# Patient Admission Scheduling with Operating Room Constraints

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**Abstract** We propose an extension of the PAS problem described in our previous work [6], which considers also constraints about the utilisation of operating rooms for patients that have to undergo a surgery. We design a solution approach based on local search, which explores the search space using complex neighbourhood operators.

**Keywords** Patient Admission · Operating Room · Local Search

## 1 Introduction

The *Patient Admission Scheduling* (PAS) consists in scheduling patients into hospital rooms in such a way to maximise medical treatment effectiveness, management efficiency, and patients' comfort.

The problem has been formalised by Demeester *et al* [8] and further studied by the same research group [2]. We have solved the PAS by local search [5] and we have obtained the best known solutions on all the available PAS benchmarks [7]. We have subsequently refined and extended the problem formulation to take into account several additional real-world features, such as the presence of emergency patients, uncertainty in stay lengths, and the possibility to delay admissions [6].

In this work, we present an extension of the PAS problem described in [6], that constitutes a first step towards the integration of the patient admission scheduling with the surgery scheduling process.

As pointed out in [3, 4], the operating room is a very critical resource, so that the scheduling of surgeries has a deep impact on the other activities of the hospital. Indeed, a patient that undergoes a surgery is expected to

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recover in the hospital for a period, thus she/he needs a bed in a ward of the corresponding specialty. As a consequence, the surgical process scheduling requires to be integrated with the other hospital operations in order to avoid resource conflicts.

The operating room scheduling is usually decomposed in three hierarchical stages (see e.g., [1, 10, 12]). The first level corresponds to a long-term strategic planning whose aim is to assign the operating room resources to surgical specialisms according to historical data or forecasts. The second step is a tactical medium-term planning; it involves the development of the master surgical schedule (MSS) which is a cyclic timetable that defines, for each day of the cycle, which operating room is assigned to a team of surgeons and for how long. The last stage (see, e.g., [11]) is the daily scheduling of the specific intervention of each patient: Emergencies and all kinds of uncertainty are tackled at this level, which is mainly operational.

This work can be positioned between the tactical and the operational level, so that inputs of the problem are all data about departments, rooms and patients, and the MSS resulting from the tactical planning. Using the classification in [9], the problem belongs to the class of "Block scheduling", because the operating room scheduling is organised in blocks assigned to specialisms.

A solution of the problem is an assignment of patients to beds in rooms for each day of their stay in hospital, satisfying all the constraints of the PAS problem (capacity, gender, specialty, age, room feature, preferences) and taking also into account the constraints related to the MSS.

## 2 PAS with operating room constraints

In order to integrate all the information about the MSS in the PAS problem, we introduce the notions of *operating room slot* and *medical treatment*:

**Operating Room Slot**: An operating room (OR) slot is the smallest time unit for which a operating room can be reserved for a specialty in a day. Each day of the planning cycle, the MSS assigns to a specialty an integer number of OR slots. Different operation rooms can be simultaneously used by the same specialty, since a specialty normally does not identify a specific surgeon but a surgical group.

**Medical Treatment**: Each patient has to undergo a medical treatment that is performed by a specialist. Some treatments include a surgery of the type of the corresponding specialty. In this case, the day of the surgery (typically either the day after the admission day or the admission day itself) and the expected length of the surgery must be specified.

Our problem consists in assigning a room to each patient for a number of days equal to her/his stay period, starting in a day not before his/her planned admission. The assignment is subject to all the PAS constraints defined in [6] and the following additional one:

**Operating Room Utilisation**: For each day and each specialty the total length of the operations for treatments belonging to the specialty must not exceed the time granted to it by the MSS.

This is a hard constraint, and it has a critical impact on the search space. Consequently it requires to reconsider the search method, and, in particular, the definition of the neighbourhood structures.

We remark that we only define the admission day of a patient taking into account the daily utilisation of the operating rooms; the problem of sequencing OR slots in a day and the surgeries within each OR slot is outside the scopes of this work, and is usually performed online (at most the day before), considering also emergency patients.

## 3 Solution technique

We refine the solution technique applied in [6], which is based on a complex neighbourhood structure and on simulated annealing (SA).

A state in the search space is composed by two integer-valued vectors: the first one represents the room assigned to each patient, and the second one is the possible delay of the admission of the patient.

In order to effectively explore the search space in which the admission of patients has to satisfy also the operating room utilisation constraint, we need to define new neighbourhoods. For example, we should consider that a specialty might appear in the MSS only in some specific days, therefore the neighbourhood relation defined in [6], that moves the admission of a patient only to the previous or following day, is not suitable. We thus have to define a neighbourhood that enables longer time leaps in one single move.

Based on these considerations, the neighbourhood is the composition of four basic moves. The first two work on the room assignment, and they are the change of the room assigned to a patient and the swap of the assigned room between two patients. The third and fourth are used to modify the admissions day of patients. One move shifts the admission of a patient forward or backward by a given number of days. The last one swaps the admission days of two patients. Both keep the room unchanged.

The cost function includes the same cost components than those of the PAS problem, but the component *distance to feasibility* takes into account not only the room capacity constraint but also the operating room utilisation.

## 4 Experimental analysis

Unfortunately, there are no real-world instances available at present for this problem, therefore we modified the instance generator designed in [6], which is available at `http://satt.diegm.uniud.it/index.php?page=pasu`. We included all the input data about the MSS, that is the number of OR slots reserved to each specialty for each day and the features of each medical treatment.

The project is ongoing and the computational results on the generated instances are very preliminary; they will be presented in the forthcoming complete version of the paper.

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