A systematic two phase approach for the Nurse Rostering problem

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Abstract

Nurse Rostering is a combinatorial problem hard to solve due to its size and complexity. Several real world details that arise in practice make computerized approaches to the problem indispensable. The specifications of the problem that we solve are those defined in the Nurse Rostering Competition INRC2010.

In this contribution, we solve the Nurse Rostering Problem by partitioning the original problem into sub-problems. Each sub-problem has size that is computationally manageable and is solved using Mathematical Programming. We implemented a two phase strategy, where in the first phase an assignment of nurses to working days occurs while in the second phase nurses assigned to each day are scheduled to certain shifts of the day. The problem is scanned several times from start to end and an extensive number of partial schedule exchanges between nurses are tried. The two phases are presented below.

Phase 1: Assignment of nurses to working days

At the first phase the working and resting days of all nurses for the specified planning horizon are defined. Then an Integer Programming problem is defined and solved for the first week (7 consecutive days) of the planning horizon. The formulation of the IP model ensures the satisfaction of the hard constraints imposed by the problem. For this reason the total number of nurses that work in each day should equal the work demand of the day and each nurse should work no more than one shift in each day. In this phase the only soft constraints that are considered are those that depend on work or rest assignment. These constraints are used at the cost function. All the possible combinations of work/rest for a week period are examined for all nurses (128 possible values for each nurse). In this way a feasible schedule of all nurses are produced, that covers the daily
demand and satisfies as many as possible soft constraints. Similar problems are solved for all next weeks, until the entire planning horizon is covered and no more improvements can be achieved.

**Phase 2: Assignment of nurses to shift types**

The solution of the previous phase defines which nurses should work in each day. An Integer Programming problem is then formulated for assigning them to specific shift types as dictated by the shift type demand of each day. The constraints of the IP model ensure that all the available nurses will be assigned to proper shift types. The IP considers only those soft constraints that depend on shift assignment. These constraints are used at the cost function. Similar problems are solved for all days, until the full planning period is covered.

The problems defined at phase 1 and 2 are solved repeatedly, until no more better schedules can be obtained. The sequence of the two phases is executed many times, starting each time from a randomly generated schedule, until the allowed running time is exceeded.

A fast cost evaluator has been implemented so as to provide cost values per nurse needed by the mathematical solvers. The evaluator is designed to provide two cost components: work assignment related cost, for using at the first phase and shift assignment related cost for using at the second phase.

The solver is implemented in Java and The GNU Linear Programming Kit (GLPK) library is used for solving all the Integer Programming problems defined above.

**Medium and Long problems**

The above mentioned approach has been employed for the sprint problems. For the medium and long problems 3 additional local search techniques are used.

The first, called CutAtOneDay, cuts the whole schedule at any day and tries to rearrange the generated schedule parts for all nurses in a different way, looking for a schedule with better total cost.

The second, called CutAtTwoDays, cuts the whole schedule at any two day combinations and tries to rearrange the generated schedule parts for all nurses in a different way, looking again, for a schedule with better total cost.
The third, called 2Opt, examines moves at the schedule between of any two nurses and accepts these changes that gives a schedule with better total cost.