An Evaluation of Certain Heuristic Optimization Algorithms in Scheduling Medical Doctors and Medical Students

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Abstract. Four heuristic algorithms based on or inspired by the well-known Tabu Search method have been used to cast heuristically optimized schedules for a clinical training unit of a hospital. It has been found experimentally that the algorithm of choice for this problem depends on the exact goal being sought where the execution time is one of the components of the goal. If only one run is allowed, then classical Tabu Search with a tenure of 5 gave the schedule with the lowest average (and fixed) penalty. If time is not of concern and many runs are allowed then the Great Deluge algorithm may generate the schedule with the lowest penalty.

1 Introduction

The scheduling of personnel can often be accomplished in two phases, the phase that deals with time-of-day or shift scheduling, and the phase that deals with day-of-week scheduling. Baker [2] has named these types of labour scheduling *tour scheduling*.

Glover and McMillan [7] have reviewed the problems of employee scheduling while more specialized reviews of the tour scheduling literature have been published by Alfares [1] and by Ernst et al. [5]. It is one thing to find *feasible* schedules, i.e. schedules that satisfy all the staffing rules, but quite another to find an *optimal* feasible schedule, i.e. one that not only satisfies the rules but also minimizes (or maximizes) some objective function.

In work described in a previous PATAT conference [9] a stand-alone system for casting schedules of medical staff in the Internal Medicine Clinical Teaching Unit of the Ottawa Hospital was built using the Java programming language. The algorithm constructed an initial feasible schedule and then heuristically optimized it to reduce its perceived 'badness'. The algorithm used was a simple version of the tabu search (TS) algorithm introduced by Glover [6] and used many times since.

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The requirement was to produce duty rosters (locally referred to as *call schedules*) for medical trainees (residents and medical students) in the Clinical Teaching Unit to man the overnight shift. The duties of a shift consist in rendering medical assistance to patients in need of it during the night when the majority of the medical trainees are no longer on duty. For each night in a 28-night cycle, a shift of (ideally) 5 persons consisting of a senior resident, 2 junior residents and 2 medical students has to be scheduled. Because of chronic understaffing the shift often consists of fewer than 5 persons. Sometimes 4 and sometimes 3 persons are used if there is not enough staff available. The staff chosen for these shifts have various 'ranks' and may belong to one of two teams. Since these evening rounds are in addition to regular day shifts that the medical trainees must work, there are very stringent requirements that prohibit the personnel from being overworked beyond a certain point. These numerous requirements are formulated as *soft constraints* and each violation of a constraint is associated with an integer penalty whose magnitude is a measure of the undesirability of relaxing that constraint. The sum of these integers is the measure of the 'badness' of the schedule. The TS algorithm is used to minimize this badness. An example of a call schedule is shown in Figure 1.

This schedule consists of a duty roster of exactly 28 days in length, each day showing the assignment of 5 or fewer medical staff members. Ideally there will be exactly 5 members but for financial reasons, only 4 or 3 may actually be scheduled. Each schedule begins on a Tuesday and ends on a Monday. The first line of Figure 1 shows that the senior resident is Dr Zaidi. He will be in charge of the unit on the first Tuesday night. He is assisted by three other persons, Shefrin, Carrier and Puglia. A fifth person is not available on that night. Some of these assistants are junior doctors while others are medical students.

The senior resident is the doctor in charge. The two teams, A and B, consist of a 'First Call', i.e. the first person to call if required, and a 'Second Call', the next person to call (if there is one). The members of a team work closely together.

Any call schedule has an associated penalty that quantifies how 'bad' it is. The components of this penalty can be broadly classified as horizontal or vertical penalties. Some nights, e.g. the third and fourth lines on the schedule, corresponding to Thursday and Friday of the first week, are fully staffed with appropriate members from each team. Other nights, e.g. the final Thursday are very short staffed, with only three medical personnel on duty. The first of these examples attracts a penalty of 0 while the second example attracts a penalty of 300. These are examples of horizontal penalties. They can be evaluated simply by scanning each line separately. Table 1 lists the various defects that each night's shift might have and the corresponding penalties.

Vertical penalties are those that arise from consecutive nights. The first Thursday and Friday of Figure 1 has one trainee, Oliveira, working for two consecutive nights. This attracts a penalty of 100. The weekends, defined to consist of Friday, Saturday and Sunday, are very sensitive. A pattern consisting of working on Friday and Sunday (but *not* Saturday) or its converse are greatly desired.