Toward a Multi-Agent Model for the Care of Patients at The Emergency Department

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Abstract

Abstract: - Though multi-agent systems have been explored in a wide variety of medical settings, their role at the emergency department care level has been relatively little investigated. In this paper, we propose a tool to assist decision-making process for the care of patients at the emergency department. This tool aims to improve the quality of care within the emergency departments with rapid access to pertinent data, integration of care's protocols and assures knowledge of the quantity and the quality of medical activity. This multi-agent model was adopted to define the behavior of entities by distributing data and tasks in an attempt to explain and predict events in the emergency department. The agents of our model acts as a collaborative team of specialists.

Key-Words: - Multi-agent system, Emergency department, Optimization, Cooperation, JADE.

1 Introduction

Historically, the emergency department (ED) was the main gateway to the hospital, and an almost obligatory passage for patients before their admission to most hospital services. The ED is a hospital or primary care department that provides initial treatment to patients with a broad spectrum of illnesses and injuries, some of which may be life-threatening and require immediate attention. Emergency departments developed during the 20th century in response to an increased need for rapid assessment and management of critical illnesses. This steady increase in the attendance of emergency services is a common phenomenon to all countries that have it. In current systems of health, the emergency departments have become important entry points of access to medical care provided to patients. Upon arrival in the ED, people typically undergo a brief triage, or sorting, interview to help determine the nature and severity of their illness. Individuals with serious illnesses are then seen by a physician more rapidly than those with less severe symptoms or injuries. After initial assessment and treatment, patients are either admitted to the hospital, stabilized and transferred to another hospital for various reasons, or discharged. The ED is also a unit of the hospital that is offered within an appropriate time and by an interdisciplinary team of professionals. The staff in emergency departments not only includes doctors, nurse practitioners but physician assistants (PAs) and nurses with specialized training in emergency medicine.

In recent years, research in multi-agent systems is exploring the advantages offered by the emerging multi-agent software engineering paradigm. By focusing on the relationship between an entity in the real world (an individual, a relationship, an organization) and its corresponding entity in the

"electronic world" (an agent, a relationship between agents, a set of agents), design can become easier and quicker. As a result, interesting multi-agent based models of complex social structures have started to emerge. The ED care system is a perfect example. It offers extremely rich interdependent sets of relationships and necessitates coordination between several tasks. Therefore, ED staff must interact efficiently. That's why we need to balance the human resources (medical staff) and material resources (treatment rooms, hospital beds, medical equipment etc.) within the emergency departments.

This article explain how agents can exploit their capacity in order to support ED staff in making decisions, either by cooperating with other agents, or with human actors that they represent in the virtual system. For instance, when a patient arrives at ED, he must perform several tests to confirm his diagnostic. Fulfilling these tests requires the availability of the necessary material for all operations and qualified staff. Furthermore, many medical procedures now involve several individuals whose decisions and actions need to be coordinated if the care is to be effective and efficient.

To provide the appropriate software support for such coordinated health care management at the ED we have chosen to adopt an agent-based approach.

The remainder of this paper is organized as follows: some of the health care applications based on agent metaphor are discussed in section2. A general description of the problem is illustrated in the section 3. The global architecture of the multi-agent system is proposed in section 3. Section 4 describes each agent of our architecture.. The implementation of the model is described in section 6. Conclusion and future work are addressed in section 7.

2 Related Work

The software-agent paradigm [2] [3] [4] was adopted due to its autonomous, reactive and/or proactive nature, which comprises important features in real-time application deployment for dynamic systems like the one under consideration. Furthermore, software agents can incorporate coordination strategies, thus enabling them to operate in distributed environments and perform complex tasks. Generally speaking, software-agent technology is considered an ideal platform for providing data sharing, personalized services, and pooled knowledge.

In the research literature, there are several agent-based applications reported in the healthcare domain. In particular, Heine et al [6] simulate an agent oriented environment for German hospitals with the objective to improve or optimize the appointment scheduling system, resource allocation and cost benefit of clinical trials. Nealon and Moreno [7] have discussed the potential and application of agents to assist in a wide range of activities in health care environments. Mabry et al [8] employ the Multi agent system for providing diagnosis and advice to health care personnel dealing with traumatized patients. Nealon and Moreno [9] have discussed various applications of MAS in health care e.g., coordination of organ transplants among Spanish hospitals, patient scheduling, senior citizen care etc. A research project, called PalliaSys is offered by [10]. It incorporates information technology and multi-agent systems to improve the care given to palliative patients. An Intelligent Healthcare Knowledge Assistant [11] was developed which uses multi agent system for dynamic knowledge gathering, filtering, adaptation and acquisition from Health care Enterprise Memory unit. Koutkias et al [12] created a Multi agent system that aims to enhance monitoring, surveillance and educational service of a Medical Contact Center (MCC) for chronic disease management in Greece.

The works mentioned above are domain specific, e.g. catering to special types of patients or providing assistance to patients for appointments or supporting doctors in diagnosing specific diseases, etc. These systems are therefore, not capable of handling problems related to tacking care of patients at ED as presented in section 1. More precisely, the efficacy of agents in this application area has still not been explored. So, in the subsequent sections we are introducing and highlighting the concept of using agent technology in this regard.

3 Problem Description

Based on detailed analysis of visits to multiple French EDs (CHRU Lille, SAMU Lille, CH of Dunkerque, CH Lens and CH Valenciennes) we identified several types of EDs and their processes. We also identified their specific requirements in order to separate and classify

particular and common issues among EDs. In France, there are two types of emergency rooms: the specialized services (called SAU) and the proximity units (called Upatou). A hospital (public or private) can have a specialized service in emergency care only if it can already take care of the most probable trauma and disease in classical hospitalization: resuscitation unit, general and internal medicine, cardio-vascular medicine, pediatrics, anesthesiology-resuscitation, Orthopedic surgery and visceral surgery, including Gynecological surgery. The hospital must have two operating rooms (and a wake-up room) with personnel on duty that allow operation at any time and services that can perform examination and analyses at any time: medical imaging (radiography, medical ultrasonography, computed tomography, angiography...), haematology, biochemistry, de toxicology laboratories, etc. The specialized service is managed by an emergency physician. An emergency physician must be on duty anytime, and a specialized physician can be called anytime depending on the specific pathology (i.e. on duty in the hospital, not in the emergency service). The team must have, in addition to the emergency physician: two nurses ; care assistants, possibly child care assistants; a social worker; a receptionist; all must have a specific education for emergencies.

A careful examination of the activity process at the ED reveals that the emergency departments are facing difficulties at the management level, which are mainly related to the unpredictable flow of patients, to the inability to control flows stream up and stream down, to the multiplicity of actors and to the reduced efficiency of care activity which consist of the interrupted tasks, qualification under or over used (i.e. a percentage of the time of the doctor is non-medical) and difficulty in quantifying (Who does what, when, how often?). So, the situation demands a system that works beyond these limitations. Then, we propose architecture based on a multi-agent system capable of handling all patients of emergency service in order to minimize the patients waiting time in the emergency department as well as the costs of care, with the respect of the quality of care. Our model aims to make possible to identify a medical actor available at a given time and to assign to him, depending on both of the flow of patients and the medical practices, a set of tasks. Where he can perform those tasks and has an aspect of flexibility relates to the possibility that could have a human resource to perform various tasks with appropriate skills (degree of knowledge).

The various agents of the proposed architecture interact to improve completeness and accessibility of information which is a key element to get better the quality of care at the ED.

4 Architecture of the proposed system

Since the care of patients in ED is a complex problem that requires a good division of tasks and data, an agentive representation is implicit in agent-based model of such real world. These characteristics suggest that the properties of intelligent agents (autonomy, pro activity, social capacity) and the architecture of multi-agent systems (distributed information processing, communication, coordination, and negotiation) is a good option for designing a system for providing clinical decision support to healthcare practitioners in the ED with the aim to satisfy the global goal improved health of a patient.

To satisfy these requirements and provide adequate decision support, we propose a dynamic and open multi-agent system MAS based on the interaction of five types of software agents [1]: the Home Agent (HA), the Identifier problem Agent (IdA), the Scheduler Agent (SA), the Monitor Agent (MA) and the Mobile Staff of medical team Agents (MSA). The HA agent as its name suggests ensures the patient's host and the creation of medical records. The IdA agent receives the medical problem and identifies the skills needed for the treatment. The SA agent makes the assignment of MSA agents to medical teams. The MA agent is in charge of the patient’s become. Finally, the MSA agent which moves from team to team in depending of the need provides the treatment and the following of the patient (Figure1).

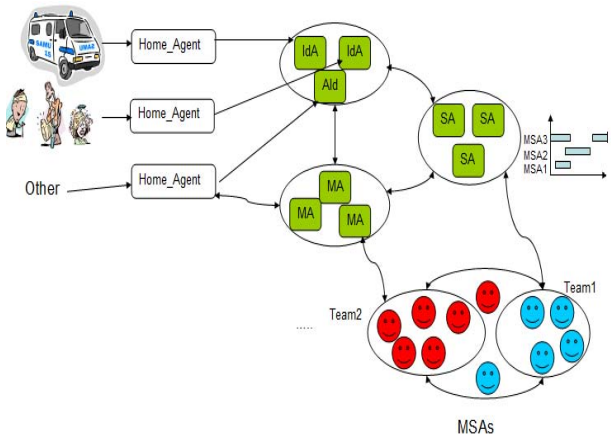

Figure 1 a multi-agent architecture

At a time t, the arrival of a patient requires the creation of a Home Agent and triggers the creation of an Identifier problem Agent, a Scheduler Agent, a Monitor Agent and a number of Mobile Staff Agents of medical team. These same agents are available if they will take care of new patients otherwise we will create agents as required. After a period of inactivity $\Delta\infty$ i.e. in the absence of patients, the agents will be destroyed and they will be automatically created if necessary. We call IdA, SA, MA and MSAs agents created at time t, the agent's society Pt. If at time t + Δε all agent's society previously created are unavailable, then the arrival of new patients triggers the creation of a new agent's society Pt + Δε and so forth. Once an agent's society Pti created at the moment ti, is available, it is ready to manage patients in the ED. However, as soon as the availability of an agent's society or HA agent reaches period of inactivity $\Delta\infty$, the agent's society or the HA agent is automatically destroyed (Figure 2).

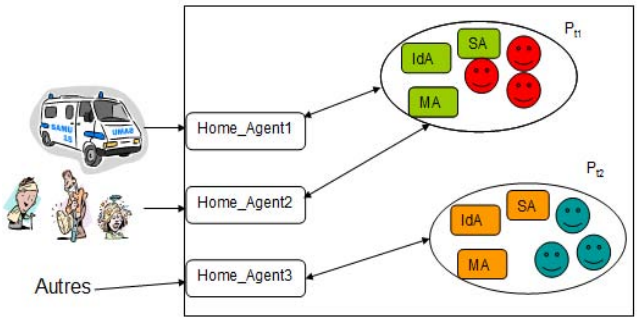

Figure 2 Dynamic behavior of the system: agent's society

The MAS is designed according to the requirements for effective diagnosis and delivering the treatment plans for patients at the ED. It provides an interaction mechanism with the healthcare professional at ED and delivers diagnosed disease and suggests treatment plans as per the supplied sign-symptoms.

5 Description of the different agents of our architecture

A set of agents was developed for solving coordination problems of different actors (physicians, patients, nurses) at the ED. The proposed MAS requires delegation of task to various agents in the system. In the following section, we will describe the organization of different agents of the system.

GUI for ED practitioner

The GUI for ED practitioner has been designed for providing an interface. It is being used for the following purposes:

• Displaying the account identification issued by the ED system,

• Feeding the main problem, sign–symptoms, and observations of the ailing patient,

• Passing the information to the HA and;

• Displaying the diagnosed disease and treatment plans.

Home-Agent (HA)

This agent interacts with the emergency's patient within the GUI by creating his medical records. Once a patient come into the ED, a HA agent is created in real time to help and save him in the system. The same agent can provide this task several times as there is an input stream of patients or it can be destroyed by the system and another HA agent is created as considered necessary, and so on. Thereafter, the HA agent sends the problem to the IdA agent then directs the patient to the recommended room care.

Identifier Problem Agent (IdA):

An available IdA agent interacts with HA to receive the main problem and some details that help in deciding the disease and generating the treatment plan. If there is still no IdA agent available in the system, a new IdA agent is automatically created. Initially, the IdA agent begins by consulting the medical history (pre-existing medical protocols). If the problem is not already covered, the IdA agent

must identify the skills needed to deal with the emergency. Finally, the IdA agent transmits generated data to the SA agent that will optimize the choice of different MSA agents of medical team as well as the material resources required depending on emergency case.

Scheduler Agent (SA):

From its inception, an SA agent plans dynamically the sequence of the tasks which implies a dynamic generation of the actors' activity plans. Knowing the profile of the agent which corresponds to the tasks that it can perform, the SA agent proposes the MSA which will carry out the announced tasks. So, the SA agent calculates an actual number of MSAs agents of medical team that will create and then assigns at each one a role as it updates whenever the flow of entry of patients varies considerably. IdA agent procured to SA agent some data that it will try to optimize. The data received correspond to a set of tasks required, to all needed skills of the MSA agents and to material resources. A SA agent must optimize the treatment plan of the patient by minimizing the waiting time of patients (forced vital emergency) and the total cost with the respect of the quality of care. All MSA agents selected correspond to the medical team. An emergency alert as a result of the need for a MSA agent triggers a process of updating the plan made by the SA agent for the medical team which may necessitate the relocation of MSAs agents from one team to another. Finally, the SA agent communicates to MA the required treatment after the intervention of the medical team. The behavior of this agent is illustrated with more details in [13].

Monitor Agent (MA)

A monitor agent can take care of patients who need particular supervision or treatment like as exit unit of quickly hospitalization, transfer to an another care unit. Thus, the monitor agent is not only in relation with MSAs, but more with the IdA agent in case of deterioration of the patient's medical condition. In addition to the monitoring on the patient's health, the MA will manage the hospital rooms and beds available in order to optimize costs.

Mobile Staff of medical team Agent (MSA)

If there is a need for cooperation between medical staffs, the SA will arrange a meeting of related medical staff in order to make more accurate decision. The MSA agent is able to move from one team to another in order to perform the solicited task by the SA agent. In addition, this agent will share the parameters of the treatment and monitoring of patients with MA agent.

In our agent-based model, agents act as federated, collaborative team of different skills on behalf of a patient. As with a team of physicians and nurses working on a patient, each agent provides specialized skills and knowledge. Each member agent's opinion is trusted as an expert in its particular domain. This description of the system shows the importance that plays the SA agent in the ED. So, generating a high quality solution is a challenging task, since different goals (i.e. all the activities are scheduled as soon as possible, the patient waiting time is minimized, the device utilization is maximized) could be achieved and a large set of constraints (i.e. every device can be used by only one patient at time, the treatments have to be performed in an exact time order) should be taken in account.

In ED complex, a robust cooperation is essential between all the members in order to offer the best services because of the vital character of the acts achieved by these members. The cooperation of these members is carried out through the cooperation of the artificial agents integrated in our system. Our continuing goal is to advance the agent based system towards a real-time system that enables resource allocation.

6 Implementation

We are developing our system, with the JADE platform (Java Agent DEveloppement Framework) [13]. JADE is a middleware that allows the execution of a flexible multi-agent systems, it offers an effective transfer of messages between agents to ensure communication between them through the FIPA-ACL language (Agent Communication Language) who meets the specifications FIPA [14]. JADE is written in Java, supports mobility, and it is one of the few existing multi-agent platform which tolerates the integration of Web services. JADE has several interesting features that at least make the process of implementation easier. One of these features is the agent Sniffer that enables user to observe message flow among agents. Figure 3 summarizes the communication between the agents of our system at the arrival of a patient. For our example, the patient received at the ED was supported by a medical team consisting of three mobile agents MA1, MA2 and MA3.

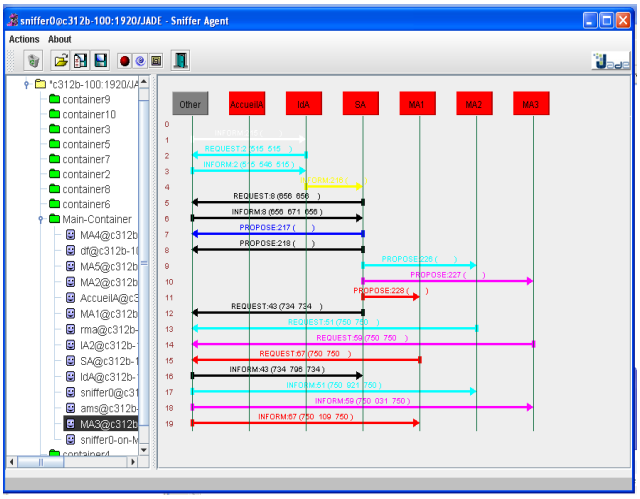

Figure 3 Exchange message between agents

7 Conclusion and future work

In this paper, we have proposed a multi-agent system for the care of patients at the ED. This application demonstrates the utility of the methodologies proposed by the multi-agent community. On the other hand, the proposed model allows to schedule the patients and to ensure their treatment plan. In a future work, we aim to manage the interactions between the SA agent and MSAs agents in case of perturbation of patient's health at the emergency department. Besides we propose to establish the scheduling of material resources in order to achieve the optimal use of resources or the optimal accomplishment of tasks.

References

[1] H.Zgaya, *Design and distributed optimization of an information system to aid urban mobility: A multi-agent approach to research and composition of services related to transportation.* PhD, Ecole Centrale of Lille, 2007.

[2] R.A.Florez-Mendez, *Towards a Standardization of Muli-Agent System Frameworks*, ACM Crossroads Student Magazine. Canada, 1999.

[3] S.Green, L.Hurst, B. Nangle, P.Cunningham, F.Somers, R. Evans, *Software agents*, A review, TCS-CS- 1997-06, Trinity Collège Dublin, roadcom Eireann research Ltd., 27th of May 1997.

[4] M.Wooldridge, *An introduction to MultiAgent Systems*, Wiley Ed, 2002.

[5] R.Willian Cockayne and Michael Zyda, *Mobile* Agents, Manning Publications Co, 1998.

[6] C.Heine, R.Herrler and K.Stefan, *Agent-based Optimisation and Management of Clinical Processes* , Proceedings of the 16th European Conference on Artificial Intelligence (ECAI'04)-The 2nd Workshop on Agents Applied in Health Care, 2004.

[7] J.Nealon and A.Moreno, *The application of agent technology to health care*, Proceedings of the Workshop AgentCities: Research in Large-scale Open Agent Environments, in the 1st International Joint Conference on Autonomous Agents and Multi-Agent Systems (AAMAS '02), pages 169-73, Bologna, Italy, 2002.

[8] Susan L.Mabry, Caleb R.Hug, Russell C.Roundy, *Clinical Decision Support with IM-Agents and ERMA Multi-agents* ,cbms, page.242, 17th IEEE Symposium on Computer-Based Medical Systems (CBMS'04), 2004.

[9] J.Nealon and A.Moreno, *Agent-Based Applications in Health Care*, in Applications of Software agent technology in the health care domain, Whitestein Series in Software Agent Technologies, Birkhauser Verlag, Basel, 2003.

[10] D.Riano, S.Prado, A.Pascual, S.Martin, *A Multi-Agent System to Support Palliative Care Units* . Proceedings of the 15th IEEE Symposium on Computer-Based Medical Systems (CBMS 2002), June 2002.

[11] ZI.Hashmi, SSR.Abidi and YN.Cheah, *An Intelligent Agent-Based Knowledge Broker for Enterprise-wide Healthcare Knowledge Procurement*, Proceedings of the 15th IEEE Symposium on Computer-Based Medical Systems (CBMS 2002), June 2002.

[12] VG.Koutkias, I.Chouvarda and N.Maglaveras, A Multi-*agent System Enhancing Home-Care Health Services for Chronic Disease Management*, IEEE Transaction on Information Technology in Biomedecine .Volume 9, issue4, pages 528-527, December 2005.

[13] A.Daknou, H. Zgaya and Hammadi,S, *Towards a tool for scheduling tasks to multiple skills in emergency services*, International Francophone Conference of Automatique CIFA 2008, Bucharest, Romania.

[14] JADE, Java Agent Development Framework - *http://sharon.cselt.it/projects/jade.*

[15] FIPA: Foundation for Intelligent Physical Agents. *http://www.fipa.org.*