A Multi-Agent Intelligent System for Monitoring Health Conditions of Elderly People

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***Abstract*—**In this paper, we propose a multi-agent intelligent system that is used for monitoring the health conditions of elderly people. Monitoring the health condition of elderly people is a complex problem that involves different medical units and requires continuous monitoring. Such expert system is highly needed in rural areas because of inadequate number of available specialized physicians or nurses. Such monitoring must have autonomous interactions between these medical units in order to be effective. A multi-agent system is formed by a community of agents that exchange information and proactively help one another to achieve the goal of elderly monitoring. The agents in the developed system are equipped with intelligent decision maker that arms them with the rule-based reasoning capability that can assist the physicians in making decisions regarding the medical condition of elderly people.

***Keywords*—**Fuzzy Logic, Inference system, Monitoring system, Multi-agent system.

I. Introduction

A. Problem Statement

IN this paper we propose a multi agent system for monitoring the health conditions of elderly people. The developed multi-agents system will provide agents that are capable of collaborating with one another, sharing elderly people information and exchanging knowledge in a proactive way. The agent is a special software working for its human client/clients to perform certain tasks that imitate human agents or systems and it has the ability to be autonomous in its action. This collaborative system will enhance the process of health condition monitoring comparing to the existing system which relay on the elderly people themselves. Normally if an elderly feels bad and there is a medical problem he/she will inform his physician. Sometime the medical condition will be severe that will prevent the patient from contacting his/her physician taking in our assumption that a lot of elderly live alone or they are living in a rural areas where is a lack of expert physicians or nurses. The proposed system can also be used in detecting the early stages of a medical problem in a patient. Agent in the proposed system is equipped with a decision engine, which will enable it getting some medical cues that can be used in early detection of a disease or medical problem. In the proposed system any information presented to any agent in the network or any decision rule added to the agent decision system will be shared with other agents not necessarily in the same medical network. The used reasoning is based on fuzzy logic [1] involving fuzzy rules and fuzzy reasoning implemented using the freeware FuzzyJess [2]. Integrating a decision mechanism into agents make them more proactive and encourage closer agent-human collaboration [3], [4]. The proposed system allows the agents to use different databases available in health organizations systems in the process of monitoring. Such databases weren't used before in the literature to monitor the health condition of elderly people. Databases in current systems are mainly used a for knowing the medical history of patients by only their physicians, improving the quality of provided services and reducing the costs of medical errors. These databases provides valuable information about patients including age, sex, medication took by the patients, symptoms appears on patients, laboratory tests results, and procedure followed by the physician at the visit time.

B. Introduction to Multi-Agent Systems

Multi-agent system has been a hot topic in recent years. And it's still be researched and developed because it will have an important effect once it comes to our life. Multi-agent system methodology offers an implementation that fits the design needs. An agent is autonomous because it has control over its actions and it pursuit them without direct involvement of its human agent or others. The agent is also social because it can cooperates and communicate with other agents and hence their humans in order to complete the required task. An agent is reactive since it is conscious about the updating of available data and changes in circumstances and responds based on in that in a timely manner. This entire make the agent rational in achieving its goals.

Agents work with each other in a cooperative way to complete certain task that cannot be done with single agent. A set of agents that help one another in solving problems by using cooperation, coordination and negotiation techniques is called a multi-agent system [3].

The multi-agent system is a complex system since the agents must be supported with interaction strategies that make them capable to select the appropriate activity at the appropriate time [5]. Agent learning focuses on learning how to communicate with other agent, learning how to coordinate different activities, learning how to manage a given task until completion, and learning from other agents.

Multi-agent systems have been widely adopted in many application domains because of its offered advantages [6], [7]. In multi agent system the complex task may be divided to different part and each part can be handled concurrently by specific agent. Different tasks or services can be distributed among the agents based on their complexity so each agent will

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deal with certain number of task rather than dealing with all tasks.

Agent talk with each other using special communication language called agent communication language (ACL). This language relies on speech act theory [5], [6]. An ACL support the agents with a variety of resources needed for exchanging information and knowledge.

II. Proposed Multi-Agent System Architecture for Monitoring Health Conditions Elderly People

A. Overview of the Proposed Multi-Agent System

Monitoring health condition of elderly people is complex medical problem since it involves different hospitals, departments and medical centers. The lack of interactions between these units is an important factor in deteriorating the health conditions of elderly people. Multi-agent systems offer an implementation that not only providing ways of interaction and communicating between medical provider units but also provides medical decisions and alert about the patient medical situation.

There are five agents in the preliminary proposed Multi-Agent System (MAS) system. Fig. 1 gives the general organization model of the proposed system. Within each health organization, there would be a unique Health organization Agent (HOA) that have many Department Agents (DAs) and many Physician Agents (PAs). Different HOAs and PAs can communicate with each other and not necessarily from the same medical network.

B. Architectures of the Agents

1. Information Center Agent (ICA)

It has the highest authority and is responsible for necessary management and information collection. It provides a gateway among the agents in the system. It controls the access to the system and it also checks the identities of the users. There is only one ICA in the system. It stores information about the elderly peoples and their unique IDs. Thus agents need to communicate with the ICA agent to find out which hospital organization is available in the system at any given time.

2. Health Organization Agent (HOA)

The HOA continuously monitors incoming and outgoing information through this HOA.

3. Department Agent (DEA)

It models each department within each Health Organization. It is similar in its architecture with health organization agent.

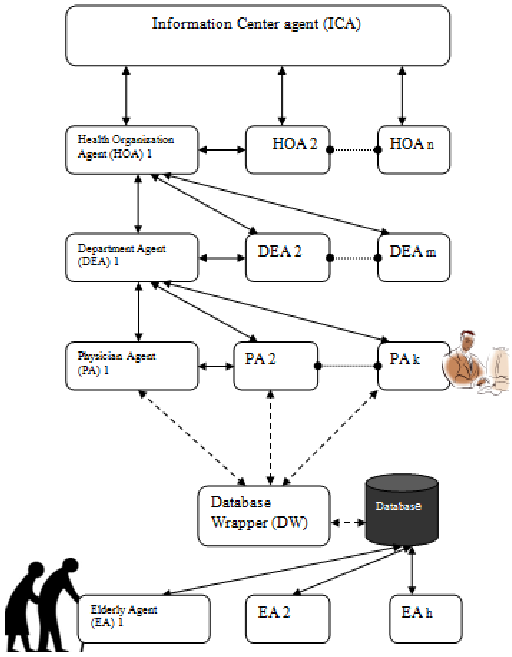

Fig. 1 The proposed Multi-Agent system for monitoring the health conditions of elderly people

4. Physician Agent (PA)

PAs helps a physician acquire useful information of the elderly people and make initial decisions about the medical situation of the patients. The PA will perform according its knowledge. The PA could also ask other agents about the rules they are using in evaluating a medical condition of an elderly person so that the agent can updates rules. The PA has the ability to track the further development of the suspected cases under the help of other agent available in the system. The PA will keep all the cases seen by or forwarded to its physician in electronic records and such records will be updated when new information is being available. The PA can decide to take any of the following actions depending on the decision reached, i.e.:

- To order some extra clinical tests.
- To continue the same medical treatment or to modify it.
- To schedule another visit for the future or transfer the patient, for example, hospitalize him if his health has deteriorated too much. Patients can also be transferred from one of the health centers to another according to the patient needs.

The PA Agent Architecture is Divided into Five Modules

- Communication module which deals with the high level communication details, managing all the incoming and outgoing messages.
- Domain specific knowledge. It keeps a set of experiences that are elicited from domain experts. It represents the agent's view of the world and maintains the variables and criteria that the *Fuzzy Inference Engine* can use to evaluate medical condition of a patient.
- System knowledge. It contains the specifications of the scenes and the performative structure. A scene is basically

a group meeting, and it is composed of a set of agents communicating with a well-defined communication protocol to perform certain task. The scenes and the connections between them form the performative structure which defines possible tracks that each agent can follow when performing a task.

- Fuzzy Inference Engine, This decision engine contains the reasoning algorithm, which is the agent's brain. It performs reasoning tasks and executes local events.
- Set of scene protocol behaviors. It models the current state of the agent in a scene. There is a scene protocol behavior for each agent.
- Deliberative engine. Using the Experience Knowledge Base, System Knowledge Base, Fuzzy Inference Engine and the current state of the agent represented in the Set of Scene Protocol Behaviors, this engine makes decision on the next action by taking into account the restrictions imposed by the system designer.

5. Elderly Agent (EA)

EAs gathers certain medical information of the monitored elderly people such as Blood pressure Levels, Blood Glucose Levels, Cholesterol levels, Temperature, Heart rate, Oxygen level in blood, and other laboratory tests such as Creatinine Laboratory Test and Potassium Laboratory Test. Creatinine Phosphokinase (CPK) Laboratory Test and Transaminases Laboratory Test (either ALT or AST). These laboratory tests are mainly used evaluating the medical condition of the elderly people. Most people in the early stages of sick feel well and have no clear symptoms that would lead a health care provider. This place a large emphasis on laboratory tests to diagnose, predict or evaluate a medical problem since they are indicative of extensive problems in the patient.

Such information will be gathered from the elderly people using two ways. The first way using regular medical instruments and the result will be input to the system through simple graphical user interface in order to be sent to the database. This can be done from elderly people houses, medical clinics or even medical laboratory centers. The second proposed way through embedded system connected with medical instruments. This embedded system will take care of sending the reading of the instruments directly to the database without any human involvement. The proposed way of sending the data to the database is not only using regular internet networks but also using GSM technology through SMS messages. Using SMS messages is very helpful in rural areas where the internet connection is not available. This was done using GSM modems by AT commands. AT commands is used to collect information by controlling GSM Modems. AT is the abbreviation of ATtention.

6. Database Wrapper Agent (DWA)

Database Wrapper Agent contains Elderly people Database and medical Codes Database. Database Wrapper provides two important functions: a) it provides frequently-used methods for database connectivity. It provides a simple layer that can deal with standard database language (e.g., SQL)., and b) it offers a wrapper that maps the human description of a case to different medical codes (ICD-9, Clinical Classification, etc.) that are commonly used in U.S and it also provides the opposite mapping. Such codes describe the medical conditions of patients, symptoms phenomenon and the procedures followed by physician in order to diagnose a case.

The PA is equipped with the rule-based reasoning capability. More specifically, we have designed a "Fuzzy Monitor Assistant System". Fuzzy logic is a well-established methodology that is effective for systematic handling of deterministic uncertainty and subjective information. Fuzzy logic is useful especially when a mathematical model of a system is not available and rules of the thumb from domain experts are available. It has been successfully used to solve challenging industrial and medical problems in practice, some of which are very difficult to solve without it. The Assistant system is a common rule-based system that uses fuzzy sets theory.

The reasoning is based on fuzzy logic. The structure of the Assistant System includes four components: Fuzzifier, Inference Engine, Knowledge Base, and Defuzzifier. The Fuzzifier translates crisp inputs into fuzzy values. The Inference Engine is the part that controls the process of deriving conclusions. It applies a fuzzy reasoning mechanism to obtain a fuzzy output using rules and the fuzzy values. The Knowledge Base contains a set of fuzzy IF-THEN rules and a set of membership functions of fuzzy sets. These rules represent the knowledge that the PA possesses. The Defuzzifier coverts the fuzzy output into a crisp value that best represents the out fuzzy set. The Defuzzifier uses the center of gravity scheme. The implication methods used in the proposed system are min (minimum), which truncates the individual output fuzzy sets, and max (maximum), which scales the resulted output fuzzy sets. The input to the implication process is a single number given by antecedent.

The monitoring task is performed by the Inference Engine that evaluates all the rules in the rule base and combines the weighted consequents of all relevant rules into a single output fuzzy set. That set is then defuzzified to produce a crisp similarity value.

The "Fuzzy Monitor Assistant System" is experience-based as experience plays a key role in the design of it. The similarity rules are used to build the Knowledge Base. The Assistant system uses a number of parameters related to physician experience. They include age, gender, medications, morbidities (chronic and acute), diagnoses, and laboratory test results. There are a total of 92 fuzzy rules.

The input and output variables will be defined in order to be used by the Fuzzy Inference Engine, and each variable is fuzzified by input fuzzy sets. The fuzzy sets used in fuzzifying the Input and Output variables are shown in Table I. Bell fuzzy sets are specified by three parameters a, b and c while the gaussian fuzzy set is specified by two parameters a and b and trapezoidal fuzzy set is specified by four parameters a, b, c, and d.

TABLE I
DEFINITIONS OF FUZZY SETS USED IN THE PROPOSED SYSTEM

Fuzzy Set Type	Fuzzy Set Definition
Trapezoidal	$\mu_{Trap}(x) = \begin{cases} 0, & a < x \\ -\frac{1}{b-a}(a-x), & a \le x \le b \\ \frac{1}{d-c}(d-x), & c \le x \le d \\ 0, & d < x \end{cases}$
Bell	$\mu_B(x) = \frac{1}{1+\left\|\frac{a-x}{b}\right\|^{2c}}, \quad c > 0$
Gaussian	$\mu_G(x) = e^{-\frac{(a-x)^2}{2b^2}}$

Due to the space limit, we will only provide part of the rules – those involved with Potassium Laboratory Tests. To get the degree of the abnormality of the potassium laboratory test, the laboratory result will be converted to its abnormality value. The abnormality value will be zero for a laboratory result in the normal ranges. For other values, the abnormality value will be calculated using fuzzy rules. The laboratory results will be the input to the system and the Abnormality Value will be the output. Both the input and the output are fuzzy variables. There are three fuzzy sets for the input variable Potassium Laboratory Test Value (Fig. 2), and three fuzzy sets for the output variable Abnormality in Potassium Laboratory Test (Fig. 3). Here are the rules:

- If Potassium Laboratory Test Value is *Low*, then Abnormality in Potassium Laboratory Test is *Low*.
- If Potassium Laboratory Test Value is *Medium*, then Abnormality in Potassium Laboratory Test is *Medium*.
- If Potassium Laboratory Test Value is *High*, then Abnormality in Potassium Laboratory Test is *High*.

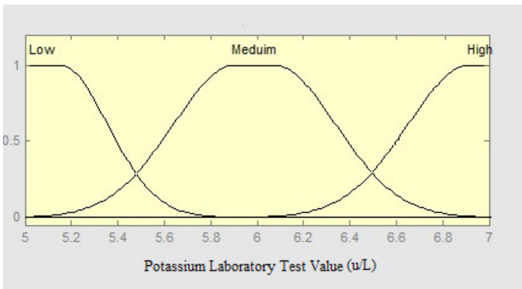

Fig. 2 Fuzzy sets for Potassium Laboratory Test Value

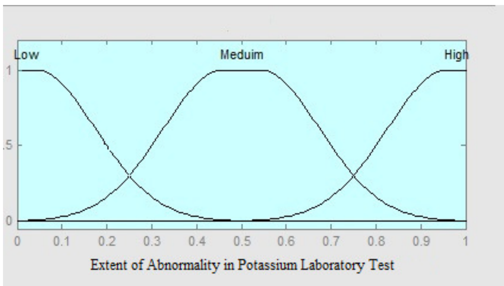

Fig. 3 Fuzzy sets for Abnormality in Potassium Laboratory Test

III. SYSTEM IMPLEMENTATION

For system construction and execution, JADE 3.7 agent platform (Java Agent DEvelopment Framework) is adopted [2]-[4]. JADE is an open-source software framework. JADE is a widely used package in multi agent system implantation [3]. JADE is following the specifications laid by The Foundation for Intelligent Physical Agents (FIPA) for multi agent system implementations [1]. It provides a set of Java classes that makes it easy to implement the systems. JADE can run on a variety of operating systems including Windows and Linux. The JADE platform includes most of agent's specifications. Each agent is implemented in JADE as a single thread. JADE provide a multi thread environment that allows the agents to execute parallel tasks. Different cooperative behaviors can effectively schedules in JADE. JADE incorporates some ready to use behaviors that commonly used by agents during performing certain task. Among the others, JADE offers a behavior that allows full integration with JESS which is a rule based engine that performs all the necessary reasoning.

Since agent are normally distributed at different location. Each location will have a runtime environment that hosts the agents, which is called a "Container". Each container has AMS and DF agents. The containers will communicate with each other using a pre defined protocol. One container needs to be assign as main container which represents the bootstrap point of a platform. It is the first container to be launched and all the other containers must join it by registering with it. For my system, the main container hosts 250 EAs and five PAs. JADE also provides tools that manage both locally and remotely agent life cycles including create, suspend, resume, freeze, thaw, migrate, clone and kill.

Agents are communicating between each other using certain communication protocols. The communication protocols used between agents have to be fixed. Agents interact through speech acts language. For example; query, inform, request, offer, accept, withdraw, and reject speech acts has been used in the developed system. Interaction between agents occurs within a scene. The developed system composed several scenes which are basically group meeting composed of a set of agents playing different roles and communicating with a well-defined communication protocol. To specify a scene, the first step is to identify which are the agents that will participate in the scene. Agents with different roles can enter and exit a scene to go to another one. The second step is to define the communication protocol [6], [7]. JADE provides messaging system that follows FIPA_ACL (Foundation for Intelligent Physical Agents - Agent Communication Language) standers. The messaging system manages message traffics and monitors the resulted queues provided to agents. [3], [6], [8].

Fig. 4 shows a conversation between the two agents in the proposed system using the Petri nets approach. The two agents can be either two PA or two EA or one EA - one PA. The interesting thing about this approach is that we can describe more precisely what is happening during a conversation between agents [3]. A Petri net is defined as a graph containing two sorts of nodes: *places and transitions*. This graph is built in such a way that the arcs can only link places to transitions or transitions to places. Places are graphically represented by circles and transitions by bars. The places correspond to the state of the agent during a conversation stage.

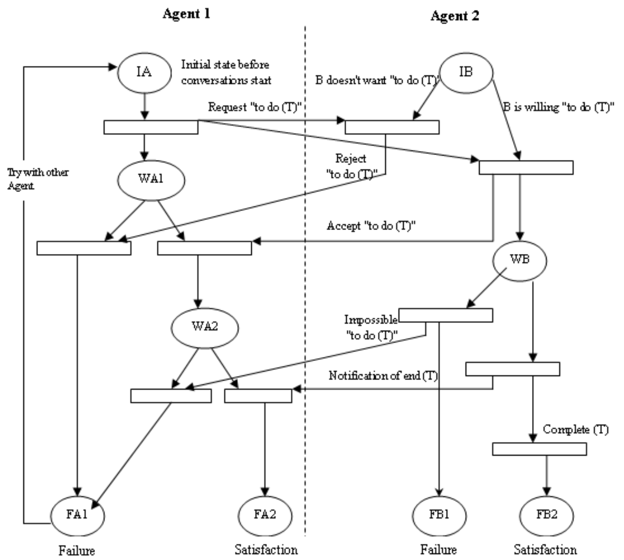

Fig. 4 Conversational model of a medical Decision task between two PAs using the Petri nets approach [9]

The transitions correspond either to synchronization due to the receipt of messages or to conditions of actions. Places IA and IB describe the initial states where the PAAs find themselves before the beginning of the conversation. Places FA1, FA2, FB1 and FB2 represent the end of conversation states. Starting from state IA, Agent 1 sends a request "to do (T)" to Agent 2 and moves in to state WA1, which represents waiting for a response. If PAA2 can't do the task, it sends a refusal to Agent1, which then goes into state FA1, which indicates that Agent 1 must look elsewhere to have its task carried out. If Agent 2 can do the task, it sends an acceptance message to Agent 1, which places Agent1 into wait for a response state WA2. During this time, Agent 2 is in state WB, while trying to carry out the task. Once finishing the task, it sends a notification of end of accomplishment to Agent1, which places Agent1 in state FA2 and places PAA2 in state FB2. If not, Agent 2 indicates that it cannot do the task, which places Agent1 in state FA1 and places Agent 2 in state FB1.

During the development of the proposed Monitoring system with JADE, the following types of Java code classes are created and implemented:

Reasoning classes, which are used for the implementation of the various reasoning models and Fuzzy Inference Engine employed by PAAs, for example, the Fuzzy. In this application FuzzyJess Toolkit from the National Research Council of Canada's Institute for Information Technology has been used. It is a set of Java classes that provide the capability for handling fuzzy concepts and reasoning [2]. It is compatible with JADE. It allows the user to use Java language to define membership functions, set antecedent and consequent of a fuzzy rule, and makes a fuzzy inference. FuzzyJess uses Jess (Java Expert System Shell). Jess provides the basic elements of an expert system including fact-list, knowledge base that contain all the rules and inference engine which controls overall execution of rules.

Graphical User Interface (GUI) classes, which provide the user with a graphical interface to the multi-agent system, initiate a search, and show the results of a query to the user. This part will be developed in our future work and will be integrated with GSM/GPRS Modem to immediately transmit the Elderly Data from EA to PA and Vice Versa.

White Board classes, JADE provides the classes used to help an agent publish and search for services through method calls. These classes help agents use the White Board.

IV. Experiment Results

We carried out some preliminary experiments to evaluate the proposed system in JADE and FuzzyJess. More specifically, we sought to assess the Agents ability to monitor Elderly people. We form the agent system by implementing five PAs and each agent has 50 Elderly People to be monitored. Each PAA has some of the 92 fuzzy rules for making medical decisions in order to evaluate how the agents work with each other in making medical decisions.

V. Conclusion

In this paper, we have proposed a multi-agent system for monitoring the health condition of elderly people. As a first step, we have designed a multi agent system and started the implementation using JADE and FuzzyJess software packages. As a next step we will use real patient data gathered from online medical instruments using embedded system with GSM modem to preliminarily assess the performance of the Multi-Agent system.

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