Improving Market-Based Task Allocation with Optimal Seed Schedules

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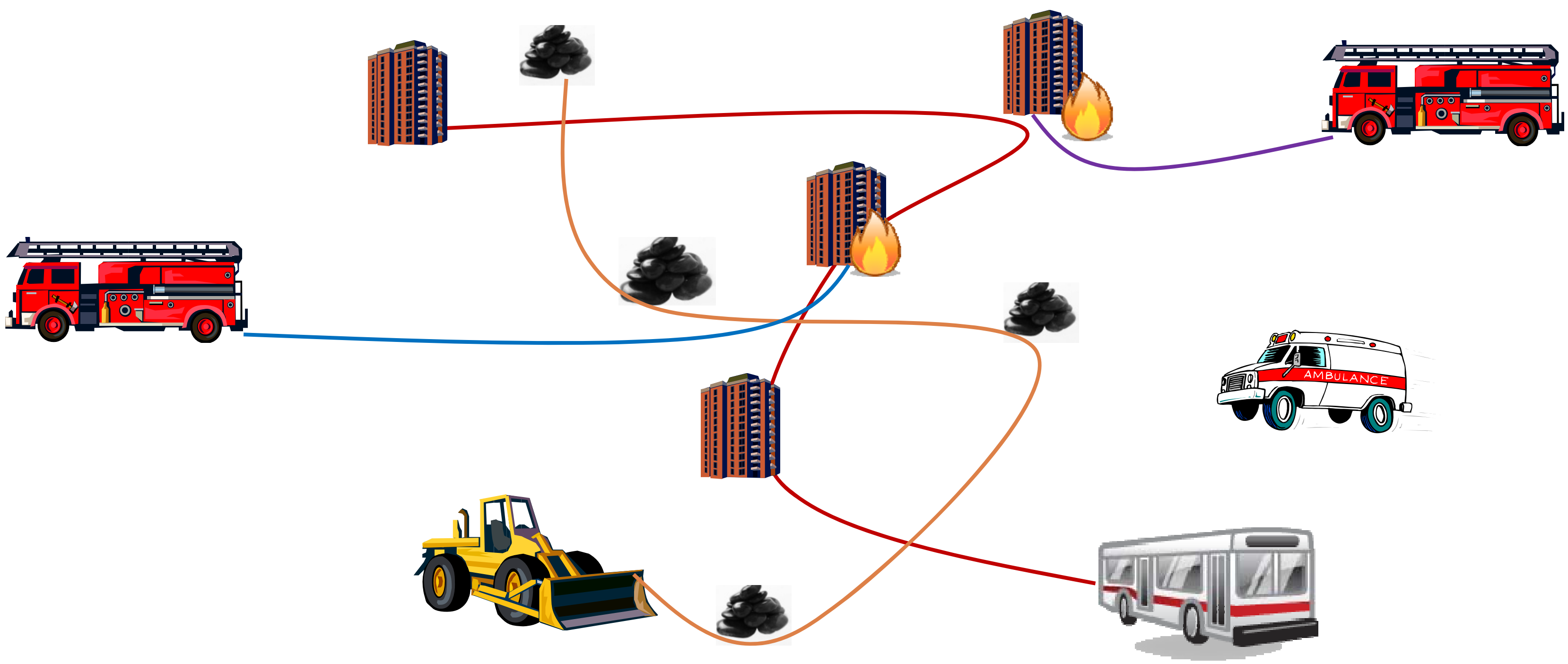
Task Allocation

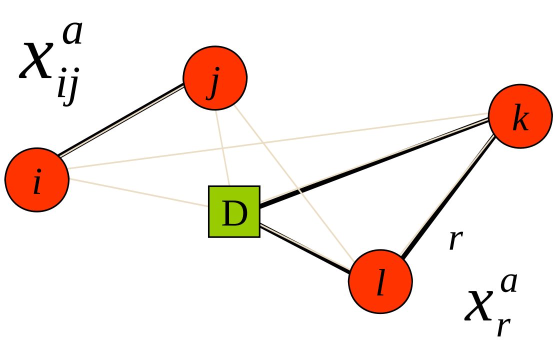
- Key component of team coordination planning
- Example: disaster preparedness and response



Tradeoff: Optimality vs. Adaptivity

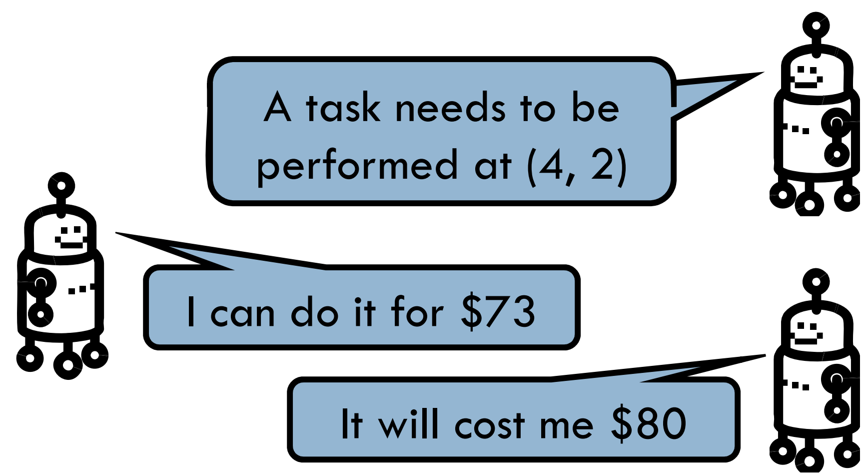
Mathematical Programming

- Optimality guarantees
- Slow to compute
  - not suitable for dynamic problems



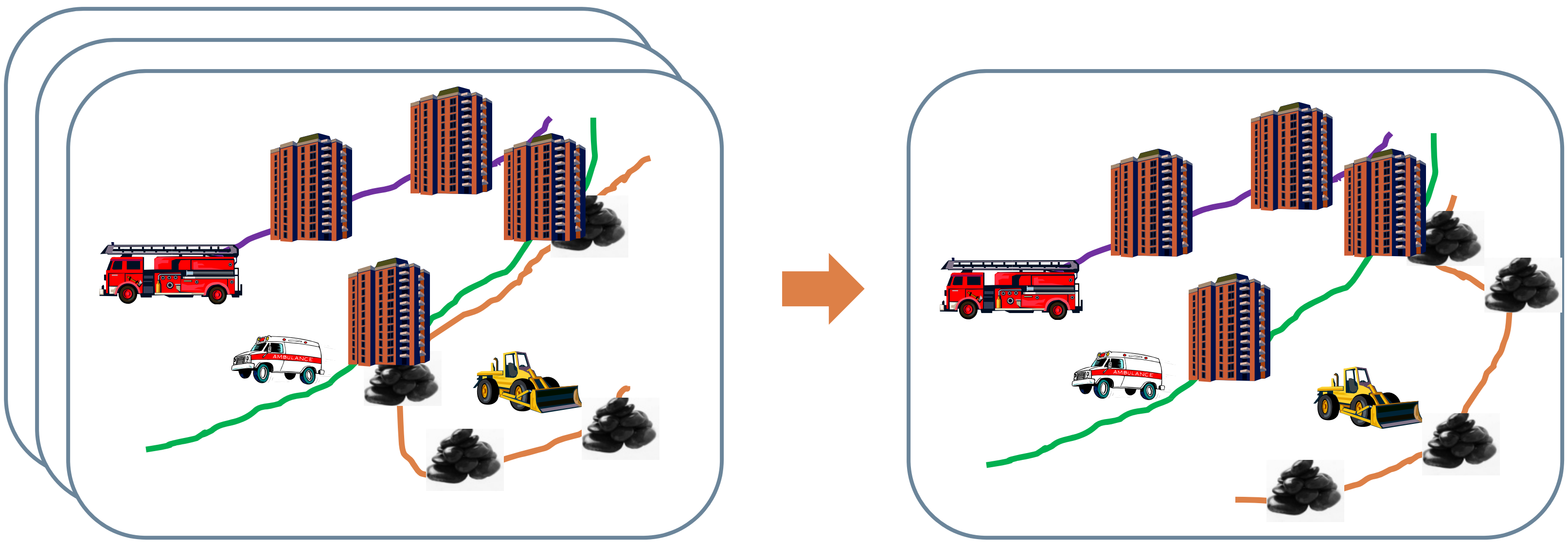
Market-Based Approaches

- No optimality guarantees
- Fast to compute
  - suitable for dynamic problems



Proposed Approach

- Optimally pre-allocate static tasks then adapt plan (heuristically) as needed to handle dynamic situations
- Can pre-compute several initial plans for various scenarios



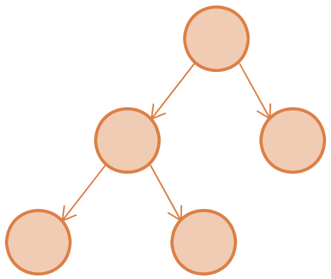
Approach Overview

Problem Decomposition

- Identify static and dynamic components of problem

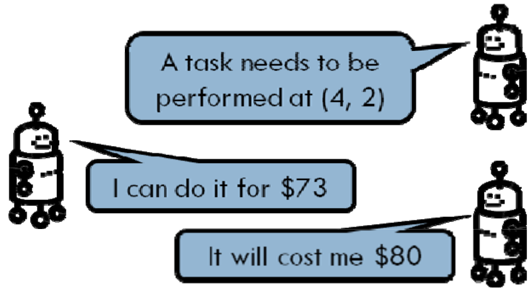
Mathematical Programming Approach

- Used to compute optimal solution to the static component of the problem
- Use a branch-and-price approach



Market-Based Approach for Dynamism

- Used to modify the initial optimal seed schedule to handle dynamic component of the problem
- Use TraderBots



Mathematical Model

Minimize:

Total Team Distance

$$\sum_{k \in agents} \sum_{r \in routes} d_r^k x_r^k$$

Subject to constraints:

One route per agent

$$\sum_{r \in routes} x_r^k = 1 \qquad \forall k \in agents$$

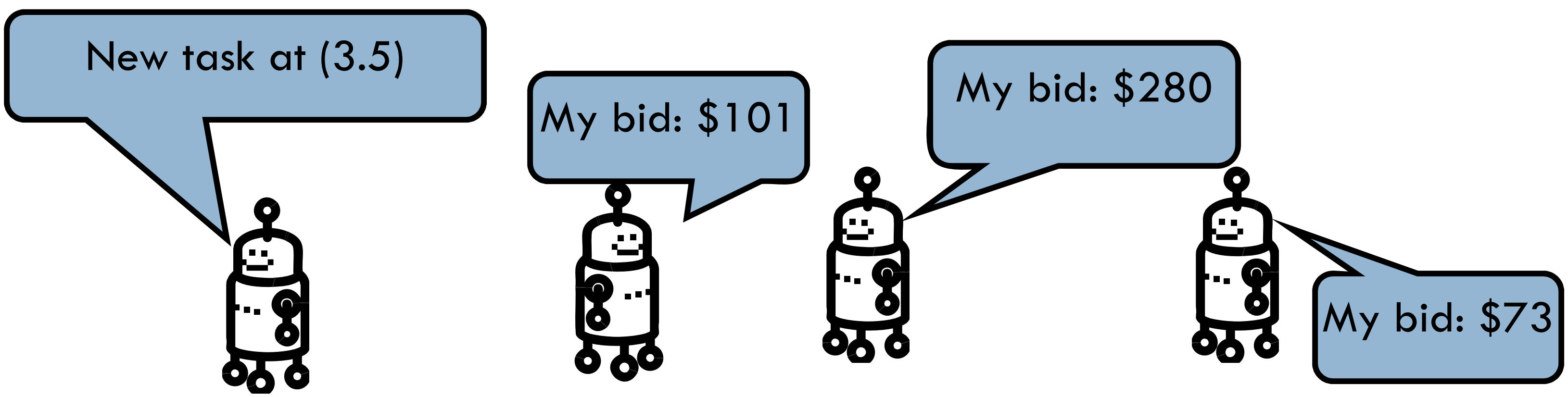
One agent per task

$$\sum_{k \in agents} \sum_{r \in routes} \pi_{jr}^k x_r^k = 1 \qquad \forall j \in tasks$$

"Route" = candidate time extended plan/task allocation for an agent

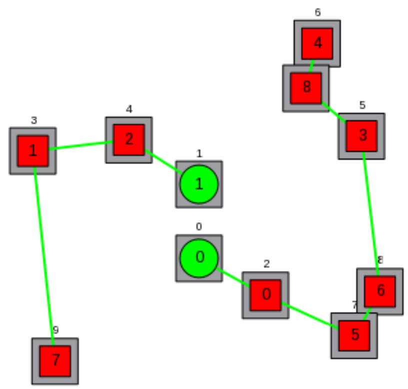
Seeded Market-Based Approach

- Start out with the initial optimal plan
- Use *market-based* approach to modify the optimal plan as changes occur
  - Hold auctions for new tasks as they arrive
  - Hold auctions for previously assigned tasks if needed (modified costs / execution failure)

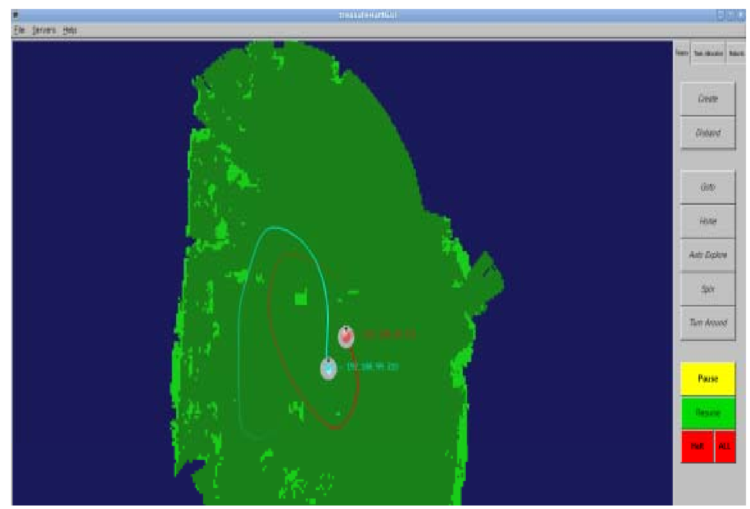


Experiments

- Simulation

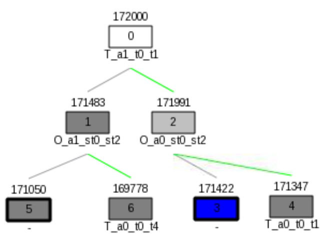


- Robots



Experiment Procedure

Use branch-and-price to compute initial optimal plan for static tasks



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Begin execution of computed plans

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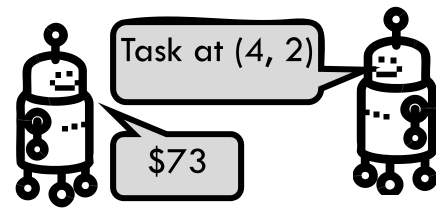
Continue execution, handling dynamism with market-based approach



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Complete Execution

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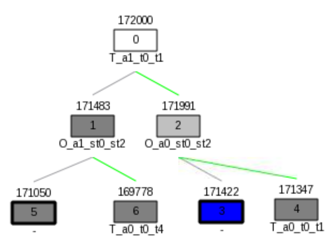
Compute "hindsight" optimal plan for static & dynamic tasks



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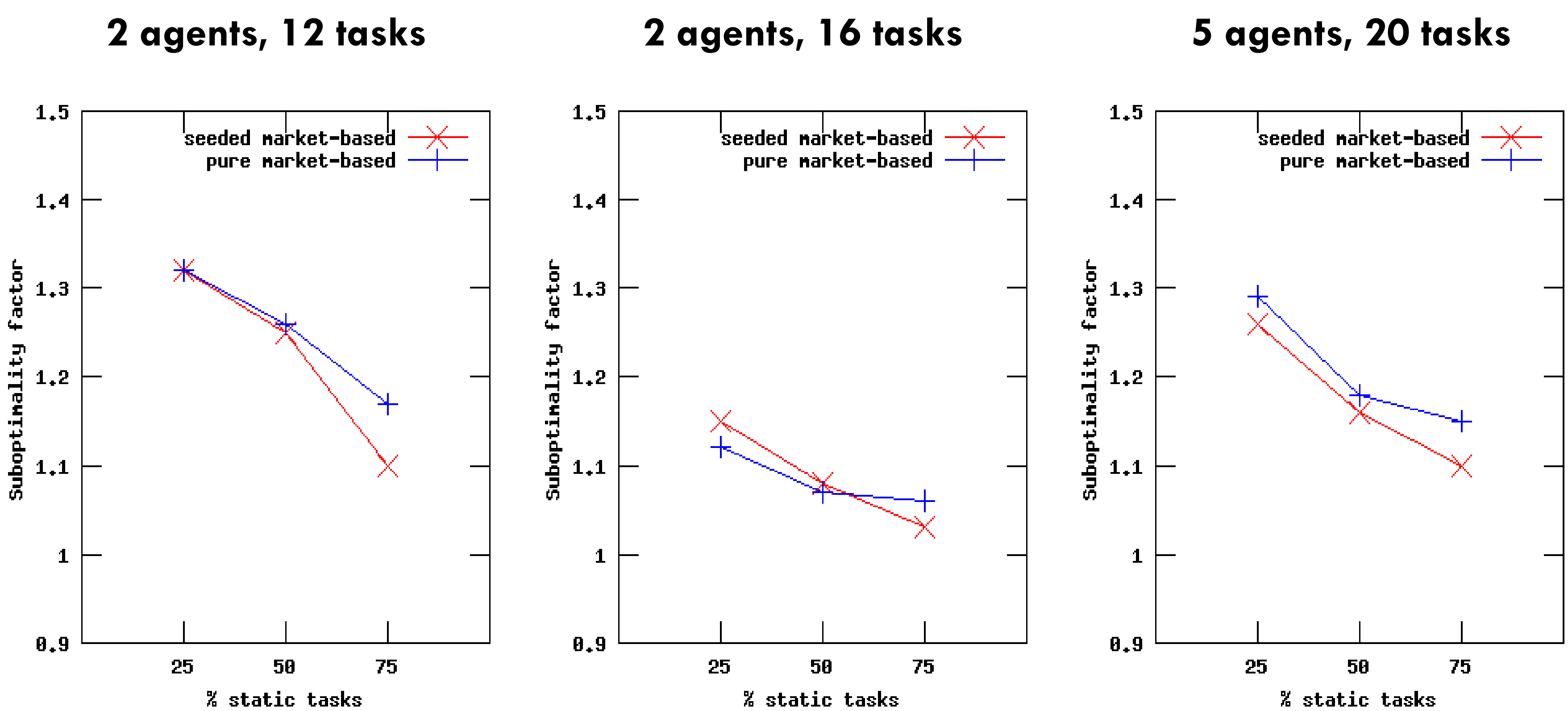
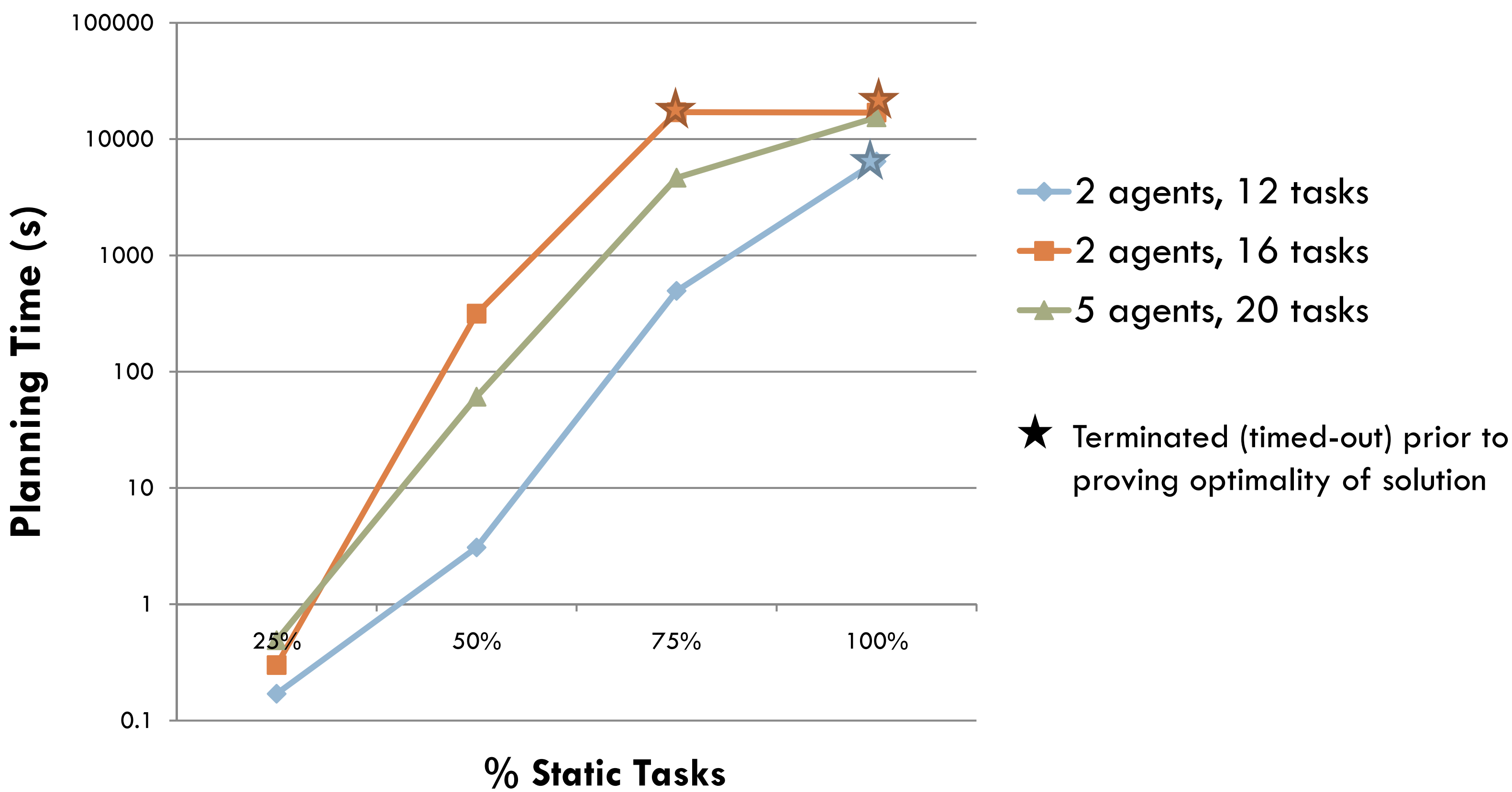
Compute "Sub-optimality factor"

$$= \frac{\textit{Actual team cost}}{\textit{“Hindsight Optimal”}}$$

Results: Simulation

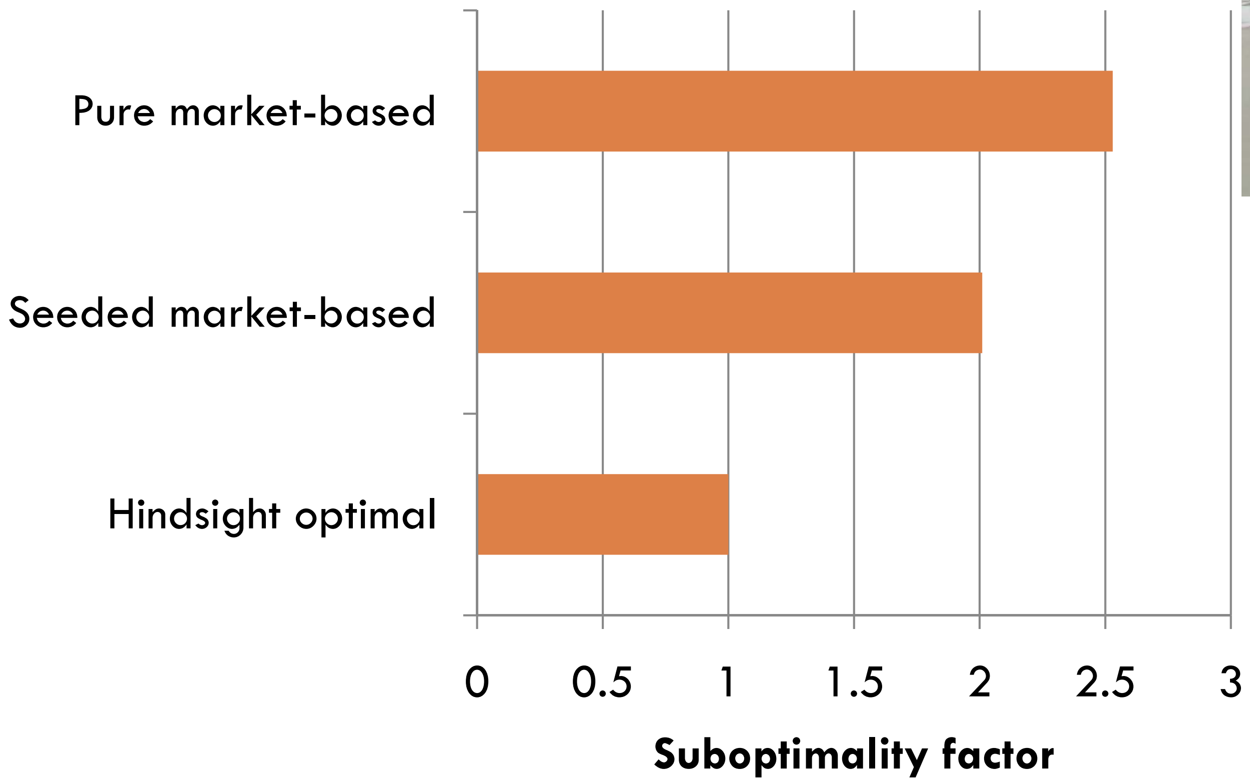


Median Planning Times for Branch-and-Price Planner (Simulation Experiments)



Results: Robots

2 robots, 11 tasks (6 static)



Conclusion

- Contributions:
  - A seeded market-based approach for task allocation
- Current & future directions:
  - Finer-grained characterization of seeded market-based approach
  - Handling inter-task order constraints (precedence, simultaneity, etc)

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Thank you! Questions?