Active Target Tracking with Self-Triggered Communications

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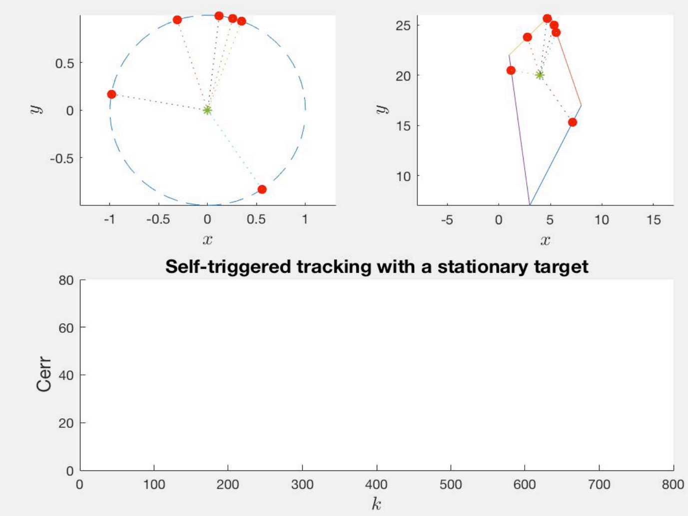
Scenario: Team of robots moving on the boundary of a convex environment must track a target moving inside the environment using distance measurements.

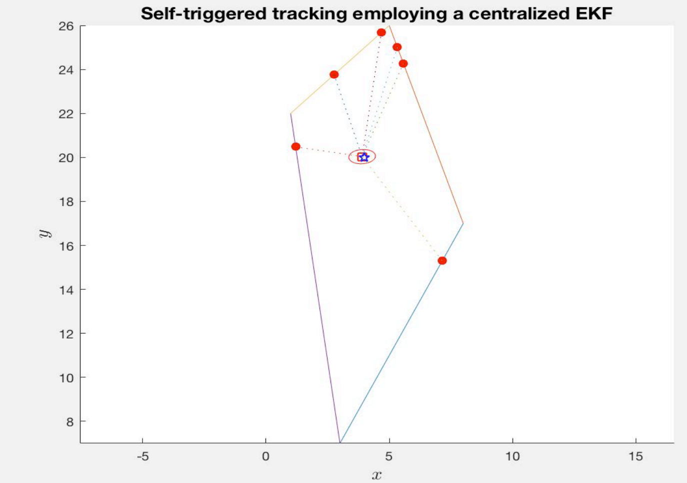
Goal: Achieve a uniform distribution on the boundary while reducing inter-robot communication. ***Instead of communicating at all times, can we decide when its best to communicate?***

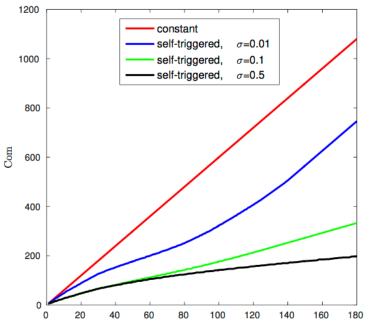
Problem 1: Track a stationary target. We propose a self-triggered decentralized strategy that decides **when to communicate** for each robot.

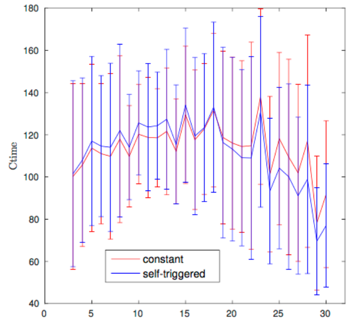
The self-triggered strategy converges (provably) and reduces the number of communication messages.

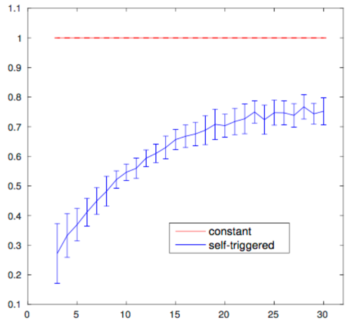
Problem 2: Track a mobile target with noisy measurements using centralized/decentralized Kalman Filter.











The material is based upon work supported by the National Science Foundation under Grant Nos. 1566247 and 1637915

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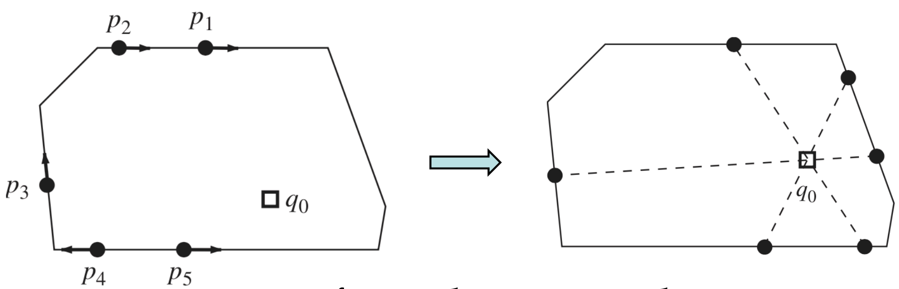
Constant communication with static target

Decentralized target tracking

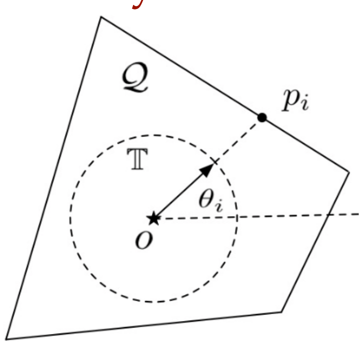


p_1~p_5 are five robots, q_o is the target

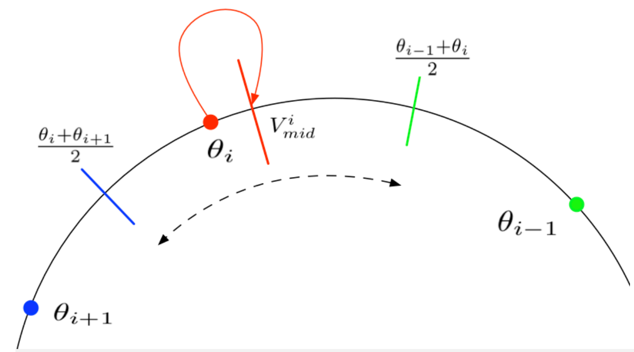
Map: convex boundary to unit circle

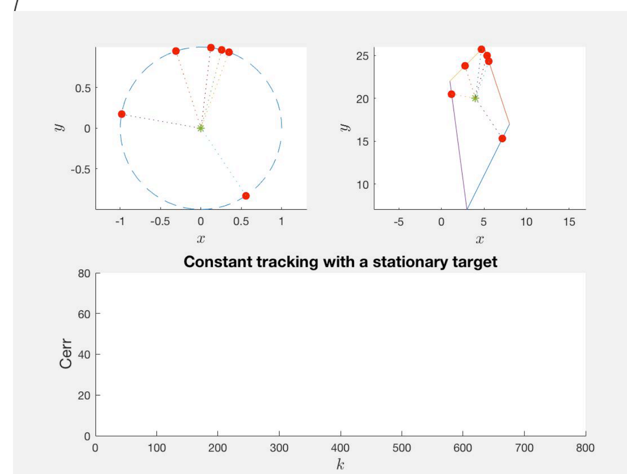
$$\varphi_o : \partial\mathcal{Q} \to \mathbb{T}$$

$$\varphi_o(p) = \frac{p - o}{\|p - o\|}$$



Sensor i goes towards the midpoint





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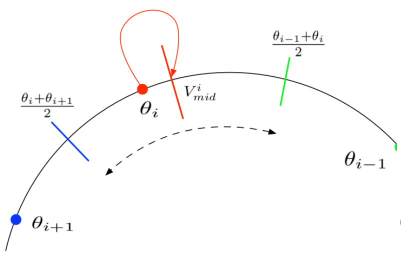
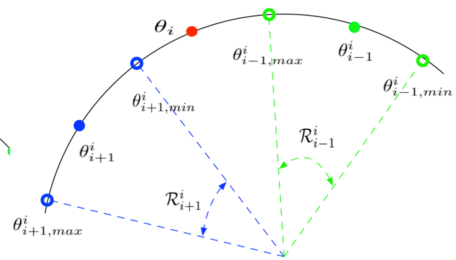
Self-triggered communication with static target

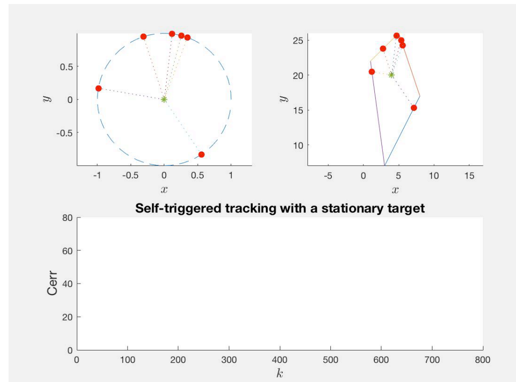
Challenge



Constant tracking

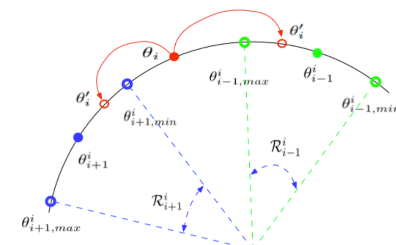


Self-triggered tracking



Triggered policy

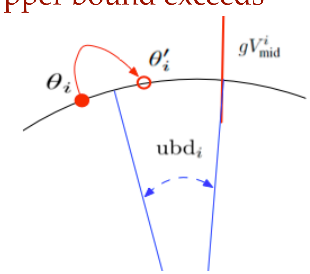
1) Break counterclockwise order



$$\theta^i_{i+1} - \omega_{\max}\tau^i_{i+1} \leq \theta'_i$$

$$\text{or } \theta'_i \leq \theta^i_{i-1} + \omega_{\max}\tau^i_{i-1}$$

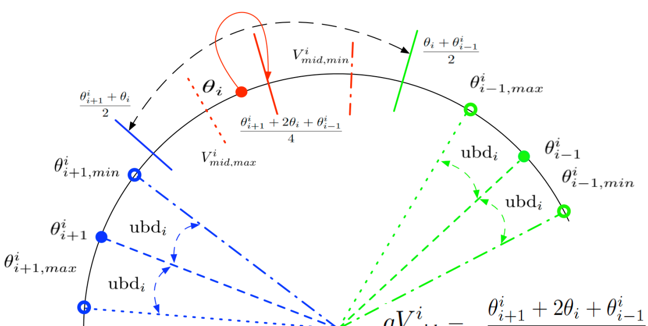
2) Upper bound exceeds



$$\text{ubd}_i \geq \max\{\|\theta'_i - gV^i_{\text{mid}}\|, \sigma\}$$

$$\text{ubd}_i := \frac{\omega_{\max}\tau^i}{2}$$

Inexact Midpoint



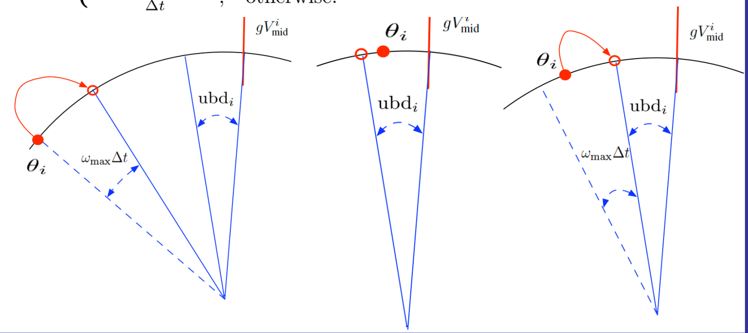
$$gV^i_{\text{mid}} = \frac{\theta^i_{i+1} + 2\theta_i + \theta^i_{i-1}}{4}.$$

$$\left|V^i_{\text{mid}} - \frac{\theta^i_{i+1} + 2\theta_i + \theta^i_{i-1}}{4}\right| \leq \frac{\omega_{\max}\tau^i}{2}. \quad \text{ubd}_i := \frac{\omega_{\max}\tau^i}{2}$$

Control Law

$$u_i(t_k) = \omega_i \ \text{unit}(gV^i_{\text{mid}} - \theta_i),$$

$$\omega_i = \begin{cases} \omega_{\max}, & |gV^i_{\text{mid}} - \theta_i| \geq \text{ubd}_i + \omega_{\max}\Delta t, \\ 0, & |gV^i_{\text{mid}} - \theta_i| \leq \text{ubd}_i, \\ \frac{|gV^i_{\text{mid}} - \theta_i| - \text{ubd}_i}{\Delta t}, & \text{otherwise.} \end{cases}$$



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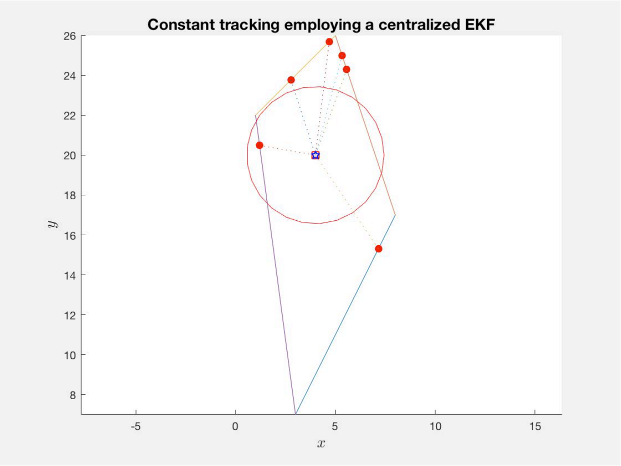
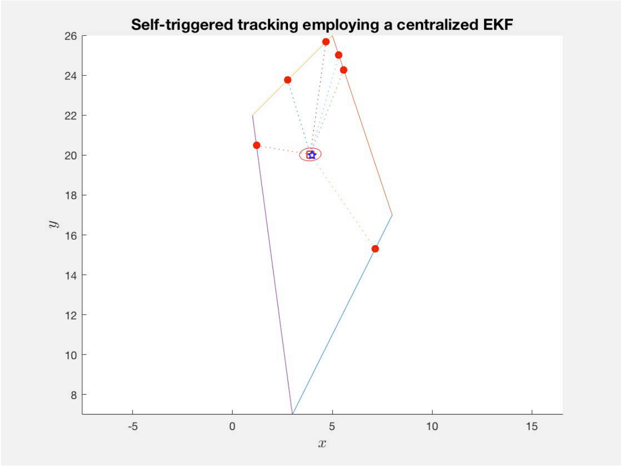
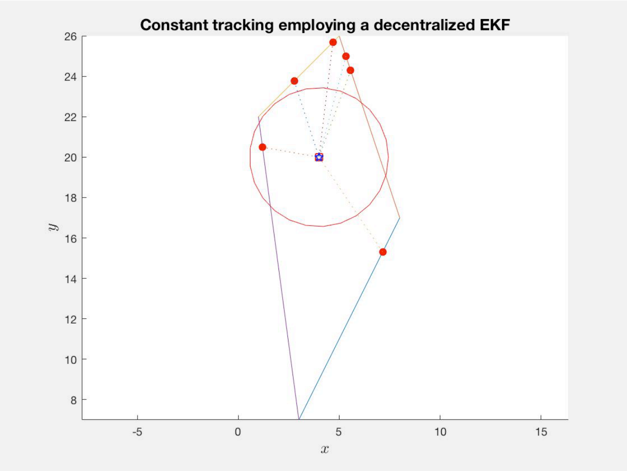
Mobile target with noisy measurements

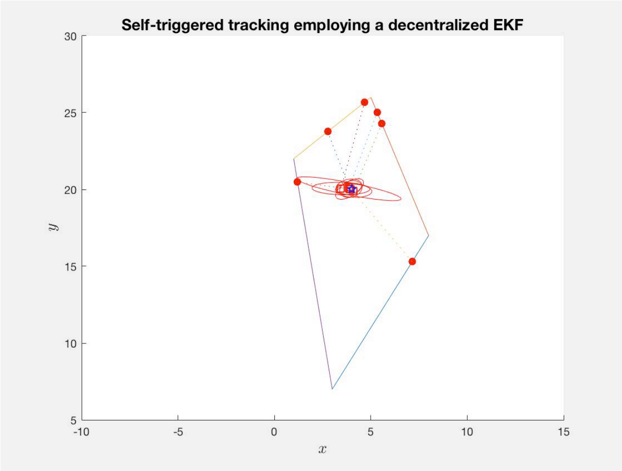
Centralized EKF: A common fusion center obtains the measurements from all the robots and computes a single target estimate at each time step.

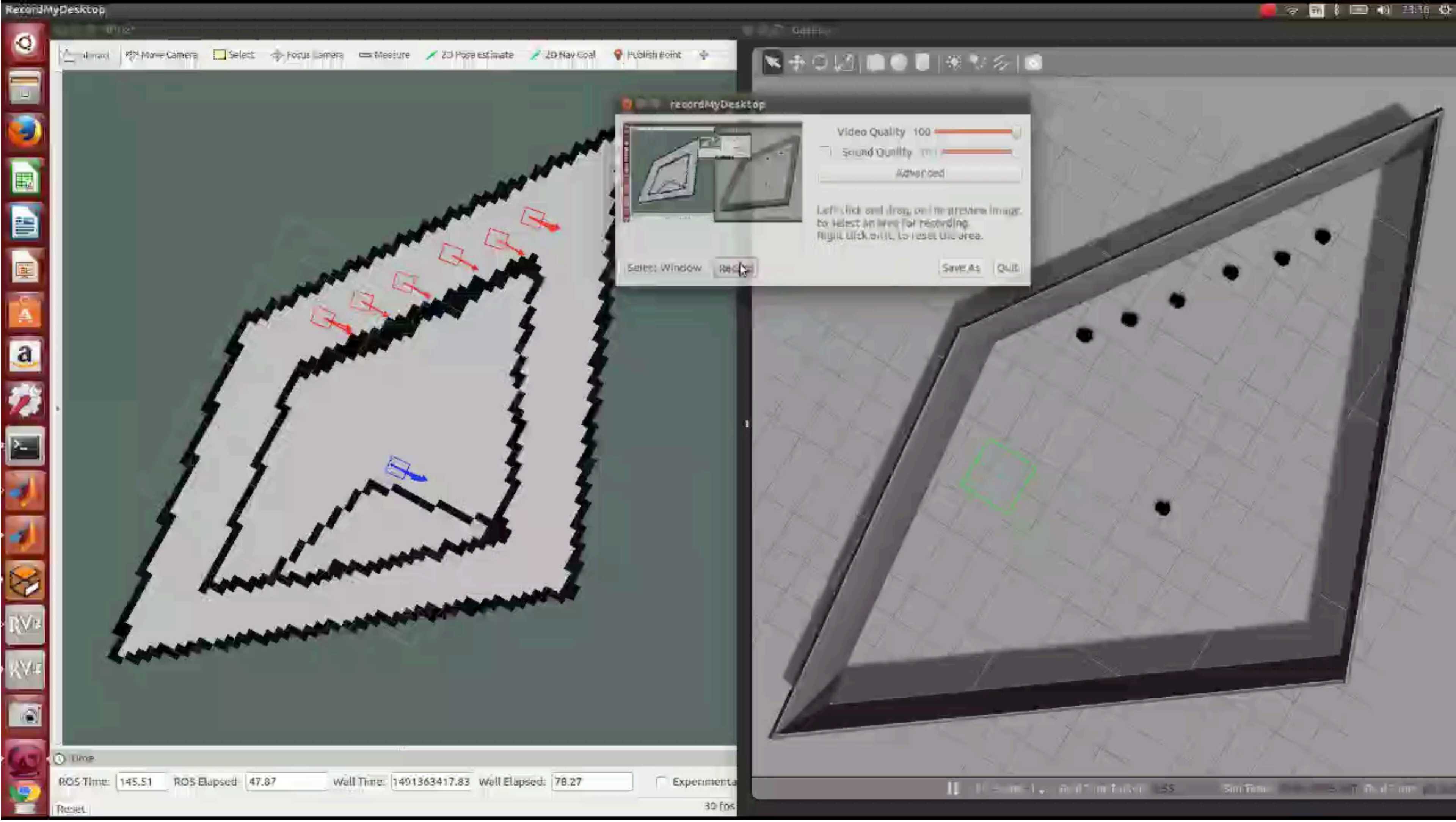




Decentralized EKF: Each robot runs its own EKF estimator. If any time step, a robot communicates with its neighbors, then it also shares its current measurement with its neighbors.







Self-triggered communication with centralized EKF

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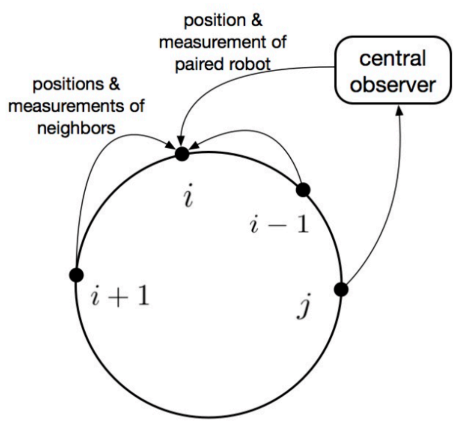
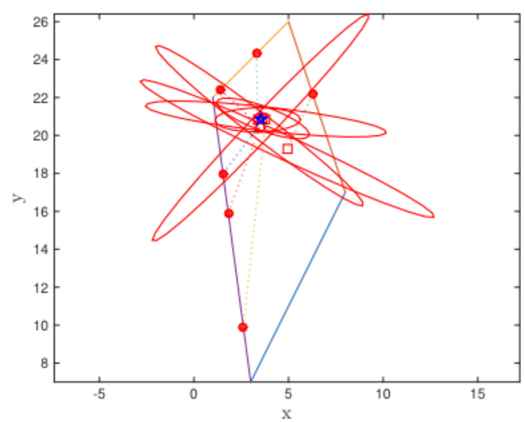
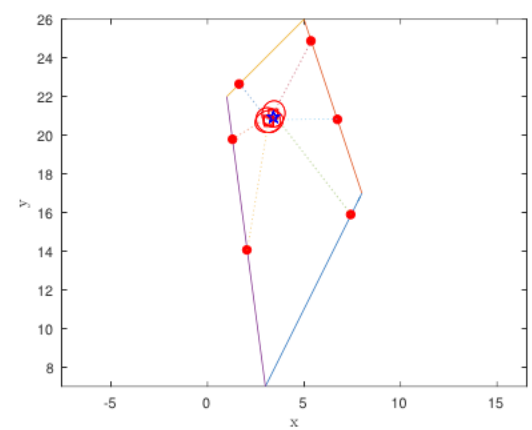
Summary: Compared with constant communication, self-triggered communication reduces the number of communication and converges comparatively

Extension: Extend the self-triggered strategy to decide not only when to communicate information, but also when to obtain measurements and which robots to communicate with by using observability metric as shown in our workshop presentation







Thank you!

Lifeng Zhou and Pratap Tokekar

L. Zhou and P. Tokekar. **A Lower Bound on Observability for Target Tracking with Range Sensors and its Application to Sensor Assignment.** ICRA workshop 2017.
FrW7 Session: Multi-robot Perception-Driven Control and Planning.
08:30 - 17:00 | Friday 2 June 2017 | Room 4711/4712

The material is based upon work supported by the National Science Foundation under Grant Nos. 1566247 and 1637915