Syllabus for MAE286
Hybrid Systems - Fall 2018

Jorge Cortés

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This course covers the modeling, analysis, and design of hybrid dynamical systems. Topics include: Basic notion of hybrid system. Examples from mechanics, vision, and multi-agent systems. Modeling approaches to hybrid systems. Switching systems. Solutions of hybrid systems. Chattering, Zeno phenomena. Graphical convergence. Stability analysis. Robustness. Lyapunov functions. Arbitrary switching: common Lyapunov functions. Slow switching: dwell time, average dwell-time. State-dependent switching: multiple Lyapunov functions. Invariance Principle. Hybrid control design. Applications.

Instructor

Jorge Cortés, `cortes at ucsd.edu`. Office at Engineering Building I, room #1608

Teaching Assistant

Dariush Fooladivanda, `dfooladi at ucsd.edu`. Office at Engineering Building I, room #1803

Course Objectives

By the end of the course, you would/should have:

1. learned and used various modeling and analysis techniques for hybrid systems
2. learned and used tools for the stability and stabilization of hybrid systems
3. known and played around with hybrid systems in a variety of scenarios

Prerequisites

Knowledge of ordinary differential equations and nonlinear dynamical systems is assumed. Familiarity with simulation software of your choice (e.g., Matlab/Mathematica/Maple).

Text

We will use a variety of sources for reference. Our main book is

(M1) R. Goebel, R. G. Sanfelice, and A. R. Teel. *Hybrid Dynamical Systems: Modeling, Stability, and Robustness*. Princeton University Press, 2012

with the following two used often throughout the course

(M2) A. J. van der Schaft and H. Schumacher. *An Introduction to Hybrid Dynamical Systems*, volume 251 of *Lecture Notes in Control and Information Sciences*. Springer, 2000

(M3) J. Lygeros, C. Tomlin, and S.S. Sastry. *Hybrid Systems: Modeling, Analysis and Control*. 2008. Unpublished. Available at http://www-inst.cs.berkeley.edu/~ee291e/sp09/handouts/book.pdf

Additional recommended readings

Depending on the specific topic we are dealing with, we will complement the books above with the following material

[A1] D. Liberzon. *Switching in Systems and Control*. Systems & Control: Foundations & Applications. Birkhäuser, 2003

[A2] J. P. Hespanha. A model for stochastic hybrid systems with application to communication networks. *Nonlinear Analysis*, 62(8):1353–1383, 2005

Course webpage

http://carmenere.ucsd.edu/jorge/teaching/mae286/f18

The webpage contains this syllabus and the list of homework due. Please check it periodically for updates and other announcements related to the course.

Calendar

Introduction and examples (M2, Ch 2; M1, Ch 1; M3, Ch 1)

Modeling

- Modeling approaches to hybrid systems (M2, Ch 1; M1, Ch 1; M3, Ch 3)
- Trajectories: time domains, notion of solution, degeneracies (M1, Ch 2; M3, Ch 4)
- Systems with state perturbations, hybrid regularizations (M1, Ch 4)
- Well-posed hybrid systems, graphical convergence (M1, Ch 5)

Analysis

- Review of stability of ODEs
- Stability and asymptotic stability (M2, Ch 5; M1, Ch3&7; A1, Ch 2-3; M3, Ch 5)
- Arbitrary switching, slow switching, state-dependent switching (A1, Ch 2-3)
- Invariance principle (M1, Ch 8; M3, Ch 5)

Design

- Hybrid control design (M2, Ch 6)
- Feedback stabilization (A1, Ch 4)
- Control with limited information (A1, Ch 5)

Homework

There will be a set of homework problems per week. The homework will be collected weekly on Thursdays (specific dates for your reference are included in the webpage). *You need to complete all exercises, although only* **1-2**, *randomly selected, will be corrected from each assignment.* No late homework will be accepted. Collaboration is allowed, but your homework should reflect your own original work and be the result of your understanding of the material.

Exams

The midterm will be on November 1 and the final on December 14 (11:30am-2:30pm), both in class

Grading policy

Homework: 30%
Midterm: 30%
Final exam: 40%

TritonEd

Your grades will be available via TritonEd. Check out http://tritoned.ucsd.edu for instructions on how to register and log in.

Academic honesty

No form of academic dishonesty will be tolerated. For the definition of academic dishonesty and its consequences, check the UCSD General Catalogue 2018-2019 at http://ucsd.edu/catalog/front/graduate-education.html

Room location and hours

Lectures take place at Center Hall (building #984), room 224A, Tuesdays and Thursdays, from 12:30pm to 1:50pm.

Office hours

Instructor: Tuesdays, from 2:00pm to 3:00pm, at EBU I, room 1603 (conference room).

Please, send an email describing the problem before coming to office hours – will try to respond as quickly as possible.