Agent Systems: Operating Room in Healthcare System

Gadila Swarajya Haritha Reddy

940117-5329
swga15@student.bth.se

Kaavya Rekanar

940521-7184
kare15@student.bth.se

Abstract—

The basic requirement for a hospital or a health care system is the operating room for any kind of surgeries or operations. There will be many resources required for a surgery in an operating room, which may include human resources as well as other technical facilities. The services offered by any healthcare system deputize the management of its resources. This paper includes the explanation of the basic agent architecture where it elaborates the topics of the scheduling of the out patients and the procedure followed by those patients assumed to be in an orthopedic department. The further explanation includes the agent communication and agent interaction including the services among them.

Keywords—

Operating room, Outpatient, GAIA, Consultancy, Healthcare system, agent interaction, communication between agents, Procedural Reasoning System (PRS)

I. INTRODUCTION

A hospital is a health care institution, which mainly functions on the person's wellbeing as its main goal. Out of the many wards in a hospital, an Operating room is an imperative factor [3]. The operating room must be optimised in such a way that there is always room for an emergency case. An emergency case can never be anticipated in advance. So, scheduled operations can take place but there must be an allowance for emergency cases as well.

For instance, if the hospital contains a group of three specialists in an orthopedic department, and two of them are unavailable at that point of time and an emergency case suddenly arrives at the healthcare and needs to be immediately attended; then the other specialist must be able to deal with the case [3], which means that every doctor must be trained in general surgeries irrespective of their specializations. The operating room is one of the well-defined technical equipped area for the treatment of large number of patients in the present real world.

This can be well stated that a healthcare system plays a crucial role in the present world. So a great importance must be given in order to improve technical as well as non-technical field.

PROBLEM STATEMENT

How to optimize the usage of operating room in a customized manner? How is the allotment of operating rooms done when there are many patients waiting to be operated?

If a patient is consulting a specialist who recommends an immediate surgery to cure the patient's problem, then a surgery will take place. But if the doctor feels that the patient can also be treated with medicines and that the operation is not mandatory then, the operation can be cancelled and the operating room can be allotted to the next patient in the waiting list. It can happen in cases where the doctor has second opinions on the criticality of the patient's condition.

II. AGENT ARCHITECTURE

Agent architecture is the prototype for agents and artificially intelligent communicating systems about the way they are arranged and the working of the system. The agents are developed using artificial intelligence and are implemented in the architecture.

There are three classes of agents into which have been classified. These classes can be listed as follows:
- Reactive
- Deliberate
- Hybrid or Planning

Procedural Reasoning System has been selected for designing the system of the operating room in healthcare in this paper.

Reactive Agent:

A pure reactive agent only acts on data and external stimulus at the moment, inconsiderate of the history. It is one of the robotic architecture. The reactive agent of the agent architecture will function in the bottom up fashion [2]. The basic need of this architecture is the subsumption architecture where it will decompose the organizations into its sub-organizations. In the subsumption architecture, the higher layer utilizes the lower layers of the healthcare system in this paper [1].

The main goal of the reactive agent is that it aims at real time interaction and also the variable responses to the dynamic lab or an office environment.

A reactive agent has been defined as,

"...Capable of maintaining an ongoing interaction with the environment, and responding in a timely fashion to changes that occur in it. Note that the term is now widely used to mean a system that includes no symbolic representation or reasoning: such an AGENT does not reflect on the long-term effects of its actions, and does not consider the coordination of activity with other agents. Thus, a REACTIVE AGENT will always respond in a timely fashion to external stimulus..."
[Agent Survey, 1994] [2]

Hence, a reactive agent cannot be used for the system due to the mentioned reasons. We need an agent, which is dynamic in nature and at the same time considers the past encounters of the patient.

The patient first comes into the Patient Block where it is decided if it is an emergency case or a non-emergency case. When the patient has been categorized based on the requirement of treatment and the treatment has been decided,

then it whether it is an outpatient case or an inpatient case.

In case of an **emergency**, it would be an in-patient case who would be directed for Surgery and then into the Operating Room (OR).

In case of a **non-emergency**, it would be an out-patient case who would be directed to the Consultation section.

Procedural Reasoning System:

A PRS consists of four parts:
1. Database
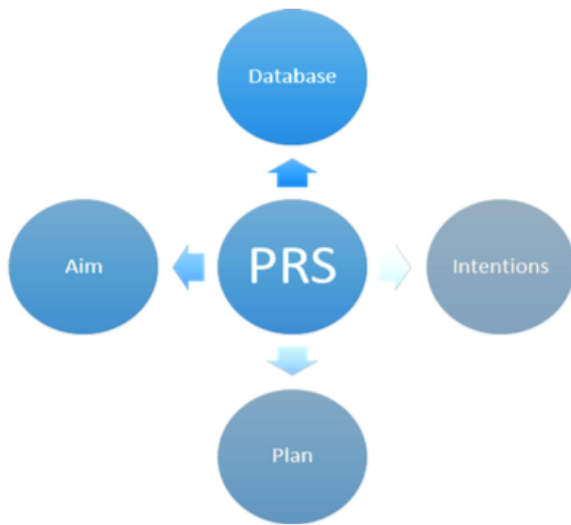2. Aim
3. Plan
4. Intentions

Figure 1: Procedural Reasoning System

What is the need of PRS?

Procedural Reasoning system has been chosen as the method to design this system as it reacts dynamically taking information from the database, which contains data about the existing methods of treatment in accordance with the symptoms of the patient, and also the medical history of the patient will be considered here unlike a pure reactive agent.

Proposed Architecture:
The five agents that are being considered are:
#Agent 1: Receptionist/ Decision maker
#Agent 2: Database handler/auctioneer
#Agent 3: Emergency caretaker
#Agent 4: Non-emergency cases dealer
#Agent 5: Scheduled operations surgeon

When a patient approaches the Receptionist (Agent 1), it decides whether the case is an emergency or a non-emergency. If the case is an emergency, then the patient is taken to Agent 2 and the necessary action is taken. If there is a need to operate the patient, then he is taken to the Operating Room 1 for surgery; or else the patient is treated however required depending upon the case.

When there is more than one emergency case at the same time, the patient requiring medical aid immediately is taken into consideration and treated first. If there are no scheduled operations at that moment then the other patient can be treated in the other operating room; but that is only a rare case and a stand by option; otherwise, the other patient would have to wait for his turn. First aid would be done by the consultant (Agent 4) but the operation (if required) will be done only when any of the operating room is free to be occupied by the patient.

If the case turns out to be a non-emergency, then the patient is taken to the consultant/non emergency cases dealer (Agent 3) and he is treated respectively.

Scheduled operations are done in Operating Room 2.

When there are no emergency cases to be attended, a scheduled operation can be done in the Operating Room allotted for emergency operations. The operations to be done in this room are chosen based on the approximate time taken to complete the scheduled operation. The maximum time limit is twenty minutes. The cases are chosen based on the bidding results of English auction. The lowest time required operation is first taken into consideration. English auction has been chosen as the smallest time can be known faster and the allotment takes less time when compared to any other auction. The scheduled operations are done based on their rank, which is decided from the bidding result in ascending order of Dutch auction. Dutch auction has been chosen because it starts with the patient having the highest need of operation and will end quickly saving time, which can be utilized in treating the patient. The other patients who are in the waiting list undergo the English auction for getting operated in OR 1 if there are no emergency cases at the moment.

Agent 2 handles the bidding activities, i.e., the auctions for both emergency and non-emergency cases. The database of all the patients requiring non emergency surgeries is also with this agent who can act in a reactive manner, having its database updated dynamically from time to time.
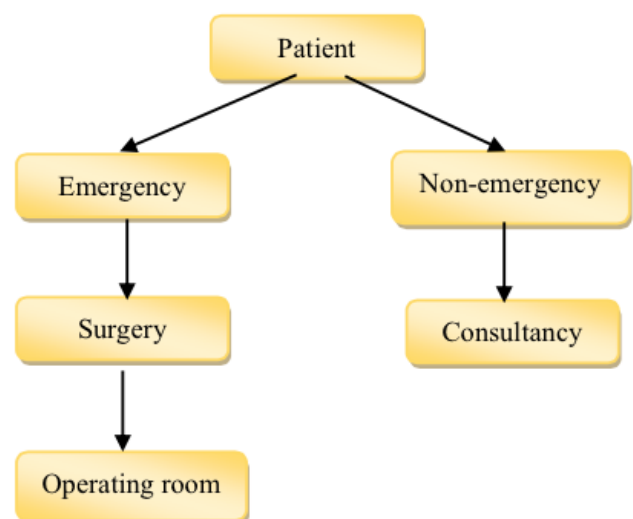

Figure 2:Architecture of the System

III. METHODOLOGY

The methodology used in this paper of the operating room in a health care system is the GAIA methodology [3]. This GAIA methodology is for the object oriented analysis and design. It is usually applicable for a wide range of multi-agent systems and comprehensive, here it deals with both kinds of levels, which are macro level and micro level [3]. Macro level can be societal and micro level can be agent in the aspects of a system. The GAIA methodology in multi-agent system is usually founded on a computational organization consisting of various interacting roles. [1]

The GAIA methodology can be briefly described as a no requirement phase, no particular modelling techniques and as well as no implementation claims. This means that the methodology will not be having particular requirements or any of the claims.

There are five phases in the GAIA methodology. They are as follows:

1. Requirements
2. Analysis
3. Architectural design
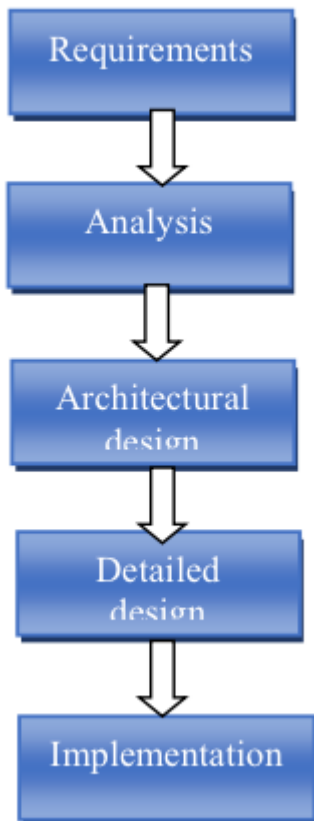4. Detailed Design
5. Implementation

Figure 3:Phases in Methodology

A. Requirements

The first phase in the GAIA methodology is the requirements phase. The basic functioning of this phase is to collect the needs or requirements which are being required by the agent based system.

The requirements will be again further subdivided into sub-organizations for easy implementation. In this paper, the organization which is to be divided is the health care system. The health care system will be divided into patient, reception, consultation, operating room. These can also be called as agents [1].

B. Analysis

The second phase in this methodology is the analysis. This analysis phase includes the requirements which are further proceeded to environmental model. The major functioning of the environmental model is the preliminary role and interaction model and also the organizational rules.

1) Preliminary Role Model
The preliminary role model includes the sub-organizations which include the functioning of various important areas in the health care system. The operating room is considered as one of the sub-organization in the health care system fields.

The roles of the health care system can be as follows:
- Out patient
- In patient
- Reception
- Orthopedic department
- Operating room
- Emergency care unit
- Non-emergency care unit

2) Preliminary Interaction Model

The preliminary interaction model includes the basic interaction among the agents. The functioning of the agents will be depended on the agents themselves pertaining to their departments. The interactions that will be performed by the agents can be listed as:
- Out Patient Request
- Response
- Confirmation
- List Updating
- Operating Room

C. Architectural Design

1) Organizational Rules

The organizational rules generally include the functioning of the agents in the well-organized manner. Both the preliminary role model and preliminary interaction model perform a combined functioning with the organizational rules. The sub-organizations along with their functioning can be called as the organizational rules. The operating room, patient, reception. Consultancy, elective surgery, emergency and non-emergency

can be listed as the sub-organizations.

In this paper, the organization can be described as a well formed procedural function. The basic step is that the patient which is an agent will be having two cases. The first case is the non-emergency case where the patient will first go to the reception for enquiry about the availability of the orthopedic doctor (surgeon). When there is the availability of the surgeon, the patient will be proceeded to the consultancy of the surgeon of a particular department. After the consultancy is finished, if the patient is suffering with a severe problem, then the patient must be proceeded to the elective surgery where the patient is to be treated in the operating room.

The second case is where the patient will be in a critical position. In such a critical state the patient is supposed to be treated with a surgery. This surgery will be carried out in the operating room.
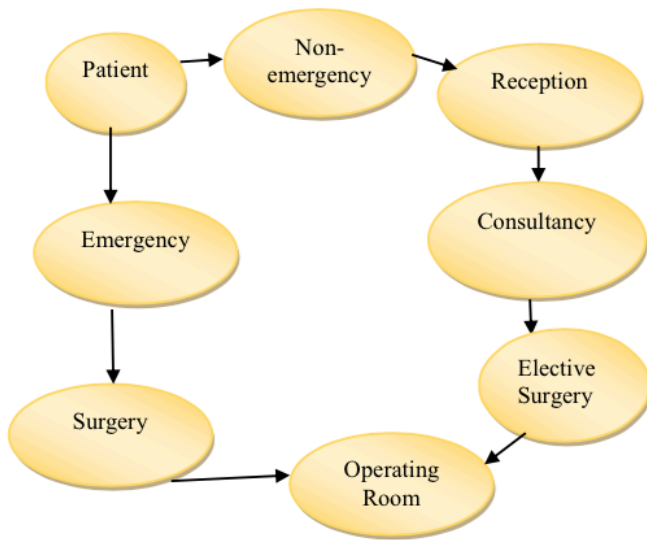

Figure 4:Architectural Design of the System

D. Detailed Design

The fourth phase in the GAIA methodology is the detailed design. The detailed design is one of the phase which includes agent model and the services model. Both the models will be having interaction among themselves as well as among the role and interaction model in the architectural design.

1) Agent Model

The agent model in the detailed design will be dealing with the agents, efficiency and their similarity. This functioning of the agents include the basic similarities among the agents that can be a patient and a receptionist or a patient and the surgeon. The dependency of the agent will be based on the efficiency of the other sub-organizations. The agent model will be functioning along with the services model, role model and interaction model for the better implementation.

2) Services Model

The second model in the detailed design is the services model. This services model will be dealing with the permissions, protocols and activities. The permissions in this service model include the permissions which will accepted or rejected by one of the agent to the other agent. For example, these permissions can be stated as a patient enquiring about the appointment to the receptionist and the receptionist accepting the request and proceeding for the consultancy to the surgeon. There will be few protocols included in the model where those protocols can also be called as the rules in few of the health care systems.

E. Implementation

The final phase of the GAIA methodology is the implementation phase. In this paper, the implementation phase includes the functioning of the organizational patterns which includes the four models of the architectural design and the detailed design.
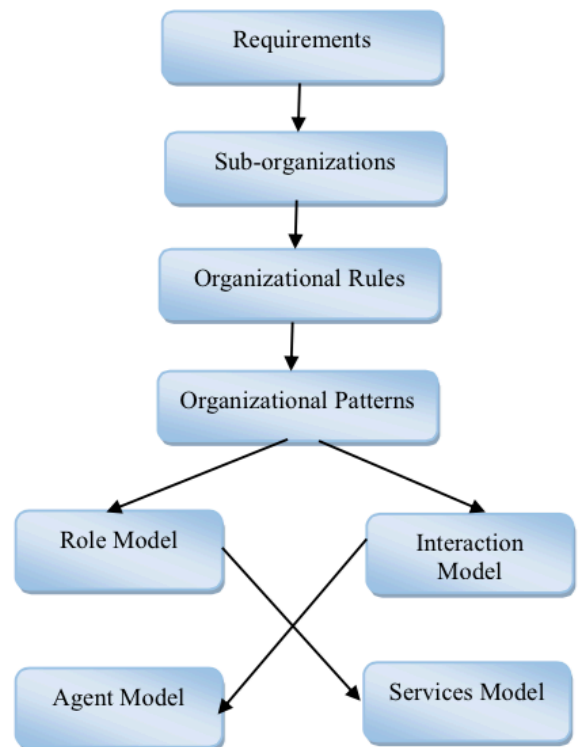

Figure 5:Detailed Design of the System

IV. AGENT INTERACTION

The agent interaction is one of the important factor in the agent based system. In this paper, the agent interaction will be explained with the help of contract net protocol (CNP). The basis of this interaction will be the auctions system. Contract net protocol is one of the protocol for task sharing in various networks.

The contract net protocol is the method used in the agent interaction because of the few complex situations in the health

care systems. Any health care system will be having few complex situations where the patient is supposed to interact with the surgeon or the receptionist.

The general implementation of the contract net protocol resembles the GAIA methodology which is mainly used in this paper. Contract net protocol (CNP) is one of the high level protocol which is essential for achieving the efficient cooperation based, where a market like protocol can be considered as an example.

Generally, the contract net protocol includes two roles. The first role is the initiator and the other role is the participant. Contract Net Protocol is usually developed for specifying the agent based problem solving the communication and control nodes in a distributed system. [5]

The task sharing can be divided into the following steps:

1. Task announcement (Initiator)
2. Bidding (Bidders)
3. Awarding the contract (Initiator)
4. Result notification (Bidder)

Task announcement: The receptionist or an operating room agent will first decide the task of consulting or surgery in an operating room by the surgeon to the patient. The number of patients will first put an application regarding their problem in an orthopedic department. The task announcer is to be considered as an initiator.

Bidding: The bidding process in this health care system will be based on the number of patients on that particular day in that healthcare system. The patients with severe injuries will be updated in the running list and with the lesser injuries will be put in the non-emergency list.

Awarding the contract: The contract will be awarded to that patient whose number of injuries and problems are more. These can be listed as appointments and will be awarded by the receptionist or the agent of the operating room to the patient for the elective surgery. The patients with higher emergency will be preferred first than with the lesser patients.

Result notification: The final step in the agent interaction is the result notification. It includes the list of the patients who are efficient for the consultancy. These patients can consult the surgeon once they have received the confirmation application. The scheduling of these patients will be considered as a bidding process and the contract will be awarded by the initiator who might be a receptionist or agent of an operating room or a consultant in any particular health care system.
In this architecture, we are using two types of auctions:

➢ Dutch auction for scheduled operations
➢ English auctions for those operations of patients who are in the waiting list

All the patients will be participating in the Dutch auction. The patient who has won the bid in Dutch auction will be taken to the Operating Room 2 for operation. All other patients except the one who is being operated participate in the English auction, if the Operating Room1 which is allotted for emergency cases is free to use.

The priority to the patients as who is to participate in the Dutch auction are based on the need of treatment. For instance, if a patient has a knee injury and also heart problem, the heart problem needs to be treated prior to the knee injury, as it is much severe when compared to the latter. So, that patient will be routed to the cardiology department and then will be treated in the orthopedic department.

Dutch auction has been chosen as it is a faster method to resolve complicated cases. The case, which needs immediate attention can be brought to notice using Dutch Auction.

English auction is chosen for scheduled operations to be done in Operating Room 1, as we cannot be sure when there would be an emergency case. So, the case which would approximately take the shortest amount of time to be treated, would be taken to Operating Room 1.

In case there are two emergency cases, it would create a dilemma to choose the patient to be handled first, because there is only one Operating Room allotted for emergency cases. Then, agent 2 would decide the case to be operated based on the severity of the treatment required.

V. AGENT COMMUNICATION

The basic requirement for the agent communication in the healthcare system is the agent communication language (ACL). Agent communication language is the language which is used for the interaction and interconnection between the agents. The Foundation for intelligent physical agents and the agent communication language is based on the speech act theory.
The foundation for intelligent physical agents (FIPA) is one of the generic model for the architecture and operation of agent based systems [1].

In this paper the description of agent communication can be given in terms of the operating room agent and the patient. The communication between these agents will be in such a way that the confirmation of the applications needed by the patient will be given by the operating room agent. These confirmations can also be called as the allocation of the patients. Sometimes the explanation of these agent communication can be represented in terms of ontologies.

Ontologies can be explained as one of the common language in computer science which represents a different language with similar meaning in the agent based system. The ontology is usually used for the exchange of messages among the agents for the purpose of functioning of the agent based system. The basic functioning of the ontology is to represent the operations in the operating room as various kinds of surgeries.

Performativity	Content
Agent type	One of the agent to enter the hospital (in patient or out patient)
Agent type	One of the agent to respond to the patient (Receptionist or operating room agent)
Agent service	Service provided by the receptionist or operating room agent to the patient
Request	The request of application asked by the patient
Response	The response given by the operating room agent to the patient
Confirmation	The confirmation to the patient for the consultancy of the surgeon
Updating	The updating of the list when new patients have arrived

Table 1: Representing Performativity and Content

Sender	Receiver	Function	Ontology
Patient	Operating room agent	Request	Asks for the appointment for consultancy
Operating room agent	Patient	Inform	Confirms the application of appointment
Patient	Operating room agent	Inform	Confirms the application about the consultancy
Operating room agent	Patient	Inform	Provides information about the surgery

Table 2: Agent Communication (Request, Inform)

VI. CONCLUSION

The operating room has been designed in such a way using Procedural Reasoning System technique where both emergency and scheduled operations can be handled simultaneously if required. A patient who is need of an operation immediately would never have to wait; similarly a patient who does not need an operation can be treated with medicines as per doctor's prescription and the next patient in the waiting list would be attending thus optimizing the working of an operating room at the most.

The agents communicate using the GAIA technique and the interaction between agents is done using the Contract Net Protocol [3].

The final conclusion of this paper is to improve the technical and human resources in order to reach the basic requirements in all the health care services. The main objective in the orthopedic department is that any surgeon, higher or lower, must be in a position to do a general surgery for a patient.

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