A game theoretic model for management of mobile sensors

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Primary objectives of current work

Study effects of multi-target tracking with mobile sensors using a game theory based algorithm

Previous properties: stationary sensors negotiating about a partitioning of the set of targets.

Now:

- Sensors are mobile
- Sensors have limited resources
- Targets are shared

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Results

Intermediate (i.e., current)

- A framework for studying negotiation-based target-to-sensor allocation
- Forced target sharing yields robustness to sensor failures
- Simultaneous consideration of multiple objectives allow sensors to escape situations where a greedy approach gets "stuck"

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Sensor agent negotiation

Previous work: Negotiation offers:

- complete allocation of sensors to targets
- every allocation had a value for every sensor (*reward*)
- the *negotiation utility* dependent on time and reward

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Previous work: Negotiation offers:

- complete allocation of sensors to targets
- every allocation had a value for every sensor (*reward*)
- the *negotiation utility* dependent on time and reward

Current work:

- offers are still target-to-sensor allocations, but may be overlapping
- every allocation has two associated values, reward and reward derivative
- the negotiation utility still depends on time

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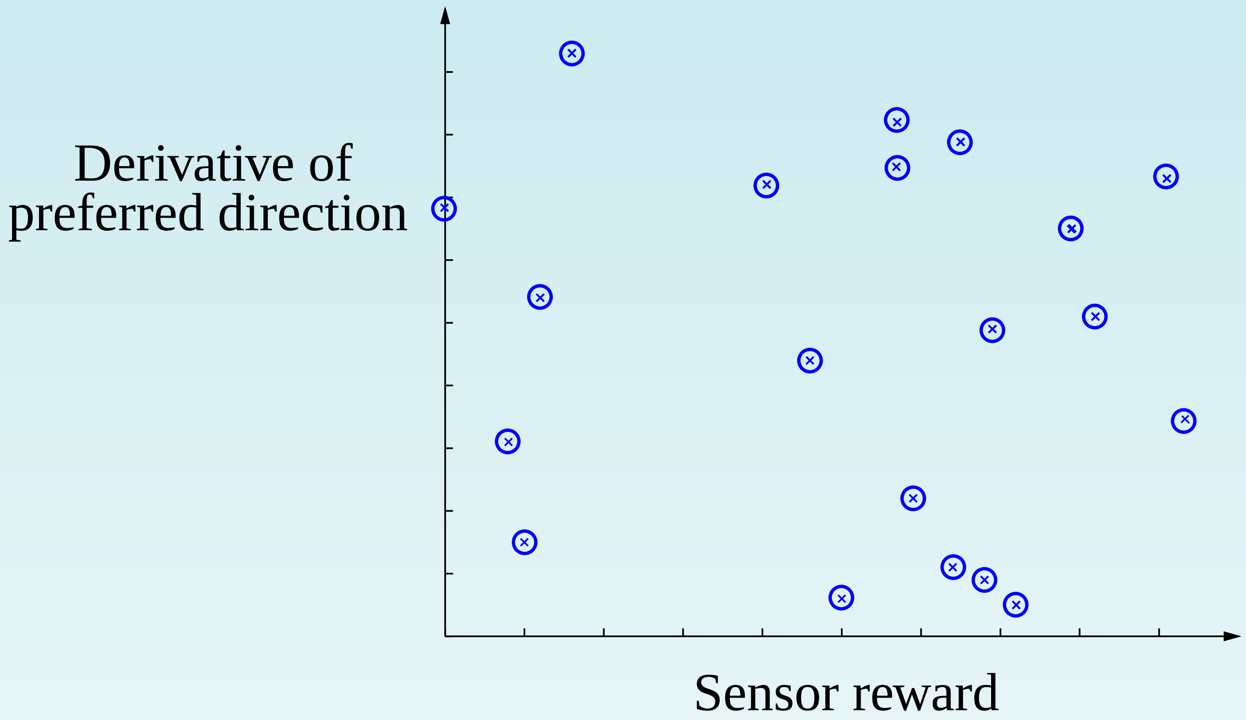
Dominance

Evaluation of offers for some sensor agent i



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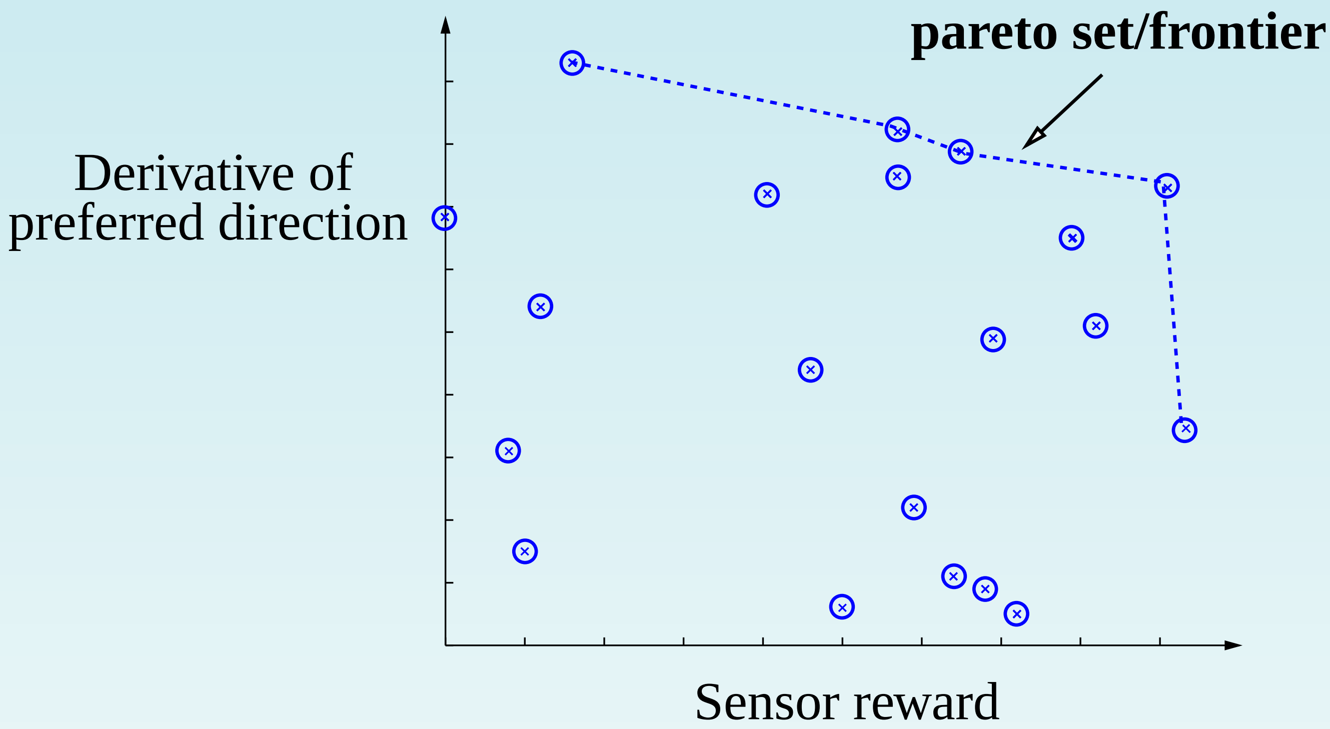

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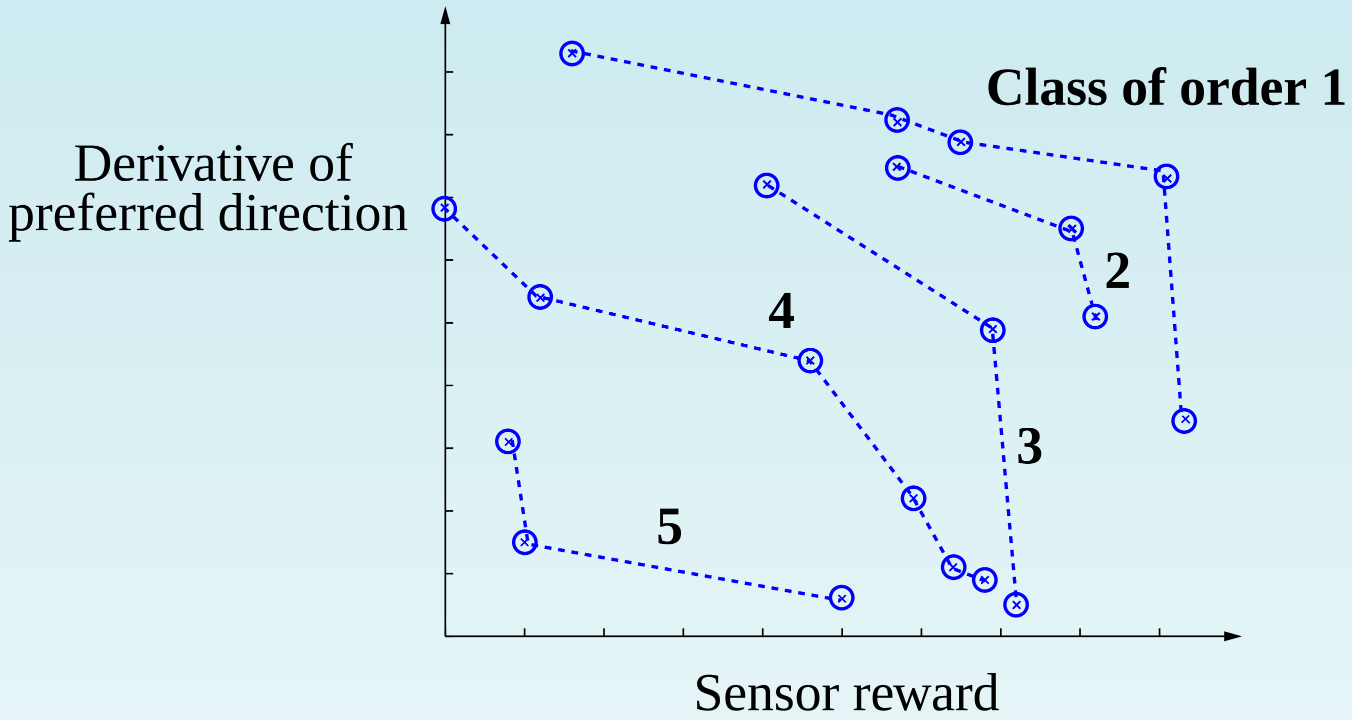

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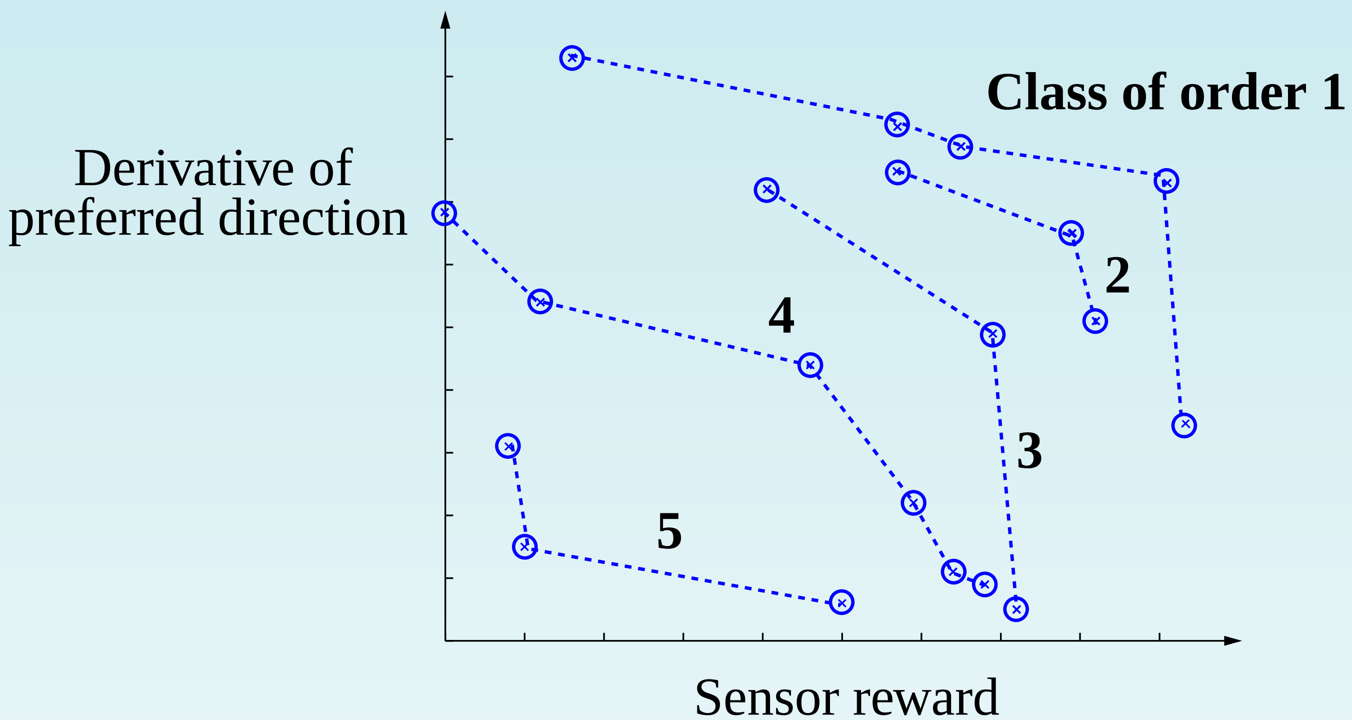

$$U_i(o, \mathbf{t}) = f(order_i(o), \mathbf{t}) = -order_i(o) - \mathbf{t}$$

Sensor reward

Individual *sensor measurement reward* for sensor i

$$r_i^m(D_i) \triangleq \sum_{j \in D_i} \gamma_{ij} \cdot r_j(S_j)$$

D_i is the set of targets tracked by sensor i and S_j the set of sensors tracking target j.

Net reward (the reward which is considered in the negotiations)

$$r_i^{net}(D_i) \triangleq \alpha_i + (1 - \alpha_i) r_i^m(D_i), \quad 0 \leq \alpha_i \leq 1 \ ,$$

For the reward on every target in our experiments, we use the *information gain* from Kalman filtering.

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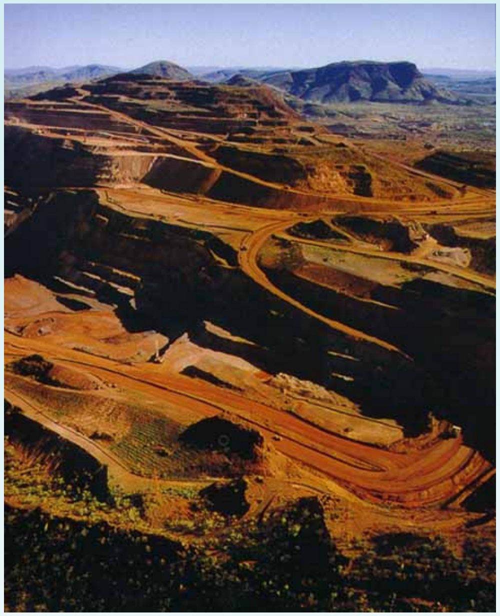
Derivative of preferred direction

A terrain function, $t(\mathbf{p}, \mathbf{e}_\theta)$, discounts the derivatives for any tuple of position $\mathbf{p}$ and any direction $\mathbf{e}_\theta$. The preferred direction has the highest discounted derivative, $\max_{\mathbf{e}_\theta} \{t(\mathbf{p}, \mathbf{e}_\theta) \cdot r'_{\mathbf{e}_\theta}\}$.



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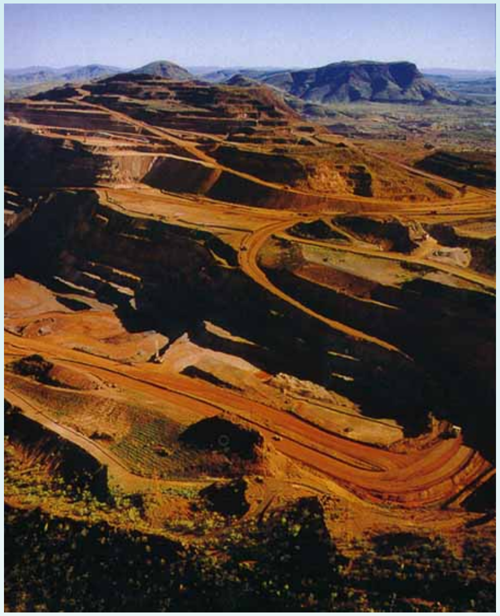

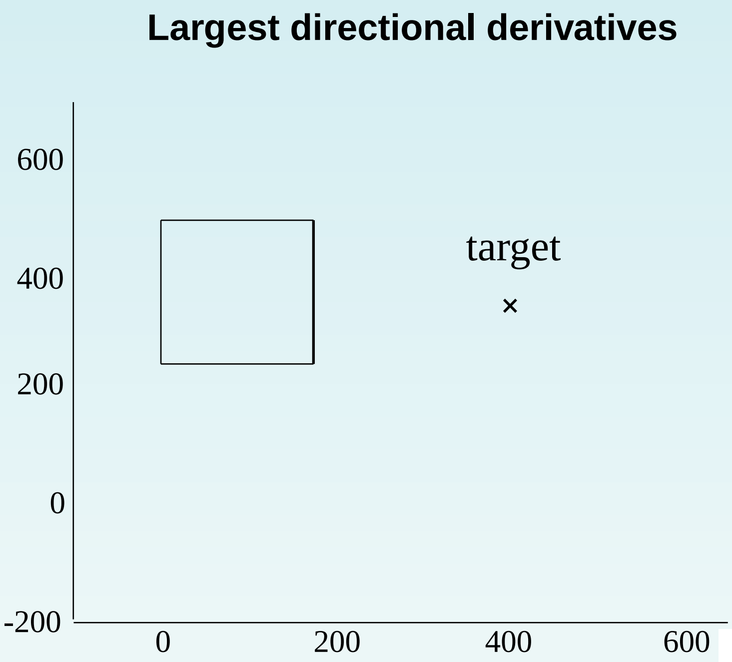

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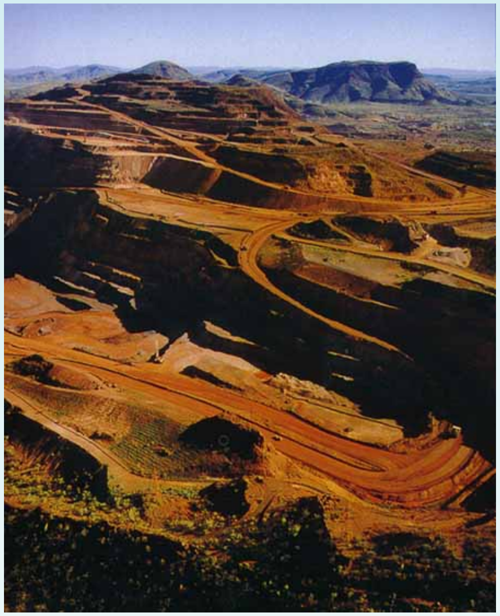

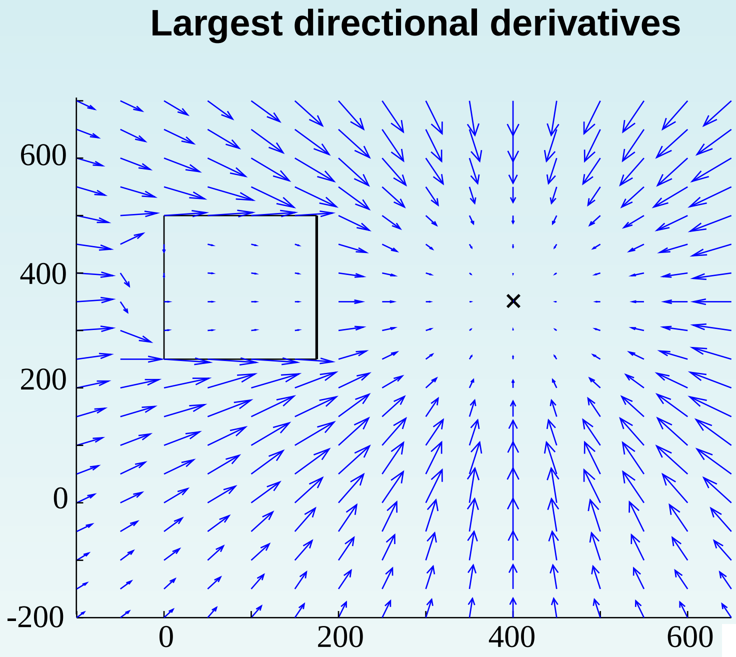

Experiment setting

- We implement an allocation strategy based on the negotiation algorithm, called the `N-tracker`.
- We also implement a reference strategy, called the `G-tracker`.
- Trackers are run independently on three scenarios, including a set of mobile sensors and a set of targets.
- With regular time intervals both trackers reconsider the target-to-sensor assignment.

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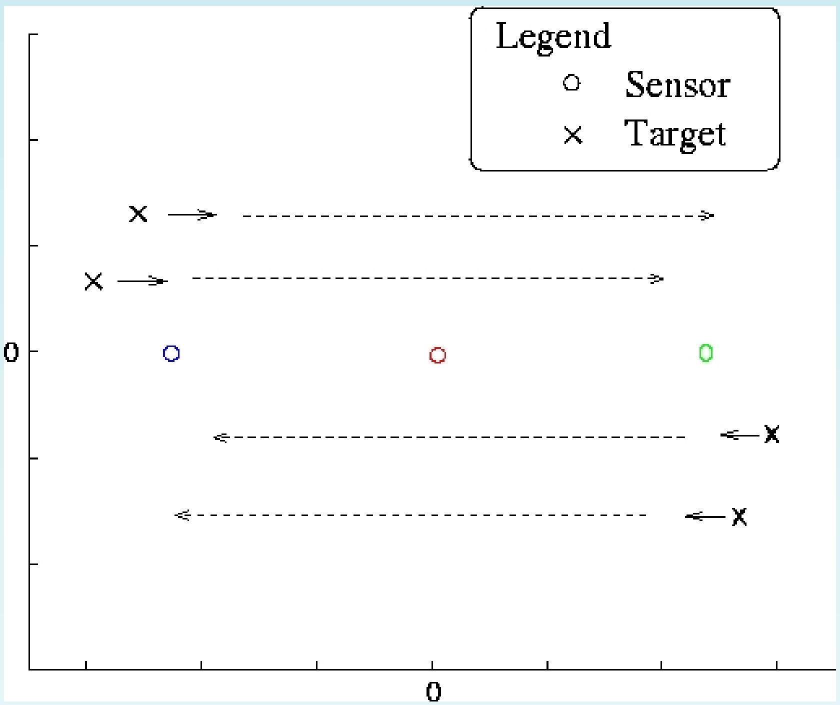
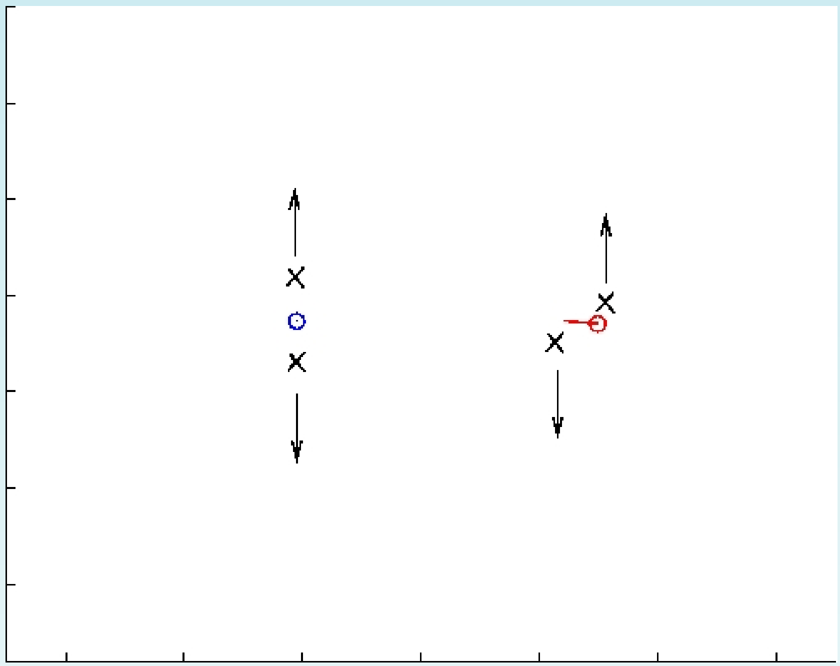
Scen1: Tracking four targets

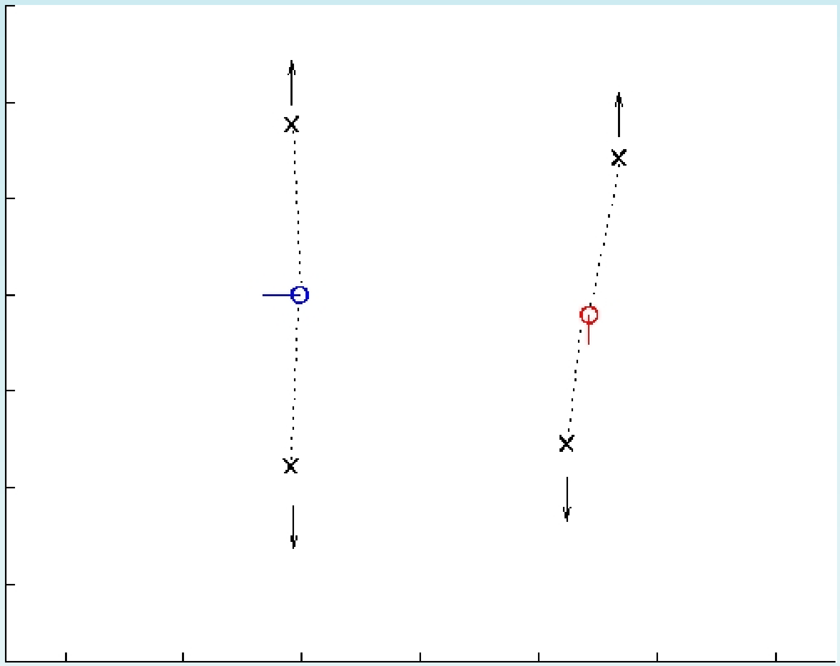


	G-tracker	N-tracker	Relative
Reward	3.7372	3.3765	**0.90**
Lost targets	1.1830	0.8693	**0.73**

Scen2: `G-tracker` getting stuck

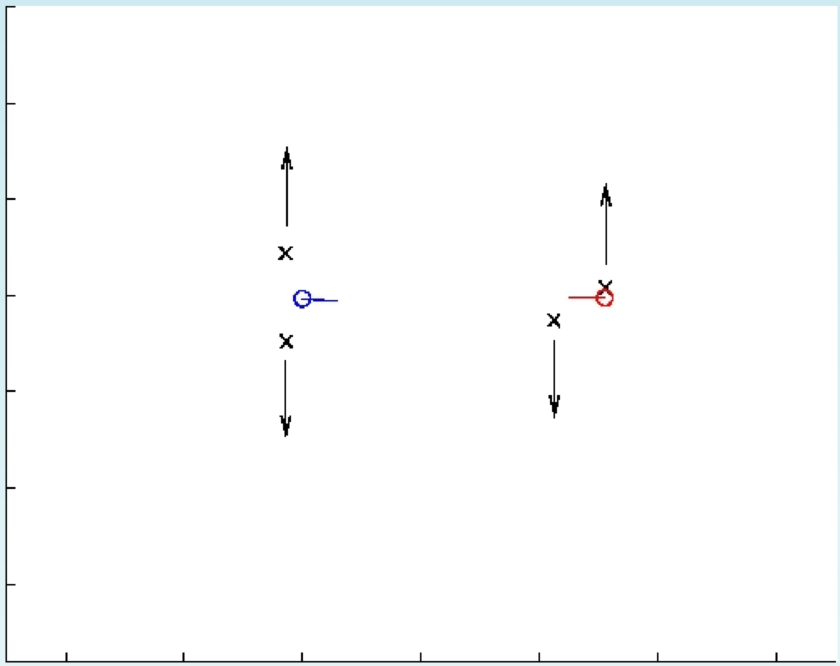


Initially



After some time

Scen2: `N-tracker` eluding deadlock



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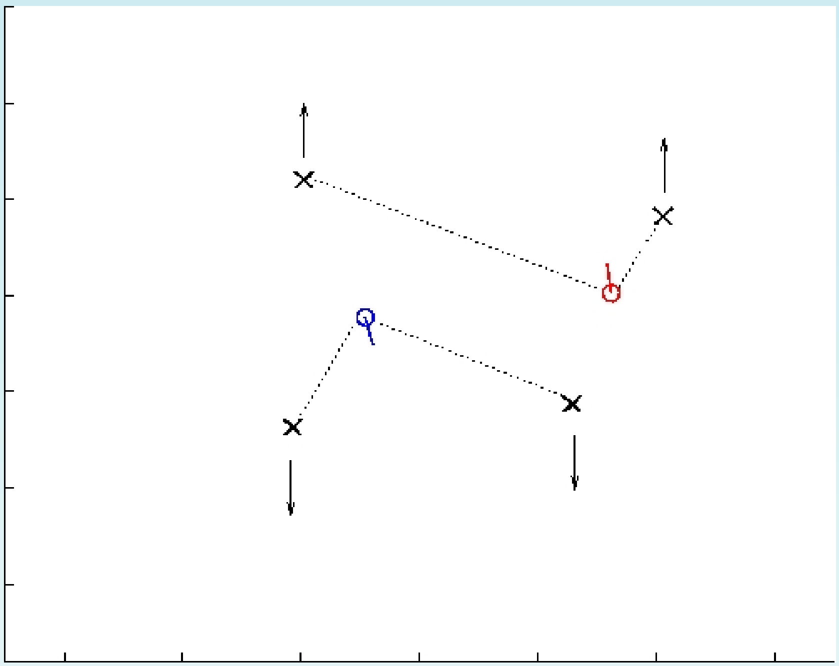
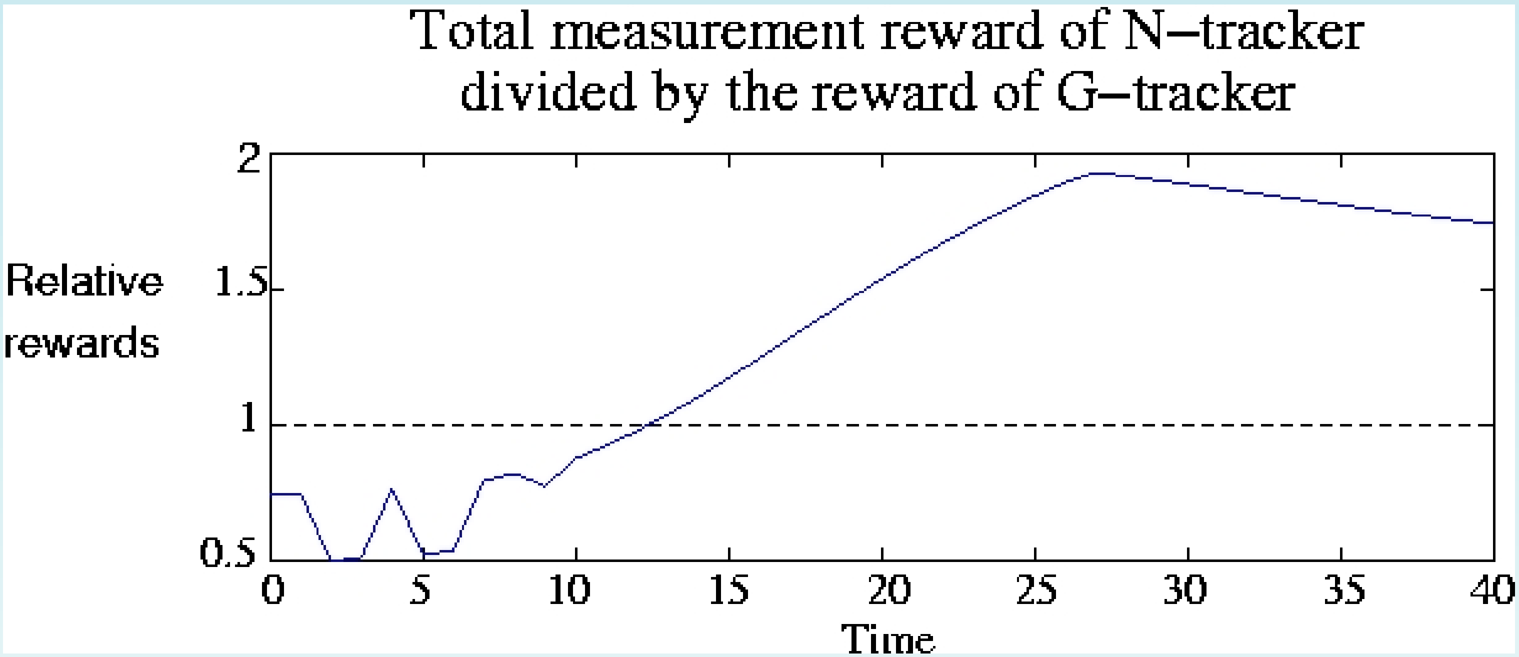


After some time

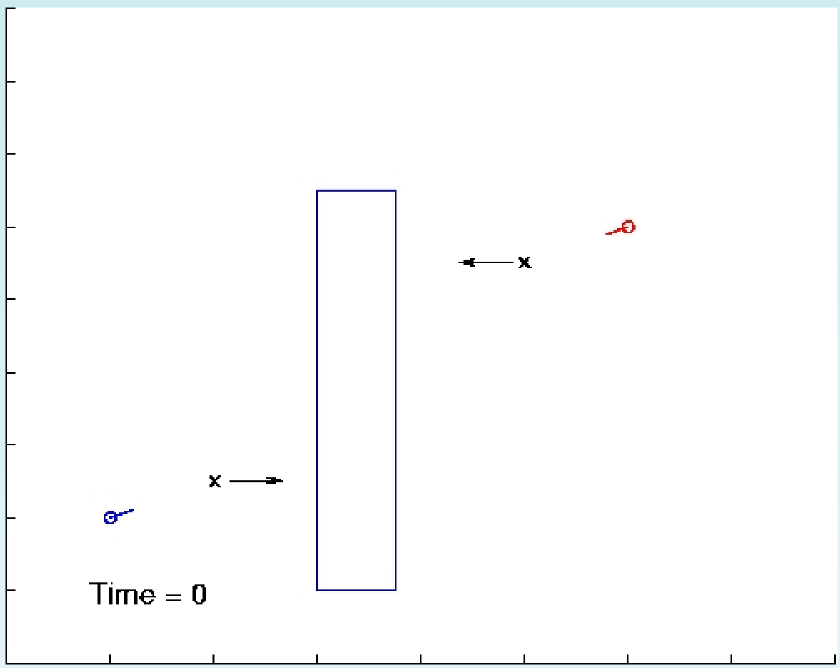
Scen2: Results



At $t = 10$: The `N-tracker` settles on which targets to track

At $t = 27$: The `G-tracker` escapes its deadlock

Scen3: `G-tracker` in bad terrain



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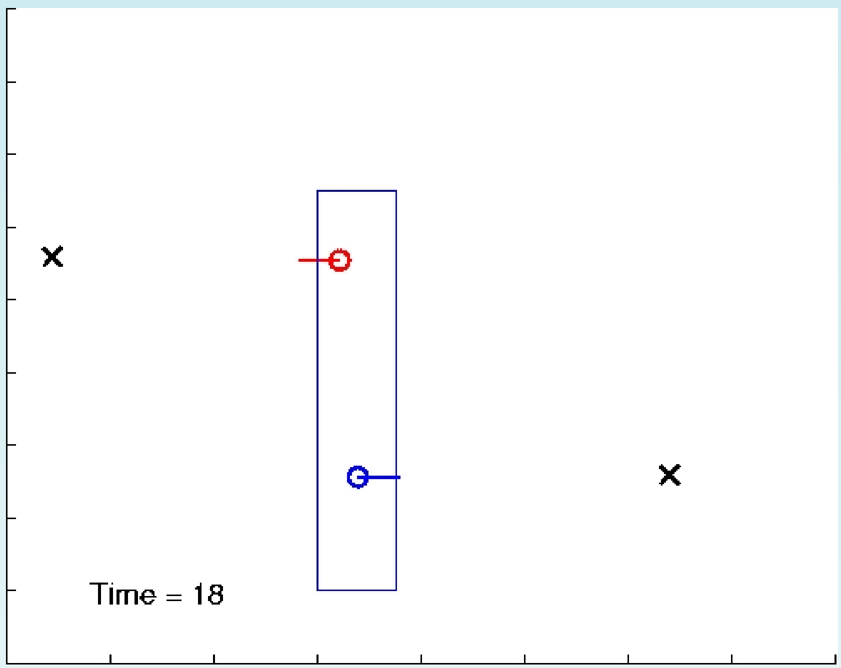

After some time

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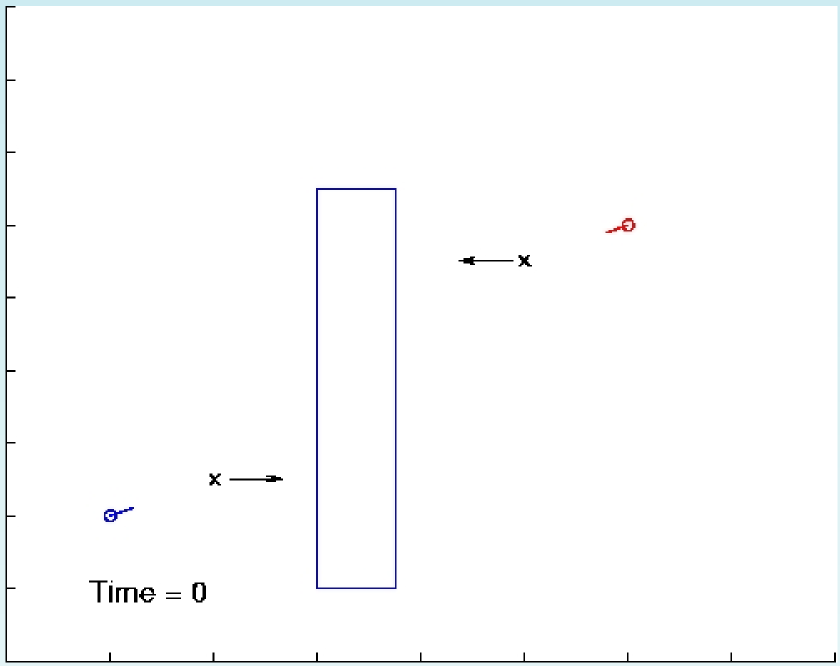
Scen3: `N-tracker` switches targets



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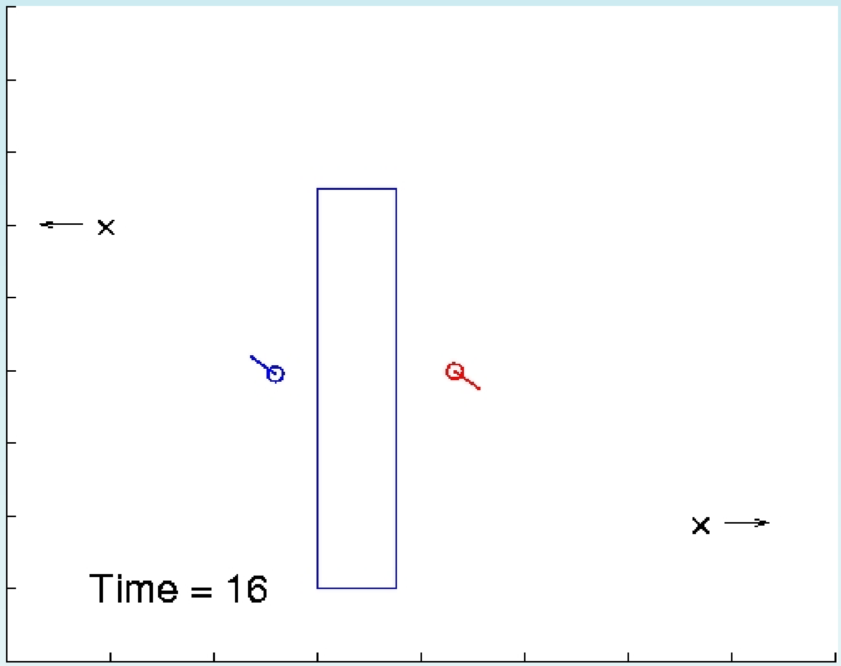

After some time

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Summary and future work

- We have developed a framework for studying negotiation-based sensor management with mobile sensors
- Results indicate that the negotiation-based strategy (the `N-tracker`) has advantages over a greedy one (the `G-tracker`).

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Future work

- Incorporate system model into expected measurements
- Agent uncertainty about world state

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