Mobile Agent Based Ubiquitous Health Care (UHC) Monitoring Platform

Su Chuan-Jun, Chiang Chang-Yu

Department of Industrial Engineering and Management
Yuan Ze University
Taoyuan, 135 Far East Road, R.O.C.

ABSTRACT

Ubiquitous health care monitoring systems in the field of e-health enable immediate analysis of individual physiological data and personalized patient feedback in real time using alarms and reminders. The systems monitor vital signs such as ECG (electrocardiography), EMG (electromyography), oxygen saturation, respiration, activity, and temperature. Patients can be remotely and ubiquitously assessed, diagnosed, and treated. In the case of rapidly deteriorating medical conditions, the systems can automatically notify associated medical staff by making mobile phone call or sending an SMS alarm to provide the patient with first-level medical support. In this research we have developed a highly distributed information infrastructure for ubiquitous health care (UHC) by using Intelligent Agent paradigm, which is able to notify the responsible care-provider of abnormality automatically, offer distance medical advice, and perform continuous health monitoring for those who need it. To confront the issues of interoperability, scalability, and openness in heterogeneous e-health environments, a FIPA2000 standard compliant agent development platform - JADE (Java Agent Development Environment) was adopted for the implementation of the proposed intelligent multi-agent based UHC system.

Keywords: e-health, JADE (Java Agent Development Environment), Mobile Agent, Health Care Monitoring

INTRODUCTION

Mobile ubiquitous monitoring systems in the field of e-health enable immediate analysis of individual physiological data and personalized patient feedback in real time using alarms and reminders. The systems monitor vital signs such as ECG (electrocardiography), EMG (electromyography), oxygen saturation, respiration, activity, and temperature. Patients can be remotely and ubiquitously assessed, diagnosed, and treated. In the case of rapidly deteriorating medical conditions, the systems can automatically notify associated medical staff by making mobile phone call or sending an SMS alarm to provide the patient with first-level medical support.

Furthermore, scarce medical personnel are traditionally occupied with observing physiology parameters on the monitor screens sitting in the monitoring center on a 24-hours-per day, 7 days-per week basis. The task of monitoring is a tedious duty for medical staff to simultaneously audit and interpret the massive amounts of information regarding a patient during the process of monitoring, performing diagnostics, and verifying therapeutic intervention. Some of complications have arisen from this situation because each medical personnel may be in charge of many patients. The development of multi-agent based mobile monitoring systems is capable of releasing medical staff from routine monitoring tasks and focusing on his/her daily works. With such a mobile monitoring system, patients benefit from better accessibility while medical staff can be more efficient and accurate in following up patient histories with easily available patient data. Families can reduce the time lost in visits to the hospital, which in turn reduces the number of occupied beds that require monitoring, making room for more critical patients. Governments also stand to benefit from reduced hospitalization time for non-critical patients. Healthcare institutions gain through reduced patient treatment costs, better resource management and significant health-economic improvements.

With the growth of the population, now e-health care is facing a big challenge to provide better public or private health care especially in monitoring aspect. For this reason, a greater solution to enhancement of the quality of e-health care is in urgent need. During the last few years several initiatives were undertaken addressing different applications of e-health issues, ranging from doctor (e.g. remote access to medical data) to patient (e.g. remote monitoring of vital signals, medical record) up to Internet based medical data access. The developments of cost-effective, automated, distributed health-care monitoring systems are urgently needed.

Due to medical resources are insufficient, some savants use agents to solve e-health care problems especially in using mobile agent. Mobile agent (MA) has attracted much attention in this decade because of the unique characteristics of the technology. A mobile agent is a program that represents a user (or user take) and can autonomously migrate between the various nodes of a network to perform computations on her behalf.

The mobile agent environment in which mobile agents execute is a software system distributed over a network of heterogeneous computers. The rationale behind the idea of developing a Mobile Agent Based Ubiquitous Health Care (UHC) platform for wide-area vital sign monitoring is its various advantages over traditional client-server approach (Graat, 2003) (Kinshuk, Hong and Patel 2002).

Java Agent DEvelopment Framework (JADE) is a framework that facilitates the development of agent applications in compliance with the FIPA specifications for interoperable intelligent multi-agent systems. The JADE agent platform tries to keep the high performance of a distributed agent system implemented with the Java language. It is also a middleware for developing distributed applications through leveraging state-of-the-art distributed object technology embedded within the Java runtime environment. Therefore, the goal of JADE is to simplify the development while ensuring standard compliance through a comprehensive set of system services and agents. JADE uses an agent model that allows high runtime efficiency, software reuse, agent mobility, and the realization of different agent architectures.

LITERATURE REVIEW

It is our conviction that agents have the potential to assist in a wide range of activities in an e-health care environment. They can maintain the autonomy of the collaborating participants, integrate disparate operating environments, coordinate distributed data, and other organization involved in health care. As explained in (Shankararaman et al., 2000), Agent Technology allows:

- To proactively anticipate the information needs of a patient, and deliver it in a periodical basis.
- To support communication and coordination, either synchronous or asynchronous, among members of a medical team, to enable the share of distributed information and knowledge sources, and to provide distributed decision making support.
- To adapt medical services to patients' needs (personalization).

A multi-agent system consists of multiple autonomous agents with the following characteristics (Jennings et al., 1998):

- Each agent cannot solve a problem unaided.
- There is no global system control.
- Data is decentralized.
- Computation is asynchronous.

Most of these characters have already been investigated in the medical domain through the use of multi-agent system architectures. For example, the GUARDIAN system (Hays-Roth and Larsson 1996) considered patient monitoring in a Surgical Intensive Care Unit. Support is provided for collaboration among specialists, each an expert in a specific domain but fully committed to sharing information and knowledge among each other and the nurses that continuously monitor the patient in the physicians care. Another example of the MAS-based system for healthcare has also been described in (Huang, 1995), in which a multi-agent system was designed to support collaboration among general practitioners and specialists about patient healthcare In patient appointment scheduling where medical procedures have become more complex and their tests and treatments more interrelated, manual and traditional software solutions have been shown to be inadequate while a multi-agent solution gave significantly improved results (Decker and Li, 1998).

A European IST project aims to design and develop a configurable agent-based framework for virtual communities focused on supporting assistance to elderly people employing tele-supervision and tele-assistance (Shankararaman et al., 2000). A distributed decision support system based on the multi-agent paradigm can support cooperative medical decision-making (Lanzola et al., 1999). There have also been developments in general patient care management (Huang, 1995) and medical training (Farias and Arvanitis, 1997). The deluge of medical information available on the Internet has led to the development of information agent to collect and organize this information, such as the Multi-Agent Retrieval Vagabond on Information Network (MARVIN) (Baujard et al., 1998), developed by the Health On the Net Foundation and the Swiss Institute Of Bioinformatics. The Independent LifeStyle Assistant (I.L.S.A.) (Karen et al., 2002) is also a multi-agent system that aid elderly people to live longer in their homes, increasing the duration of the independence from round the clock while maintaining important social connectedness and reducing caregiver burden. Those multi-agent systems have to be devised to provide aid in carrying out activities of daily living, and health care maintenance.

RESEARCH METHODOLOGY

Requirement Analysis

Traditional health monitoring process consumes numerous time and traveling expenses for care-receivers to visit hospitals or health care sectors frequently. It is quite inconvenient for them, especially elders or long-term care-receivers, to be present at the hospitals on a long trip regularly. However, health monitoring usually requires frequent vital signs check-up to ensure their health condition. With the growth of this population, e-health monitoring is now facing a profound challenge to provide better public health care nationwide. There is an urgent need to develop a system that is capable of performing ubiquitous electronic health monitoring automatically and autonomously to users who are usually mobile and situate in a low bandwidth, high latency, asynchronous transaction, and unstable connection environment.

- The system requirements for the proposed UHC are therefore at least the following: Openness: Each instance of UHC installation situates at home with a technophobic client and a typically non-standard monitoring device. The UHC thus must be easily deployable configurable, and updated. UHC is required to facilitate the evolution of a specific installation by providing an open architecture in which new devices and knowledge based modules may be integrated.

- Modularity: Due to the complexity of health monitoring domain, distributed and encapsulated expertise will be critical to the viability of UHC. "Modularity"is thus another crucial requirement for UHC to achieve the extendability by partition the functions into smaller logical units that can be modified, enhanced, or added functionality.

To satisfy these requirements, a mobile multi-agent information platform UHC that is implemented by JADE and allows MAs to work on behalf of health care professionals, to collect distributed users' vital sign data, and to spontaneously inform abnormal situations to associated health care professionals in real time is proposed in this research.

UHC System Design

E-health care is a complex task which involves the sharing of expertise about medical knowledge, medical data, and services among care-receivers, specialists, as well as medical personnel. Moreover, an e-health care platform is composed by an open architecture, distributing physiological information and resources, multi-systems with heterogeneous components, storing bio-signals acquired from patients, and secure infrastructure. Consequently, a significant desire in the health care monitoring practice is stimulated to integrate several disparate and stand-alone subsystems and corresponding information repositories.

In this research, JADE has been adopted among various multi-agent platforms as the underlined architecture and implementation of UHC due to the following advantages (Kinshuk, 2002):

1. Distributed autonomous applications development - In order to achieve the objectives of UHC, agents that are autonomous, intelligent, and capable of communicating and collaborating need to be implemented. JADE simplifies such a development.
2. Negotiation and coordination - In UHC, JADE provides easy-to-use software libraries (i.e. patterns of interaction between agents) to solve negotiation and coordination among a set of agent, where the resources and the control logics are distributed in the environment.
3. Pro-activity - JADE agents have been designed to control their own thread of execution. These agents can be easily programmed to initiate the execution of actions without human intervention just on the basis of pre-defined goals and state changes. The property of proactivity is essential in designing physician agents of UHC, which requires controlling their own actions guided by regulations.
4. Multi-Party applications - Peer-to-peer architectures that JADE used are more efficient than client-server architectures for developing multi-party applications. Sometimes, the server might become the bottleneck and the point of failure in the entire system. The implementation of UHC based on JADE architecture that allows clients (medical staff or patients) to communicate each other without the intervention of a central server and subsequently reduces the network traffic.
5. Interoperability - JADE complies with the FIPA standard that enables end-to-

end interoperability between agents of different agent platforms.

6. Versatility - JADE provides a homogeneous set of APIs that are independent from the underlying network and Java version. It also provides the same APIs for J2EE, J2SE, and J2ME environments. This feature makes UHC a heterogeneous client (PC, PDA, mobile phone, etc.) environment..
7. Ease of use - JADE APIs and ready to use functionalities can shorten the system development cycle (some estimations have been give that indicates the reduction of development time cab be up to 30%).

The JADE-implemented UHC is hence expected to be capable of integrating disparate information sources and isolated heterogeneous components to perform autonomous health monitoring. The UHC is composed of six types of architectural components as depicted in Figure 1: (1) User Agent, (2) Resource Agent, (3) Physician Agent (4) Diagnostic Agent (5) Knowledge-based Data Server, and (6) External Services.

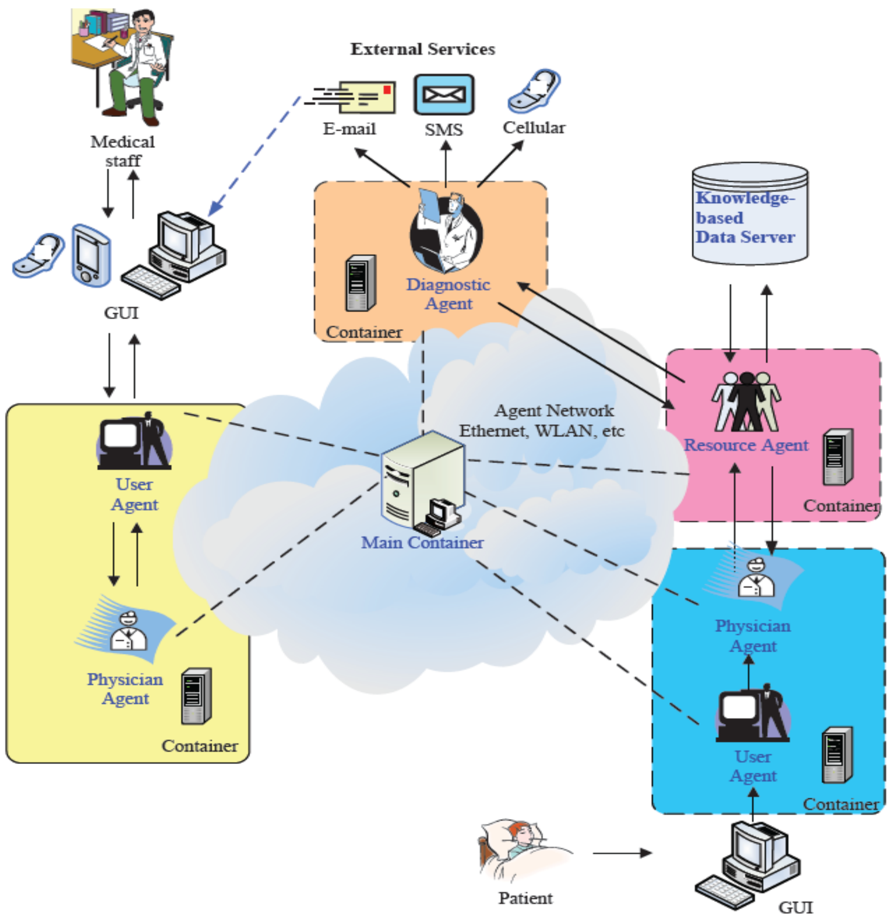

Figure 1. The UHC structure.

User Agent

The user agent is a type of stationary agent and it is a user's intelligent gateway to the platform. It is regarded as a bridge to interface with physician agents and users. The user agent acts as an interpreter of users and heterogeneous agent communications. When receiving the requests from users, it will to drive internal services in the platform. .Therefore, the user agent is a mechanism of access control resources and authenticates users before starting physician agent. The user agent is responsible for the final presentation of results by physician agent or by diagnostic agent to users.

Resource Agent

The resource agent operates at a higher level of trust and mediates access resources from physician agent to host computers and it's also another type of stationary agent.

It can be “static” because they don’t have the ability to migrate between hosts. The resource agent usually resides on the host (container) to provide expert advice or services locally. Hence, it is deemed as a secure agent and granted to access the resources of data server. The resource agent plays an important role in dynamically accessing the resources in our recommend platform. Therefore, the physician agent can ask resource agent to directly access the resources of the data server, since physician agent are restricted to communicate only with agent container and also other agents in the platform. The resource agent would take the place of the interface to bridge the users to the databases.

Physician Agent

The physician agent is a mobile agent and it is used by the medical staff or patient. It can help the medical staff perform monitoring tasks and help patient perform the data transmit. The physician agent enables medical staff to monitor the conditions of patients in real time without being around the patients. Besides it also helps the diagnostic agent to examine the status of outpatients at remote locations. In this first phase, medical staff can use their devices (e.g. computer, PDA, cell phone) to trigger physician agents as delegates for them (see figure 1). Medical staff have tasks of monitoring patients to finish while they are fully occupied with other emergency situations, then they initiated the physician agent to help them. In order to activate a physician agent, an order from the medical staff via user agent must be dispatched to agent main container. As soon as the agent main container received such an order, a physician agent would be subsequently initiated. Before the physician agent migrates to another agent container, it has already authenticated, gotten agent identifiers (AID) and determined the privileges to be granted by the agent main container. The physician agent then will be sent to the Internet through Ethernet, wireless local area network (WLAN), etc. After connected to Internet, the agent will continue doing the assigned monitoring job depending on the characteristics of a given clinical case. The physician agent is devoted to data acquisition, after roaming in the networks to collect related physiological data of patients. Eventually, the physician agent carries the collected information with it and returns to the medical staff’s devices.

Diagnostic Agent

The diagnostic agent is another type of stationary agent. In the proposed platform, the diagnostic agent can be considered a data-analyzed engine. It is capable of analyzing collection of short-term changes and health status data of patients. The main task of diagnostic agent is to (1) identify receive patterns from patients (2) indicate or predict a sudden change in patients’ status. After detecting the collected data, the diagnostic will supply medical staff with the periodic information. If detecting abnormalities in collected data, the diagnostic agent will send to medical staff with emergency information via the external services. The next step, when it comes to some critical life-death situations, it will provide patients with needed automation assistance (e.g., call ambulance).

Knowledge-based Data Server

Efficient and effective patients monitoring is a complex endeavor that is highly dependent on disseminating time-critical information (Lee et al., 2000). The time-critical information involves not only the records of patients' conditions but also knowledge sharing of expertise and medical practices. The physiological data collected by physician agent are the results of observation or examination forming the basis of further diagnoses and therapies. Each patient is an individual case with individual patterns, complications, and disease. Therefore, the knowledge-based data server is considered in this section in order to promote the performance of the proposed platform. The knowledge-base data server is split into two main information repositories: (1) PatientStatus and (2) PatientProfiles. These two repositories are the storage units that are utilized to deposit the physiological information collected by physician agent. The "PatientStatus" repository involves every monitoring physiological data from patients (e.g. HR, SpO2, etc). The "PatientProfiles" repository contains up-to-date electronic records for patients: the limits of monitored parameter values and some basic information of patients. When user agent delivers patients' monitoring data to resource agent, the resource agent stores the data in the "PatientStatus" repository; at the same time, it copies these data and sends to diagnostic agent. The diagnostic agent will analyze patients' physiological information in real time.

External services

The external services will be initiated by diagnostic agent after analyzing the incoming physiological data of patients. The external services embrace the hardware and services in the platform including E-mail and short message services (SMS), etc. It is an extensible component varied on different scenario of applications. The result of the physiological data analysis is the prediction for diagnostic agent to consider while determining the provision of next action for medical staff. If the prediction of the patient's signals results in abnormal situation, the diagnostic agent will take proper actions such as issuing an alert message according to the analyzed outcomes. Moreover, if some emergency situation of patients occurs, the external service for automatically dialing ambulance is going to be launched.

CONCLUSIONS

Multi-agent systems have a set of properties that make them suitable for use in solving the many problems that are encountered in the healthcare domain. In previous studies, as described in Section 2.4, many agent technologies have been applied in the healthcare field. Nevertheless, not all existing multi-agent systems can provide good solutions for the healthcare monitoring domain.

In this research, we have developed a UHC system based on the JADE platform to address the specific requirements of a distributed healthcare environment. From the different aspects of usage requirements, UHC provides different functions to cater to each user. From the viewpoint of the medical staff, the workload is reduced by the substitution of routine patient-supervision tasks. Using a personal device, medical staff can, at any time and from any location, view the vital signs of patients, who are generally widely spread across many locations. Furthermore, in UHC, the diagnostic agent substitutes for a physician, performing the first step of diagnosis. While from the point of view the patients, patient care is improved by the immediate transits as well as by the communication between agents, which provide more reliable information, delivered in a more convenient manner.

From the viewpoint of the system, UHC provides a patient monitoring environment that is simple and efficient. Furthermore, it provides a ready exchange of information, and as permanent data is collected only once, less time is spent in searching for mislaid data, thereby increasing efficiency. The communication via asynchronous message passing between agents can solve the problems that would arise when using blackboard; this is because blackboard is not suitable for a scalable system (Graat, 2003). In UHC, each agent has its own mailbox through which it can receive messages sent by other agents; this is a better mode of communication than blackboard. The method of asynchronous message passing does not require centralized management information and also provides good privacy for patient personal information. Ultimately, documentation is diminished as a consequence of the elimination of hand-written records, clinical reports, medical errors, etc.

UHC provides a new opportunity to integrate and analyze the immense amount of data encountered in patient monitoring. It can not only respond to inquiries for medical information relevant to a person's medical history but also monitor the patient status and alert its owner about unhealthy trends as well as inconsistencies in the health records. It clearly presents an innovative technique to assist healthcare practitioners in collecting, filtering, and examining the relevant information for a patient, providing basic diagnosis and suggesting actions in an efficient manner. The development of UHC will be critical for the future of healthcare monitoring.

REFERENCES

Baujard O., Baujard V., Aurel S., Boyer C. and Appel, R. D. (1998). A Multi-agent Softbot to Retrieve Multilingual Medical Information on the Web. Medical Informatics. Volume 23 No. 3, pp. 187-191.

Decker, K S and Li, J. (1998). Coordinated Hospital Patient Scheduling. International Conference on Multi-Agent Systems - ICMAS_98, Paris, France.

Farias, A. and Arvanitis, T. N. (1997). Building Software Agents for Training Systems: A Case Study on Radiotherapy Treatment Planning. Knowledge-Based Systems. Volume 10. pp. 161-168.

Graat, G. (2003). Agent-based Information Retrieval Supported by Information Markets. M.S. Thesis, Faculty of General Sciences, Maastricht University, Netherlands.

Hays-Roth, B. and Larsson, J. E. (1996). A domain specific architecture for a class of intelligent agent monitoring systems. Journal of Experimental and Theoretical Artificial Intelligence. Volume 8. pp. 149-171.

Huang, J., Jennings, N. R, and J. Fox J. (1995). An Agent-based Approach to Health Care Management. Applied Artificial Intelligence: An International Journal, London, Volume 9 No.4, pp.401-420.

Huang, J., Jennings, N. R., and Fox, J. (1995). An Agent Architecture for Distributed Medical Care. Wooldridge, M. J. and Jennings, N.R. Editors., Intelligent Agents, Lecture Notes in Artificial Intelligence, Springer-Verlag, pp. 219-232.

Jennings, N. R., Sycara, K. and Wooldridge, M. (1998). A roadmap of agent research and development. Autonomous Agents and Multi-Agent Systems. Volume 1 No.1, pp. 275-306.

Karen, Z.H., John, P., and Christopher, W.G. (2002). An Open Agent Architecture for Assisting Elder Independence. The First International Joint Conference on Autonomous Agents and MultiAgent Systems (AAMAS). pp. 578-586.

Kinshuk, K., Hong, H. and Patel, A. (2002). Adaptivity through the Use of Mobile Agents in Web-based Student Modelling. International Journal on E-Learning. Volume 1 No.3, pp. 55-64.

Lanzola, G., Gatti, L., Falasconi, S. and Stefanelli M. (1999). A Framework for Building Co-operative Software Agents in Medical Applications. Artificial Intelligence in Medicine. Volume 16 No.3, pp. 223-249.

Lee, R., Conley, D., and Preikschat, A. (2000). eHealth 2000: Healthcare and the Internet in the New Millennium. Wit Capital, Retrieved from the WorldWideWeb: http://www.witcapital.com/.

Shankararaman, V., Ambrosiadou, V., Panchal, T. and Robinson, B. (2000). “Agents in health care”, Workshop on Autonomous Agents in Health Care. pp. 1-11.

Shankararaman, V., Ambrosiadou, V. and Robinson, B. (2000). Agents in Medical Informatics. Proc. of IASTED International Conference on Applied Informatics, Austria.