ASEN 6519 Special Topics - Section 006
Hybrid Systems: Theory, Computation, and Applications

Spring 2019

Lecture information

Tuesday and Thursday 2-3:15pm in ECCR 155

Instructor

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Course description

In many modern engineering applications -- robotics, automation, real-time software, aeronautics, air and ground transportation systems, systems biology, and process control, to name a few -- the states of the system undergo a mixture of real-time (continuous) and instantaneous event (discrete) transitions. This mixture can be dictated by the fundamentally non-smooth or discontinuous nature of some physical phenomena (e.g. mechanical impact, network rerouting, and cell differentiation) or intentional by design (integration of discrete logic or digital computers with continuous physical processes). The result of such a coupling of discrete and continuous dynamics is a hybrid system. More specifically, hybrid systems are continuous variable systems with a phased operation, capturing both discrete event (linguistic behavior) and "lower-level" continuous behavior of the system. For this very reason, hybrid systems have recently been at the center of intense research activity in the control theory, computer-aided verification, and artificial intelligence communities.

This course provides an introduction to hybrid systems. We start by presenting a modeling framework for hybrid systems that combines elements from automata theory and differential equations. We then introduce a set of techniques that can be used for design and analysis of hybrid systems. We also present recent advances in the theory for formal verification and control of these systems and show the applications of the theory to the design of the control architecture for complex and uncertain systems.

This course is designed to be aligned with the objectives of the CEAS's Autonomous Systems Interdisciplinary Research Theme and is open to AES, CS, ME, and ECEE students.

Prerequisites

The course is essentially self-contained, and the students are only expected to be familiar with *linear algebra* and basic *differential equations*.

Recommended preparation: The students should be proficient in *linear algebra*, basic *differential equations*, and some scientific programming language (e.g., MATLAB). Basic knowledge of controls concepts is helpful but not essential.

Grading and Evaluation

Classwork consists of some homework exercises worth 40%, a paper presentation and class participation worth 20%, and a substantive project worth 40% of the grade.

Course Outline

- Introduction, motivation, and examples
- Mathematical background
- Trajectories of hybrid systems
- Existence of Executions
- Stability of hybrid systems
- Formal analysis and control of dynamical systems
    - Transition systems, simulations, and bisimulations
    - Temporal logics
    - Model checking and verification
    - Analysis and control for finite systems
    - Analysis and control for continuous-time dynamical systems
    - Analysis and control for discrete-time dynamical systems
- Stochastic Hybrid Systems
- Applications
    - Symbolic motion planning and control
    - Sampling-base motion planning