

EE631 Cooperating Autonomous Mobile Robots

Lecture: Cooperative Control of Large Systems

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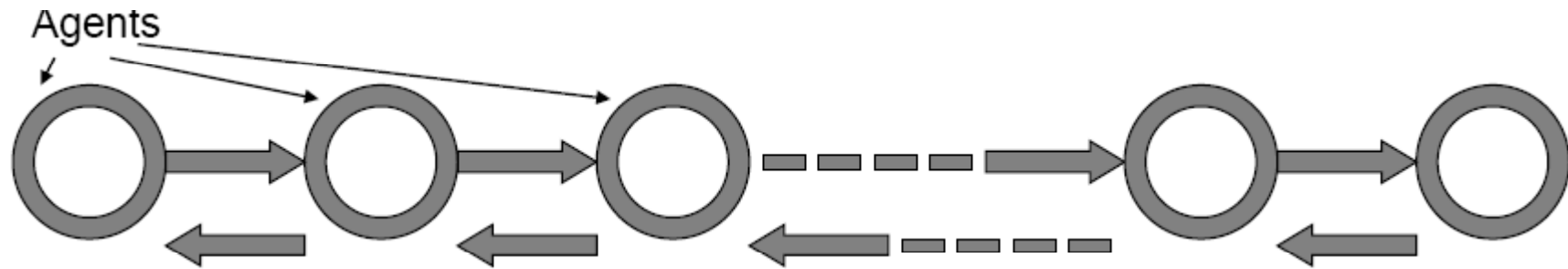
Introduction

- Cooperative control is a term used to capture those problem areas in which some type of repetition of identical or non-identical subsystems, which are interconnected together, occurs.
- Components of large systems:
 - Agents that are autonomous and self driven
 - Interconnection topology which may be fixed or time-varying
 - Interactions between agents which may be linear or nonlinear

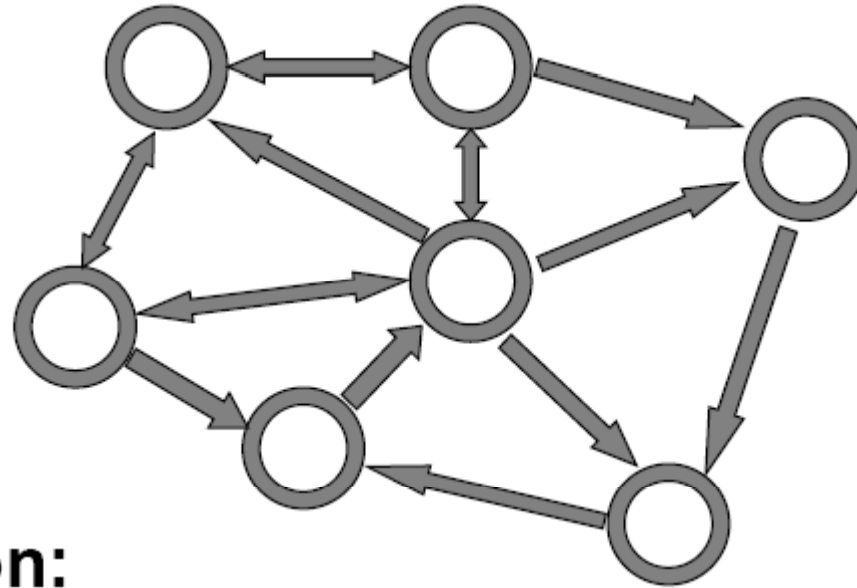


Examples of Cooperative Control Systems

- In nature:
 - Motion of clusters of birds, fish, insects, etc. moving together
 - Cell structure of mammals and life-forms
- In man-made systems:
 - Vehicle platoon in transportation systems
 - Network systems
- In various organs of human body
 - Intestinal system



Agents may interact in a **cascade** structure or in a **neighborhood** structure.



Assumption:

Agents are **identical in structure**, but may have **different parameters**.

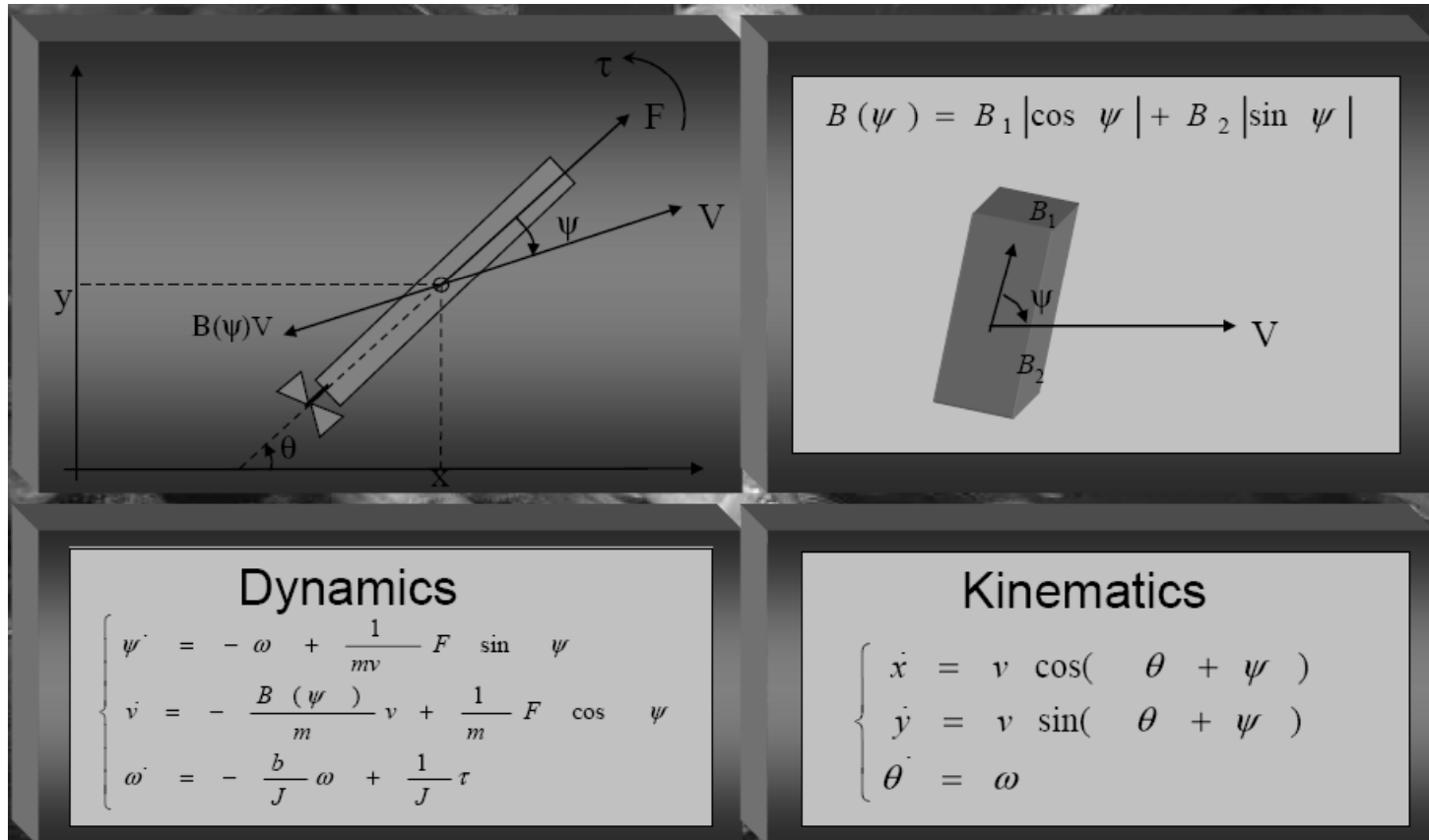
Near-Identical Objects

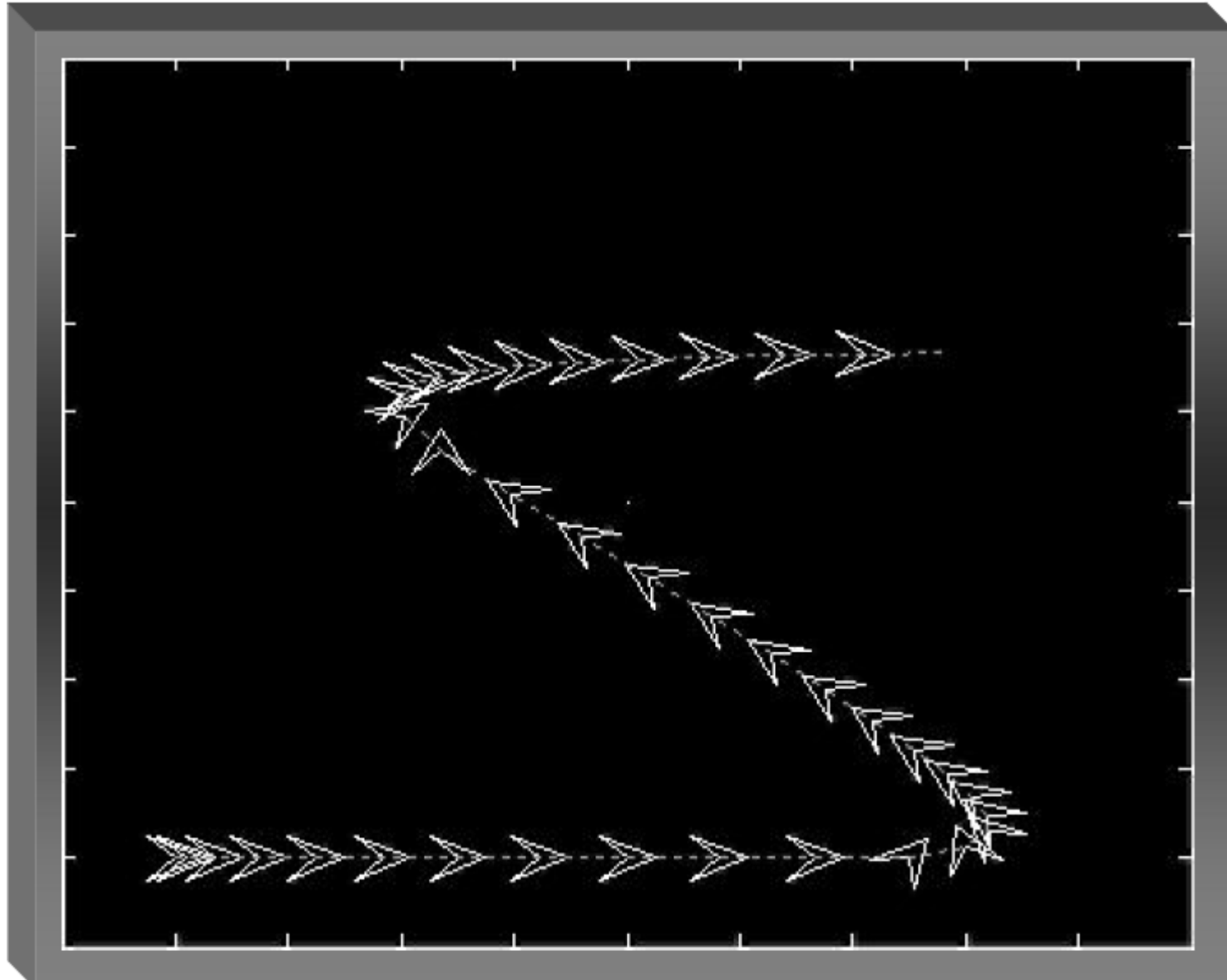


- It is desired to develop an understanding of such interconnected systems; in particular,
 - When the number of subsystems is very large
 - When the control of such inter-connected system is constrained to be decentralized

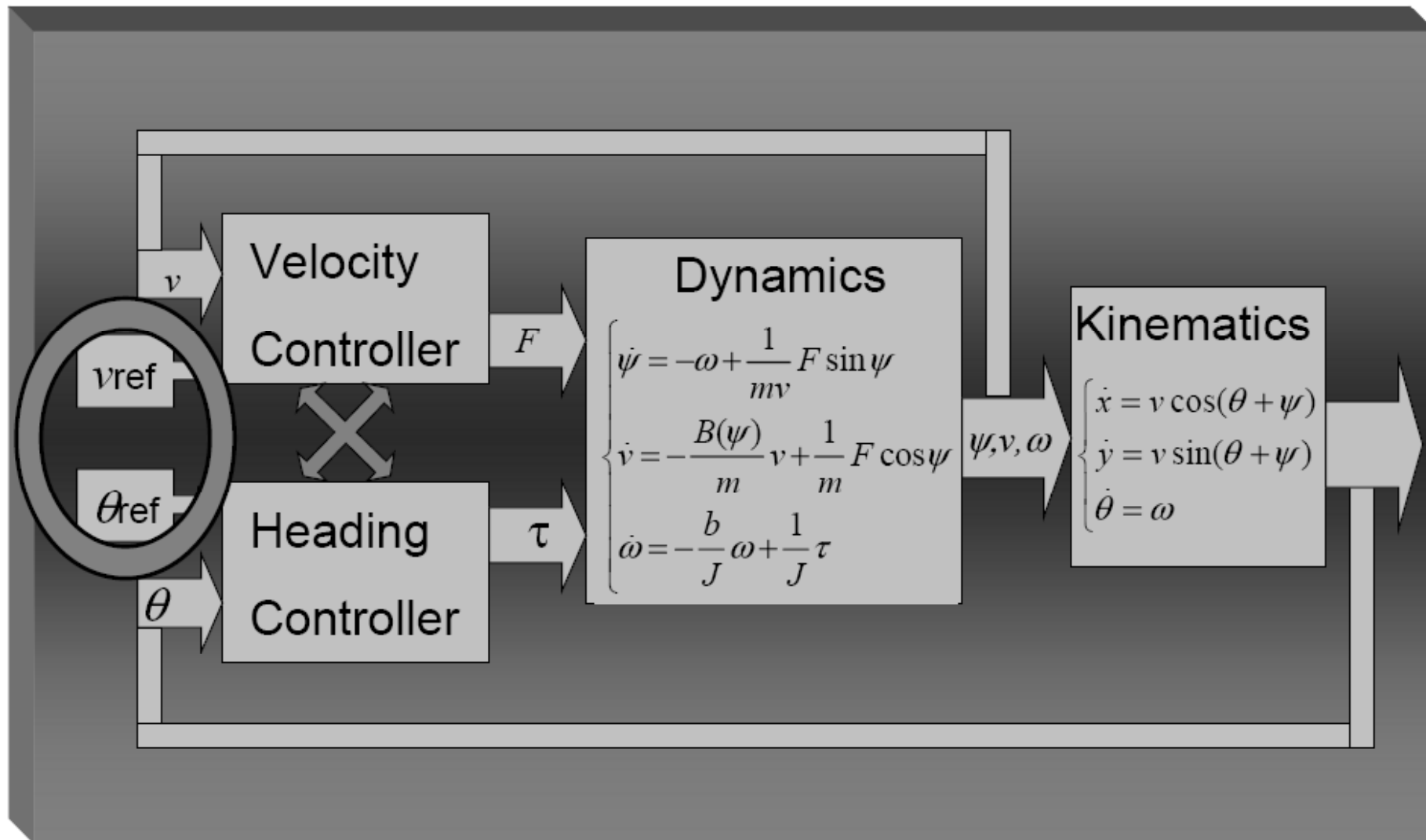
Control of “Fish”

- Motion of underwater object is modeled as a nonlinear system





Slides from Davison and Khatir



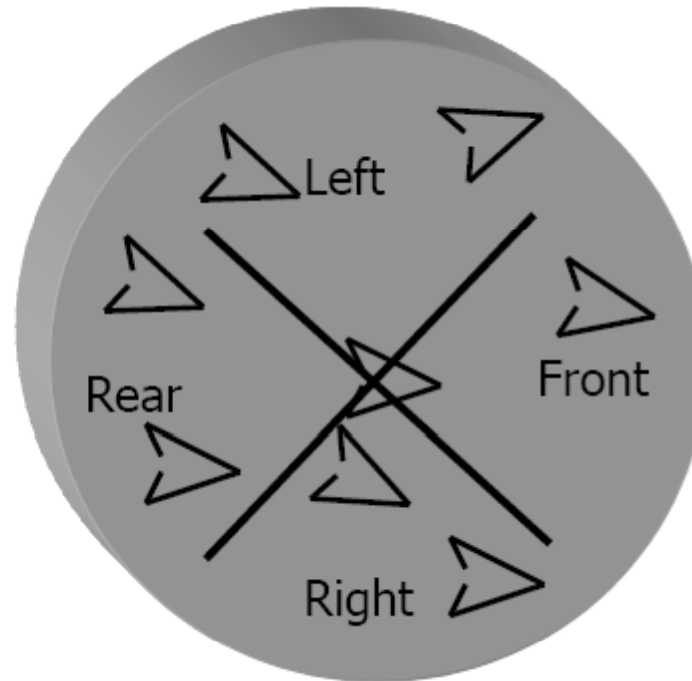


$$V_{ref_i}(t+1) = \frac{V_i(t) + \sum_{j \in \{\text{Neighbors of Agent } i\}} V_j(t)}{1 + N\{\text{Neighbors of Agent } i\}} \quad \forall i \in [1, n]$$

Averaging

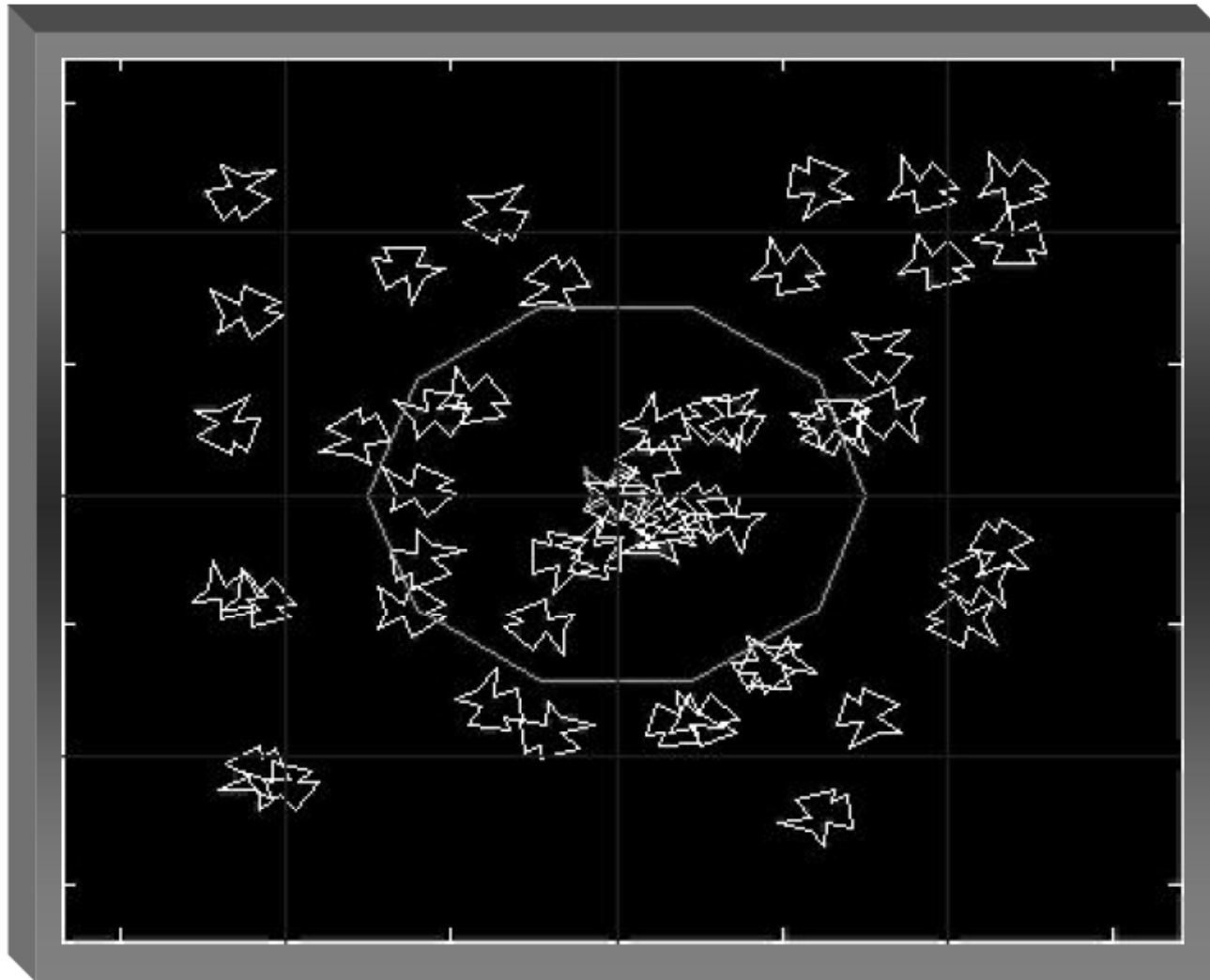
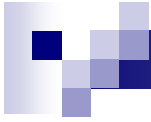
$$\theta_{ref_i}(t+1) = \frac{\theta_i(t) + \sum_{j \in \{\text{Neighbors of Agent } i\}} \theta_j(t)}{1 + N\{\text{Neighbors of Agent } i\}} \quad \forall i \in [1, n]$$

Attraction and Repulsion



In each section:

Repel very close agents,
Attract far agents, but not very far agents.

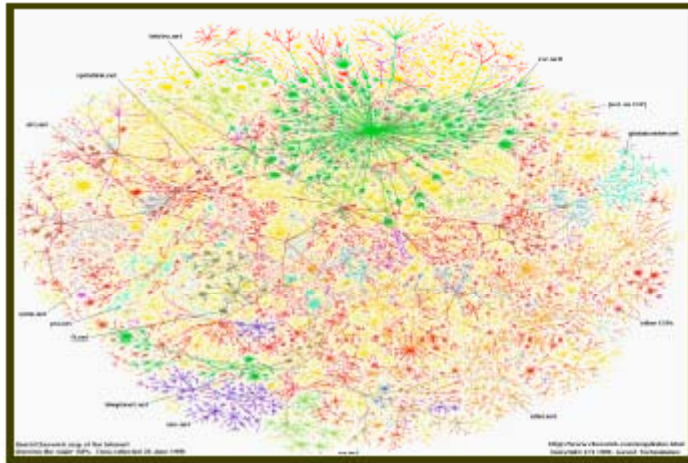


Cooperative behavior of passing obstacles

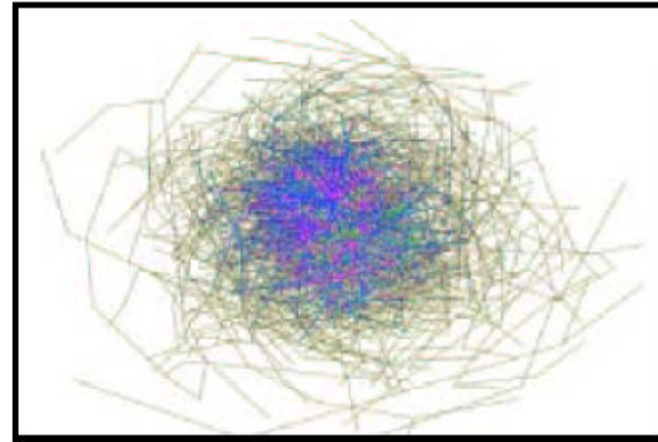


Man-Made Networked Systems

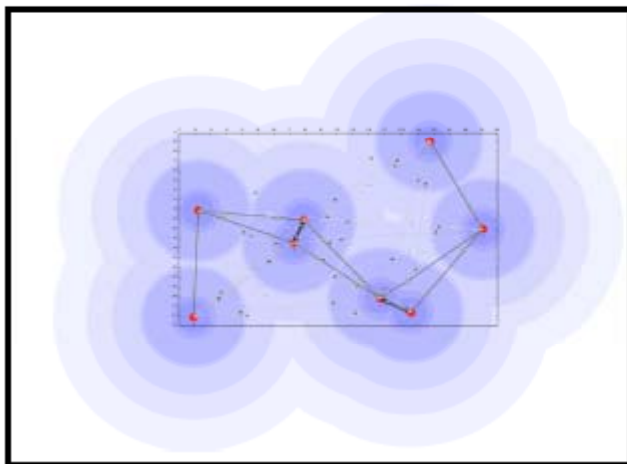
- Food webs
- Electric power grids
- World-Wide Web
- Telephone call graphs
- Etc.



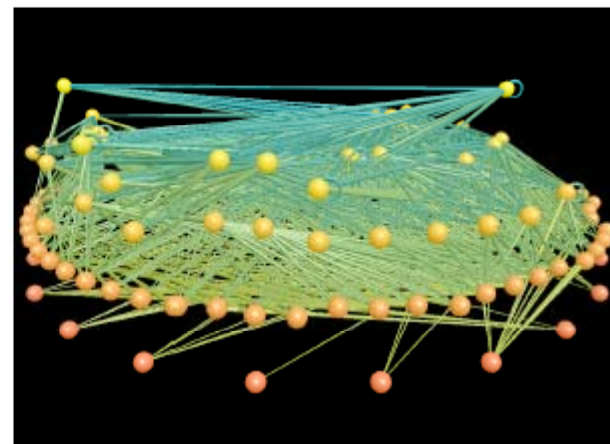
The Internet



File sharing peer to peer system



A Sensor Network



Food Web of
Little Rock Lake, WI



Complications in Networked Systems

- Structural complexity: the wiring diagram could be intricate tangle
- Network evolution: the wiring diagram could change over time
- Connection diversity: links between nodes could have different weights, signs etc.
- Dynamic complexity: the node could be nonlinear dynamic systems
- Node diversity: different kinds of nodes
- Meta-complication: one complication could affect another over time



In Summary

- Early stage of exploring the fascinating subject
- Fundamental problems in cooperative control is to be defined
- Next, we'll focus on a problem called “consensus”, which is relatively well studied, and discuss its application in vehicle formation control



Readings:

- Cooperative Control of Large Systems, by M. E. Khatir and E. J. Davison, IN Cooperative Control, A Post-Workshop Volume 2003 Block Island Workshop on Cooperative Control, Edited by V. Kumar, N. Leonard, A. S. Morse, page 119-136.
- Exploring Complex Networks, by S. H. Strogatz, Nature 410, 268-276 (8 March 2001)