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An Entire Operating Theater Management System

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Abstract: *The Operating Theater (OT) is one of the most critical and expensive hospital resources since a high percentage of hospitalizations are due to surgery. The main objectives are to perform the operation at the right time without incurring excessive waiting times and to optimize the use of medical resources in order to achieve maximum profitability. With the unpredictability and disruptions ingrained in the process (OT), its management is a very complex procedure. Management problems in the (OT) have been identified with well-known problems in the field of manufacturing or transport. This prompted us to look for a model used in industrial applications that would allow us to solve the problems of (OT) process as a whole. This paper attempts to illustrate the use of communicating and intelligent multi-agent systems on a multi-agent platform JADE to optimize the performance and responsiveness of (OT). We present the hybrid architectural concepts and the development of the control system for the management of the operating theater process in its entirety. We describe the functions and algorithms of the modules based in Distributed Artificial Intelligence.*

Keywords: *Distributed Artificial Intelligence, dynamic planning, Hybrid Control, Multi Agent Planner, Operating Theater.*

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I. Introduction

In a context characterized by fierce competitiveness and a constant search for improved performance, hospitals face the major challenge of adapting their management system to ensure their survival. Health care production is no longer focused exclusively on the goal of medical excellence, but must incorporate the criterion of efficiency and excellence of the management system. Faced with this challenge, care sector managers need tools to ensure that all the resources at their disposal are used efficiently and effectively, while ensuring a high quality of care for patients.

The operating theater is financially one of the heaviest sectors of a hospital. The optimization of its operation is therefore one of the first concerns of the economic managers of the hospital. Given the many disruptions inherent in its process, the large number of highly qualified human resources, the very expensive material resources, the great difficulty in coordinating surgical procedures with the availability of resources, this sector is also by far the most complex to manage.

II. Problematic

With the changing context of modern operating theaters leading to greater competitiveness and high diversity and density of surgery performed in operating theaters, their operation has become extremely complicated. The problem of the management of the operating theater has been frequently studied in the past and has given rise to an abundance of literature, particularly with regard to the planning of surgeries [Erdogan et al., review 2010] [5], [Cardoen et al., review 2010] [3], [Gul et al., review 2015] [9]. This literature reveals a use of exact or logical approaches to planning with deterministic or stochastic data but data for static events. These approaches do not take into account or worse ignore some of the disturbances. However, the operating room process is often subject to many forms of disruption, mainly related to emergency surgeries, cancellations, the random duration of interventions and the validity of resources. These unforeseen but very frequent events could make planning unnecessary during the implementation phase. The economic objectives and the targeted performance objectives when optimizing planning will therefore be far from being achieved. Whatever the finesse, precision and complexity of the methods used to establish planning, the end result can be disappointing because planning, a central element of management can often become obsolete at crucial moments in the course of the intervention process. As a result, new paradigms and control and management techniques, different from those used in the past, have become essential to assist managers in the operation of this sector.

III. Motivation

Our research aims to develop a method for planning surgeries in the operating theater that takes into account the extremely disturbed nature of the process of performing interventions in this sector of hospital. The innovation to emphasize of the proposed approach is that makes it possible to establish an initial calendar optimized with static data, but also allows the automatic maintenance in near real time of the planning according to dynamic data appearing during the implementation phase. There, during our literature review, we discovered another community of methods, the Distributed Artificial Intelligence community. The first applications found having similarities with our study are in the field of freight and date from the 90s. Declick was done: The idea is to manage the assignment of surgical interventions to the rooms of an operating theater, of the same manner of mission's assignment to the vehicles of a transport company: by means of a multi-agent system (MAS).

IV. Operating Theater Model

In this work, we propose architecture of the operating theater management system, based on an Intelligent Multi Agent System (MAS), for assistance in conducting the operating process of modern surgery rooms. The intelligent multi-agent system is a distributed artificial intelligence technique that, to our knowledge, had never been used before in the field of OR, but was used with "Big Success" to solve various problems in other areas of application such as energy systems, transport, etc. This technology has considerable potential for solving management problems in modern surgery rooms.

A multi-agent system (MAS) is a distributed system in which a group of autonomous entities called intelligent agents whether human or software pursue their objectives reactively, proactively and socially (N.R. Jennings et al) [15]. MAS has been proposed as an appropriate modeling approach for areas such as electronic commerce (R.H. Guttman et al) [18], multi-robot systems (J. Ota. Et al) (10), security applications (J. Pita et al) [16], industrial manufacturing etc. After expanding the MAS application domain, the planning technique with Multi-Agent Planner (MAP) is emerging.

Multi-Agent Planning (MAP) has distinguished itself. This new methodology pursues the integration of planning capabilities into intelligent agents. So, a group of agents can develop an action plan that achieves a set of common goals. As a result, the MAP greatly expands the scope of automated planning methods while being inherently different from conventional methods, most of which are operational research. MAP stands out as a simple and Distributed Articial Intelligence (DAI) powerful planning method for applications managed by a multi-agent system (MAS) where multiple entities or intelligent agents plan by communicating together and combining their knowledge, information and capabilities (N.T. Nguyen et al) [17]. MAP is used either to produce a distributed schedule (an individual schedule by Agent), or to produce a common schedule for multiple agents, that is, a schedule for multi-agent execution. Here, we emphasize that our work is the first case because our goal is to produce a schedule for each operating room and for each day, that is, a schedule distributed by (Room-Day-Agent).

The cooperative MAP approach adopted assumes that all agents are fully collaborative and interested in the joint creation of a distributed plan leading to common objectives. To do so, we have selected a planning strategy among the different levels of coordination possible, that is, to specify the levels of autonomy or cooperation needed. In addition, advanced techniques for solving the problem of cooperative planning between agents often use heuristic methods. The scope of so-called local heuristics is rather low because each agent perceives the quality of the overall plan according to his own schedule. This motivated the centralization of the decision-making power in the only Manager-Agent of the operating room via the use of a "global heuristic" to control the distribution mechanism of surgeries during the planning phase. In what follows, we present the architecture of this multi-agent's planner system.

At the bottom of the control system lays the physical stratum containing human resources and operating theater. For the software aspect, the proposed architecture comprises two layers: the distributed artificial intelligence layer consisting of a multi-agent system and the mediating layer that provides interfaces between the Multi-Agent System and the physical layer.

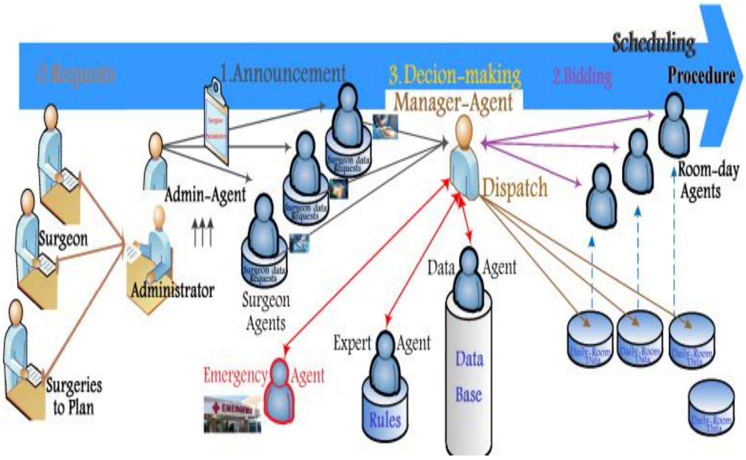

Figure 1: Multi-agent Planner system for management of an operating theater

The MAS is composed of seven types of agents, namely: Admin Agent, Manager Agent, Room-Day Agents, Surgeon Agent, Emergency Agent, Database Agent and Expert Agent.

• ***Emergency-Agent*** represents the emergency department; it has a specific graphic interface that allows it to announce emergencies.

• ***Admin-Agent*** is the link with surgeons, through which requests for surgeries or cancellations are made.

• ***Manager-Agent*** (MA) seeks to optimize the overall performance of the operating room; its decisions are based on predefined criteria and rules. (MA) is the sole decision-maker for the scheduling function. In communication protocols used such as (ST) and (CNP), the Manager-Agent is the only initiator. All Room-Agents are potential participants. When he receives a request to insert a surgery (which may be an emergency or not) into the planning, he enriches its file, containing the characteristics of the surgery requested, by additional specific data obtained from the expert agent and from the database agent. He starts the protocol (CNP) to find an assignment for this surgery. It analyzes the offers of the RoomDay-Agents and decides on the attribution of the intervention to the winning Room-Agent.

• ***Surgeon-Agents*** In the planning process, they represent subsets of requests for surgeries from a surgeon or possibly from a surgery department. (Surgeon-Agent) downloads (from the database), filters and if needed stores the features concerne the surgeries that he will try to introduce into the schedule (eg, specific "hardware resources", estimated duration, requirements,). This is done to speed up the management at each Surgeon-Agent level. Indeed, the data are available locally in its own database, in addition to their existence in the general database. Surgeon-Agent communicates with Admin-Agent to retrieve the list of requests from the surgeon he represents. He can possibly contact Admin-Agent to inform him of the failure to plan an intervention.

• **Room Day-Agents** (RA)s are the basic subset of the planning system, which includes the individual schedules of each RoomDay. Each RoomDay-Agent represents a physical surgery room on a given day. Each (RA) is responsible for establishing its individual plan by collaborating with the Manager-Agent. The (RAs) participate in negotiations of (CNP) protocol. They use their own local planner to supplement or adjust their individual schedule. (RA)s work together to provide (MA) the elements of a good decision. In addition, individual plans are updated, as needed, by communication with the database agent. A complete management system supposes the existence of means of feedback at the end of the surgery. It is also the responsibility of (AR) to return the useful data to DataBase Agent.

• **DataBase-Agent**; is responsible for filtering, classifying and storing data in a predefined format and extracting that data as needed.

• **Expert-Agent** (EA) has the responsibility for the accumulation of laws and rules, relating to know-how or the operating theater jurisdiction, and it is responsible for its extraction. He mainly cooperates with the (MA) by giving to him the knowledge that will enable him to make an informed decision. It has a specific database in which the rules and laws are cumulated.

The intermediate layer establishes a correspondence table between the multi-agents system layer and the physical one. It contains the specific data of the physical layer that is needed for a good representation of it by the multi-agent system. It also contains the logical interfaces between these two layers.

V. Hybrid Control

The proposed management system is structured by a hybrid control architecture that is qualified by: Optimized overall operating theater performance (minimizing costs at equal service, maximizing surgeon and patient satisfaction)

Reactive in the implementation phase to adapt the process to deal with unforeseen events (such as completion delays or the advent of an emergency) and to automatically find management solutions for doing so dealing with frequent disruptions (like unavailability of resources).

1 GLOBAL CONTROL

Predictive planning for the operating theater includes three important functions: programming, planning and scheduling. These management functions have been studied very frequently in the past. We find literature reviews that analyze the scope and methods of a large number of studies. We quote Cardoen et al. (2010) [3] and Guerriero and Guido (2011) [6]. In the rest of the document, we present the planning module corresponding to each management function that is part of the hierarchical control of the hybrid architecture.
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1.1 Programming of patients in the medium term

Patient programming is a means of managing the operating theater, situated at the very beginning of the management system. It consists of recording the interventions to be planned for a future period in a pre-calendar, based on the surgeons' requests. In (Persson and Persson, 2009) [23], authors work on the generation of waiting lists of patients who are candidates for surgery. We distinguish three models of patient programming:

- Open Booking: a centralized programming and free from any previous decision, it is made chronologically, as requests come in, or periodically. Despite its simplicity organization, it causes malfunctions such as the under-utilization of resources or, on the contrary, hourly overruns.
- Block Scheduling: an initially skeleton of program is proposed, consisting of well-defined time blocks, within which surgeons or services record their interventions.
- Modified Block scheduling: introduces the notion of adjustable time slot, so with a possibility of its extension.

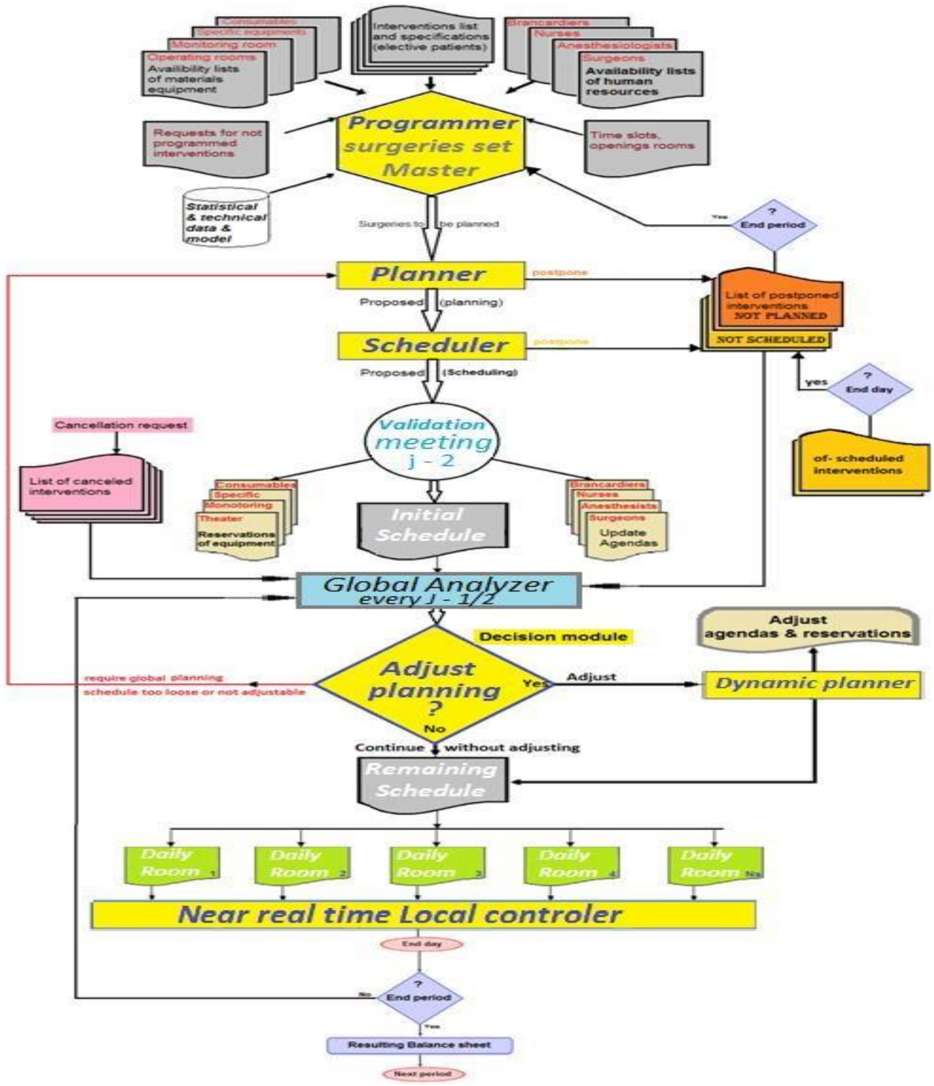

Figure 2: Hybrid control flowchart for the management system.

This decision is preceded by a so-called pre-operative phase in which some necessary (or Imposed by the rules) realizations are made (such as surgery and anesthesia consultations).
For a given room and for a given day, so from the MAS point of view, for a given RoomDay-Agent; the constraints of the intervention programming problem are as follows:
- Each intervention is assigned to one and only one time slot.
- Each time slot can only be assigned to one and only one intervention.
- The sum of the durations of the interventions must not exceed the hours of legal opening of the operating room.
- The intervention intervals of each surgeon must not be outside the pre-defined availability intervals of the surgeon.
- The number of interventions requiring a bed must be less than the number of beds available in the hospital ward.

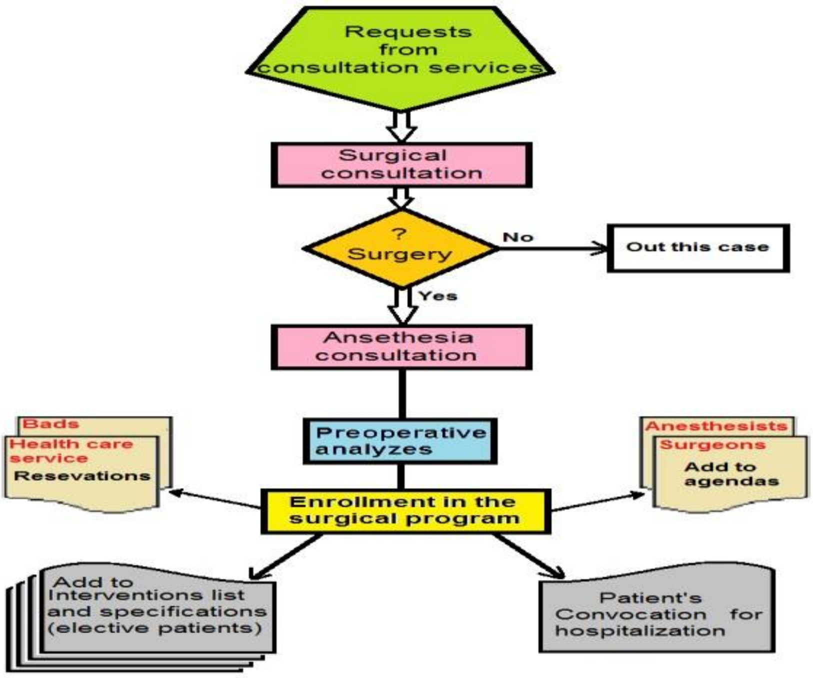

Figure 3: Management of the preoperative phase

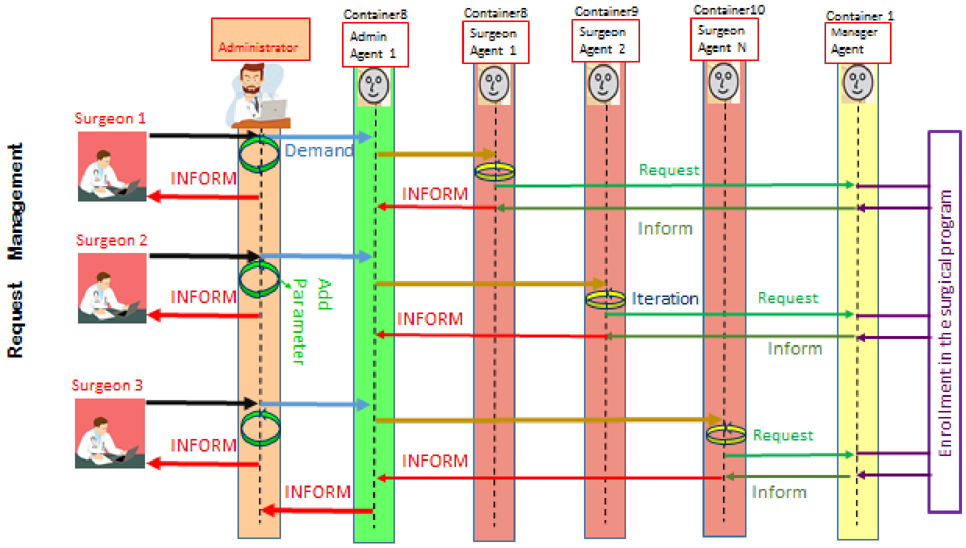

Figure 4: Request management in preoperative phase

The Manager-Agent receives from Surgeon-Agent a request with the specific parameters in attachment. If necessary to complete the specifications of the intervention to be performed, he obtains data provided by DataBase-Agent and Expert-Agent. The Manager-Agent must select and reserve the appropriate room and time slots for this surgery. If there is only one RoomDay that would be appropriate, MA sends to it a direct message that contain the specifications of the surgery. If this is not the case, the management agent acts as initiator and launches the Contract NET Protocol to found a location of the intervention. It sends a call for proposals to all RoomDay-Agent (general broadcast)

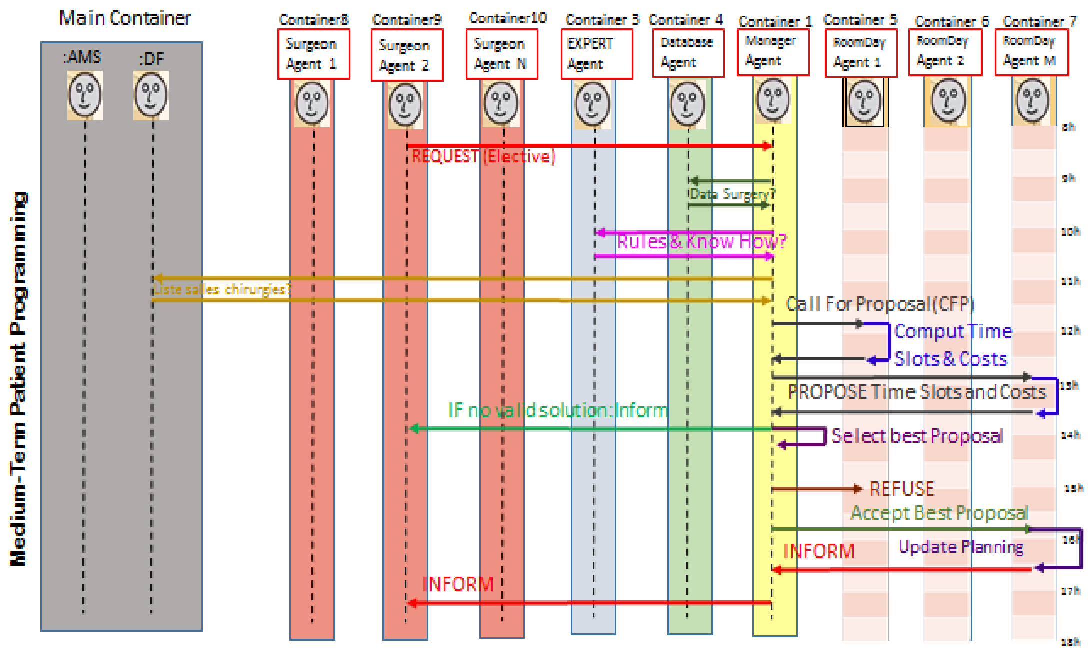

Figure 5: Enrollment in the surgical program.

Two cases are possible; the first case an appropriate place is not found in this case the Manager-Agent informs Admin-Agent of the failure to program this intervention. If an appropriate place is found, then Manager-Agent reserves the place and informs Admin-Agent.

A limited number of interventions may not be programmed due to lack of adequate space. It will then be up to the administrator to relax some constraints and resubmit them to the programming tool or force the programming using an interactive placement tool.

The quality of the tool can be judged on two criteria: the rate of the surgeries affected compared to the requested surgeries and the rate of performance which is the same previous indicator but with the cost aspect.

1.2 Predictive planning

This function concerns the distribution of elective interventions in the operating theater rooms and over the days of the week. The planning is done with static, deterministic or stochastic data, respecting a wide range of constraints mainly concerning the availability of human and material resources. (Guinet and Chaabane, 2003) [7] seek to determine the subset of interventions to be performed each day of a given planning horizon. In some studies, the planning of the operating theater involves the attribution of an operating room but also a precise time slot of one day for each elective intervention. In this case, planning also serves as an orderly schedule. Our approach fits into this type of study because the planning with MAS places each intervention directly in a room-day at a specific time window.

Fourteen half-hour time slots were set in normal operating hours of the operating theater to allow seven hours of operation; six half-hour slots were set in overtime to allow three overtime hours. It should be noted that the hourly cost of overtime is significantly higher than the normal hourly cost.

1.2.1 Preferences and priorities

It is obvious that a surgeon is also a doctor and the hours of operation are only part of his calendar. In fact, it may possibly operate elsewhere in another hospital or simply be in consultation. Nevertheless, these data are crucial for planning. Surgeons each have dedicated "**hours on bloc**" that correspond to the hours of work assigned to them, each day of the week, as well as hours of their availability in the operating theater. We have defined a matrix of (1) and (0) which is a table of correspondence between all the surgeons and all the slots of the week. Thus, the Timesheet (i, j) is equal to 1 if the surgeon i is available at the time slot j, otherwise, the Timesheet (i, j) is equal to (0).

In addition, it is assumed that each patient is associated, with respect to management, to one and the same surgeon, in that the operation of this patient is on his list, he is the only one responsible for the operation in the planning phase. Nevertheless, in practice, especially in public hospitals, another surgeon can intervene and perform the operation. This is not uncommon, especially during times of overload or imbalance in load distribution between surgeons. Thus, we established a correspondence table between the operations on one side and the surgeons on the other. Thus, capacity (i, j) is a number between 0 and 1 estimating the probability that the surgeon i performs the operation j. Thus, for example, if capacity (i, j) is equal to zero, it means that the surgeon can not perform this operation. The objective being to be able to take into account in planning that it is possible to have more than one surgeon to perform an operation.

In current practice, OR staff assigns a color indicator for priority of each intervention. The goal is to distinguish those to be done next week from those that can be delayed. Min D & Yih Y (2010 b) [13] authors conclude that: “The consideration of **patient priority** results in significant differences in surgery schedules from the schedule that ignores the patient priority”. This degree of priority is calculated according to a multitude of criteria: progression of the disease, pain, dysfunction, disability, priority of the young patients, patients whose date of the operation has already been postponed and patients affected by a "nosocomial infection". This parameter has a great influence on the optimization of planning but the method of calculating this degree of priority is not part of our study. We considered that the priority of patients was a given data of the planning problem. Thus, the vector Prior (i) contains at its (i) th component a number between 0 and 1 representing the weight of the priority of surgery i.

1.2.2 Virtual cost

To introduce the concept of the virtual cost of an intervention consider the following situation: Suppose that to perform an intervention (j) we have two propositions: the surgeon (i) performs the surgery (j) in a time interval with one part in overtime; or the surgeon (k) performs the surgery (j) without the overtime. At first, on the basis of the real cost, the second proposition is better. If we add that: capacity (i, j) = 1 and capacity (k, j) = 0.8 the decision is not as obvious as before. We thought that patient no preference should be taken into account when calculating the cost used as an optimization criterion. In the case of the previous example, the allocation of the intervention to the doctor of small capacity can be considered, but with a certain penalty in the cost function. We define a generalized notion of the cost function, called virtual cost, as follows:

$$virtual(j) = cost(j) + \alpha_c * (1 - p_{ij}) * cost(j)$$

In other words, we add a fictitious extra cost that corresponds to the non-preference of the patient. Therefore, moving an intervention to a lower preference resource implies a deliberately increased cost function. The scheduling mechanism is executed by an algorithm based on an evaluation logic that is central to the decision to assign ressources to an intervention. During the creation of a new program, the evaluation of requests at the level of Manager-Agent takes into account: the priority of the surgery, location preferences in terms of surgeon and time slots through the virtual cost, the category of requesting operation and the state of the planning under construction.

1.2.3 New schedule

We now explain the planning mechanism for a new schedule. The methodology is distinguished by the existence of a single "decision maker" (Manager-Agent), who has control over the planning. Manager-Agent negotiates the calendar with RoomDay-Agents, using information obtained from Surgeon-Agents about the surgeries to plan. The negotiations are spread over double iterations. During a round, each Surgeon-Agent (with surgeries not yet planned) sends Manager-Agent a message requesting a time slot emplacement for the surgery that it has selected. Then the decision process starts. For each request to be treated, MA enriches the file of this surgery with information and rules associated with it. MA is launching a "Call for Proposals (CNP)" for RoomDay-agents that may be suitable for this surgery. Each RoomDay-Agent uses the specifications and constraints contained in the CFP to select the best possible location still available. He makes his proposal to MA, containing the proposed time slot and the cost of the surgery. If he does not find a suitable place, he is always obliged to answer the MA to inform him. MA accepts the best proposal he receives and orders to place the corresponding "reservation" in the current calendar; he refuses the others and informs the corresponding RoomDay-agents.

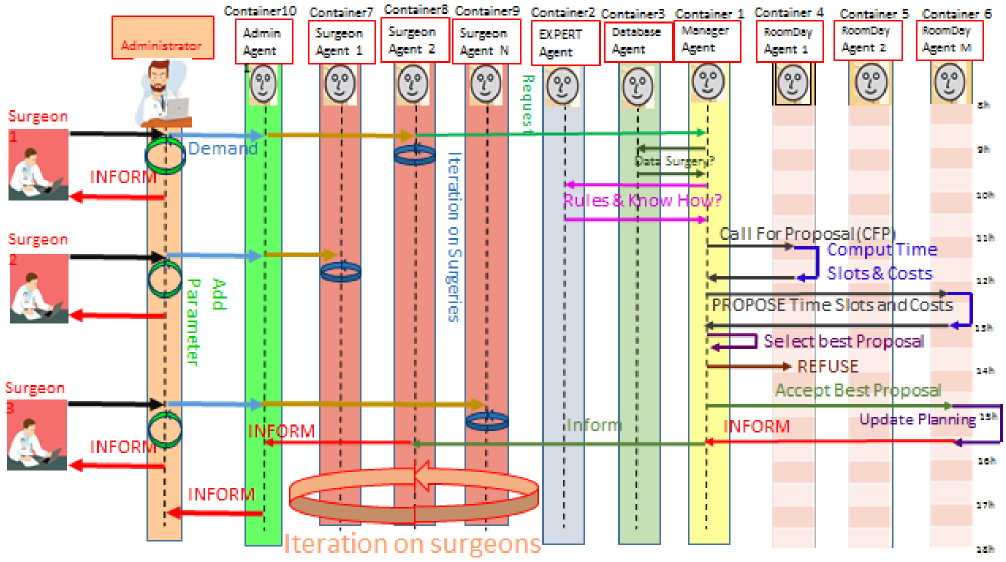

Figure 6: Algorithm to create a new schedule.

If MA does not receive a suitable proposal, it means that the planning of the intervention has failed. After each failed placement of a surgery, Manager-Agent consults the Surgeon-Agent about the surgery that was rejected. Surgeon-Agent returns a request about this surgery in which the constraints were lightened or not. Note that at this level, the set of constraints can be more or less flexible according to the chosen policy. For example, we can refuse to go beyond normal working hours during a first internship, and then accept it during the second internship. We may or may not agree to violate time slots preferences for surgeons.

Manager-Agent receives the new request and launches a (CNP) to find a suitable location. Following a positive response from Room Day-Agents the surgery will be placed. If the answer is still negative, the main process of negotiations is paused and the placement algorithm for rejected surgeries starts. Once the previously rejected proposals are added, Manager-Agent returns to the main thread. The regular iterations for fulfilled locations ends when all received requests are empty (all activities have been planned) or when unplanned activities cannot be fulfilled. Note that this approach ensures that all Sergeon-Agents have the same opportunities to operate, since each agent can, in one turn, reserve a place for one of its interventions.

1.2.4 Placement for rejected surgeries

This algorithm processes an existing planning, to find the acceptable emplacement for inserting one or more interventions. When an activity submitted in a regular cycle is rejected, this algorithm is used to find an acceptable location for it in the current calendar. All rejected surgeries are stored and ranked according to their priority. Then they are treated one by one, MA looking to find a location for them.

The following explain the mechanism of this algorithm: Manager-Agent goes around all RoomDays containing an appropriate location for this operation. It calculates the evaluation function of each operation already programmed at an appropriate place in this Room Day. He selects the surgery that has the lowest evaluation value among all the others. The balance of comparison between the two evaluation values of this intervention and the one to be placed will serve as the basis of the decision for the proposed replacement transaction. If the activity to be placed remains without an appropriate location, MA places it in the Dummy-room. If the exchange takes place, the surgery extracted from the schedule that is now without a location is returned to its owner Surgeon-Agent, who will be forced to modify its constraints and submit it to a next regular negotiation round. In addition, a mechanism for preventing this phase from ending with an "endless loop" is established.

1.2.5 Optimization Algorithme

The use of this algorithm is optional; it would allow you, if you want to partially modify the planning to improve the performances without breaking the constraints to respect. It consists in easing the constraints and then initiating an intervention exchange between RoomDay-Agents to balance the distribution of the workload. Manager-Agent, knowing the load of each RoomDay-Agent, asks the most loaded one, to propose one of its interventions to the sale. RoomDay-Agent calculates the virtual cost of extracting each of its operations. He selects according to the individual performance criteria the best intervention to extract from his schedule. He offers it for sale to Manager-Agent. MA activates the CNP procedure and launches CFPs at RoomDays-Agents to "buy" this intervention. Each RoomDay calculates the insertion proposals of this intervention and sends its proposal to MA. Manager-Agent analyzes the received proposals and decides based on the general performance criteria to whom to affect this operation. If he finds a proposal that results in a significant performance improvement, MA performs the transaction by ordering the update of the individual calendars and by informing the Surgeon-Agents involved in the change. If no, MA cancels the transaction project. Manager-Agent reiterates this same optimization mechanism as long as a prefixed stop criterion is not reached. The following figure shows the optimization sequence.

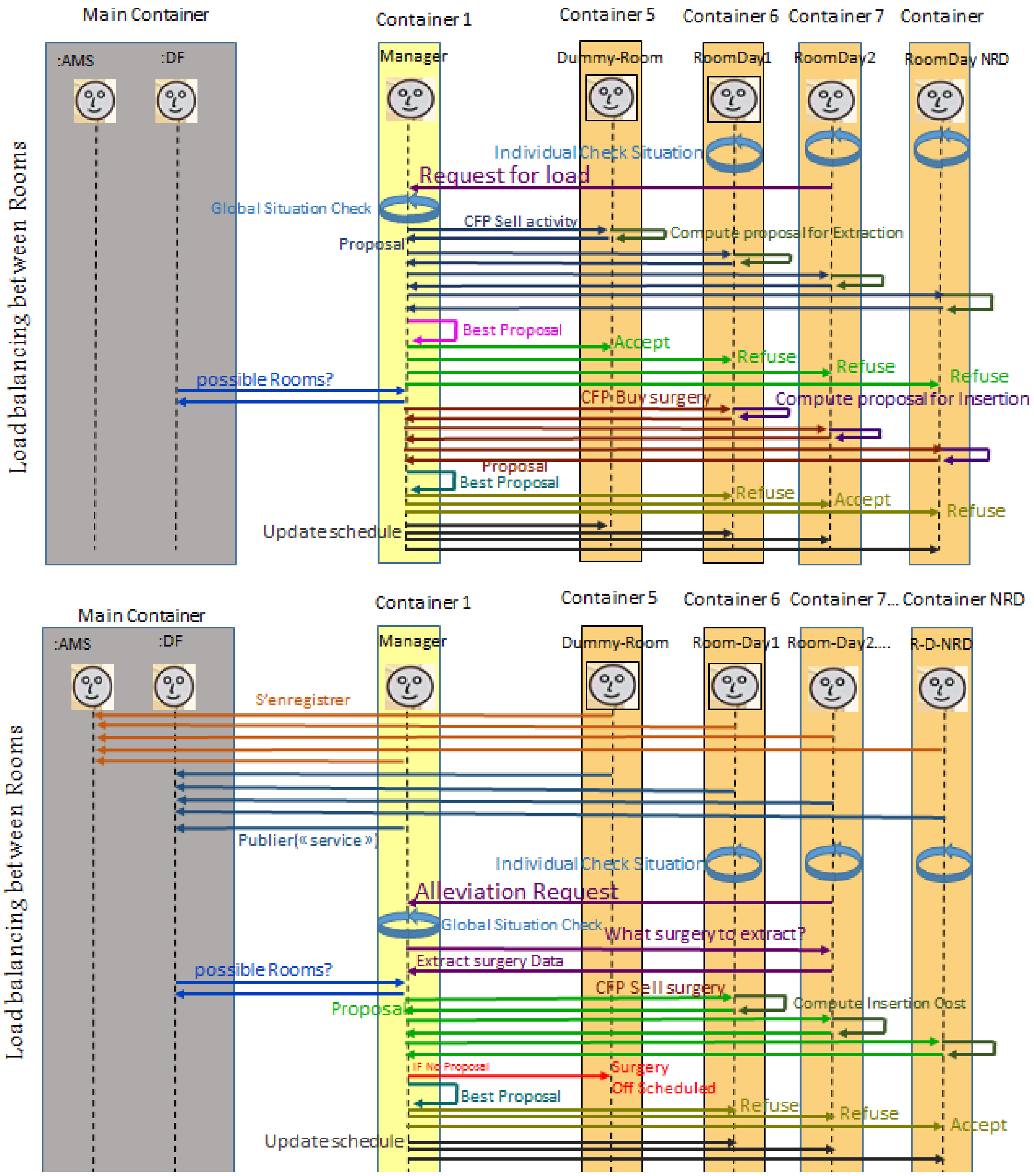

Figure7: Optimization sequence.

1.3 Predictive scheduling

(Predictive scheduling) Classically, scheduling defines the last step of predictive management. Its main objective is to prevent collisions. Thus, at any time of the day, he can not have the incompatibility of having, the presence of a surgeon in two different rooms at the same time. The secondary objective is to plan in detail the sequence of activities in the operating room and recovery room to optimize the work of nurses, health care providers and stretcher bearers, as well as the use of beds in the recovery room. An additional interest can be obtained is to place the interventions long and serious in the morning and to place those at high risk of contamination at the end of the day. So, task scheduling depends primarily on the availability of resources and the precedence of surgical interventions.

In (Pham & Klinkert 2008) [24], each intervention is a sequence of activities, resources are assigned to each activity and a time slot separates two consecutive activities. A Mixed Integer Linear Programming (MILP) is used to solve the problem of scheduling. (Cardoen et al. 2009) [1&2] propose "the Operating Table" a sequence of all the surgical interventions planned in a given room on a given day. (Dekhici et al. 2010) [4]; (Jebali et al. 2006) [8] and (May et al. 2011) [12], Sequencing of surgical procedures are treated as a Hybrid Flow Store (HFS). (Roland et al. 2006) [19], (Roland et al. 2010) [20] consider all human resources, but do not take into account the postanesthesia recovery step. (Vijayakumar et al. 2013) [22] A MILP and a heuristic are used to sequence the maximum possible surgeries with prefixed available resources. (Meskens et al. 2013) [14] Constraint programming (CP) performs the schedule while considering the affinity between human resources as an additional constraint. (Lee & Yih 2014) [11], the order of surgeries is determined by a genetic algorithm. The approach used to solve the problem is that of a flexible workshop with fuzzy activity time. A heuristic determines the start times of the interventions depending on the availability of resources.

Traditional planning methods use tedious equations for exact methods and use complex algorithms for operational research methods. In addition to its ability to allow easy modification of an existing plan, the distributed artificial intelligence planning method allows, by introducing appropriate rules, to obtain a suitable schedule compatible with the objectives and interests mentioned above.

-The first rule prohibits collisions. When "MA" reserves in a room during a given day, a time slot for a surgeon to perform an operation, it is necessary at the same time to mark as saturated with respect to this surgeon all the equivalent slots of the other rooms, on the same day. For the sake of clarity in the description of this mechanism, let us give the following example, (MA) reserves the slots [t1; t2] in the room (i) during day (j) so that the surgeon S can perform an operation. Then, according to this rule, all intervals [t1; t2] in the schedules of other rooms, on day (j), must be marked as forbidden for surgeon S.

-Two other criteria must be taken into account in the scheduling function, the **severity** of the intervention and the **infectious risk**. Scheduling the interventions according to their severity consists in carrying out in first, the most serious and longests. Scheduling the interventions according to their infectious risk is to carry out in last the surgeries with high infectious risk. A trick to solve this problem of scheduling would be to replace, in MA's decision, the real cost by the virtual cost, which corresponds to add a fictitious extra cost, all the greater if we move away from the desired location.

Scheduling according to the severity criterion:

$$virtual(S_1) = [1 + \alpha_{sevrity} \frac{p}{N_p}] * cost(S_1)$$

Scheduling according to the criterion of the infectious risk:

$$virtual(S_1) = [1 + \alpha_{inf} \frac{(N_p + 1 - p) * ASA}{N_p}] * cost(S_1)$$

With ASA it is a risk factor recognized by the American Society of Anesthesiologists. In the case where we want to take into account several criteria at the same time we recommend to use a linear combination of the extra costs corresponding to the various criteria mentioned previously.

1.4 Lacks of global control

In order to be able to properly manage the operating room process, ie to achieve the economic objectives and the objectives of the care services rendered to patients, it is obviously necessary: to be able to carry out the optimized planning but also be able to carry out emergencies and deal with hazards. Such a management system must be intrinsically characterized by the ability to achieve the overall performance objectives that have been optimized based on the selected criteria, on the one hand, and the speed of "adequate" response to events that appear in real time, on the other hand.

Predictive global control functions assume a deterministic context (Van Brussel; et al., 1998) [21]. They can very partially take into account aleas and give an acceptable result for activities disturbed a little. But when the frequency of the disturbances begins to increase the results deteriorate quickly. An event that disrupts the normal course of the process may occur at any time. While the process should not be interrupted instantly, the management system must assist it to support them as soon as possible. Thus, it is necessary to rethink planning whenever a surgical procedure ends and it is eventually necessary, to change plans.

2 LOCAL CONTROL

Faced with the difficulties mentioned, we sought to make a significant contribution in the field of operating theater management. The proposed solution concerns the whole process. It consists in structuring the management system according to hybrid control architecture, then in developing the appropriate method to implement all function of the management system. The proposed approach uses the community multi-agent systems of means to control the process.

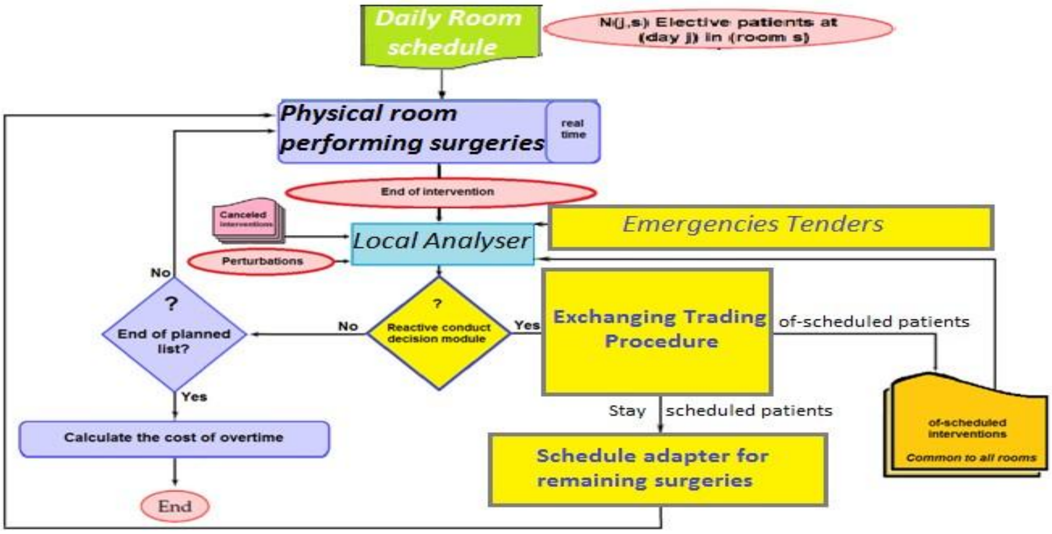

Figure 8: Real time local Controller chart

In another paper we present the modules constituting local control such as dynamic planning and emergency assignment. In particular, we explain how we adapted the two very well-known communication procedures, "Contract Net Protocol" and "Simulated Trading" to develop the modules of dynamic management.

VI. Conclusion

We presented the architecture of a management system of an operating theater. This control architecture is an association of two distinct but complementary parts: the hierarchical control part realized by the predictive planning and the cooperative control part realized by the dynamic planning. We have described the functions and algorithms of the planning modules constituting the control model based on distributed artificial intelligence. This type of control, required by this sector of health, is still lacking. Our contribution aims to fill this gap by providing the right solution to both improve performance and responsiveness. The management system also integrates the system for evaluating the performance of the process. The performance measures will be generated automatically. Some will be used in the feedback loop to adjust the process.

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