Solving the Multi-Stage Nurse Rostering Problem

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1 Introduction

The nurse rostering problem consists of assigning work shifts to nurses in a hospital, given a time-dependent demand to be met and work agreements to be satisfied [2]. We consider a dynamic version of the problem, which was first formulated as the challenge for the second nurse rostering competition (INRC-II).

In this formulation, given a planning horizon of multiple non-overlapping stages, nurse rosters have to be selected one stage at a time. A stage is a part of the planning period for which the demands are completely known at its start. In principle, a stage could be anything from one week to a number of months. In the competition setting [3], a stage was one week. Fully detailed planning is required for one stage only, while keeping sufficient capacity to satisfy the requirements of the coming stages for which the demands are unknown.

Still, the constraints under which the nurses operate have to be satisfied across the borders of the stages. In particular, the objectives related to the

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total number of assignments and the number of working weekends for a nurse are evaluated only at the end of the whole time horizon. As a consequence, the availability of the nurses for the current week has to be estimated based on some forecasting. For the sake of brevity, we refer to the specification paper of the competition [3] for the detailed formulation.

The inspiration for the problem comes from real world situations in which constraints on the nursing personnel and capacity are set at a longer time than the demands can be known. The competition setting was based on the hypothesis that the overall capacity would be sufficient to match the (partly unknown) demand and that a planning for one stage should avoid to overly stress capacity and constraints for the ones to come.

2 Search methods

We implement two solvers for this problem, based on Mixed Integer Linear Programming and Simulated Annealing, respectively. The first one is an exact method based on the problem formulation proposed in [6] and makes use of the MILP solver CPLEX (v. 12.5) [5], while the second one is implemented using EasyLocal++ (v. 3) [4].

We propose a general strategy for dealing with the global objectives. At each stage, for every nurse we estimate their current bounds on the number of assignments based on their history, their contract and the number of remaining weeks in the planning horizon. The computed limits are rational values that are suitably rounded according to parametric thresholds.

In addition, a "discounted" weight is given to global objectives since their actual violations are only an estimate. The discount is higher in the initial weeks, and goes to 0 for the last one.

This strategy has quite a few parameters, ranging from the thresholds for the rounding to the levels of discount, along with the parameters of the search methods. Different configurations are compared in a statistically-principled way using *json2run* [7] and *irace* [1].

3 Discussion

Experiments are ongoing both on the competition instances (public and hidden) and on new data with a longer horizon. Moreover, since the Simulated Annealing solver is basically applicable to any stage length, we also introduce datasets with multi-week stages. In particular, we consider cases of size up to 32 weeks, with stages of 1, 2, or 4 weeks.

Preliminary results on competition instances show that our solvers are at the level of some of the finalists. Current work on the Simulated Annealing solver involves the definition of composite neighborhoods that swap assignments of nurses on more than one day simultaneously. Besides, we plan on investigating more forecasting strategies and examine them on both of our solvers.

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