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Hybrid Multi-Agent System for Alzheimer Health Care

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Abstract. This paper presents a dynamic multi-agent system for monitoring Alzheimer patients' health care in execution time in geriatric residences. The system architecture implements autonomous deliberative case-based agents with reasoning and planning capabilities, with the ability to operate in wireless devices and capable of obtaining information about the environment through RFID technology. ALZ-MAS description and preliminary results of the prototype in a real environment are presented.

1 Introduction

Agents and multi-agent systems (MAS) have become increasingly relevant for developing distributed and dynamic open systems. ALZ-MAS (ALZheimer Multi-Agent System) is aimed to improve the efficiency of health care in geriatric residences, increasing the patients' quality of life. This paper will describe ALZ-MAS, and explain how this distributes and dynamic multi-agent system has been designed and implemented. A case study is then presented, with the system working in a real environment, with initial results and conclusions analyzed. Is also examined the residential health care problem and the possibilities of Radio Frequency Identification (RFID) as a technology for ascertaining patients location in order to generate plans and maximize safety.

This paper focuses in the development of deliberative agents using case-based reasoning (CBR) architecture, as a way to implement adaptive systems to improve assistance and health care support for elderly and people with disabilities, in particular with Alzheimer's. Agents in this context must be able to respond to events, take the initiative according to their goals, communicate with other agents, interact with users, and make use of past experiences to find the best plans to achieve goals. The development of a deliberative agent that incorporates a Case-Base Planning (CBP) reasoning mechanism, derivative from CBR systems [1], specially designed for planning construction is proposed. CBP-BDI facilitates learning and adaptation, and therefore a greater degree of autonomy than that found in pure BDI (Believe, Desire, Intention) architecture [2]. A

CBR-BDI agent [3] uses case-based reasoning as a reasoning mechanism, which allows it to learn from initial knowledge, to interact autonomously with the environment as well as with users and other agents within the system, and to have a large capacity for adaptation to the needs of its surroundings. We shall refer to the CBR-BDI agents specialized in generating plans as CBP-BDI agents. BDI agents can be implemented by using different tools, such as Jadex [4]. Jadex agents deal with the concepts of beliefs, goals and plans; they are java objects that can be created and handled within the agent at execution time.

2 Residential health care problem

There is an ever growing need to supply constant care and support to the disabled and elderly [5] and the drive to find more effective ways to provide such care has become a major challenge for Europe and its scientific community. During the last three decades the number of Europeans over 60 years old has risen by about 50%. Today they represent more than 25% of the population and it is estimated that in 20 years this percentage will rise to one third of the population, meaning 100 millions of citizens [6]. This situation is not exclusive to Europe, since studies in other parts of the world show similar tendencies. In the United States of America, people over 65 years old are the fastest growing segment of the population and it is expected that in 2020 they will represent about 1 of 6 citizens totaling 69 million by 2030. Furthermore, over 20% of people over 85 years old have a limited capacity for independent living, requiring continuous monitoring and daily care.

The importance of developing new and more reliable ways to provide care and support to the elderly is underlined by this trend [6], and the creation of secure, unobtrusive and adaptable environments for monitoring and optimizing health care will become vital. Some authors [5] consider that tomorrow's health care institutions will be equipped with intelligent systems capable of interacting with humans. Multi-agent systems and architectures based on intelligent devices have recently been explored as supervision systems for medical care for the elderly or Alzheimer patients, these intelligent systems aim to support them in all aspects of daily life, predicting potential hazardous situations and delivering physical and cognitive support.

3 Radio Frequency IDentificacion (*RFID*)

RFID is an automated data-capture technology that can be used to electronically identify, track, and store information about products, items, components or even people. RFID systems are basically integrated by four elements:

- *RFID Tags:* Consist of an antenna and a small silicon chip that contains a radio receiver, a radio modulator for sending a response back to the reader, control logic, some amount of memory, and a power system.

- *Readers:* The RFID reader sends a pulse of radio energy to the tag and listens for the tag's response. The tag detects this energy and sends back a response that contains the tag's serial number and possibly other information as well.
- *Antennas and Radio:* The RFID physical layer consists of the actual radios and antennas used to couple the reader to the tag to transfer information.
- *The Network:* Most RFID tags transmit a number to computer hardware with data processing software.

RFID chips are typically read through use of an intense magnetic field operating at a radio frequency of 100kHz to 15MHz. As shown in Figure 1, the field induces a current in the transponder's coil, which in turns powers the chip. The chip transmits a low-power response that is then detected on a different radio frequency by the reader which sends it to a computer [7]. RFID chips for controlling protected areas consist basically on the storage of a unique ID number into a transponder which operates on the 125kHz frequency, mounted on a bracelet worn on the patient's wrist or ankle, and several sensors installed over protected zones. If a monitored user approaches to a protected zone, the alarm is triggered on, reading the user's ID, with and informing a central computer [7].

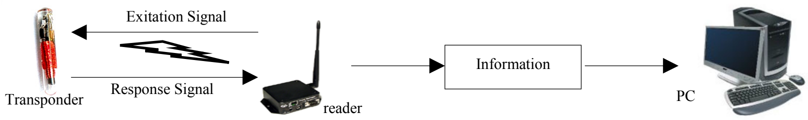

Fig. 1. Functioning of RFID technology

4 Agents Architecture

The agents implemented present a deliberative architecture, based on the BDI (Belief, Desire, Intention) model [2]. In this model, the internal structure and capabilities of the agents are based on mental aptitudes, using beliefs, desires, and intentions. This method facilitates the incorporation of CBR systems [1] as a deliberative mechanism within BDI agents, facilitating learning and adaptation and providing a greater degree of autonomy than pure BDI architecture. To introduce a CBR motor into a BDI agent it is necessary to represent the cases used in a CBR system by means of beliefs, desires and intentions, and implement a CBR cycle. A case is a past experience composed of three elements: an initial state or problem description that is represented as a belief; a final state that is represented as a set of goals; and the sequence of actions that makes it possible to evolve from an initial state to a final state. This sequence of actions is represented as intentions or plans. In a planning agent, the reasoning motor generates plans using past experiences and planning strategies, so the concept of Case Base Planning is obtained [8]. CBP consists of four sequential stages: retrieve stage to recover the most similar past experiences to the current one; reuse stage to combine the retrieved solutions in order to obtain a new optimal solution; revise stage to evaluate the obtained solution; and retain stage to learn from the new experience. Deliberative CBP-BDI agents are able to incorporate other reasoning mechanisms that can coexist together with the CBP. The CBP motor is divided into four sequential stages and different algorithms can be used in each one.

5 Case study: ALZ-MAS

The Alzheimer Santísima Trinidad Residence of Salamanca has been interested in improving the services offered to its patients and has collaborated in the development of the technology presented here, providing their know-how and experimenting with the prototype developed. Figure 2 shows a diagram of the first floor of the Santísima Trinidad Residence of Salamanca containing the main facility rooms, while all the patients' rooms are located in the second floor. This residence has capacity for 60 patients, an average of 6 nurses, one social worker and 5 more employees with other responsibilities. 30 patients to test the system were selected, so the hardware implemented at the Residence basically consisted of 42 ID door readers, one on each door and elevator, 4 controllers, one at each exit, one in the first floor hall and another in the second floor hall, and 36 bracelets, one for each patient and the nurses. The ID door readers get the ID number from the bracelets and send the data to the controllers which send a notification to the Manager agent. To test the system 30 patient agents, 10 nurse agents, 2 doctor agents and 1 manager agent were instantiated.

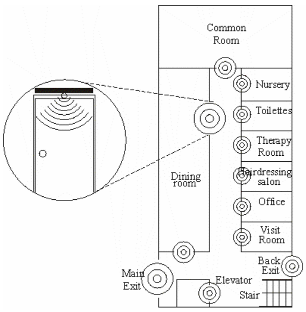

Fig. 2. Sensor positioning in the first floor of the Santísima Trinidad Residence of Salamanca

5.1 ALZ-MAS Architecture

The characteristics of multi-agent systems make them appropriate for implementing into geriatric residences to improve health care of the patients. Studying the requirements of the problem, five roles have been chosen: the Patient role manages the patient's personal data and behaviour (monitoring, location, daily tasks, and anomalies); the Doctor role treats patients; the Nurse role schedules the nurse's working day obtaining dynamic plans depending on the tasks needed for each assigned patient; the Security role controls the patients' location and manages locks and alarms; and finally, the Manager role manages the medical record database and the doctor-patient and nurse-patient assignment. The interactions between the roles involved in the system made us consider a number of protocols: request a treatment, inform about monitoring data, inform about care results, request a doctor assignment, request a nurse assignment, inform about assignment, request a patient's daily plan, inform about a patient's daily tasks, request a patient location, inform a nurse about a lock activation, report alarm activation, request doctor situation, doctor reports on his schedule, request a nurse situation, nurse reports situation, patient reports an anomaly, patient reports on personal data and previous medical records. For example, when the nurse wants to know the tasks required for the patient, the Nurse role executes a protocol RequestPatientPlanif through which is able to make a request to the patient role. The patient role acts to give a suitable response to the nurse role and executes the InformPlanif protocol to communicate the planned tasks to the Nurse role.

The conclusions obtained after the analysis and design process let us conclude that ALZ-MAS is composed of four different agent types:

The *Patient agent* manages the patient's personal data and behaviour (monitoring, location, daily tasks, and anomalies). Every hour validates the patient location, monitors the patient state and sends a copy of its memory base (patient state, goals and plans) to the manager agent in order to maintain backups. The patient state is instantiated at execution time as a set of beliefs and these beliefs are controlled through goals that must be achieved or maintained. The beliefs that were seen to define a general patient state were: weight, temperature, blood pressure, feeding, oral medication, parenteral medication, posture change, toileting, personal hygiene, and exercise. The beliefs and goals used for every patient depend on the plan (treatment) or plans that the doctors prescribe. The patient agent monitors the patient state by means of the goals. To know if a goal has been achieved or has failed, it is necessary to maintain continuous communication with the rest of the ALZ MAS agents. At least once per day, depending on the corresponding treatment, the patient agent must contact the nurse agent. The patient agent must have periodic communication with the doctor agent. Finally the patient agent must ensure that all the actions indicated in the treatment are taken out.

The *Manager agent* plays two roles the Security role that controls the patients' location and manages locks and alarms; and the Manager role that manages the medical record database and the doctor-patient and nurse-patient assignment. It must provide security for the patients and medical staff and the patients, doctors' and nurses' assignments must be efficient.

The *Doctor agent* needs to interact with the Patient agent to order a treatment and receive periodic reports, with the Manager agent to consult medical records and assigned patients, and with Nurse agent to ascertain the patient evolution.

The *Nurse agent* schedules the nurse's working day obtaining dynamic plans depending on the tasks needed for each assigned patient. This agent manages nurses' profiles, tasks, available time and resources. The generated plans must guarantee that all the patients assigned to the nurse are given care. The nurse can't exceed 8 working hours. Every agent generates personalized plans depending on the nurse's profile and working habits.

Manager and Patient agents run in a central computer, but Doctor and Nurse agents run on mobile devices, so a robust wireless network has been installed.

5.2 CBP Capabilities

A Nurse agent has been developed, as an autonomous deliberative cased-based planner (CBP-BDI) agent. This is the main agent in ALZ-MAS and its principal characteristics are described next. The Nurse agent implements the reasoning cycle of the CBP system by means of three capabilities: Update, KBase and VCBP (Variational CBP). The Update capability implements the retrieve and retain stages, while the KBase capability implements the reuse stage and the VCBP capability the revise stage, where the nurse opinion is evaluated. The VCBP capability is also in charge of dynamic re-planning task. By means of its Give Care capacity, Nurse agent supervises each care task and generates the corresponding report. The Consult Nurse Data capability allows it to execute different queries on stored data. Given a set of beliefs *B* compatible with the problem *E*, it is possible to generate a plan base CBP that contains all the possible plans produced by the combinations of compatible beliefs. In this case, the beliefs of the Nurse agent are tasks, resources and time.

Table 1. Implementation of the re-planning process.

Algorithm: Dynamic Planner

```
Tasks B, Objectives O, Resources R
Plan plan
while planner
    if current belief taski < dimPlan then
       if current belief taski == true then
            B ← B – {task_i}
            O ← O(task_i)
            R ← R(task_i)
            current belief++
       else /*current belief == false */
            Replan
    else
          if current R < available R then
             Replan
          else
             /*Plan finish*/
          update bayesian weight (current plan)
          if  global plan then
             update bayesian weight (global plan)
```

A task is a Java object that contains the data of the patient for whom it asks for the service, the description of the service and the max times to carry it out. For each task, one or more goals are established, of such form that all tasks must be fulfilled. A goal is created, executed until it is reached (by defect it comes qualifies with retry). The goal contains the data of the task that must be executed, and a condition of context that guarantees that the times designated for the accomplishment of the task are marked. The goal can change of state, for each case, a plan is triggered (a Java procedure), that is in charge to shoot new sub-goals, which inform to the Nurse agent the evolution of the task (it was obtained, was not reached, exceeded the assigned time, etc.). In Table 1, a pseudo-code of the scheme for implementing the planning model of the agent and illustrating the flow of information processed is presented.

6 Results and Conclusions

Figure 7 shows the average number of nurses working simultaneously (each of the 24h of the day) at the Residence, before and after the implantation of ALZ-MAS prototype, with data collected from October ‘05 to March ‘06. The prototype was adopted on January 15th, ‘06. The average number of patients was the same before and after the implementation.

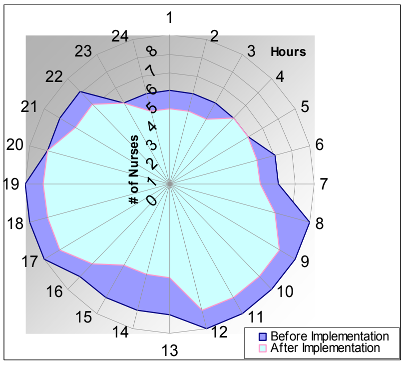

Fig. 7. Number of nurses working simultaneously

The tasks executed by nurses were divided in two categories, direct action tasks and indirect action tasks. The Nurse agent can act on the indirect action tasks. During the first period the problem was analyzed, the residence was observed and data was retrieved. Finally, an average of the time spent by nurses in the carrying out of the tasks for every patient, having into account that a task depends on the dependency level of a patient and the nurse skill. Analysis focused on time spent on indirect tasks; daily times obtained before and after the implementation for each task can be seen on table 2.

Table 2. Font sizes of headings. Table captions should always be positioned *above* the tables.

	Monitoring	Written Reports	Daily Visits	Other	TOTAL
Before Implementation	167	48	73	82	370
After Implementation	105	40	45	60	250

The system facilitates the more flexible assignation of the working shifts at the residence; since the workers have reduced the time spent on routine tasks and can assign this time to extra activities. Their work is automatically monitored, as well as the patients' activities. The stored information may be analyzed with knowledge discovery techniques and may help to improve the quality of life for the patients and the efficiency of the centre. The security of the centre has also been improved in two ways: the system monitors the patients and guarantees that each one of them is in the right place, and secondly, only authorized personnel can gain access to the residence protected areas.

In the future, health care for Alzheimer's patients, the elderly and people with other disabilities will require the use of new technologies that allow medical personnel to carry out their tasks more efficiently. Some potential of deliberative CBP-BDI agents has been shown in a distributed multi-agent system focused on health care. ALZ-MAS integrates Wi-Fi and RFID technologies, being sensitive to context and adaptable to user necessities, providing a high level of human-system interaction in a natural and simple way.

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