

Course description: Autonomous CyberPhysical Systems

Instructor: Jyo Deshmukh

Introduction

How do we systematically design driverless cars, unmanned aerial vehicles, various kinds of robots, and assistive medical devices? These are all examples of cyber-physical systems (CPSs); a CPS is a system that consists of two main parts: (1) physical components (electrical, electronic, mechanical, hydraulic, *etc.*), and (2) software that is used to control the behavior of the physical components. An autonomous CPS is a system that is designed to operate *without human intervention*. A key design challenge for such systems is that they are *safety-critical* – any failure of such a system can lead to catastrophic harm to human lives or property. Thus, it is not enough to learn how to design such systems, it is fundamental to learn how to design them in a fashion that ensures safe operation.

In this course, we will first study the basics of CPS design from this safety mindset. Thus, we will first understand how we can represent the computation done by CPS using mathematically precise and unambiguous models. In the second part of the course, we will learn how to use symbolic tools such as formal languages and temporal logics to specify the desired safe behavior of CPS applications, and how these tools enable systematic testing and verification of CPS models. In the third part of the course, we will study the architectures and algorithms used in model autonomous systems. 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 safe autonomy.

More information here: <https://jdeshmukh.github.io/teaching/cs513-autocps-fall-2023/index.html>

Learning Objectives

1. Gain basic familiarity with cyber-physical systems (CPS).
2. Learn how to develop software for a CPS using a model-based development approach.
3. Learn how to write formal specifications for CPS models and perform testing.
4. Learn basics of simulation-based testing and falsification.
5. Learn ingredients of modern autonomous systems, and the autonomous systems software stack.

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) *Written homework assignments*: We will have 4 homework assignments through the semester.
- 2) *Mini-Projects*: The course will have two mini-projects that will teach students the basic pipeline of autonomous system design from a safety perspective.
- 3) *Project*: Students will have to do a project that can be done either in a team of 1 or 2. Each project will have to be approved by the instructor pending a formal project proposal. Informal proposals over email are encouraged prior to the formal project proposal. Projects can be of three types:
 - a) *Research project*: Here, the team is expected to choose a fundamental question related to the course material and identify possible solutions to the problem. The final product should be a 10-page research paper in at most a 12-point font, 1" overall margins and at most single spacing.
 - b) *Survey project*: Here, the team considers a large body of literature related to a topic and writes a paper summarizing the key research directions and results in that topic. The final product should be a 20-page paper in at most 12-point font, 1" overall margins and at most single spacing.
 - c) *Programming Project*: Here, the team can build a tool for analyzing an autonomous CPS or construct the model of an autonomous CPS. Projects involving hardware implementations

following a thorough model-based development process are encouraged; however, support for deployment to hardware will be limited.

4) *Examinations*: The course has no exams.

Pre-requisites

- Some familiarity with automata, basics of control, calculus will be helpful but is not required.
- This course is aimed at graduate students, but upper-level undergraduates can take this course if interested.

Textbooks

The course will not use any specific textbook, but the following books can be used for supplementary reading:

- 1) Principles of Cyber-Physical Systems by Rajeev Alur, MIT Press.
- 2) Introduction to Embedded Systems - A Cyber-Physical Systems Approach, by Lee & Seshia, Second Edition, MIT Press. <http://leeseshia.org>
- 3) Verifying Cyber-Physical Systems: A Pathway to Safe Autonomy, by Sayan Mitra.

Readings

- None. All required reading will be covered by lecture slides.

Grading and Evaluation

Students will be graded based on the following breakdown.

	Weight
Written Homework Assignments	40%
HW1 (10%)	
HW2 (10%)	
HW3 (10%)	
HW4 (10%)	
Mini-Projects	30%
Mini-Project 1 (15%)	
Mini-Project 2 (15%)	
Final Project	25%
Project Proposal (Not graded)	
Project/Final Paper (20%)	
Final Presentation (5%)	
Participation (Slack, Class)	5%

Project/Paper Grading: Projects will be graded based on the quality of prototype tools, demos, or the developed models. Survey papers will be graded based on their comprehensiveness. Technical papers will be graded based on their novelty and technical results.

Course Schedule:

See <https://jdeshmukh.github.io/teaching/cs513-autocps-fall-2023/schedule.html>

Academic Conduct

From <https://dornsife.usc.edu/engl/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” <https://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>.

Discrimination, sexual assault, intimate partner violence, stalking, and harassment are prohibited by the university. You are encouraged to report all incidents to the Office of Equity and Diversity/Title IX Office <http://equity.usc.edu> and/or to the Department of Public Safety <http://dps.usc.edu>. This is important for the health and safety of the whole USC community. Faculty and staff must report any information regarding an incident to the Title IX Coordinator who will provide outreach and information to the affected party. The sexual assault resource center webpage <http://sarc.usc.edu> fully describes reporting options. Relationship and Sexual Violence Services <https://engemannshc.usc.edu/rsvp> provides 24/7 confidential support.

Note on Collaborative Work

For collaborative projects, students are expected to have equal distribution. If there is any perceived imbalance in the collaborative project, the student should bring this to the attention of the instructor or the teaching assistant.

Support Systems for Writing, Learning Disabilities, etc.

Several USC’s schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more. Students whose primary language is not English should check with the American Language Institute <http://ali.usc.edu>, which sponsors courses and workshops specifically for international graduate students. The Office of Disability Services and Programs <http://dsp.usc.edu> provides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, USC Emergency Information <http://emergency.usc.edu> will provide safety and other updates, including ways in which instruction will be continued by means of Blackboard, teleconferencing, and other technology.