Operating Room Management System: Patient Programming.

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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. 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.

We first present the hybrid architectural concepts and the development of the control system for the management of the operating room process in its entirety. We then describe the patient programming function and the associated module algorithm based on distributed artificial intelligence.

1 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. 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

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economic managers of the hospital, this sector is also by far the most complex to manage.

2 PROBLEMATIC

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] [2], [Cardoen et al., review 2010] [1], [Gul et al., review 2015] [4]. This literature reveals a use of exact or logical approaches to planning with deterministic or stochastic data but very often data for static events. These approaches do not really take into account or, even worse, ignore some of the disturbances. 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. As a result, new paradigms of control and management techniques, different from those used in the past, have become essential to assist managers in the operation of this sector.

3 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. The idea is to manage the assignment of surgical interventions to the rooms of an operating theater by means of a multi-agent system (MAS).

4 OPERATING THEATER MODEL

In this work, we propose architecture of the operating theater management system, based on an Intelligent Multi Agent System (MAS). The intelligent multi-agent system is a distributed artificial intelligence technique that has considerable potential for solving management problems in modern surgery theaters.

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) [8]. MAS has been proposed as an appropriate modeling approach for areas such as electronic commerce (R.H. Guttman et al) [10], multi-robot systems (J. Ota. Et al) [5]; security applications (J. Pita et al) [16], industrial manufacturing etc.

Multi-Agent Planning (MAP) has emerging. 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 (N.T. Nguyen et al) [9]. MAP is used either to produce a distributed schedule, or to produce a common schedule for multiple agents. Our goal is to produce 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 centralized of the decision-making 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-agents planner system.

At the bottom of the control system lays the physical stratum containing human resources and operating theatre. 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.

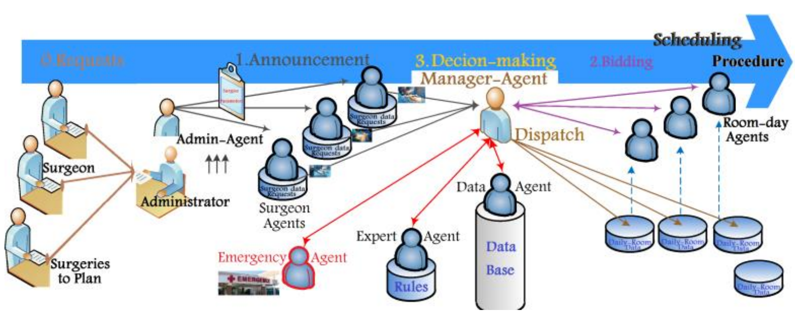

Fig. 1:Multi-agent Planner system for an operating theater management.

The MAS is composed of:

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

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

• **ManagerAgent** seeks to optimize the overall performance of the operating room; its decisions are based on predefined criteria and rules. In communication protocols used such as ST and CNP, the Manager-Agent is the only initiator. When he receives a request to insert a surgery into the planning, he enriches its file, containing the characteristics of the surgery requested, by additional specific data. He starts the protocol CNP to find an assignment for this surgery. He decides on the attribution of the intervention to the winning RoomAgent.

• **SurgeonAgents** In the planning process, they represent subsets of requests for surgeries from a surgeon or possibly from a surgery department. Surgeon-Agent communicates with Admin-Agent to retrieve the list of requests from the surgeon he represents.

• **RoomDayAgents** : Each RoomDayAgent represents a physical surgery room on a given day. Each RA is responsible for establishing its individual plan by collaborating with the MA. The RAs participate in negotiations of CNP protocol. They use their own local planner to supplement or adjust their individual schedule. In addition, a complete management system supposes the existence of means of feedback at the end of the surgery to return the useful data to DataBase Agent.

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

• **ExpertAgent** (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.

The intermediate layer 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.

5 HYBRID ARCHITECTURE FOR CONTROL

Control of the entire process of the operating theater is ensured by a management system structured according to a so-called hybrid architecture that is distinguished by two type of control the **predictive hierarchical control** and the **cooperative real time control**.

The predictive planning process for operating room surgeries involves three main stages: programming, planning, and scheduling. Predictive management functions have been studied very frequently. We find literature reviews that analyze the scope and methods of a large number of studies. We cite, for example, Cardoen et al. (2010) [1] and Guerriero and Guido (2011) [3].

We present in this paper the planning module corresponding to Patient programming. It is a means of managing the operating theater, situated at the very beginning of the management system (Kharraja 2003) [6]. It consists of recording the interventions to be planned for a future period in a pre-calendar, based on the surgeons' requests). (Persson and Persson, 2009) [11] works on the generation of waiting lists of patients who are candidates for surgery. The literature reports three models of patients programming (Marcon 2003a) [7]:

- 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.

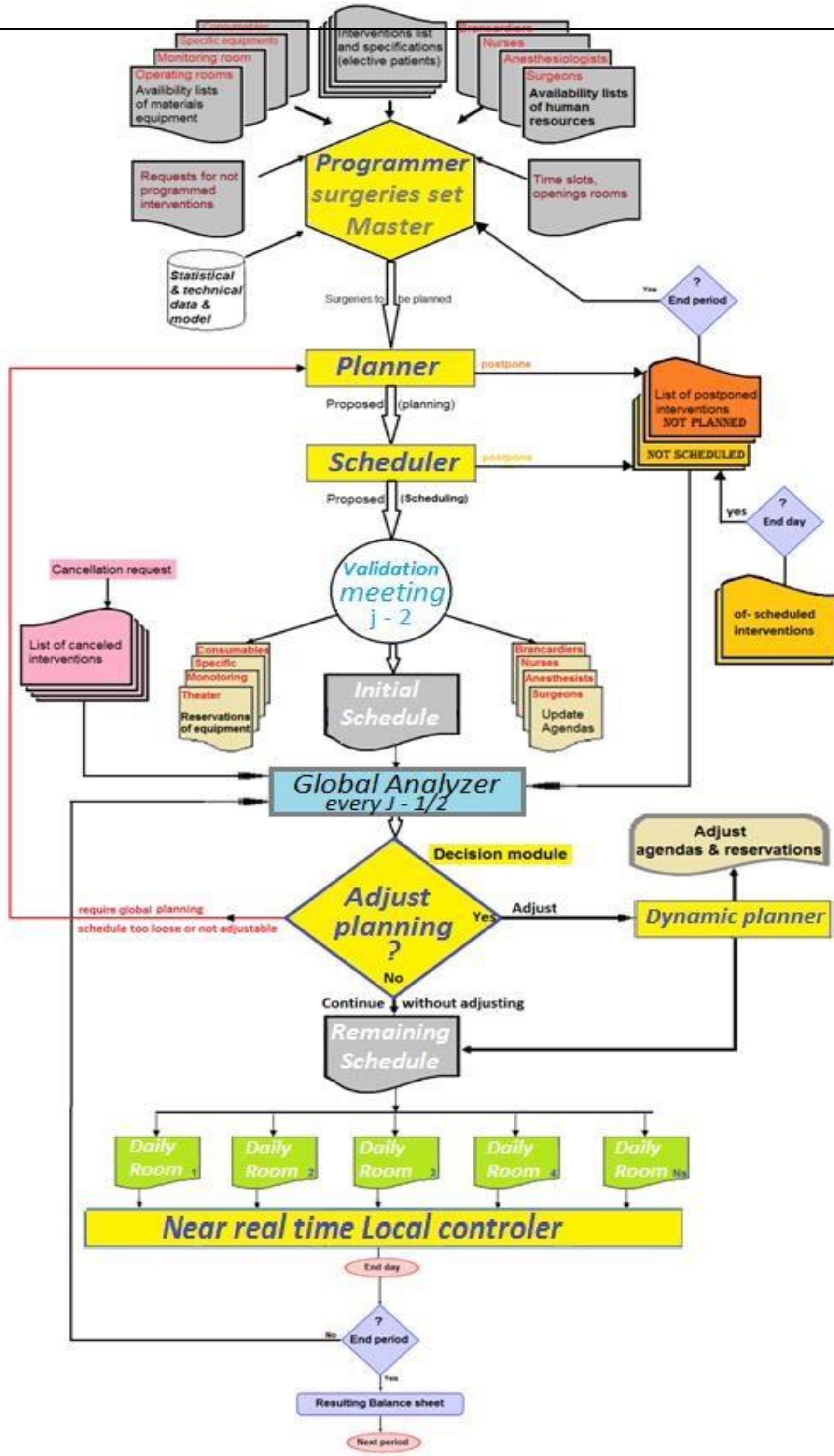

Fig. 2: Hybrid control architecture for the operating theater management.

This planning function 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 anaesthesia consultations).

For a given room and for a given day, which corresponds in MAS to a given RoomDayAgent; 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 theater.
- 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.

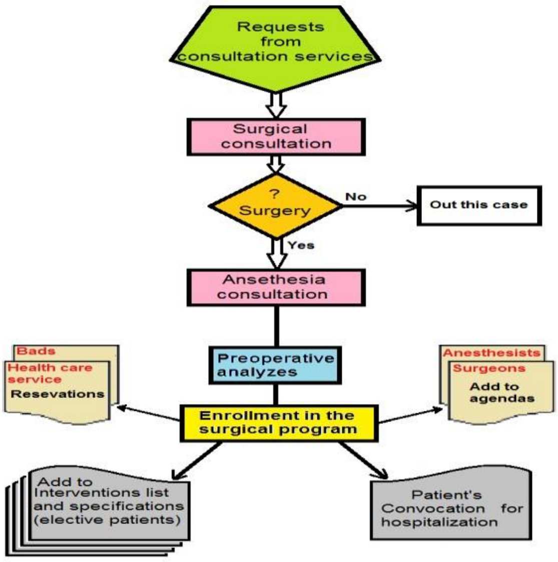

Fig. 3: Management of the preoperative phase

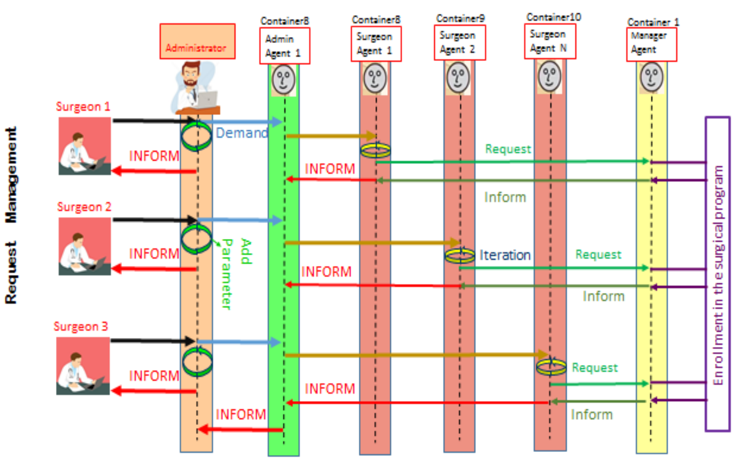

Fig. 4: Request management in preoperative phase

The ManagerAgent receives from Surgeon-Agent a request with the specific parameters in attachment. It communicates with DataBaseAgent and ExpertAgent to complete the specifications and possibly the relative rules for this operation. 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 ManagerAgent acts as initiator and launches the CNP to found a good location. It sends (general broadcast) a (CFP) to all RoomDayAgents.

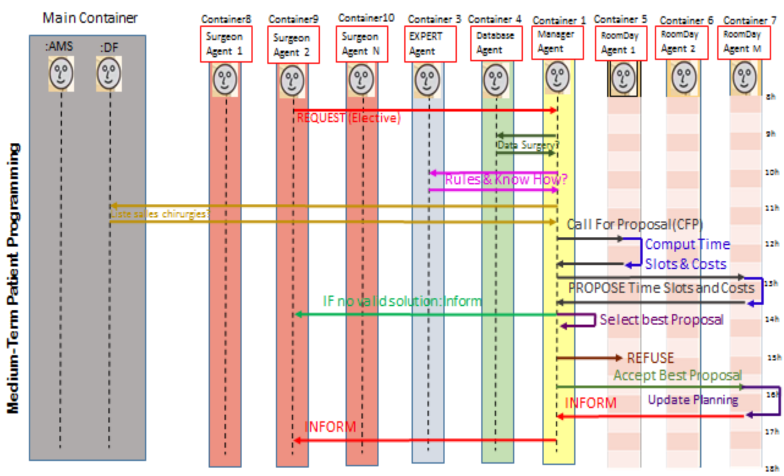

Fig. 5: Enrollment in the surgical program.

Two cases are possible; the first case an appropriate place is not found in this case the ManagerAgent informs AdminAgent of the failure to program this intervention. If an appropriate place is found then ManagerAgent reserves the place and informs AdminAgent.

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.

6 Conclusion and perspective

In this paper, it is proposed a methodology based on Multi-Agents System to plan the patients for a surgery in an operating theater. The structure of the programming software tool for this application is presented and we have detailed its mechanism and its decision logic.

We deliberately limited our paper in this article to the theoretical approach of AI. Nevertheless, the theoretical approach proposed is supported by a concrete implementation on real data and a classification of the management parameters in agreement with the hospitals which are the sponsors of this study. But these elements are not presented in this article to avoid falling into the problem of auto-plagiarism later for future publications. So, the verification of this approach by the implementation of this methodology and related tests, as well as the analysis of the results, is the subject of another communication in a scientific journal.

References

1. Cardoen, B., Demeulemeester, E., & Beliën, J. (2010). Operating room planning and scheduling: A literature review. European Journal of Operational Research, 201(3), 921–932.
2. Erdogan, S.A., Denton, B.T., “Surgery Planning and Scheduling: A Literature Review,” Wiley Encyclopedia of Operations Research and Management Science, 2010
3. Guerriero, F., & Guido, R. (2011). Operational research in the management of the operating theatre: A survey. Health Care Management Science, 14(1), 89–114.
4. Gul, S., Denton, B.T., Fowler, J., “A Multi-Stage Stochastic Integer Programming Model for Surgery Planning,” INFORMS Journal on Computing, 2015
5. J. Ota. Multi-agent robot systems as distributed autonomous systems. Advanced Engineering Informatics, 20(1):59–70, 2006. 1
6. Kharraja S., 2003, Outils d’aide à la planification et l’ordonnancement des plateaux-médico-techniques. Génie industriel, Saint-Etienne: université JeanMonnet, pp. 153.
7. Marcon, E., Kharraja, S. d., Smolski, N., Luquet, B., & Viale, J. P. (2003). Determining the number of beds in the post anesthesia care unit: A computer simulation flow approach. Anesthesia & Analgesia, 96(5), 1415–1423.
8. N.R. Jennings, P. Faratin, A.R. Lomuscio, S. Parsons, M. Wooldridge, and C. Sierra. Automated negotiation: prospects, methods and challenges. Group Decision and Negotiation, 10(2):199–215, 2001. 1
9. N.T. Nguyen and R.P. Katarzyniak. Actions and social interactions in multi-agent systems. Knowledge and Information Systems, 18(2):133–136, 2009. 1, 84
10. R.H. Guttman, A.G. Moukas, and P. Maes. Agent-mediated electronic commerce: a survey. Knowledge Engineering Review, 13(2):147– 159, 1998. 1
11. Persson, M., & Persson, J. A. (2009). Health economic modeling to support surgery management at a Swedish hospital. Omega, 37(4), 853–863.