Improved graph pruning for multi-agent pathfinding using heuristics

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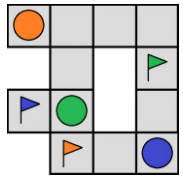


Description

MAPF (Multi-agent pathfinding) is a task of navigating a set of agents in their shared environment from their initial locations to target destinations while the main aim is to avoid collisions between them. In our work, we are trying to find the **smallest timestep** at which all the agents will be standing at their goal positions.

Determining an optimal plan in terms of its length is a computationally hard problem **(NP-hard)**.

This problem has numerous practical applications in **robotics, logistics, automatic warehousing, airplane taxiing, video game control, traffic junctions** and more.

Optimal algorithms fall into two categories:
Search-based: effective on large sparse maps where few conflicts are expected to occur.
Reduction-based: faster on small highly interactive instances but less effective on large ones.

Our work

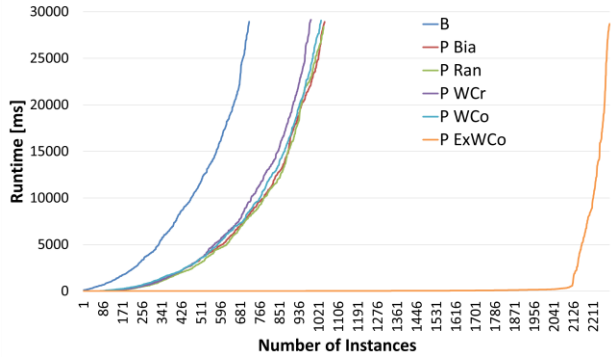
To mitigate the main drawback (scalability) of the Reduction-based approach we introduced in our previous work the **subgraph pruning method** [1]. This method aims at cutting out regions which are unnecessary from the map based on the agents **shortest-paths** and thus speeding up the overall computation time.

Our subsequent study [2] extended the subgraph method with multiple shortest paths, but higher computation cost led us to the original **single-path strategy** as it provided best balance between efficiency and computational time needed.

The **heuristics** explored in this work, which results were published in [3], describe different single-path strategies for path selection and ordering to **optimize the pruning process**. These strategies provide various methods for refining the search space based on agent **movement preferences**, **priority sorting mechanisms**, and **conflict prevention techniques**.

Achieved results

We proposed five progressively more complex heuristic approaches (Bia, Ran, WCr, WCo and **ExWCo**) for selecting **ground vertices** based on agent's paths, each of which focused on improving the previous one in some way or another. In the figure below, we can see comparison of the number of instances solved by the tested algorithm by a given time-limit where **B** refers to the baseline Reduction-based algorithm and **P** refers to the **Prune-and-cut Strategy** described in our original subgraph pruning work [1].



From the results showed in the figure above we can see that **ExWCo,** which avoids collision even for the cost of prolonged path, showed **exceptional** results in comparison with other techniques.
We can conclude that the **ExWCo** heuristic approach managed to achieve **better scalability** for the Reduction-based algorithm on the large maps.

Our previously published work:
[1] **Matej Husár**, Jiří Švancara, Philipp Obermeier, Roman Barták and Torsten Schaub: **Reduction-based Solving of Multi-agent Pathfinding on Large Maps Using Graph Pruning.** *In proceedings of the 21st International Conference on Autonomous Agents and MultiAgent Systems* (AAMAS 2022, p. 624-632).
[2] Jiří Švancara, Philipp Obermeier, **Matej Husár**, Roman Barták and Torsten Schaub: **Multi-Agent Pathfinding on Large Maps Using Graph Pruning: This Way or That Way?** *In proceedings of the 15th International Conference on Agents and Artificial Intelligence* (ICAART 2023, p. 199-206).
Publication made from this work:
[3] **Husár, Matej**, Jiří Švancara, and Roman Barták: **On Path Selection for Reduction-Based Solving of Multi-Agent Pathfinding Using Graph Pruning.** *In proceedings of the 18th International Symposium on Combinatorial Search* (SoCS 2025, p. 186-190).