Multi-Agent Perimeter Monitoring for Uncertainty Reduction

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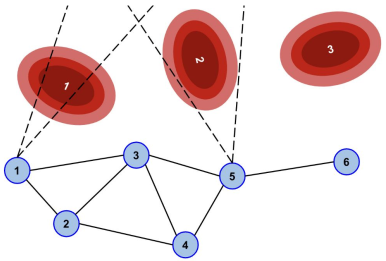
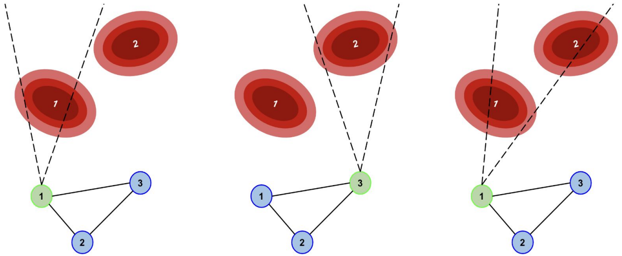
Overview

- Defenders must position themselves among a limited set of defensive positions in order to maximize their observations of enemy agents.
- Sensors return noisy observations, so maximal observations leads to reduction in uncertainty about the enemy.
- Links to existing research areas of path/perimeter defense and sensor/area coverage.

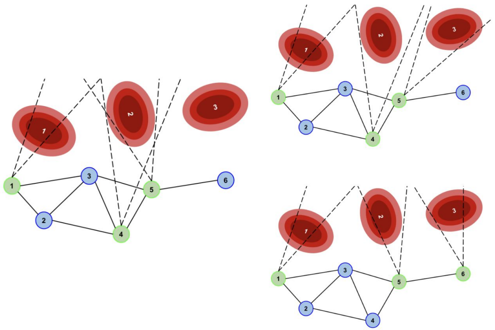


Single Agent Behavior

Left: An agent is initially positioned at defensive position *1*, with its FoV only observing enemy agent *1*.
Middle: An agent can move along edges to a new defensive position.
Right: An agent can remain in its defensive position and adjust FoV to improve observations.



Multi-Agent Behavior



Left: A multi-agent system is initially position so that agents at *4* and *5* have overlapping views of enemy agent *2*.

Top: As with single agents, an agent can simply adjust its FoV.

Bottom: Or, multiple agents can both act and adjust their positions, gaining a closer view of enemy agent *3*.

Formulation

- *n* agents occupy *m* defensive positions, tracked in an occupancy matrix $\mathbf{X} \in \mathbb{R}^{m \times n}$, with field of view angles tracked in $\Theta \in \mathbb{R}^{n}$.
- Approaching enemy agents are modeled as $\mathcal{P} = \{\mathcal{P}_1, \ldots, \mathcal{P}_p\}$ - probability distributions with means and variances.
- Our goal is to find a combination of defensive positioning and field of view angles to maximize coverage of enemy agents in order to reduce their uncertainty:

$$\max_{\mathbf{X},\Theta} \sum_{i}^{n} f(\mathbf{x}_i, \theta_i, \mathcal{P})$$

Considerations

- *Distance*: Defenders closer to enemy agents provide more valuable observations (illustrated in the set of figures to the left).
- *Observational Overlap*: Observations from fields of view that overlap on the same enemy agent should only be credited to a single defender.

Evaluation Plans

- Identify relationship of number of defenders, number of agents, and field of view angle widths. How does this affect convergence?
- Do existing algorithms address this proposed problem? Evaluate assignment methods such as the Hungarian algorithm.