

Lecture on Hybrid Dynamical Systems (HDS)

Some Information about the course :

- Instructors: Sophie Tarbouriech (Course)
Isabelle Queinnec (Lab-class)

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- Time: January 20 - February 27, 2023

— Prerequisite:

- Notions on linear system theory
- Mathematical backgrounds

— Course materials

• The lecture is based on recent results of the literature as for example

— C. Priour, I. Queinnec, S. Tarbouriech,
L. Zaccarian. Analysis and synthesis of reset
control systems, Foundations and Trends in Syst.

and Cont., 6(2-3), pp. 117-338, 2018

— R. Goebel, R. G. Sanfelice, A. R. Teel.

Hybrid dynamical systems, Modeling,
Stability and Robustness, Princeton University
Press, 2012.

• Most of the results proposed during
this course are issued from common works
with several colleagues from national and
international labs or universities

- Topic of the course: hybrid dynamical systems.

- Objectives of the course:

- Get familiar with hybrid dynamical systems, or at least of some classes of hybrid dynamical systems as reset control systems
- Obtain overview of modeling, analysis and (maybe) control methods

- Modeling, analysis and control of tractable classes of hybrid dynamical systems

- Apply hybrid dynamical systems modeling and control to simulation case study

⇒ This is a fundamental, theory course and not a hands-on course

⇒ So, be prepared to expect definitions, theorems, proofs, ...

- Some information about the organization

(2h) ST - Jan. 10 : slots 1-2 (9h15 - 11h30) : course
↳ Introduction

(2h) IQ - Jan. 27 : slots 3-4 (9h15 - 11h30) : Lab. des
↳ First initiation to the
simulation of HDS

(2h) ST - Feb. 30 : slots 5-6 (14h00 - 16h15) : course
↳ solutions

(2h) ST - Feb. 01: slots 7-8 (14^h - 16^h 15): Course

↳ solutions
Exercises (Bouncing ball)

(2h) ST - Feb. 03: slots 9-11 (9^h 15 - 12^h 45): Course

↳ solutions + Exercises
stability

(2h) ST - Feb. 07: slots 12-13 (14^h - 16^h 15): Course

↳ stability
Exercises

(2h) **ST** - Feb. 10 : slots 14-15 (9h15 - 11h30): Course

↳ Lyapunov
Exercises

(2h) **IQ** - Feb. 16 : slots 16-17 (9h15 - 11h30): "Lab-class"

↳ BE2: sampled-data systems
stability analysis / Lyapunov

(2h) **ST** - Feb. 17 : slots 18-19 (9h15 - 11h30): Course

↳ Study of research papers

(3h) ST_{IQ} - Feb-27: slots 20-22 (9^h15 - 12^h45): course
+
"lab-class"

↳ Presentation/discussion
on the papers studied
Conclusion of the course

~> Course: 14h } could vary a bit
Lab-class: 8h } depending on the progression
+ Exercises of the course

- Exam: March 14 (9h-11h)

- Organization of the course
 - Presentation with slides and/or on board
 - All the notes and slides will be given together with a list of associated references

- Organization of the Lab-class
 - Use of SIMULINK and MATLAB
 - Use of the toolbox developed by Ricardo Sanfelice

— Preparation of a lecture/seminar on a chosen topic:

- ~> 4 work groups (3-4 students/group)
- ~> Study of a paper or chapter on HDS
- ~> Presentation to the class next slot

- Let me now specify the contents of the course

1. Introduction

- Definition of what is a hybrid dynamical systems

- Presentation of several examples:

in particular bouncing ball

from continuous-time and discrete-time backgrounds

↳ will be also the topic of the first lab-class

2. Notion of solutions

- Notion of hybrid time domain
- Notion of well-posedness
- various type of solutions

- Zeno solution

→ mainly based on chapter 2 of the book of Goebel, Sanfelice and Teel

→ will be illustrated during lab-class

3. Stability analysis

- Background on stability and convergence notions

- Equilibrium points, attractor

- Definition of UGAS (Uniform Global

Asymptotic stability)

4. Lyapunov theory

- Lyapunov theorems

- Lyapunov functions

Some examples will be proposed

→ Mainly based on chapter 3 of the book of Goebel, Sanfelice and Teel

5. Generalized solutions

- Effect of state perturbation
- Systems with discontinuous term

→ Chapter 4 of the Book of Goebel

Sanfelice and Teel

6. Extensions / conclusions

- La Salle principle
- Robustness ...

it will depend on
the time and
the course
progress

The grade from this lecture will be based

— on the study / presentation of the papers

— on the exam

— finally on the reports from the lab-classes