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Aarogya – An Intelligent Multi-Agent Paediatric System

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Abstract— Paediatric healthcare structure in India is largely concentrated in the urban areas leading to lack of expert, affordable and accessible healthcare for the rural children. The existing healthcare softwares either are not readily available to the rural population or is fragmented leading to lack of coordination between the expert doctors and the patients. The proposed system Aarogya uses the JADE platform to implement artificially intelligent multi agent paediatric healthcare system which overcomes the problems faced currently making communication between a paediatrician and the patient not only effective but also reliable. The system works on two platforms namely the doctor platform and the user platform communicating via the Internet. The user uses a cell phone to answer a set of adaptive questions which are translated by an agent to the corresponding symptoms and are further mapped to the ailment using ontology. The treatment of the ailment is retrieved from the doctor's database and provided to the user. Aarogya also provides a scheduler agent to schedule appointment with the doctor in case of an emergency.

Index Terms — Paediatrician, JADE, Internet, multi- agent system, ontology, artificial intelligence.

1 Introduction

As per the 2011 census about 72.2% of the Indian population is living in rural or remote areas. According to SRS Bulletin [1] released in September 2014 by the Government of India, average infant mortality rate in rural areas is 44/1000 while it is 27/1000 in urban areas.

The healthcare practitioners in these areas are not specialized in dealing with infant or childhood diseases. Accessibility to health facilities is a critical factor in effective health treatment for people in rural areas of lesser-developed countries like India. 31% of the population travels more than 30 kms to seek healthcare in rural India[2].These facts are for real, and the reasons behind the poor healthcare infrastructure can be attributed to lack of investment incentives for the private sector, gross inefficiency in public healthcare system, and a chronic lack of quality doctors and medical professionals.

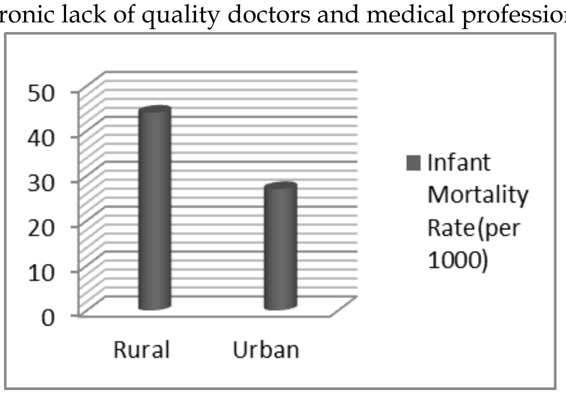

Figure 1

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Thus, an Intelligent Multi-agent Pediatric System (IMPS) - Aarogya is presented for providing clinical decision support to healthcare practitioners in rural or remote areas of India for young infants or children up to the age of 5 years.

Aarogya provides a time saving and efficient communication link between the rural population of India and the pediatricians. The system is not just limited to bridging the physical gap but also incorporates an expert system based on JADE multi agent system architecture to diagnose and provide the validated and authorized treatments for the most common and widely prevalent neonatal diseases.

The document is organized as follows. Section 2 provides an overview of the multi agent system and its advantages over other prevalent healthcare systems. Section 3 describes the JADE architecture that provides a dedicated and an effective platform for implementation of agents. Section 4 exemplifies the proposed system as an efficient solution featuring all its functionalities. Section 5 then explains in detail the working of every feature of Aarogya. Section 6 explains the ontology to be used while Section 7 gives an overview of how this ontology will be used to generate an adaptive questionnaire and thereby compute the disease based on the answers. The screen shots of the implemented and running agents are included in Section 8. Section 9 mentions the future scope of the system and how it can be scaled and expanded. Finally, Section 10 concludes the paper.

2 Related Work & Multi-Agent System

The prevalent healthcare systems in rural India like the mobile vaani are limited to a fragmented structure where the constant availability of the doctor is mandatory and the communication between the doctor and the patient is limited to a visual or at least an audio dialogue. Also the system lacks in intelligent computational abilities [2] and is static in nature. It cannot respond to the changing environment and is limited to a specific behavioral pattern. The other conceptual health care systems proposed also require a constant feeding of data and inputs to a computer terminal thus restricting the mobility of the system as a whole [3]. Even if mobile systems are proposed or prevalent they lack proactivity and reactivity to the changing needs of the user which is the highlight of an agent based mobile healthcare system.

Agents are intelligent, autonomous, computational entities that can be viewed as perceiving their environment through sensors and acting upon their environment through effectors. To say that agents are computational entities simply means that they physically exist in the form of programs that run on computing device. To say that they are autonomous means that to some extent they have control over their behavior and can act without the intervention of humans and other systems. Agents pursue goals to carry out tasks in order to meet their design objectives and in general these goals and tasks can be supplementary as well as conflicting[4]. However the capacity of individual agents is limited by its knowledge, computing resources and its perspective. The most powerful tool for handling complexity are abstraction and modularity which are definitely offered by a system where a number of or a group of agents work together to perform a task. Such a system is said to be a Multi Agent System (MAS)[4]. A multi-agent system (MAS) is one that consists of a number of agents, which interact with one another, typically by exchanging messages through some computer network infrastructure and is thus intelligent. In the most general case, the agents in a multi agent system will be representing or acting on behalf of users [5] or owners with very different goals and motivations.

The Multi Agent Systems can be used specifically when following domains are encountered:

i. The domain contains problem that can be decomposed into several sub-problems, which may have some kind of inter-dependencies. [6]
ii. The knowledge is administered in various places.
iii. A number of entities need to join their problem-solving abilities, keeping their autonomous nature intact to solve a complex problem.

Keeping all the above in mind and knowing the artificial intelligence tha MAS provides we can feel that applying agent-based techniques to the problems in the medical domain can be beneficiary for the civilization. And we think that is the main reason why Multi Agent Systems are opted as one of the most interesting and effective technologies to solve various health related problems to revolutionize the medical paradigm. [7]

A multi-agent-based system can assist in better healthcare in the following ways. [8]

1. Proactive healthcare with emphasis on prevention – where patients with early symptoms can be attended to by the doctors before an acute attack occurs.
2. Enhanced patient–doctor interaction – whereby agents can provide patients with information about their medication or treatment procedures which is not usually presented in a normal face-to-face consultation because of lack of time or the reserved nature of the patient.
3. Enhanced information exchange – agents can provide terminology at a level which the patient can understand. Often doctors may communicate information using technical healthcare terms which the patient may not fully comprehend.
4. Healthcare services to geographically remote patients – whereby the Internet plays a major role in providing the backbone communication link between the doctor and the patient in a remote environment. Furthermore, a reduction in travel time and expenses for rural patients should be evident.

3 Methodology

The JADE architecture to be used for the development of Aarogya utilizes the following notions. An application based on JADE is made of a set of components called Agents each one having a unique name. Agents execute tasks and interact by exchanging messages. Agents live on top of a Platform that provides them with basic services such as message delivery. A platform is composed of one or more Containers. Containers can be executed on different hosts thus achieving a distributed platform. Each container can contain zero or more agents. A special container called Main Container exists in the platform. It must be the first container to start in the platform and all other containers register to it at bootstrap time. It includes two special agents: the AMS that represents the authority in the platform and is the only agent able to perform platform management actions such as starting and killing agents or shutting down the whole platform (normal agents can request such actions to the AMS). The DF that provides the Yellow Pages service where agents can publish the services they provide and find other agents providing the services they need.

Agent behavior represents a task that an agent can carry out and is implemented as an object of a class that extends jade.core.behaviours.Behaviour. Every agent maintains the queue of the behaviors that it supports. Once the behavior is completed, it is removed from the queue. The following are the different types of behaviors:

- Generic Behavior
- Cyclic Behavior
- One-shot Behavior
- Ticker Behavior

Using only a single thread per agent completely eliminates the scheduling operation performed by the thread dispatcher. Switching between behaviors is extremely faster than that of threads and hence performance is improved. No multiple threads mean that there is no need of any synchronization which avoids some overhead.

4 Proposed System

The backbone of the proposed implementation is the multi-agent system comprising of intelligent software agents that can initiate communication, monitor events, and perform tasks without the direct intervention of humans or others. Aarogya works on two independently communicating platforms namely the user agent and the doctor agent.

The user platform: The user/patient can locate the nearest doctors in his neighborhood and choose which doctor to communicate with. Then by answering a set of simple yet well-structured adaptive questionnaire the user's predicament is mapped and translated to the possible ailment by Aarogya. Based on the severity of the situation the intelligent agent may choose to prescribe medicines or fix an immediate appointment.

The doctor platform: Aarogya is also a personal assistant to the doctor (pediatrician) user as it can perform tasks such as scheduling appointments. And hence Aarogya majorly acts as a doctor to all rural people in and around the vicinity of the doctor providing immediate treatment advices and also fixing an appointment if need be. The agent will be multi linguist and can be easily understood and utilized by any strata of the society.

5 Implementation

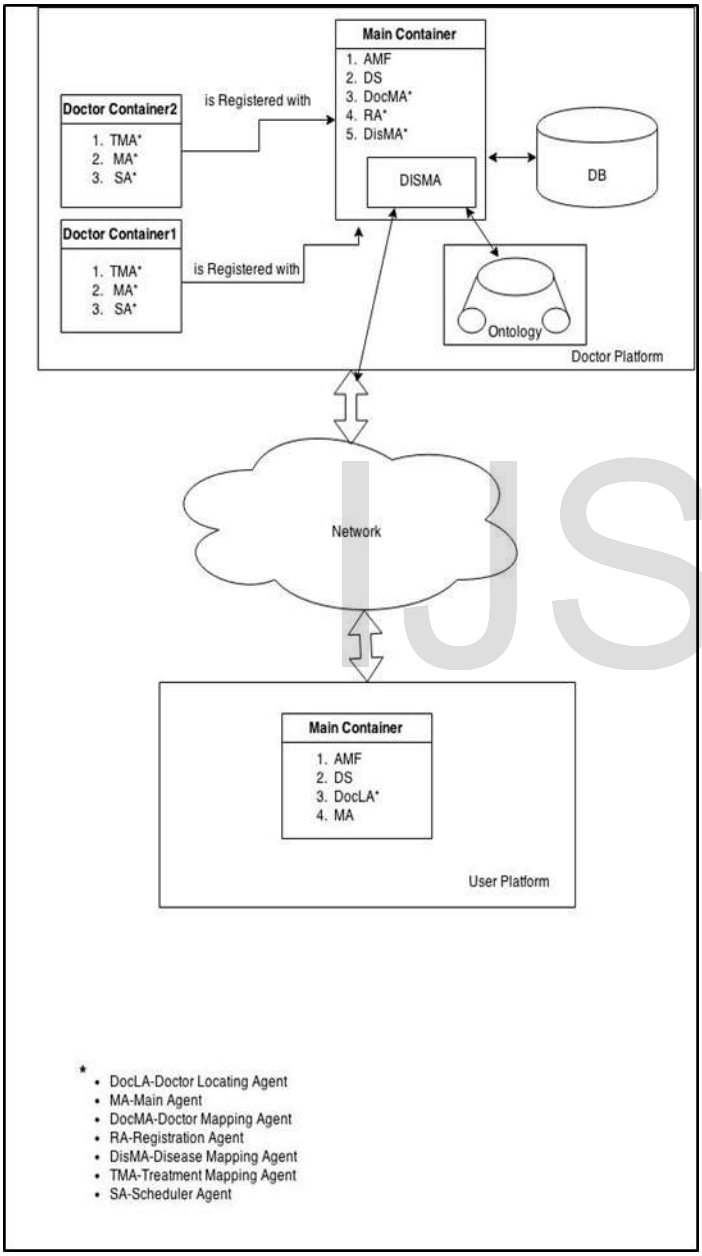

Figure 2

A. User Platform:

The User Agent comprises of the following agents:

1. DocLA(Doctor locating agent): This functionality of this agent is to access the location of the first-time user through GPS (Global Positioning System) and provide a list of doctors registered with the system within a particular radius. The user can now choose a doctor as per his/her convenience of accessibility and preference. The user is now associated with this selected doctor for all future predicaments. Thus there is a one-to-one mapping between the user and doctor.

2. MA(Main agent) : For a first time user, the main agent provides the GUI to register the new user. Also, it provides the adaptive questionnaire to determine the symptoms and sends the data received from the user to the Main container of the doctor platform. The MA displays the treatment details received.

B. Doctor platform:

The doctor platform comprises of a main container and many doctor containers which are registered with the main container.

Main Container – Contains all agents which access the main database.

1. DocMA(Doctor Mapping Agent) : The agent maps the user requests to the corresponding doctor that the user is associated with.

Step 1: User sends a request.
Step 2: Identify the user unique code.
Step 3: Retrieve the details of the corresponding doctor agent from the database.
Step 4: Pass the doctor agent details to the DisMA.
Step 5: Send the “treatment” received from the TMA of Doctor Container back to the User Platform.

2. RA(Registration Agent) : Registers users and doctors by storing their details in the database.

3. DisMA(Disease Mapping Agent): Accesses the ontology and provides an adaptive questionnaire to identify the disease and passes the information to the corresponding doctor container as computed by the DocMA.

Doctor Container – Contains all the agents performing functionalities of the doctor and those accessing the local database of the doctor.

1. TMA(Treatment Mapping Agent): Based on the disease received as input from the Main Container, it retrieves the corresponding treatment from the local database of the doctor container and sends it back.

Step 1: Receives input from DisMA of Main Container.
Step 2: Retrieves the treatment corresponding to the diease.
Step 3: Send the treatment back to the Main Container.

2. SA(Scheduler Agent) : Schedules and maintains the appointment directory of the doctor.

3. MA(Main Agent): Provides the GUI for registration of the doctor and passes the information to the RA in the Main Container.

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6 Ontology

Ontologies are content theories about objects, their properties, and relationships among them that are possible in a specific domain of knowledge and thus aid in creating an intelligent system [9]. In knowledge based systems, ontology is that part of the system which specifies what things exist and what is true about them. Ontological analysis clarifies the structure of knowledge. Ontology related to a domain forms the heart of any system of knowledge representation for that domain. Without ontologies, there cannot be a vocabulary for representing knowledge. Ontologies enable knowledge sharing since they capture the intrinsic conceptual structure of the domain using a suitable knowledge representation language. This language can be shared with others that have similar needs for knowledge representation in that domain thereby eliminating the need for replicating the knowledge analysis process. The ontology we will be working with is written in OWL (Web Ontology Language). OWL is an ontology language that defines the concepts you can use to write ontology. Using OWL the ontology of the system will be designed which will in turn represent the knowledge base of the system. As the Knowledge Base is structured using ontologies, the adaptive questionnaire and its working will be dependent on the definition of the ontology.

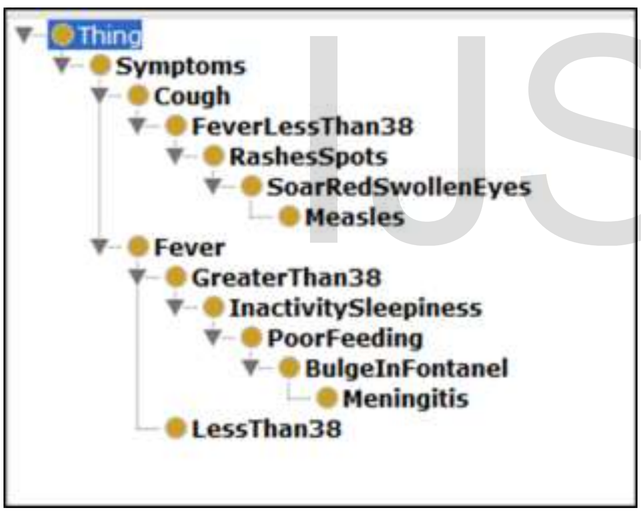

Figure 3

7 Ontology Driven Adaptive Questionnaire For Intelligent System Management

To develop generic questionnaire ontology, we identified and extracted structural elements from a number of medical questionnaires. The main classes in the ontology include: Questionnaire, Subquestionnaire, StartOfQuestionnaire, Question, FurtherQuestion (adaptive question) and Answer. To define how the questionnaire is structured and how it behaves we use a number of properties. There are four main sets of properties: structural properties, composition properties, type properties and finally, adaptive properties. A Type property is used to define the nature of the classes in the Questionnaire, Structural properties are used to describe the structure of the questionnaire, while Composition properties are used to combine classes together. Finally Adaptive properties determine the dynamic (i.e. adaptive) behaviour of the questionnaire

Table 1 is an example of the type of questions and answers which would generate the adaptive behaviour of Figure 3.

Table 1: example of Questions and answers

	Questions	Answer
Q1	Has the baby been inactive lately?	No
Q2	Is the baby coughing?	No
Q3	Does the baby have fever?	Yes
Q3.1	Is the temperature more than 38°C	Yes
Q3.1.1	Has the fever been fluctuating?	Yes
Q3.1.2	Does the child have sore eyes?	No

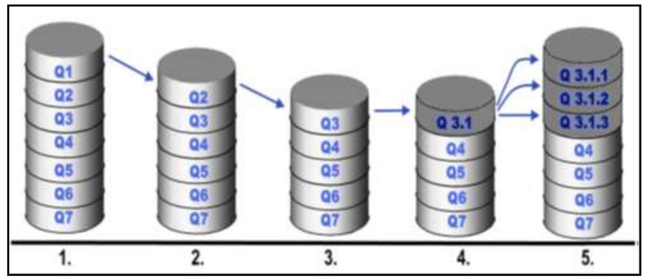

Figure 4

The run-time behaviour of the adaptive questionnaire is illustrated by Figure 4, in which each step corresponds to a system iteration (i.e. a full Figure 1 loop). Question 1 (*Q*1) does not have any adaptive properties and leads directly to *Q*2 regardless of the answer (step 1→2). Question 2 does have adaptive properties, however, the user input did not trigger a call for further questions and thus also leads directly to the next question *Q*3 (step2→3). In step 3→4, unlike the previous case, the answer to *Q*3 triggers the call for a further question. This additional question (*Q*3.1) now seats on top of the stack (next question to appear on the UI).

Finally, the answer to *Q*3.1 triggers the call for three additional questions (*Q*3.1.1, *Q*3.1.2 and *Q*3.1.3). These additional questions now seat on top of the question stack, in the order of priority asserted in the ontology. Depending on the adaptive properties of the remaining questions, the process of adding further questions could be iteratively repeated until the engine finally reaches the bottom of the stack (end of questionnaire)[10]. A recurring concern when implementing context sensitive self-adaptation in a medical questionnaire is: "is it safe? What are the liabilities involved and can we trust the system to make adequate judgement?" As already suggested in the introduction, Aarogya uses the medical database of the expert paediatricians.

8 Implementation

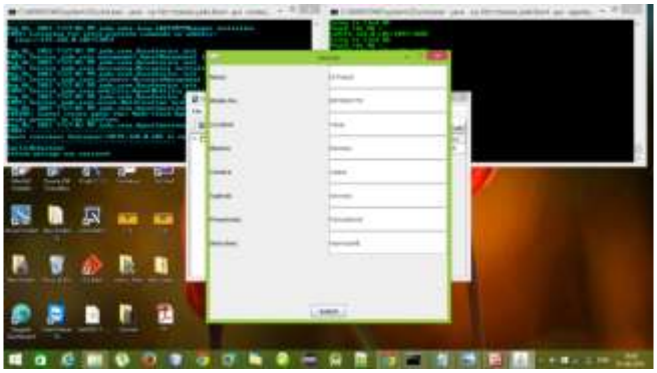

Figure 5

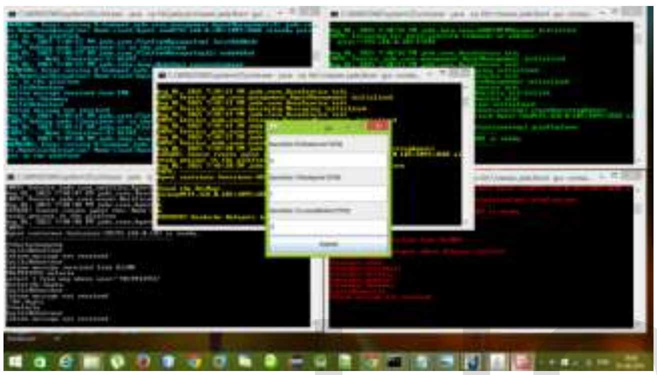

Figure 6

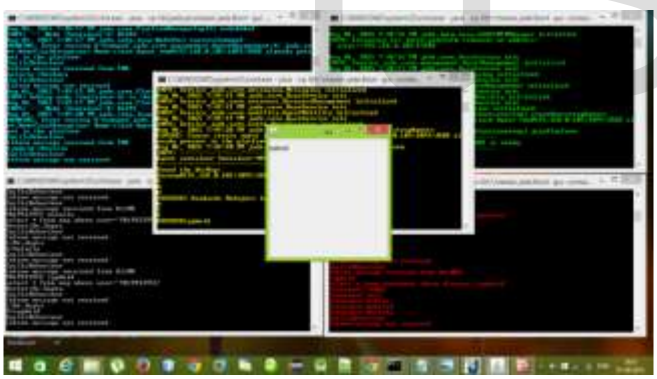

Figure 7

9 Future Work

The future work includes incorporation of expert agents using JESS platform. The knowledge base of Aarogya can be scaled to encapsulate more children diseases. Aarogya and be expanded further to provide healthcare to not only children but also adults thus translating to a full-fledged expert healthcare system. The doctor platform of the system can implement a dedicated web crawler to assist the doctor for studying and researching medical journals and papers effectively.

10 Conclusion

Thus, by incorporating the multi agent system, ontology and adaptive questioning, Aarogya contributes to next-generation e-health from three points of view: Improving the quality of healthcare, facilitating the access to specialized healthcare and reducing cost. This system bridges the gap between the ever-so-busy pediatricians and in-need patients simplifying the organization and management on the doctor's side and working in the direction of deceasing infant mortality rate.

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