EECE 571M/491M
Introduction to Hybrid Systems and Control
Syllabus

Dr. Meeko Oishi
`http://courses.ece.ubc.ca/491m`

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Instructor

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Office hours: Monday 1-3pm (tentative)

Course Location and Time

MCLD 254 (Monday, Wednesday) and MCLD 410 (Friday), 10:00am-11:00am

Grading

35%	Problem Sets
30%	Midterms
35%	Final Project

Course Description

Hybrid systems are pervasive in engineered and bioligcal systems, including systems which involve multiple agents, hierarchical structure, or mode-logic, for example. They are characterized by the interaction of both continuous and discrete dynamics, and require new methods and tools which draw upon continuous control and finite automata theory.

This is a combined upper-level undergraduate and first-year graduate course in hybrid control systems. The course will cover fundamental results in hybrid control theory, and introduce students to current areas of research. The main emphasis will be on methods and computational tools for the analysis and control of hybrid systems with linear continuous dynamics. Topics will include modeling, stability, optimality, controllability, and observability, and will be introduced through engineering and biological system examples.

Prerequisites

Undergraduates: EECE 360. Students will need a functional knowledge of differential equations and linear algebra.

Course Updates

Updates will be posted on the course website.

Course Readings/Text

Recommended text:

B. Friedland, *Control system design: An introduction to state-space methods*, McGraw-Hill, 1986.

Recommended references:

J. Lygeros, S. Sastry, and C. Tomlin, *Hybrid Systems*, preprint 2005.
H. Khalil, *Nonlinear Systems*, Prentice Hall, 2002.
S. Lafortune and G. Cassandras, *Introduction to Discrete Event Systems*, Springer, 1999.

Course Outline

1. **Introduction.** Motivating examples of hybrid systems in engineering and biology.
2. **Modeling of continuous, discrete, and hybrid systems.** Formal description of timed, affine, polyomial, nonlinear, switched, controlled, and autonomous systems.
3. **Linearization and phase-plane analysis.** Taylor's series approximation. Graphical analysis of 2D systems. Nodes, centers, focii, saddles. Multiple equilibria, periodic orbits, limit cycles. Poincare-Bendixson.
4. **Linear systems review.** Similarity transformations, Jordan normal form, modal decomposition. Diagonalization.
5. **Stability of linear systems.** Review of linear system stability: BIBO, asymptotic, exponential stability. Quadratic Lyapunov functions for linear systems. Positive definiteness.
6. **Controllability/observability of linear systems.** Review of standard observability tests. Stabilizability / detectability. Separation principle. Reduced-order observers and controllers.
7. **Stability of linear hybrid systems** Indirect method; general Lyapunov stability. Multiple Lyapunov functions. Matlab tools (LMI Toolbox). Linear quadratic Lyapunov functions, Piecewise linear quadratic Lyapunov functions. Common Lyapunov functions.
8. **Switched control of linear hybrid systems.** Continuous and discrete controller synthesis for switched systems. Performance of switched controllers. Common Lyapunov functions. Stability under unconstrained switching; stability under hyper-surface switching.
9. **Controllability/observability of linear hybrid systems.**
10. **Stabilizing control.** Linear controllers for nonlinear systems. Gain scheduling.
11. **Related hybrid control topics.** Optimal control of linear hybrid systems. Hybrid estimation.
12. **Student presentations.**

Course Policies

While collaboration and discussion is encouraged on all problem sets unless otherwise specified, each student must hand in their own individual work. Copying will not be tolerated. Late homeworks will be accepted but will be penalized 10% per day: $y = (0.9)^d x$, where x is the raw score, d is the number of days late, and y is the recorded score.

Students must inform the instructor as soon as they are aware of conflicts with the midterm or the final project presentation.

Course Project

Undergraduates: Students will work independently or in small groups of two to three to model, analyze, and design a controller for a hybrid system. Students can select from a range of projects provided by the instructor, or can create their own project, in consultation with the instructor. The project will require the application of hybrid system methods and tools to a specific problem. Students must justify a hybrid modeling framework, analyze the system's behavior and performance, synthesize a controller, discuss computed or analytical results, and demonstrate an understanding of potential problems in actual implementation (in measurement errors, computational complexity, or actuation). Students will provide a written presentation of their project.

Graduates: Students will work independently on a project as described above, ideally related to their current research. Graduate students will provide both written and oral presentations of the project for evaluation.