Collectives in a Test-bed

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THIRTY YEARS OF SYSTEMS RESEARCH EXCELLENCE

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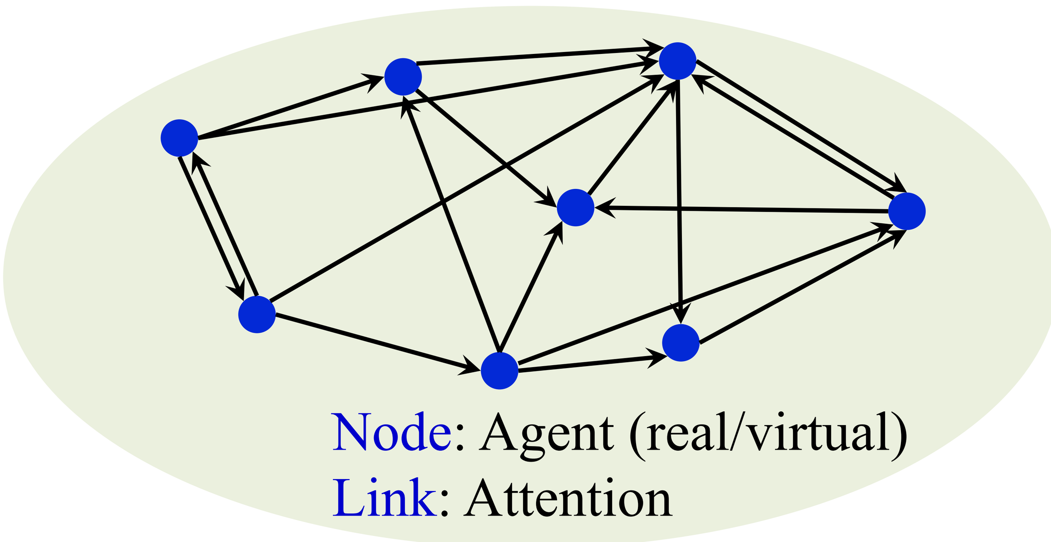
Background and Motivation

- Pursuit and collective behavior are ubiquitous in nature (e.g. dragonfly contest, fish schools, bird flocks)
- In the search for mechanisms that give rise to collective motion, various **mathematical models** have been proposed
- It is of interest to investigate the performance of these models in a laboratory environment

Attention Graph



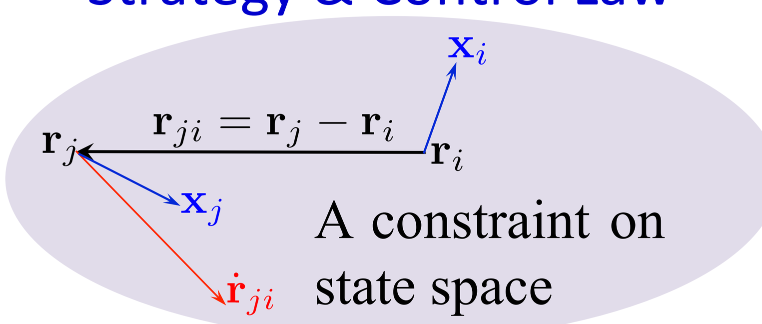
Agent Dynamics

$\dot{\mathbf{r}} = \nu \mathbf{x}$

$\dot{\mathbf{x}} = \nu u \mathbf{y}$

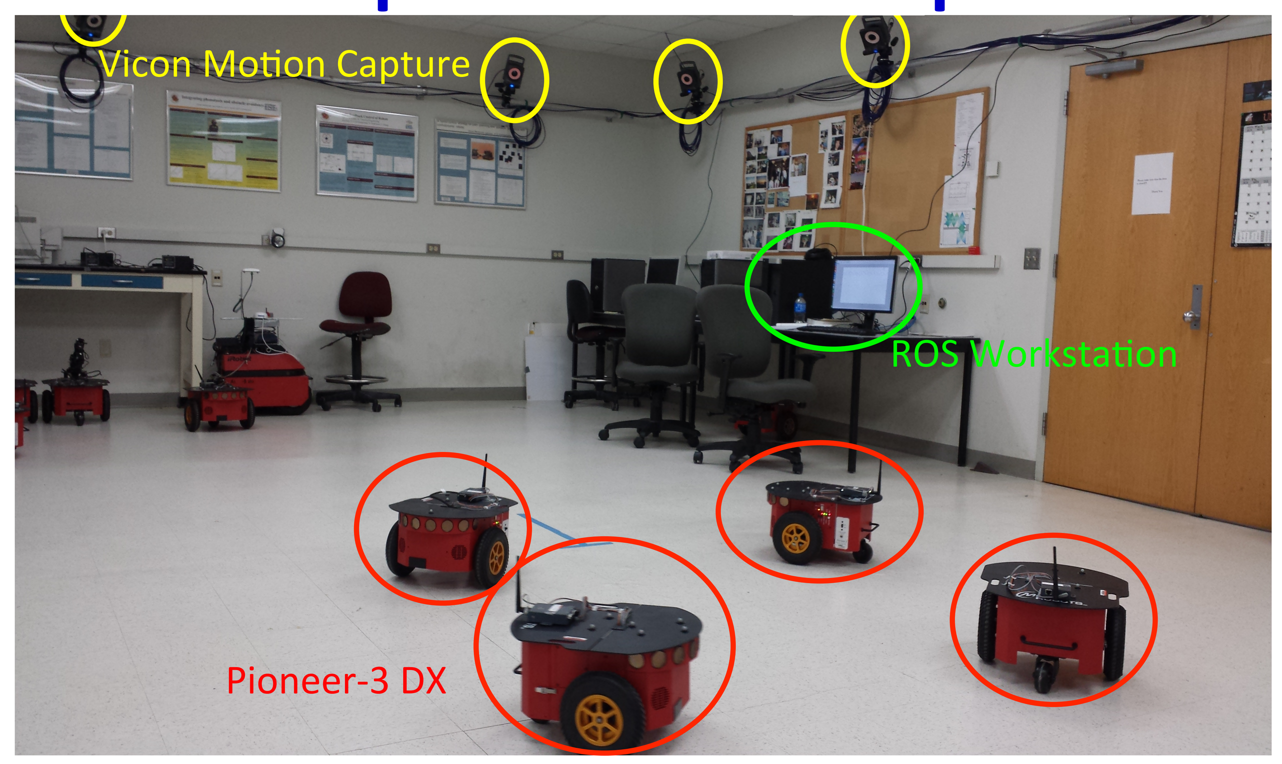
$\dot{\mathbf{y}} = -\nu u \mathbf{x}$

Strategy & Control Law



Collective Motion

Experimental Set-up



References:

[1] K. S. Galloway, B. Dey. *Station Keeping through Beacon-referenced Cyclic Pursuit.* Accepted for *American Control Conference (ACC)*, July 2015.

[2] U. Halder, B. Dey. *Biomimetic Algorithms for Coordinated Motion: Theory & Implementation.* Accepted for *International Conference on Robotics and Automation (ICRA)*, May 2015.

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Mutual Motion Camouflage

- Attention Graph: **Dyadic Cycle**, *i.e.* each agent pays attention to the other.
- Strategy: Each agent employs **motion camouflage** strategy on the other.
- Control Law:

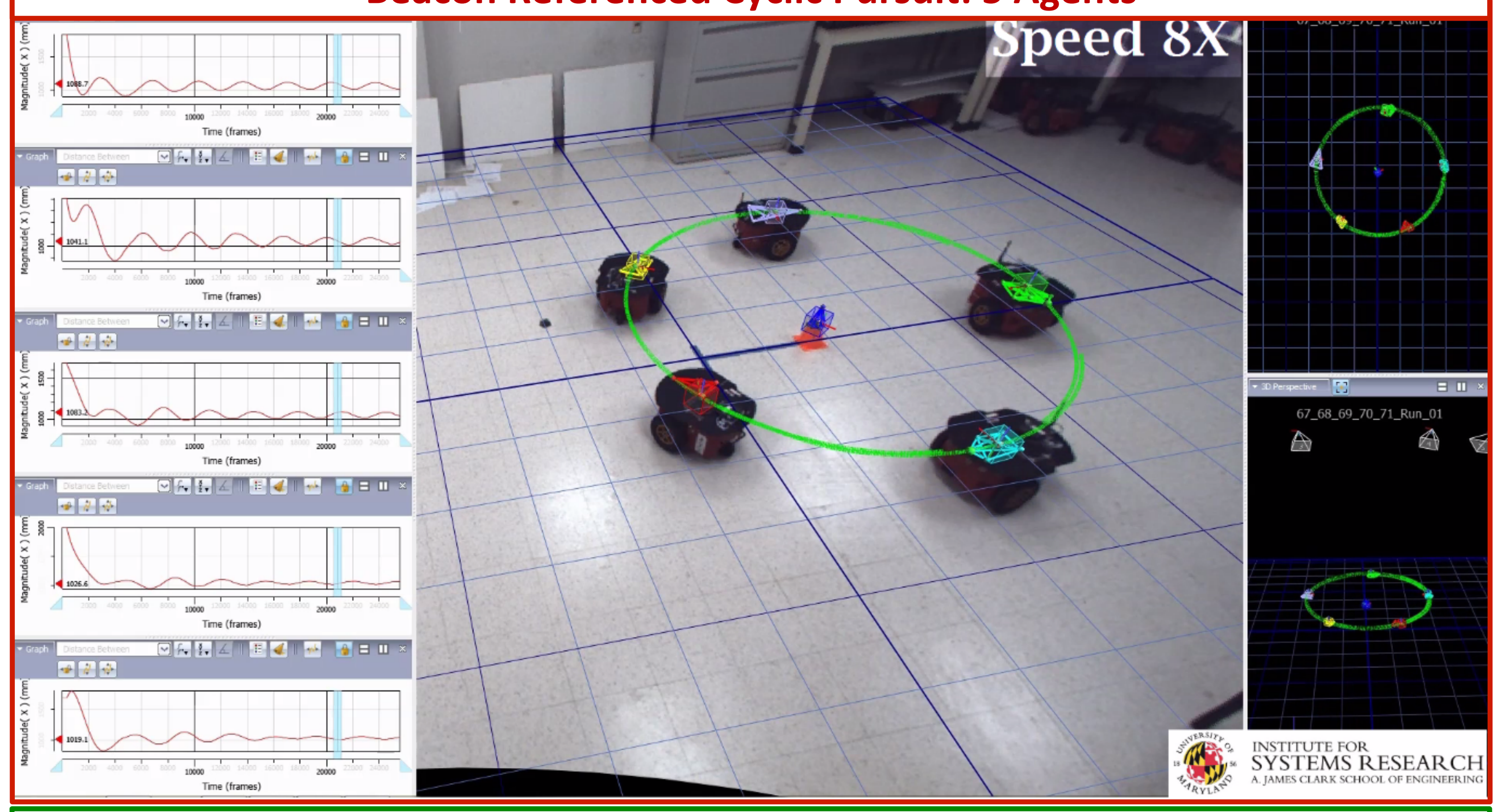
$$u = -\mu\lambda + k_d \lambda \gamma (E(\rho,\gamma) - E_d), \quad \rho = |\mathbf{r}_{12}|, \gamma = \frac{\mathbf{r}_{12} \cdot \dot{\mathbf{r}}_{12}}{|\mathbf{r}_{12}|}, \lambda = \frac{\mathbf{r}_{12} \cdot \dot{\mathbf{r}}_{12}^{\perp}}{|\mathbf{r}_{12}|}$$

Beacon Referenced Cyclic Pursuit

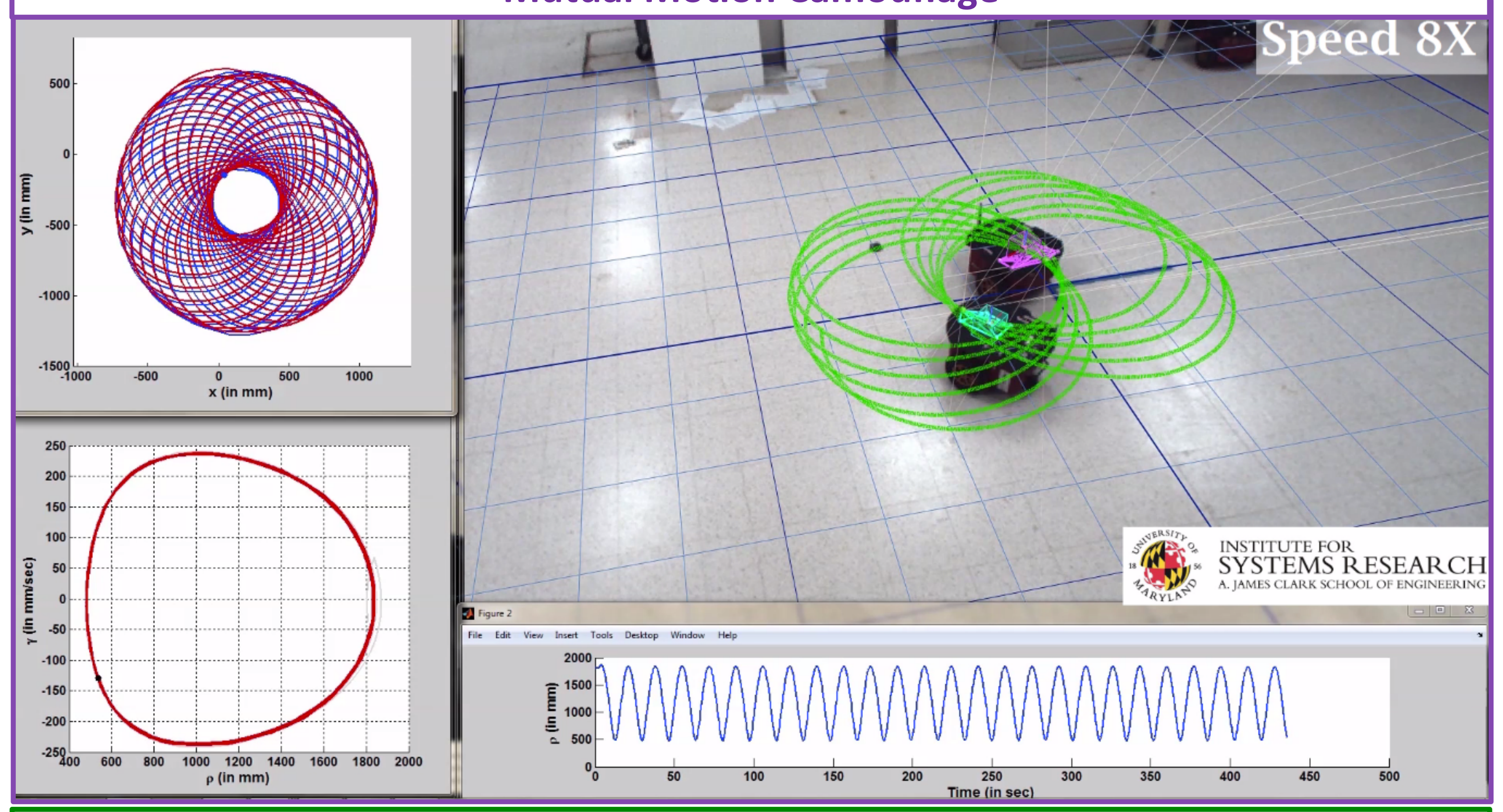
- Attention Graph: **Cycle with a spoke** ("i"-th agent pays attention to the beacon and the "$i+1$"-th agent)
- Strategy: **Constant bearing pursuit**
- Control Law:

$$u_i = (1-\lambda)\left[-\mu_i \left(R(\alpha_i)\mathbf{y}_i \cdot \frac{\mathbf{r}_{i,i+1}}{|\mathbf{r}_{i,i+1}|}\right) - \frac{1}{\nu_i |\mathbf{r}_{i,i+1}|}\left(\frac{\mathbf{r}_{i,i+1}}{|\mathbf{r}_{i,i+1}|} \cdot R(\pi/2)\dot{\mathbf{r}}_{i,i+1}\right)\right] + \lambda\left[-\mu_i^b \left(R(\alpha_{ib})\mathbf{y}_i \cdot \frac{\mathbf{r}_{i,b}}{|\mathbf{r}_{i,b}|}\right)\right]$$

Beacon Referenced Cyclic Pursuit: 5 Agents



Mutual Motion Camouflage



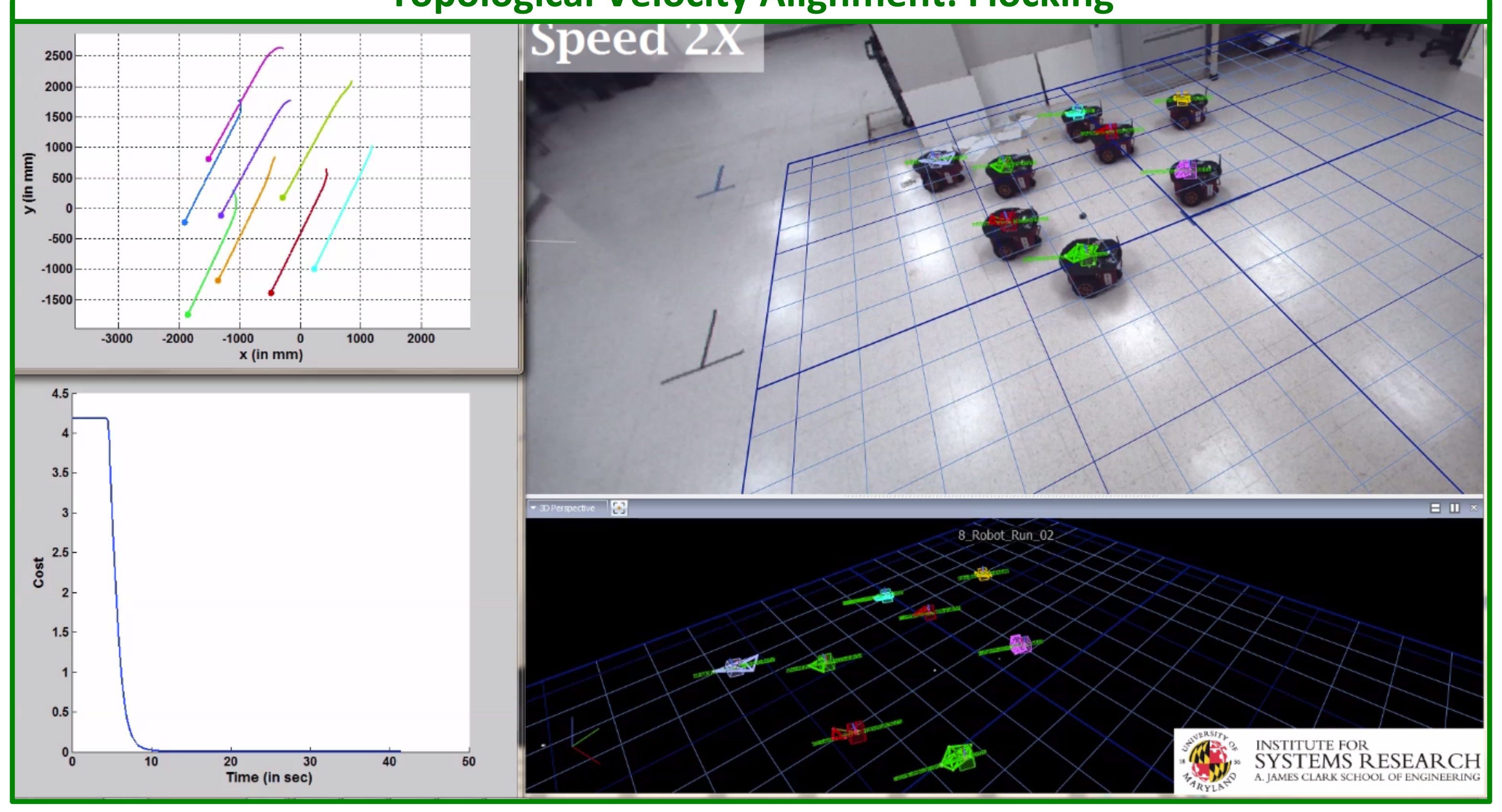
Topological Velocity Alignment

- Attention Graph: Each agent pays attention to its k-nearest neighbors, i.e. the attention graph is **time varying.**
- Strategy: Each agent attempts to **align** its **velocity** parallel to the **direction of motion** of its **neighborhood center of mass.**
- Control Law:

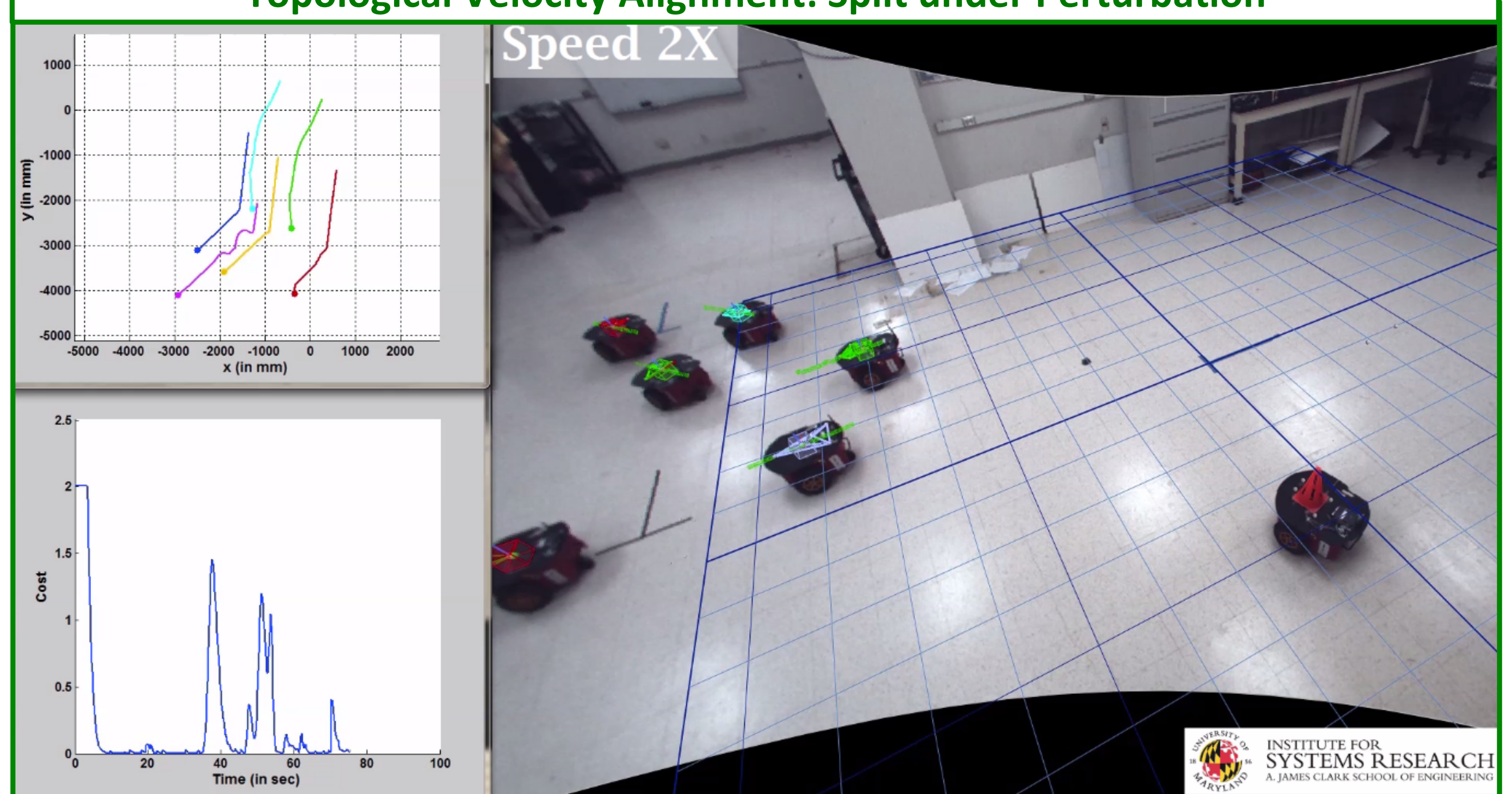
$$u_i = \left(\frac{\mu}{\nu_i}\right)\left[\mathbf{x}_{\mathcal{N}_i} \cdot \mathbf{y}_i\right], \quad \text{where} \quad \mathbf{x}_{\mathcal{N}_i} = \frac{\mathbf{v}_{COM}}{|\mathbf{v}_{COM}|} \quad \text{and} \quad \mathbf{v}_{COM} = \frac{1}{|\mathcal{N}_i|}\sum_{j \in \mathcal{N}_i} \nu_j \mathbf{x}_j$$

- Extension to three dimensional case is straightforward.
- The control law becomes undefined if the velocity of the neighborhood center of mass vanishes. However, this is handled in implementation by neighborhood extension.

Topological Velocity Alignment: Flocking



Topological Velocity Alignment: Split under Perturbation



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