KHE26: Progress Towards an Efficient, Practical Nurse Rostering Solver

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This talk

- The nurse rostering problem
- The KHE26 solver
- Success in practice
- Results
- How the results were improved

The nurse rostering problem

- Assign nurses to shifts in hospital wards
- 24 / 7 operation, so morning, afternoon, night etc. shifts
- *Cover constraints* for shifts: 3 to 5 nurses, at least 1 senior nurse, …
- *Resource constraints* for nurses:
  - At most one shift per day
  - Counters: at most 20 busy days; at most 2 busy weekends, …
  - Sequences: at most 5 consecutive night shifts, …
  - Unwanted patterns: day shift after night shift, incomplete weekends, …

About the KHE26 nurse rostering solver

- Built on the KHE solve platform (read, write, evaluate solutions, etc.)
- Aims for *success in practice*
- Runs in polynomial time (weighted bipartite matching, ejection chains)
- Uses the XESTT data format, which is good because:
  - Many well-known instances are available in XESTT
  - XESTT uses only 9 constraint types (3 cover, 6 resource)

The solver's algorithm (simplified)

- Find initial solution using time sweep (PATAT 2018)
- Repair using several methods, but mainly
  - Polymorphic ejection chains (PATAT 2012)
- Run 12 independent solves in parallel, keep the best solution. Integral part of solver, not just for testing.

The aim: success in practice

A solver is **successful in practice** if, on every instance likely to occur in practice:

- It finds a solution with cost within 10% of the best known within 5 minutes
- And it finds a solution with cost within 5% of the best known within 60 minutes

Points to note:

- An alternative to finding new best solutions, not a replacement.
- Implies testing on a wide range of instances.
- Challenging despite not requiring new best solutions.

Results – work in progress

Results not in paper, but from my diary (5 minute runs):

Data set	Percent worse
Curtois original instances (*)	14%
First International Nurse Rostering Competition (Long and Medium)	7%
First International Nurse Rostering Competition (Sprint)	1%
Second International Nurse Rostering Competition (4 Week) (**)	11%
Second International Nurse Rostering Competition (8 Week)	-
Curtois and Qu (2014)	-

These are **averages** over all instances in the set.

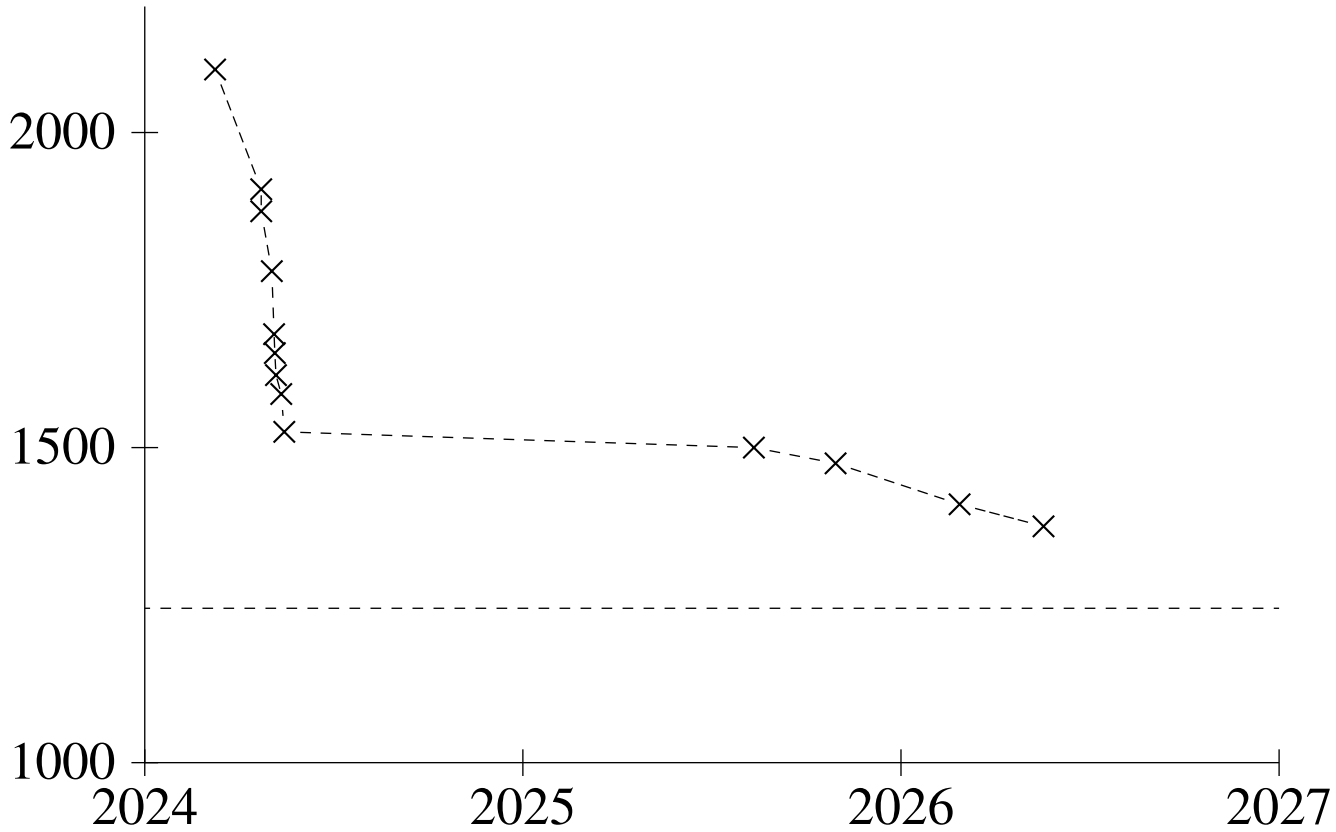
(*) Omitting some instances whose solutions have almost zero cost.

(**) These results appear in full in the Proceedings. KHE24 was 34% worse here.

The key issue raised by this talk

How can the results be so much improved, when the basic structure of the solver has hardly changed?

Improvement in the the INRC2-4-100-0-1108 results



Significant changes since KHE24 (omitting outlying costs)

Improvement	Before	After
Turn off unhelpful code	2100	1910
12 solves (5 mins each) instead of 24 solves (2.5 mins each)	1910	1875
Better repairs for undersized busy and free sequences	1875	1780
Proportionately more time given to ejection chains	1780	1680
Bug fix (some max widening values were wrong)	1680	1650
Include repairs that widen to end of cycle	1650	1615
Unassigning optional tasks at end when swapping	1615	1585
Parameter tuning (amount of initial optimal assignment)	1585	1525
Using history to find assignments at start of cycle	1525	1500
Keep best assignment for each resource type separately	1500	1475
Reimplement ejection chains, add ejecting moves	1475	1410
Improved memory handling	1410	1375

Resource Solvers

Task domain reduction
Resource flow
Workload packing
Tilting the plateau
Propagating unavailable times
Making expensive tasks unassignable
Constraint classes
Multi-tasks

Task grouping (5 kinds)
Requested task assignments
Assignment by history
Optimal resource reassignment
Weighted bipartite matching
Time sweep
Ejection chain repair
Do-it-yourself solving

Conclusion

- Slow but substantial progress
- Based on analysing defects in existing solutions
- Improvements found for one instance usually apply to many
- Work in progress