EE C291E/ME C290S: Hybrid Systems: Computation and Control

Claire Tomlin

TTh 9:30-11:00

`http://inst.eecs.berkeley.edu/~ee291e/`

Advances in networked embedded computing and communication devices have fueled the need for design techniques that can guarantee safety and performance specifications of embedded systems, or systems that involve the integration of discrete logic with the analog physical environment. Hybrid dynamical systems are continuous state systems with a phased operation. The phases of operation capture the system's discrete event or linguistic behavior, while the continuous variable dynamics capture the system's detailed or "lower-level" behavior. Hierarchical organization is implicit in hybrid systems, since the discrete event dynamics represent planning which is based on an abstraction of the continuous dynamics. Hybrid systems are important in applications in real-time software, robotics and automation, mechatronics, aeronautics, air and ground transportation systems, systems biology, process control, and have recently been at the center of intense research activity in the control theory, computer-aided verification, and artificial intelligence communities. In the past several years, methodologies have been developed to model hybrid systems, to analyze their behavior, and to synthesize controllers that guarantee closed-loop safety and performance specifications. This class presents recent advances in the theory for analysis, control, verification, and learning of hybrid dynamical systems, and shows the application of the theory to a variety of examples. ¡/p¿ ¡p¿ We will present hybrid automaton models and related modeling approaches. In hybrid controller synthesis, we will treat different control system setups such as game theoretic and optimal control, and we will present recent advances in integrating learning-based approaches into such methods. Finally, we apply the theory in case studies to complex problems such as automated highway systems, air traffic management systems, networks of unmanned vehicles, closing the loop around sensor networks, and systems biology.

Prerequisites:
Background in systems and control, such as EECS 221A or ME 232 is desirable. EECS 222 is offered concurrently and is a useful class to take with this one.

Office Hours:
TTh 11-12

Grading and Evaluation:
Class work consists of readings, some homework exercises, and a substantial individual project.

- Homework 40%
- Class Project 50%
- Participation 10%

One way to get the full 10% for participation is to attend lecture, keep your video on, and partipate in class discussions. You can also get the full 10% participation by participating in online discussions about readings in the class.

Class Project:
The projects can either be in the form of a review of an area of the literature or, preferably, involve the exploration of original research ideas. The length of the project can be inversely proportional to its originality. If the project is a review of the literature, it needs to be thoroughly digested and homogenized. The project should be chosen in consultation with the instructors. The schedule is as follows:

- Project Proposal (two page summary) **due before term break**
- Project Report (10-12 pages) and poster **due final week of classes**

Joint project proposals (with groups of 2 or 3 per group) are encouraged.

An initial suggestion of some project ideas are:
Investigation of a subclass of hybrid systems: linear hybrid systems (ellipsoidal calculus, switched Lyapunov functions); discrete-time hybrid systems; stochastic hybrid systems.
Multiple objective systems; topics from game theory (n-player pursuit evasion games, cooperative games); safety-based control; optimization of hybrid systems.
Observability of hybrid systems; hybrid state estimation; model identification.
Topics in safe learning: integrating learning into safety-based control.
Topics in human-machine systems: modeling, analysis, and control.
Applications: groups of coordinating vehicles; multi-modal robotic systems; perception-based robotics; identification of modes in ATC observed data; gait modeling, stability and control; engine control; guidance of a UAV; biological modeling and control; embedded control and real time scheduling.

Course References:
The course is based on a set of lecture notes and articles which will be made available throughout the term.