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Integrating RFID in MAS through "Sleeping" Agents: a Case Study

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1. Introduction

Intelligent Agent technology is an important, exciting and relatively new paradigm in software design. The term intelligent agent is now used as an umbrella term representing a wide range of software with different characteristics and abilities [1]. This fact led to many definitions of intelligent agent, but the authors agree with the definition proposed by Wooldridge and Jennings [2] stating that an intelligent agent is a problem solving entity characterized by the following properties:

- autonomy, the agent does the major part of its tasks without user intervention
- social ability, the agent is able to communicate with other agents (or human beings) to solve a given problem. This property has an enormous importance because it requires that the agent is able to understand a language, to know when and with who this should communicate and so on.
- Proactiveness, the agent takes the initiative to act on the surrounding environment when appropriate
- Responsiveness, the agent is aware of the surrounding environment and can react to its variations.

The natural evolution of the intelligent agent technology is the Multi Agent System (MAS) technology [3].Systems of this kind are composed of a set of intelligent agents interacting and collaborating each other to solve complex problems that are beyond the individual capability or knowledge of each agent.

There are many applications of MAS in various problems. For example MAS technology was used in [4] to increase the reliable of a distributed sensor network, in [5] this technology was used for databases integration, in [6] as decision support system for an intelligent transport system, in [7] a MAS that implements mine detection, obstacle avoidance and route planning was proposed.

In this work the authors will show the advantages that MAS technology can obtain combining the autonomy and proactivity of the intelligent agents and the intrinsic mobility of the RFID devices.

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RFID is a generic technology concept that refers to the use of radio waves to identify objects. RFID is a non-contact interrogation method for identification of objects. An RFID system essentially consists of three parts:

1. RFID tag itself that is a device of various shapes (the shape varies according to the application in which the tag will be used) composed of memory unit and an antenna that is used to communicate with the remote reader device. The dimension of this memory is continuously increasing and today there are some RFID tags with various kilobyte of memory.
2. the RFID transponder is a device supplying and communicating with the tag by means of a radio wave. There are various types of RFID reader varying in resolution, reading distance, etc.
3. a backend information management system that is the system that use the data stored in each RFID to accomplish the various tasks (supply chain management, factory automation, etc.).

In this work the authors propose to use the high memory capacity RFID for introducing the new concept of "sleeping agent". In order to show the suitability of this concept in real world applications, the authors propose as case study a model of clinical risk management system based on a MAS employing sleeping agents.

The remaining part of this work is organized as follows: in section II there is a brief related works overview, in section III the RFID technology is introduced while in section IV the sleeping agent is presented. The analyzed case study is described in section V while the proposed MAS is presented in VI. Finally conclusions and remarks are proposed in section VII.

2. Related works

Due to the flexible and dynamic characters of intelligent agents, they are being used widely as an interface system between user and information retrieval systems for whatever application.

An example of this kind of applications can be an expert system developed for the user assistance to a better understanding of scientific data retrieved from environmental monitoring systems (these collected data are actually translated by expert chemists or biologists) [4].

In practical application, each agent is defined as a software entity, that is capable of flexible autonomous action in order to meet its design objective [8]. A multi agent system can be defined as an organization composed of autonomous and proactive agents that interact with each other to achieve common or private goals [9 - 10].

According with Qiao and Zhu [11], in conceptual schemes of each agent it is possible to recognize five components:

- Perception, a channel for an agent to receive information from the external world.
- Effector, an interface for an agent in order to modify or influence the state of MAS.
- Communication, a mechanism for an agent to exchange communication with other members of the agent society.
- Objectives, list of roles that an agent can play
- Knowledge processor, a knowledge base system that stores and processes the necessary knowledge for an agent so that this one can play the role the MAS has assigned to it.

To create a structured, flexible, and scalable MAS we can layer different functions and components needed to solve the problem [12]. A good abstraction can be achieved and a large class of different problems solved by using a layered approach.
Each layer represents a single functionality in order to minimize the interlayer communications and localize (by one or more agents) the activity. The number of agents performing functions in each layer is defined according to the goals that layer must satisfy.
There are many applications where the MAS systems are successfully used. In [13] the authors propose a MAS to implement mine detection, obstacle avoidance and route planning with a group of autonomous agents with coordination capabilities. [14] presents multi agent system approach and software prototype aimed at the air traffic control in airport airspace.
Since one of the most important characteristic of the intelligent agents is their ability to communicate among them to reach a common goal, there are interesting works on the negotiation policies that agents can have. An interesting example of these works is [15].

3. RFID technology and applications

RFID is one of the most successful pervasive computing technologies. Born as a replacement for traditional barcode, nowadays its wireless identification capability is changing heavily many human activities such has health centers, logistic and production chain, etc.
Each RFID tag contains a unique identifier, so, if a RFID is attached to an item, reading its presence is equal to reading the presence of that item. From this point of view they are not too different from the barcode. The real advantages of the RFID become clearer considering their reader devices. A RFID reader is able to read simultaneously more than one RFID also through physical barriers and from a distance [16]. This fact makes these devices interesting for many applications. For example, in the fields of physical distribution, the technology to recognize multiple items in a cardboard box or a shopping basket at a time attracts attention.
RFID tags are classified into two types. One is the passive type that is battery-less, and the other is an active type that has its own battery. The passive type tags are cheap and have long lifetime. For this reason, they can be used in several places.
The main limit of this kind of RFID devices is their small amount of memory (typically 96 bits). This quantity is enough to store an electronic product code but it needs the connection to a local or remote database to obtain additional information about a specific tagged item. This requires a network infrastructure that guarantees secure, reliable and speedy access to a central database where the additional data are stored. In [16] there is an interesting analysis of the security issues concerning this kind of applications.
Nowadays RFID tags with high quantity of memory are becoming ever more popular. These devices become the keys of new kind of applications storing all the data on a given item locally in its RFID. For example, the Boeing has announced its intention to use high memory RFID to track the maintenance and repair history of parts for its upcoming Dreamliner 787 family of airplanes [17].
In this work the authors propose to use this kind of RFID to store the agent code.

4. The sleeping agent

The sleeping agent is an intelligent agent embedded in a tag RFID with high memory capacity. Its main task is to interact with other agents to satisfy its goals or to cooperate to reach a global goal. These objectives are defined according to the specific application domain in which they are used.

They are defined "sleeping" because they are not ever running processes in the system on which the MAS is running. Normally, they are stored in an RFID in wait state (sleeping) and are loaded/awoken into the main system when the MAS needs their activities. At this time, the sleeping agent performs its task and, if it is required by the application, it is stored again in its RFID with an updated state.

Considering that RFID tags are devices used to identify an object in a contact less way, one of their primary application field is the logistic.

The main innovation of the sleeping agent relies on the fact that it makes each object, identified by a RFID, an active entity. It can interact with the surrounding environment exploiting all the characteristics of an intelligent agent.

Since the sleeping agent is not an ever running process in the system, its use allows for implementing model of systems composed of several entities whose activities are asynchronous. Two interesting examples of such systems are the following:

- distributed supply chain simulations: in this application each item can be represented by a sleeping agent doing its work when needed (e.g. in correspondence of some transport node). Using an agent rather than a simple identifier introduces into the system a high level of flexibility. Indeed, with this approach, thanks to the sleeping agent, each item can interact with the supply chain to optimize it.
- health care centers: in this application, there is the need to identify reliably each patient. A RFID with a sleeping agent is given to each patient (e.g. using a wristband). The sleeping agent becomes a kind of patient's avatar representing he/she in each interaction with the health center services (diagnoses, medical doctor, etc.). In the long period in which the patient stays in bed without having other services by the health care center, the sleeping agent stays in the RFID without overloading the computer system where the MAS is running.

These two examples are fields in which the classical RFID technology is reaching good results in terms of performance and spreading. For this reason in this work a MAS modeling a health care system using the sleeping agent is presented.

5. Case study

Healthcare systems represent an interesting testbed for the integration of MAS with RFID technologies. Furthermore, the employment of sleeping agents is particularly suited for this framework since it allows for reengineering healthcare systems efficiently as it will be shown hereinafter.

In the latest years, healthcare has become one of the most important sectors of interest for the Information and Communication Technology (ICT) market. This occurs because the same nature of the "clinical practice" is mainly focused on the information management and analysis. On the other hand, the exponential growth of the technological ability to acquire biological data in digital format, which can be extended to extract useful information for diagnostic and therapeutic aspects, plays an important role in this slow but substantial transformation. Two visible examples of this change are the major spread of personal computers within hospitals and the enormous amount of messages sent using the internal network of healthcare facilities to exchange information among the various operators.

A critical challenge is then how to globally publish, in a semantic integrated view, information coming from geographically distributed information sources such as databases, programs, etc. In the Italian context for example, many medical databases/archives are owned by the Public Administration, and they are often managed at a regional or at a provincial level. Two noteworthy examples of such databases are the INAIL ’s and the INPS ’s archives where most of the citizen heath related data are stored.

Focusing the attention on patient care, the clinical risk management represents an important aspect. The clinical risk management refers to the procedures for avoiding risks associated with direct patient care in order to minimize errors in the clinical practice and improve the quality of the service offered. It is the analysis about the probability of a patient being victim of an adverse event or inconvenience resulted, although involuntary, from improper medical care provided during the period of hospitalization.

The safety of the patient can be assured only by designing secure organizational systems and perhaps more importantly, by establishing and implementing procedures to reduce all high-risk situations in clinical settings. Indeed, according to a recent survey by National Institute of Health, the first cause of accident risk is just the lack of proper procedures, followed by a poor work organization and only at the end the causes are linked to logistical situations and inadequate structures. Referring to the first type of clinical risk, the most frequent mistakes are: incorrect diagnoses (medical error), the prescription of inappropriate therapy (for pharmacological principle, unfitting care for specific subjects, wrong dosage) or inaccurate interventions. The common denominator of all these clinical acts is the traceability of patient and all cares connected to this one [18].Another important aspect concerns the process phase standardization that could provide a quality system for obtaining secure patient data (UNI EN ISO 9000:2000).

Traceability systems in the hospital context are generally:

- Traceability system of wards (including also emergency ward)
- Traceability system of pharmaceuticals: from the delivery of the drug produced by the manufacturer to the administration of the single dose
- Traceability system of medical devices
- Traceability system of blood bags
- Traceability system of implantable device

Numerous experiments carried out in the early nineties have implemented traceability systems in view of technological supports in use. Current tendency is to focus, in particular, on the management of patients’ physical paths (patient flow). A more rational management of the physical patient flow could solve the typical hospital problems such as: delays, long waiting times, queues, erased interventions, patients placed in inappropriate care setting, nursing staff under stress, waste and high costs etc.

From a technological point of view, hospital information systems (like many distributed complex systems) are committed to face with the following problems:

- data redundancy
- legacy systems
- unstructured data
- security
- traceability

Data redundancy concerns the possibility of conflicting information due to data replication across multiple locations, while legacy systems take into account the pre-existing technology already in use. Unstructured data require of course a special assessment since they cannot be processed in their natural form.

To overcome the aforementioned criticalities and to face with the strict requirements regarding efficient traceability a re-engineering effort is due in the traditional healthcare system. Two models regarding patient identification and assistance during the hospital stay can be compared. In particular, these two representative models characterize respectively traditional (generally barcode-enhanced) systems and those based on RFID technology [19,20]. The main difference is that the barcode model considers hospital as an organization structured in functional blocks, while the RFID (re-engineered) model considers the patient at the center of the clinical process. This difference reflects the operating principle: it will be passive in the case of optical systems and active for Radio Frequency Systems. This difference of course impacts also on the hospital organization in relation to the quality of health services for the patient.

The presence of separate functional areas that are typical of barcode system, draws attention to the problem of risks associated with information duplication. Indeed, in these systems the uniqueness of the chosen communication channel (i.e. “medical record” in the system database) determines that the contact among different information flows can occur only after or before the processes have been developed by each functional unit.

Contrarily, at the base of the re-engineering process a new patient-centred data model is requested. The model is basically characterized by the disappearance of the medical record concept, seen as an instrument for getting information about activities produced by the system in relation to the patient, to whom it is associated, Therefore the concept of “health condition” replaces the medical record and refers to the patient condition in a specific moment. Since the health condition is linked by a univocal relationship to the patient that it describes, it is clear that there is a direct relationship with the activities related to: physical examinations made by the medical staff; drug management (prescription, administration) made by the pharmaceutical staff and performance of other hospital operations for monitoring patient health condition (analysis and investigations) together with other correlated actions.

A patient-centred model is then able to intercept all important entities characterizing hospitalization but from a different view RFID model introduces simplification without introducing any substantial approximation of the modelled reality.

Furthermore, in a traditional system, asynchronism of communication can lead to lack of communication phenomena, which can be associated to the delta time characterizing the accesses for reading or writing the medical record. The presence of a single communication node determines a possible break thus leading inevitably to the collapse of the whole macro system with all the relative risks connected to this. Contrariwise, in an interconnected model, similar to that using RFID technology, it is ensured that the temporary absence of information flow does not inhibit data exchange to all other entities of the system, which can continue to operate even under reduced conditions.

The application of RFID model can be considered as useful also for the optimization introduced in operation traceability. On the other hand, a system producing a single intra-hospital communication output and characterized by sequential writing access, can easily suffer from the possibility of being improperly altered, differently from what actually occurs if the exchange of data and information among the operators takes place in real-time.

In conclusion, the use of RFID technology produces several advantages to health care processes with only a slight reengineering of specific structures. A more rational use of

hospital information systems allows for a better organization of clinical data. Moreover, it is noteworthy to remember the launch of RFID and Wi-Fi compliant transponders on the market. These allows for unifying access points, thus simplifying them, (from a specialized portal to a pervasive wiring) and obtaining, through triangulation techniques and/or the power density calculation, the precise location of monitored entities.
It is well known that the process for examining the clinical risk must start from the identification of risks analytically, and therefore define the potential risks according to predetermined international grading scale in order to organize and implement the risk reduction project. A possible solution for reducing the incidence of errors related to "mistaken identity" seems to be the use of identification wristbands with advanced RFID or barcode systems at the time of admission to hospital. Of course, this solution cannot be considered as the only or essential strategic element in the clinical risk management for the patient safety.

6. Proposed multi-agent system architecture

As seen in the previous paragraph, RFID can be used to improve many aspects of clinical risk management. The main advantage of the RFID based model compared to the one based on barcode is that the former sees the patient as the centre of the clinical process with clear advantage in terms of optimization of clinical risk and resource.
The authors propose a multi-layer MAS architecture as shown in figure 1. In each layer there are agents that have same features and common goals, but they are able to satisfy their own scope with different approaches and with different results. The designed layers are:

- User area: In this area there is an instance of sleeping agent for each patient in the clinical setting. This sleeping agent is stored in the RFID that the patient receives when he/she comes into a health centre. It is possible to consider this agent as an avatar of the patient in the proposed model of health centre. The main task of this agent is to interact with all the other agents into the system to satisfy the patient necessity. This agent is defined "sleeping" because it is not permanently allocated in the main system, where the clinical model is running. Indeed, this agent is loaded into the system only when the patient needs some services (he/she goes into a certain ward, he/she receives some pills, etc.). When the patient necessity has been satisfied the sleeping agent can return back into the RFID with its new updated state or it can stay in running state to accomplish other tasks. In this way, it is possible to save a big amount of system resources in terms of memory and processing time. It should be highlighted that the couple RFID-sleeping agent is the point of contact between the real world health centre and the MAS based clinic model and it is absolutely transparent for the patient.
- Interface area is designed to allow for the communication between the agents in the user area and those in the brokerage area. In this area various problems about systems compatibility and security are faced.
- Brokerage area: In this area there are two classes of agents: broker agent and coach agent. The broker agent receives the service requests from the upper layer and it analyzes a local database in which services offered by MAS (that are the same that in the real world the health center offers) are stored. Starting by one query, it produces as many messages as the request needs. The language, that Broker uses to communicate, is

generated using understandable and common language for all agents. The Coach is a complementary agent of the Broker, because it is able to assemble the information contained in the messages sent by the lower level as response to a broker query. At the end of the process the Coach sends a message to the Interface that translates the answer in a language understandable by the sleeping agent and/or the user.

- Analysis area: in this area all the services provided by the clinic: medical doctor, analysis devices, etc are modeled as "service agents".
- Knowledge area: In this area there are all the information sources present into the health centre (e.g. databases used by the medical doctor to store information about patient, connections to other regional or national databases, etc.).

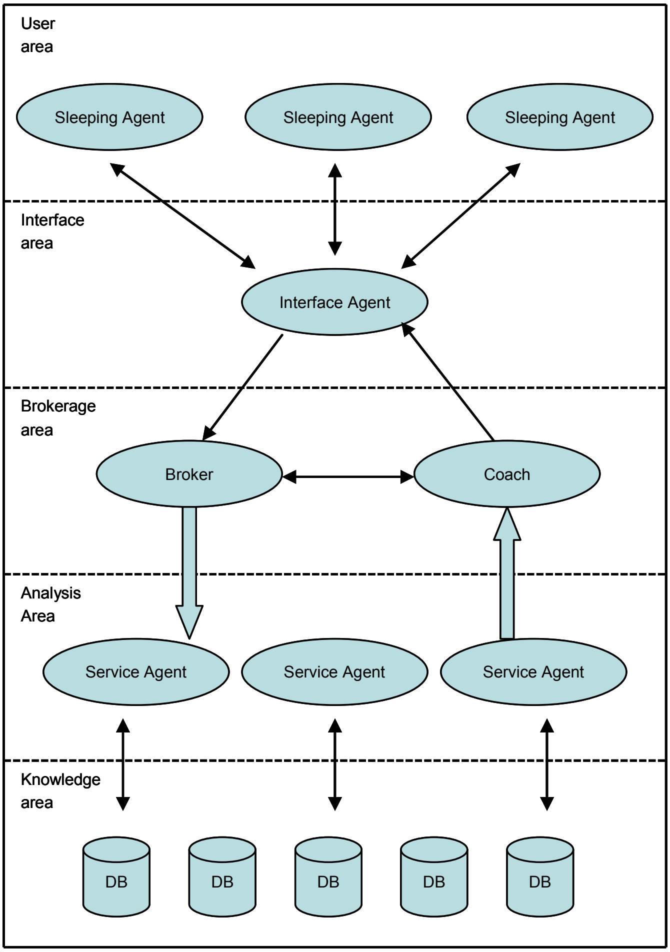

Fig. 1. A schematic overview of the proposed MAS

The adoption of an agent with standard characteristics would require the allocation of computational resources always associated to it. The introduction of sleeping agent represents a possible problem solution. This agent frees its allocated resources when the patient is in standby (namely the patient does not interact with healthcare system i.e. when he/she stays in his/her room). This statement introduces an important advantage to the system: it reduces the computational cost since it is based on a distributed asynchronous communication model. The interaction between patient and health care center are handled in automatic by the sleeping agent in a transparent way for the user.

On the other hand, a RFID becomes patient ownership in the proposed system. The sleeping agent is stored in the RFID memory, letting the patient transport information about himself/herself across the healthcare centers. This represents the second advantage introduced by the proposed system: i.e. proactive event-driven solution to patient data flow. This approach improves also the security of the data management system. Indeed, the sleeping agent can handle also the private key of an asymmetric cryptography system. Data are stored in the database using the cryptography and they can be read only with the physic presence of the patient.

7. Conclusions

In this work the authors propose a new kind of intelligent agent based on the new finding in RFID technology. The sleeping agent can be used to implement MAS systems to solve various problems. As case study the authors proposed a MAS modeling a health care center. In this model the sleeping agent is resident on a patient's RFID wristband. This kind of agent is the virtualization of a single patient in the healthcare system and plays the role of a proactive user for the clinical information system. The sleeping agent memorized on a RFID is a convenient solution to the problem of patient identification and traceability that allows for several benefits in terms of data integration, computational effort, asynchronous communication, privacy and so on.

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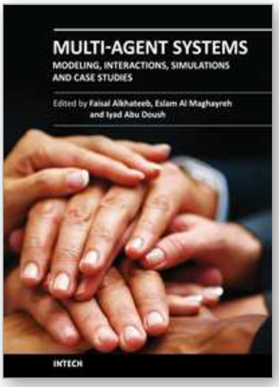

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A multi-agent system (MAS) is a system composed of multiple interacting intelligent agents. Multi-agent systems can be used to solve problems which are difficult or impossible for an individual agent or monolithic system to solve. Agent systems are open and extensible systems that allow for the deployment of autonomous and proactive software components. Multi-agent systems have been brought up and used in several application domains.