Multi-Agent RRT*: Sampling-based Cooperative Pathfinding

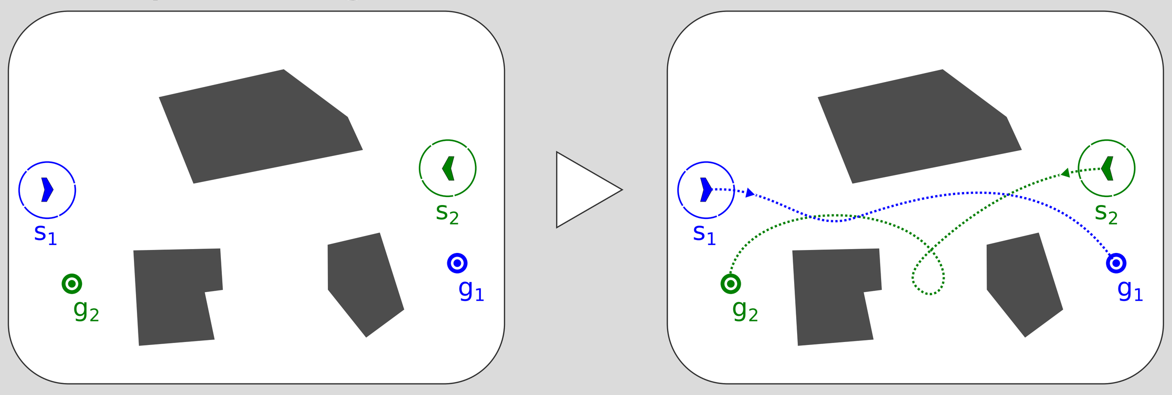
Michal Cap[1], Peter Novak[2], Jiri Vokrinek[1], Michal Pechoucek[1]

[1]Agent Technology Center, CTU in Prague [2]Algorithmics Group, TU Delft

Problem

Find an optimal set of conflict-free trajectories for n mobile agents.

Example (2 agents):



Solution is a path in joint state space of all n agents:

$$J = C_1 \times \ldots \times C_n$$

where C_i is d-dimensional configuration space of agent i.

Existing methods use A* to search for a path in J. **However, in many cases A* exhibits poor performance in J,** which is high-dimensional space that contains large basins of attraction to local minima. Due to the basin filling behaviour of A*, it takes long time to escape such regions during the search.

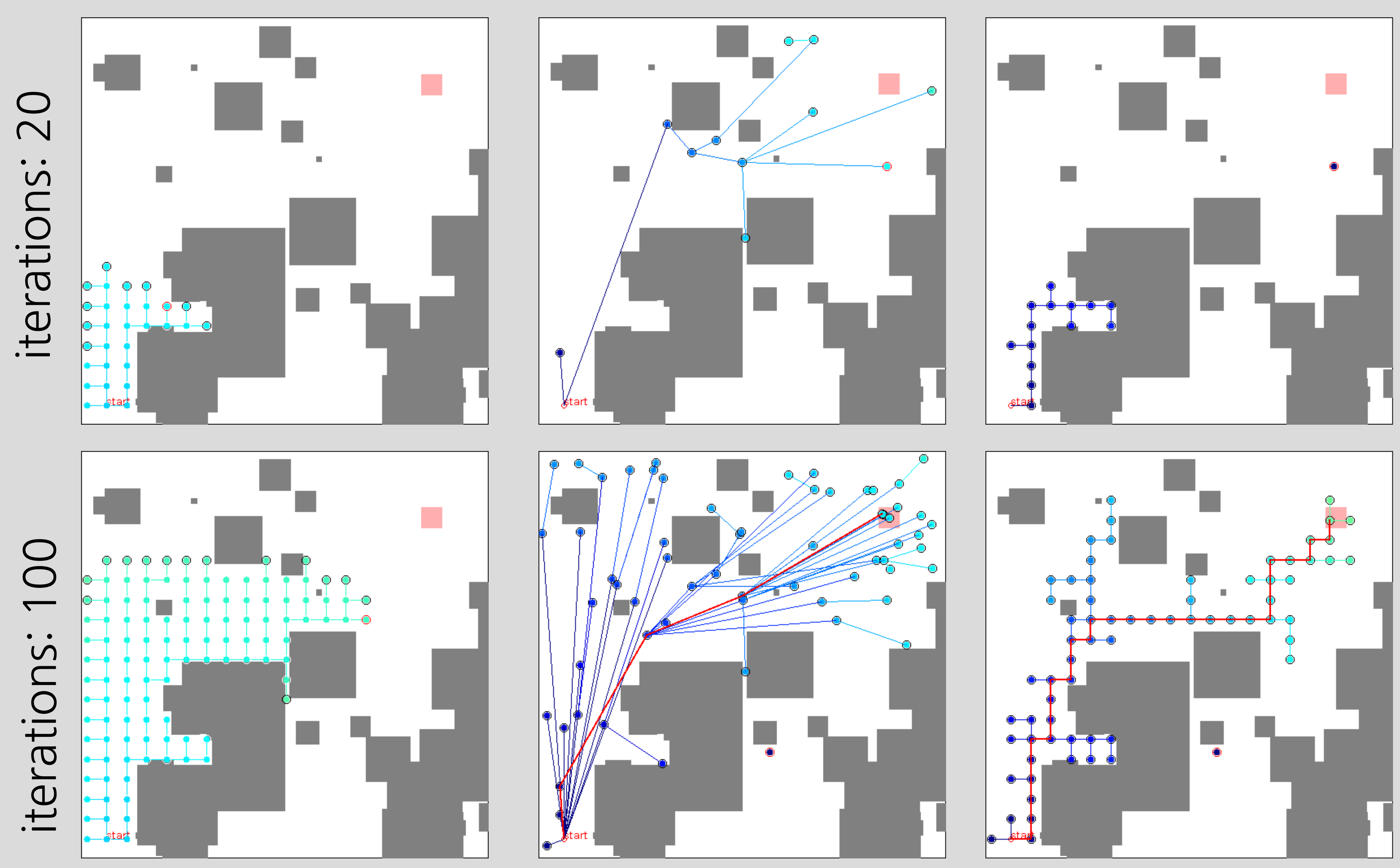
Solution

Use RRT* to search for a path in J

RRT* is a recently proposed (Karaman 2011) anytime variant of rapidly-exploring random trees (RRT), a sampling-based algorithm widely used for motion planning in high-dimensional robotic spaces.

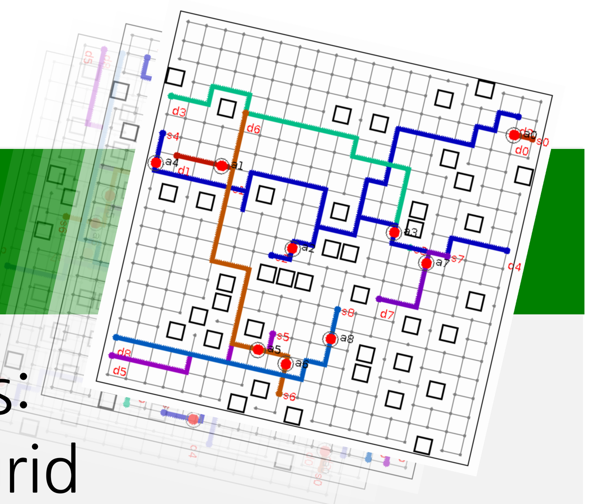
Graph RRT* -- To allow fair comparison with the state-of-the-art anytime algorithm for cooperative pathfinding (Standley 2011), which works on graphs, we adapted RRT* to also plan on graphs.

Illustrative example in single-agent case:



Behaviour of the three methods on a simple pathfinding problem

Experiment



We generated 6000 problem instances:

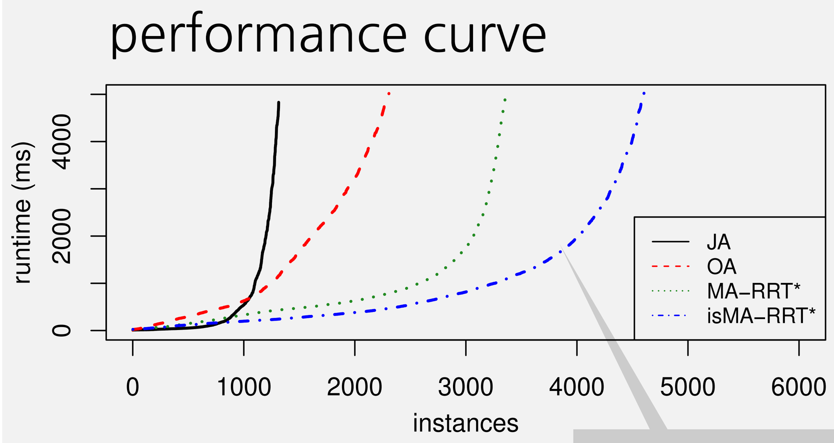
- agents' motions discretized as a 4-grid
- grid sizes: 10x10, 30x30, 50x50, 70x70, 90x90
- no of agents: 1, 2, 3, 4, 5, 6,7, 8, 9, 10
- for each combination of the grid size and the number of agents, we generated 120 instances with random obstacles (obstructing 10% of space) and random start and destination positions for each agent
- each algorithm allowed max 5s to find a solution

Results

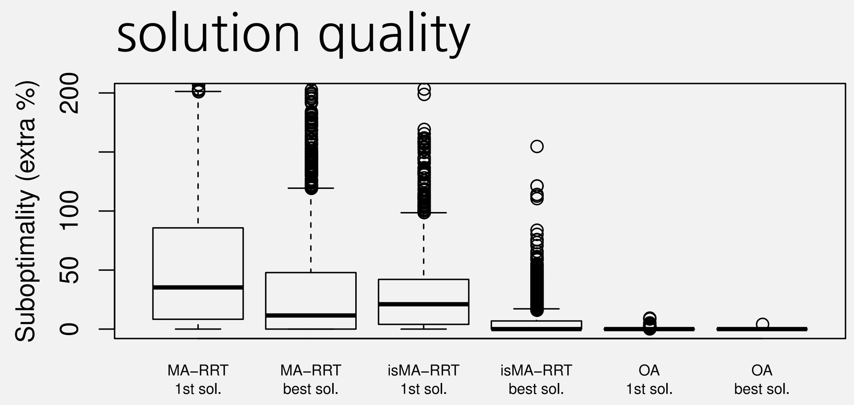
JA = A* in J
OA = Optimal Anytime (Standley 2011)
MA-RRT* = RRT* in J
isMA-RRT* = RRT* in J with sampling biased towards single-agent optimal paths

Performance

performance curve



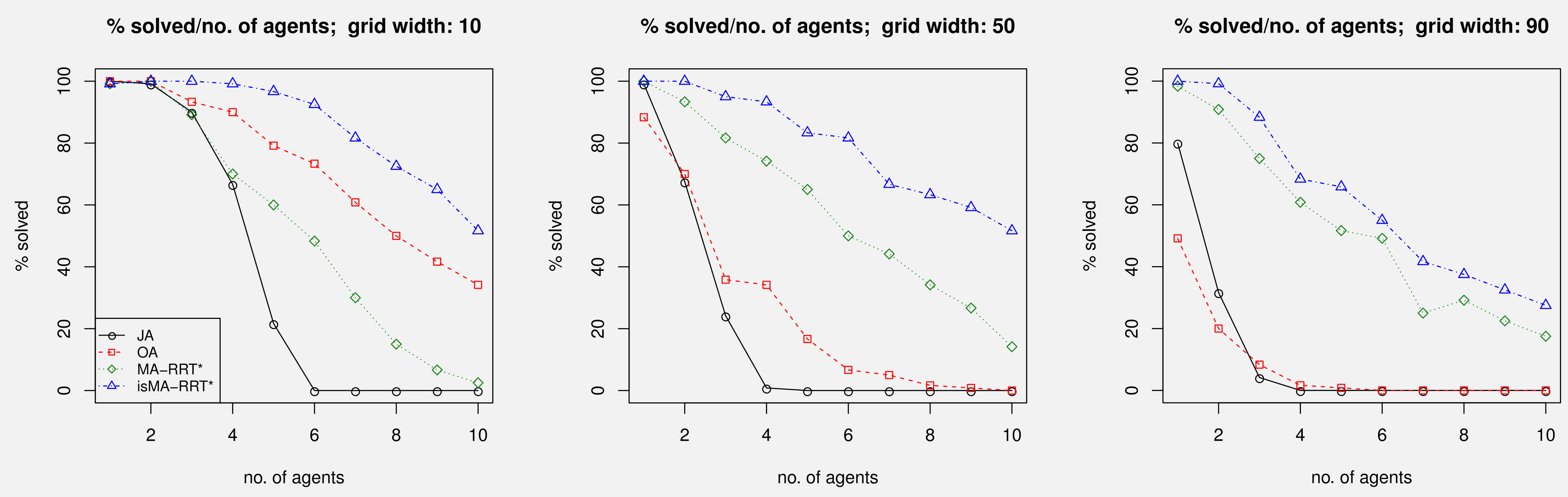
solution quality



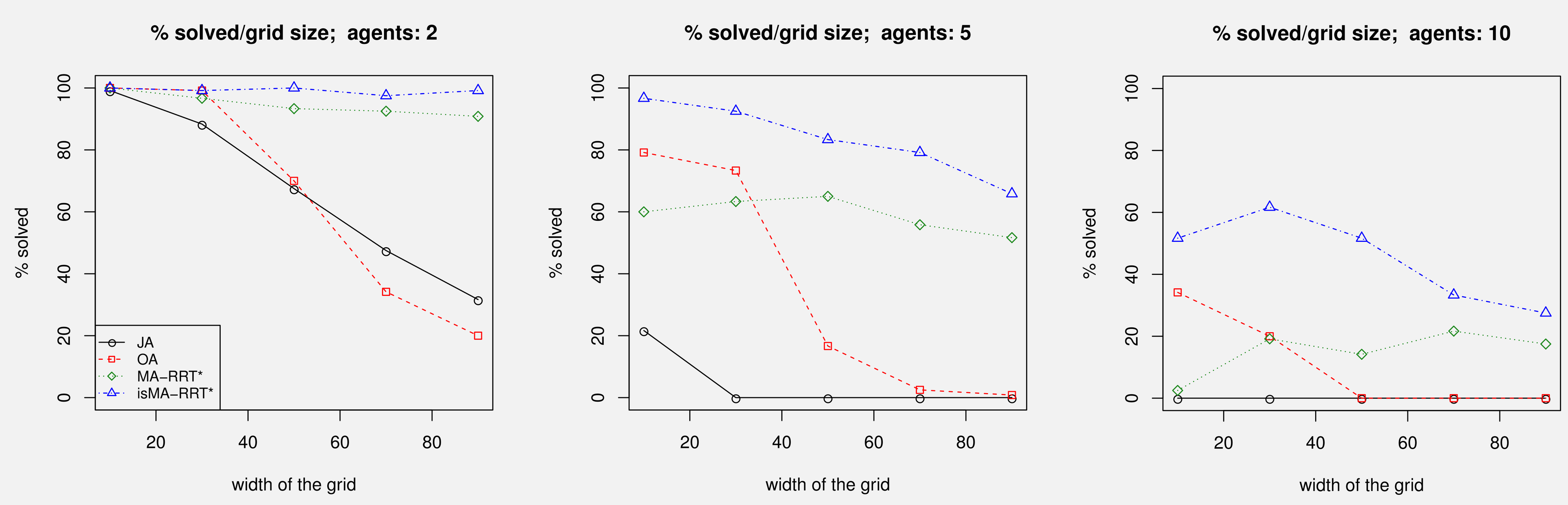
For each algorithm, we recorded the runtime when the first valid solution to a particular problem instance was returned. Then, we sorted the values (for each algorithm independently) and plotted it. We can see that JA resolved 21% of the instances, OA 38%, MA-RRT* 56% and isMA-RRT* 77% of 6000 instances from our problem instance set in the runtime limit of 5 seconds.

Scalability

% of instances solved / agents



% of instances solved / grid size



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References

Karaman and Frazzoli. *Sampling-based algorithms for optimal motion planning*. IJRR, June 2011.
Trevor Scott Standley and Richard E. Korf. *Complete algorithms for cooperative pathfinding problems*. IJCAI 2011.