# A Multi-agent Medical System for Indian Rural Infant and Child Care

**Vijay Kumar Mago[1] and M. Syamala Devi[2]**
[1]Department of Computer Science, DAV College, Jalandhar, India.
[2]Department of Computer Science and Applications, Punjab University, Chandigarh, India.
v_mago@yahoo.com. syamala@pu.ac.in.

## Abstract

In this paper, a Multi-agent System (MAS) 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. The government is unable to appoint child specialists in rural areas because of inadequate number of available pediatricians. It leads to a high Infant Mortality Rate (IMR). In such a scenario, software agents provide a realistic solution. The agent-based prototype has been developed that involves a knowledge component called an Intelligent Pediatric Assistant (IPA); and User Agents (UA) along with their Graphical User Interfaces (GUI). The GUI of UA provides the interface to the healthcare practitioner for submitting sign-symptoms and displaying the expert opinion as suggested by IPA. Depending upon the observations, the IPA decides the diagnosis and the treatment plan. The UA and IPA form client-server architecture for knowledge sharing.

## 1 Introduction

A majority of the Indian population is living in rural or remote areas. The healthcare practitioners in these areas are not specialized in dealing with infant or childhood diseases. They simply refer child related critical cases to specialized doctors in urban areas. There is also an acute shortage of funds and adequate trained child specialists in India. According to the National Commission on Population (India), in 2002, approximately Rs. 643.1 million were needed for infrastructure and services of 1,774 more pediatricians were required. Hence, the government is unable to appoint child specialists in rural areas. All this leads to high Infant Mortality Rate (IMR) i.e. 68/1000 live births.

The National Commission on Population observes that main contributors to high IMR in India are states having majority of population residing in rural areas as shown in Table 1.

| STATES | Orissa | Madhya Pradesh | Uttar Pradesh | Rajasthan |
|---|---|---|---|---|
| IMR | 98 | 98 | 85 | 83 |

Table 1. IMR within Indian States (1999) per thousand

The responsibility of providing treatment to young infants/children in rural India is with the general health care practitioner posted in Primary Health Center (PHC) or rural dispensaries. Because of the shortage of funds and inadequate trained specialists, the government appoints a child specialist at Community Health Care Center (CHC) only. Therefore, CHC serves as a first referral center to PHC and dispensaries. At some rural places, even less qualified health care professionals are somehow managing the situation. They lack proper knowledge to diagnose and treat the patient. Whenever they face any critical problem related to childhood diseases, they refer these patients to CHC. This increases the number of patients for the child specialist at CHC. The main diseases that young infants and children suffer from include: Pneumonia, Diarrhea, Measles, and Malaria etc. These are often curable at local levels if proper diagnosis and treatment plans are administered timely.

The situation demands a system that works beyond these limitations. One can think of incorporating the concept of client-server architecture with an expert system on the server and a dumb client or a telemedicine system. But the problem with client-server architecture, without the involvement of agents, is the loss of collaborative and proactive behavior that is often required in such cases and limits the scope for future expansions. The problem with the telemedicine is that, it needs direct involvement of a pediatrician to diagnose the disease. Because of these limitations software agents are more suitable in this domain. A number of research papers supporting the usage of software agents to handle such circumstances have been produced in recent years. Some of the health care applications based on agent metaphor are discussed in section 2.

In this paper, a Multi-agent system (MAS) is presented to help healthcare professionals to diagnose the disease of young infant/child, classify it (severe, moderate, mild), and identify the treatment plan. The Intelligent Pediatric

Assistant (IPA) has been developed for deciding the diagnosis as per the sign-symptoms provided by the healthcare professional. It also keeps track of the number of diseases diagnosed from a particular rural/remote site. The GUI of User Agent (UA) provides the practitioner a user interface to feed in the measured values and observations. The UA and IPA use the disease ontology that specifies the vocabulary and semantics for understanding the child related diseases. The GUI of IPA is used to display the activity of PHC practitioners. The system works without the direct involvement of a pediatrician as IPA is responsible to emulate a child specialist in dealing with some childhood diseases. The system has been designed to support even a naïve healthcare practitioner in dealing with child diseases.

## 2 Related Work

Software agents are proving to be promising because of their reactive, proactive, autonomous, collaborative and knowledge-sharing capabilities.

[Nealon and Moreno, 2002] have discussed the potential and application of agents to assist in a wide range of activities in health care environments. [Lieberman and Mason, 2002] discuss a browsing assistant agent 'Letizia' that has been developed to find serendipitous connections when a user searches something related to medicine, and a software agent 'Aria' that has been developed to integrate the annotation and retrieval of images into a single, integrated application. [Heine et al, 2004] simulate an agent oriented environment for German hospitals with the objective to improve or optimize the appointment scheduling system, resource allocation and cost benefit of clinical trials. [Mabry et al, 2004] employ the Multi agent system for providing diagnosis and advice to health care personnel dealing with traumatized patients. An Emergency Medical Assistant (ERMA) using Intelligent Monitoring agents has been developed to demonstrate the system for the trauma environment with particular emphasis on types of shock and stabilization of arterial blood gases. [Zachewitz, 2004] develops agent based system to improve vaccination rates in Germany. Agents have been developed to maintain consistency of patient's medical record at pharmacy level, specialist level and at family doctor level. [Greenwood et al, 2003] are concerned with the accurate dosage advice for diabetic patients and aim to produce a Personal Digital Assistant based system into which patients enter various details about their diet and physical condition.[Nealon and Moreno, 2003] discuss various applications of MAS in health care e.g., coordination of organ transplants among Spanish hospitals, patient scheduling, senior citizen care etc. [Riaño et al, 2002] have worked on a research project, called PalliaSys. It incorporates information technology and multi-agent systems to improve the care given to palliative patients. [Mea, 2001] has developed TOMAS (Telemedicine-Oriented Medical Assistant ) which is used by each specialist to transfer microscopic images and data of

a patient for collaborative diagnosis in the department of pathology. [Iqbal et al, 2002] have developed an Intelligent Healthcare Knowledge Assistant which uses multi agent system for dynamic knowledge gathering, filtering, adaptation and acquisition from Health care Enterprise Memory unit. [Koutkias et al, 2005] created a Multi agent system that aims to enhance monitoring, surveillance and educational service of a Medical Contact Center (MCC) for chronic disease management in Greece. [Tian and Tianfield, 2003] discuss a case study involving various agents for providing consultation and therapy to patients suffering from diabetes.

The works mentioned above are domain specific, e.g. catering to special types of patients or providing assistance to patients for appointments or supporting doctors in diagnosing specific diseases, etc. These systems are therefore, not capable of handling problems related to young infants/children, especially in Indian scenario as presented in section 1. More precisely, the efficacy of agents in this application area has still not been explored. So, in the subsequent sections we are introducing and highlighting the concept of using agent technology in this regard

## 3 Multi Agent System for Infant and Child Care

A multi agent system is concerned with intelligent connected systems that interact and decide for themselves what they should do in order to achieve the design objectives. Agents with specific abilities can be developed and deployed in the domain of our problem. In the following section, the functionality of the proposed MAS model is presented to provide an overview of the system.

### 3.1 Functional Model

The MAS is designed according to the requirements for effective diagnosis and delivering the treatment plans for young infant/child in the child-care setting described above. It provides an interaction mechanism with the healthcare professional at a rural site and delivers diagnosed disease and suggests treatment plans as per the supplied sign-symptoms. Figure 1 illustrates the abstract interaction model of the system. The UA is located at PHC while IPA is located at CHC. The IPA is behaving as a server to User Agents. The sequence of interactions that takes place between the UA and IPA is discussed below:

The main problem is posed before the patient in the form of questions denoted as
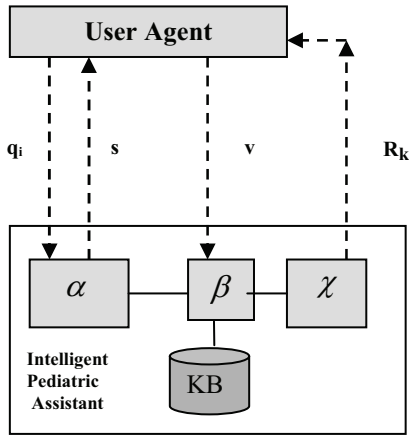
$$q_i \in Q \text{ , where } Q = \{q_1, q_2 \ldots q_k\}, \text{ set of all possible questions.}$$

The $q_i$ is passed by the UA to the IPA. 'S' is a set that contains all possible symptoms that a child may be suffering from. i.e.

$$S= \{Symptom_1, Symptom_2 \ldots Symptom_N\}$$

Now depending on $q_i$, IPA intelligently selects some of the sign-symptoms to be answered by the health care

Figure 1 An abstract agent-based interaction model.



professional by observing and or querying the patient. $\alpha$ is a function responsible for selection of sign-symptoms from S depending upon $q_i$.

$$\alpha (q_i) = s \text{ where } s \subseteq S \qquad (1)$$

where s = { $Symptom_1$, $Symptom_2$… $Symptom_M$} , M<=N. The relation between $q_i$ and selected set of sign symptoms is R.

R: $Q \rightarrow 2^S$ (This relation is a mapping from set of questions to power-set of sign-symptoms.)

UA responds back with values for these sent symptoms as a vector

$$v = \{val_1, val_2,….,val_M\}$$

IPA maps all this processed data with the KB using β, that contains (s,v) ordered pair of symptoms and their possible value/range.

$$\beta (q_i, s, v) = (d_k, tp_k) \qquad (2)$$

$\beta$ returns information regarding disease and its treatment plan on the basis of following relations:

$$P : 2^{\{s \times v\}} \rightarrow D , \text{(many-to-one relation)}$$

This governs the rule for assigning priority.

where D is a set containing treatable diseases

$$D = \{d_1, d_2,….d_p\}$$

$$T:D \rightarrow TP \text{ (one-to-one relation), where}$$

$$TP=\{tp_1,tp_2,…..tp_p\}$$

$d_k$ is the diagnosed disease and $tp_k$ is its corresponding treatment plan.

$d_k \in D$ and $tp_k \in TP$.

The function $\chi$ is used to generate a report, $R_k$, that contains the diagnosed disease and its treatment plan. This is sent back to UA.

$$\chi (d_k, tp_k) = R_k \qquad (3)$$

The report, $R_k$, also contains the level of severity for the diagnosed disease.

## 3.2 Application Scenario

The MAS provides a clinical decision support to a healthcare professional dealing with the child diseases. For instance, a mother brings her one year old child with complaints of loose motions and fever. After observing the child health, if the rural health practitioner feels the need of assistance of a child specialist, he uses the GUI of UA located at his site to pass the sign-symptoms and other observations to the IPA. The IPA uses (1) to generate related questions that indicate possible diseases like bacterial infection, viral disease, malaria, malnutrition or food allergy. In the second phase, UA supplies back the observed and measured values corresponding to the questions generated earlier by IPA. UA answers the questions like: checking for general danger signs (convulsions y/n; unconsciousness y/n) bloody diarrhea y/n; Sunken eyes y/n; able to drink y/n; stiff neck y/n; bulging fontanelle y/n etc. IPA uses (2) to: decide the possible disease, choose the degree of severity and generate treatment plan. Figure 2 depicts a hypothetical case scenario of a child suffering from moderate dehydration.

| Symptom/ Sign | Disease | Treatment | Severity level |
|---|---|---|---|
| Restlessness, irritable Sunken eyes | Some de-hydration | Oral treatment with ORS solution according to WHO treatment guidelines | Moderate |

Figure 2 Disease Identification and Treatment Plan.

The presence/absence or values of some of the sign-symptoms need due importance. That is why, some sign-symptoms are given more priority than others. For example presence of 'lethargy or unconsciousness' is assigned higher priority than 'sunken eyes'. This will help to classify the disease into very severe (requires urgent treatment & referral) or less severe (requires conservative treatment without referral) category. The summary report is then sent back to UA for actions to be taken by the healthcare professional.

## 3.3 Architecture

The proposed MAS requires delegation of task to various agents in the system. In the following section, we will describe the organization of different agents of the system.

**GUI for health care practitioner**

The GUI for PHC practitioner has been designed for providing an interface. It is being used for the following purposes:

- Displaying the account identification issued by IPA,
- Feeding the main problem, sign–symptoms, and observations of the ailing child,
- Passing the information to the UA and;
- Displaying the diagnosed disease and treatment plans.

**User Agent**

The User Agent interacts with the GUI on the client side and the IPA on the server side. The UA uses the child disease ontology for understanding the meanings of the messages sent by GUI and the IPA. The ontology is based on

protocols provided by [WHO, 2003] for understanding neonatal and childhood illness. This agent exhibits the reactive and autonomous attributes as UA reacts to a question supplied by GUI and forwards it to the IPA for an appropriate decision-making without human intervention. It is located at PHC along with its GUI.

### The Intelligent Pediatric Assistant
The IPA, located at CHC, interacts with the UA to receive the main problem and asks some more related questions that help in deciding the disease and generating the treatment plan. IPA and UA share common child disease ontology and vocabulary for interactions. The vocabulary for diseases like: Jaundice, Dehydration, Diarrhea, Pneumonia, Malaria, Measles, Mastoiditis, and Anemia has been created. The IPA interacts with its GUI to display the PHC practitioners seeking help currently. This information can be useful in accessing the performance of a PHC.

IPA's behaviour is reactive and autonomous .It responds/reacts to questions asked by UA and decides about the disease and the appropriate treatment plan autonomously without the direct intervention of human being. The said behaviors have been implemented using JADE.

### GUI for Pediatrician
The GUI of IPA has been designed for providing an interface to the Pediatrician, situated at CHC. The purpose is to monitor the condition at the calling rural site. It also displays the total number of cases that have been tackled for a particular PHC.
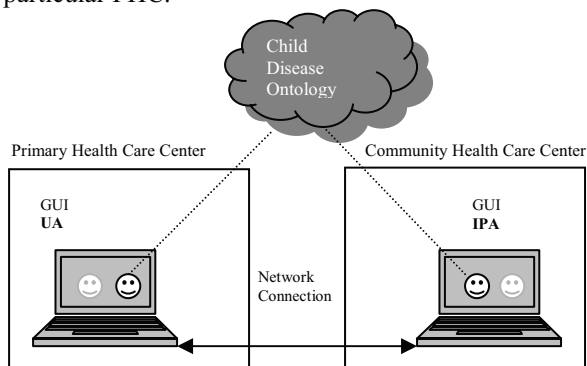


Figure 3 Basic Architecture of the system.

The Figure 3 shows the location of different agents discussed so far. The GUI's are meant to provide the interfaces while UA and IPA use a common vocabulary to diagnose the disease and generate treatment plans suitable for various severity levels.

In the following section, the development of these agents with their specification will be discussed.

## 3.4 Implementation
For construction and execution of the system, JADE (Java Agent DEvelopment Framework) is adopted. JADE is an open-source software framework, aiming to assist the development and execution of agent applications in compliance with specifications laid by FIPA (Foundation for Intelligent Physical Agents). Communication between different agent platforms that are executed as per system requirement is achieved through the FIPA-compliant HTTP Protocol that JADE supports. [Bellifemine et al, 1999] discussed the FIPA compliance of JADE.
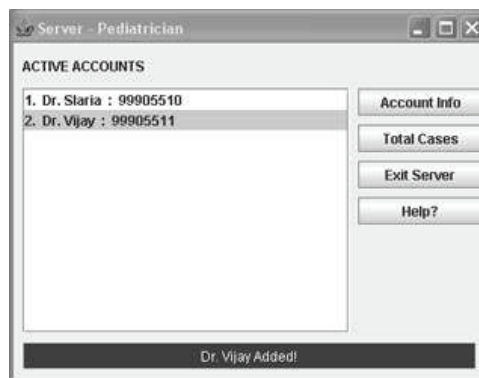


Figure 4.1 Intelligent Pediatric Assistant.

In this section, we shall discuss some of the interfaces and working of the system. The rural healthcare practitioner, using interface of UA, registers himself with the IPA. Account identification is being allocated by IPA. Figure 4.1 depicts active PHC practitioners with IPA.

The communicative act for registration to the IPA is a 'Request' as shown below:
(REQUEST
 :sender ( agent-identifier :name
Health_Prac2@vijay:6677/JADE )
 :receiver (set ( agent-identifier :name
Pediatrician@vijay:6677/JADE :addresses (sequence
IOR:0000000….00026000000020002 )) )
 :content "((action (agent-identifier :name
Pediatrician@vijay:6677/JADE :addresses (sequence
IOR:0000000000....00026000000020002)) (\"Register
Doctor\" :name \"Dr. Vijay\" :password max)))"
 :language fipa-sl
 :ontology Disease_Ontology )



Figure4.2a GUI at Primary Healthcare Center

Figure 4.2a shows the inputs being filled by the PHC practitioner using the interface of UA. It also displays the diagnosed disease and its treatment plan as suggested by the IPA.



Figure 4.2b Values of the sign-symptoms asked by IPA

The PHC practitioner simply supplies the main problem for which the child has been brought to the dispensary/ health facility. The UA sends this information to the IPA, who in turn sends some more questions before reaching to a conclusion, as shown in figure 4.2b.

Figure 4.3a displays diagnosing of a critical case where a patient, who is more than 2 months old but less than 5 year, arrives with a problem of 'difficult breathing'. This information is passed to the UA which in turn sends it to IPA. The IPA asks more question, as listed in Figure 4.3b, to be answered by the PHC practitioner. The diagnosis is being shown in the Figure 4.3a.
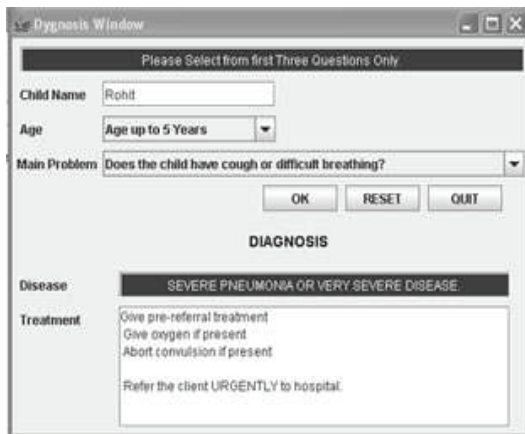


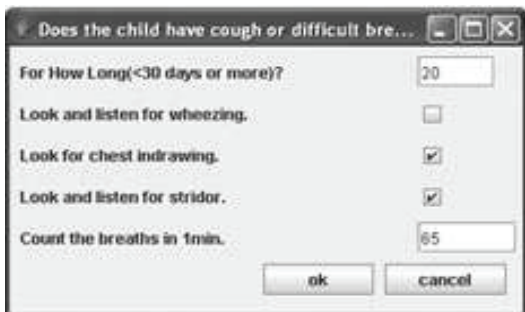Figure 4.3a GUI at Primary Healthcare Center



Figure 4.3b Sign-symptoms asked by IPA

An agent communication act adopted by IPA to respond back after diagnosis of the disease and deciding the treatment plan is shown below:
( INFORM
 :sender ( agent-identifier :name
Pediatrician@vijay:6677/JADE :addresses (sequence
IOR:000000000000011…00000020002 ))
 :receiver (set ( agent-identifier :name
Health_Prac1@vijay:6677/JADE ) )
 :content "((result (action (agent-identifier :name
Pediatrician@vijay:6677/JADE :addresses (sequence
IOR:000000000000011494...0000020002))
(Problem_4 :A_4_1 20 :A_4_2 65 :A_4_3 false :A_4_4
true :A_4_5 true)) (solution :disease \"SEVERE
PNEUMONIA OR VERY SEVERE DISEASE.\" :results
\"Give pre-referral treatment. Give oxygen if present. Abort
convulsion if present
 Refer the client URGENTLY to hospital.\")))"
 :reply-with
Health_Prac1@vijay:6677/JADE1140246218296
:language fipa-sl
:ontology Disease_Ontology )

## 4 Discussion and Scope for Future Work

The rural healthcare delivery system in India can be improved by integrating it with the advancements of information technology. For that we need a system that demonstrates features such as, autonomy, reasoning, knowledge-sharing and cooperation. A promising solution to this requirement is agent-based system. The system based on agent metaphor can be used to sense a particular situation, analyze it and make a search for the desired goals.

The prototype system that has been discussed above is suitable to the prevailing situation of healthcare in rural India for tackling some diseases being handled by a pediatrician at CHC. This system can be enhanced to incorporate some more expert agents. There are situations where a pediatrician seeks help from other domain specialists like Neonatologist, Cardiologist, Neurologist, and Endocrinologist. The future work includes the incorporation of such agents. To incorporate reasoning capabilities, Java Expert System Shell (JESS) that works well with JADE can also be considered.

To make the system fault tolerant, a replication or cloning of IPA will also be considered in future. A higher level health care center, e.g. Civil Hospital at district level, can be kept in mind for replication and monitoring purposes. JADE supports cloning as well as mobility of agents. Porting the system to mobile devices is also an attractive option

## 5 Conclusion

The prototype MAS medical system will assist the PHC practitioner in tackling cases that are outside his/her expertise. It will also help the rural patients to reduce their traveling efforts to visit CHC at long distances.

The objective of this system is to exhibit the strength of agent technology in handling healthcare problems of young infants/children. The system is to provide assistance to the PHC practitioner for diagnosis of childhood diseases and generation of timely treatment plan so as to reduce the IMR. The medical personnel at PHC are supposed to treat most of the cases themselves effectively, and not refer them to CHC unnecessarily. The pediatrician at CHC can monitor the specific cases at PHC also.

## Acknowledgement

## References

[WHO, 2003]World Health Organization (WHO) and Government of India," Students' Handbook for IMNCI (Integrated Management of Neonatal and Childhood Illness)", 2003.

[Nealon and Moreno, 2002]Nealon, J. and Moreno, A., "The application of agent technology to health care", Proceedings of the Workshop AgentCities: Research in Large-scale Open Agent Environments, in the 1st International Joint Conference on Autonomous Agents and Multi-Agent Systems (AAMAS '02), pages 169-73, Bologna, Italy, 2002.

[Lieberman, and Mason, 2002]Lieberman, H. and Mason, C. , "Intelligent agent software for medicine", Stud Health Technol Inform '02, No. 80, pages 99-109, 2002.

[Heine an et al, 2004]Heine, Christian , Kirn, Stefan, and Herrler, Rainer, "Agent-based Optimization and Management of Clinical Processes", Proceedings of the 16th European Conference on Artifical Intelligence (ECAI'04)-The 2nd Workshop on Agents Applied in Health Care, 2004.

[Mabry et al, 2004]Susan L. Mabry, Caleb R. Hug, Russell C. Roundy. "Clinical Decision Support with IM-Agents and ERMA Multi-agents," cbms, page. 242, 17th IEEE Symposium on Computer-Based Medical Systems (CBMS'04), 2004.

[Zachewitz, 2004] Ludger Zachewitz, " A multi-agent system for Establishing electronics Healthcare record ", ECAI 2004 16th European Conference on Artificial Intelligence - Workshop 7: Agents Applied in Health Care , pages. 31-37, August 2004.

[Greenwood et al, 2003] Greenwood, S., Nealon, J.L. and Marshall, P., "Agent-Based User Interface Adaptivity in a Medical Decision Support System" in Applications of Software Agent Technology in the Health Care Domain, Whitestein Series in Software Agent Technologies, Birkhäuser Verlag, Basel, pages 35-48, 2003.

[Nealon and Moreno,2003] Nealon, J.L. and Moreno, A., "Agent-Based Applications in Health Care" in Applications of Software Agent Technology in the Health Care Domain , Whitestein Series in Software Agent Technologies, Birkhäuser Verlag, Basel, pages 3-18, 2003.

[Riaño et al, 2002] Riaño, David, Prado, Susana, Pascual, Antonio and Martín, Silvestre, "A Multi-Agent System Model to Support Palliative Care Units", Proceedings of the 15th IEEE Symposium on Computer-Based Medical Systems, 2002.

[Mea, 2001] Vincenzo Della Mea, "Agents acting and moving in healthcare scenario: a paradigm for telemedical collaboration", IEEE Transaction on Information Technology in Biomedicine. pages 10-13, 2001

[Iqbal et al, 2002] Hashmi, Zafar Iqbal , Abidi, Syed Sibte Raza and Cheah, Yu-N , "An Intelligent Agent-based Knowledge Broker for Enterprise-wide Healthcare Knowledge Procurement", pages. 173, Proceedings of the 15th IEEE Symposium on Computer-Based Medical Systems, 2002.

[Koutkias et al, 2005] Vassilis G. Koutkias, Ioanna Chouvarda, and Nicos Maglaveras, "A Multiagent System Enhancing Home-Care Health Services for Chronic Disease Management", IEEE Transaction on Information Technology in Biomedicine. Volume 9, issue 4, pages 528-537, December 2005.

[Tian and Tianfield, 2003] Tian, Jiang and Tianfield , Huaglory, "A Multi-agent Approach to the Design of an E-medicine System", MATES 2003, LNAI 2831, pages 85–94, Springer-Verlag Berlin Heidelberg ,2003

[Bellifemine et al,1999]Fabio Bellifemine, A. Poggi, and G. Rimassi, "JADE: A FIPA-compliant agent framework," in Proceedings of the Practical Applications of Intelligent Agents and Multi-Agents, pages 97- 108, April 1999.