# New Techniques for Pairwise Symmetry Breaking in Multi-Agent Path Finding

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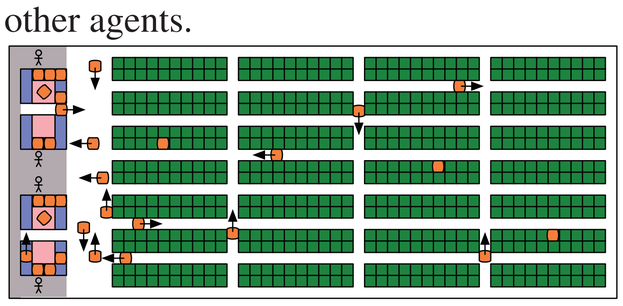
## Abstract

We consider two new classes of pairwise path symmetries which appear in the context of Multi-Agent Path Finding (MAPF). The first of them, *corridor symmetry*, arises when two agents attempt to pass through the same narrow passage in opposite directions. The second, *target symmetry*, arises when the shortest path of one agent passes through the target location of a second agent after the second agent has already arrived at it. We propose to break these symmetries using specialized constraints while preserving optimality. We experimentally show that our techniques can significantly speed up Conflict-Based Search, a state-of-the-art MAPF algorithm.

## 1 Background

### Multi-Agent Path Finding (MAPF)

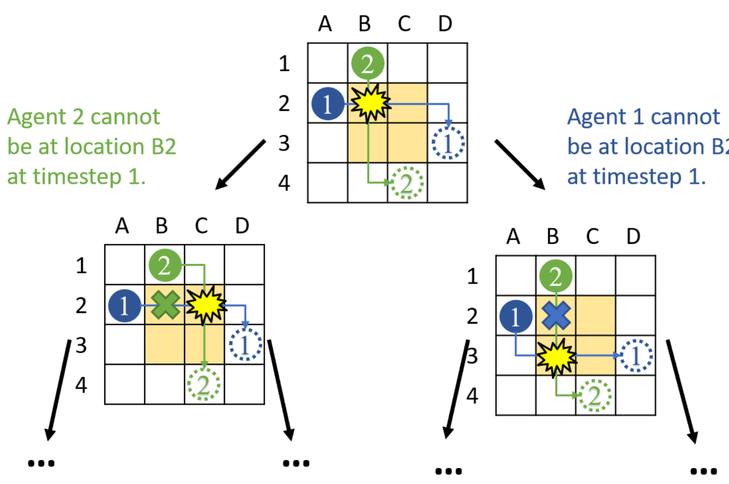
MAPF is the planning problem of finding a set of paths for a team of agents on a given graph. Each agent must move in discrete timesteps from a start location to a target location while avoiding collisions with other agents.



[Picture credits: P. R. Wurman et al. Coordinating Hundreds of Cooperative, Autonomous Vehicles in Warehouses. AI Magazine 29, 1 (2008), 9-20.]

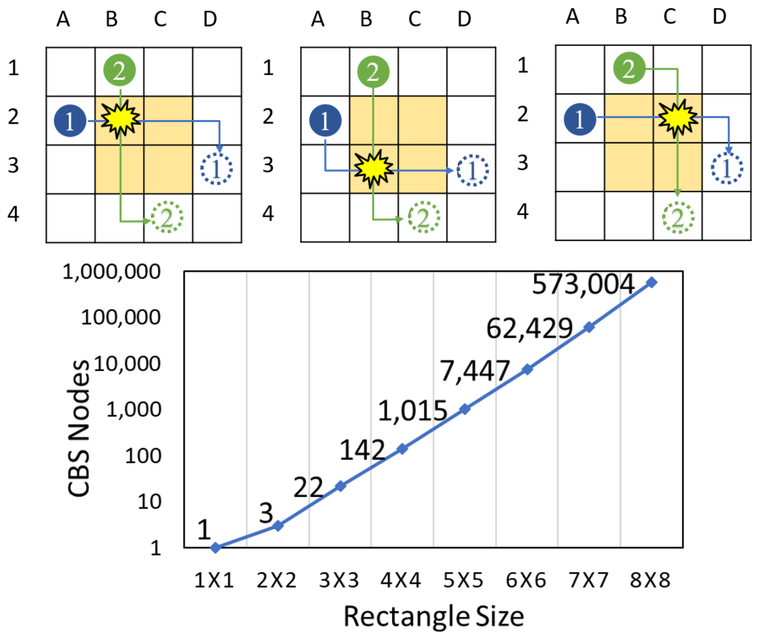
### Conflict-Based Search (CBS)

CBS is a state-of-the-art algorithm that solves MAPF optimally, whose main idea is to plan paths individually first and resolve collisions afterward.



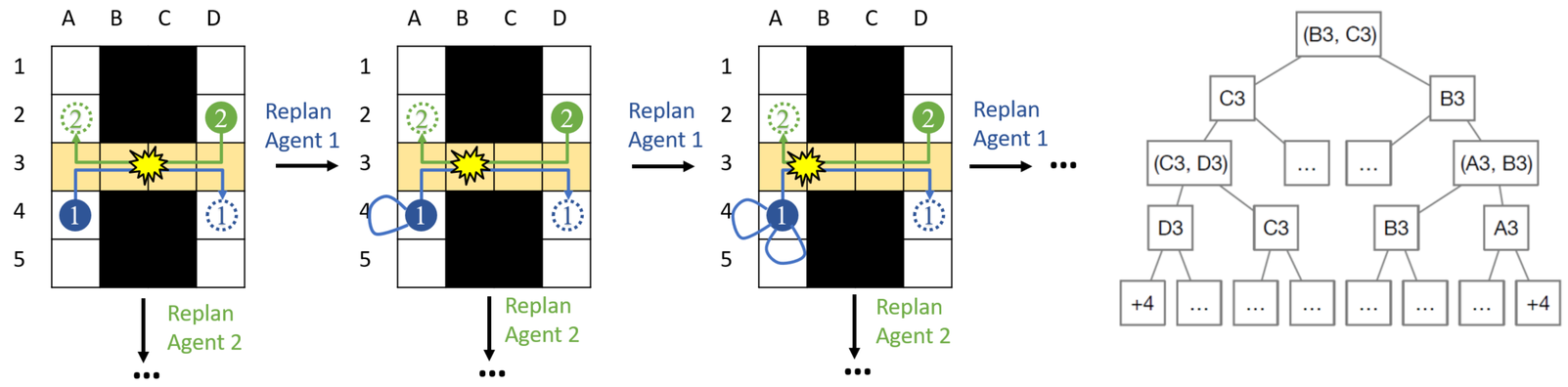

### Rectangle Symmetry

Rectangle symmetry arises when two agents attempt to cross each other in an open area while all pairs of their shortest paths collide somewhere inside a rectangular area.



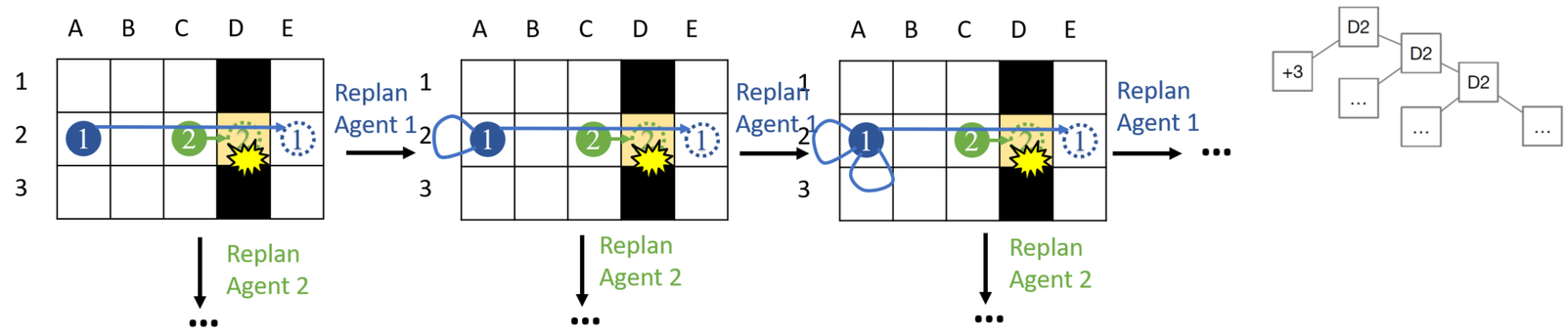

## 2 Corridor Symmetry in MAPF

Corridor symmetry arises when two agents attempt to pass through the same narrow corridor in opposite directions.



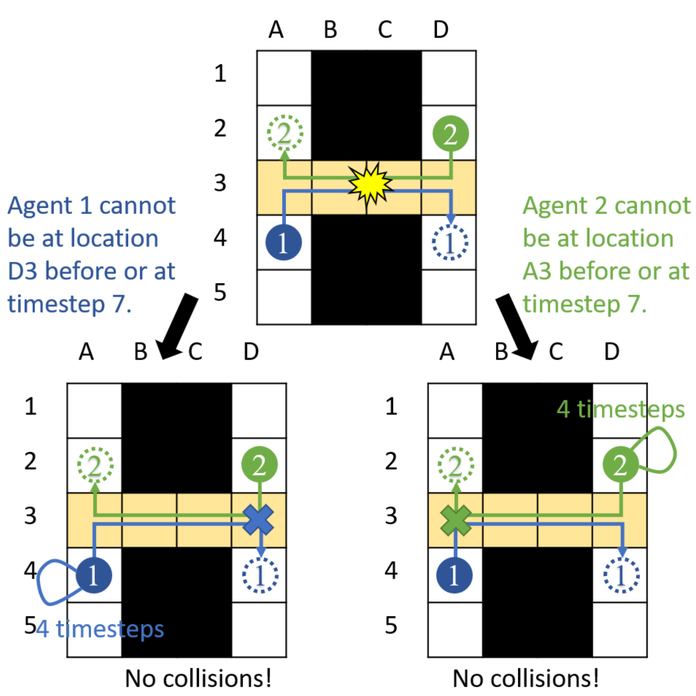

## 3 Target Symmetry in MAPF

Target symmetry arises when the shortest path of one agent passes through the target location of a second agent after the second agent has already arrived at it.

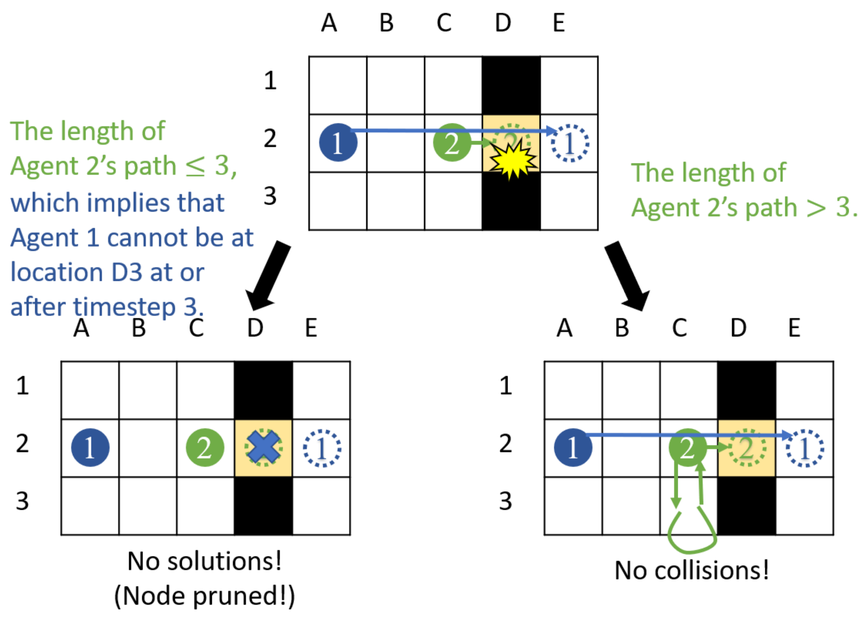



## 4 Symmetry-Breaking Constraints

### Breaking Corridor Symmetry with Range Constraints

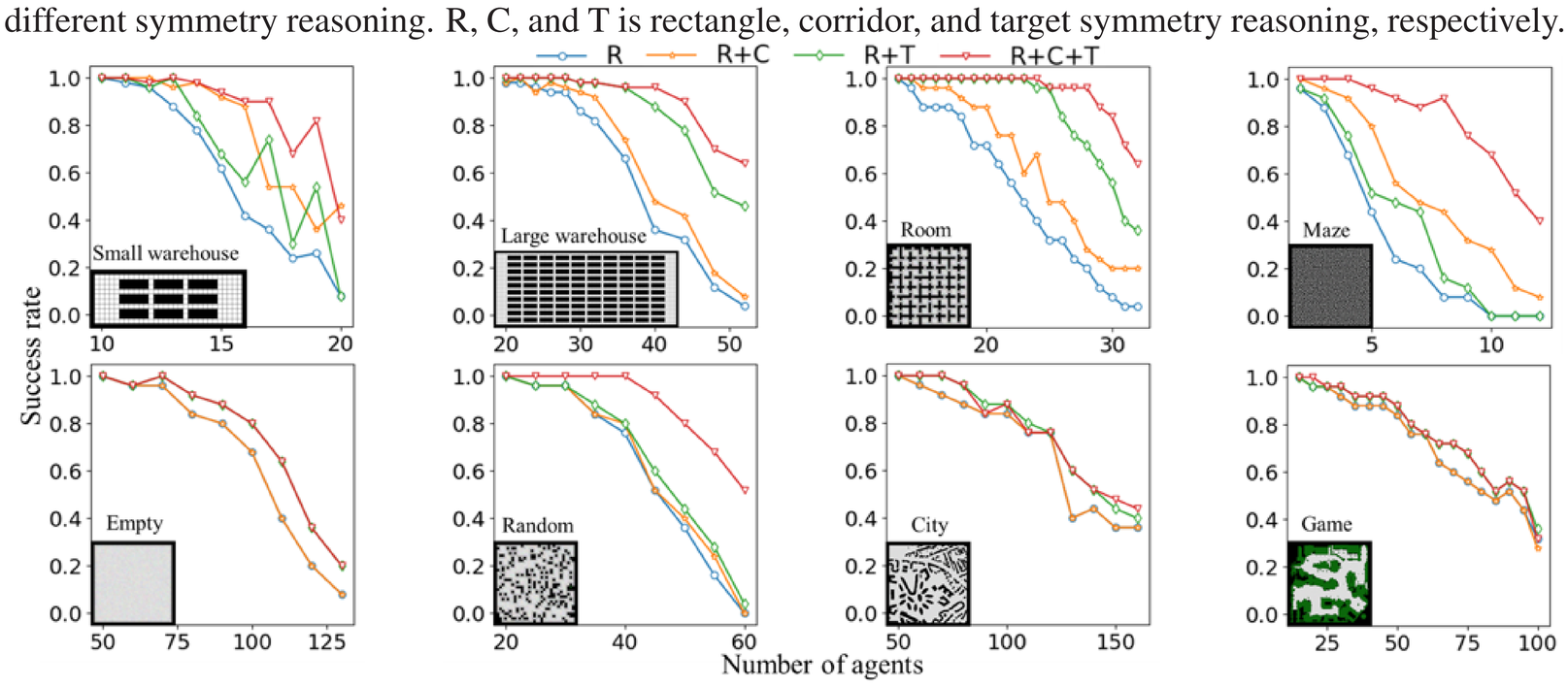



### Breaking Target Symmetry with Length Constraints




## 5 Empirical Evaluation

The figures show the success rate (i.e., the percentage of solved instances within one minute) of CBS with different symmetry reasoning. R, C, and T is rectangle, corridor, and target symmetry reasoning, respectively.

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