Syllabus for MAE286
Hybrid Systems - Fall 2024

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`

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. appreciated the complexities in the evolution of hybrid systems and its trajectories
3. learned and used tools for the stability analysis and stabilization of hybrid systems
4. known and played around with hybrid systems in a variety of scenarios

Prerequisites

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

Text

We will use a variety of sources for reference. Our main references are

(M1)

(M2)

Additional recommended readings

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

[A1]

[A2]

[A3]

Useful software

You will find useful the HyEQ Toolbox in Matlab. All the info is available at `https://hybrid.soe.ucsc.edu/software`. The current stable version is v3.0, and you can download it here. There is a brief webinar that covers the basics about how to use the toolbox.

Course webpage

http://terrano.ucsd.edu/jorge/teaching/mae286/f24

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 (M1, Ch 1. See also M2, Ch 1; A1, Ch 2; A2, Ch 1)

Modeling

- Modeling approaches to hybrid systems (M1, Ch 1. See also A1, Ch 1; A2, Ch 3)
- Trajectories: time domains, notion of solution, degeneracies (M1, Ch 2. See also A2, Ch 4)
- Systems with state perturbations, hybrid regularizations (M1, Ch 4)
- Well-posed hybrid systems, graphical convergence (M1, Ch 5)

Analysis

- Stability and asymptotic stability (M1, Ch 3&7. See also A1, Ch 5; A2, Ch 5)
- Invariance principle (M1, Ch 8. See also A2, Ch 5)
- Stability under arbitrary switching (A3, Ch 2)
- Stability under constrained switching: slow switching, state-dependent switching (A3, Ch 3)

Design

- Uniting control (M2, Ch 4)
- Event-triggered control (M2, Ch 5)
- Feedback design via control Lyapunov functions (M2, Ch 10)
- Invariance-based control (M2, Ch 11)
- Temporal logic (M2, Ch 12)

Exams

The midterm will be on Thursday, October 31, 2024

The 2nd midterm will be on Thursday, December 5, 2024

Project presentations will be on Thursday, December 12, 2024

Homework

There will be a set of homework problems per week. Homework assignments are due weekly, on Fridays at midnight (specific dates for your reference are included in the webpage). *You need to complete all exercises, although only* **two***, 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.

We use an all electronic homework submission and grading process through Canvas. Homework instructions will be posted there. You can handwrite legibly or type, then scan your homework as a PDF file for submission. Please check the quality of your PDF file before submission. If we cannot read it, we cannot grade it! Please turn in a readable and organized homework. Here is a suggestion: include your name and your ID # on top of each and every page, answer questions in logical order, and start answering a question always on the top of the page.

To efficiently address questions related to homework, we use Piazza at https://piazza.com/ucsd/fall2024/mae286_fa24_a00. Anybody can take a stab at posting answers to questions and we will monitor it regularly, but do not expect immediate turnarounds!

Grading policy

Homework: 30%
Midterm: 25%
2nd Midterm: 25%
Projects: 20%

Canvas

Your grades will be available via Canvas. Check out https://canvas.ucsd.edu/courses/59025 for instructions on how to register and log in. Please **check it regularly** to make sure your homework scores are being transcribed correctly.

Academic honesty

No form of academic dishonesty will be tolerated. We take this very seriously. For the definition of academic dishonesty and its (ominous) consequences, refer to the UCSD General Catalog 2024-2025 at http://www.ucsd.edu/catalog/

Prior to starting the course, you should visit https://academicintegrity.ucsd.edu/forms/form-pledge.html and take the UCSD Academic Integrity Pledge.

Lectures and hours

Lectures take place at Engineering Building 2, room 305, Tuesdays and Thursdays, from 9:30am to 10:50am.

Office hours

Specific access information is provided on Canvas in the announcement "Office Hours"

Jorge: Tuesdays, from 3:00pm to 4:00pm, at EBUI, room 1603.