



Artificial Intelligence Methods (G52AIM)

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***Case Study – AI Methods for
Nurse Rostering Problems***



Outline

- Problem description
- A hybrid algorithm
 - Constructive heuristics
 - A variable neighbourhood search
- Algorithm performance on benchmark problems
- Conclusions



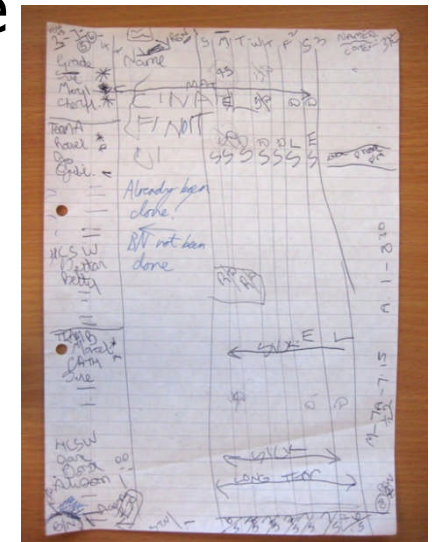
Problem description

- Hospitals operate 24/7, introduces constraints related to different shifts and weekends
- Different grade and skill mixes
- Cover requirements can vary
- Difficult optimisation problem with many **constraints** and **objectives**
- Time consuming, frustrating and stressful problem



Problem description

- Schedule a number of shifts to nurses in rosters, satisfying a set of constraints
 - Enough number of shifts (of different types) coverage on each day during the scheduling period
 - Working/resting hours limit, complete weekends, skill levels, personal preferences, etc
 - ...





Problem Formulation

- Hard constraints
 - binding, feasibility, or imperative planning rules
- Soft constraints
 - floppy, non binding, preference planning rules
- Weights
 - to specify relative priorities
 - weighted sum objective function



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Too few resting time (10)

Too few consecutive late shifts (5)

Too few consecutive night shifts (5)

Total Penalty 176
Unassigned Shifts 0

Minimum Cover

E	1	2	2	2	1	1	1	1	2	2	2	1	1	1	1	2	2	2	1	1	1	1	2	2	2	1	1	1
D	2	1	1	1	2	1	1	2	1	1	1	2	1	1	2	1	1	1	2	1	1	1	2	1	1	1	2	1
DH	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
L	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
N	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1



Research in Nurse Rostering

- Meta-heuristics heavily used
 - Tabu Search
 - Simulated Annealing
 - Variable Neighbourhood Search
 - Genetic Algorithms
 - Ant algorithms
 - ... , etc



Research in Nurse Rostering

- Heuristics
 - Advantages
 - Can exploit problem specific information
 - Do not require expensive software packages
 - Disadvantages
 - More programming involved
 - Can be inconsistent



Case Study

- Variable neighbourhood search (VNS) showed to be very effective on a number of optimization problems
- Employ at least two neighbourhood operators
- Traverses between different search space defined by several neighbourhood structures
- Effective on escaping from local optimum, thus no need of delicately designed acceptance criteria



Case Study

- HARMONY™
 - Automated workforce management software
 - Developed by ORTEC, The Netherlands, an international consultancy company on planning, scheduling, optimisation and decision support
- This work improved the algorithm in HARMONY™



Case Study

- The problem

12 Full-time nurses	36 hours/week
1 Part-time nurse	32 hours/week
3 Part-time nurses	20 hours/week

			Demand						
Shift type	Start time	End time	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Early	07:00	16:00	3	3	3	3	3	2	2
Day	08:00	17:00	3	3	3	3	3	2	2
Late	14:00	23:00	3	3	3	3	3	2	2
Night	23:00	07:00	1	1	1	1	1	1	1



Case Study

- Hard constraints
 - HC1: daily coverage requirement of each shift type
 - HC2: for each day, a nurse works at most one shift
 - HC3: max number of working days per month
 - HC4: max number of on-duty weekends per month
 - HC5: max number of night shifts per month
 - HC6: no night shift between two non-night shifts
 - HC7: min two free days after a series of night shifts
 - HC8: max number of consecutive night shifts
 - HC9: max number of consecutive working days
 - HC10: no late shifts for one particular nurse



Case Study

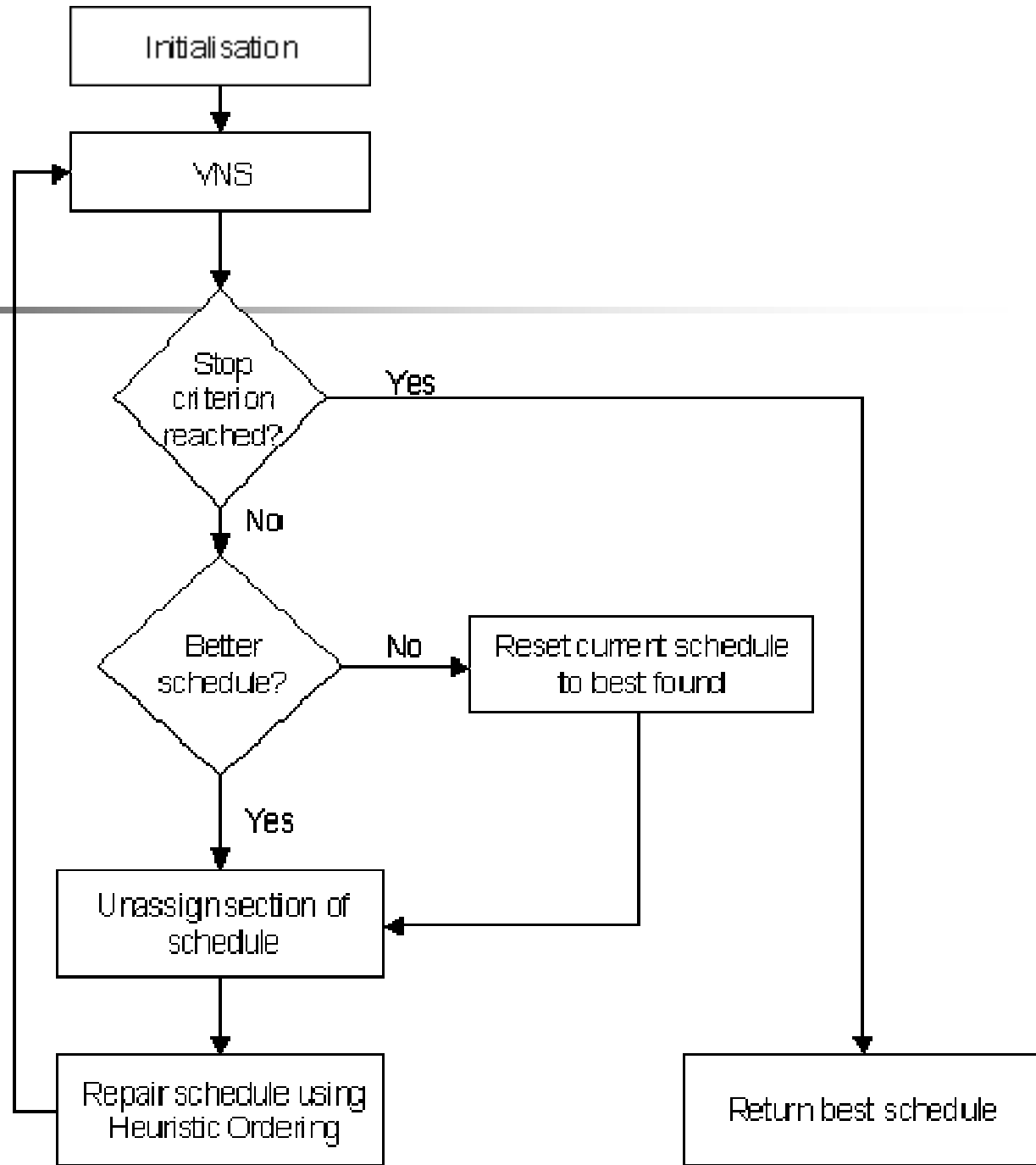
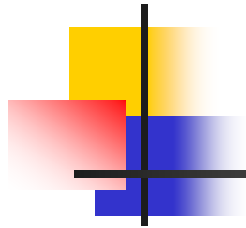
- Soft constraints

SC1	either no shifts or two shifts in weekends	1000
SC2	avoiding a single day between two days off	1000
SC3	length of a series of night shifts	1000
SC4	Min number of free days after a series of shifts	100
SC5	Max/Min number of consecutive assignments of a specific shift type	10
SC6	Max/Min number of weekly working days	10
SC7	Max number of consecutive working days for part-time nurses	10
SC8	avoiding certain shift type successions (e.g. a <i>day</i> shift followed by an <i>early</i> one, etc)	5



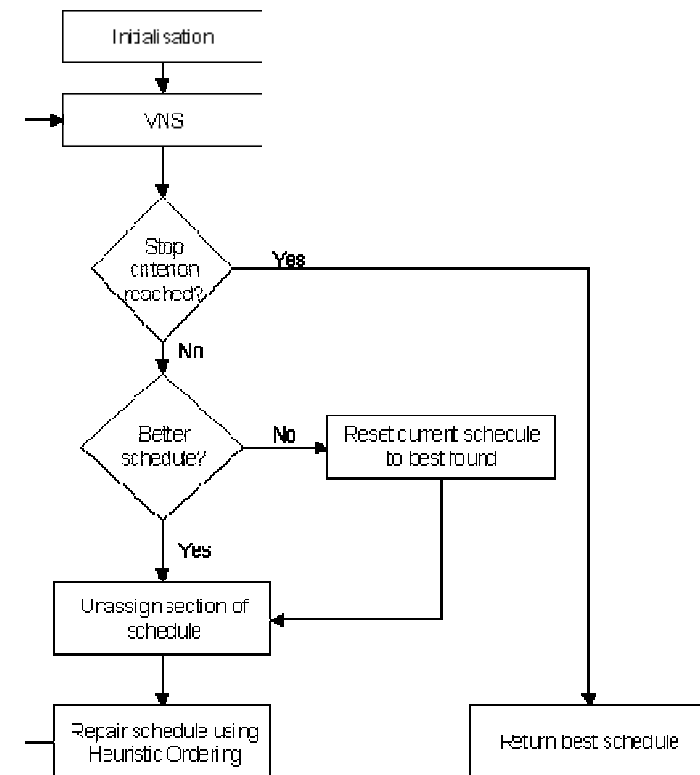
Case Study – hybrid algorithm

- Hybrid Algorithm
 - Construction
 - Heuristic ordering of shifts
 - VNS
 - Improvement upon rosters
 - Repair method
 - Remove worse part of roster and re-construct



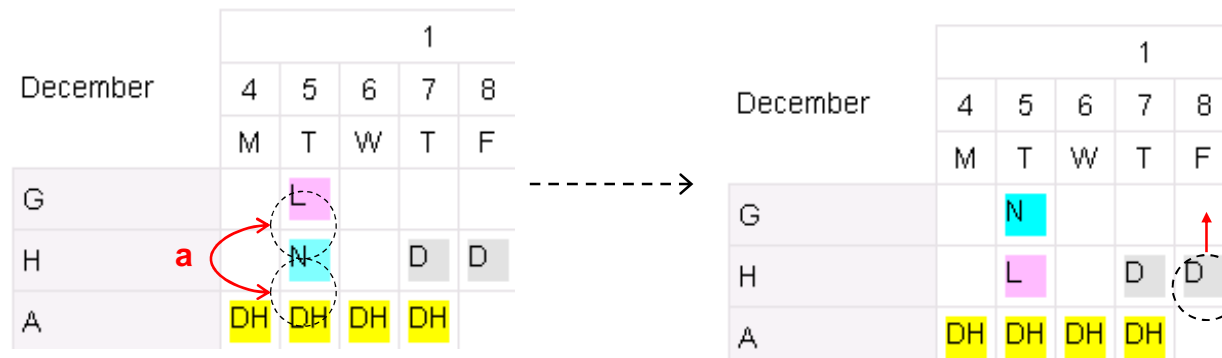
Case Study – hybrid algorithm

- Heuristic ordering
 - Order shifts for construction in initialisation and repair
 - More troublesome shifts assigned first
 - Criteria to evaluate the shifts
 - Type of shifts, number of employees able to cover it, etc



Case Study – hybrid algorithm

- Variable Neighbourhood Search
 - Neighbours of a solution
 - those schedules that can be obtained by making a “move” e.g. single shifts swapped between any two nurses, etc
 - Two neighbourhood operators
 - Assign a shift to another nurse
 - Swap shifts between nurses



Case Study – hybrid algorithm

- Repairing method
 - After VNS reached to a local optimum
 - Un-assign a section of roster for further possible improvement
 - Re-assign shifts ordered by heuristic ordering

