ELECTRONICS AND ELECTRICAL ENGINEERING

ISSN 1392 – 1215 *2008. No. 6(86)*

ELEKTRONIKA IR ELEKTROTECHNIKA

SYSTEM ENGINEERING, COMPUTER TECHNOLOGY

T 120

SISTEMŲ INŽINERIJA, KOMPIUTERINĖS TECHNOLOGIJOS

Identification and Monitoring of Patients Using RFID and Agent Technologies: Synergy and Issues

C. Turcu, Cr. Turcu, V. Popa, V. Gaitan

"Ştefan cel Mare" University of Suceava

13, University Street, 720229 – Suceava, Romania, phone: +40-741-221404, e-mail: cturcu@usv.ro

Introduction

In the last ten years, information and communication technologies (ICT) have progressed to such an extent that they have become accessible to worldwide organizations and even individuals. More recently, ICT have become increasingly common in most health care settings (home, residential facility or hospital).

The medical field, regarded on all its levels (local, regional, national and international) may be assimilated to an open environment characterized by a shared and distributed decisional process; this environment ultimately presupposes sharing and exchanging information among various participants (patients, physicians, laboratories, clinics, etc.).

Perhaps one should not forget to mention special events such as the three editions of the *eHealth Conference* debating the numerous contributions of ICT to health; the 2003, 2004 and 2005 participants reiterated the strategic importance of a full exploitation of new information technologies in the public administration of health for the benefit of the citizen as a consumer of both health care services and health information.

In the last few years, the whole medical world has shown a major preoccupation with ensuring and improving the quality standards of medical care and services. Software applications have particularly attracted the attention of medical professionals because their utility covers areas ranging from risk reduction in diagnosing patients and the establishment of treatment schemes to graduate and postgraduate medical training, health threats surveillance, the management of trans-border health challenges and crises or health literacy. Since the European citizens are increasingly mobile, it is imperative that people become aware of the pressing need for a more integrated and interoperable European health information space.

Most health systems in Europe face similar issues and the enlargement of the EU means that there are new opportunities and challenges for those involved in providing high quality health services and seeking to improve health in their communities. At the same time, it is expected that every national health care system should adopt its own long-term strategies in keeping with the *Action Plan for a European eHealth Area.*

The inefficient use of healthcare information is likely to be a major problem in large and complex health organizations. This is especially relevant when patient data, which is produced in heterogeneous environments, at various places and by different health professionals, should be available for authorized individuals at any point of care. Consequently, the cost of non-automatic data collection, storage or integration is vast. On the other hand, the lack of an efficient information flow implies a delayed management of clinical report updates, mainly for some laboratory result and an increased length of stay or delays in outpatient consultation and surgeries. In conclusion, many of the frustrations encountered by participants in the health care system can be traced to the inability of current information systems to provide adequate, accurate, timely, and appropriate information. Poor information flow has become an impediment to efficient delivery of high-quality health care.

RFID and health care

While RFID is already widely used in the business world—for example, to locate packages or track inventory—its applications in health care are just emerging. The possibilities are as promising as they are varied, and include [1]:

- Tracking pharmaceuticals from the manufacturer, distributor, and pharmacy to the point of administering medication to the patient;
- Tracking movable equipment, furniture, medical devices, and other valuable items both to provide ready access when needed and to reduce losses;
- Identifying the location of caregivers in hospitals and other institutions to ensure the most efficient assignment in response to emergencies;
- Ensuring the proper identification of laboratory specimens, including biopsy samples and containers of blood or urine to reduce medical errors;

- Tracking patients—both for the purposes of redundant identification prior to the administration of medications or surgery and for protecting infants, Alzheimer's patients, and others with special vulnerabilities;
- Managing controlled substances, pathogens, and other materials that pose a public health risk.

Our research team is involved in some projects where RFID technology is used for the identification and traceability of products and subsets in enterprises [2], products inventory or farm management. In these projects some structural optimizing solutions for information storage on RFID tags were developed [3].

Many of these applications were not designed to exchange information. Hence their inefficiency. Furthermore, non-communicative applications generate redundant or contradictory data. The idea of our system (named SIMOPAC) could help the development of an electronic patient record and facilitate the communication process among health professionals.

Agent technologies and health care

The use of the agent/multi-agent system (MAS) paradigm has increased sharply as an important field of research within the Artificial Intelligence area. This paradigm has been applied to different fields such as process control [4], mobile robots [5], air traffic management [6], industrial field [7], intelligent information retrieval [8][9] etc.

A lot of agent definitions can be found in the literature, yet there is no one to have been fully accepted by the scientific community. A definition that is seldom mentioned was proposed by Wooldridge and Jennings [10]. According to them, an agent is defined by its flexibility, which implies that an agent is:

- *reactive*: agents perceive the context in which they operate and react to it appropriately;
- *proactive*: an agent has to be able to try and fulfil his own plans or objectives;
- *social*: an agent has to be able to communicate with other agents by means of some kind of language.

Also various authors have proposed different definitions of agents, these commonly include supplementary concepts such as:

- *autonomy* (agents have capabilities of task selection, prioritization, goal-directed behaviour, decision-making without human intervention);
- *persistence* (code is not executed on demand but runs continuously and decides for itself when it should perform some activity);
- *cognition*: agents perform information processing and reasoning, based on their internal knowledge base, in terms of rules;
- *communication*: agents participate in communication acts, interacting and sharing knowledge with other agents of the MAS.

The term *agent* selected as name for a tool implies that the latter should be able to meet the above mentioned requirements. Nowadays, a small percentage of the existing software follows this definition.

Given their well-established properties, the agent technologies seem the most appropriate choice to solve most health care problems. This appropriateness results from the capabilities of the agents to provide solutions in a domain characterised by the distributed nature of data, the complexity of the software solution, the lack of centralised control, the need to ensure the independence of the health care entities, the need to communicate and coordinate in order to provide specific services to individuals, and the need to receive information and advice proactively [11].

The proposed system

The proposed system deals with immediate strategy of restructuring the national health system, ensuring the premises of offering medical and informing services, to the qualitative level imposed by EU standards. The architectures of the SIMOPAC allow the collection, integration and availability of medical information at all point of care. The proposed system structure is presented in figure 1.

The hospital structure comprises one or several modules, depending on the number of medical divisions taken into consideration, for example the emergency and the radiology division. The internal bus is designed to facilitate data sharing among the modules. The Internet server connects the medical divisions to the external environment. Represented at the top of figure 1, the component elements of the system corresponding to various group-participants such as family physicians, specialist physicians, laboratories, pharmacies, and patients, are provided access to the Internet network. More than one data server may be included in the system; these servers are designed to facilitate the storage of dynamic data, namely information about patients and medical imagery. The system is also endowed with an interactive interface for communication and reporting.

Among the novelties in this project, mention should be made about the *electronic personal identity card (PIC)* which ensures the identification of patients. Furthermore, our PIC has been developed using RFID technology: the information is stored in a transponder (tag) – an electronic chip with memory. Our preference for passive transponders has been dictated by their low costs. These transponders are written and read by equipments generically named *readers*, by an electromagnetic field emitted from their antenna, from which the transponders extract their necessary energy of functioning. In the absence of the field, the transponders do not function, but store information.

For the proposed system, PICs will memorize and store a whole range of valuable facts and details such as patient identification codes, personal health records, blood type, individualized emergency procedures, etc. The reader type to be selected depends upon the responsibilities and special needs of various health professionals such as family physicians, medical specialists, nurse practitioners, clinical biochemists, pharmacists, emergency doctors and

nurses, etc. Wireless mobile devices (PDAs) have also been taken into consideration and represented in Fig. 1. These portable units can easily be used in ambulances and emergency situations when any delay or incorrect decision may endanger people's lives. Sometimes the patients in need of urgent medical assistance cannot provide vital information concerning their blood type, Rh factor, chronic diseases or allergenic substances; hence the usefulness of handheld readers which can provide paramedics or emergency doctors with vital information about their patients/victims and allow them to adopt and apply the most suitable medical procedures. Moreover, as no connection to a central server is required to retrieve information, especially in uncovered areas, these mobile readers have ruled out all time-consuming processes.

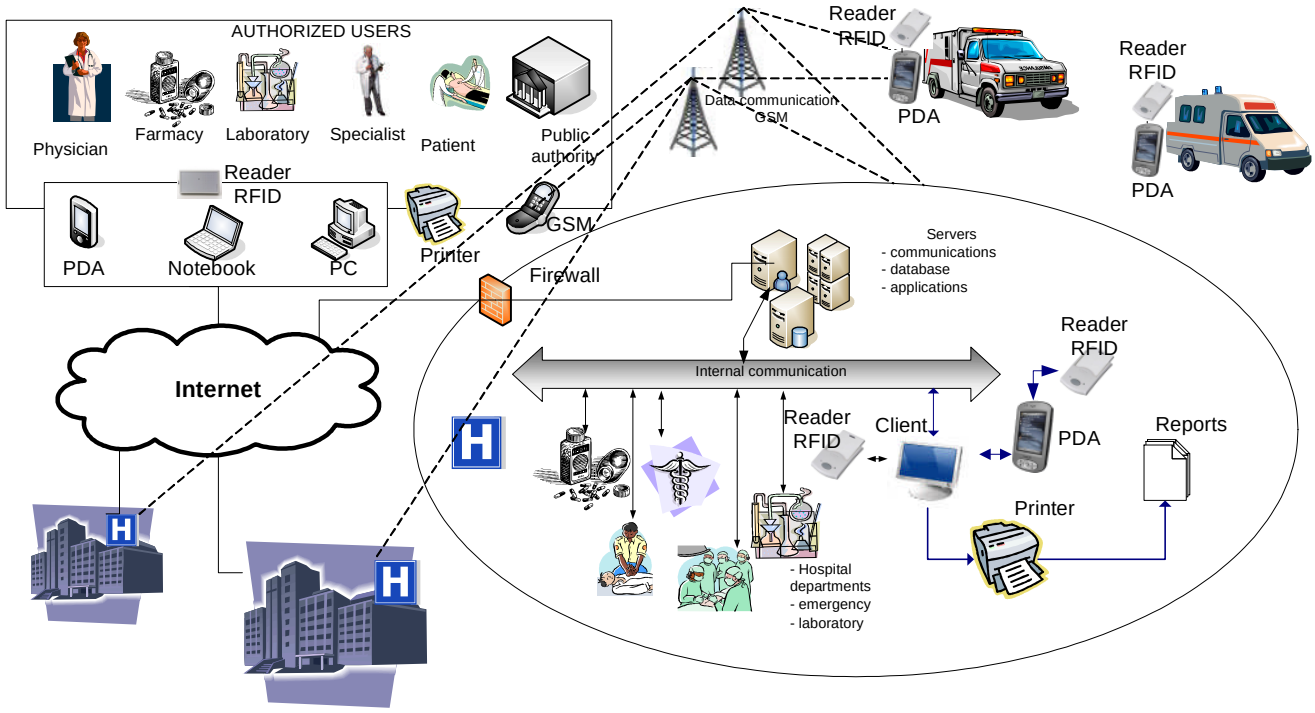

Fig. 1. The architecture of the SIMOPAC system

The implementation of the systems raises several geographical implications as one and the same patient may be consulted by some specialist physician in another county. Therefore, a special attention has been given to the representation of data and communication methods; as a major novelty in this project, we have proposed the usage of *web services* and *multi agent technologies* to enable the efficient communication among various components within the system. Furthermore, the system proposed can assist health professionals in the management of most activities in the medical field. Thus, given the action method proposed, any health care agent can:

- preserve the autonomy of participant actors;
- integrate different operating backgrounds;
- coordinate all patient–related information (even when it is distributed at the level of more medical units, insurance companies or governmental bodies);
- can improve the overall management of medical information.

For instance, one or more health care agents can provide specialized services to one and the same patient, depending every patient's needs (e.g. laboratory tests, medication); moreover, every patient's medical record can be updated and kept up-to-date.

The conceptual novelty of the system is based on its flexibility and adaptability. The agents' community has a dynamic evolution, depending on system's specific situations.

The design-team will construct several system usage scenarios and provide alternative solutions for various situations occurring in cases such as the administration of medicines and food, transfusions, or transplants.

Various RFID applications will be employed to write the PICs and then easily retrieve data from the same PICs. Wired or wireless communication access will depend on specific technical conditions. The whole system will be designed in such a way as to allow the easy retrieval of information from all damaged PICs and its transfer to new PICs. Furthermore, the design team will look for innovative methods that will prevent any unauthorized users from changing or altering the data stored on the PIC. It is imperative that all project partners be involved in the joint development of both the electronic format of the information to be stored on the PIC and the user interfaces for the readers in accordance with enforced technical standards and specifications.

Both the design and the implementation of the system are complex issues; aspects such as the management of confidential information, the selection of the most appropriate certification and security procedures are to be carefully considered. Data encryption and certified and controlled database access have been chosen to protect and secure the confidentiality of the information on patients.

Moreover, the need to secure the information flow and to create the so-called *trust chain* represents another major concern. As long as various categories of health care actors, from medical staff to insurance agents, will gain access to people's medical files or records, it is of outmost importance that storage and retrieval information standards be employed. Already enforced at the international level, the E 1869-97 standard specifies the essential principals governing the confidentiality, access and security of medical information.

Some simple scenarios

The following paragraphs describe some simple scenarios that may occur within the system.

Scenario A: In the case of an intervention in an area where there is no GSM signal, the personnel of the ambulance uses a RFID reader in order to read the information on the patient's PIC. According to this, the personnel can initiate specific actions considering the eventual chronic diseases that the patient may suffer of, reactions to medication etc. (all this information is stored on the patient's PIC).

Scenario B: If the intervention takes place in an area where there is GSM signal, as soon as the patient's PIC has been read together with the specific actions initiated by the ambulance's personnel a call it being sent to the nearest hospital or to the hospital the ambulance belongs to. In this situation, the agent community will act in order to collect the information regarding the patient from the other actors in the system (labs, physician, specialists, pharmacy, hospital departments etc.). Therefore, when the patient gets to the hospital, the medical personnel can have at disposal the relevant information concerning the patient's analysis, the history of the monitoring parameters of the patient, the patient's general evolution in time. The major advantage of the system consists in distributing the information concerning to the patient, eliminating the disadvantages of a central data base when it comes to its measures and the accessing time needed.

Scenario C. A patient can initiate a session in order to transmit the measurements of his vital parameters to his physician or specialist. These measurements can be achieved form simple microdevices like blood pressure monitor, glucometer etc. During a session a patient can also responde to a number of questions asked by his physician or specialist, each questionnaire being structured depending on the patient's disease. The multi-agent system analyses the information transmitted by the patient, cumulates this with the patient history (vital parameter measurements, medication, previous medical interventions and agent actions) and generates some specific actions oriented to the patient for example notification sending to his physician, appointment with specialist, educational plan generating for the patient etc.

Agents

In order to assure a high functionality level for the system various types of agents will be designed and implemented. Some of them are presented below.

a) *Information retrieving agents*: due to the distribution of information about a patient the exploration of resources is a very important problem in this application; these agents must deal with information acquiring but also with the selection of the interesting documents;
b) *Visualization agents*: the retrieved information must be formatted and displayed in a proper order; time ordering of the lab results or patient's health states can represent one criteria for these agents;
c) *Scheduler agents*: these agents are responsible with appointment between patients and medical personal, generating alarms for patients etc.
d) *Educational agents*: these agents generate educational plans for patients. These plans are based on the physician/specialist's recommendations but also on the measurements of the patient's vital parameters. For example if blood pressure is out of range educational plan can contain special indications about diet, medication/alternative medication and preventive actions to be executed by the patient;
e) *Monitoring agents*: these agents deal with abnormal situations when the patient's vital parameters are out of normal range. They are activated after the patient introduced new measurement and their actions are based on a consequent analyse of the current and historical measurements of the vital parameters. The monitored parameters can be grouped in a vector

$$V_{MP_i} = [mp_1 \quad mp_2 \quad ... \quad mp_N]^T, \tag{1}$$

where mp_j is the value of the j^{th} monitored parameter during the day i. Based on V_{MPi} vector analysis a patient's state on a day i is deducted:

$$S_i = f(V_{MP_i}), \tag{2}$$

where f is a perception mechanism. The state S_i can be cumulated with S_{i-1}, S_{i-2}, …, S_{i-K}

$$V_{H_i} = [S_i \quad S_{i-1} \quad ... \quad S_{i-K}] \tag{3}$$

and the new structure is applied to the g perception mechanism

$$H_i = g(V_{H_i}). \tag{4}$$

The equations above describe the C scenario. The MAS system must generate adequate actions in order to assure a quick transition from S_i to the improved state S_{i+1} if S_i is a worst one (figure 2).
In order to generate a current action, previous MAS actions can be also considered [12].

f) *Admin agent*: this agent is responsible with all admin activities in the multiagent system; it manages the entire actions of the community.

During implementation, depending on identified necessities and parteners' decisions several types of agents

can be also implemented.

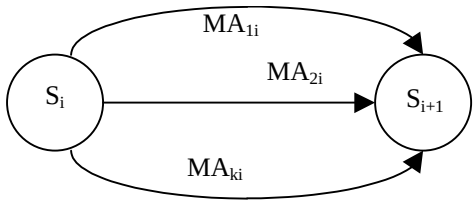

Fig. 2. Transitions between states – MA_{ki} = k^{th} MAS action on the i day

Potential users

The proposed system addresses the needs of many end users:

- various providers of medical services within the national health care system (family physicians, medical specialists, hospitals, medical testing laboratories etc.); the implementation of the solutions proposed will help the Romanian healthcare system meet the EU quality requirements in the medical field;
- patients – as main beneficiaries of medical services;
- various units of medical, academic and scientific research; the research results will connect the Romanian research milieu to the European one (Strategic orientations and options towards Romania's informational technology and communications, chapter 4);
- educational and instructional units at the national level; the implementation of the solutions proposed will ensure the correlation between the quality of our national instructional process and the stresses and strains of human resources in the field of health care and medical assistance;
- various public bodies in the medical field such as the National Health Insurance Body will have access to private information and yet never infringe on the confidentiality right governing the relationship between physicians and their patients; they are expected to employ the information in order to estimate the health status of certain communities or that of the whole national population, and only then prepare action plans or look for various types of resources to improve people's health.

Conclusions

The project addresses problems of outmost interest for the whole Romanian health care system and introduces novel approaches and technical methods:

- the whole system design follows new conceptual models which resonate with the latest advances in Informational Society; hence the reduction of subjectivism in monitoring processes, a more thorough evaluation of medical assistance and treatment, and the enhancement of quality in medical services;
- the usage of web services and multi-agent technologies for the implementation of complex distributed systems (e.g. functions of communication management);
- as an absolute novelty at the national level, RFID technologies are employed to identify patients;
- a secure system access ensuring the confidentiality, integrity and security of data;
- the implementation of RFID applications using transponders functioning on different frequencies (125 KHz, 13.56 MHz etc.) and readers observing the ISO15693 standard (approved in 2003);
- the suggestion to introduce a unique national identification code to be stored in the electronic identity cards;
- the participation of specialist members of the implementing team in the establishment of a new standard for the applications in the medical field;
- the establishment of some relevance indices for the information to be stored in the electronic identity cards; several European registration systems have been studied in order to see how the selection of relevance indices can be applied nationally;
- competitive access to medical records.

Acknowledgments

This work is supported by the Romanian Ministry of Education and Research under Grant PNCDI II, D11-011/2007.

References

1. **Jang, M. B.** A Study on Implementation of Efficient Patient Care Application System using RFID // IEEE International Conference on e-Technoloy, e-Commerce and e-Service. – Hong Kong. – 2005.
2. **Turcu, C., Prodan, R., Popa, V.** A Generalized Integrated RFID-Based System for the Identification and Traceability of Products and Subsets in Enterprises // ECUMICT, Gent. – Belgium. – 2006.
3. **Turcu, C., Prodan, R., Cerlinca, M., Cerlinca, T., Turcu, C.** Information Storage on RFID Tags: Some Structural Optimizing Solutions // Proceedings of the 1st RFID Eurasia Conference. – 5-7.09.2007. – Istambul, Turkey. – ISBN: 978-975-01566-0-1, IEEE Catalog Number: 07EX1725. – P. 202–205.
4. **Jennings N. R., Corera J. M., Laresgoiti I.** Developing industrial multi-agent systems // First International Conference on Multi-agent Systems (ICMAS-95). – 1995. – P. 423–430.
5. **Neves M. C., Oliveira E.** A Control Architecture for an Autonomous Mobile Robot // Agents'97 Conference, ACM. – 1997. – Accessed at: www.fe.up.pt/~eol/ PUBLICATIONS/ aa97.zip.
6. **Ljungberg M., Lucas A.** The OASIS air-traffic management system // Proceedings of the Second Pacific Rim International Conference on Artificial Intelligence PRICAI. – 1992. – Seul, Korea.
7. **Letia I. A., Groza A.** Using Agent Similarities In Business Rules For The Supply Chain // Advances in Electrical and Computer Engineering. – ISSN 1582-7445. – 2004. – No. 1. – P. 49–56.
8. **Julian V., Carrascosa C., Soler J.** Una Arquitectura de Sistema Multi-Agente para la Recuperación y Presentación

de Información // IV Congreso ISKO-España, EOCONSID. – 1999. – P. 291–296.
9. **Stein K., Schlieder C.** Handling information overload: a MAS architecture for distributed information brokering // AAMAS. – 2005. – Utrecht. – P. 1275–1276.
10. **Wooldridge M., Jennings N. R.** Intelligent Agents: Theory and Practice // The Knowledge Engineering Review. – 1995. – Vol. 10(2). – P. 115–152.
11. **Nealon J., Moreno A.** The Application of Agent Technology to Heath Care AgentCities Working Group on Health Care. – 2003. – UK.
12. **Koutkias V., Chouvarda I., Maglaveras N.** A Multiagent System Enhancing Home-Care Health Services for Chronic Disease Management // IEEE Transaction on Information Technology in Biomedicine. – 2005. – Vol. 9, No. 4. – P. 528–537.

Submitted for publication 2008 05 20

C. Turcu, Cr. Turcu, V. Popa, V. Gaitan. Identification and Monitoring of Patients Using RFID and Agent Technologies: Synergy and Issues // Electronics and Electrical Engineering. – Kaunas: Technologija, 2008. – No. 6(86). – P. 17–22.

We discuss some important aspects of SIMOPAC – a proposed RFID and agent technologies-based system for the identification and monitoring of patients. The declared goal of the SIMOPAC system consists in activating in distributed medical environment and, in private, in solving the problems related to patients' identifying and monitoring in accordance with the latest technologies: radio-frequency identification, co-operative solving of problems within a distributed environment (intelligent multi-agent technologies) and a communication infrastructure ensuring the multi-point access to the medical information transmitted through the system. This project is still an on-going work. Ill. 2, bibl. 12 (in English; summaries in English, Russian and Lithuanian).

Ц. Турцу, Цр. Турцу, В. Попа, В. Гайтан. Идентификация и контроль пациентов используя технологии RFID и агентов // Электроника и электротехника. – Каунас: Технология, 2008. – № 6(86). – С. 17–22.

Обсуждается некоторые важные аспекты SIMOPAC – предложена система на основе технологий RFID и агентов для идентификации и контроля пациентов. Цель системы SIMOPAC состоит в формировании распределенной медицинской окружающей среды и в решении проблем, связанных с идентификацией и мониторингом пациентов используя новейшие технологии: радиочастотную идентификацию, распределенную окружающую среду и интеллектуальные технологии мультиагентов и инфраструктуру коммуникаций, гарантирующую доступ к медицинской информации, переданной через систему. Проект все еще продолжается. Ил. 2, библ. 12 (на английском языке; рефераты на английском, русском и литовском яз.).

C. Turcu, Cr. Turcu, V. Popa, V. Gaitan. Pacientų identifikavimas ir stebėsena taikant RFID ir agentų technologijas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2008. – No. 6(86). – P. 17–22.

Aptariami kai kurie svarbūs siūlomosios RFID ir agentų technologijos pagrindu sukurtos pacientų identifikavimo ir stebėsenos sistemos SIMOPAC aspektai. Šios sistemos tikslas – sukurti paskirstytąją medicininę aplinką ir spręsti problemas, susijusias su pacientų identifikavimu ir stebėsena, taikant naujausias technologijas: radijo dažnių identifikaciją, paskirstytąją daugelio agentų technologijos aplinką ir komunikacijų infrastruktūrą. Tai leidžia naudotis medicinine informacija iš daugelio prieigos taškų. Projektas dar nebaigtas. Il. 2, bibl. 12 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).