Artificial Intelligence for Robot Coordination at Scale

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PhD Students: Philip, Yulun, Jingtian, Yorai, Rishi, Yutong **Masters:** He (Rivers)

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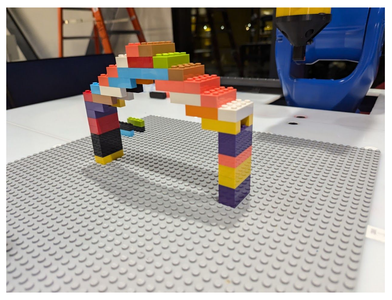
Overview

- We focus on developing fundamental algorithms that enable large teams of autonomous agents to accomplish collaborative tasks intelligently in dynamic environments.
- Areas of interest:
  - Large-scale multi-agent path finding (MAPF) and coordination
  - Integrated task and motion planning
  - Integrated planning and execution under uncertainty
  - Learning-guided planning
- Example applications:

Philip's Research

Using Multiple Robot Arms for Assembly

- Larger Workspace
- Increased Throughput
- More complex collaboration tasks

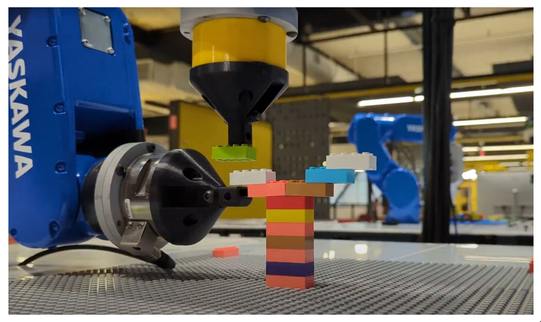


Area of Research

- Assembly Sequence Planning
- Task Planning and Assignment
- Efficient Multi-Arm Motion Planning
- Safe Execution and Plan Repair
- Integration with manipulation policy

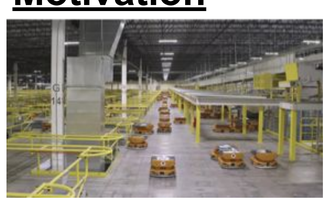
Example Demonstration:

Building Legos with Two Arms



Yulun's Research

Motivation



Good multi-robot system

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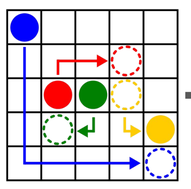

MAPF Algo

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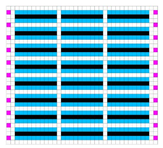
Environment



Physical Layout

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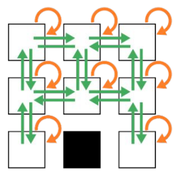
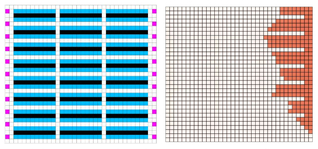


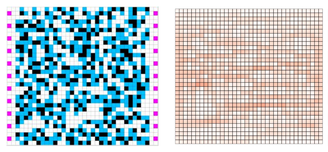
Virtual guidance

Key takeaway: Optimizing ***environments*** in which MAPF algorithms operate significantly improves performance of multi-robot systems.

Layout Optimization

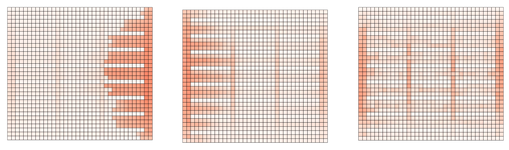


Human-designed Layout
Heavy traffic congestion



Our optimized Layout
Balanced traffic

Guidance Graph Optimization

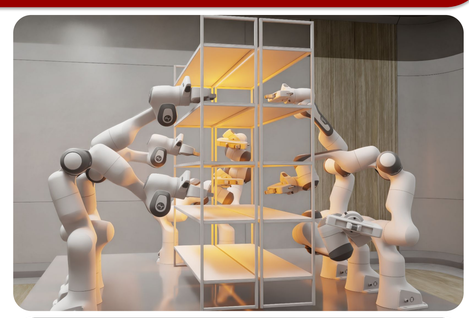


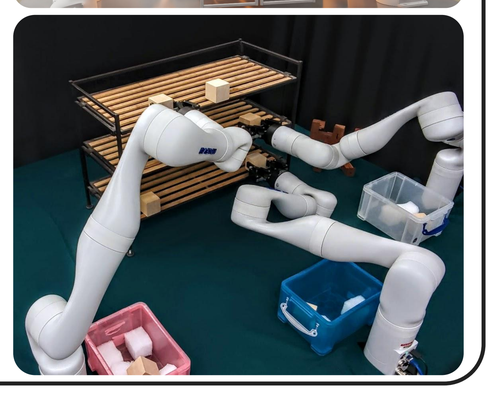
No guidance | Human-designed guidance | Our guidance

Yorai's Research

Are Multiple Robot Arms Better Than One?

- **Yes:** enable autonomy in new tasks (e.g., collaborative assembly).
- **Yes:** solve tasks more efficiently than a single arm could.
- **Maybe:** effective algorithms are still being developed.



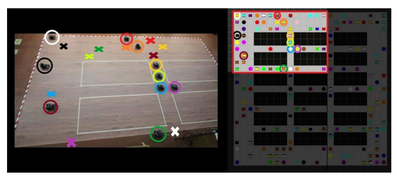


Active Areas of Research

1. Multi-arm motion planning.
2. Multi-arm task-and-motion-planning.
3. Data driven collaborative manipulation.

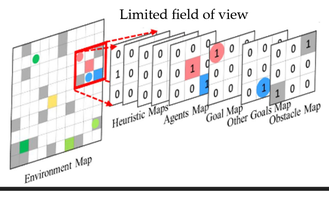
Yutong's Research (Visiting PhD Student)

Can we learn a decentralized policy shared by all agents based on partial observation to plan paths step by step?



How to use the learned policy ?

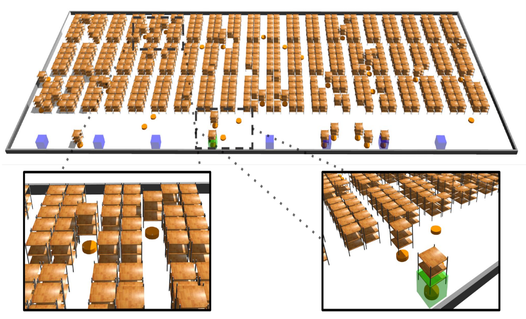
1. Directly apply the policy to MAPF tasks.
2. Combine the policy with search-based algorithms to complement each other's weaknesses and make 1+1>2.



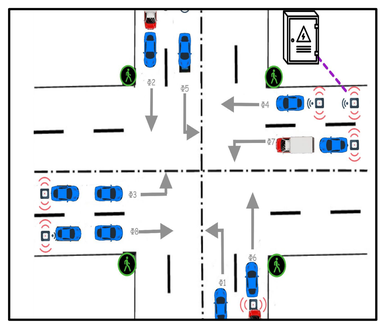
Jingtian's Research

Motivation

Finding collision-free trajectory for large-scale multi-robot system considering their dynamics and kinematics



- State-of-art MAPF methods shows scalability in finding paths for thousands of agents.
- Real robots are limited by dynamics and kinematics constraints.
- Apply MAPF methods to real robots.



Rishi's Research

Faster, Better, Scalable Algorithms

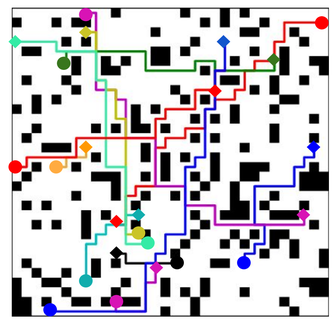
- How can we plan for 100s-1000s of agents?

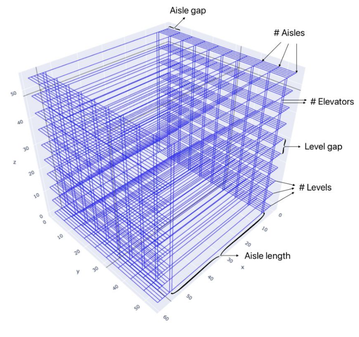
Leveraging Machine Learning with Heuristic Search

- How can we boost learnt policies using search?

Towards Realistics Multi-Agents Systems

- How can we effectively plan for non-2D complex agent groups?

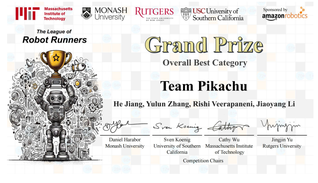




River's Research

Large-Scale MAPF Planning

- We won an international MAPF competition with up to 10,000 agents!



MAPF Execution under Delays

- How to replan fast online to handle unexpected delays? Optimize the Action Dependency Graph!