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A prototype of a multiagents system for a telemedicine environment

P Miranda* and J Aguilar†

*GIBULA, Facultad de Ingenieria, Universidad de Los Andres, Merida 5101, Venezuela. Email: dmiranda@ing.ula.ve
†CEMISID, Dpto. de computacion, Facultad de Ingenieria, Universidad de Los Andres, Merida 5101, Venezuela

In this paper we propose a telemedicine system model based on multi-agent systems. Then, we develop a telemedicine system prototype based on this model. The system is composed of seven agents, such as: a medical database management agent, an application agent for medical images processing, an application agent for videoconference, and an intelligent application agent for the 3D reconstruction of the left ventricle. The system was developed using Java and the Access database management system.

Keywords: Multi-Agent Systems, Distributed Systems, Telemedicine, Multimedia, Telecommunications, Medical Computer Science, Biomedical Engineering.

1. INTRODUCTION

Nowadays, there is a large necessities to integrate geographically dispersed centers of health activities, such way to facilitate information/abilities exchange between them, for example, databases which store medical histories, signals, images, and other data [2, 3, 6, 7, 14, 15]. The utilization at the same time of the computation, telecommunications and multimedia technologies allows to define new strategies to distribute health services. The medicine has implemented new remote consultation, surgery and diagnosis methods, based on these strategies. This area is called *telemedicine* [2, 3, 6, 7, 15]. In general, Telemedicine Systems (TS) are systems that allow to establish remote sessions for consultation, diagnosis and treatments in any medical specialty. There is a large number of TS, which are very specific to a given medical specialty. A typical problem between them is their incompatibility at the level of the image storage formats and of the communication protocols. For this reason, it is necessary to think about new methods to integrate them.

On the other hand, the Multi-Agents Systems (MAS) theory allows the integration of autonomous entities. The MAS activities are described by the interaction between relatively autonomous and independent entities, called agents [1, 4, 5, 13, 17, 19]. In this work we propose a general TS based on MAS, and we develop a prototype of this system. The prototype (called APROTEL) is composed of seven agents, such as: a medical database management agent, an application agent for medical images processing, an application agent for videoconference, and an intelligent application agent for the 3D reconstruction of the left ventricle (OMAG). In order to develop this last agent, we propose multiobjective optimization mechanisms based on AG's [9, 10, 11]. APROTEL was developed using Java and the Access database management system.

2. RELATED WORK

In [14] has been presented a system to exploit the Internet/Intranet technologies for exchanging patient information among health care providers. This system support real-time consultations among health care providers, secure access to multi-media patient records, authentication/digital sign-off, among others services. The system, called ARTEMIS, employs technologies such as JAVA for the browser and CORBA-based middleware for interoperability at the server-end, and has been deployed in southern West Virginia in a community care network. In [15] has been developed a prototype telemedicine system which integrate functions as the transmission of medical images, collaboration and video conferencing, and provided human interfaces for telemedicine. This paper presents an overview of an experiment of the telemedicine system wich has been conducted in the Nagoya area, and describes the advancement and prospect of telemedicine by implementing high-speed broadband networks. In [17] is proposed an agent-based intelligent clinical information system to integrate the information among hospitals. Functional entities are divided according to tasks and implemented as collaborating agents.

In [16] has been presented a web-based expert system that has been developed by the University of British Columbia as a tool for health care investigators to design and implement their clinical trials. The web-based clinical trial expert system (WebCTES) guides health care professionals and students through the reasoning process of conducting clinical trials. The system contains a domain-specific knowledge base and a list of typical tasks or operations common to all clinical trials. In particular, WebCTES is made up of five modules, each representing a principle of scientific conduct: *question, design, statistics, ethics*, and *standard operating procedures*. A system was developed in [18] to use gestural interface technology and interactive robotics to facilitate motor development, functional mobility, and speech and language development of children with a wide range of disabilities. The prototype Gestural Interface and Robotic Technology system is an interactive robotic rehabilitation tool, disguised as a toy, which can be controlled via almost any part of the body, through voice-activation, or through a Web-enabled computer interface. In [19] was presented the telemedical environment based on VMDs implemented with Java mobile agent technology, called aglets. The agent based VMD implementation provides ad-hoc agent interaction, and supports for mobile agents and different user interface components in the telemedical system. They developed a VMD agent framework with four types of agents: data agents, processing agents, presentation agents, and monitoring agents. Data agents abstract data source, creating uniform view on different types of data, independent of data acquisition device. Processing agents produce derived data, such us FFT power spectrum, from raw data provided by the data agents. Presentation agents supply user interface components using a variety of user data views. User interface components are based on HTTP, SMS and WAP protocols. Monitoring agents collaborate with data and processing agents providing support for data mining operations, and search for relevant patterns. Typical example is monitoring for possible epileptic attacks. We have applied VMDs to facilitate distributed EEG analysis. They found that the flexibility of distributed agent architecture is well suited for the telemedical application domain.

In [20] is presented the MULTIPATH project. The objective of the MULTIPATH project is to study, develop and test an integrated environment for telepathology services by using affordable and widely available telecommunication and information technologies. The main caracteristics tobe reach with the project are: 1) remote consultation, 2) access to a distributed morphometry laboratory, 3) quality assessment of cytology and histology laboratories, 4) tools for remote interaction with a distributed multimedia archive for training, continuing education and reference, which are critical issues for this objective. In [21] is provided a framework to support agents' services for digital hospital and intelligent telemedicine applications. In order for their framework to be clinically relevant, they draw on experience and knowledge acquired in the field of urology, dialysis, emergency, hospice telemedicine, and PACS (Picture Archiving and Communications System). The framework can be used to build many types of "write-once-run-anywhere" digital hospital applications and dynamically adapted to a variety of restrictions. These are some of the work in the domain of telemedicine system at the world.

3. MULTIAGENT SYSTEMS AND TELEMEDICINE SYSTEMS

The classic artificial intelligence approach considers intelligence like an individual characteristic, without taking in account the social context where the individual is immersed. In the reality, the human being establish organizations to solve problems where the resources are shared and the activities are a collective and nonindividual phenomena. Different techniques have been proposed to integrate autonomous entities. One of this is called Multi-Agent Systems (MAS). A MAS is a network of "problem solvers" that work together to solve problems which could not be solved individually [4, 5]. These problem solvers are called agents, and can be heterogeneous. They can act by themselves over their environment (they are autonomous). The agents have a partial representation of their environment and can communicate with other agents. Each agent has individual objectives, and its behavior is the result of its observations, knowledge, capacities, and interactions with other agents and the environment.

A TS is a type of health system, which allows a remote exchange of medical information using telecommunication technology. The information to exchange can be information of the patient, x-rays, CT images, ultrasound analysis, interviews, patient examinations, medical specialist consultations, and so forth [2, 6, 7]. A TS has a distributed processing and requires certain elements for its suitable operation. A TS requires a Real Doctor's office (RO) where the patients are nursed, and a Virtual Doctor's office (VO) where a doctor can access a patient through images, voices and data, without existing limits of distance among them [3, 12]. The VO must have an equipment control system to control the medical equipment that is in the RO. In a TS is possible to have multiples ROs and VOs. Figure 1 shows a generic model of TS. This model allows to establish telemedicine sessions in all medical specialties [12].

4. A TELEMEDICINE SYSTEM BASED ON MAS

In this section we proposed a TS based on MAS for the generic model of the Figure 1. The agents must carry out the following functions:

- To establish telemedicine sessions for any medical specialty.
- To define the software and hardware for each medical activity.
- To maintain the communication between the ROs and the VOs.
- To allow the remote control of medical equipment from the VOs.
- To manage the databases.

Figure 2 shows our MAS, which is composed of seven agents. Next, we describe each agent according to its functions, knowledge, capacities, communication and principal procedures.

Planning Agent (AG_PLA)

Functions: To coordinate work sessions according to the modality and specialty.

Description: This agent coordinates the different activities of the Telemedicine System to reach a specific goal. It must have a reasoning mechanism to determine the set of activities and to manage the set of resources of the system. It is a intelligent agent

Knowledge: Specialties List, Activities List.

Capacity: It must accept new specialties and activities.

Communication: Specialist Agent, Communication Agent, Virtual Planning Agent (indirectly).

Main/Behavior Procedures:

- *Start_Session ("specialty", "modality")*: To establish work sessions according to "specialty" and "modality" selected by the user.

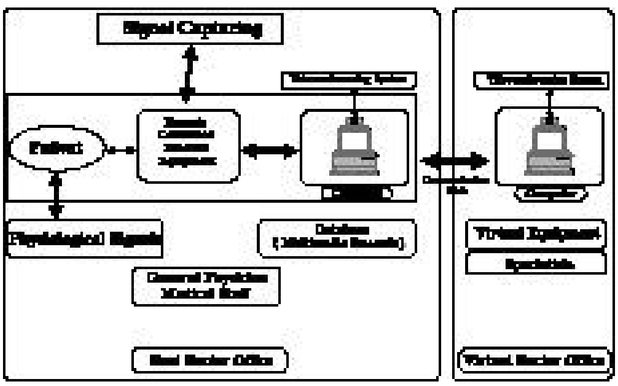

Figure 1 Ageneric TS model

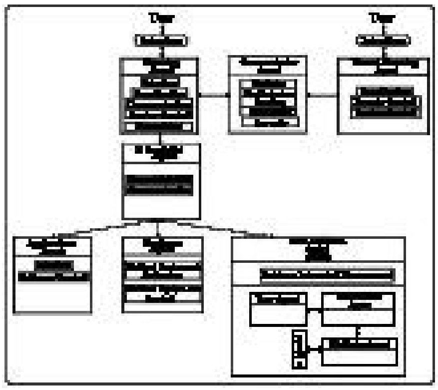

Figure 2 Our generic TS based on MAS

- *Communication ("agent", "parameters to agent")*: To establish communication with "agent" and send "parameters to agent" to execute actions.
- *End_Session ("status")*: To establish the end of the session of work according to modality and specialty selected and return state in variable "status".

N Specialist Agent (AG_ESP j)

Functions: To define the hardware and software necessary according to the modality and specialty.

Description: This agent determines the set of resources to use for one specific activity. It must have a reasoning mechanism for that. It is a intelligent agent

Knowledge: Activities List, Hardware and Software List.

Capacity: It must allow modifications of the number and the type of activities to handle.

Communication:Application Agent, Hardware Agent, Database Agent, and Planning Agent.

Main/Behavior Procedures:

- *Establish_H/S("modality")*: To send modality of work to the application agent and to the hardware agent.
- *Communicating_Agent ("agent","agent's parameters")*: To establish communication with a given "agent".

Application Agent (AG_APLI)

Functions: To serve as an interface among the TS and a given application.

Description: It is a reactive agent that allows the access to a given application. With this agent we allow the utilization of a heterogeneous platform at the level of the software.

Knowledge: Applications list and the mechanisms to execute them.

Capacity: It must accept new applications.

Communication: Planning Agent, Specialist Agent.

Main/Behavior Procedures:

- *Active_Application("application", "path", "command"):* To execute "application" in the path specified in "path" with command specified in "command".

Hardware Agent (AG_HAR)

Functions: To control the utilization of the medical equipment.

Description: It is a reactive agent that allows the access to a given hardware. With this agent we allow the utilization of a heterogeneous platform at the level of the hardware.
Knowledge: Medical Equipment List and the mechanisms to work with them.
Capacity: It must accept new hardware.
Communication: Communication Agent, Specialist Agent.
Main/Behavior Procedures:

- *Active_Hardware(“application”, “path”, “command”):* To execute application using the medical equipment specified in “path” with command specified in “command”.

Meta-Database Agent (AG_BD)

Functions: To manage databases.
Description: It must manage the different store medias and the different type of information
Knowledge: Databases Model, Database Manipulation Languages.
Capacity: It must accept different Databases and must allow their integration. The integration of Databases using MAS is widely detailed in [7]. In that paper is presented a Distributed Data Base System (DDBS) based on MAS.
Communication: Specialist Agent.
Main/Behavior Procedures: See [7]

Communicator Agent (AG_COM)

Functions: To verify, maintain and monitor the communicational links between the RO and the VO.
Description: It controls the communication media (it is called by the planing agent), but it must optimize the utilization of the communication media.
Knowledge: Communicational link types list, RO/VO list.
Capacity: It must accept any communicational link type.
Communication: Planning Agent, Virtual Planning Agent.
Main/Behavior Procedures:

- *Select_Site():* To select site or host to establish communication.
- *Select_Link_Type():* To send established communicational link type to planning agent.
- *Verif_Connection():* To verify connection.
- *Mon_Net():* To monitor state of the network.

Virtual Planning Agent (AG_PLA_VIR)

Functions: To coordinate activities with the Planning Agent.
Description: It is a reactive agent that is called by the planing agent when an activity must be executed by the Telemedicine System in a remote site. It must control the different tasks to be executed on the remote site requested by the planing agent
Knowledge: Activities List, RO List, and Remote Commands List.
Capacity: It must plan and decide activities to make.
Communication: Planning agent (indirectly), Communication Agent.
Main/Behavior Procedures:

- *Begin_Session(specialty, modality):* To establish a new session according to a given specialty and modality.
- *Communication(agent, parameters to agent):* To establish communication with other agents.
- *Execute_Command (action, site):* To execute a command in a given site.
- *End_Session(status):* To establish the end of a session.

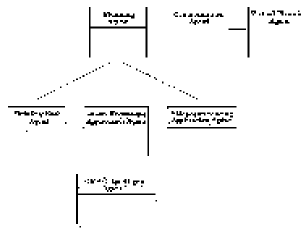

Figure 3 APROTELSystem

5. PROTOTYPE OF THE TELEMEDICINE SYSTEM BASED ON SMA

In this section we present a TS prototype based on the previous model, called APROTEL. APROTEL is a distributed system prototype of the MAS which is composed of a medical database management agent, an application agent for medical images processing, an application agent for videoconference, an intelligent application agent for the 3D reconstruction of the left ventricle, a communication agent to access APROTEL from Internet, a planning agent and a virtual planning agent. They are shown in Figure 3. APROTEL has been developed according to a client-server approach (RO-VO). The computational platform consists in a PC with Windows 98, and the Access database management system.

The planning agent and the virtual planning agent display the main menus of APROTEL on the RO and VO sites. The menus have all options that can be made in APROTEL (see Figure 4).

The communication agent is composed of different modules. The modules are implemented like HTML pages that invoke Java applet. RO and VO only need to have a http client program to use those modules. The database agent uses APIs (Application Program Interface) that allows databases access from Java (that means, database remote access). This implementation allows any type of

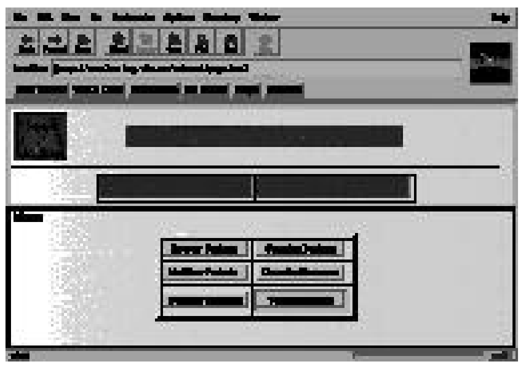

Figure 4 APROTEL main menu (Planning or Virtual Planning Agent)

computer and operating system on APROTEL. The application agent for image processing is composed of several processing servers, which receive images from clients. At this moment, this agent can filtrate images using an average filter approach, and invokes an intelligent agent called OMAG (Multiobjetive Optimization based on Genetic Algorithms), which allows to make a 3D reconstruction of the left ventricle using genetic algorithms [9, 10, 11]. In such sense, APROTEL presents the capacity to remotely process images. The application agent for videoconference is invoked from the menu of the planning agent. APROTEL allows to establish videoconference sessions doing use of any videoconference package for PC.

APROTEL can be invoke from Internet if we know the Web page address (URL). The user accesses the main page specifying the URL (communication agent). Then, a password is required (virtual planning agent). Finally, the menu options are displayed. Each option invokes an agent. The user can invoke the database agent (see Figure 5), the image processing agent (see Figure 6), or the videoconference agent.

APROTEL can invoke any medical image processing type. For example, APROTEL has an intelligent application agent that allows a 3D reconstruction of the left ventricle based on the AG's (see Figure 7). At the further, we will add different 3D reconstruction heuristics based on simulated annealing and logic fuzzy.

The specialty agent and hardware agent were not necessary in this prototype. The hardware agent is not necessary because APROTEL doesn't manipulate medical equipment. The specialty agent is not necessary because the users of APROTEL require only images processing, databases access and videoconference. That means, the planning agent can directly invoke the application agents (image processing agent, etc.).

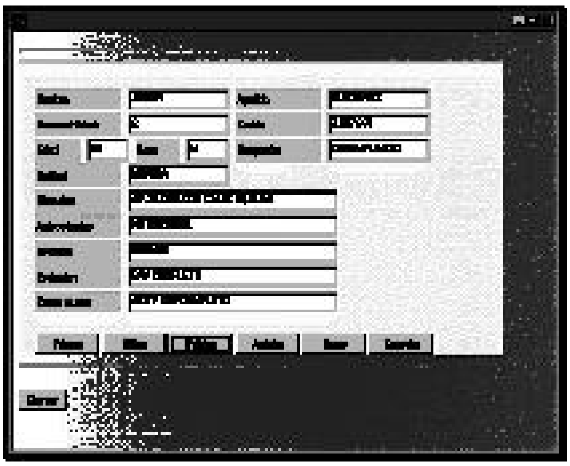

Figure 5 The database Agent

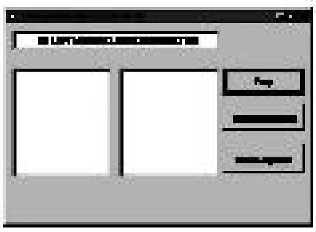

Figure 6 The image processing agent

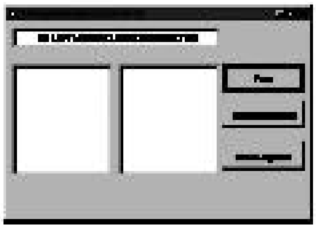

Figure 7 Intelligent Application Agent to 3D reconstruction

Particularly, APROTEL can be extend to include a hardware agent (p.e. ultrasound equipment to catch images) to be processed by the image processing application. Another extension include a specialty agent (p.e. a cardiology system) can be used by the previous agents to do medical diagnostic (it can be based on an expert system). Maybe, for this case we would need a more sophisticate planing agent (with reasoning capabilities) to coordinate APROTEL. Of course, it can be extended also to include new applications

6. CONCLUSIONS

In this work we have proposed a generic model of a TS based on MAS. Our model allows to develop agents individually. The complexity of each agent depends on its capacities and functions. We have implemented a prototype of this model. The prototype is composed of seven agents: a medical database management agent, an application agent for medical images processing, an application agent for videoconference, an intelligent application agent for the 3D reconstruction of the left ventricle, a communication agent to access APROTEL from Internet, a planning agent and a virtual planning agent. We have used Java and the Access database management system to implement our model. APROTEL can be extended according to new necessities. At the future, we will work on the integration problem of different intelligent agents in our system.

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