On the Multi-objective Nature of Nurse Scheduling

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1 The QMC Nurse Scheduling Problem

Many nurse scheduling problems are described in the literature and most papers focus on solution techniques (see [4, 5]). Here, we investigate the interactions between constraints in a nurse scheduling problem at the Queen's Medical Centre (QMC) in Nottingham, UK. Our aim is to assess if the constraints in nurse scheduling problems are multi-objective in nature in order to better inform the design of multi-objective meta-heuristics to solve these problems. The approach we follow here is to iteratively improve an initial schedule using only one group of constraints to measure solution fitness while recording the 'reaction' (improvement, detriment or no-effect) on the other groups of constraints. We do this for each group of constraints and then we calculate correlations with the data gathered. Our results are interesting because they allow us to have an insight into the interaction between the different nurse scheduling constraints.

In the QMC nurse scheduling problem, 20 to 30 nurses should be scheduled over a planning period of 28 days. There are three shifts: early (E), late (L) and night (N) each with different coverage demand (number of nurses required with certain qualifications and training). Besides satisfying coverage demand, the schedule should also satisfy working regulations and as many nurses' preferences as possible. The are 6 hard constraints (must be satisfied): *OneShiftADay* - a nurse can work only one shift per day; *MaxHours* - nurses work a maximum number of hours; *MaxDaysOn* - nurses work a maximum number of consecutive days without a day-off; *MinDaysOn* - nurses work a minimum number of consecutive days; *Succession* - some shift combinations are not permitted, e.g. night shift followed by early shift; *HardRequest* - nurses express 'hard' preferred shifts (or days-off) for some days and such hard requests must be met. There are 6 soft constraints (should be satisfied): *SoftRequest* - nurses express 'soft' preferred shifts (or days-off) for some days and such soft requests should be met if possible; *SingleNight* - nurses prefer to work night shifts in blocks of two or more; *WeekendBalance* - nurses should not work more than 3 out of 4 consecutive weekends; *WeekendSplit* - nurses prefer to work both days of the weekend or none at all; *Coverage* - the coverage demand for each shift should be satisfied as closely as possible; *CoverageBalance* - the deficit/surplus of coverage demand should be balanced for all shifts in the planning period. A detailed description of the Queen's Medical Centre nurse scheduling problem can be found in the following url: `http://www.cs.nott.ac.uk/~kxl/research/QMC/qmc.html` and in [1]. Techniques applied to this particular problem are mainly based on case-based reasoning, e.g. see [2].

2 Investigating Multiple Objectives

We split the above soft constraints into three groups. Group 'Work Regulations' includes *SingleNight*, *WeekendBalance* and *WeekendSplit*. Group 'Coverage Demand' includes *Coverage* and *CoverageDemand*. Group 'Nurse Preferences' includes *SoftRequest*. We use the following methodology to assess the conflicting nature of these groups of soft constraints:

1. Generate an initial schedule and improve it (minimise penalty) iteratively using 'Work Regulations' only to measure solution fitness (hard constraints are always enforced). We used a hybrid meta-heuristic made of squeaky wheel optimization, multi-neighbourhood search and great deluge to carry out the search for improved schedules.

2. While the solution fitness improves ('Work Regulations' are more satisfied), trace the effect (improvement, detriment, no-effect) on 'Coverage Demand' and 'Nurse Preferences'.

3. With the data gathered in step 2, calculate correlation between the three groups of soft constraints to assess their conflicting (multi-objective) nature.

4. Repeat steps 1-3 five times for each of the seven data sets (March to September 2001).

5. Do steps 1-4 for Group 'Coverage Demand' and then for Group 'Nurse Preferences'.

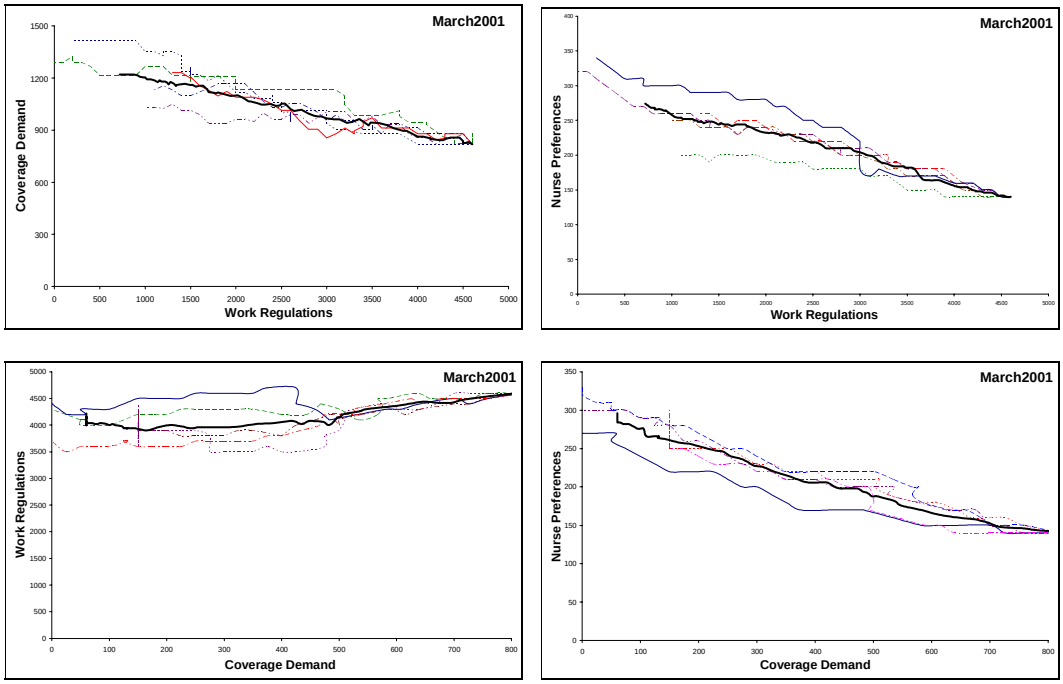

Figure 1: Illustrating the conflicting nature of the constraints in the QMC nurse scheduling problem.

To illustrate our observations see Figure 1 for the March 2001 instance where each line represents an execution of steps 1-2 above. When improving 'Work Regulations', both 'Coverage

Table 1: Conflicting nature between groups of constraints in the QMC problem.

	Group WR	Group CD	Group NP
Group WR	—	conflict	conflict
Group CD	independent	—	conflict
Group NP	independent	independent	—

Demand' and 'Nurse Preferences' seem to worsen (top-left and top-right graphs). When improving 'Coverage Demand', 'Nurse Preferences' seem to worsen (bottom-right graph), but the effect on 'Work Regulations' is not entirely clear (bottom-left graph). This would suggest that 'Work Regulations' (weakly) conflicts with improving 'Coverage Demand'. However, after calculating correlation coefficients it turns out that 'Work Regulations' is in fact independent when improving 'Coverage Demand', i.e. i.e. 'weak conflict' observed is not significant.

Our results suggest that the conflicting nature of the three groups of soft constraints is as summarised in Table 1. Some multi-objective approaches to nurse scheduling have already been published in the literature (see references in [6]) but it is not always entirely clear which constraints are truly conflicting. Our results help us to group constraints into different conflicting objectives in a meaningful manner for the application of multi-objective approaches to nurse scheduling. We are using this information to approach the QMC in a multi-objective fashion [3].

References

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