Hyper-Heuristics for Personnel Scheduling Problems

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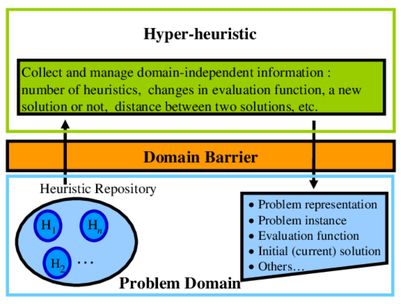
Problem and Contribution

- **Goal:** Use general solution methods for complex real-life personnel scheduling
- **Issues:** Complex requirements frequently change, problem-specific methods are hard to adapt
- **Contributions:**
  - Investigation of different state-of-the-art hyper-heuristics on three real-world domains
  - New low-level heuristics
  - New best solutions
  - Practically relevant problem versions

Solution Method



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- Hyper-heuristics are problem-independent
- Choose among a set of low-level heuristics
- Problem domain returns change in solution value and execution time
- Evaluating ALNS, solution-chain methods (CH), adaptive dynamic heuristic sets (GIHH), single and multi-solution method (HAHA)

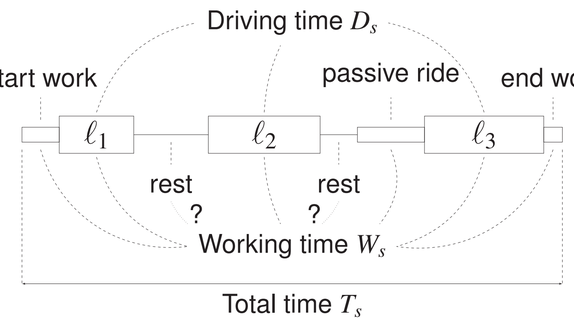
Low-Level Heuristics

- Local search heuristics:
  - First Improvement (1 or 10 steps)
  - Best Improvement (1 or 10 steps)
  - Random Improvement
- Mutation heuristics:
  - Random improvement with different metropolis acceptance criteria
  - Random walk with 1 or 10 steps
- Domain-specific moves
- Domain-specific destroy and repair heuristics, very important for structural solution changes

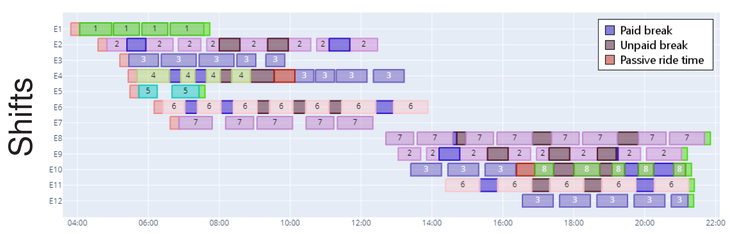
Real-Life Problem Domains

Bus Driver Scheduling

- Input: Predetermined bus legs (vehicle, start and end time, start and end position)
- Complex break constraints:



- Solution: Assignment of drivers



- Moves: Swap individual legs or sequences
- Destroy-repair: Remove whole employee or whole tour, reassign best position

Rotating Workforce Scheduling

- Input: Varying demand for shifts

Shift	Mo	Tu	We	Th	Fr	Sa	Su
D	1	1	1	1	1	1	1
A	1	1	1	1	1	1	0
N	1	1	1	1	1	1	1

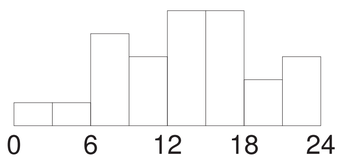
- Number of employees n
- Constraints on lengths of sequences of shifts and days off
- Solution: Rotating schedule

Empl.	Mo	Tu	We	Th	Fr	Sa	Su
1	D	D	D	D	N	N	-
2	-	-	A	A	A	A	N
3	N	N	-	-	D	D	D
4	A	A	N	N	-	-	-

- Three different objectives to optimize free weekends
- Moves: Swap shift or sequence of shifts between rows
- Destroy-repair: Remove whole day or consecutive weeks, reassign best position

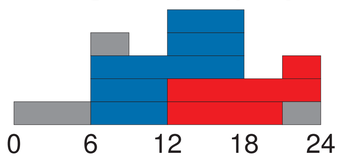
Minimum Shift Design

- Input: Demand and shift types



shift type	t_1	t_2
min start	6:00	12:00
max start	6:00	21:00
min length	6:00	6:00
max length	12:00	12:00

- Solution: Set of shifts with number of assigned employees



shift start	shift end	empl.
6:00	18:00	3
12:00	24:00	2
21:00	9:00	1

- Combined optimization objectives:
  - T_1: Sum of excesses of workers (overcover)
  - T_2: Sum of shortages of workers (undercover)
  - T_3: Number of different shifts
  - $\mathbf{T_4}$ (not considered before): Deviation of the average shift length from the defined window
- Moves: Add shift, remove shift, modify shift
- Destroy-repair: Remove class of shifts or whole day, reassign best shifts from existing classes or overall best shifts

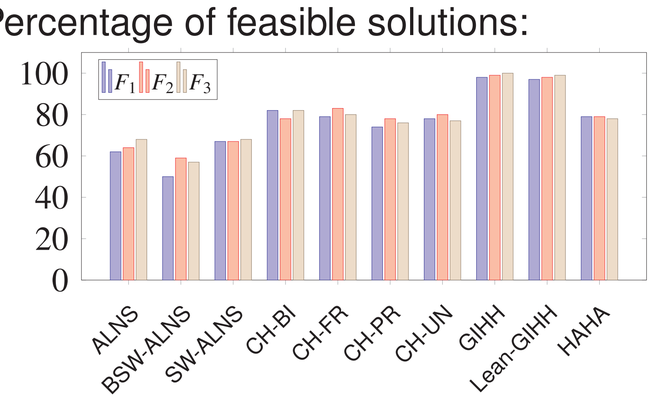
Evaluation

Bus Driver Scheduling

- Hyper-heuristics outperform previous heuristic methods
- New best solutions for some of the largest instances compared to Branch and Price
- Best results by Lean-GIHH, GIHH, CH-PR

Rotating Workforce Scheduling

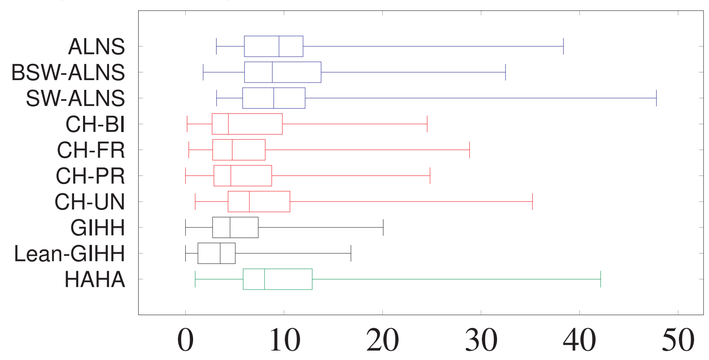
- Percentage of feasible solutions:



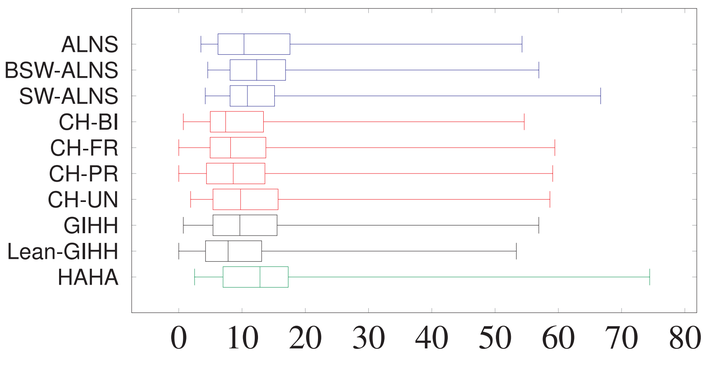
- Several new best solutions compared to previous Minizinc model

Minimum Shift Design

- Gap (%) to optimal results without T_4:



- Gap (%) to lower bound with T_4:



Overall Evaluation

- Number of best results:

Method	BDS	F_1	F_2	F_3	MSD	$+T_4$
ALNS	3	10	7	7	10	11
BSW-ALNS	4	9	6	5	16	16
SW-ALNS	5	11	6	7	16	18
CH-BI	4	12	11	11	28	32
CH-FR	9	13	13	8	25	30
CH-PR	11	12	13	8	25	38
CH-UN	5	12	12	9	18	19
GIHH	13	**17**	**20**	**16**	28	25
Lean-GIHH	**15**	16	15	15	**76**	**46**
HAHA	1	13	8	11	9	14

- Best performance by GIHH and streamlined version Lean-GIHH

Future Work

- Implementation of Lean-GIHH in productive system
- Deep evaluation of effect of individual low-level heuristics
- Work on own hyper-heuristic

[1] Figure from Burke, Edmund et al. The Cross-Domain Heuristic Search Challenge - An International Research Competition. 2011.

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