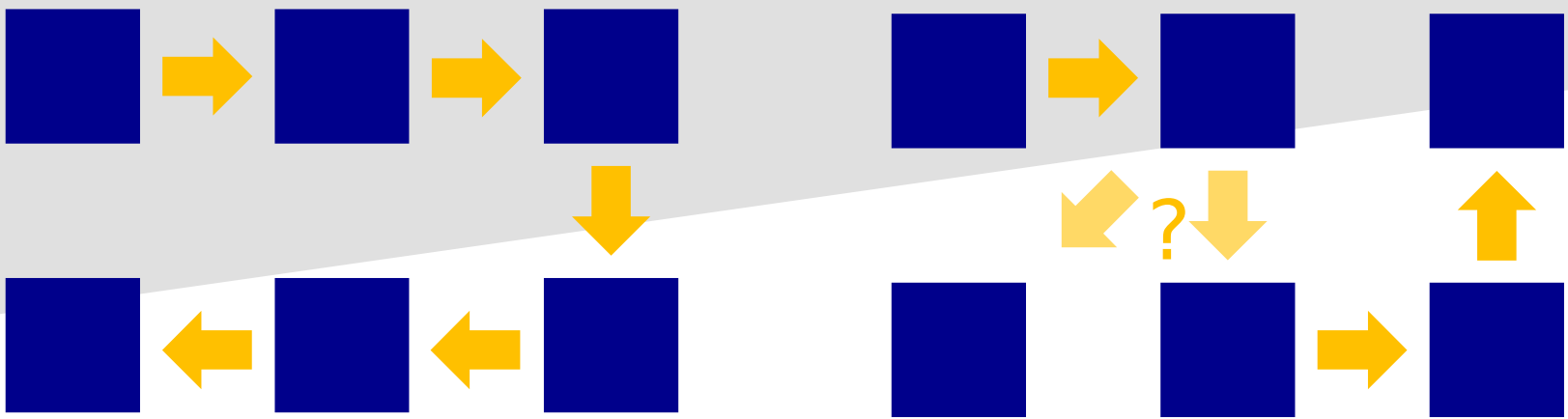
Optimized Directed Roadmap Graph for Multi-Agent Path Finding using Stochastic Gradient Descent

Christian Henkel, Marc Toussaint

SAC2020

University of Stuttgart

Motivation



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Motivation II

- Fixed order of **production steps**
- Fixed production **cycle**
- Problems:
  - **Variants**
  - **Disturbances**

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- **Flexible** allocation of production station
- Distributed layout
- Use case for **AGV**s
- Robustness through **flexibility**
- Higher **complexity**

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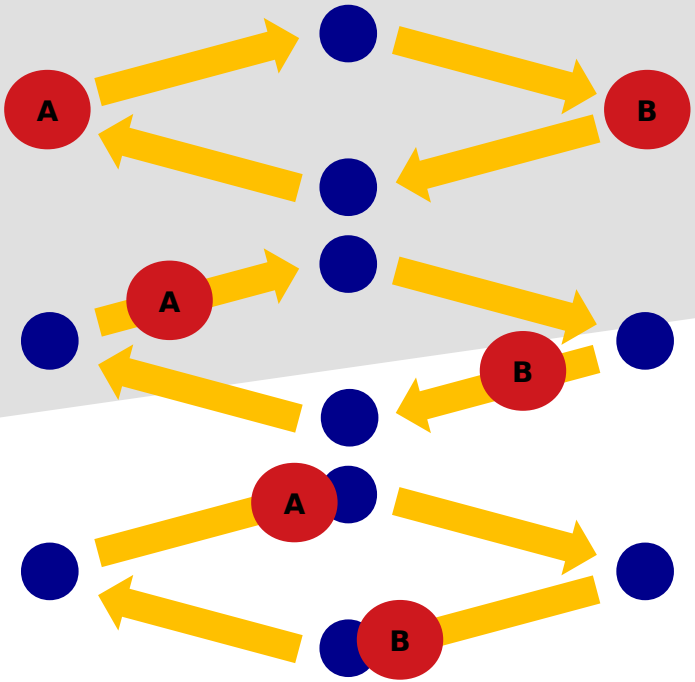
Points on Directed Graphs

- Consider agents to be **point-shaped**
- i. e. have no spacial coverage

- All agents start at **random positions**
- Constant velocity

- *Collisions?*
- Head-to-head on **same edge**
- → **Directed edges**



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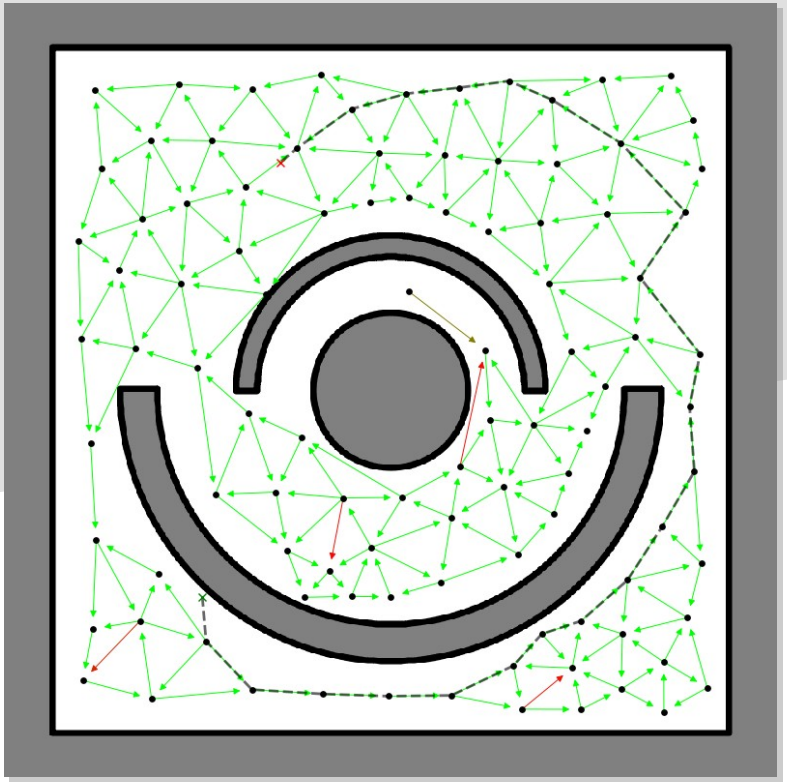
And With Spatial Robots?

- Collisions can happen
- → will be avoided by local planner
- → As they happen

- Need to be **rare**
- → Construct roadmap accordingly
- → **Directed**

- Adopted to environment
- Based on agents



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Building the Roadmap

Roadmap we need

- **Directed edges**
- In a way to allow for maneuverability

- **Vertex positions** equally spread out

Relaxed Roadmap for optimization

- **Edges** in both directions (undirected)
- "*directionality*" as parameter $d_e \in \mathbb{R}$
- edges against current directions have higher cost

- **Vertex positions** continuous, to be optimized

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Optimization of the Roadmap

- Random **vertex** positions in free map space
- **Edges** generated by Delaunay Triangulation
- Random directionality parameter → **Direction**

- Optimized Parameters:
- Vertex positions x, y
- Directionality of edges d_e

- Per Iteration
- Random set of **start and goal poses**
- Plan single-agent paths in relaxed roadmap (undirected)
- Optimization target: minimize **path costs**
- Using **Stochastic Gradient Descent**
- Adopt vertex **positions** and **directionality**
- → *Final product: Directed roadmap*

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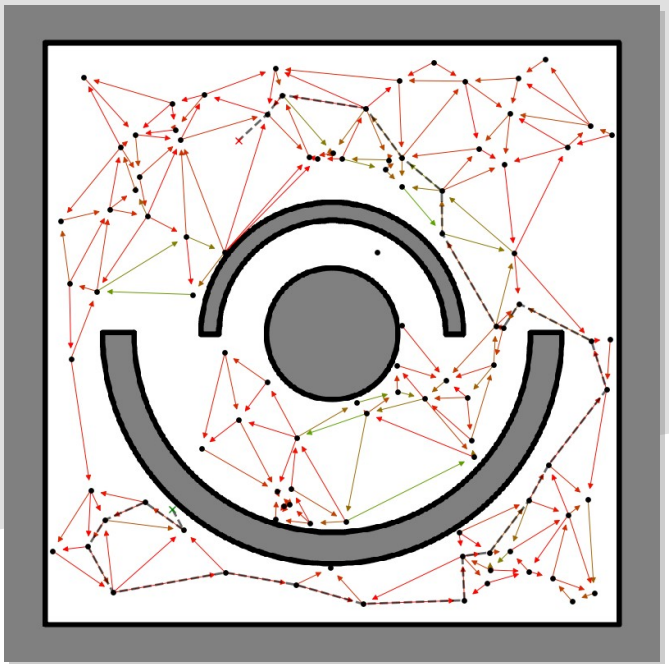
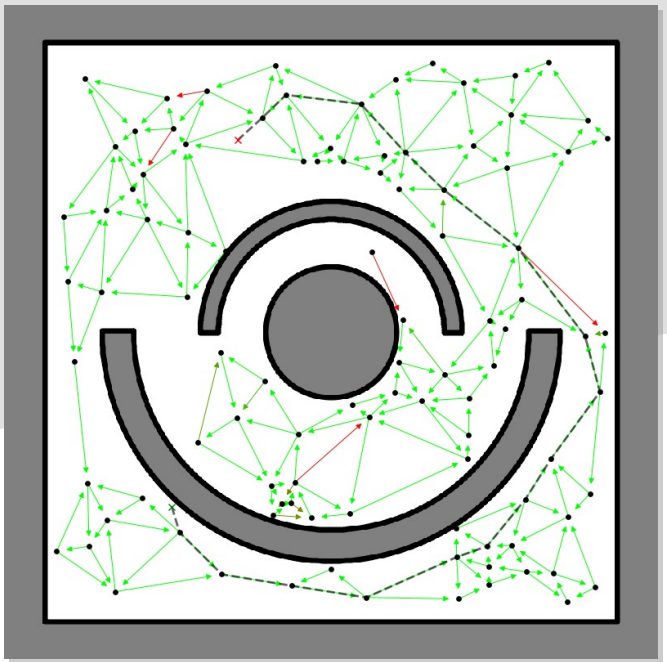
Optimization Progress

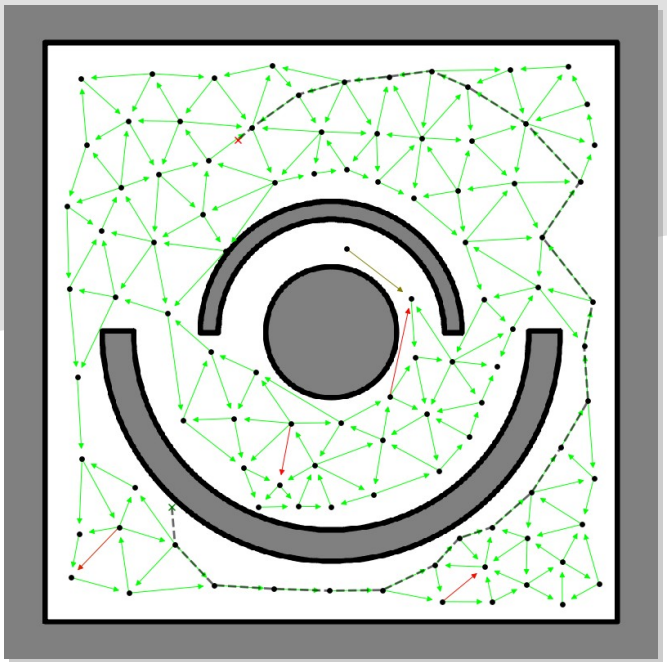
After 50 Iterations



After 1000 Iterations



After 4000 Iterations



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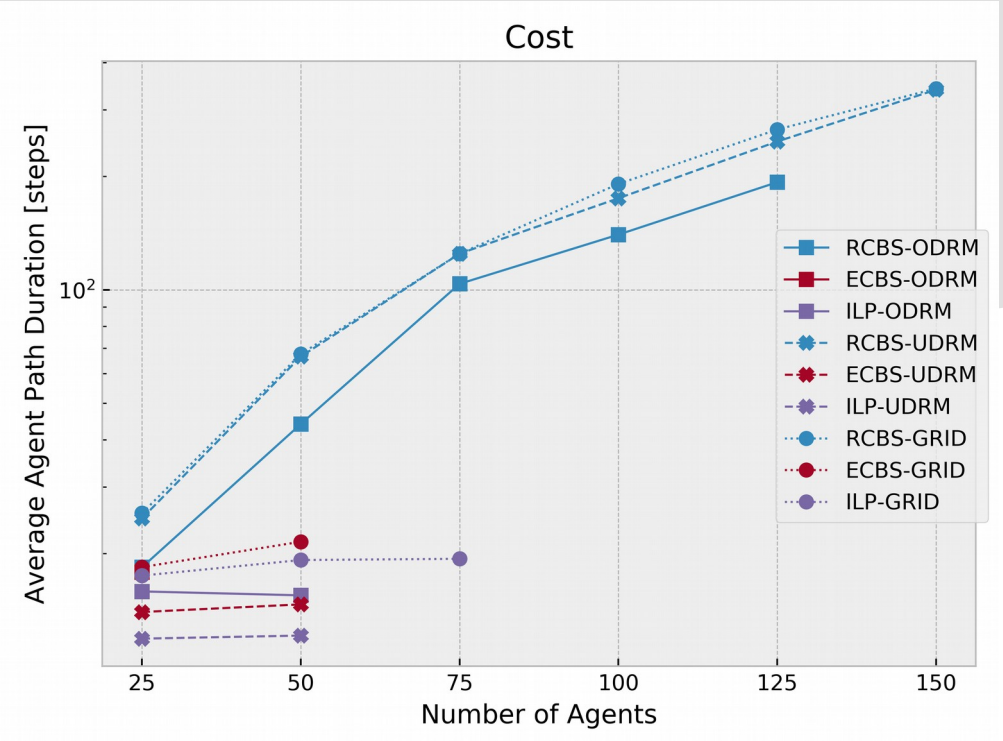
Evaluation Centralized

- Various centralized planners on various roadmaps

- **Random** Conflict Based Search
- **Enhanced** Conflict Based Search
- Integer Linear Programming (**optimal**)

- Optimized Directed Roadmap (**ours**)
- **Undirected** Roadmap Graph
- **Grid** (undirected, same # of vertices)



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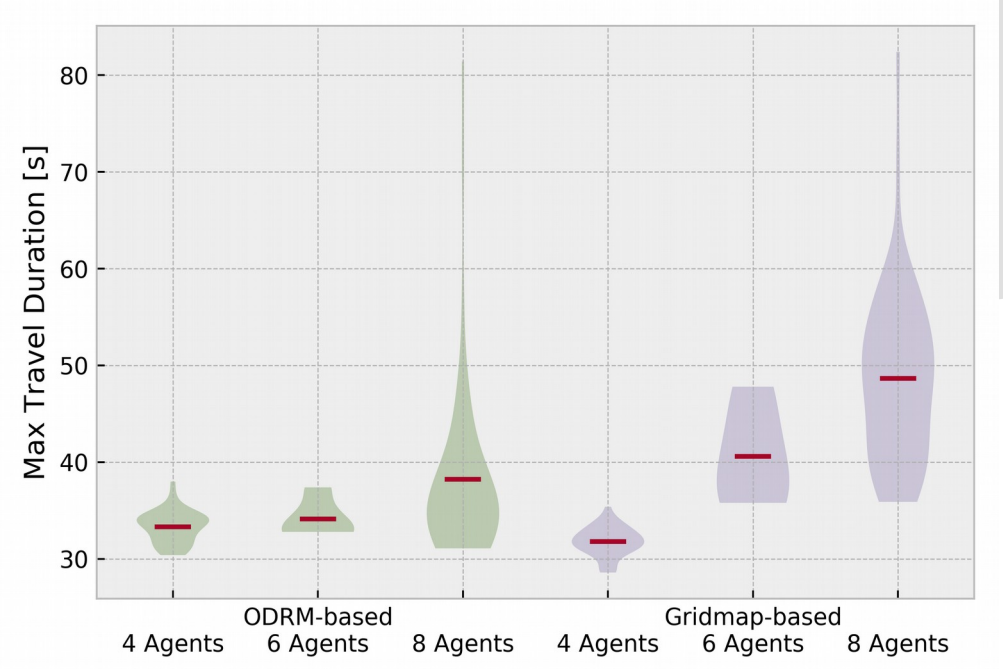
Evaluation Decentralized

- Local planner: Timed Elastic Band Method
- Resolves local collisions at runtime

- Global planner: agent-wise A* on our ODRM
- And on regular gridmap for comparison (with higher resolution than in previous experiment)



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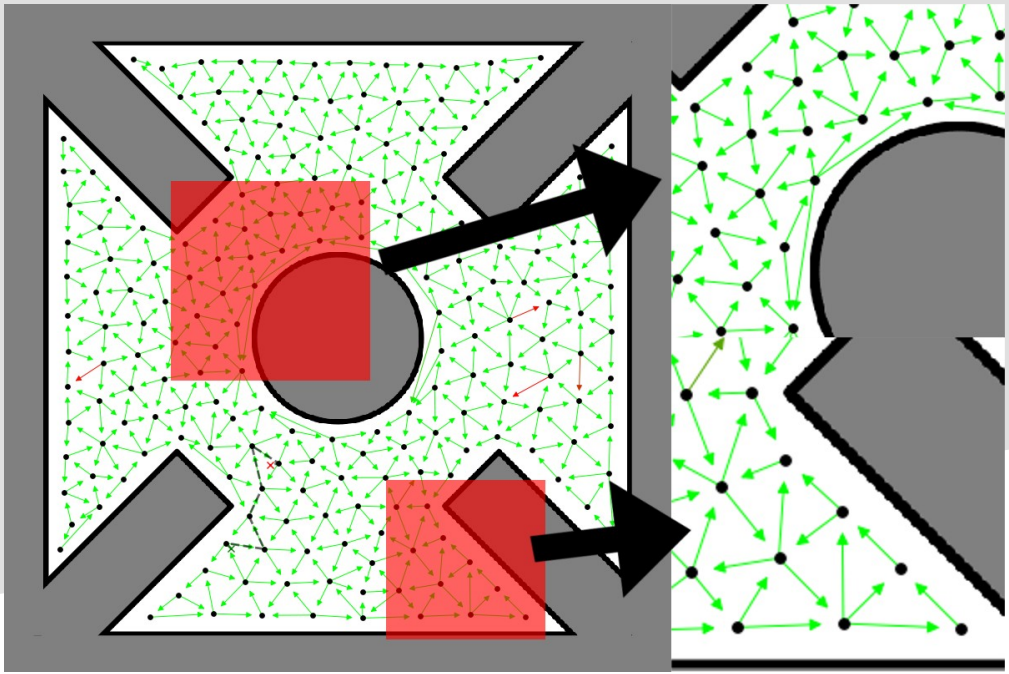
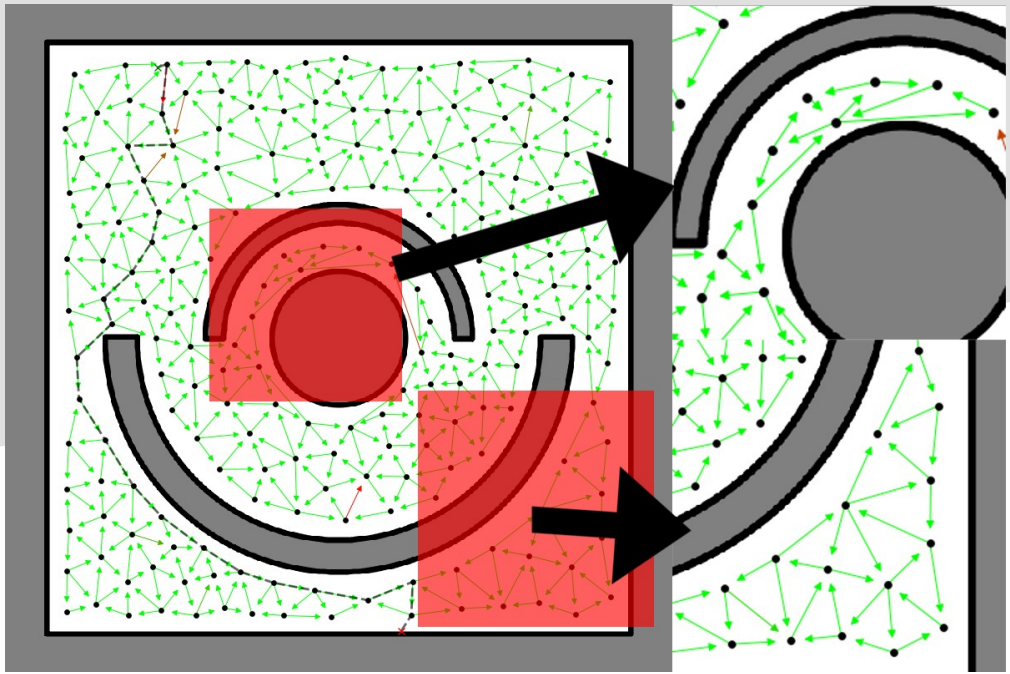
Emergent Properties





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Thank you for watching!

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