Analysis and Design of an Agent System for Operating Room Planning Implementing GAIA

Hari Sagar Ranjitkar, hara10@student.bth.se
Jedidiah Waltedji jewc10@student.bth.se

Abstract— **this paper focuses in the analysis and design of an agent system for operating room planning. The importance of surgical areas in hospitals has been growing due to the high demand in various kinds of medical equipments, personnel and resources. The proper cooperation among different departments such as gynaecology, orthopaedics, paediatric, general surgery is necessary for efficient management of surgical area. Proper analysis and design of agent system helps to reduce patient waiting time in general as well as in emergency cases, proper utilization of various medical resources leading to high life saving and economic benefit.**

Keywords— multiagent system, general surgery, GAIA, ontology, methodology

I. INTRODUCTION

Health is wealth. Now days, people are much aware of health and conscious about the eating and drinking habits. People are inclined towards doing training in different kinds of gym centers. Even though huge numbers of people are suffering from various kinds of diseases and compel them to consult doctors and visit the hospitals for various kinds of treatment. Surgery is the very important part of treatment in different health wards, hence huge manpower and their proper management is necessary. Surgical department consist of involvement of many hospital staffs like doctors, nurses and small to large medical equipments and various surgical resources. The services of surgical department range from general surgery to sophisticated surgeries like cardiovascular, thoracic, paediatric and other acute and chronic surgery.

It is really challenging task for different national and international standard hospitals to manage the medical staffs, equipments and resources in most economic manner without affecting the quality of services. Among the various technologies used for the proper management of surgical departments, computer based multi agent system may be a good approach for managing the surgical department in proper and efficient way. For analysis and design of agent system for operating room planning, we have divided it into different sections. Multi-Agent System (MAS) is very important while describing operating room planning which will be explained next.

II. MULTI AGENT SYSTEMS

Some of the definitions for MAS are as follows.

'An autonomous agent is a system situated within and a part of an environment that senses that environment and acts on it, in pursuit of its own agenda and so as to effect what it senses in the future' [3].

"A multiagent system is one that consists of a number of agents, which interact with one another, typically by exchanging message through some computer network infrastructure" [2].

Wooldridge and Jennings have given the better definition of an agent system. According to them agent is described as 'hardware or software based computer system that provides the following three traits'. They are Autonomous, Social ability and Reactivity.

Different agents in MAS have their own responsibilities and they cooperate, negotiate and coordinate among each other producing successful multi agent interaction. Sometimes an agent can be seen as the self-reacting object in order to fulfill some goals rather than following explicit command received in any given condition and time. Agents in MAS have their own goals. In operating room planning, various methods, resources are shared among each other in different departments and they have their own limit in sharing i.e. not all the information of one department can be shared with another department since some information are confidential and must be limited within the certain department. MAS can be used in an uncertain, dynamic and complex environment for the autonomous behaviour of operating room planning. MAS handles the different conditions both in general and emergency cases so as to provide better facilities and services to the patients by careful consideration of various structure and decisions and provide to operating room planning system. The important things that are given more emphasis are the availability of the resources, surgeons, prioritizing the patient according to general and emergency cases, and capacity of Intensive Care Unit (ICU).

There can be sometimes unpredictable situations such as a patient from general surgery has to be shifted to an emergency case surgery. In operating room planning system processes involving dynamic environment are also necessary. Otherwise, the systems could be complex and unmanaged leading patient to wait even longer time which gives poor output. So, the departments continuously interact with each other with the resources and conditions in general as well as complex situations along with the backup of expertise in such scenario. MAS is well suited for such type of unpredictable and complex situations.

III. METHODOLOGY

Various methodologies such as Tropos, Prometheus, Z language are available but MAS GAIA is much better and widely used agent oriented analysis and design.

GAIA methodology uses the concepts of roles, organization, interaction, and response. [1]

It is obvious that only a single agent in operating room planning system is not able to solve problems encountered in the hospitals so multi agent systems are necessary and widely used to solve large and complex problems. MAS implementing GAIA will be discussed in the next section for the operating room planning system.

The GAIA methodology can be understood better by using the following figure.

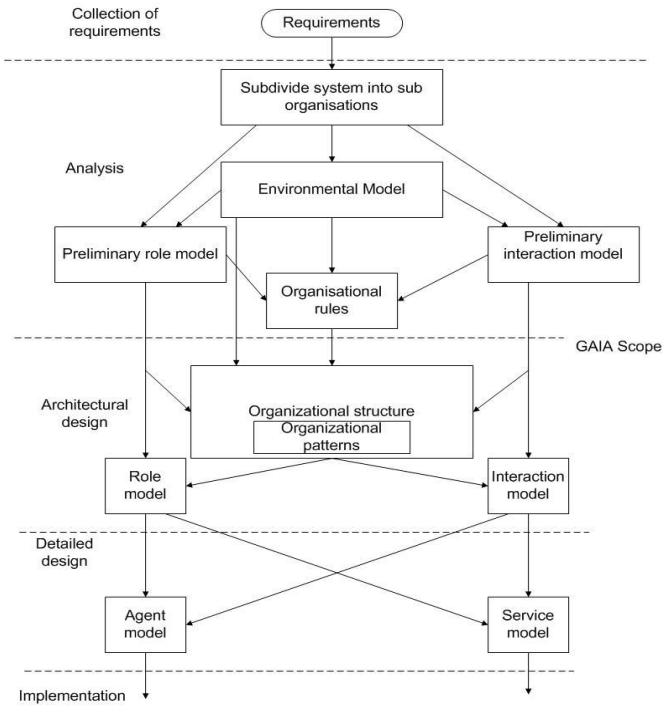

Fig.1 GAIA methodology

The GAIA methodology provides an agent-specific set of concepts through which a software engineer can understand and model a complex system [2]. The methodology has three phases; analysis phase, architectural design phase and detailed design phase. The analysis phase collects and organizes specifications that are helpful for the basis for design of the computational organization. The architectural design phase contains definition of the system's organization structure and the completion of the preliminary role and interaction model [1].Finally, the third detailed designed phase covers the definition of the agent model and service model [1].

GAIA facilitates only an abstract and high level design in the design stage. This consist of agent model which finds the different agent types, roles that are implemented by the agent model as well as the diversity available in the system. The service model of GAIA methodology helps to identify important services of agent types concerning to inputs, outputs, pre-conditions and post conditions [2].

IV. AGENT COMMUNICATION

If two agents are communicating about the some domain then they should agree upon the terminologies they use so as to describe this domain [2]. This behaviour is known as ontology. Ontology can be referred as semantics of content whereas content language consists of both logic and ontology. Some of the Agent Communication language (ACL) content languages are Foundation for Intelligent Physical Agents (FIPA), Knowledge Interchange Format (KIF), Knowledge Query and Manipulation language (KQML), SQL, Prolog. This plays a very important role in operating system planning. For instance, the resource manager agent should provide the necessary surgeon equipments and other materials to the operating scheduler section in timely manner and properly since the delay or improper resource providing may cause the death of patient especially with inpatients that are in ICU or the case is even worse if the patients are in CCU. The required number and size specifications of various surgeon tools should be delivered properly by the resource manager to operating system planning. The operating system planning agent should check for the surgeon tools before the operation of the patient is started in frequency basis and communicate with the resource manager agent if some tools are missing, lacking or inappropriate.

If certain surgeon tools are updated or upgraded with the latest technologies, the operating room planning agent should communicate with the appropriate training providers and facilitate training to the doctors, nurses or other staffs in order to get updated in using latest technology tools in order to increase the efficiency and performance. Some of the important performatives that are used for good communications among various agents assuming FIPA ACL are.

1. Cfp: It stands for call for proposal and used for initiating the negotiation between different agents [2]. Two important content of cfp message are action and condition. For instance, the action can be sell the operating room planning agent surgeon tools and the conditions can be the price should be US $ 5000 in maximum and the delivery of the tools should be not more than 3 months. The various resource provider agents then send the proposal to operating room planning agent then taking into account the provided action and conditions. This cfp performative is very crucial part in task-sharing systems like contract net protocol [2].

2. Inform: In FIPA ACL inform in another very important performative. The exchange of information among various agents takes place via inform. The content of inform is a statement and it confirms that the sender of this inform performative believe the content of inform and also wishes the receiver to believe as well. For example, if the operating system planning informs the resource providers that it needs 200 scissors, 200 gloves for operation within certain condition like within 3 months, then it means the sender confirms it and the receiver also believes it. If the operating system planning changes its statement near the deadline of the delivery, then certain penalty may incur to it.

3. not-understood: This performative is very vital for the error handling in FIPA ACL. If the sender sends a message to the receiver and the receiver does not understand, it sends the message to sender stating that the recently received message is not-understood. This performative contains action and statement. The action part deals with the misunderstanding about the purpose whereas the statement part illustrates the reason of not understanding the message. In context of operating room planning, if the message is sent by the sender with only the number of scissors and without including the size or type of scissors it leads to misunderstanding to the receiver and it sends back the message via not-understood.

4. reject- proposal: This performative notifies the sender that the proposal that has been sent to a particular receiver via cfp has been rejected by the receiver. It consists of two parts. The first one is the proposal itself which is rejected and the second one is the statement stating the reasons for rejecting the proposal. In operating room planning system, the proposal may be rejected by the certain receivers if they think that the price is lesser than their expectation or the delivery time is too short.

5. Propose: It allows the sender to send proposal to other agents in response to the cfp proposal sent by the sender [2]. Generally, the sender sends proposal to various agents via cfp.

V. MULTI AGENT INTERACTION

For achieving an agent system to successfully reach to its goals there should be better coordination and cooperation among various agents dynamically. The multi agent interaction can be via Contract Net Protocol (CNP) or Auctions.

CNP is a task sharing protocol in network problem solvers where an initiator recognizes a problem and initiates the protocol. The potential contractors send bids to the manager then a series of steps are performed. [2] They are:

a. The initiator notifies tasks via broadcast calling.

b. The bidders commence bidding responding to the announcement.

c. Initiator rewards the proper and potential agent to go forward for the contract.

d. All the bidders get the notification of every action.

Auction is the process of selling and buying of different products by bidding. Some agents in MAS act as seller and some act as buyer. It can be of two type viz. highest auction and lowest auction (reverse auction). In highest auction bidding the winner is the bidder who bids the highest amount for certain product. Every auction has its starting price of bidding. After this, the seller gives the product to the highest bidder. Some bidding is free i.e. no charge is taken for bidding whereas some seller or auctioneer charges small amount in every bid for the bidders.

This second choice is more common in lowest auction bid or reverse auction in which the lowest bidder wins the auction. Also, it is to be noted that there is certain time frame for the bidding.

Moreover, there are different types of bidding methods or protocols. In one of the methods of bidding which is called First price auction, the bidders cannot see the bidding amount of other bidders for the same product. So, it is also called sealed bid. Similarly there is another bidding method called English auction in which a bidder can see the bid placed by another agent or bidder. English auction is a highest unique bid. Another bidding method is Dutch auction which is just opposite of English auction. In this auction the seller gradually decreases the amount for the certain product until the buyer confirms to buy that product with the amount in consent with seller.

We have discussed about the problems as well as tools and methodologies for the analysis and design of agent system for operating room planning. Now we are going to focus on analysis and design of agent system.

VI. THE ANALYSIS

In operating room planning, the whole health care can be divided into sub systems since sub systems are more manageable. The sub systems are said to be coordinating and cooperating with other sub systems as well as with the whole health care system if the entire system is inclined towards the fulfillment of sub task. Similarly, the system should coordinate with other sub systems.

VII. ORGANISATIONAL STRUCTURE

The operating room planning in hospitals are structurally organized in two ways. One way is the primary care in which the doctors and nurses do a general checkup. The second way is to shift the general case to surgery case in case hospital staff need certain time before the exact cause of disease is identified. In this case patient has to wait for 90 days. Since 90 days is a long time, it is really a big problem for patients. So, multi agent system should be coordinated in such a way that the waiting time of patient can be reduced.

VIII. ENVIRONEMENTAL MODEL

It is difficult to provide general modeling abstractions and general modeling techniques because the environments for different applications can be very different in nature [4]. We have tried to depict an environmental model for operating room planning for hospital in the following diagram.

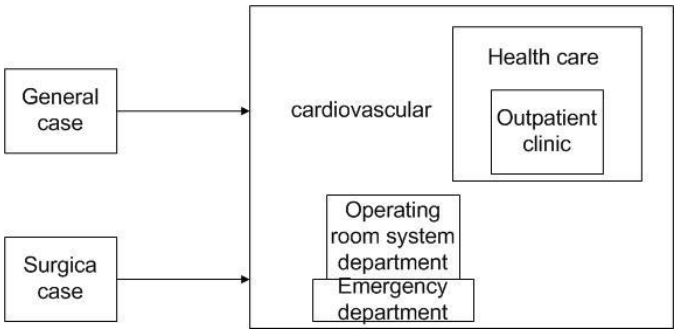

Fig. 2 A view of environment model in hospital

The environment model in the above figure 2 consists of two cases. They are general case (non-emergency case) and surgical case (emergency case). The general case and the emergency case are interrelated to each other. For instance if the general case takes very less time than the more patient will be accumulated towards surgical case or emergency case increasing the work load in emergency case. So, little waiting time from general to emergency case is necessary but the 90 days waiting time is obviously the long period of time.

IX. ORGANISATIONAL RULES

There should be some organizational rules for better control and coordination among agents in MAS. So far we are concerned to operating room planning in hospitals, the following organizational rules helps to operate the system smoothly.

1. Patient should get treatment according to queue without any kinds of bias.
2. The hospital assets should not be used for personal purpose.
3. There should be proper coordination and interaction among different levels of staffs.
4. The personal enmity of certain group or individual of staffs should not reveal during treatment of patient since it is only the patient who is going to suffer.
5. The hospital management should provide necessary equipments, methods and resources so as to accomplish the treatment successfully that can be either non-emergency case or emergency case.
6. Staffs should be helping patients even after successful surgical operations since patient may be too weak for certain time.
7. Team work and professionalism should be shown among the staffs for running the operating room planning system in hospital smoothly.
8. Each staff should be updated about the new rules and regulations of the hospital and the operating room planning system should be also updated so as to provide uniformity in medical reports with all other standard maintaining hospitals.
9. Taking proper care of patient should be the only aim of the system.

X. THE ROLE MODEL

This section depicts the different roles of the various staffs in operating room planning system in order to have proper coordination among them resulting to successful solution of patient problems.

1. Surgeon- The role of surgeon is to perform the operation or surgery of patients.
2. Patient- The role of patient is to get service or treatment which can be general or emergency.
3. Registration of patient- This role deals with the registry of new coming patient.
4. Waiting time Counter of patient- This role determines the waiting time of patient and keeps the record.
5. History of patient- this role helps to get the details of the patient if he/she has visited earlier and performed any kind of treatment. This role is really helpful for both the patient and the hospital system regarding faster service time. The repetitive test of various thing of patient is eliminated if the

patient has already performed the test and it has not been a longer period of time. Similarly the service will be faster if seen from the side of the operating room planning system.

6. Physician (doctors and nurses) - this role is responsible for providing medical treatment to the patient.

7. Primary surgical staff- this role is responsible to coordinate with secondary surgical staff in order to successfully complete the surgical operation of the patient. Primary surgical staff is the ones who use the surgical equipments directly in the body of the patient.

8. Secondary surgical staff- this staff are the helpers of primary surgical staff. They just provide the tools to the primary surgical staff or keep record of the different status of patient in different interval of time. The proper cooperation is necessary before, during and after the surgical operation of patient between primary and secondary surgical staff for successful surgical operation.

9. Surgeon planner-this role plans for the surgeon and set the operation time with the surgeon.

10. Intensive care unit (ICU) - this role is responsible for handling the sudden and emergency cases if the operation seems to be unsuccessful. This role either use expert surgeon or refer to another hospital immediately. In some conditions the expert doctors from other hospitals are consulted.

XI. PRELIMINARY INTERACTION MODEL

The preliminary interaction model depicts the inter relationship among various roles in MAS. The relationship is identified as per the protocol description. We have described this model by dividing into three protocols. They are operating room section protocol, emergency section protocol and Outpatient protocol. For each of this protocol we have divided them into sub protocols and described what are their initiators, partners, input, processing and output.

1. Operating room section protocol- This protocol has been divided into four sub protocols which we are explaining in more detail.

a. Protocol Name- Receive Request
Initiator- Emergency section
Partner- Outpatient
Input-Patient with priority
Processing- Operating room section gets the order or request for performing and arranging the surgical operation of the patient.
Output- surgery success

b. Protocol Name- Resources Available
Initiator- Operating room section
Partner- Outpatient, emergency section
Input-Doctors, nurses, physician, medical equipment
Processing- Operating room section gets the resources by the assistance of emergency section and outpatient.
Output-Resources available.
c. Protocol Name- Surgery Arrangement

Initiator- Operating room section
Partner- Outpatient, emergency section
Input-Doctors, nurses, physician, medical equipment, patient with priority
Processing- Operating room section manages surgery facilitation for performing surgical operation in certain monthly calendar date.
Output- Surgical operation.
d. Protocol Name- Check, Shift or discharge
Initiator- Operating room section
Partner- Outpatient, emergency section
Input-Doctors, nurses, physician, medical equipment, surgical operating patient
Processing- Operating room section checks the status of patient and decide for the upcoming action to perform. According to the condition of patient he/she may be shifted to Intensive care Unit (ICU) or discharged from the healthcare ward.
Output- Shift to ICU or discharge.

2. Emergency section protocol- This protocol is also divided into 4 sub protocols and described each using its protocol name, initiator, partner, input, processing and output. The detail goes like this.

a. Protocol Name- Request Receive

Initiator- emergency section
Partner- emergency section
Input- patient
Processing- the patient requests the emergency section for the emergency treatment.
Output- Waiting list is prepared
b. Protocol Name- Resources Available

Initiator- emergency section
Partner- operating room section
Input-Doctors, nurses, physician, medical equipment
Processing- emergency room section manages the resources.
Output-Resources available
c. Protocol Name- Surgery Request

Initiator- emergency section
Partner- Operating room section

Input-Doctors, nurses, physician, medical equipment, queued emergency patient
Processing- emergency section request to manage surgery facilitation to Operating room section
Output- Surgical operation
d. Protocol Name- Queue Maintenance

Initiator- emergency section
Partner- emergency section
Input-patient requiring surgical operation, queuing patient
Processing- emergency section manages queuing patient list and updates it. Once the surgery of the patient is successful, next patient in priority or from the queue is given the next turn.
Output- waiting list of patient is updated.
3. Outpatient protocol- As for the above two protocols, this protocol also consist of 4 sub protocols. The detail goes like this.

a. Protocol Name- Request Receive

Initiator- outpatient
Partner- emergency section
Input- patient
Processing- the patient requests the outpatient section for the surgical operation. This protocol also determines whether the surgical operation is necessary or not for the patient by consulting with the specialist according to the health report.
Output- Waiting list is prepared
b. Protocol Name- Resources Available

Initiator- outpatient section
Partner- operating room section
Input-Doctors, nurses, physician, medical equipment
Processing- emergency room section manages the resources.
Output-Resources available
c. Protocol Name- Surgery Request

Initiator- outpatient section
Partner- Operating room section
Input-Doctors, nurses, physician, medical equipment, queued patient
Processing- outpatient section request to manage surgery facilitation to Operating room section
Output- Surgical operation
d. Protocol Name- Queue Maintenance

Initiator- outpatient section
Partner- outpatient section
Input-patient requiring surgical operation, queuing patient
Processing- Outpatient section manages queuing patient list and updates it. Once the surgery of the patient is successful, next patient in priority or from the queue is given the next turn.
Output- waiting list of patient is updated.

XII. PROCEDURES OF TREATMENT

We have divided this section in to three parts.
1. General surgery section
2. Surgery section planning
3. Operating room Scheduling

1. General Surgery Section- This section is responsible for allocating which surgical group is provided for which patient. Surgical groups can be few to many depending upon the nature of treatment required for the patient.

For some critical treatment of particular patient there may be the case that the entire surgical group should be necessary for the successful surgical operation. In some cases only a single group of surgery may be sufficient to handle the patient. The surgical group is allocated to the particular operating room and it is handled by operating room scheduling department. The operating room planning or allocating the operating rooms according to the nature of case is the very important task. The general surgery section should also give some space for the new patient who needs surgery since sometimes as we mentioned earlier it may be the case that all the surgical group are busy with the certain patient who is in the very critical condition. So, proper work distribution of surgical group is very important and this is the responsibility of general surgery section and it includes both the general surgery and emergency case.
2. Surgery section planning- This section is responsible for managing the surgery in a well-planned manner. Its task includes
a. Making the list of patient who needs surgery.
b. Put the patient in different levels of priority.
c. Keep up to date of medical equipments and resources
d. Managing operating room and Intensive care unit (ICU)
e. Keep information of the patient before and after the surgery.

This section allocates the queued surgical patient according to the nature of surgery and complexity. It uses three types of priority viz. no priority, single priority, double priority.
No priority type is for that patient who does not need surgical operation or very minor operation. Single priority type is for those patients who need operation and the patient is in the condition of waiting for some time. Double priority patients

are the critical patients and they need operation within a week. It is obvious that the waiting time of patient decreases from no priority to double priority.

Similarly, the surgical operation rules that we have explained earlier should also be followed by the surgeons. This section is also responsible for managing operating room and ICU. Next, the nurses should be available for the patients who have just completed the surgery and needs some proper care before they can be discharged from the hospital.

3. Operating room Scheduling - This section is responsible for scheduling the operating room for the patient who needs surgery. This is done by the nature and complexity of the surgery required by the patient and the type of priority of the patient which we described just earlier in surgery section planning. It is also responsible for providing ICU rooms when necessary.

XIII. AGENT MODEL

The agent model is responsible for identifying the different agents in the operating room planning system and the interaction and coordination among the agents. Each agent has its own role and responsibilities. Some of the important agents that are necessary for the successful and smooth operation in operating room planning system are as follows.

1. Agent patient
2. Agent Physician
3. Agent Operating Scheduler Section
4. Agent Resource Manager
5. Agent Intensive care unit
6. Agent post operation

Now, we are going to describe each.

1. Agent patient- In operating room planning system there can be null to many agent patient. Since there can be the case that there is no patient in the hospital in due various reasons.

2. Agent Physician- This agent includes doctors, nurses and other supporting staffs. There should be more than one instance or count for agent physician but normally it is more than ten.

3. Agent Operating Scheduler Section – This agent is responsible for scheduling the operation of the patients by using the resources available and different levels of priority of patients.

4. Agent Intensive care unit- This agent shifts the critical patients or patient with double priority to the ICU section.

5. Agent post operation- This agent provides proper care to the patients who have just completed the surgery and in the process of discharge from the hospital.

XIV. AGENT ARCHITECTURE

In operating room planning various agents that we discussed earlier in MAS, coordinate and cooperate with each other to give better services to the patient. So, proper use of agent architecture ensures that the waiting time of patient is reduced using available medical equipment and resources by the different agents like patient, physician, ICU and so on.

The three kinds of agent architecture are most common.

a. Reactive reasoning architecture-

This agent architecture is focused on rapid reaction or response to changes detected in the environment. It includes the subsumption architecture.

b. Deliberative reasoning architecture- It focuses in the long term action planning.

c. Layered/Hybrid architectures- This architecture is formed by mixing both the reactive reasoning architecture and deliberative reasoning architecture.

Subsumption architecture- It is the method of decomposing complex intelligent behaviour into simple behaviour modules and these modules are then organized into different layers. This architecture has been better described by Brook. According to him the following cases exist in this architecture.

a. No symbolic representation- It is not necessary to represent explicitly to the symbolic Artificial Intelligent purposes to get intelligent behaviour of that kind.

b. No Symbolic reasoning- It is not necessary to represent explicitly the abstract reasoning of symbolic Artificial Intelligent purposes to get intelligent behaviour of that kind.

c. Simple behaviour modules can be obtained from complex intelligent behaviour by the decomposition method.

In subsumption architecture, there are two very important points that has been proposed by Brook. They are

a. **Situatedness and embodiment** 'Real' intelligence is situated in the world, not in disembodied systems such as theorem provers or expert systems. [2]

b. **Intelligence and emergence** 'Intelligent' behavior arises as a result of an agent's interaction with its environment. Intelligence is an 'eye of the beholder'; it is not an innate, isolated property. [2]

Hybrid architecture in operating room planning- In operating room planning system use of both the architectures that is reactive architecture and deliberative architecture can be used so as to follow the better architecture since benefits of both the architecture can be utilized. So, hybrid architectures like

InterRap and touring machines can be helpful in operating room planning system.

In context of operating room planning, the agent architecture that suits well is CNP rather than auctions. Because it is easier to broadcast and call for proposals to various agents at once so that the appropriate proposal can be accepted by the operating room planning agent in terms of price and quality. For example, the qualities of the surgeon tools are very important as compared to the price since it is the matter of patient's life. So it is a good decision to buy quality tools in spite of little higher price.

Auctions like highest bidding or lowest bidding are not suitable in case of operating system planning system since they are more prices oriented although some specifications are provided in the tools that are to be bought via auctions. Also, there is chance of not winning any auctions whereas in CNP there is very less chance that everybody rejects the proposal.

XV. SERVICE MODEL

Service model in operating room planning is responsible for providing services to the patient by the proper coordination and interaction among the various agent types. Each agent has its own task and what it performs can be said as the service of that agent.

'Service model as its name suggests, the purpose of service model in GAIA methodology is to identify the services associated with each agent class or equivalently, with each of the roles to be played by the agent classes. Thus, the services model applies both in case of static assignment of roles to agent classes as well as in the case where agents can dynamically assume roles.' [1]

Comparing this statement of service model with operating room planning scenario, each agent is supposed to provide services to another agent. For example physician agent provide service to patient agent with some static set of services like putting in the queue or waiting list of patients by operation scheduler department, changing the priority of patient etc. But apart from these kinds of predefined allocated services to the agents the services can be dynamic i.e. away from the predefined services. For example there can be a case when a same physician is required for the more critical situation of patient when he /she are busy with other less critical treatment. At that time the doctor (physician agent) should be able to switch the task towards much critical situation and handover the task to his/her co-worker or helper to handle the less critical patient for the time being. This kind of role can be regarded as the dynamic role. So, static role along with the dynamic roles maximizes the quality and level of services to higher extent.

XVI. ACKNOWLEDGEMENT

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XVII. CONCLUSION

We developed the multi agent system for the operating room planning using GAIA methodology. Health is wealth so, providing the better services to the patients by physician with the limited available medical resources and equipment was the really challenging task. The technology is growing in rapid manner and the multi agent system should be implemented to adjust with the growing technology to provide better services to the needy. This results in the huge economic benefit and enormous progress. Although the huge economy and huge man power is required to accomplish this task, the investors may be willing to invest if they can be convinced by the effective utilization with multi agent systems.

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