Nurse Rostering

Problem specification
for the project of the course
Advanced Scheduling Systems (2014-15)

December 20, 2014

The Nurse Rostering Problem [1, 3] consists in the scheduling of a fixed number of nurses using a set of shifts, such that in each day a nurse works a shift or has a day-off. Nurses may have multiple skills, and for each skill we are given different coverage requirements.

The problem we propose here is a simplified version of the one defined for the 2nd International Nurse Rostering Competition [2].

Input data

The problem is defined by the following information:

Skills: The list of skills included in the problem (head nurse, regular nurse, trainee, . . . ). Each nurse has one or more skills, but in each working shift she/he covers exactly one skill request.

Contracts: Each nurse has one specific contract (full time, part time, on call, . . . ). The contract sets limits on the distribution and the number of assignments within the planning horizon (in our case, 1 week). In detail, it contains:

• minimum and maximum total number of assignments in the planning horizon;
• a Boolean value representing the presence of the Complete week-end constraint to the nurse, which states that the nurse should work either both days of the week-end or none of them.

Nurses: For each nurse, the name (identifier), the contract and the set of skills are given.

Shift types: For each shift type (early, late, night, . . . ), it is given a matrix of forbidden shift type successions. For example, it may not be allowed to assign to a nurse an early shift the day after a late one.

Requirements: It is given, for each shift, for each skill, for each day, both the optimal and the minimum number of nurses necessary to fulfil the working duties.

Nurse requests: It is given, a set of triples, each one composed by the nurse name, the week day, and a shift. The presence of a given triple represents the request of the nurse not to work in the given shift in the given day. The special shift name Any represents the request of not working in any shift of the day, i.e., having a day-off.

Conventionally, the week starts with Monday, so that the data is stored in the order Mon, Tue, . . . , Sun.

Solution

The output produced by the solver is a list of assignments of nurses to shifts and skills. Each entry contains the nurse name, the week day, the shift, and the skill. As an example, consider the entry ⟨Mary, Tue, Night, HeadNurse⟩, that states that the nurse Mary works on Tuesday the night shift with the role of head nurse.
Constraints

As customary, we split the constraints into hard and soft constraints. The former must be always satisfied, and the latter contribute to the objective function. The weight of each single soft constraint is shown in parenthesis prior to its description below.

Below is the list of hard (H) and soft (S) constraint types:

**H1. Single assignment per day:** A nurse can be assigned to at most one shift per day.

**H2. Under-staffing:** The number of nurses for each shift for each skill must be at least equal to the minimum requirement.

**H3. Shift type successions:** The shift type assignments of one nurse in two consecutive days must belong to the legal successions provided.

**H4. Missing required skill:** A shift of a given skill must necessarily be fulfilled by a nurse having that skill.

**S1. Insufficient staffing for optimal coverage (3):** The number of nurses for each shift for each skill should be equal to the optimal requirement. Each missing nurse is penalised according to the weight provided. Extra nurses above the optimal value are not considered in the cost.

**S2. Preferences (1):** Each assignment to an undesired shift is penalised by the corresponding weight.

**S3. Complete week-end (3):** Every nurse that has the complete weekend value set to true, must work both week-end days or none. If she/he works only one of the two days Sat and Sun this is penalised by the corresponding weight.

**S4. Total assignments (2):** For each nurse the total number of assignments (working days) must be included within the limits (minimum and maximum) enforced by her/his contract. The difference (in either direction), multiplied by its weight, is added to the objective function.

File formats

In this section we describe the format for the input file (instance) and output file (solution).

**Instance**

The first part of the file contains the number and names of skills for nurses.

```
SKILLS = 2
HeadNurse
Nurse
```

The shift types section indicates the number of shift types available, and for each one, the identifier (its name) and the forbidden shift types sequences as \(\langle\text{preceding\_shift\_type}\rangle\langle\text{number\_forbidden\_successions}\rangle\langle\text{succeeding\_shift\_type\_list}\rangle\). In the following example, the successions Late \(\rightarrow\) Early, Night \(\rightarrow\) Early and Night \(\rightarrow\) Late are forbidden.

```
SHIFT\_TYPES = 3
Early 0
Late 1 Early
Night 2 Early Late
```

In the contract section it is listed the name of the contract type, and the lower and upper limits on working days and rest days. In detail, it establishes the minimum and the maximum number of total assignments in the planning horizon, and the presence (1) or absence (0) of the complete weekend constraint.

```
CONTRACTS = 2
FullTime (4,5) 1
PartTime (2,3) 1
```
The nurse section reports the total number of nurses available, and for each nurse his/her identifier (the name), the contract type, the number of skills owned and their names.

NURSES = 5
Patrick FullTime 2 HeadNurse Nurse
Andrea FullTime 2 HeadNurse Nurse
Stefaan PartTime 2 HeadNurse Nurse
Sara PartTime 1 Nurse
Nguyen FullTime 1 Nurse

Then all the data about coverage requirements and nurse preferences is listed. A coverage requirement is specified by the shift type, the skill, and for each day of the week (from Monday to Sunday), the minimum coverage and the optimal coverage.

REQUIREMENTS
Early HeadNurse (1,1) (0,0) (0,0) (0,0) (0,0) (1,1) (0,0)
Early Nurse (1,2) (1,1) (1,1) (0,1) (1,1) (1,1) (0,1)
Late HeadNurse (1,1) (0,1) (1,0) (0,0) (0,0) (0,0) (0,0)
Late Nurse (1,1) (1,1) (0,1) (1,1) (1,1) (1,1) (1,1)
Night HeadNurse (0,0) (1,0) (0,0) (0,0) (1,1) (1,1) (0,0)
Night Nurse (0,1) (1,1) (1,1) (1,1) (0,1) (0,1) (1,1)

Finally, the number of shift off requests is reported with the following grammar: \langle \text{nurse} \rangle \langle \text{shift type} \rangle \langle \text{day} \rangle.
The special shift type \text{Any} means that the nurse would like to have a day off.

SHIFT_OFF_REQUESTS = 3
Sara Any Thu
Sara Night Sat
Stefaan Late Sat

Solution
The solution file gives the assignment of nurses to shifts and skills. Each single assignment is shown (in any order), reporting the name of the nurse, the day, the shift type and the skill considered. Days off are neglected.

Patrick Mon Late HeadNurse
Patrick Tue Night HeadNurse
Patrick Fri Early Nurse
Patrick Sat Early Nurse
Patrick Sun Late Nurse
Andrea Mon Early Nurse
Andrea Tue Late Nurse
Andrea Wed Late HeadNurse
Andrea Sat Early HeadNurse
Andrea Sun Early Nurse
Stefaan Mon Early Nurse
Stefaan Tue Early Nurse
Stefaan Wed Early Nurse
Stefaan Thu Early Nurse
Stefaan Fri Night HeadNurse
Stefaan Sat Night HeadNurse
Stefaan Sun Night Nurse
Sara Tue Night Nurse
Sara Wed Night Nurse
Sara Thu Night Nurse
Sara Fri Night Nurse
Nguyen Mon Late Nurse
Nguyen Thu Late Nurse
Nguyen Fri Late Nurse
Nguyen Sat Late Nurse
Nguyen Sun Night Nurse
References

