Syllabus for MAE286
Hybrid Systems - Fall 2010

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, # 1608

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 calculus, linear algebra, and ordinary differential equations is assumed. Familiarity with simulation software of your choice (e.g., Matlab/Mathematica/Maple).

Text

We will use a variety of sources for reference. There are two main books we will resort to:

[M1] 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

[M2] R. Goebel, R. G. Sanfelice, and A. R. Teel. *Hybrid Dynamical Systems: Modeling, Stability, and Robustness*. 2010. Not yet published

Additional recommended readings

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

[A1] R. Goebel, R. G. Sanfelice, and A. R. Teel. Hybrid dynamical systems. *IEEE Control Systems Magazine*, 29(2):28–93, 2009

[A2] D. Liberzon. *Switching in Systems and Control*. Systems & Control: Foundations & Applications. Birkhäuser, 2003

[A3] P. Tabuada. *Verification and Control of Hybrid Systems: A Symbolic Approach*. Springer, New York, 2009

Course webpage

http://tintoretto.ucsd.edu/jorge/teaching/mae286/

The webpage contains this syllabus and the list of homework due.

Calendar

Introduction and examples (M1, Ch 2; M2, Ch 1; A1)

Modeling

- Modeling approaches to hybrid systems (M1, Ch 1; M2, Ch 1)
- Trajectories: notion of solution, degeneracies (M2, Ch 2; A1)
- Safety, reachability, and other properties of hybrid automata (A3)
- Well-posed hybrid systems, graphical convergence (M2, Ch 5)

Stability analysis

- Review of stability of ODEs
- Stability and asymptotic stability (M1, Ch 5; M2, Ch3&7; A2, Ch 2-3)
- Arbitrary switching, slow switching, state-dependent switching (A2, Ch 2-3)
- Invariance principle (M2, Ch 8)

Design

- Hybrid control design (M1, Ch 6; A1)
- Feedback stabilization (A2, Ch 4)
- Control with limited information (A2, Ch 5)

Homework

There will be a set of homework problems per week. Homework assignments are due weekly (specific dates for your reference are included in the webpage). No late homework will be accepted.

Midterm October 28

Final project

Everybody should read *all* papers from a list provided by the instructor and select *one* of them for presentation to the class in the final week. When presenting, the criteria for evaluation are clarity of the presentation, displayed understanding of the content, and handling of questions. When being part of the audience, the criteria are quality and pertinence of questions raised. A written report consisting of a summary of the paper, the lessons learned from the presentation and the Q&A and a 1-page description of ideas for future work is also required.

The webpage contains a list of papers together with some useful instructions.

Grading policy

Homework: 25% Midterm: 25% Presentation: 20% Questions: 15% Written Report: 15%

WebCT

Your grades will be available via WebCT at http://webct.ucsd.edu

Room location and hours

Lectures take place at the Warren Lecture Hall, room 2110, Tuesdays and Thursdays, from 2:00pm to 3:20pm.

Office hours

Instructor: Mondays, from 2:00pm to 3:00pm. Please, send me email describing the problem before coming to office hours. Be prepared to show attempts at solving the problem. If you have any questions about the course, please send me email. I will try to respond as quickly as possible. Additionally, I will share questions that are particularly good (and their answers) with the rest of the class by broadcasting my answer to the entire class.