Solving a bi-objective nurse rerostering problem by using a utopic Pareto genetic heuristic

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Abstract Nurse rerostering arises when at least one nurse announces that she will be unable to undertake the tasks previously assigned to her. The problem amounts to building a new roster that satisfies the hard constraints already met by the current one and, as much as possible, fulfils two groups of soft constraints which define the two objectives to be attained. A bi-objective genetic heuristic was designed on the basis of a population of individuals characterised by pairs of chromosomes, whose fitness complies with the Pareto ranking of the respective decoded solution. It includes an elitist policy, as well as a new utopic strategy, introduced for purposes of diversification. The computational experiments produced promising results for the practical application of this approach to real life instances arising from a public hospital in Lisbon.

Keywords Nurse scheduling · Rerostering · Bi-objective heuristics · Genetic algorithms

1 Introduction

The rerostering problem is a scheduling-type problem that frequently arises in hospital units where no reserve pool of nurses exists. Here, the roster for the nurses of a given unit must often be adapted in view of the scheduled nurses’ unexpected absences. However, like many other rescheduling problems, this rerostering problem has received little attention in OR literature.

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As witnessed in hospital units in Portugal, the nurse rerostering problem has been studied by using two single-objective multi-commodity flow models and tackled by mixed binary linear formulations or genetic heuristics in Moz and Pato (2003, 2004, 2007). The abovementioned single-objective problem consists in minimising the violations related to a group of soft constraints—by forcing a nil dissimilarity between the current and the new roster—subject to the hard constraints imposed by Portuguese Law, working contracts and institutional requirements. This being so, the solutions to such optimisation problem will tend to satisfy other soft constraints whenever satisfied by the current roster. However, in practise, there is a trade-off between similarity of both rosters and compliance with other soft constraints. Hence, to handle this trade-off, a bi-objective problem was formulated and the respective solutions were obtained from a goal programming model (Moz and Pato 2005).

In the literature, a reference was found to a nurse rerostering problem in Tien and Kamiyama (1982). However, it concerns a situation where a reserve pool of nurses exists. More recently, other rescheduling problems have been analysed by Cumming et al. (2000) and Petrovic et al. (2002). Nevertheless, all of these studies have little in common with the present nurse rerostering issue, though all have been identified as being more difficult than the corresponding scheduling issues. In fact, the methodologies usually applied to the rostering problem cannot be adapted to rerostering that easily. For a recent survey of methods for rostering see Burke et al. (2004), Cheang et al. (2003) or Ernst et al. (2004).

Due to the high complexity of this problem, whose single-objective version has been classified in Moz and Pato (2007) as NP-hard (Garey and Johnson 1979), the authors adopted a heuristic methodology. This strategy was also dictated by the need for a solving engine requiring modest human and computing resources, to be incorporated in a decision support system and run in each hospital unit. The choice of a genetic heuristic was prompted by the favourable experience obtained from genetic heuristics by several authors working with difficult bi-objective scheduling-type problems, such as Carrasco and Pato (2001) and Burke et al. (2001). In this context one should also consult a recent survey of Silva et al. (2004) on multiobjective heuristics for scheduling problems, which includes nurse rostering.

The utopic Pareto genetic heuristic described in this paper was developed by introducing the bi-objective criterion into the fitness function, in a Pareto fashion, and running it, while maintaining all the other features considered in the abovementioned genetic heuristic for a single-objective case (Moz and Pato 2007). In an attempt to enhance the behaviour of the heuristic, an elitist policy was adapted from the one due to Gandibleux (2000), as well as a new utopic strategy developed in order to induce diversity in the population and attain a low level of at least one of the objectives. The bi-objective genetic heuristic was computationally tested, using real life rerostering instances taken from a surgical unit of a Lisbon public hospital.

Section 2 of this paper presents the nurse rerostering problem itself and the respective bi-objective model, whereas Sect. 3 is devoted to the presentation of the bi-objective genetic heuristic and Sect. 4 to the computational experiments. Finally, in Sect. 5 some comments are made.