Anytime Planning for Decentralized Multi-Robot Active Information Gathering

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Active Information Gathering

Our work considers the problem of Active Information Gathering, and specifically the problem of controlling a team of robots to track multiple moving targets.

Problem Formulation

Given $n$ robots and a planning horizon $T$, choose control policies to maximize information about the target:

- Mutual information
- Entropy
- Probability of error

Robot Motion Model

$$x_{i,t+1} = f(x_{i,t}, u_{i,t})$$

Sensor Observation Model

$$z_{i,t} = h(x_{i,t}, u_{i,t})$$

Distributed Control and Estimation

The robots use a decentralized coordinate descent algorithm, where each robot sends its trajectory to the next one, which optimizes by holding all previous trajectories fixed. For estimation, each robot maintains a local estimate of the target information matrix, and the robots perform a joint update step.

ARVI: Anytime Reduced Value Iteration

ARVI is an efficient search to monotonically improve the solution and respect real-time constraints.

Algorithm 1: Anytime Reduced Value Iteration

1. Initialize: $\pi_0 = \pi^{opt}$, $\mathbf{J}_0 = \mathbf{J}^{opt}$
2. For $t = 0, 1, 2, \ldots$ do
3. For all $u_i (\forall i) \in U_i, \mathbf{J}_{t+1} = \mathbf{J}_t + \mathbf{J}_t^{opt}$
4. Solve for $\pi^{opt}_{t+1}$ by holding all previous trajectories fixed
5. For all $u_i \in U_i (\forall i) do$
6. $x_t = f(x_t, u_t)$
7. $x_{t+1} = g(x_t, u_t)$
8. Sort $x_t$ in ascending order according to $\log(d(x_t))$
9. $\mathbf{C}_0 = \mathbf{C}_0 + \mathbf{C}_0^{opt}$
10. For all $u_i (\forall i) do$
11. if $x_t \in \Omega_0$ which is a cut
12. $Q_{t+1} = Q_{t+1}^{opt}$
13. $\Omega_0 = \Omega_0 + \Omega_0^{opt}$
14. return $(\pi_{t+1}, \mathbf{J}_{t+1})$

Results and Conclusion

We evaluated the algorithm in both simulation and experiments. The simulation evaluated the effects of communication radius and planning time. The experiment had 3 quadrotors track 5 moving ground robots.

Conclusion and Future Work

- Proposed algorithm demonstrates effective real-time trajectory generation for multi-robot target tracking.
- Future work will investigate:
  - Other applications such as SLAM or Environmental Monitoring
  - Alternative specifications including resilient problems where the robots must be robust to failures in the team