Dissimilar Path Generation for Multi-Agent Pathfinding via Combinatorial Auction

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GOAL-ORIENTED AUTONOMOUS LONG-LIVED SYSTEMS
OXFORD ROBOTICS INSTITUTE

AIMS
EPSRC Centre for Doctoral Training in Autonomous Intelligent Machines & Systems

UKRI
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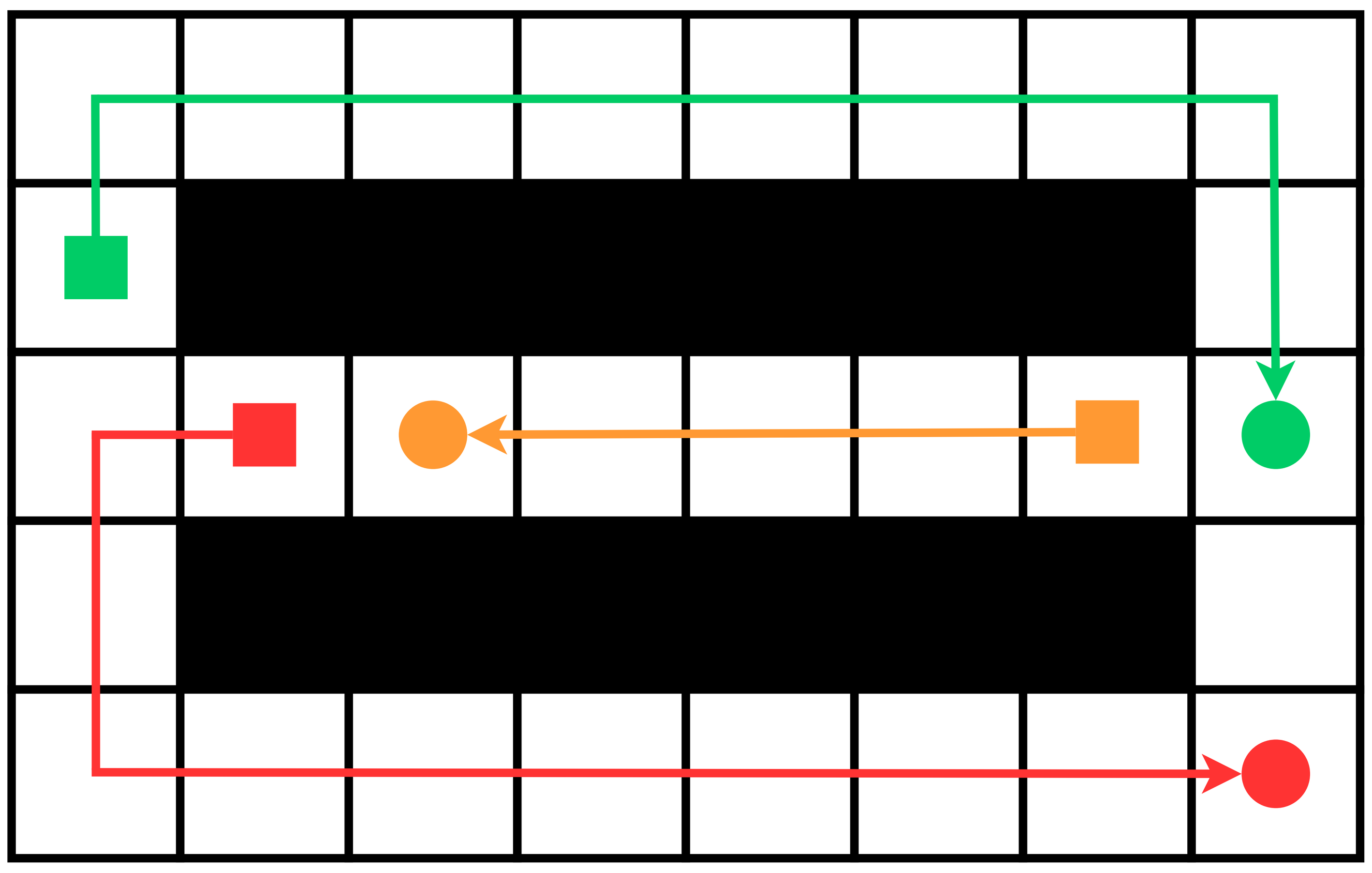
Overview

- **Non-cooperative multi-agent pathfinding (MAPF)** problems can be solved by a **combinatorial auction**.
- These approaches **incentivise participation** from competing agents, while **preserving their individual autonomy**.
- Agents submit bids for paths, and a central auctioneer allocates paths to **maximise social welfare**.
- Total number of paths in a graph scales exponentially with graph size, so **agents must be selective** about the paths they submit as bids.



Agent Bid Generation Goals

- Systematically generate a fixed number of paths that **give the auctioneer sufficient flexibility** to find a good path allocation for all agents.
- Resulting paths should **maximise likelihood that the auctioneer can find a feasible allocation**, while still producing **low-cost solutions**.

Contributions

- An algorithm for **systematic generation of dissimilar paths** which provide demonstrable benefits for MAPF by combinatorial auction.
- Experimental evaluation shows improved performance over *k*-shortest paths baselines.

Path Generation Algorithm

- Adaptation of work from Jeong et al. (2011) on **dissimilar path generation** for the MAPF context.
- Starts by selecting the shortest path as the first bid.
- Iteratively generates a set of **candidate paths** by incrementally modifying the last selected path.
- Selects the next path from the candidates based on a **dissimilarity metric** designed to produce paths that do not have the agent at the same place at the same time:

$$P_{rs}^{k+1} = \arg\max_{P \in C_{rs}} \frac{1}{k} \sum_{j=1}^{k} \frac{\left| P_{rs}^{j} \cap^{t} P \right|}{\left| P_{rs}^{j} \cup^{t} P \right|}$$

Experimental Evaluation

- Evaluation over 50 trials on a small warehouse map.
- In **high congestion scenarios**, the algorithm **significantly increases the chances of the auctioneer finding a feasible allocation**.
- The algorithm allows **lower-cost solutions** to be found on average in all scenarios.

Algorithm	**Number of agents**				
	6	**8**	**10**	**11**	**12**
Iterative iBundle	48 (6.47)	34 (7.62)	23 (8.53)	11 (7.83)	1 (–)
VCG simple	48 (6.42)	37 (7.56)	24 (8.53)	12 (7.83)	1 (–)
VCG dissimilar	45 (5.52)	40 (5.52)	28 (5.89)	27 (5.85)	15 (–)

Future Work

- Improvements to **scalability** for larger maps:
  - ✦ Random thinning of candidate set.
  - ✦ Online optimisation based on available computation time.
- Modelling of regions that are likely to act as **bottlenecks**.
- Further experiments using other algorithms for non-cooperative MAPF.