Heuristic Augmentation of SAT Solvers for MRCPSP

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1 MRCPSP

Multi-Mode Resource Constrained Project Scheduling Problem

NP-hard scheduling problem that concerns activities with several **execution modes** connected by **precedence relations** [1].

Precedence Relations
Define a partial order in which activities must be tackled.

"I can't start working on the roof 🏠 if the walls 🧱 aren't finished!"

Activity Execution Modes
Define the duration and (renewable and non-renewable) resource demands.

"I can be done in 4 days if you give me 2👷 and 3💵. With 1👷 and 1💵 the best I can do is 6 days!"

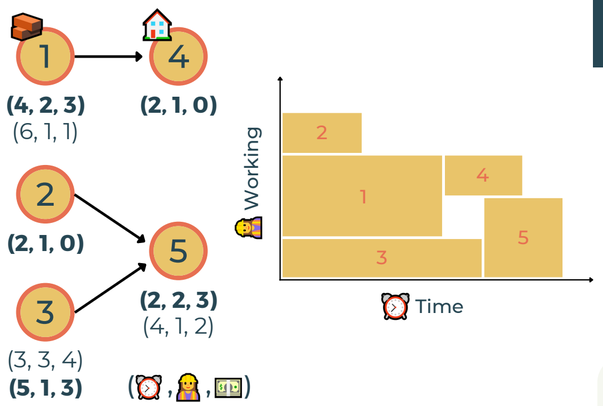

Figure 1: Precedence graph and optimal solution of example MRCPSP instance [2].

Can heuristics be used to increase the performance of SAT Solvers for MRCPSP?

2 Methodology

(Priority-Rule) Heuristic

Generates various schedules based on different activity and mode selection priority rules and selects the best feasible schedule.

- Cheap and fast
- Decent upper bound solutions
- Possibly infeasible solutions

1

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MaxSAT Solver

Maximum **Sat**isfiability Solvers encode MRCPSP as a Boolean formula and gradually find better schedules.

- Certify optimality
- Flexible and extendable
- Require upper bound to work

2

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Improved Solver

MaxSAT solver with improved decision making by...

- Being given the initial solution found by the heuristic method (when available)
- Focusing on finding a feasible mode allocation with Longest Feasible Mode (LFM) priority rule

3

3 Heuristics

Select an Activity > **Select a Mode** > **Schedule at EFT***

Try different rules:
Latest Start Time
Latest Finish Time
Remaining Work

Try different rules until one works:

*Earliest Feasible Time

EFFT
Mode that allows for the Earliest Feasible Finish Time
Why?
Best Performance
Shown by Lova et al. [3]
3
(3, 3, 4)

LFM
The Longest Feasible Mode
Why?
Most likely Feasible
Modes are typically cheaper
3
(5, 1, 3)

WPM
Creates fictional Worst Possible Mode
Why?
Provides Upper-Bound
Needed for SAT encoding
3
(5, 3, 4)

4 Results (Original vs. Improved)

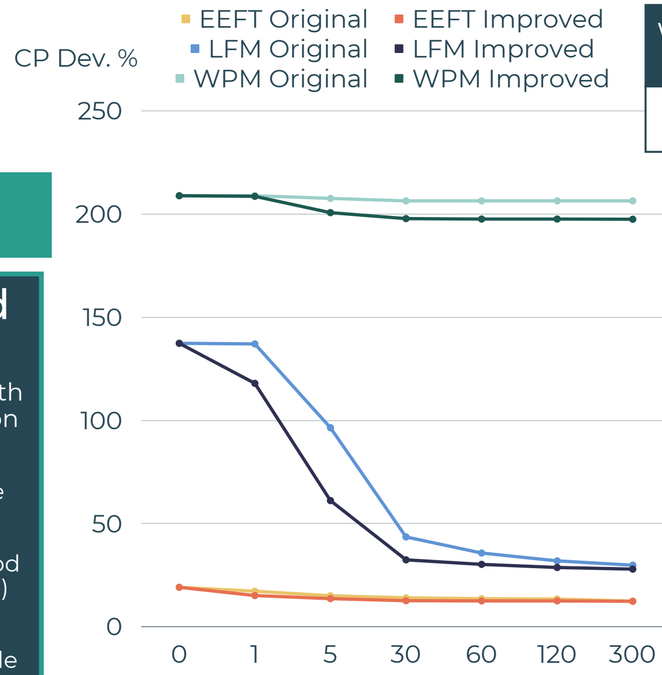

Figure 2: Average % deviation from critical path (CP Dev. %) of original and improved MaxSAT solver on the MM100 dataset at different timestamps. The critical path is the optimal solution when resource constraints are relaxed.

WORST POSSIBLE MODE	SUM OF LONGEST MODES
92.7 MB	3.91 GB

Table 1: Average encoding size of worst possible mode (WPM) and sum of longest modes (SLM) upper bounds on MM100 dataset.

5 Conclusions & Limitations

- The feasibility of a MaxSAT solving approach to MRCPSP remains largely dependent on initial upper bounds.
- The WPM allows for reasonable encoding sizes but still fails to provide sufficiently tight upper bounds on the largest datasets (MM100).
- Providing an initial solution to the MaxSAT solver allows it to find solutions faster but it does not find better ones.
- Having the MaxSAT solver focus on finding feasible mode allocations with the LFM priority rule allows it to find better solutions, but only for a subset of instances.
- While promising, more work is needed on augmenting the MaxSAT solver to find feasible mode allocations.

[1] Artigues et al. Resource-Constrained Project Scheduling. 1st ed. Wiley-ISTE, 2008.
[2] Kolisch et al. "Local search for nonpreemptive multi-mode resourceconstrained project scheduling". In: IIE Transactions 29.11 (Nov. 1997), pp. 987–999.
[3] Lova et al. "Multi-mode resource constrained project scheduling: Scheduling schemes, priority rules and mode selection rules". In: Inteligencia Artificial, Revista Iberoamericana de Inteligencia Artificial 10 (Dec. 2006), pp. 69– 86.