CS 599
Autonomous Cyber-Physical Systems

Units:	4
Term:	Spring 2019
Day:	Wednesday
Time:	

Instructor:	Jyo Deshmukh
Office:	SAL 340
Office Hours:	
Contact Info:	jyotirmoy.deshmukh@usc.edu Skype: jyotirmoy.deshmukh

Teaching Assistant:	
Office:	
Office Hours:	
Contact Info:	
Email:	

Course Description.

Autonomous ground and aerial vehicles, complex robots, medical devices, and smart infrastructure systems are all examples of cyber-physical systems. Such systems are characterized by two main aspects: (1) physical components (e.g. electrical, electronic, mechanical, hydraulic mechanisms), and (2) software that is used to control the behavior of the physical components. Increasingly, such CPS applications are seeking to become autonomous with the help of artificial intelligence components trained using machine learning algorithms. In this course, we study different aspects of such *autonomous cyber-physical systems* (ACPS).

We will consider the basics of models of computation, control algorithms, software architectures, formal specifications, testing and verification approaches for ACPS. We will also study elements of Artificial Intelligence that help ordinary CPS applications become autonomous. A key focus throughout the course will be on formal methods to reason about correctness of ACPS. The course will position you to gain the skills required for industrial development of autonomous systems, and will also enable you to think about research problems in autonomy.

Learning Objectives.

1. Gain basic familiarity with modeling for CyberPhysical Systems.
2. Learn how to develop software for a CPS using a model-based development approach.
3. Learn how to write formal requirements for CPS models and perform model-based testing and verification.
4. Learn various ingredients for autonomy based on AI and control techniques such as path planning, reinforcement learning, basics of computer vision, basics of model-predictive control, probabilistic reasoning.
5. Learn basics of the software stack for autonomous systems.

Pre-requisites. None
Co-requisites. None
Concurrent Enrollment. None
Recommended Preparation. Basics of Control, Basics of Automata Theory.

Course Notes.

Course Structure. In this course, bulk of the teaching will be accomplished through lectures and assigned readings. In addition, we will have the following elements:

1. *Homework assignments*: We will have 4 written homework assignments through the semester. Two assignments will be written, and two will be programming assignments.
2. *Project*: The course will have a project, with structure outlined below.
3. *Examinations*: The course has no final exam, but we will have two mid-term exams.

Project Structure. The purpose of the class project is for you to practice model-based development of a cyber-physical system application and adding some elements of autonomy to the system. Students will work in teams of two or three. The general expectation from the project is as follows. Each team will create a (deterministic or probabilistic) physical model for a CPS application. The team will then develop a controller using this model with the goal of providing some level of autonomy to the chosen CPS application. Teams will have the freedom to choose any control strategy, ranging from strategies from control theory to AI-based techniques such as reinforcement learning, imitation learning, etc. The expected behavior of the closed-loop model will be formally specified using an appropriate requirement formalism. The team will use either verification or testing techniques to build confidence in the satisfaction of the requirements by the closed-loop model.

A few examples of CPS applications that the students can choose are provided below:

1. A UAV application, such as a quadrotor drone.

2. Autonomous vehicle subsystems such as lane changing, collaborative merging on a highway, stop-sign detection, collision avoidance, autonomous intersection management, or platooning.
3. A medical device system such as a pacemaker, an automatic insulin delivery system.
4. A ground robot with limited sensing capabilities
5. A biological process or a biochemical reaction

Project Timeline:

Jan 11	-	Jan 31	Identifying team members
Feb 1	-	Mar 5	Informal project discussions with instructor during office hours.
		Mar 6	Project Proposal Due.
		April 24	Final Presentation.

Grading Breakdown for the Project. (Total weight = 25%):

- Project Proposal : 5%
- Project Demo: 15%
- Final Presentation: 5%

Technological Proficiency and Hardware/Software Required. Students are highly encouraged to be well-versed with Matlab® and Simulink®.

Required Readings and Supplemental Material. The course does not have a formal textbook. Following books will be used for reference:

- Principles of Cyber-Physical Systems by Rajeev Alur, MIT Press.
- Introduction to Embedded Systems - A Cyber-Physical Systems Approach, by Lee & Seshia, Second Edition, MIT Press. http://leeseshia.org

Grading Breakdown.

Category	Weight
Homework	4x10 = 40%
MidTerms	2x15 = 30%
Project	25%
Attendance & Participation	5%

Grading Scale. Course final grades will be determined using the following scale:

Grade	Range
A	90-100
A-	85-89
B+	80-84
B	75-79
B-	70-74
C	60-69
F	≤ 59

Assignment Rubrics.

1. Homework assignments will be graded for correctness of answers and provided explanation/proofs. Partial credit will be given wherever applicable.
2. Projects will be graded for the technical depth, novelty, repeatability of the experiment performed. Projects with a greater use of the concepts learned during the course will receive a higher grade.
3. Both mid-term examinations will be take-home. Tests will be graded for correctness, thoroughness and creativity in answers. There will be partial credit given based on the demonstrated effort to solve the given problems.

Assignment Submission Policy. Assignments are expected to be turned in to the instructor/TA by the designated deadline.

Grading Timeline. Graded assignments will be returned to students in a time period not exceeding 2 weeks from the submission of the assignment.

Additional Policies. None.

Course Schedule: Weekly Breakdown

Date	Topic
1/7	Course Overview, Introduction, Models of Computation
1/14	Timed and Dynamical Systems
1/21	Linear, Nonlinear Control, Stability Analysis
1/28	Hybrid Systems: Design, Control and Semantics
2/4	Observation, State estimation
2/11	Matlab Tutorial/Guest Lecture
2/18	Intro to Temporal Logic
2/25	Signal Temporal Logic: Writing specifications & Testing
3/4	Project Proposal Presentation
3/11	Spring Break
3/18	Path Planning & Probabilistic Models
3/25	Guest Lecture & Reinforcement Learning
4/1	Perception and Sensing
4/8	CPS Security, Privacy and Communication
4/15	Safety Verification, Reachability Analysis
4/22	Barrier Certificates, Mining Requirements
4/29	–
5/6	Final Project Presentations

Statement on Academic Conduct and Support Systems

Academic Conduct: Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words - is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, "Behavior Violating University Standards" `policy.usc.edu/scampus-part-b`. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, `http://policy.usc.edu/scientific-misconduct`.

Support Systems:
Student Counseling Services (SCS) (213) 740-7711 24/7 on call

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention. engemannshc.usc.edu/counseling

National Suicide Prevention Lifeline 1 (800) 273-8255
Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. `www.suicidepreventionlifeline.org`

Relationship and Sexual Violence Prevention Services (RSVP) (213) 740-4900 24/7 on call
Free and confidential therapy services, workshops, and training for situations related to gender-based harm. engemannshc.usc.edu/rsvp

Sexual Assault Resource Center
For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: `sarc.usc.edu`

Office of Equity and Diversity (OED)/Title IX Compliance (213) 740-5086
Works with faculty, staff, visitors, applicants, and students around issues of protected class. `equity.usc.edu`

Bias Assessment Response and Support
Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. `studentaffairs.usc.edu/bias-assessment-response-support`

The Office of Disability Services and Programs
Provides certification for students with disabilities and helps arrange relevant accommodations. `dsp.usc.edu`

Student Support and Advocacy (213) 821-4710
Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. `studentaffairs.usc.edu/ssa`

Diversity at USC
Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. `diversity.usc.edu`

USC Emergency Information
Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible. `emergency.usc.edu`

USC Department of Public Safety UPC: (213) 740-4321 HSC: (323) 442-1000 24-hour emergency or to report a crime.
Provides overall safety to USC community. `dps.usc.edu`