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Applications of Mobile Agents in Healthcare Domain: A Literature Survey

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Abstract

Mobile agent technology is emanating as a new paradigm in the area of distributed and mobile computing, and has been engaged in many areas from network management tasks to information management. It makes considerably simpler to model, implement, and maintain distributed systems, including sensor networks and cloud computing. It provides an infrastructure not only for executing autonomous agents but also migrating them between different computers. In the recent years, mobile agent paradigm has emerged as a viable approach for the evolution of autonomic systems in the healthcare domain. This paper reviews the applicability and usefulness of mobile agents in a wide variety of healthcare applications such as medical data management, medical information retrieval, health data integration, decision-making support, telemedicine, securing medical information and coordination of distinct medical activities.

Keywords*: Context awareness, decision making, distributed data, healthcare, mass casualty, mobile agent, telemedicine*

1. Introduction

Healthcare is one of the most urgent matters in human societies, as the life quality of citizens directly depends on it. Additionally, healthcare is one of the most difficult domains to undertake due to its intrinsic complexity. The healthcare sector is not only largely distributed and fragmented but it also exhibits a high degree of diversity with strong local autonomy [7]. Also, this domain is very information – intensive and mission-critical [8]. Traditional computation paradigms fail when trying to model an environment due to large volume of medical data with its complexity and variety.

In this review, we study the productive use of mobile agent paradigm in the healthcare domain. Mobile agents programming is one of the emerging paradigms for structuring applications over the internet in which programs travel throughout a network to execute on machines other than the originating host. It is an agent that decides 'when to move', 'where to move', what to execute', and 'how to execute it' [6]. Due to their adaptive, proactive and cooperative nature, these have been deployed in a large range of applications in healthcare domain such as decision making support, accessing distributed data sources, or the coordination of healthcare activities.

The rest of the paper is structured as follows: Section 2 presents the mobile agent paradigm and its characteristics which are adequate to tackle the medical problems. Section 3 describes the basic applications of mobile agent in healthcare domain. Section 4 portrays the literature survey of relevant papers. Finally, some concluding remarks about review along with future work are presented in respective Sections 5 and 6.

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2. Mobile Agent Paradigm

The word "Mobile Agent" unifies two words- "Mobility" and "Agent". A mobile agent is a set of executable programs that migrate from one machine to another (hence mobile) in heterogeneous networks representing users in various tasks (hence agent). Consequently, mobile agents are not limited to the computer where they are created, but they can move freely among computers [10]. The mobile agent can defer its execution at any arbitrary point, jumps to another machine and recommences the execution there [9].

Prior to the appearance of Mobile Agents, many approaches have been proposed and developed for communication between client and server such as message passing, remote procedure call and remote evaluation. In Remote Procedure Call (RPC), the client sends the data as parameters to a procedure that resides at the server. The procedure will be executed on the server and the results will be sent back to the client. In Remote Evaluation (REV), the procedure itself is sent from the client to the server to be executed rather than calling a remote procedure at the server and server returns the result. In contrast, a mobile agent (MA) is a program (encapsulating code, data and state) sent by a client to the server [1]. The basic process of three paradigms is depicted diagrammatically in figure 1. A basic difference between client-server and mobile agent paradigm is (figure 2): in client-server paradigm, there are number of interactions between client and server in form of requests and replies which increases the load of network but this load reduces in mobile agent paradigm as the only interaction of client is with mobile agent which migrates to server site and make local interactions with it [1].

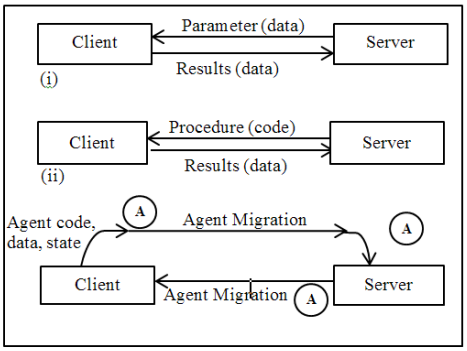

Figure 1. Basic Operation Performed by RPC (i), REV (ii)

A mobile agent has three ingredients: agent code, agent state and agent attributes. Agent code represents the program written in a suitable language that defines the agent's behavior. Agent state involves agent thread along with the execution stack to represent the agent's internal variables etc. which enables it to resume its execution. Agent attributes represent the information portraying the agent, its origin and proprietor, its movement history, concerned resources, authentication keys *etc*. A mobile agent exhibits several characteristics which are described in Table 1.

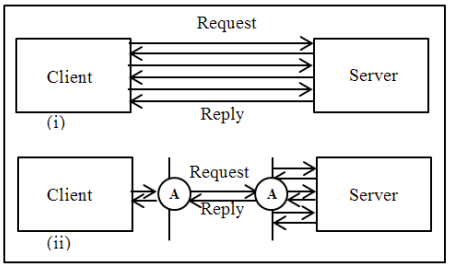

Figure 2. Client-Server Paradigm (i) VS Mobile Agent Paradigm (ii)

Our attraction to mobile agents is not motivated by the technology per se, but preferably by the benefits the agents provide for creating distributed systems. Lange has given following seven main benefits or reasons to answer why we should use mobile agents [2].

- They reduce the network load.
- They overcome network latency.
- They encapsulate protocols.
- They execute asynchronously and autonomously as well.
- They adapt dynamically.
- They are naturally heterogeneous.
- They are robust and fault-tolerant.

Table 1. Characteristics of Mobile Agents [1]

Characteristics	Explanation
Autonomous	Ability to act without direct external interferences
Interactive	Communicates with the environment and other agents
Adaptive	Ability to respond to other agents or their environment
Mobility	Ability to migrate or transport itself from one node to another within the same or different environment autonomously
Proxy	Ability to act on behalf of someone or for the benefit of some entities (e.g. software systems)
Proactive	Ability to take an initiative in responding to an environment
Intelligent	Have certain degree of intelligence, based on knowledge in order to act efficiency
Coordinative	Ability to perform data transfer activities in sharing with other agents within the given environment
Learning	Ability to gain information about the current environment, which will help to modify its behavior
Cooperative	Ability to coordinate with other agents to achieve a common purpose
Ragged	Ability to deal with errors when confronted and during their occurrence

3. Applications of Mobile Agents in Healthcare Domain

Mobile Agent technology is becoming more prominent and has been deployed in many applications such as e-commerce, mobile data computing, personal assistance, networking etc. Typically, the deployment of mobile agent technology involves several agents amalgamating to achieve our ultimate target. Each agent is assigned a particular task of which is a breakdown of the whole operation [16].

This paper advocates the appliance of mobile agents in wide variety of health care scenarios ranging from information filtering/retrieval to resource coordination/deployment to supporting mobile users (Figure 3) [3-6, 11- 15, 18-20, 22-25, 27-29]. Healthcare is an ample open environment outlined by shared and distributed decision making and management of care, demanding the communication of complex and diverse forms of information between a variety of clinical and other settings [21].

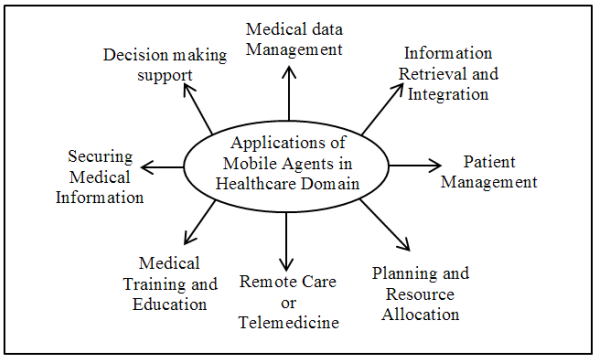

Figure 3. Applications of Mobile Agents in Healthcare Domain

The emergency of healthcare typically involves the coordination of the effort of several individuals (*e.g.*, medics, paramedics, receptionists, managers, social workers) with different skills and needs and located in different places, usually without being under the supervision of a single centralized coordinator. Security of medical data is a demanding concern and, in many situations, these data cannot be accessed in a particular place. There is an immense amount of medical knowledge available electronically in various formats. The penetration of computerized systems is a hard and slow process due to the disinclination of individuals involved in healthcare. Under these circumstances, mobile agent technology is an acceptable choice to be used in healthcare applications.

Mobile agents offer a natural way of tackling distributed problems with heterogeneous sources by cooperating and coordinating their activities, and also surrogating pro-actively performing tasks that may be valuable to the user [5]. The different fields analyzed in the review process are summarized in Table 2.

Table 2. Analyzed Fields of Mobile Agent Based Applications

Field	Description
Medical data integration	Provision of consolidating information across heterogeneous medical data sources
Health data management	Systems centred on acquiring, analysing and protecting medical information vital to providing quality patient care
Information retrieval	Approaches aimed to retrieve medical information from heterogeneous databases
Decision making support	Approaches converged to assist professionals in the accomplishment of healthcare operations such as treatments or diagnostics
Coordination of medical activities	Systems centralized on the coordination and scheduling of human and material resources
Remote care/ Telemedicine	Systems focused on remotely monitoring the status of patients allowing extensive care
Securing Medical Information	Approaches to improve the safety and privacy of patient data

4. Literature Survey

This section presents the several relevant papers to describe the significant applications of mobile agents in healthcare domain. The key idea about each paper is discussed below:

- **HL7 Ontology And Mobile Agents For Interoperability In Heterogeneous Medical Information Systems, by B. Orgun and J. Vu (2006): [24]**

In prevailing healthcare scenario, patients change hospitals and have multiple health episodes in multiple healthcare facilities, culminating in patient related information being fragmented into various systems. It has been observed that the urgency to access patient information grows with the urgency to consolidate the information across the diverse systems in a healthcare organization which is termed as providing interoperability among these sources. In this paper, the authors have described an electronic Medical Agent System (eMAGS) that makes use of numerous cooperating mobile agents actively access, decipher, learn and exploit the information accessible on various health systems. This multi-agent system with an ontology based on HL7 facilitates the flow of patient information across a whole healthcare organization.

The eMAGS architecture consists of various agent servers, an agent broker and an ontology server. Agent servers link the database applications (e.g. surgery, patient billing, patient management *etc.*,) to the eMAGS network which contain the data in different formats, with different field names and/ or data types representing information possibly corresponding to the same patient. An agent broker keeps track of all the agents in the system at any given time and a library of all the participating applications and databases in the healthcare organization. The ontology server is a pivotal depository of mappings between HL7 and subscribing database operations.

- **A Mobile Agent Approach for Secure Integrated Medical Information Systems, by C.–H. Liu, Y.-F. Chung, T.-W. Chiang, T.-S. Chen and S.-D. Wang (2006): [29]**

In this paper, the authors have proposed the combination of Virtual Integrated Medical-information Systems (VIMS) with the Mobile Agent technology. Mobile Agents aid in transmitting data across various hospitals and VIMS is used to integrate data from various HIS. It has been found that this proposal is highly advantageous due to following reasons:

– Patient data can be quickly acquired by the hospitals saving a lot of time.

– Unnecessarily repetitive tests of patients are not performed in different hospitals which ultimately saves time in case of emergency.

– The medical resources are economized without repetitive checks and medication tests.

The proposed structure consists of following components: Visualized Interface (VI), Medical Information Module (MIM), Virtual Integrated-data Index Module (VIIM), Clinical-data Index Storage (CIS) and Mobile Agent Scheduler (MAS). VI is an interface to display patient data. MIM includes various medical information systems (medical imaging storage and transmission systems, laboratory information systems, pharmaceutical systems, and so on). These medical information systems produce different kinds of medical information in different formats such as numbers, texts, images, sounds etc. VIIM is used to integrate this heterogeneous information without the concern of medical personnel to upload and convert the information. According to patient's id, name or other basic information, the integrated information is indexed by VIIM and is stored in CIS for medical use upon request.

When a patient visits the hospital, the medical personnel requests for the patient's relevant medical records using VI (Visualized Interface), if at this point, records from external institutions and hospitals are needed, MAS dispatches mobile agent to external institutions and hospitals to carry out the request and gather information. When the mobile agent reaches the external institution, passes the verification test by the MAS of the external institution, gathers information from the CIS of the external institution and move on to the next institution. When all the required institutions have been visited, the mobile agent moves back to the institution it belongs to. The search results are stored in CIS and are displayed through VI which helps doctor in making a better diagnosis. The

proposed system ensures secure and efficient data-sharing. Unauthorized users can't access the data carried by mobile agents. Only relevant and permitted information is transmitted. Moreover, the system can apply access controls to protect data confidentiality and allowing confidential data to be accessed by only authorized users, thereby achieving both data security and efficient data sharing.

- **Role of Mobile Agents in Medical Information Retrieval in Mass Casualty Scene – A Performance study in Web Environment, by M. V. Prem and S. Swamynathan 2011): [3]**

In this paper, the authors have discussed the use of Mobile agent technology in communication between different remote locations. When an emergency occurs, especially in mass casualty incidents, lots of victims need medical attention as early as possible. This paper advocates the use of mobile agents for faster and accurate acquisition of data, where proper health care equipment or analysis of medical information is not possible.

This paper has illustrated an emergency situation where a group of people are affected by an eye infection. Searching and enquiring the specialists for each and every case takes time. Also, if all of them start contacting specialists by sending details of each and every patient, it will certainly results in chaos and congestion. As a result of which, none of them will get the service. But if specialists himself contact each and every patient, it will lessen the communication traffic, but it will take a lot of time. This is the situation where use of mobile agents is visible against the traditional request-reply approach (figure 4).

Infected people visits nearby health care centers. Local medical officer analyses the received information from patients and stores in the local system. Special medical officer dispatches an agent or multiple agents to all servers that save the results of basic tests taken on infected eyes. These officers get the solutions for their data.

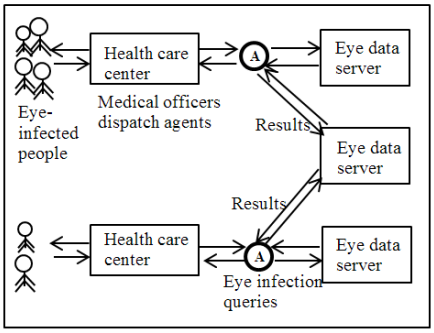

Figure 4. Mobile Agents in Mass Casualty Scene (Eye Infection) [3]

- **Mobile Agents for Critical Medical Information retrieving from the emergency scene, by A. Martin-Campillo, R. Marti, S. Robles and C. Martinez-Garcia (2009): [15]**

In this paper, the authors have considered an emergency situation where multiple vehicles are collided on a highway where mobile agents help in retrieving partial information of medical records upon request from the emergency scene. During emergency situations, especially in mass casualty incidents (MCI), the first responder medical personnel after arriving the scene, triage the victims they find. The aim of the first responder medical personnel is to stabilize the victim before they can be evacuated to the hospital. When all the patients are triaged, medical personnel search for victim's personal items that could identify them and they contact to their families and get their medical related information.

The next step is to make use of mobile agents to forward requests to VEPMRs (Virtual Electronic Patient Medical Record) which contain all the medical data about patients which are spread over a set of different locations. To achieve this purpose, medical institutions have to be part of the medical network where every member shares the information it has. As a result, every time a patient visits the doctor, each surgery and each test done is recorded inside the distributed database to be accessible in the whole medical network. It is clear that having all the medical information about a patient, a quicker and better diagnosis is obtained, thus, a better treatment is obtained. The knowledge of some data like blood type, chronic diseases, or contagious diseases, without the need for tests, could save more lives as the medical team saves time and money (Figure 5).

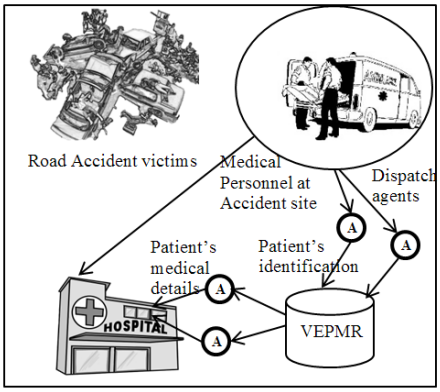

Figure 5. Mobile Agents in Mass Casualty Scene (Road Accident) [15]

But during incidents like hurricanes, floods, or tsunamis, the most communication networks get disrupted which hinders the use of VEPMRs. So we use mobile agents on ad-hoc networks to forward requests of VEPMRs to the medical network. This allows the retrieval of patient's medical record in the place where the emergency has occurred, without any need of deployment of network infrastructure.

To sum up, when an emergency occurs, especially during mass casualty incidents, lots of victims need fast medical attention. Apparently, faster and accurate acquisition and analysis of data is required. During emergency, various features of mobile agent convince its use rather than the classical approaches [3]:

– Agents are capable to operate in highly dynamic environments

– They are capable to work in decentralized and distributed networks.

– They are able to search and store the distributed information, verify, process, analyze and interpret it for later use and management.

- **Context-Aware Mobile Agents For Decision-Making Support In Healthcare Emergency Applications, by f. Burstein, a. Zaslavsky and n. Arora (2005): [6]**

In this paper, the authors have brought together the concepts of context-awareness [17], mobile agents and decision-making support for the healthcare emergency domain. This paper specifically advocates the use of mobile agents to support the deployment of ambulatory services in real time, thus, ambulatory services are chosen as a context in this agent-based application. This architecture involves individual medical records that are highly fragmented and scattered across multiple medical institutions. Also, an ambulance frequently moves between various points across the city. As a result, the users are subjected to unplanned disconnections since mobile connections tend to have low bandwidth and are unreliable in nature.

An emergency situation is considered, where a middle-aged man suffers from a heart attack while on his way to work. The on-lookers immediately call for ambulance providing details such as location and nature of accident, any identification of patient (if possible) etc. While on the way to accident site, paramedics launch two mobile agent assistants. One agent travels to the hospitals near to the accident site, to get the details of available doctors, nurses, beds and facilities provided (*e.g.*, 24-hour emergency). Other agent retrieves the patient's medical history along with the route details to the selected hospital. By the time paramedics reach the emergency site, their on-board terminal in ambulance already reflects the nearby hospitals ranked from the most relevant to the least relevant. Also, patient's medical details and current road details are available. Thus, mobile agents help as decision support tool that aids the paramedic by entitling him with real-time, mission-critical information at the point-of-care. On the way to the selected hospital, a message is delivered to the associated hospital agent. By the time ambulance reaches the hospital, this information has enabled the emergency room and staff to prepare for the arrival of the patient.

To sum up, the mobile agents help in time-critical decision situations where the accuracy of the data is crucial for good decision outcome.

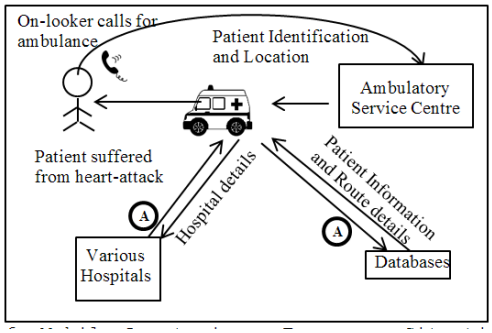

Figure 6. Mobile Agents in an Emergency Situation [6]

- **Agent-based Context-Aware Healthcare Information Retrieval Using Dropt Approach, by a. Kehinde, a. Adesina, e. Daniel and s. Dele (2012): [11]**

In this paper, the context-aware computing technology is a key element to construct the information retrieval systems by sensing the changes in the users' activities, to predict users' interests and then retrieve information and present using the DROPT (Document Ranking Optimization) approach. DROPT is a ranking technique for documents retrieved from a corpus which is developed w.r.t document index keywords and the query vectors. This is based on calculating the weight of keywords in the document index vector which is calculated as a function of the frequency of a keyword across a document.

The authors have proposed a Context-Aware Healthcare Information system (CAHIS) which allows different agents within the healthcare environments to co-operate in order to reduce tasks complexity by providing the right relevant information to the right user in the right location. The proposed architecture consists of five types of agents: User interface agent interacts with humans and acts as a mediator between the external user and the rest of the system (other agents). Reformulate agent processes the input raw query from the user agent and sends the refined query to the match agent. Search agent gathers information from the web and the results are sent to the document agent whose task is to index the documents using the normalized keywords and sends the highest indexed documents to the match agent. The match agent compares the refined queries against the indexed documents and the matching result is a list of potentially relevant documents that are sent to the display agent who performs the ranking function and show the documents to the user through the user interface agent according to their relevance weights. The user

model agent guides the user in query formulation process and to store and manage the user's interest in the form of a user profile.

- **Context-aware Mobile Medical Emergency Management Decision support System for Safe Transportation by F. Burstein, P. D. Haghighi and A. Zaslavsky (2011): [25]**

In this paper, the authors have proposed a novel architecture for context-aware decision-support for medical emergency management in mass gatherings. It combines mobile communication technologies with pervasive computing techniques to facilitate and enable effective decision making that aims specifically to improve transportation safety.

The authors have illustrated a mas gathering event and a proposed architecture has been supposed to address following technical challenges:

– Perceiving different types of mass gatherings and hazardous factors

– Knowing emergency response team and activities

– Awareness of available medications through RFID signals

– Coordination between various emergency services/sections

– System level awareness of extrinsic localized environmental actions with sensors

– Coordination between hospitals, transportation services and other emergency services

– Understanding and conceptualization of emergency transportation approaches

The proposed DSS can run on both on-board computers of ambulances and computers/laptops of the medical emergency team and organizers. The GPS system in ambulances helps to provide awareness to the driver of the current location, speed, direction and angle of the vehicle which aims to improve the safety of transportation.

- **Agents Applied In Health Care: a Review, by d. Isern, d. Sánchez and a. Moreno (2010): [5]**

In this paper, the authors have described 15 agent-based systems that they analyzed during their review process. These systems fall into five categories or subdomains of applications. In the domain of Medical data management, NeLH, VEPR and CHIS are analyzed. These systems focus on the retrieval and processing of medical data. Under the category of Decision support systems, Singh *et al.*, Health Agents, HeCaSe2 are evaluated. These agent-based systems aim to assist the professional in the execution of healthcare processes, Agent, Hospital, CARREL and MIA fall into the category of planning and resource allocation. These systems are centered on the coordination and scheduling of human and material resources. Aingeru, Koukias *et al.*, and Cervantes *et al.*, come under the domain of remote care that aim to remotely monitor the status of patients allowing pervasive care. Composite systems include SHARE-IT, K4Care and GerAmI which offer complete and integrated solutions for healthcare management for a concrete organization. The authors have concluded that agent-based systems offer added values over classical traditional approaches (*e.g.*, reusability, flexibility, reliability, robustness, adaptability and maintainability).

- **Secure Mobile Agent for Telemedicine Based on P2P Networks, by W.-S. Hsu and J.-I. Pan (2013): [14]**

Telemedicine refers to an application area that couples the technology of computer and communication with medical service [26]. The telemedicine exists in different forms: tele-education, tele-consultation, tele-surgery, tele-monitoring [14]. As advocated by innumerable probers, mobile agents are broadly perceived as aiding medical and telemedicine applications.

The principal idea of this paper is to design a safe agent-based telemedicine based on P2P networking architecture. When a mobile agent holding patient information travels from one place to another place through the Internet, it can be attacked by other malicious agents. So, the proposed architecture uses a two-layer safety mechanism for mobile agents (*i.e.*, time-limited black boxes and RSA un-detachable signature technologies), to provide a solution for agent-based telemedicine services. In this paper, four security requirements are proposed: confidentiality, reliability, integrity and non-repudiation. The proposed P2P network architecture that is based on the JXTA protocol uses two telemedicine service model types: predictable service model and unpredictable service model.

For predictable service model, tele-surgery, tele-education and tele-consultation is performed online by two hospitals for the purpose of clinical teaching. When one hospital performs tele-surgery, it renews the announcement urgently, notifying all members in the peer group to the message. If any hospital desires to participate, they can perform tele-surgery by instantly delivering the images and data. For unpredictable service model, an urgent medical treatment service for the emergency room is considered as an example. Each hospital announces the medical treatment resources (e.g., number of doctors, nurses, beds etc.). When a patient requires a service, he sends the request to the emergency service center, where the agent activates an advertisement search, locating a resource that is most advantageous to the patient. The agent transmits the patient data and health history to the hospital. Therefore, the hospital knows the patient's condition and makes quick preparation of equipment and medical treatment resources. Moreover, the emergency service center sends an ambulance to the patient. This helps patients to procure care in real time reducing expenditures related to medical resources and personnel costs.

- **Multi-Agent System Architecture For Heart Failure Management in a Home Care Environment, by V. G. Koutkias, I. Chouvarda and N. Maglaveras (2003): [20]**

In this paper, the authors have proposed a multi-agent system to support heart failure management in home care environment. During the measurements session, each patient may send the details e.g. blood pressure, temperature etc. or bio-signals such as ECG which can be taken at home using micro-devices. Patients can be asked questions related to their present life-style and possible symptoms, since the corresponding answers explain their current health condition. Cardiologists review patient data on a regular basis. The basic tasks performed by mobile agents are: medical data access, medical data processing, reasoning, communication with other agents, negotiation for decision making, and learning capabilities. Different types of agents are used to observe different types of parameters received from patient such as agents observing a discrete value parameter (*e.g.*, systolic blood pressure), agents observing a continuous-time parameter (*e.g.*, ECG signals) and agents observing a life-style related parameter (*e.g.*, answers to the Yes/No questions). In addition, the agents take into account the patient medical history and the interventions applied by corresponding cardiologists. Each agent applies different processing schemes and different symptoms are identified. A negotiation plan is required to generate an accurate overall outcome.

- **A Mobile Agent-Based Technique For Medical Monitoring (Supports Of Patients With Diabetes), by Z. Chaouch and M. Tamali (2012): [18]**

In this paper, the authors have proposed a mobile-agent based system called DiabMAS (Diabetes Multi-Agent System) for remote medical monitoring of diabetic patients (Figure 7). The purpose of using an agent is to reduce the traffic, thus dispatching the agent where the tasks are done due to which the exchanged messages become local and therefore, reduce network load.

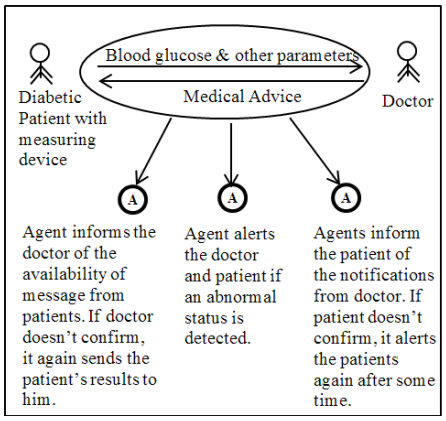

Figure 7. Mobile Agents in Remote Monitoring (DiabMAS) [18]

The key idea of this paper is to monitor patients and ensuring the continuity of care, reducing costs by reducing the movement of patients and professionals and improving service delivery as well as patient satisfaction.

- **A Distributed E-Health Model Using Mobile Agents, by A. A. Pouyan, S. Ekrami and M. Taban (2011): [19]**

In this paper, the authors have considered a three layer agent-based model to represent the e-health care (remote care) which portrays recording, measuring, managing, and finally conducting patient-related and specific-condition services through internet at the real time. The three layers are: Patients, healthcare clinic, and the central hospital (Figure 8).

A dynamic virtual team is formed which consists of doctors, nurses, practitioners and any department (*e.g.*, radiography, laboratory *etc.*). These all are mobile agents. A patient is assigned to a particular medical team by a specific agent, who represents the description of a patient, his situation and his health signs to the health clinic. According to the duties assigned to each medical team, some information or prescriptions are added to the database which is shared with other parts. Diagnostic team sends request (dispatches an agent) to the central hospital in order to acquire information from the knowledge-based data server. Doctors also obtain information about patients using agents from different departments.

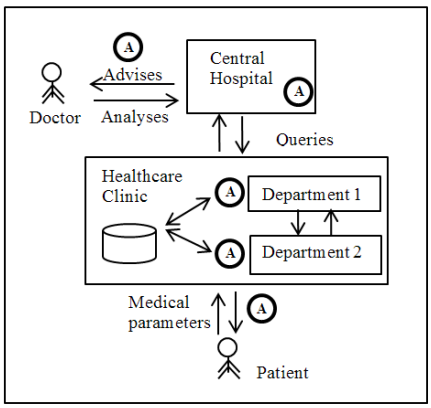

Figure 8. Three Layer E-Health Model Using Mobile Agents [19]

- **Agents Acting And Moving In Healthcare Scenario – a Paradigm for Telemedical Collaboration, by V. D. Mea (2001): [27]**

In this paper, the author has described an approach to analyses and develops the telemedicine systems based on multi-agent paradigm. A scenario is considered where a medical specialist (*e.g.*, dermatologist or radiologist) has to routinely visit his patients. Sometimes, if the case is difficult, he needs a second opinion from other expert or sometimes he himself gives second opinion to other specialists. In both cases, relevant data *i.e.*, an abstract of medical records with appropriate images (*e.g.*, skin photographs or radiographs) is shared between the referring and consultant specialists. Here, the need of multi-agents is recognized. Fixing an appointment between two specialists is concern of negotiation and collaboration and can be taken through the collaborative effort of two user agents. Each specialist has an important agent named TOMAS (Telemedicine-Oriented Medical Assistant) which has two generic features: an agenda for managing appointments and methods for access to patient records.

- **JADE Implemented Mobile Multi-Agent Based, Distributed Information Platform For Pervasive Health Care Monitoring, by C. - J. Su and C. - Y. Wu (2009): [22]**

In this paper, the authors have developed a mobile multi-agent information platform MADIP on top of JADE. The main motive behind is to develop a system capable of performing ubiquitous electronic health monitoring automatically and autonomously to users who are usually mobile and situated in low bandwidth, high latency, asynchronous transactions and unstable connection environment. MADIP consists of six components: User agent, resource agent, physician agent, diagnostic agent, knowledge-based data server, and external services. These components correspond to the human agents in the real world scenarios.

The MADIP permits the physician to detect abnormalities of patients and view the patient data in real time ubiquitously, using a PDA or a laptop or a desktop computer. In this paper, two scenarios are implemented. In first scenario (physician's perspective), doctor makes an order to collect the patient's up-to-date health data through PDA or other device. Upon receiving the order, user agent delegates the task to physician agent through the agent network (as shown in Figure 9). The doctor may switch off his device and indulge in other work. In the meantime, the physician agent surfs in the logical agent network and when needed information is found, a request is sent to the resource agent. At first, resource agent authenticates the physician agent. If passed, the resource agent retrieves the requested data set and passes to the physician agent. When all the data needed is acquired by the physician agent, it returns to the original host and passes the

data to the user agent which displays the result on the device of doctor via GUI when he is back online.

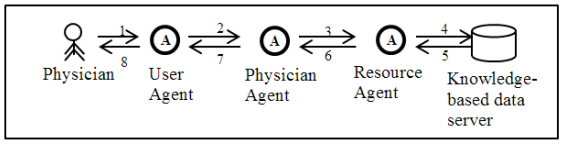

Figure 9. Sequence of Interaction of Agents in MADIP (physician's Perspective Scenario) [22]

In the second scenario (regular user's perspective), the patient checks his health condition (blood pressure, pulse rate, temperature, heart rate etc.) and initiates his user agent by his device. The user agent delegates job to physician agent via the agent network. The physiological data is sent to the resource agent by the physician agent which stores the data in the database and sends the copy of user's profile (patient profile) to the physician agent. The physician agent sends the patient's health data and patient's profile to the diagnostic agent that checks the patient's data against profile that contains the abnormality criteria. If an abnormal condition is detected, the associated physician(s) are immediately notified and suggest suitable follow-up procedures based on patient's health history based on external services such as e-mail, SMS or cellular call (as shown in Figure 10).

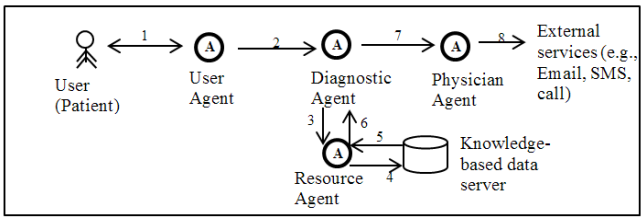

Figure 10. Sequence of Interaction of Agents in MADIP (regular user's Perspective Scenario) [22]

To sum up, the proposed MADIP architecture is able to relieve hospital personnel from the time-consuming task of constant monitoring of patients and to provide patients a mobile, ubiquitous and personalized healthcare. The usability of this system has also been tested in the ERP/MC laboratory of Yuan Ze University.

- **A Mobile Agent Approach for Ubiquitous and Personalized eHealth Information Systems, by P. Germanakos, C. Mourlas and G. Samaras (2005): [4]**

The authors of this paper have focused on presenting the common challenges and implications of the present eHealth environment. Nowadays, the growth of mobile penetration rate is faster as compared to desktop based Internet access. Moreover, the needs of mobile users are different from those of desktop users. Mobile applications should be characterized by context-awareness, accessibility, flexibility, quality and security in a ubiquitous interoperable manner in order to deliver quality on demand real time information. However, these applications suffer from numerous problems which are categorized into: local mobility, closed mobility, limited mobility and interrupted mobility. Thus, the special emphasis is placed on the emergence of wireless and mobile technologies and advancements in the specific area and how this affects the designing and development of pervasive information systems for the emergency of adaptive and personalized eHealth services. Finally, the mobile agent paradigm has been examined arguing that it could be effectively used for the development of the aforestated system.

- **Designing of Patient-Focused Mobile Agent in the Ubiquitous Medical Examination System, by J. Song, S. Kim and S. Kim (2006): [28]**

This paper aims to design an agent system which is divided into three components: mobile agent, agent information center and hospital information system. Mobile agents include mobile devices carried by the users that have all relevant information such as personal information (name, sex, age, address, phone number *etc.*), location information (GPS position information), sensor information (body temperature, pulsation) and medical information (relevant medical information, medical schedule *etc.*). Agent information center manages collected information from mobile agent. Mobile agent and Agent information center requires wireless transmission and it is difficult to ensure secure transmission. A scenario is considered in which a user is using a mobile device that has sensors attached to it to detect temperature, blood pressure and blood glucose level. When the sensors attached to the mobile device detect abnormal increase in blood pressure, it requests for the hospital information that is more appropriate to the user. Finally, a comparison is done by the authors between the current medical examination systems and patient-focused mobile agent system.

- **A Mobile Multi-Agent Information System for Ubiquitous Fetal Monitoring, by C.-J. Su and T.-W. Chu (2014): [23]**

The traditional fetal monitoring process is highly time consuming and requires the gravid women to frequently travel to hospitals or obstetric clinics, resulting in considerable inconvenience. Before the introduction of EFM (Electronic Fetal Monitoring) systems, the doctors and obstetricians periodically monitor the baby's heartbeat using a stethoscope on the gravid's abdomen. The pattern of the fetus's heart beat usually reflects its health. The obstetrician usually needs to keep a constant watch over the fetal heart monitors to respond appropriately. As a result, developing a distributed automated diagnostic system can aid obstetricians and promote home-based fetal monitoring. This paper aims to design and develop a mobile multi-agent based distributed information system to allow automatic fetal monitoring in real time from any location using smart phones, PDAs, laptops or desktop computers.

The suggested system inspects the fetal monitoring data recorded remotely in accordance with the doctor's guidelines while the gravid is at work or engaged in household chores. Mobile agent technology offers the likelihood of automatically executing the monitoring tasks with less human intervention. JADE is selected as a framework for implementing IMAIS due to its FIPA (Foundation for Intelligent Physical Agents)—compliant interoperability, openness, simplified development of distributed applications and its huge API library for the development of mobile applications. The IMAIS system architecture consists of six components: User interface agent, resource agent, medical (obstetrician) agent, diagnostic engine, knowledge-based data server and external services (as shown in Figure 11) [22, 23, 30].

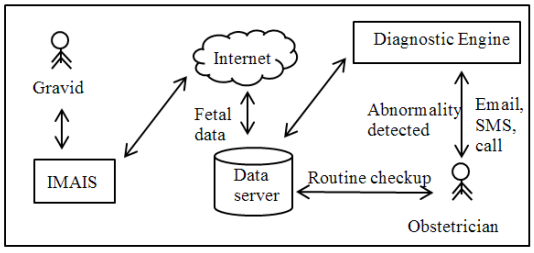

Figure 11. High Level View of IMAIS System Design [23]

- **Mobile Agents Using Data Mining for Diagnosis Support in Ubiquitous Healthcare, by R. M. A. Mateo, L. F. Cervantes, H.-K. Yang and J. Lee (2007): [12]**

The agent-based intelligent support system is required in medical industries because it allows the doctors and nurses gather quick information to assist in making diagnostic and treatment decisions. In this paper, the authors have proposed an expert mobile agent (EMA) using data mining to support the diagnosis of patient in ubiquitous healthcare. A framework is suggested that supports the mobility of mobile agent which executes neuro-fuzzy classification algorithm on patient data. Neuro-fuzzy systems are the hybrid of artificial neutral networks and fuzzy systems.

This multi-agent system consists of various components: Hospital Manager (HM), Facilitator Agent, Room Manager (RM), Monitor Agent, Service Modules and Expert Mobile Agent. Hospital Manager is concerned in managing the services in the hospital supporting the decision-making and management. It communicates to the other agents through facilitator agent who acts as a broker between the HM and the RM. A room manager coordinates the tasks of agents in the patient's room and can request for the services needed by the patients to the HM via the FA. Monitoring agents are used to handle the healthcare sensors and other sensors used for monitoring the patient. Service modules are used to support the diagnosis of patient, decision making and management of the hospital which are managed by HM. Expert mobile agents are used by doctors and specialists. The main function of EMA is to help on the patient diagnosis by checking the current data and processing it with the data mining tool.

The data mining model used for diagnosis has two phases. The first phase includes the training of EMA's fuzzy system from the previous data of patients. A pre-processing method based on the expert profile is used to filter the relevant data from its expertise. In the second phase, the EMA are deployed to execute the classification of data. Simulation results have shown that neuro-fuzzy classification provides a high accuracy in classifying the data as compared to other high accurate classifiers.

- **Deployment of Secure Mobile Agents for Medical Information Systems, by T.-L. Chen, Y.-F. Chung, F. Y. S. Lin (2012): [32]**

In remote care, mobile agent technology has many advantages such as reducing network load and latency, allowing off-line operation, ability to run smoothly in environments of low bandwidth, high network load or even that is unstable. In spite of many advantages, it has risk in its information security. While roaming in the Internet, the mobile agent can come under the contact of malicious agents. In this paper, the authors have proposed the use of Chinese Remainder Theorem and discrete algorithm to classify different levels of monitoring staff and consequently to grant permission and access according to their levels. Security analysis of the proposed system is conducted by simulating a variety of typical attacks by verifying the system's feasibility and efficiency. The proposed system satisfies four needs of the medical institutions: patient privacy, data security, real time patient information and non-repudiation of medical information [31, 32].

- **A Secure RBAC Mobile Agent Access Control Model for Healthcare Institutions, by S.-P. Cátia, B. A. Alexandre, C.-C. Ricardo and E. C. Manuel (2013): [13]**

The authors have analyzed that in order to provide patient's data privacy, the mobile agents must satisfy following properties: availability, integrity, confidentiality and non-repudiation. Furthermore, it has been analyzed that the access control is the first barrier that a mobile agent finds while communicating with the external institution. Access control involves following three security processes: identification, authentication and

authorization [31]. In healthcare systems, the most widely used access control mechanism is RBAC (Role Based Access Control). This paper offers to establish a mobile agent access control model based on RBAC model that favors the exchange of information between different health institutions that fall within the same circle of trust and this circle is formed by the usage of PKI (Public Key Infrastructure).

In this paper, the authors have explained the creation and migration process of mobile agents. When a mobile agent is dispatched to acquire medical information from external health institutions, a mobile agent carries several attributes to guarantee its identification, authentication and authorization at the external institutions. These several attributes are: user ID, user role permission, data query, patient ID, criticality code, time to response, reason code, list of external institutions, description, requester signature and health institution signature. A Break the Glass (BTG) mechanism is used in case of emergency which allows a user to override the access control rules stated by the access control manager. Audit control mechanisms are used to ensure that authorized users don't misuse their privileges. A scenario is also illustrated in which a gravid woman admits in a nearby hospital emergency department (ED) with severe abdominal pain. But due to emergency situation, she forgets her medical reports at home. Her prenatal care was done in other hospital (say A). The doctor who assists the patient in ED triggers the mobile agent to hospital A and gets back with the required results.

5. Conclusions

Mobile agents are employed to manage process and retrieve medical data distributed through several heterogeneous knowledge sources and present them upon request to the user. Mobile agents also aid in assisting the professionals in the decisions to be made during the process of healthcare. In the medical domain, the security of health data is an integral matter which is typically stored in local repositories. Agents are a good option to reach this target. Since the client-server communication works very slowly if there is more traffic on the network, mobile agents play a vital role in performing an immediate assessment of victim's health condition during a mass casualty incident. Above all, mobile agent technology seeks to execute duties in an automated way with minimal human interference. Requiring lesser human resource makes possible to use the saved human resource for other medical purpose. It has been observed from the analysis of the systems that the employment of multi-agent systems in real healthcare settings, integrated in the routine work of experts, is still in its infancy. Most of the scrutinized systems are academic research projects, with prototypes that attempt to show the feasibility and adequacy of using agent technology to solve a particular complex and distributed problem.

6. Future Scope

Despite the fact that the agent technology is a very promising approach to be used when addressing healthcare problems in distributed environment, there is still much work to be done before agent based systems are routinely used in medical environments. Data mining techniques should be implemented in order to retrieve the appropriate data from distributed data sources using mobile agents which leads to the concept of "mobile agent-based distributed data mining".

Being basic ultimate users of healthcare management systems, doctors and patients should be involved in the development of the project from the beginning, from the requirements analysis to the design and to the implementation phases. They should be particularly engaged in the definition of the system's functionalities and in the design of an interface with which they seem comfortable, achieving transparency between the user's interaction and the implementation technology, and smoothing the learning curve which typically hinders the engineering prototypes.

Another stimulating opportunity occurs from the implementation of agents running in mobile devices, which is a technology most people can easily engage with, including elder and disabled people.

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