A hyper-heuristic approach for assigning patients to hospital rooms

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One of the tasks hospital admission administrators are faced with is the problem of optimally exploiting the infrastructure. Patients need to be assigned to a room that is suitably equipped and staffed for treating the patients' clinical condition, taking into account policies imposed by the hospital organisation. Given that the number of (especially elderly) patients is growing, it is becoming increasingly difficult for administrators to handle this task manually in an efficient manner.

Demeester et al. (2010) introduced the Patient Admission Scheduling problem in order to support this decision process. The problem can be described as follows. For a given planning period, patients need to be assigned to a hospital room for each night of their stay. Patients are characterised by their age, gender and pathology, and should be treated in rooms and departments that are in correspondence with these characteristics. In addition to that, it is assumed that patients are already attributed an admission date, and that an expected average length of stay has been determined for their diagnosis. Patients will stay in the hospital for this period without returning home. This period is fixed and cannot be changed.

Treatment of the patient's pathology may require the presence of certain equipment in the assigned room. For example, certain patients might require a ventilation machine to be present in their room. As such, their stay is also characterised by a set of needed and preferred room properties. Patients may also express some preferences concerning the room they wish to stay in. Finally, patients do not necessarily need to stay in the same room for their entire stay. It is possible that it is beneficial to move a patient to another room at some point during their stay. Transfers of patients are thus allowed, but should be avoided as they cause patient discomfort.

The hospital is divided into several departments, each of which are specialised in treating certain kinds of pathologies and which may or may not have some age

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restriction (for example, paediatrics may be restricted to patients younger than 16). Each department has a set of rooms, which are equipped variably and have a certain bed capacity. This capacity may not be exceeded. Furthermore, rooms can be restricted to patients of a certain gender. A room can be restricted to male or female patients, or it can be so that patients of a different gender may not be assigned to the same room, but it does not matter whether either male or female patients stay in the room. In other words, the gender of the room in this case is determined by the gender of the first patient.

In practice, most of these constraints are considered soft. For the patient admission scheduling problem, only the room capacity constraint and the fixed period of stay are modelled as hard constraints. All other constraints are modelled as soft constraints. The goal is to find a complete assignment of patients to rooms that minimises violations of these (weighted) soft constraints.

Demeester et al. (2010) tackled the patient admission scheduling problem using a hybrid tabu search method. In this study, we apply a hyper-heuristic method to select perturbative low-level heuristics for solving this optimisation problem. Hyper-heuristics have been progressively used for solving a wide range of combinatorial optimisation problems. The reason for applying them to different problems is related to their generic nature. The generality is provided by isolating hyper-heuristics from any problem dependent structure: a hyper-heuristic does not know anything about the problem to be solved. It manages a set of lower level heuristics and tries to apply them to the problem in an appropriate fashion. While solving a problem instance, a hyper-heuristic determines which heuristics should be called in which order and when. In effect, the hyper-heuristic method that we consider can be described as a "*heuristic to choose heuristics*" (Burke et al. 2003a).

The characteristics of the low-level heuristics may affect the performance of a hyper-heuristic. Their improvement capabilities and their speed concerning moving from one solution to another solution are some important elements regarding the quality of a heuristic set. Taking these elements into account during a heuristic selection process may help to give more meaningful decisions. In Chakhlevitch and Cowling (2005) a heuristic set with many heuristics was reduced into a small heuristic set for determining a better heuristic subset. In Burke et al. (2003b) and Kendall and Hussin (2005a,b) simple tabu strategies were proposed to make some heuristics tabu based on their performances. In Han and Kendall (2003) a similar approach was utilised to prevent the heuristics that do not affect the value of the objective function being called in a genetic algorithm based hyper-heuristic.

In this study, we apply a heuristic exclusion procedure based on these elements for improving the overall quality of the heuristic set. We divide the search into phases of a certain number of iterations, which is a parameter to our algorithm. During each phase we measure the performance of all heuristics. The performance metric used, is based on the relative improvement per execution time of each heuristic. At the end of a phase the better performing heuristics are retained, while the lesser performing heuristics are made tabu for a certain number of phases (which is also a parameter to the algorithm). This way we try to obtain an elite subset of heuristics, while still allowing for variation of this subset as the search progresses. It is important that this subset can vary over time. It is quite possible that a computationally expensive heuristic is not interesting at the beginning of the search (where simpler, less expensive heuristics are also effective), but necessary at the end of the search where it is more difficult to find solutions that improve on the current solution.

For the patient admission scheduling problem we use the heuristics described by Demeester et al. (2010) and Ceschia and Schaerf (2009), as well as some variations on these heuristics. We will test our method on benchmarks available from the patient admission scheduling website (Demeester et al. 2008) and we will compare our results with those available from the literature.

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