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

A task needs to be performed at (4, 2)
- I can do it for $73
- It will cost me $80
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:

\[ \sum_{k \in \text{agents}} \sum_{r \in \text{routes}} d_r^k x_r^k \]

Subject to constraints:

\[ \sum_{r \in \text{routes}} x_r^k = 1 \quad \forall k \in \text{agents} \]

\[ \sum_{k \in \text{agents}} \sum_{r \in \text{routes}} \pi_{jr}^k x_r^k = 1 \quad \forall j \in \text{tasks} \]

“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)

New task at (3.5)
- My bid: $101
- My bid: $280
- My bid: $73
Experiments

- Simulation

- Robots
Experiment Procedure

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

Begin execution of computed plans

Continue execution, handling dynamism with market-based approach

Compute “Sub-optimality factor”

Task at (4, 2)

$73

Compute “hindsight” optimal plan for static & dynamic tasks

Complete Execution

Actual team cost = “Hindsight Optimal”

Korsah, Kannan, Fanaswala, Dias. “Improving Market-Based Task Allocation…”
Results: Simulation

2 agents, 12 tasks

2 agents, 16 tasks

5 agents, 20 tasks

Korsah, Kannan, Fanaswala, Dias. “Improving Market-Based Task Allocation…”
Median Planning Times for Branch-and-Price Planner (Simulation Experiments)

![Graph showing planning times for different configurations.]

- 2 agents, 12 tasks
- 2 agents, 16 tasks
- 5 agents, 20 tasks

*Terminated (timed-out) prior to proving optimality of solution*
Results: Robots

2 robots, 11 tasks (6 static)

- Pure market-based
- Seeded market-based
- Hindsight optimal

Suboptimality factor

Korsah, Kannan, Fanaswala, Dias. “Improving Market-Based Task Allocation…”
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?