

Research Thrusts in Network Systems & Distributed Control

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With generous support from: National Science Foundation and the Department of Defense



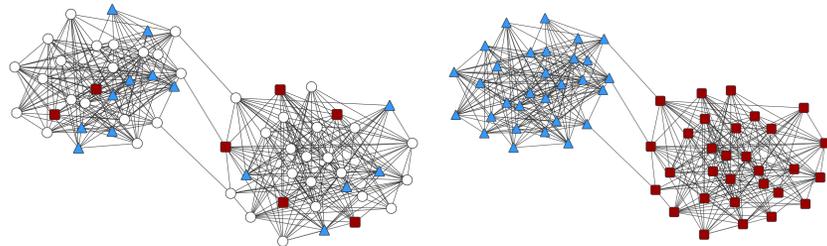
Overview

Our approach is a joint theoretical and experimental effort to tackle fundamental questions related to **robotic coordination**, **power grids**, **social networks**, as well as other **network systems**.

Competitive propagation in social networks

We have considered the propagation of multiple competing "products" on social networks. By comparing four different adoption behaviors: self/social adoption and conversion. We find that:

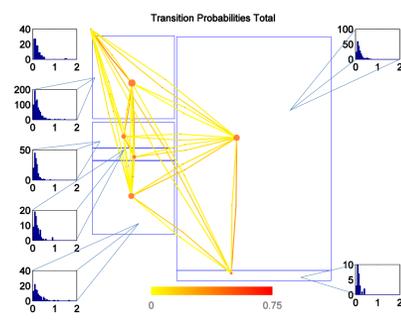
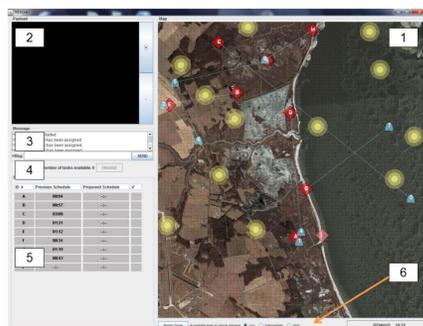
- ▶ Self-conversion dominates all other adoption processes;
- ▶ Without self-conversion, social conversion becomes dominant; and
- ▶ Without self-conversion, if there are multiple products and networks with clustering structures, a meta-stable state may emerge in which each product occupies a cluster.



Decision Support for Human Supervisory Control

We look at systems where humans oversee an automated process and provide feedback which affects system behavior. The general process used to approach this problem is as follows:

- ▶ Use sensors to characterize "user state" and predict behavior (e.g., eye-trackers)
- ▶ Utilize eye-tracking data to model scan-paths as Markov chains
- ▶ design decision supports and automation schemes to improve human performance (e.g., where/how long operator should focus)



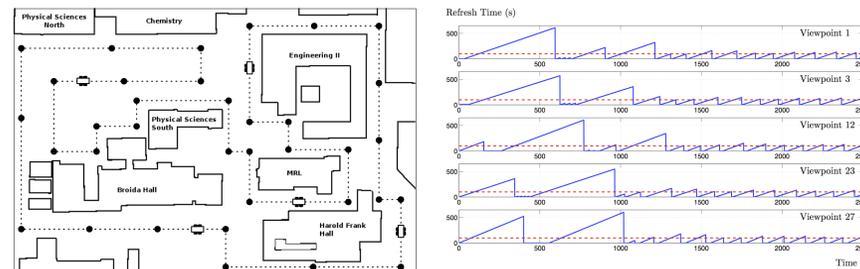
Cooperative Patrolling

We have explored how to surveil an environment with a team of autonomous robots.

Refresh Time Cost Function: longest weighted time between two consecutive visits of viewpoints

$$RT(\mathbf{X}) = \max \{ \phi_\alpha(t_a(\alpha, t_d) - t_d) \}$$

where $t_a(\alpha, t_d)$ is the earliest arrival time by any robot at viewpoint α after departure at time t_d .



One-to-Base Partitioning

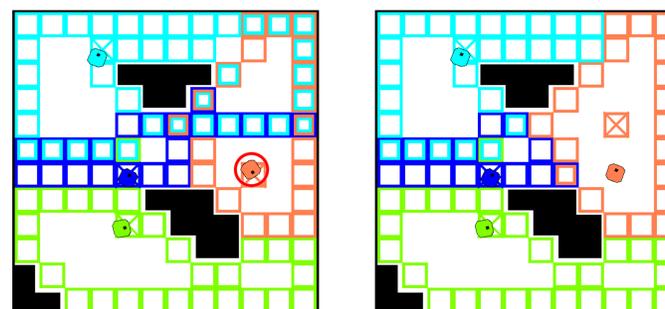
We have explored several methods to partition space into territories, given heterogeneous agents, to optimize expected distances to tasks.

One-to-base Cost Function:

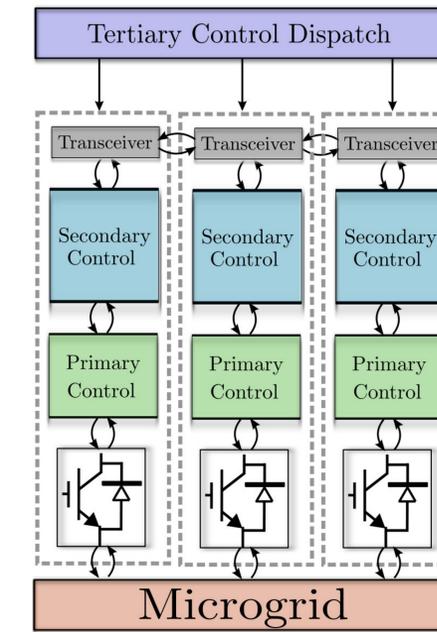
$$\mathcal{H}_{\text{inf}}(\mathbf{w}, \mathbf{c}) = \sum_{k \in \mathbf{Q}} \min_i \left\{ \frac{\text{dist}(c_i, k)}{w_i} \mid k \in \mathbf{Q} \right\} \phi(k)$$

For above functions, when robot i talks to base:

- 1: Pick $k \in \mathbf{P}_i \setminus \mathbf{c}$ minimizing cost function
- 2: **for** every other robot j
- 3: Add vertices to \mathbf{P}_i that are closer to i
- 4: Remove vertices from \mathbf{P}_j that are in both but closer to i



Distributed Control in Inverter-Based Microgrids



3. Tertiary Control

- ▶ Goal: optimize operation
- ▶ New inverse-optimality results

2. Distributed Secondary Control

- ▶ New distributed PI controllers
- ▶ regulate frequency, voltage, load sharing

1. Primary (Droop) Control

- ▶ New nonlinear stability analysis
- ▶ Breakthroughs in physics of AC power

Droop Control

$$\omega_i = \omega^* - m_i(P_i - P_i^*)$$

$$E_i = E_i^* - n_i(Q_i - Q_i^*)$$

Collective Cellular Motion

- ▶ Collective motion is observed in nature at all scales from birds flocking to cellular collective migration. In most cases agent motion motivated by purely local cues leads to large-scale group-behavior.
- ▶ Using accurate models of cell movement and interactions, we attempt to model a collective of cells as a distributed system and distill the essential ingredient required for these highly synchronized motions crucial to various cell phenomena.

