ADAPTIVE TASK ALLOCATION TO HETEROGENEOUS AGENTS

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General Framework

Given:
- A set of \( k \) heterogeneous agents \( \mathcal{A} = \{A_1, A_2, ..., A_k\} \), where each agent belongs to one of \( m \) types.
- Set \( \mathcal{D} = \{d_1, d_2, ..., d_m\} \), where \( d_i \) denotes the start location of the \( i \)th agent.
- A set of tasks \( \mathcal{T} \) comprising of a set of generic tasks \( \mathcal{T}_0 \) and sets of type-specific tasks \( \mathcal{T}_i \) of each type \( i, 1 \leq i \leq m \).
- A complete graph \( G \) on the set of nodes \( \mathcal{T} \cup \mathcal{D} \).

Objective: Find an allocation of tasks to agents such that:
- all tasks are covered by at least one agent.
- task-agent compatibility constraints are met.
- maximum cost for any agent to complete its allocated tasks is minimized.

Problem Formulation

Heterogeneous Agent Path Problem (HAPP):

\[
\min \max \sum_{v_j \in \mathcal{T}} P^*(\mathcal{S}_j) \quad \text{subject to} \quad \bigcup_{j=1}^k \mathcal{S}_j = \mathcal{T}, \mathcal{S}_j \cap \mathcal{S}_i = \emptyset, \forall j \neq i
\]

\( P^*(\cdot) \): Cost of optimal path (starting from node \( v_j \)) on a given set of tasks
\( f(j) \): Returns type of agent \( A_j \)
\( \mathcal{S}_j \): Tasks allocated to agent \( A_j \)
\( \mathcal{V}_j \): Type-specific tasks allocated to agent \( A_j \)
\( \mathcal{R}_j \): Generic tasks allocated to agent \( A_j \)

Salient Features

- Robust adaptive allocation of tasks to agents that can handle failure of agents and cater to new tasks.
- Most existing work on heterogeneous agents focuses on minimizing the sum of costs incurred by all agents. We minimize the maximum cost - important in time critical applications where maximum latency needs to be low.
- We consider functional heterogeneity. Most works encapsulate heterogeneity in terms of vehicle dynamics.
- Several works on paths for homogeneous agents to minimize min-max cost. We extend these works to task allocation to heterogeneous agents while minimizing the maximum cost of the path.

Key Idea:

- Consider type-specific tasks and generic tasks separately. We can now use algorithms for homogeneous agent task.
- Two approaches: Path Split and Tree Split
- Existing algorithms for homogenous agent tasks allocation.
  - Min-max Path Cover Problem (Yu et. al., 2017).
  - Min-max Tree Cover Problem (Even et. al., 2004).

Conclusion and References

- Robust adaptive allocation of tasks to agents that is resilient to agent failures.
- Polynomial time approximation algorithms with bounds on worst case performance that is irrespective of number of agents or tasks.
- Future work: Distributed algorithm to solve HAPP.
- Several works on paths for homogeneous agents to minimize min-max cost. We extend these works to task allocation to heterogeneous agents while minimizing the maximum cost of the path.