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# A Patient Monitoring System Based on Agent Technology under JADE

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**Abstract—Information technologies have played key roles in the medical field. New needs are regularly emerging, and computer technology is in the Frontline of the answers to those demands. Classical computation paradigms fall short when trying to model an environment with a large number of users and complex processes and interactions. The aim of this paper is to propose a conceptual model for the development of a Medical Information System (MIS) operating in a distributed environment, and based on Multi-Agent Systems (MAS) and allows intelligent patient monitoring. To demonstrate the feasibility, we developed a prototype under JADE (Java Agent DEvelopment Framework).**

***Keywords—Medical Information System, Multi-Agents System, Medical Patient Record, Patient monitoring, Platform Jade.***

## I. INTRODUCTION

Actually, the Information Technology (IT) has an all-important function in healthcare organizations. The Medical Information Systems (MIS) are in fast development. The main purpose is to convert paper-based practices into computerized processes in order to ensure the health care delivery and enhance service's quality. Medical Information Systems can provide better coordination between health professionals, allowing the reduction of the number and incidence of medical errors. In addition, it enables cost reduction of care and can provide a means to improve hospital management [5]. In light of the internship conducted in the "Ibn Zohr" hospital in Guelma city, there is no computer-based hospital information system worthy of this name in a public hospital in Algeria. The hospital IT system is reduced to a few isolated initiatives focused mostly on accounting and hospital administrative management rather than medical data management. Conventional health care systems based on traditional computational paradigms do not model an environment with a large number of users and complex interactions [6].

Agent-based systems are one of the new paradigms for analyzing, designing, developing, and deploying complex, real-time distributed systems [1]. The use of multi-agent systems in healthcare domain has also opened the ways to find out new applications [4]. In the literature, the use of intelligent software agents has been proposed to address a variety of medical and health-related issues, such as patient scheduling, organ and tissue transplant management, community-based care, patients and access to treatment; decision supports systems, training, hospital management, senior care, self-care and automatic health monitoring [3]. Our goal is to design an MIS based on the intelligent system, in which each subsystem is dedicated to the realization of part of the overall task autonomously to satisfy its own local objectives (the doctor at the service level provides consultation, treatment, and monitoring; Laboratories perform analytical tests, etc...). The key function of our system is to facilitate the information sharing by allowing different actors the access to a medical data. This also allows improving caregiver working conditions and increasing the care quality level.

The organization of this paper is as follows: The Section 2, relates similar works. In section 3, we propose a MAS-based architecture for a distributed MIS and patient monitoring. Then, Section 4 provides the system implementation. In Section 5, we conclude, and we suggest further extensions.

## II. RELATED WORKS

In the literature, the use of smart agents has been proposed to address a variety of medical and health-related issues [3]. The target user determines the application type. We can identify, among them, those that provide services for patients, applications that provide services for health staff and applications designed to support healthcare organizations [7].

- Patient-centred applications are applications in which the primary purpose is to provide a specific service to a patient. They include applications that personalize the given care [8]. Older person surveillance in which these systems can send alarms to a supervisor if an anomalous situation is detected [9], or recommends certain tasks to the patient [10].
- Staff-centred applications are designed to support medical practitioners in daily care. Most of these applications are designed for personal assistants, whose purpose is to collect and provide the most relevant medical data at the appropriate point of care [11]. Other applications are designed as a decision support systems [12].
- Healthcare organizations-centered applications are the most prevalent. These systems mimic real relationships in medical organizations in order to follow treatment [13], learn more about the internal behavior of the organization and detect weaknesses [13], improve the exchange of information between heterogeneous sources [14], simulate the behavior of complex diseases [15], or implement some tele-assistance platforms [16].

## III. Architectural Specification

The development process includes three essential steps:

### A. System Analysis

The identification of the operational subsystems and subsequently the agents was carried out by analyzing the patient's way from admission to discharge. The following figure shows a typical path of a patient

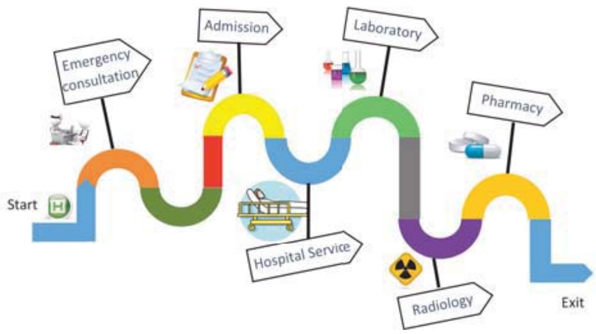


Fig. 1: Typical path of the patient

From the patient journey, we observed the actors and the following subsystems representing the units hospital namely services:

- Emergency Service / External Consultation (Consultant physician)
- The Admission Office (Agent Office entrance)
- A Medical Hospital Service (Chief physician, Attending physician)
- Medical Analysis Laboratory (Laboratory Technician)

In order to offer efficient patient care, these services communicate and exchange a lot of information processed locally. The following figure shows the flow of data exchanges between the different actors involved

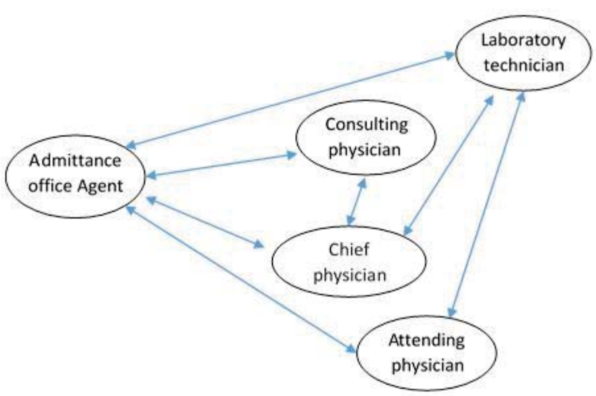


Fig. 2: A flow of data exchange between the actors.

### B. Agents identification

We identified the following agent's classes for each environment. They all have the same structure but the associated treatments are different:

- *Emergency Service Agent (ES_Agent)*
- *Admission Office Agent (AO_Agent)* : It manages patient admission and billing. It directly receives the inputs from the patient and assigns a unique ID to each patient.
- *Laboratory Agent (Lab_Agent)* : Management of the laboratory staff and validation of tests and analyzes.
- Hospital Service Agents :
  - *The Chief Physician Agent (CP_Agent)* : It manages the record of all doctors working in that hospital service; it validates the patient's admission. It administers his medical records from admission to discharge. Furthermore, it keeps the record of all rooms in a ward, beds that are allocated to the patient and vacant beds.
  - *The Attending Physician Agent (AP_Agent)* : It prescribes the treatments, administers medication, and asks to make biological and radiological examinations. And finally, it gives exit notice to the patient.
- *Control System Agent (CS_Agent)* : It assigns the right and controls the access to the system for all users.

### C. Agent-based architecture design

The architecture proposed in this work makes it possible to connect the various distributed subsystems in order to satisfy the organizational goals of the global SIM. It is an extensible architecture insofar as it is possible to link other structures (Medical hospital services). The subsystems involved in the study represent the hospital services, namely: the admission office, a medical hospital service, and a medical analysis laboratory.

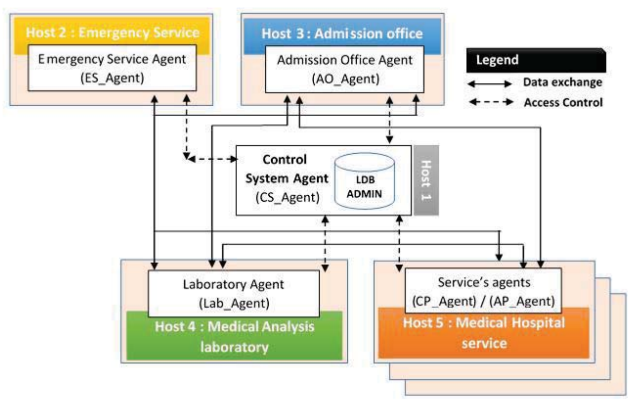


Fig. 3: Global architecture of the system

Each structure includes:

- ***Authentication agents****:* responsible for the authentication of human actors

- ***Communication agent*** allows establishing the communication by sending the message between the different interconnected subsystems.
- ***Internal Management Agent*:** responsible for the execution of the internal tasks associated with each subsystem.
- ***External Management Agent*:** responds to external solicitations
- ***GUI_Iinterface***: Responsible for linking the user with the system by presenting the functionalities of the system in the form of a graphical interface.
- The ***Local DataBase*** (LDB) containing the prepared and processed data.

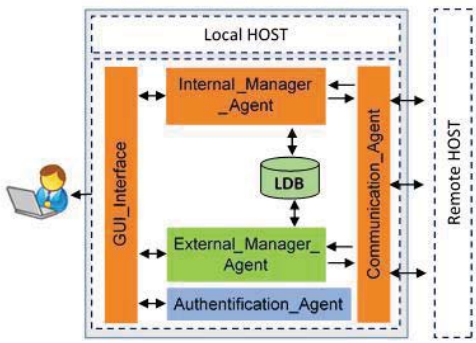


Fig. 4: Internal Architecture System

The interaction between the agents is performed through communication. It is modeled as the Input that agents receive and the Outputs that they produce.

## IV. Platform Design

We use the JADE platform, and FIPA-ACL performs [2] to develop our framework. Each running instance of the JADE runtime environment is called a container because it can contain multiple agents. The set of active containers is called a platform. Only one special master container must always be active in one platform, and all other containers register as soon as it starts. For the development of the interfaces, we chose the Java language. We used MySQL to manage the database. Each structure has its own database for security and performance reasons. The amount of data processed locally is greater than that shared between the different structures. In addition, processing time at the local scale is much faster.

The following figure (Fg. 5) shows the interface of the medical patient record. The interface is presented as a set of tabs, where each describes the patient care at a stage of his journey at the hospital. The system collects patient data which are inherently scattered between different structures of the hospital. Then make them displayed on a single form in real time. This data will be sent at the request of the hospital staff.

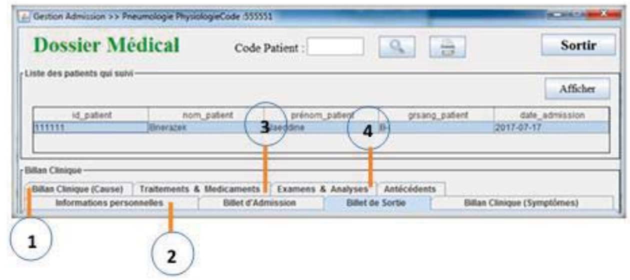


Fig. 5: Medical Patient Record

This record consists of a set of information related to Emergency Service (1), the Admission Office (2), a Medical Hospital Service (3) and a Medical Analysis Laboratory (4). It is supposed to accompany a patient during his episodes of care in a hospital (Fig. 6).

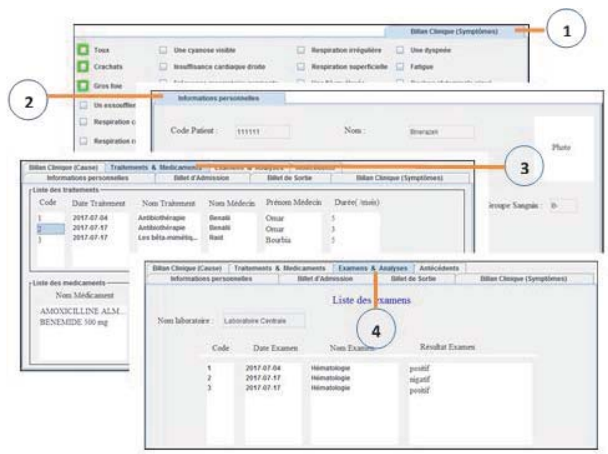


Fig. 6: The various tabs of MPR

All this information correctly filtered and presented, describing the clinical situation of a patient as well as its history, allows doctors to determine the best treatment, thus improving the quality of care and the health of the patients. This system can be considered as a Medical Decision Support System (MDSS).

### *A. The peer-to-peer architecture and network configuration*

The peer-to-peer architecture (P2P) is a computer network model where all nodes play both the role of client and server. The main feature of this model is decentralization: materials, search mechanisms, localization, security, and routing. In our case, we have used four distributed hosts to implement the prototype. The communication between agents living on different platforms is based on modules called MTP (Message Transport Protocol).

### *B. Inter-Agent Communication*

In this paper, we refer to FIPA-ACL model to describe the communication act when the agents exchange asynchronous messages. These messages are encoded with an ACL language and decoded upon arrival by the receivers. Thus, we will have weakly coupled open systems, and the collaboration is ensured by message exchange only.[17]. In order to supervise and control the communication and the behavior of agents, we use Remote Monitoring Agent (RMA) of JADE platform. It is a graphical console for platform management and control. It also displays the flow of interactions between agents from Sniffer Agent. The following figure illustrates the interactions between the agents involved in the visualization of the part of the patient's medical record.

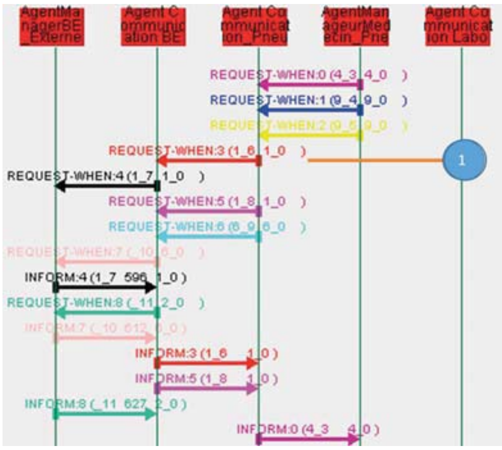

Fig. 7: Inter-Agent Communication

The ACL language defines the format of all these messages. The figure 8, gives an example of an exchanged message between the both agent_communication of hospital service agent and admission office agent. It sends a message of type REQUEST-WHEN and the receiver respond with a message of type INFORM.

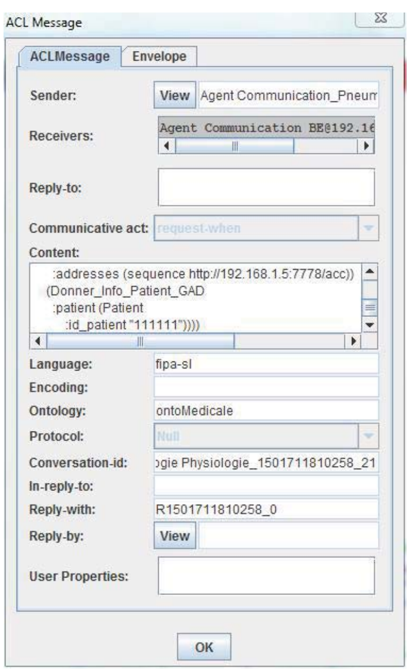


Fig. 8: ACL language

## V. CONCLUSION

In this paper, we designed and implemented an MIS distributed based on the MAS paradigm in order to respond to the expectations of patients and healthcare personnel. The main focus of this paper is to automate the hospital system, minimize the communication gap between health professionals and share instantly all patient record information. The proposed architecture consists of a set of autonomous agents. Each of them represents an independent actor who is geographically distant. We chose a distributed environment with a peer to peer architecture for the deployment of the system. Thus, knowledge is fully distributed among the agents, ensuring high flexibility and an elevated rate of failure resistance. We used the Java programming language and the JADE platform for development, allowing us to run simulations of the interactions inter-agents.

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