Multi-Agent Pathfinding with Matching using Increasing Cost Tree Search

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1/7/2021

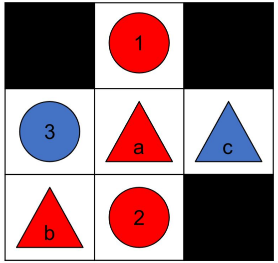
CSE3000

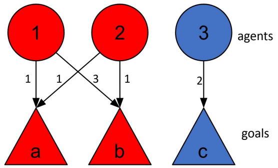
1 Multi-agent pathfinding with matching

In **Multi-agent pathfinding (MAPF)**, the goal is to move *k* agents to their goals without collisions.

Multi-agent pathfinding with Matching (MAPFM) generalizes MAPF to allow agents to be matched with one or more goals: each agent and goal is assigned a color, and in a solution agents may move to any goal of the same color. There are as many goals as agents of each color.

Objective: minimize the **Sum of Individual agent Costs (SIC)** *C*, the total amount of time spent travelling to the goals by agents.





Edge labels indicate the shortest path cost from agent to goal

2 Increasing Cost Tree Search

Increasing Cost Tree Search (ICTS) is a two-level algorithm for MAPF.

Level 1. Starting with the sum of the shortest path costs *C**, all combinations of individual agent costs adding up to a target *C* are enumerated. This is done by a breadth-first traversal of an **Increasing Cost Tree**, with cost combinations as nodes.

Level 2. For each combination of agent costs, all combinations of agent paths corresponding to those agent costs are searched for a solution. This is done using **MDDs**, data structures that can compactly represent paths.

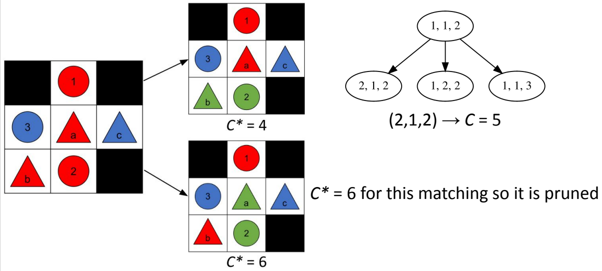
3 Research questions

1. *How can ICTS be used to solve MAPF with matching?*
2. *How does ICTS compare to alternative algorithms for MAPFM?*

Two strategies for solving MAPFM using ICTS were identified.

4 Exhaustive ICTS

Matchings are enumerated as MAPF instances and solved using ICTS. To improve performance, the lowest *C* found so far can be used as upper bound in the search. Additionally, matchings can be ordered by *C** to heuristically improve the bounding.



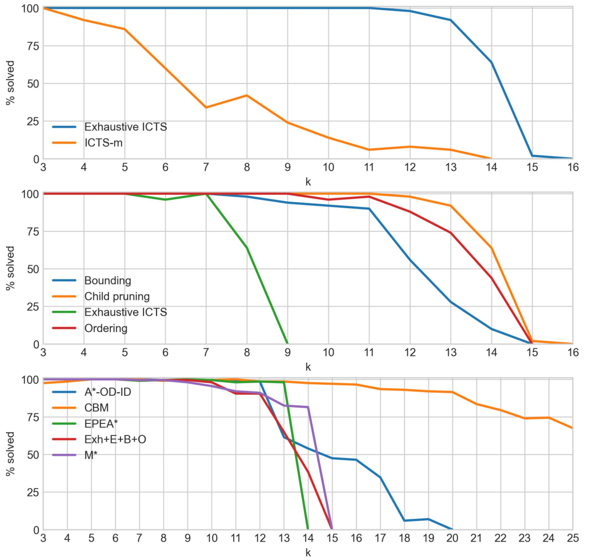
5 ICTS-m

Both levels of ICTS were modified to optimally solve MAPFM.

Level 1. Instead of C*, the sum of shortest paths to any matching goal is the first target *C* considered.

Level 2. For each agent, all paths to any matching goal corresponding to its ICT-node cost are generated.

6 Experimental results



Each graph indicates the fraction of problems solved as function of k within 120s by different algorithms. Each problem was set on a 20x20 grid with 25% of tiles being obstacles and the *k* agents were evenly divided into three teams.

7 Conclusion

Exhaustive ICTS clearly outperforms ICTS-m but does not scale well. Both bounding and ordering make a significant difference in terms of performance. Exhaustive ICTS performs similar to other exhaustive methods, but exhaustive methods in general are often outperformed by CBM.