IEEE International Conference on Robotics and Automation 2017

Active Target Tracking with Self-Triggered Communications

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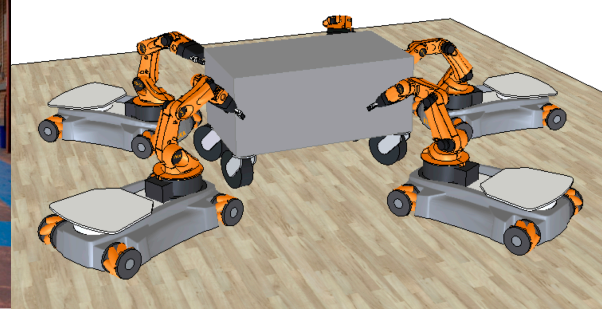
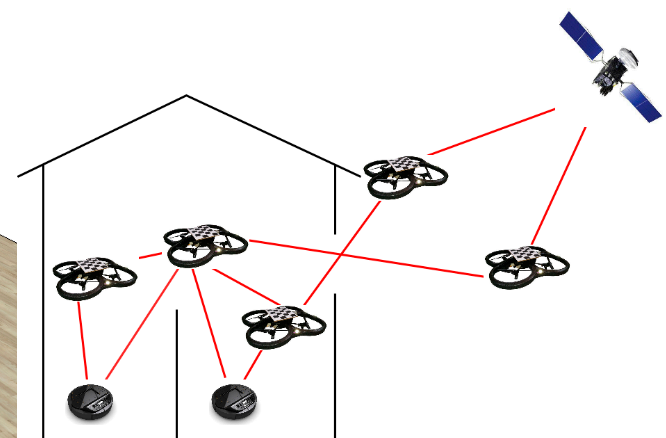
RAAS Lab

VirginiaTech
Invent the Future

Motivation

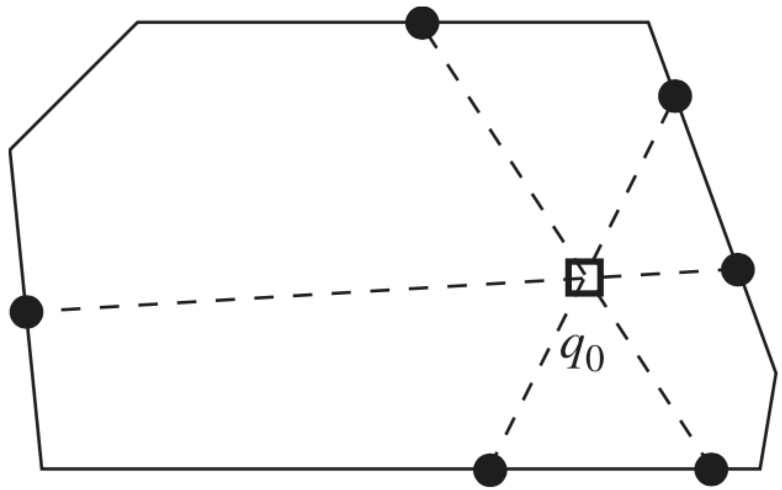
- Better coordination → Higher communication requirements → More power consumption
- **Goal**: *reduce communication without sacrificing performance*





[Leung et al.. IROS '10] [Petitti et al.. ICRA '16] [Hausmanet al. IJRR '15]

Target Tracking

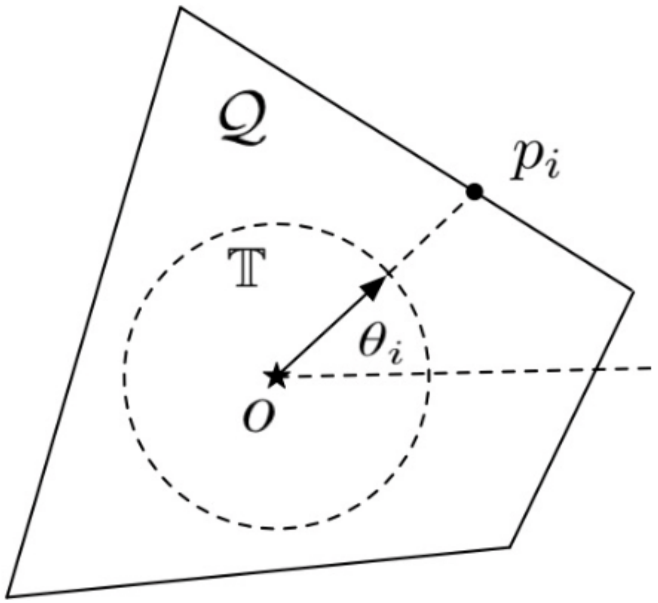


- Target moves inside the convex environment
- Robots can move only on the boundary
- Robots obtain range measurements
- **Goal**: *form uniform distribution around the target*

[Martinez & Bullo. *Automatica '06*]

Problem Formulation

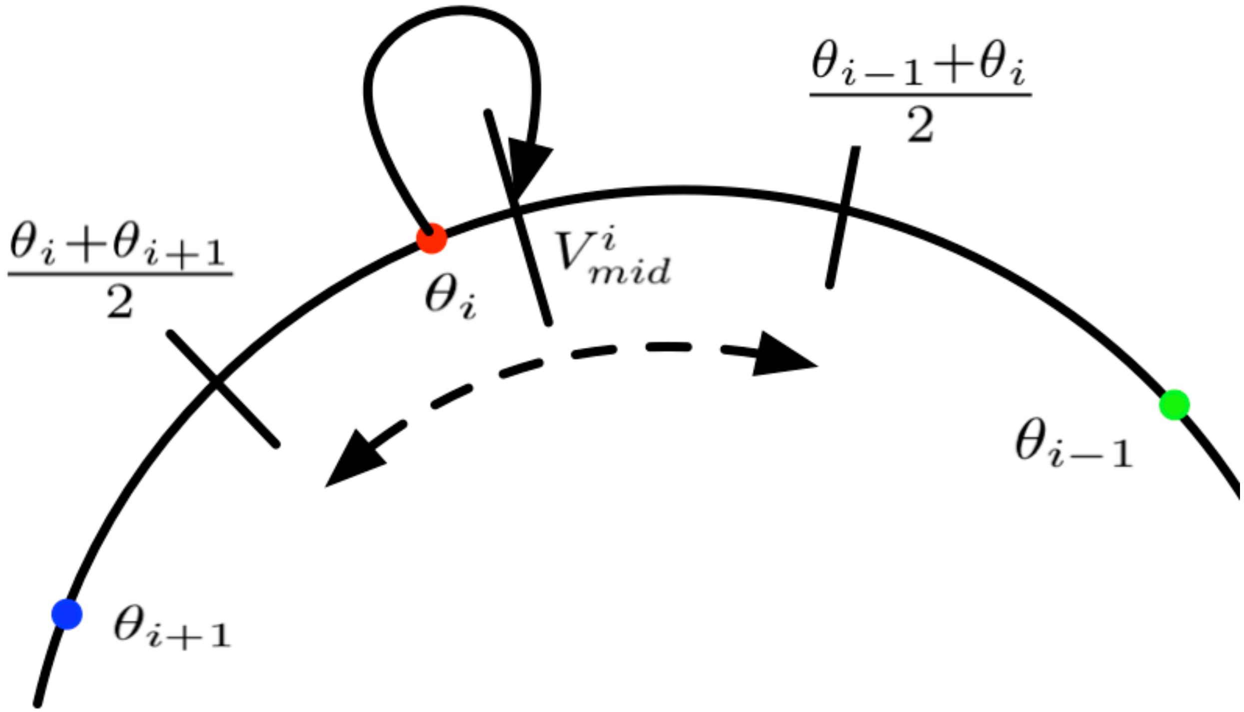
- Assume stationary target (for now)
- Map the convex boundary to a unit circle
- Robot communicates to acquire the angular positions of its neighbors



Stationary target: center of circle

Martínez & Bullo. *Automatica '06*

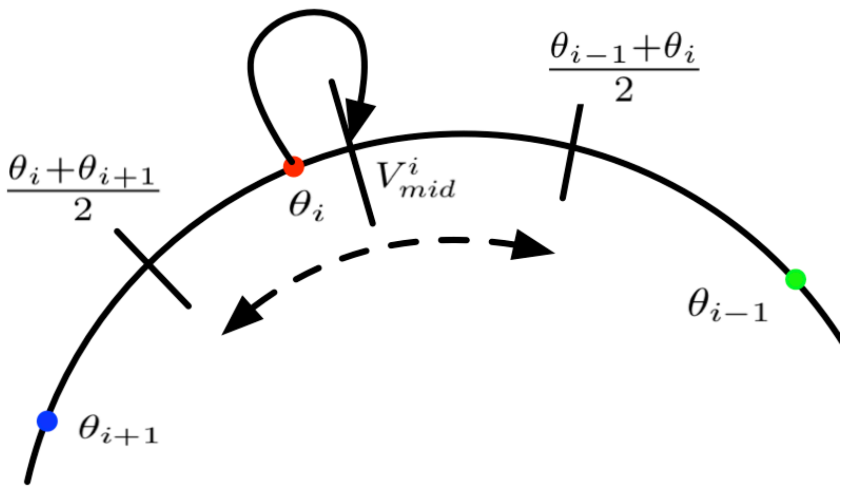
Constant Decentralized Tracking



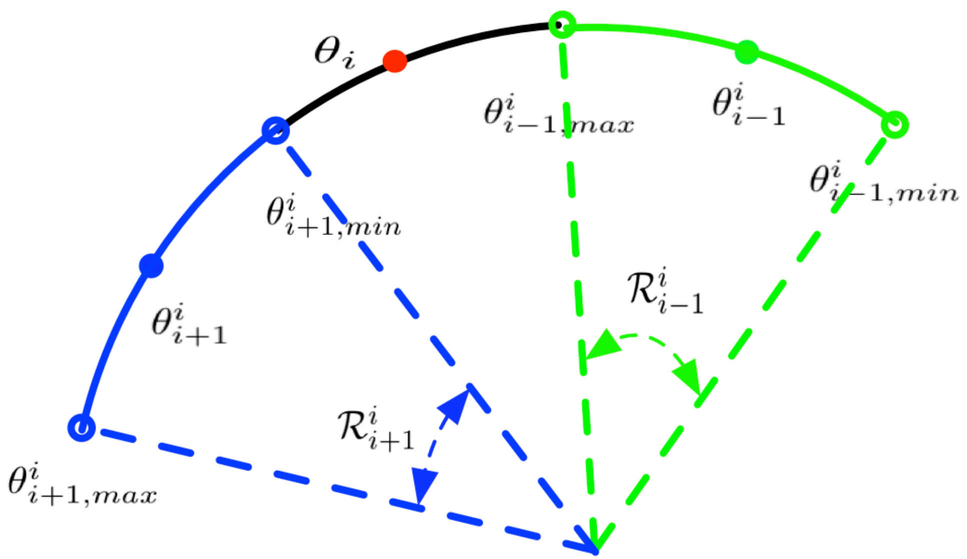
Robot i goes towards the midpoint V^i_{mid}.

Martínez & Bullo. *Automatica '06*

Can convergence still be achieved without constant communication?



Constant tracking

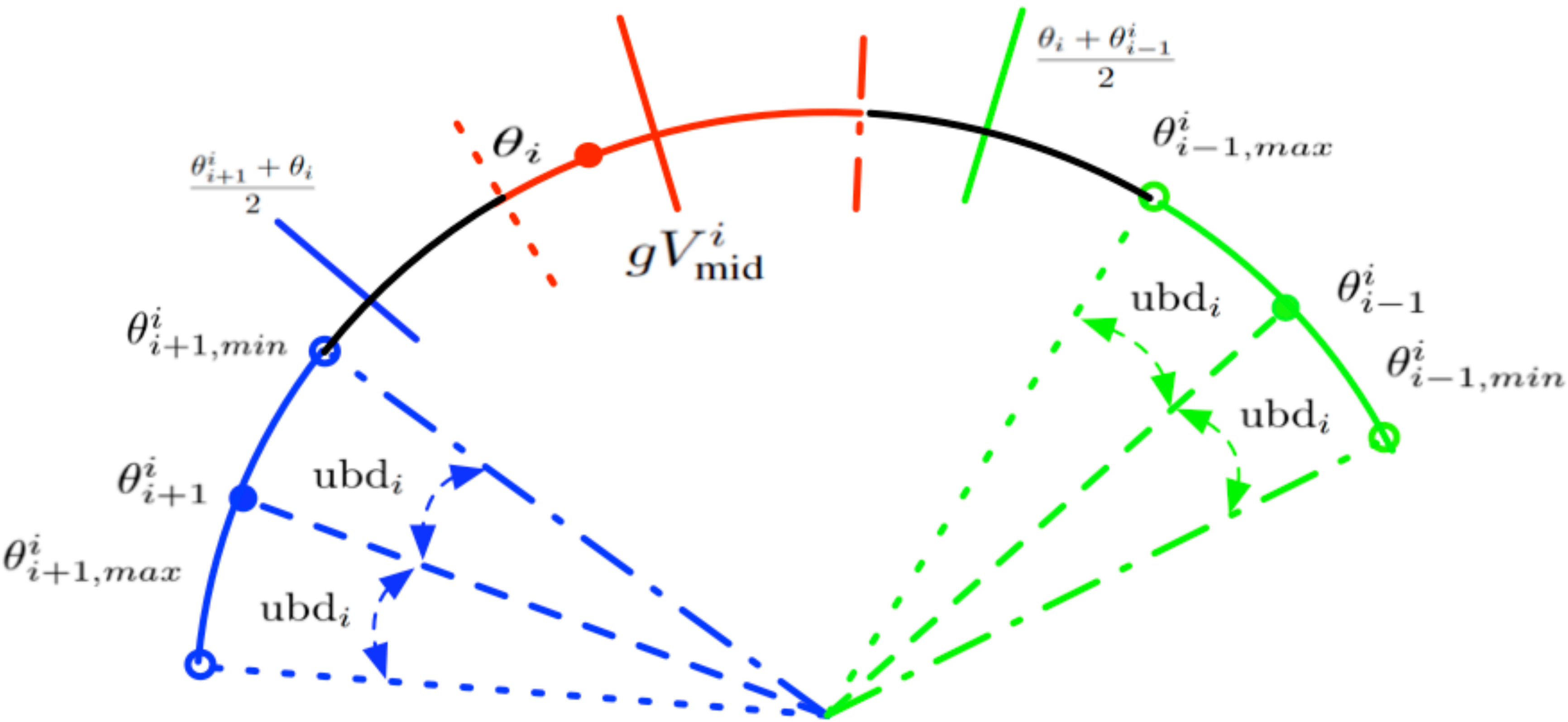


Self-triggered tracking

Challenge: keep track of inexact midpoint

Inexact Midpoint

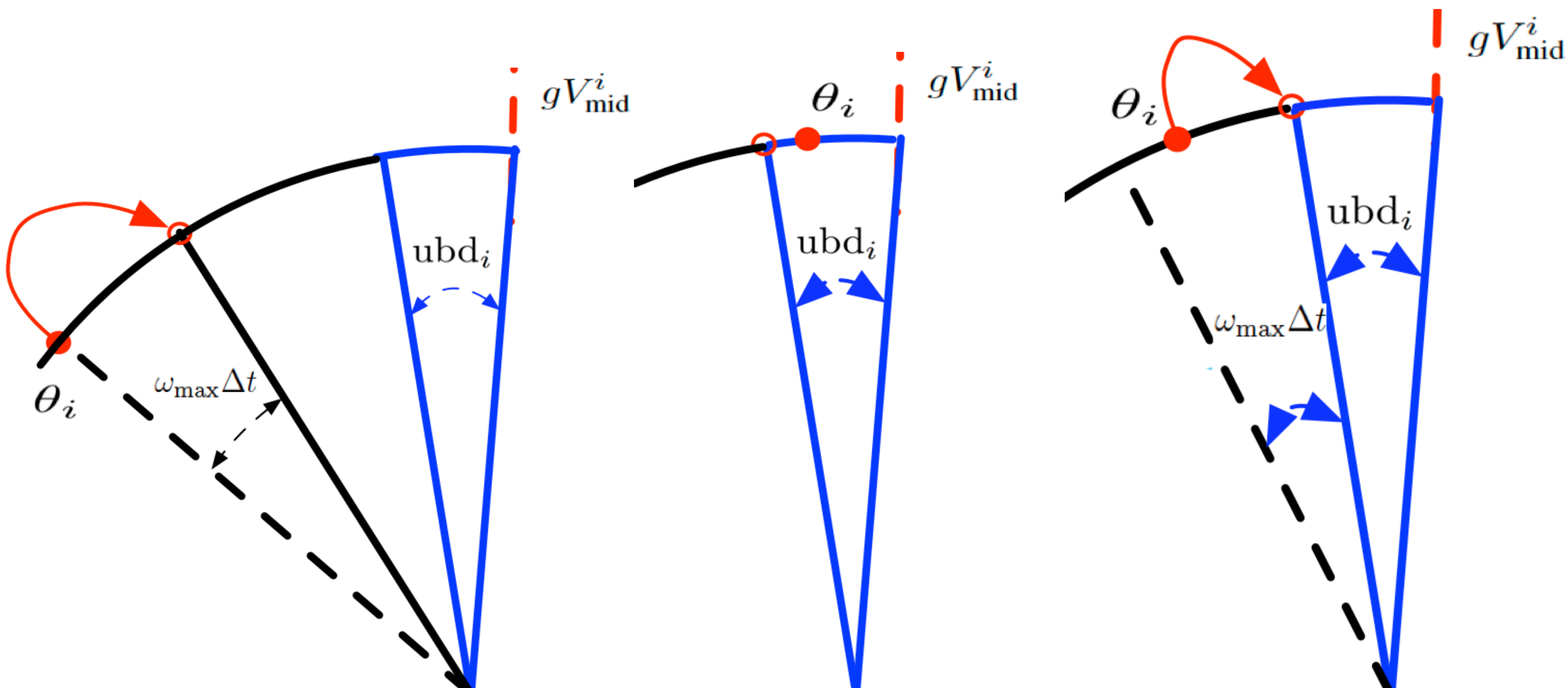
$$\left|V^i_{\text{mid}} - gV^i_{\text{mid}}\right| \leq \text{ubd}_i.$$



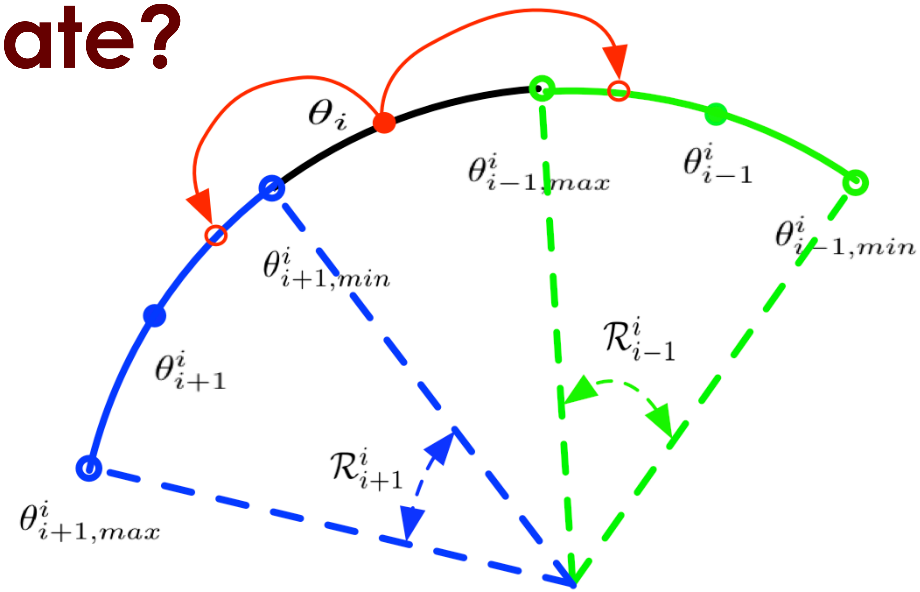
$$gV^i_{\text{mid}} = \frac{\theta^i_{i+1} + 2\theta_i + \theta^i_{i-1}}{4}. \qquad \text{ubd}_i := \frac{\omega_{\max}\tau^i}{2}$$

Control law when not communicating

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



When to communicate?



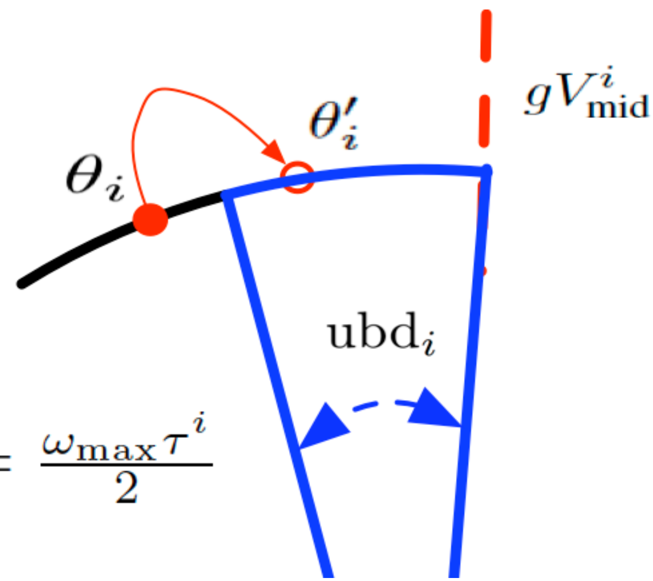
Break counterclockwise order

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

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

Larger upper bound

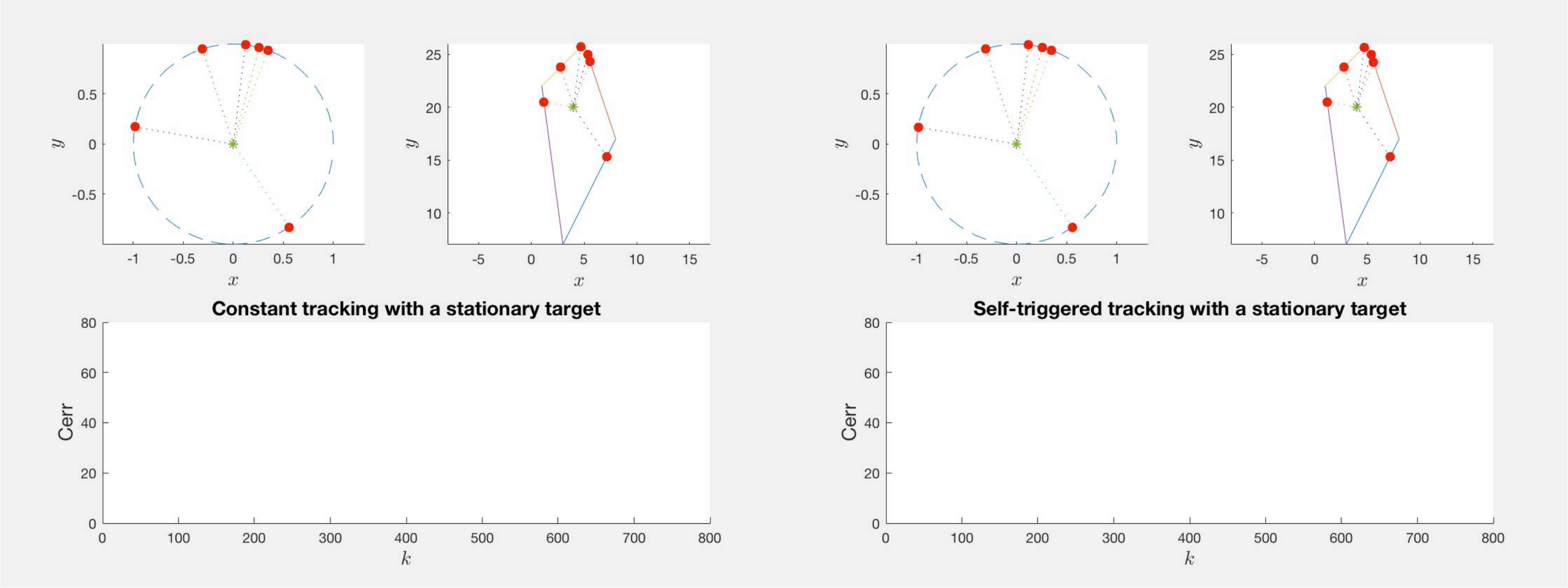
$$\text{ubd}_i \geq \max\{\|\theta'_i - gV^i_{\text{mid}}\|, \sigma\}$$



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

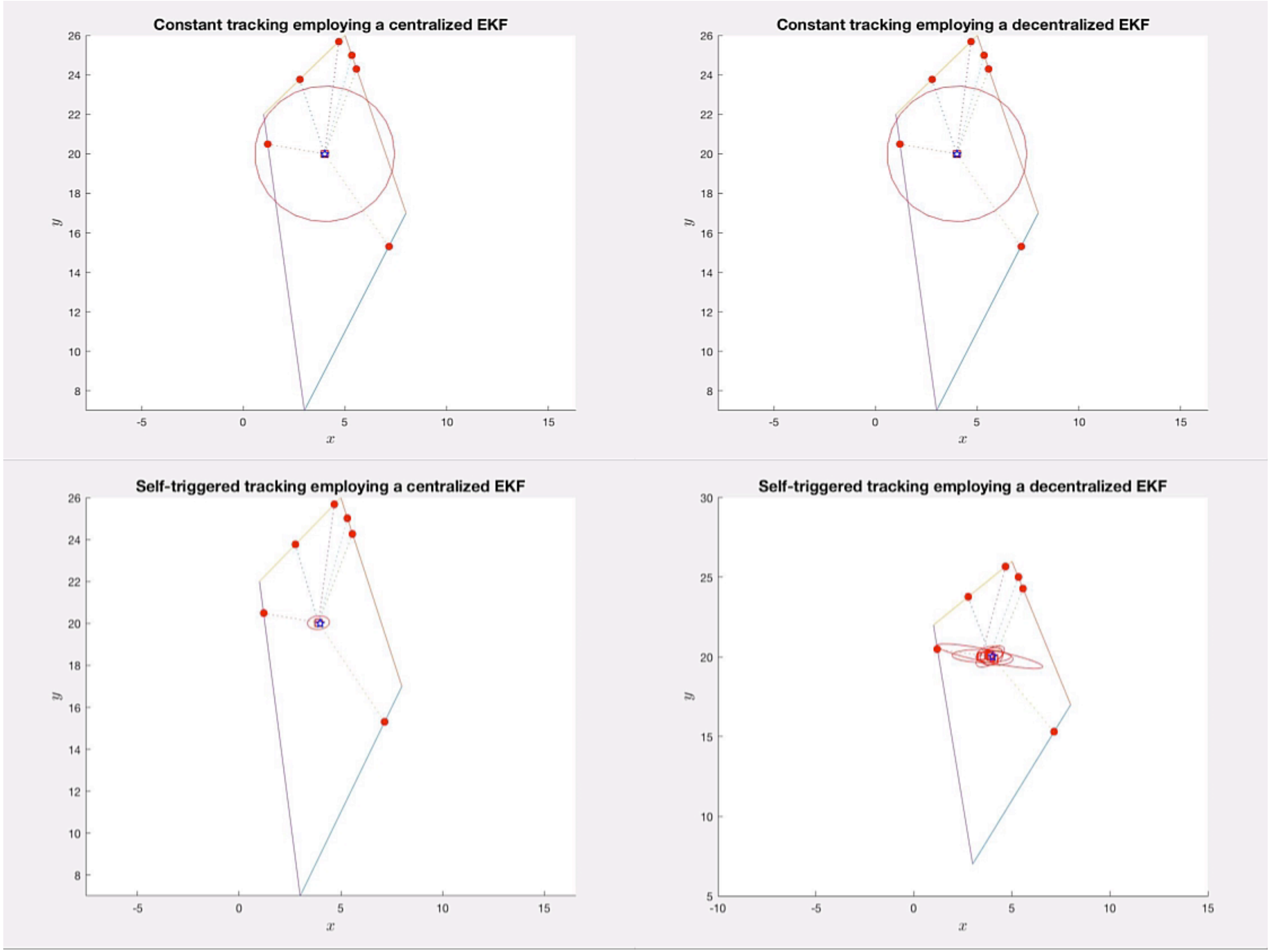
Comparison of constant tracking and self-triggered tracking with static target

We prove the self-triggered tracking strategy converges to a uniform distribution.



[Nowzari & Cortés. Automatica '12]

Moving Target with Noisy Measurements



Summary & Extension

- Self-triggered strategy:
  - reduces the amount of communication
  - converges almost as fast as constant communication
- Extension work:
  - Decide not only ***when*** to communicate information, but also ***which robots to communicate with***
  - Recent results: “using observability to select robots to communicate with to improve the estimate of the target.”

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

Citations

MartíNez, S., & Bullo, F. (2006). Optimal sensor placement and motion coordination for target tracking. *Automatica*, *42*(4), 661-668.

Leung, K. Y., Barfoot, T. D., & Liu, H. H. (2010, October). Decentralized cooperative simultaneous localization and mapping for dynamic and sparse robot networks. In *Intelligent Robots and Systems (IROS), 2010 IEEE/RSJ International Conference on* (pp. 3554-3561). IEEE.

Petitti, A., Franchi, A., Di Paola, D., & Rizzo, A. (2016, May). Decentralized motion control for cooperative manipulation with a team of networked mobile manipulators. In *Robotics and Automation (ICRA), 2016 IEEE International Conference on* (pp. 441-446). IEEE.

Hausman, K., Müller, J., Hariharan, A., Ayanian, N., & Sukhatme, G. S. (2015). Cooperative multi-robot control for target tracking with onboard sensing 1. *The International Journal of Robotics Research*, *34*(13), 1660-1677.

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Thanks for listening!

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

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