

# Pathfinding and Routing

## NAIL137

### Execution on robots

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# MAPF so far ...

- Everything is in simulation
- Everything is done in the planning phase

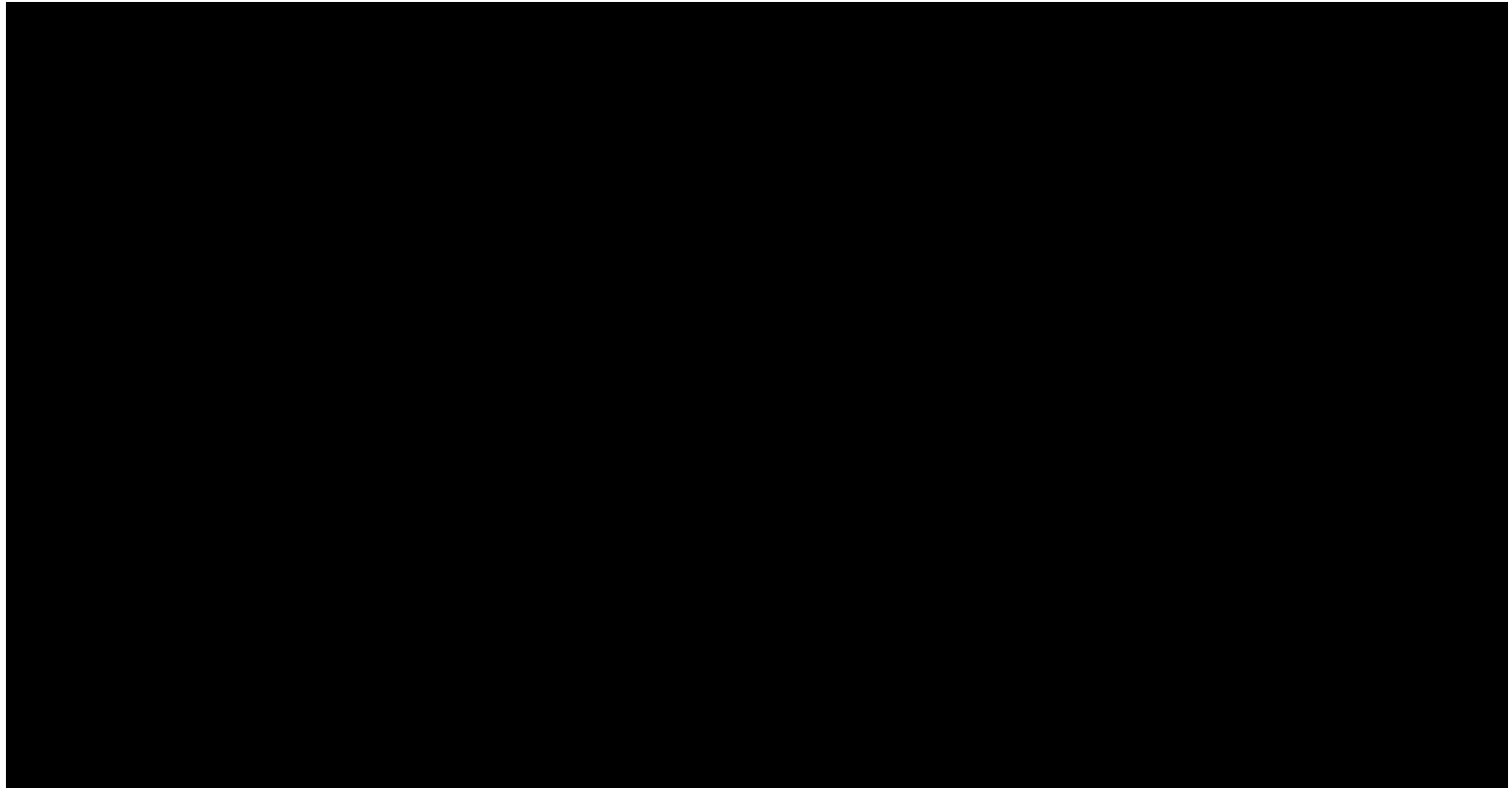
# MAPF on real robots

- Setup needs to match the use-case and available hardware
  - Sparse environment
    - Decentralized approach
    - Localization by the agent
  - Dense environment
    - Centralized approach
    - Communication requirement
    - Different localization

# Robots at MFF



# Ozobots



## Multi-Agent Path Finding on Real Robots

Demo #6

Roman Barták, Jiří Švancara, Ivan Krasičenko



# Sparse environment

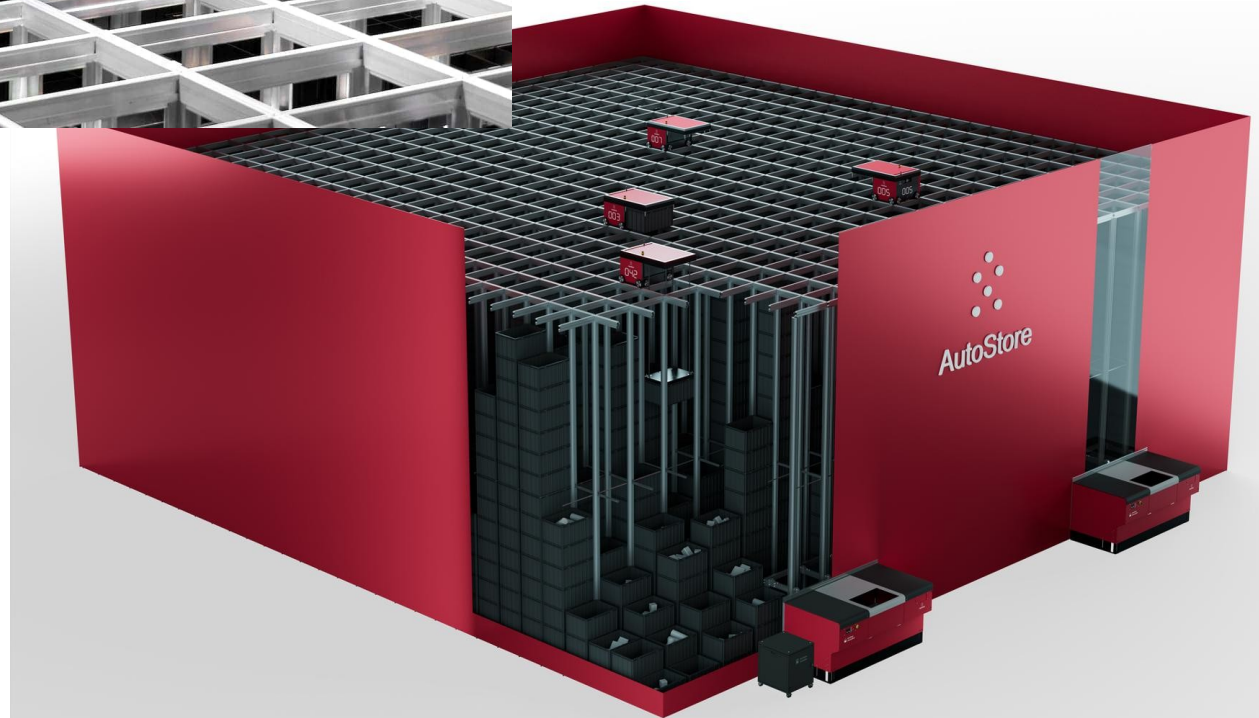




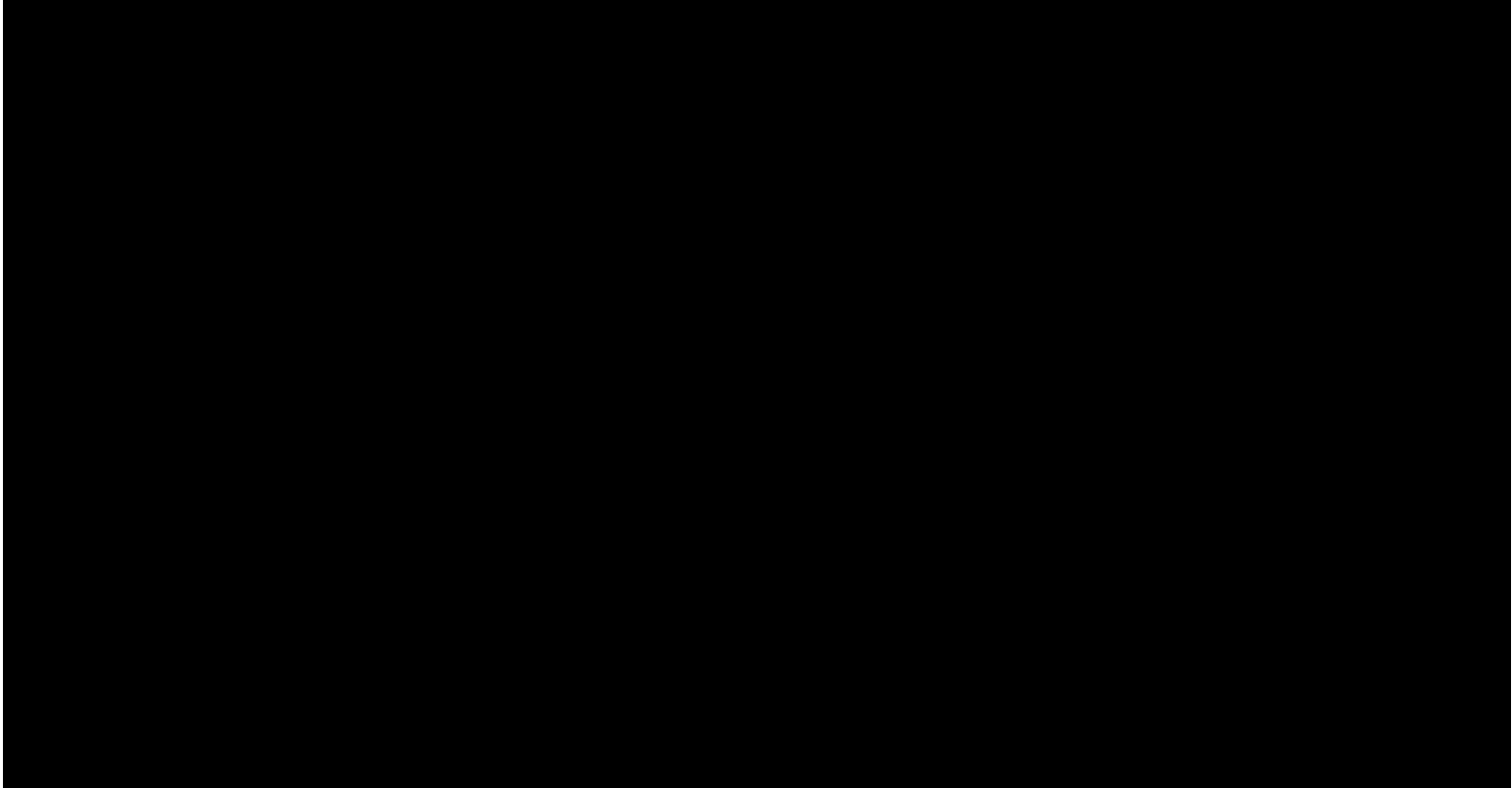
# Dense environment



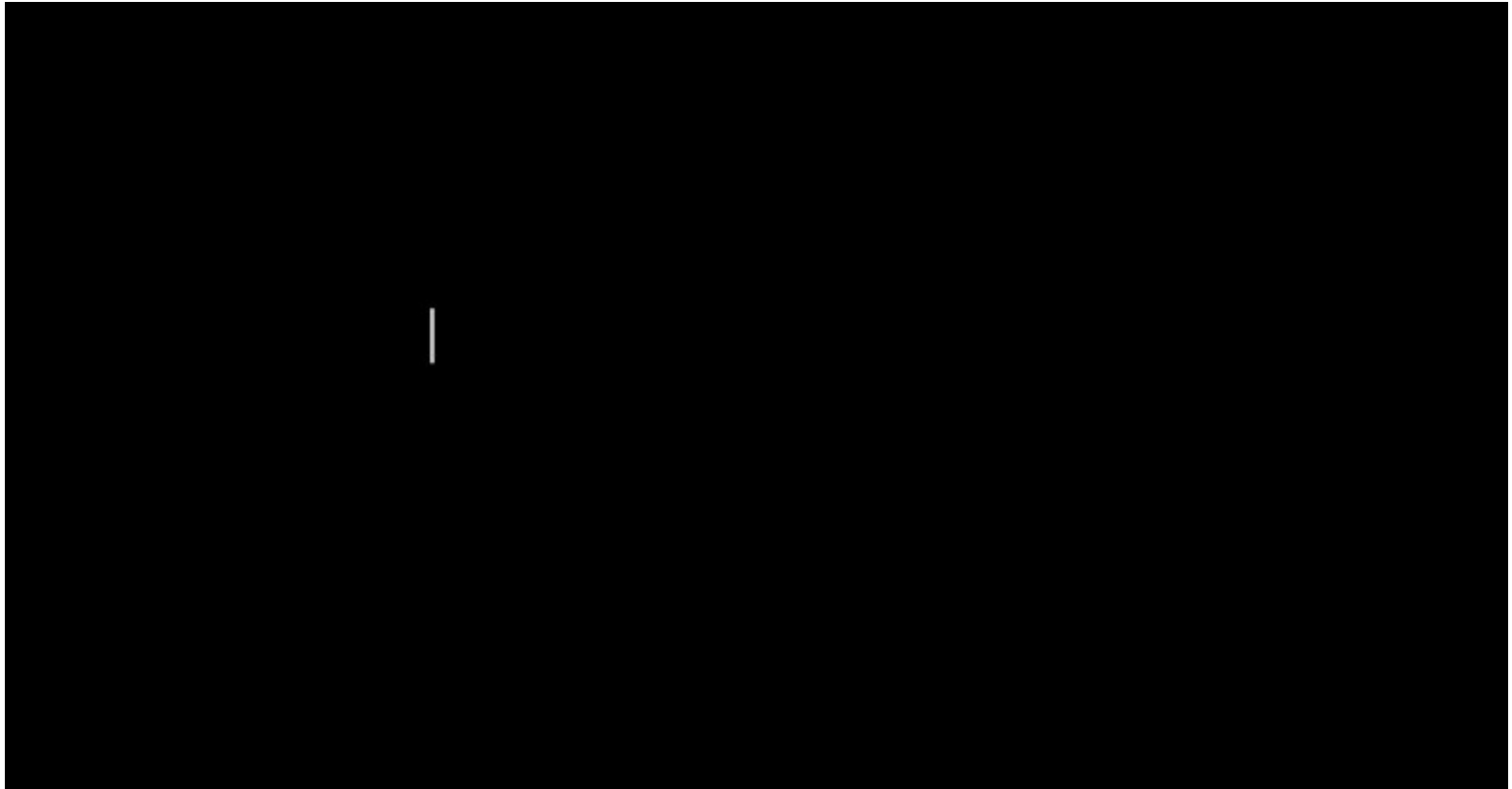
# Dense environment



# Dense environment

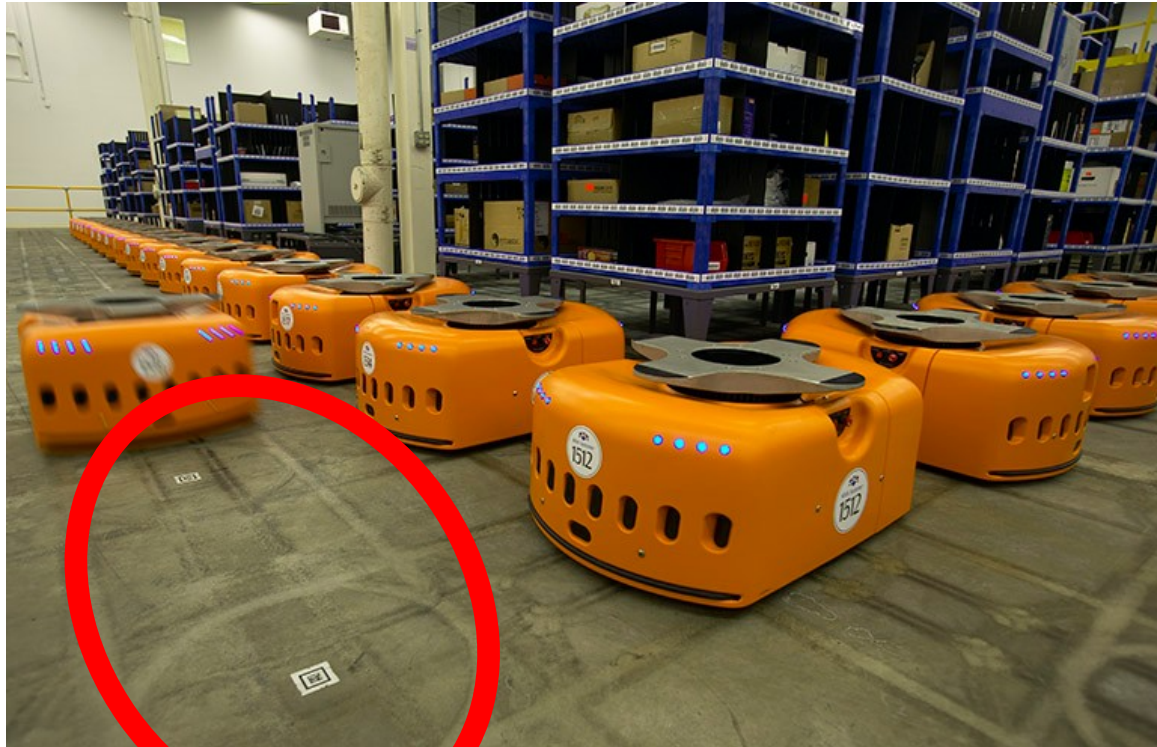


# Automated Guided Vehicles, Autonomous Mobile Robots



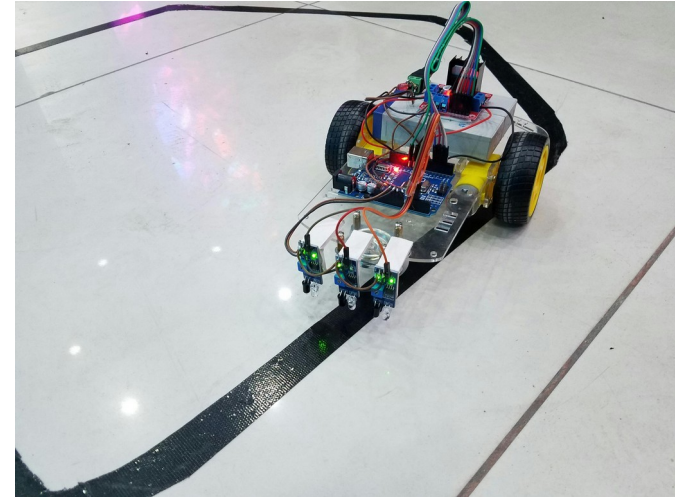
# Localization

- AMR still need localization and guidance!



# Localization

- QR-like markers
- Lines
  - Optical
  - Magnetic
- Image-based localization
- Motion capture localization



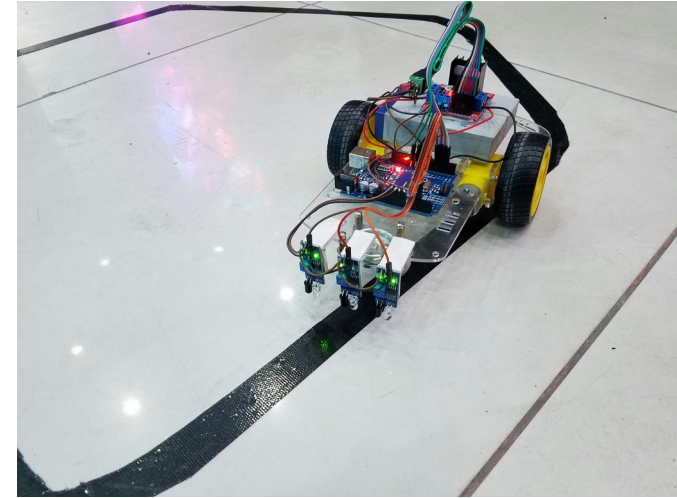
# Localization

- QR-like markers

Done by the agent



- Lines
  - Optical
  - Magnetic



- Image-based localization

Done by central entity



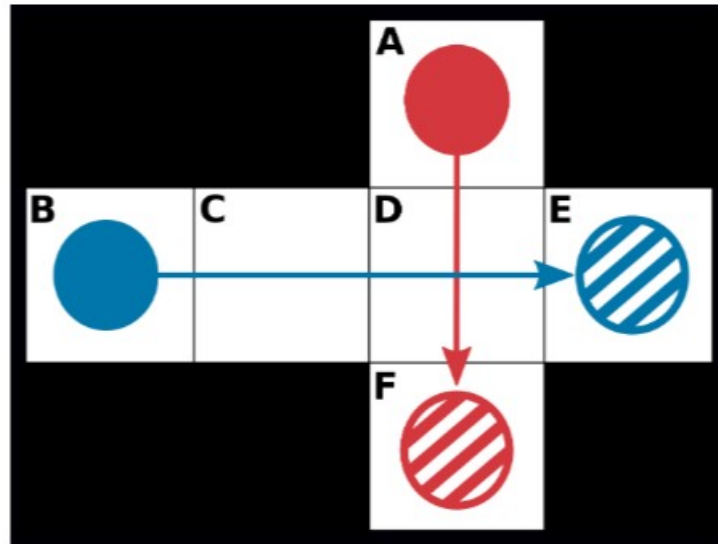
- Motion capture localization



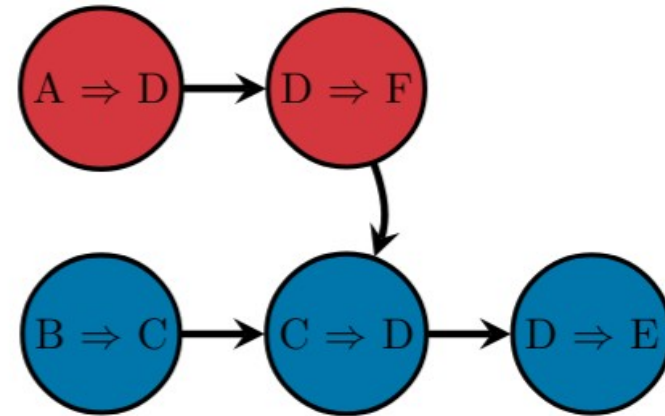
# Safe execution of MAPF

- Why? There might be delays
  - 1) Communication delay
  - 2) Localization delay
  - 3) Robotic reasons
- Settings
  - Centralized planner
  - Communication agent  $\leftrightarrow$  central unit
  - Localization by agent

# Action Dependency Graph (ADG)



(a)



(b)

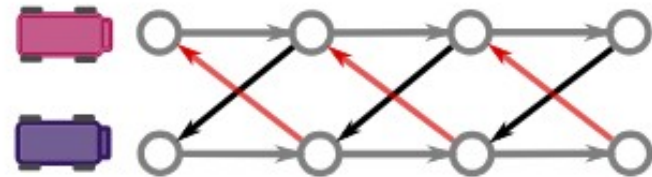
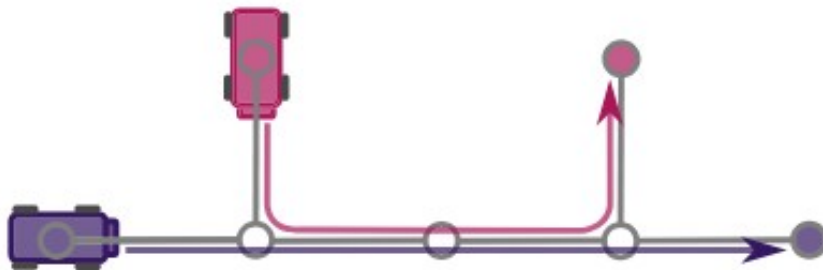
Figure 2: Example MAPF solution (a) and its ADG (b). Filled circles are agents and striped circles are their goals.

# ADG - properties

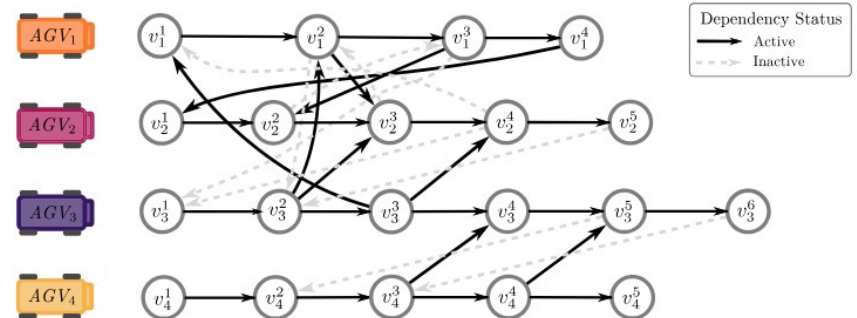
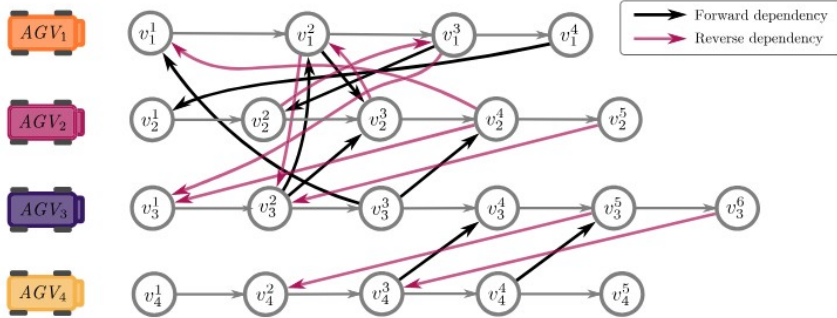
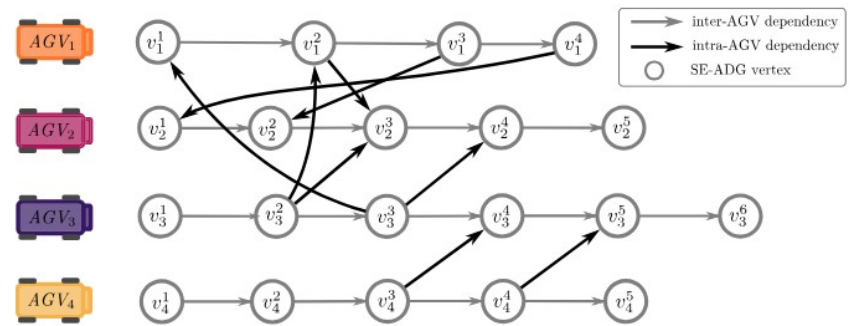
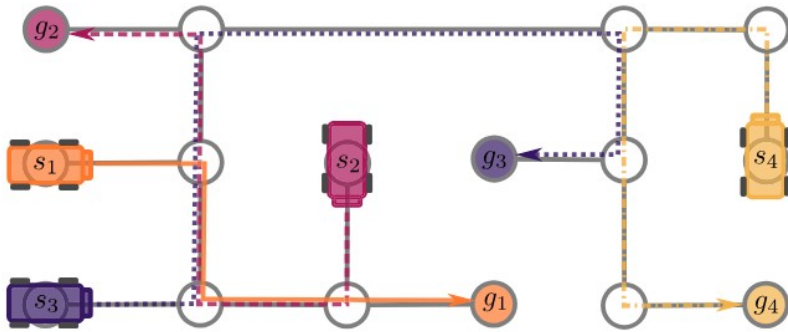
- ADG is DAG (cycles are bad!)
- Build from plan in poly. time
- Waiting times are not included
- Waiting is added implicitly
- Makes the plan 1-robust!!!

# Switchable ADG

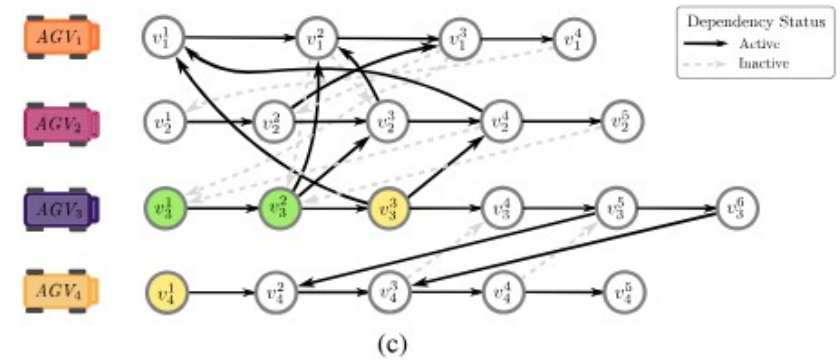
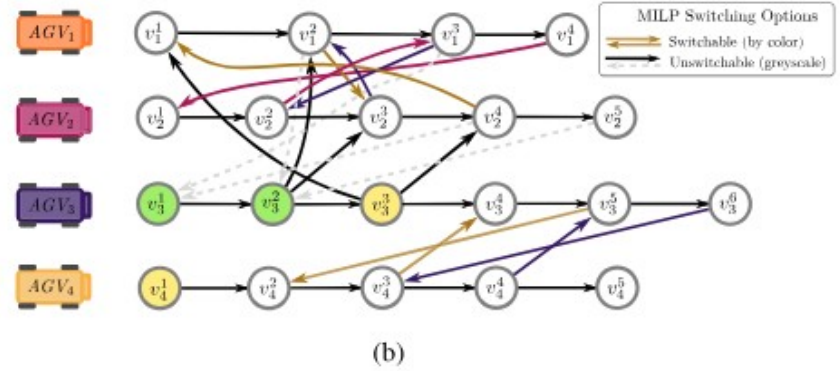
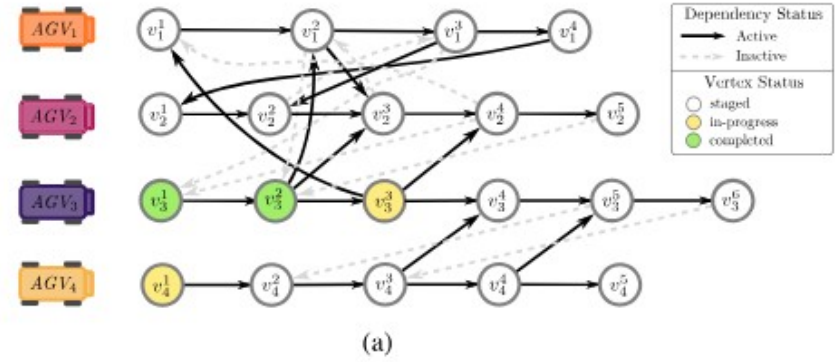
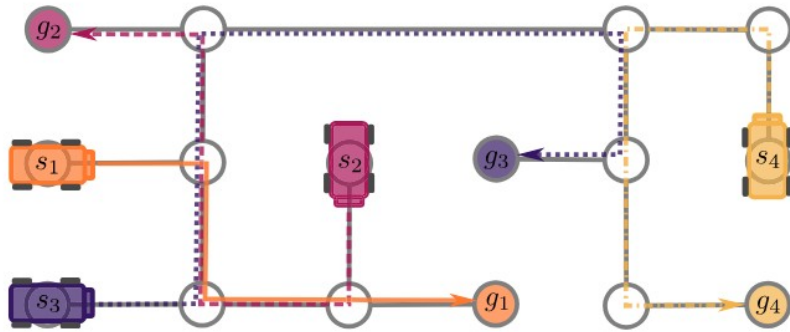
- What if the delay is too long?
- Can we switch order of agents?
  - Yes, if it does not create cycle
- Do we want to?
  - Yes, if it reduces cost
  - Solve by ILP



# Switchable ADG



# Switchable ADG



# Fix bigger issues

- Retime – adhere to ADG, just postpone
- Reschedule – switchable ADG
- Replan – calculate new MAPF plan

