Scalable Rail Planning and Replanning: Winning the 2020 Flatland Challenge

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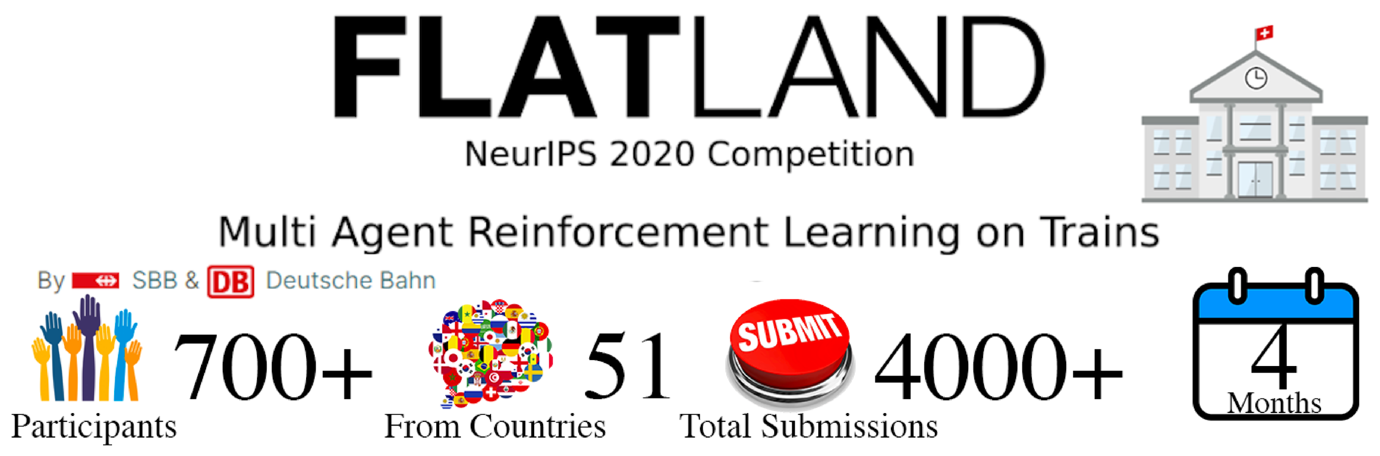
Abstract

Multi-Agent Path Finding (MAPF) is the combinatorial problem of finding collision-free paths for multiple agents on a graph. This paper describes MAPF-based software, which incorporates many state-of-the-art MAPF or optimization technologies, for solving train planning and replanning problems on large-scale rail networks under uncertainty. The software recently won the 2020 Flatland Challenge, a NeurIPS competition trying to determine how to efficiently manage dense traffic on rail networks.

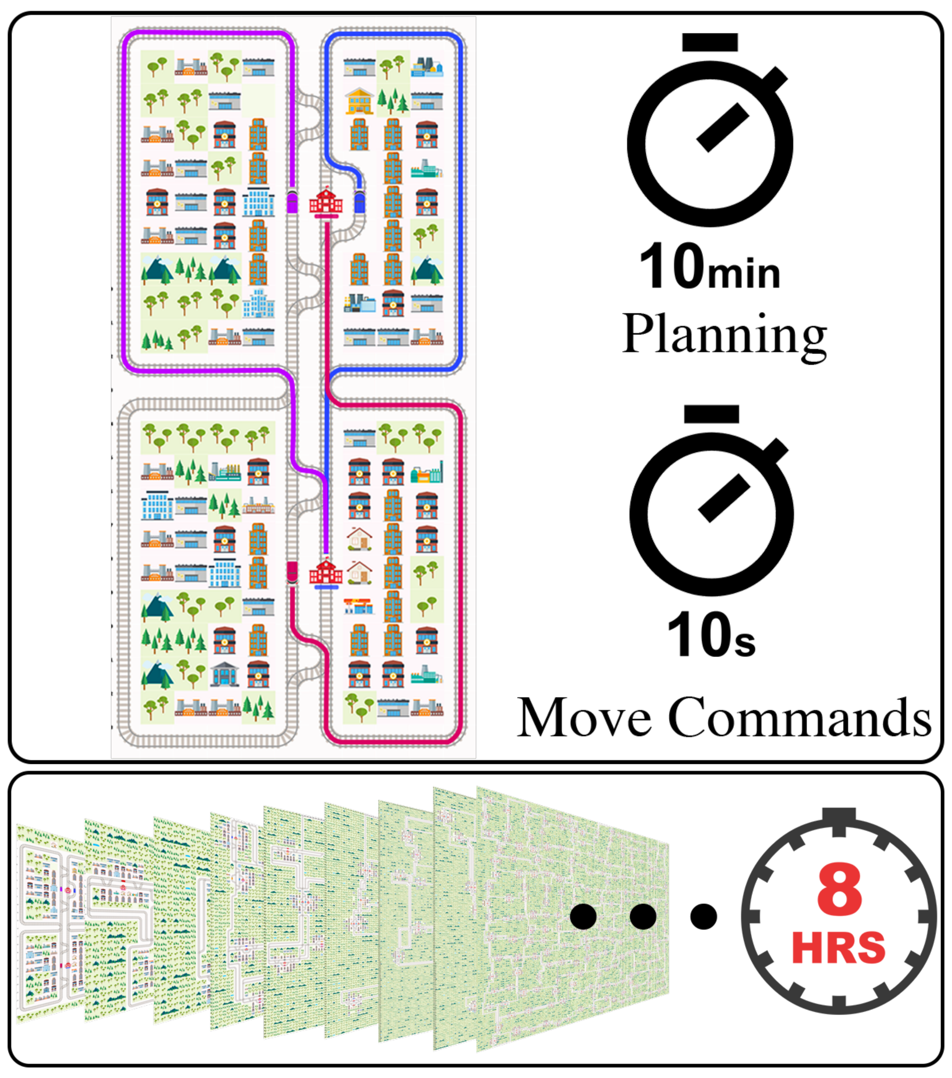
Scan the QR code to watch a fantastic demonstration video! (https://youtu.be/Pw4GBL1UhPA)

Flatland Challenge

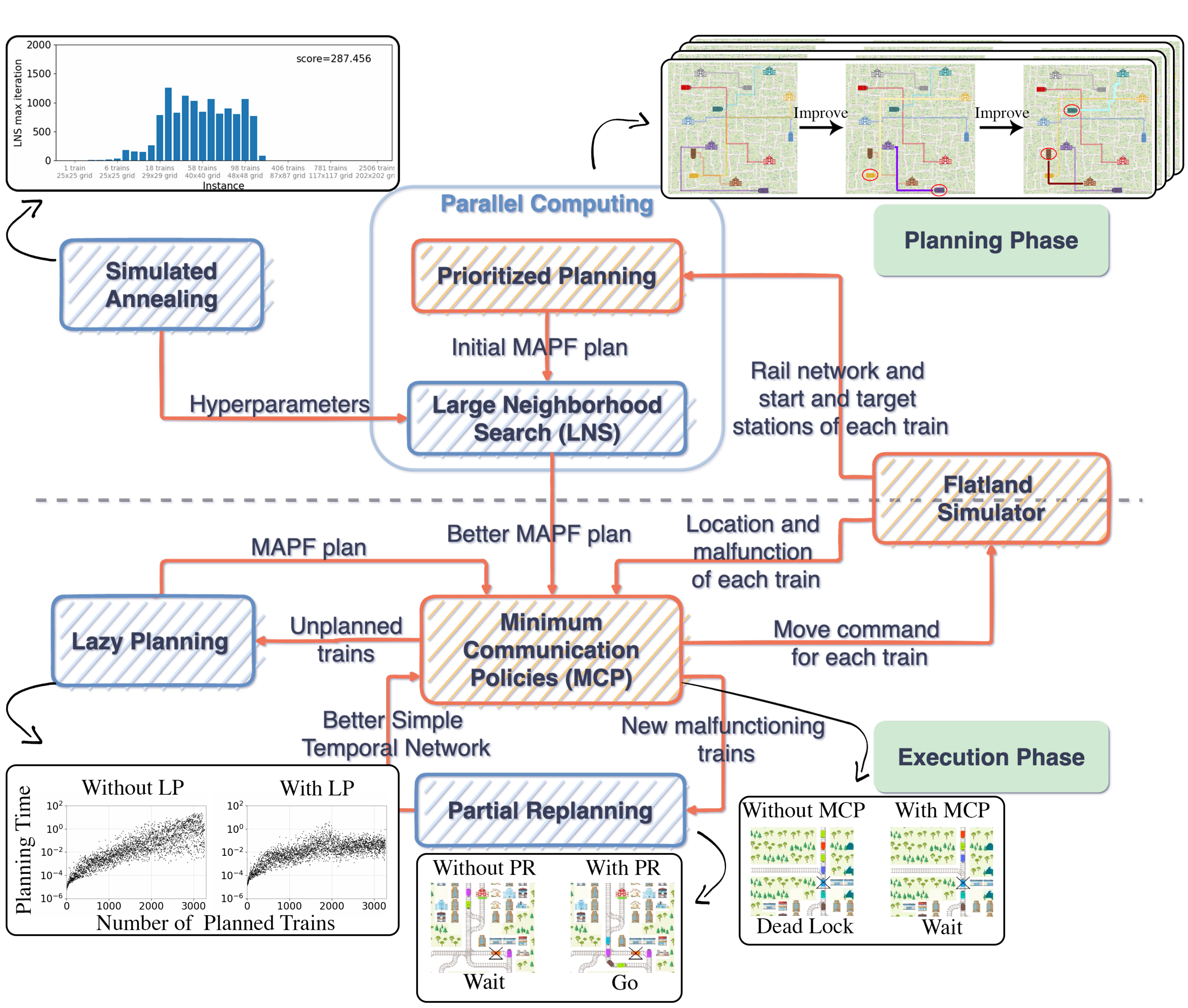


In the 2020 NeurIPS Flatland Challenge, participants:

- need to move trains to their target stations without collisions and properly handle malfunctions during execution.
- are given 10 minutes per instance for initial planning and 10 seconds per timestep to generate move commands for trains.
- are asked to maximize the total reward over an infinite number of instances of increasing difficulty within 8 hours.



Solution



Planning Phase

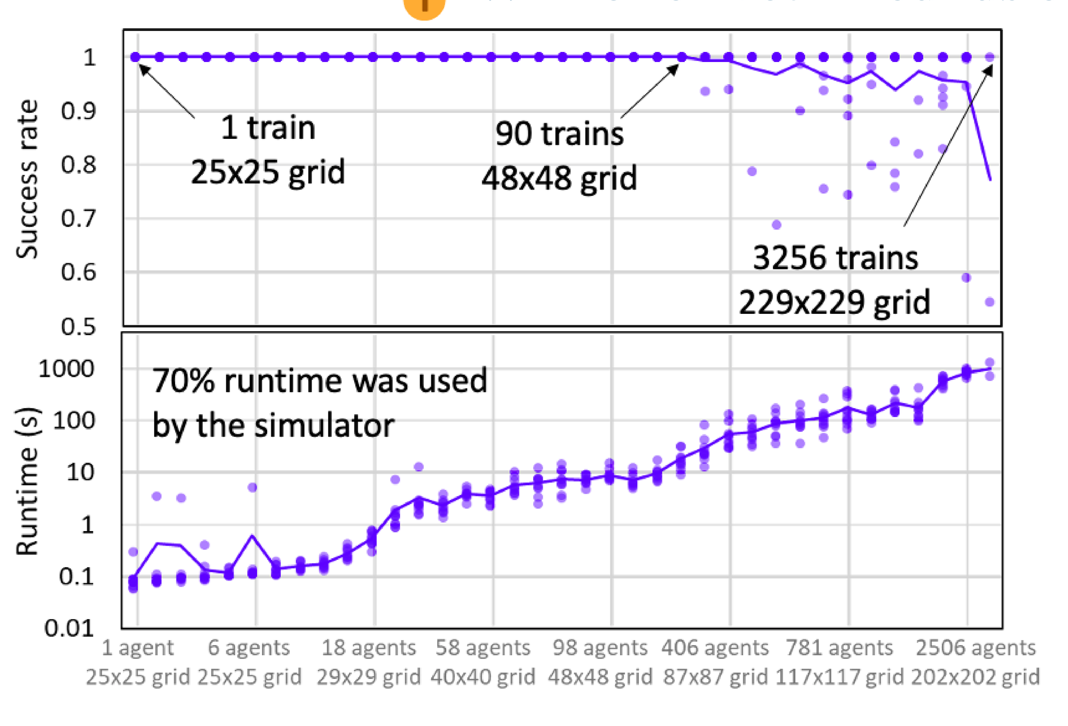
- We use Prioritized Planning (PP) to generate a collision-free initial MAPF plan.
- To improve the quality of the MAPF plan, we keep replanning a subset of trains via Large Neighborhood Search (LNS) until an iteration limit is reached.
- We use Simulated Annealing to determine LNS iteration limits for instances of different sizes to trade-off solution quality with runtime.
- We run 4 LNSes in parallel with different initial priority orderings and pick the best result.

Execution Phase

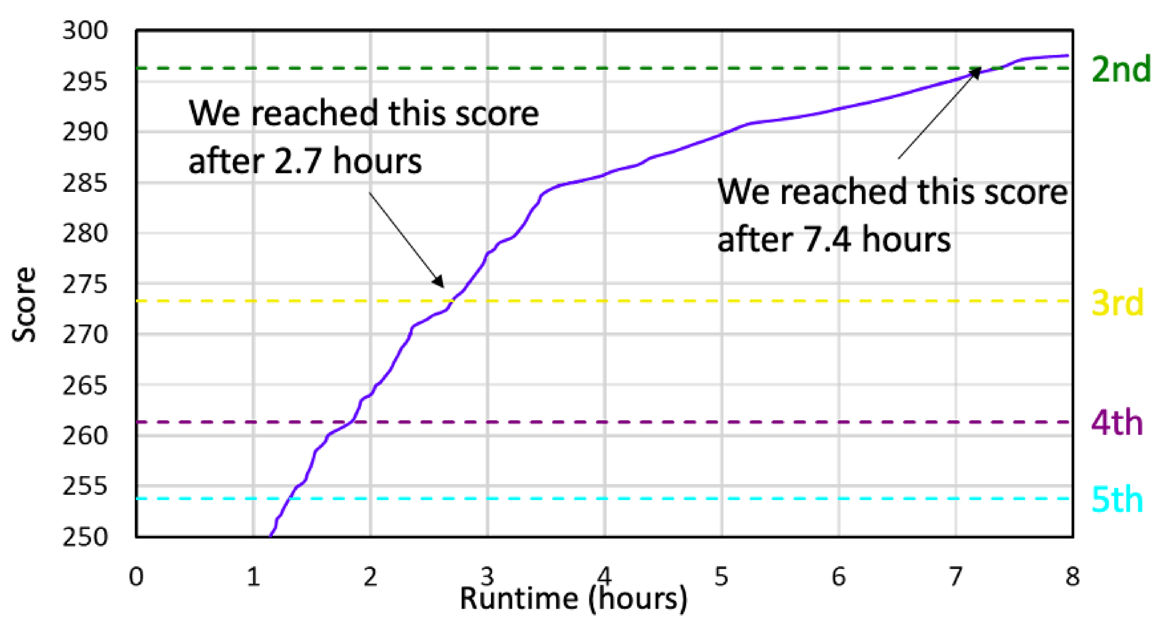
- We use Minimum Communication Policies (MCP) to send move commands to the simulator and avoid potential deadlocks caused by train malfunctions during execution.
- MCP sometimes stops trains unnecessarily. We develop a Partial Replanning (PR) mechanism to avoid such unnecessary waits.
- We use a Lazy Planning (LP) scheme that plans paths only for some of the trains during the planning phase, then lets the trains move, and plans paths for the rest of the trains during the execution phase. This improves the planning speed when there are thousands of trains to schedule.

Outcome

Winner of Both Rounds of 2020 NeurIPS Flatland Challenge



Success rate and runtime on different instances.
*The challenge provides 10 instances (dots on the plot) on each map size.



Accumulated score comparing with other teams over time.

Get the Paper

Scan the QR code to download the full length 2021 ICAPS paper! (https://bit.ly/34SrdfM)

Acknowledgments

Jiaoyang Li performed the research during her visit to Monash University. The research at the University of Southern California was supported by the National Science Foundation (NSF) under grant numbers 1409987, 1724392, 1817189, 1837779, and 1935712 as well as a gift from Amazon.
The research at Monash University was partially supported by the Australian Research Council (ARC) under grant numbers DP190100013 and DP200100025 as well as a gift from Amazon.
The research at Simon Fraser University was supported by the Natural Sciences and Engineering Research Council (NSERC) under grant number RGPIN-2020-06540.