ECE8823 - Fall 2011
Networked Control Systems

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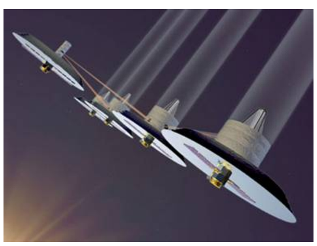
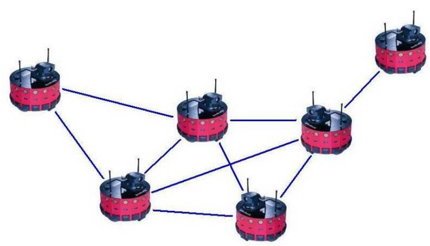
A networked control system consists of a set of dynamical units that interact over a signal exchange network for its coordinated operation and behavior. Such systems have found many applications in diverse areas of science and engineering, including multiple space, air, land, and underwater vehicles, energy and power systems, physiology, and medicine.


COURSE DESCRIPTION

Currently, significant research efforts are underway in the controls, systems, and communications communities to lay down a foundation for the analysis and control of networked systems. This course will provide an overview of the tools and techniques that have proven instrumental for studying networked control systems as well as outline potential research directions.

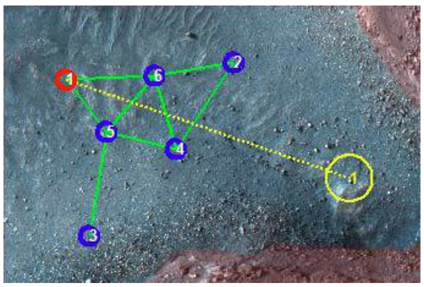
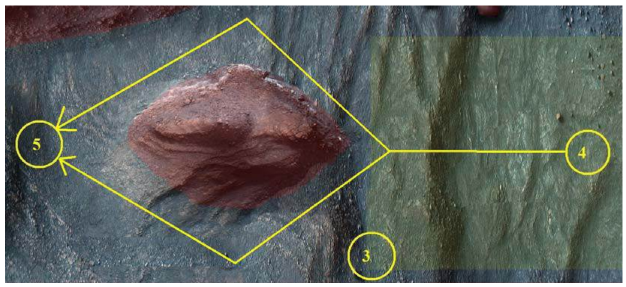
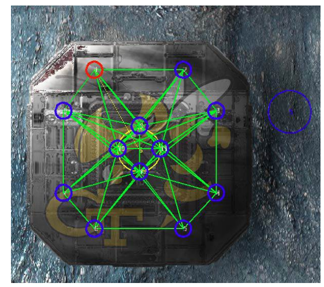
The course will be divided into five parts, corresponding to the following topics:

(1) Network Models (graphs, random graphs, random geometric graphs, state-dependent graphs, switching networks)
(2) Decentralized Control (limited computational, communications, and controls resources in networked control systems)
(3) Multi-Agent Robotics (formation control, sensor and actuation models)
(4) Mobile Sensor Networks (coverage control, voronoi-based cooperation strategies)

(5) LANdroids (mobile communications networks, connectivity maintenance)

COURSE WEBSITE
This page: http://users.ece.gatech.edu/~magnus/ece8823.html

WORKLOAD
Your responsibilities in this class will fall into two main categories:
1. The homework sets (one problem set roughly every third week) = 50%. The credit will be divided between programming assignments and theoretical exercises. The last homework will be project-based and will involve all the tools developed in the course, as shown below.

2. The midterm and final exams = 20% + 30% = 50% They will cover all the material presented in the class. They will be closed-book, closed-note, closed-calculator exams.

PROGRAMMING
The objective with the programming assignments is to see how to bridge the gap between what is done in class and how to actually apply it. The assignments will be Matlab-based.

READING
The course textbook is Mehran Mesbahi and Magnus Egerstedt, *Graph Theoretic Methods in Multiagent Networks*, Princeton University Press, 2010. (See http://press.princeton.edu/titles/9230.html.)
The textbook will be supplemented with some suggested reading material, e.g.,
Distributed Control of Robotic Networks, by F. Bullo, J. Cortes, and S. Martinez, Princeton, 2009.
Algebraic Graph Theory, by C. Godsil and G. Royle, Springer, 2001.
Networked Embedded Sensing and Control, edited by P. J. Antsaklis and P. Tabuada, Springer 2006.

TIME AND PLACE
The lectures will be held at 12:00-1:30 Tuesdays and Thursdays in Van Leer C241.

PREREQUISITS
There are no formal prerequsits beyond graduate standing, but some knowledge of linear algebra, linear control systems, and differential equations will certainly make your life a little easier. For example, ECE6550 would be the perfect background for this course.

HONOR CODE
Altough you are encouraged to work together to learn the course material, the exams and homeworks are expected to be completed individually. All conduct in this course will be governed by the Georgia Tech

honor code.

SCHEDULE

Date	Lecture subject	Reading/Homework
Aug. 23	What are networked control systems?	§1
Aug. 25	Rendezvous: A canonical problem	§1
	GRAPH-BASED NETWORK MODELS	
Aug. 30	Proximity graphs	§2
Sept. 1	Algebraic and spectral graph theory	§2
Sept. 6	Connectivity: Cheeger's inequality	§2
	THE AGREEMENT PROTOCOL: STATIC CASE	
Sept. 8	Reaching decentralized agreements	§3
Sept. 13	Consensus equation: Static case	§3, **HW1** (graph theory)
Sept. 15	Leader networks and distributed estimation	
Sept. 20	Discrete time consensus	§3
	THE AGREEMENT PROTOCOL: DYNAMIC CASE	
Sept. 22	Switched networks	§4
Sept. 27	Lyapunov-based stability	§4, **HW2** (static consensus)
Sept.		

29	Consensus equation: Dynamic case	§4,7
Oct. 4	Biological models: Flocking and swarming	
Oct. 6	Alignment and Kuramoto's coupled oscillators	
Oct. 11	Review	
Oct. 13	**MIDTERM**	
Oct. 18	**Fall recess - NO CLASS**	
	MULTI-AGENT ROBOTICS	
Oct. 20	Formations	§6
Oct. 25	Graph rigidity	§6, **HW3** (dynamic consensus)
Oct. 27	Persistence	§6
Nov. 1	Formation control	§6
Nov. 3	Leader-follower networks	§10
Nov. 8	Network controllability	§10
Nov. 10	Network feedback	§10, **HW4** (formation control)
	MOBILE SENSOR AND COMMUNICATION NETWORKS	
Nov. 15	Sensor networks: Coverage control	§7
Nov. 17	Gabriel and Voronoi graphs	§7
Nov. 22	Communication models	§5
Nov. 24	**Thanksgiving - NO CLASS**	
Nov. 29	Random graphs	§5
Dec. 1	LANdroids: Communication networks	**HW5** (project)
Dec. 6	At the research frontier	
Dec. 8	Review	

Dec. 15	**FINAL EXAM:** 11:30-2:20

ECE New Course Request

COURSE OBJECTIVES AND OUTCOMES

Core undergraduate courses (required courses or those that satisfy specific degree requirements such as probability/statistics or senior lab elective) MUST have course educational objectives and outcomes defined when submitted for permanent catalog listing. Courses proposed for satisfying certain degree requirements (e.g., senior lab electives) may be required to include certain objectives and/or outcomes. ***The following page provides detailed instructions and examples.***

20. Course Educational Objectives (Maximum of 6 objectives; maximum of 150 character each)
In brackets at the end of statement, identify the Student Outcome(s) to which that objective is contributing.

As part of this course, students …

1. apply their knowledge of systems and controls to analyze and model networked systems [a]
2. demonstrate an understanding of algorithms for distributed control deisgn [c,e]
3. transfer theoretical tools and concepts onto applications in robotics, sensor networks, and communication networks [a,c,e]
4.
5.
6.

21. Course Educational Outcomes (Maximum of 15; maximum of 150 character each)

Upon successful completion of this course, students should be able to …

1. model networked control systems over a number of different information exchange mechanisms
2. develop decentralized control algorithms
3. understand fundamental tradeoffs between performance and communications requirements
4. design formation control algorithms for multi-agent robotics applications
5. explain node and ensemble level behaviors
6. charaterize consensus and gosspi algorithms and evaluate their relative merits
7. solve coverage and connectivity problems in mobile sensor and communications networks
8.
9.
10.
11.
12.
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15.