AE 8803: Cyber-Physical Systems and Distributed Control

Course Syllabus

Instructor: Prof. Kyriakos G. Vamvoudakis

Dept.: The Daniel Guggenheim School of Aerospace Engineering
Office: Knight Building 415-B

Phone: 385-3342

E-mail: kyriakos@gatech.edu

Web: http://kyriakos.ae.gatech.edu/

Time & Location: TR 8:00 AM - 9:15 AM

Guggenheim 244

Office Hours: TR 11:00 AM - 12:30 PM or by appointment

These are the "formal" office hours. However, you are more than welcome to stop by my office any time, should you have any questions regarding the course material. Additionally, appointments can be arranged to discuss any questions regarding the course material. The easiest way to reach me is, however, via e-mail.

Course Web Page: All relevant information on the class will be disseminated electronically at canvas.

Required Texts: There is no required text. The instructor will provide notes and research papers.

Prerequisites: Undergraduate linear algebra, probability and signal processing, understanding of modern (state space) control theory

Required Software: Student Edition of Matlab

Course Description and Topics: In this course, we will review several recent advancements in cyber-physical systems and distributed control. Topics will include core principles of CPS, differential equations to model physical processes, graph theory and CPS communication structures, examples with single and double integrator dynamics, time varying structures and matrix analysis of graphs, control loops in CPS, cooperative optimal control, cooperative adaptive control, game theoretic frameworks for secure cooperative control, control and estimation over lossy and attacked networks, intrusion and fault detection in CPS, differential and temporal logic for safety of execution, machine learning in CPS.

Course Topics:

I. Introductory Topics

A. Introduce the core principles behind CPS
B. Differential Equations as Models of Physical Processes
C. The Concept of Synchronization in Complex Systems
D. Known Networks

II. Graph Theory and CPS Communication Structure

A. Graph Theory
B. Eigen structure of Graph Laplacian Matrix
C. Single Integrator Dynamics and Average Consensus
D. Leader and Leaderless Cases
E. Motion Invariants for First-Order Consensus
F. Comparison of Discrete and Continuous Time Systems
G. Double Integrator Dynamics
H. Bipartite Consensus
I. Time Varying Graphs
J. Matrix Analysis of Graphs
K. Advanced Topics and Research Papers

III. Control Loops and Importance of Control and Actuation in CPS

A. Lyapunov Techniques for Control
B. Potential Fields and Motion Control
C. Pinning Control

IV. Cooperative Optimal Control

A. Stability and Optimality
B. Performance Selection
C. Constraints on Graph Topology
D. Advanced Topics and Research Papers

V. Cooperative Adaptive Control

A. Synchronization
B. Adaptive Tuning Laws
C. Stability
D. Advanced Topics and Research Papers

VI. Secure Cooperative Control

A. Game Theoretic Frameworks
B. Research Papers and Advanced Topics

VII. Control and Estimation over Lossy and Attacked Networks

A. Introduction
B. Basics of Hybrid and Impulsive Systems
C. Hybrid Games
D. Advanced Topics and Research Papers

VIII. Intrusion Detection and Fault Detection in Cyber-Physical Systems

A. Introduction
B. Advanced Topics and Research Papers

IX. Differential and Temporal Logic

A. Introduction on Safety of Execution of CPS
B. Advanced Topics and Research Papers

X. Topics on Machine Learning and CPS

A. Advanced Topics and Research Papers

Tentative Grading Policy
Tentative Grading: Homework and Paper Presentations 25%-Midterm Project 35%-Final Project 40%

Student Learning Outcomes:

1. Understand distributed control and shared resources in cyber-physical systems.

   Assessment- homework design projects.

2. Understand the basic different types of graphs that dictate the flow of information.

   Assessment- homework design projects and examinations.

3. Ability to perform designs with various tools using MATLAB.

   Assessment- design and simulation projects assigned in homework.

4. Understand cooperation and control over adversarial and "lossy" networks.

   Assessment- design and simulation projects in homework.

5. Understand intrusion detection and identification.

   Assessment- design and simulation projects in homework, exams.

6. Learn to perform a literature search and prepare a research paper with a unified presentation and exposition on a selected topic.

   Assessment- Final Project Report.

Homework Assignments:

- Due at the beginning of the class on the due date. Solutions to the homework will be posted on the web at the time that they are due. Therefore, NO LATE HOMEWORK will be accepted.
- Electronic submissions will be accepted before the class starts.
- Late homework will not be accepted without formal documentation of extenuating circumstances (e.g. a note from a Dean, a physician, etc.).

Course Policies: 1. NO CELL PHONES are allowed during lecture. 2. Be on time to class. Tardy is discouraged. 3. No make-up exams/quizzes. If you miss the exam, a zero score will be assigned to the missed exam/quiz. 4. If you miss a class due to personal emergency or medical reasons, please be sure to inform the instructor by e-mail. 5. Homework assignments are to be submitted by the due date. You may discuss homework problems with your classmates, but you are responsible for your own works. 6. After an assignment grade has been posted online, students must see the instructor within one week if they wish to discuss the assignment and their work.

Principles of Community: Students are expected to be polite and professional when interacting with one another and with the instructor. Abusive or insensitive behavior will not be tolerated.

Academic Support: The instructor will provide assistance through normal protocols, such as office hours, but cannot serve as a private tutor.

Special Accommodations: Special accommodations can be made for students with disabilities. Please bring any such issues to the instructor's attention *no later than the second week of class*.

Tentative Roadmap			Spring 2019 (AE 8803)	
Number of Lecture	date	day	Topic	Reading Assignments
1	8-Jan	tue	Introduction to CPS	-
2	10-Jan	thurs	Differential Equations as Models of Physical Processes (Physical Part)	-
3	15-Jan	tue	Graph Theory and Communication Structure in CPS (Cyber Part)	-
4	17-Jan	thurs	Graph Theory and Communication Structure in CPS (Cyber Part)	-
5	22-Jan	tue	Graph Theory and Communication Structure in CPS (Cyber Part)	Provided Research Papers
6	24-Jan	thurs	Graph Theory and Communication Structure in CPS (Cyber Part)	Provided Research Papers
7	29-Jan	tue	Control Loops and Importance of Control and Actuation in CPS	-
8	31-Jan	thurs	Control Loops and Importance of Control and Actuation in CPS	Provided Research Papers
9	5-Feb	tue	Control Loops and Importance of Control and Actuation in CPS	Provided Research Papers
10	7-Feb	thurs	Cooperative Optimal Control	-
11	12-Feb	tue	Cooperative Optimal Control	Provided Research Papers
12	14-Feb	thurs	Cooperative Adaptive Control	-
13	19-Feb	tue	Cooperative Adaptive Control	Provided Research Papers
14	21-Feb	thurs	Secure Cooperative Control	Provided Research Papers
15	26-Feb	tue	Secure Cooperative Control	Provided Research Papers
16	28-Feb	thurs	Control and Estimation over Lossy and Attacked Networks	Provided Research Papers
17	5-Mar	tue	Control and Estimation over Lossy and Attacked Networks	Provided Research Papers
18	7-Mar	thurs	Intrustion Detection and Fault Detection in CPS	Provided Research Papers
19	12-Mar	tue	Intrustion Detection and Fault Detection in CPS	Provided Research Papers
20	14-Mar	thurs	Differential and Temporal Logic for Safety of Execution of CPS	Provided Research Papers
21	19-Mar	tue	Holiday/Spring Break	-
22	21-Mar	thurs	Holiday/Spring Break	-
23	26-Mar	tue	Differential and Temporal Logic for Safety of Execution of CPS	Provided Research Papers
24	28-Mar	thurs	Differential and Temporal Logic for Safety of Execution of CPS	Provided Research Papers
25	2-Apr	tue	Topics on Machine Learning and CPS	Provided Research Papers
26	4-Apr	thurs	Topics on Machine Learning and CPS	Provided Research Papers
27	9-Apr	tue	Topics on Machine Learning and CPS	Provided Research Papers
28	11-Apr	thurs	Topics on Machine Learning and CPS	Provided Research Papers
29	16-Apr	tue	Advanced Topics	Provided Research Papers
30	18-Apr	thurs	Advanced Topics (Projects are Due)	-
31	23-Apr	tue	Project Presentations	-
31	25-Apr	tue	Project Presentations	-

These descriptions and timelines are subject to change at the discretion of the Instructor.