheduled the *SA* constructs two itineraries, one with the remote systems that are known to have patient information and other with the complementary MAID systems retrieved from a directory services agent. These itineraries are delivered to two independent *MA*. Upon *MA's* return this agent is notified that the process is finished and

the *MA* have returned with the collected information. This agent will also receive a message from the Local Broker Agent (*LBA*) informing about referenced documents retrieval success in order to eliminate the event from its list.

3.2 Mobile Agent

The *MA* actions are crucial to the purpose of this system as they are the ones in charge of discovering and carrying new information about a given patient.

These agents' actions are implemented using a Finite State Machine (*FSM*) which describes its roles and roles transitions during the different stages of moving, remote systems interaction, etc.

As soon as the agent receives the message from the *SA*, it saves the necessary data (itinerary and patient id) and moves to the first place. While in the remote platform, messages are exchanged with the remote broker agent (*RBA*). This message exchange has the purpose of obtaining the new local interface role, allowing the *MA* to retrieve the document references. During the initial exchange of messages a simple authentication is performed.

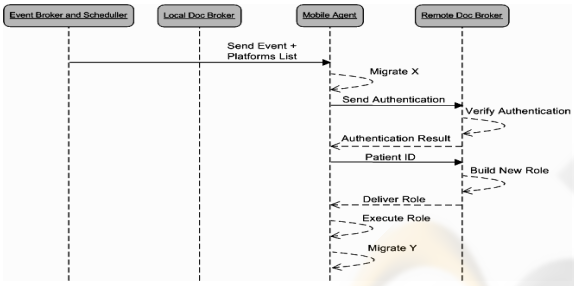

Figure 2: Agent interactions taking place during Information Search Phase.

As soon as the *MA* receives the role, it adds it to its *FSM* defining the necessary additional state transitions. From this moment on the agent is ready to get existing data through the execution of the new role. The retrieved data include a document reference list and a list of platforms that the visited system knows to have documents related to the patient the *MA* represents. By doing so, it will discover new sources of information. When the *MA* finishes its itinerary it will go back to the original platform. Upon arrival he notifies the *SA* of its return and delivers the gathered information to the *LBA*.

3.3 Remote Broker Agent

This agent stays in the local system and acts as an interface agent to incoming agents. It has to be implemented in accordance to each platform specificity, as all remote system at this point are MAID systems they are implemented the same way in all nodes. It is in charge of authenticating and providing the interface behavior to the incoming agent.

3.4 Local Broker Agent

This agent is in charge of receiving the result of the references retrieval process. After receiving new references from the *MA*, it stores them into the database and starts the document retrieval process trough the external services provided by each platform. After the documents being retrieved they are made available to the end user (Doctor, Nurse, etc) through existing user interfaces. The documents are saved in the file system digitally signed, guaranteeing the documents integrity.

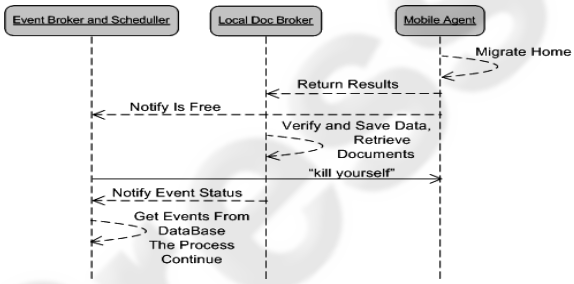

Figure 3: Agent interactions taking place during Document Retrieval Phase.

3.5 Agent Interactions

The UML activity diagrams describe the interactions between the different agents during information references search (Fig. 2) and document retrieval (Fig. 3).

4 DISCUSSION

This prototype extends the MAID systems by implementing a set of interfacing agents enabling the retrieval of remote documents. It addresses a scenario where multiple MAID systems coexist. We feel that multi-agent technologies can help implement integration between heterogeneous healthcare Information Systems in a satisfactory manner.

4.1 Integration Achieved

Regarding **ubiquity**, our implementation enables the exchange of information between each integrated system in a similar way. All information is

equidistant to each system. To face the problem of latency of communications, or even momentary lack of connectivity between different institutions when the healthcare professional needs the patient information, the system tries to collect useful patient data a prior, i.e., before the user request. Scheduled appointments trigger data discovery and report collection. Agents facilitate ubiquity as they allow MAID to operate in an asynchronous faction, which is more powerful than other technology solutions like web services that rely on synchronous communication.

Regarding **synchronization**, our proposal takes two different approaches. When integrating patient data in an institution, MAID collects all updated reports from the departmental IS so that its local repository stays updated. In this scenario on the other hand, when integration occurs between different MAID systems our method is more like **lazy synchronization**, i.e., the information is updated only when a healthcare professional access to the system is scheduled. Although, this approach may raise problems in unscheduled accesses, we feel that full synchronization stresses network resources too much.

Although **single system image** is usually regarded as being a user interface issue, MAID delivers the same functionality of single image not to human users but to requesting systems that may have user interfaces themselves.

Consistency and integrity were not a major concern in this implementation. Nevertheless it should be noticed that MAID has already some data quality checking in place, namely to detect wrong patient identifications (Cruz-Correia, Vieira-Marques et al. 2006). For full consistency checking, it is essential to have documents introspection which stresses the use of informatics standards like XML to describe documents, or even healthcare related standards like HL7-CDA or OpenEHR. Unfortunately, the Portuguese reality is still far from having healthcare IS that give access to their data through this standards.

Transparency is very difficult to obtain when dealing with documents generated in heterogeneous IS, because they lack normalization regarding presentation. To achieve a high level of transparency it is essential to use structured documents (e.g. XML).

4.2 Implementation Issues

By providing interfacing behaviours to incoming mobile agent there is no need for complex interactions reducing interface agent congestion which would arise from multiple agents requesting database queries.

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