COM-502

Dynamical system theory for engineers

Thiran Patrick

Cursus	Sem.	Type
Computational science and Engineering	MA2, MA4	Opt.
Computational science and engineering minor	E	Opt.
Computer science	MA2, MA4	Opt.
Cybersecurity	MA2, MA4	Opt.
Life Sciences Engineering	MA2, MA4	Opt.
Mechanical engineering	MA2, MA4	Opt.
Neuro-X minor	E	Opt.
Neuro-X	MA2, MA4	Opt.
Robotics, Control and Intelligent Systems		Opt.
SC master EPFL	MA2, MA4	Opt.
Systems Engineering minor	E	Opt.

Language of teaching	English
Credits	6
Session	Summer
Semester	Spring
Exam	Written
Workload	180h
Weeks	14
Hours	**4 weekly**
Courses	3 weekly
Exercises	1 weekly
Number of positions	

Remark

Cours biennal

Summary

Linear and nonlinear dynamical systems are found in all fields of science and engineering. After a short review of linear system theory, the class will explain and develop the main tools for the qualitative analysis of nonlinear systems, both in discrete-time and continuous-time.

Content

- **Introduction:** Dynamics of linear and non linear systems. Definitions; Unicity of a solution; Limit Sets, Attractors.
- **Linear Systems:** Solutions; Stability of autonomous systems, Geometrical analysis, connection with frequency domain analysis.
- **Nonlinear Systems:** Solutions; Examples.
- **Large-scale notions of stability**: Lyapunov functions. Hamiltonian systems, gradient systems.
- **Small-scale notions of stability**: Linearization; stability and basin of attraction of an equilibrium point, stability of periodic solutions, Floquet Multipliers. Graphical methods for the analysis of low-dimensional systems.
- **Structural stability,** Bifurcation theory.
- **Introduction to chaotic systems**: Lyapunov exponents, computation using ergodic theory, period doubling route to chaos, topological conjugacy.
- Time permitting: chosen advanced topic (e.g, a topic in stochastic approximation, mean-field approach, optimization, network dynamics, ...).
- The class is methodology-driven. It may present some limited examples of applications, but it is not application-driven.

Keywords

Dynamical Systems, Attractors, Equilibrium point, Limit Cycles, Stability, Lyapunov Functions, Bifurcations, Lyapunov exponents, Measure Theory.

Learning Prerequisites

Required courses

- Linear algebra (MATH 111 or equivalent).
- Analysis I, II, III (MATH 101, 106, 203 or equivalent).
- Circuits & Systems II (EE 205 or equivalent) or a Systems & Signals class (MICRO 310/311 or equivalent).
- A first-year Probabilty class, such as MATH-232, MATH-231, MATH-234(b), MATH-234(c), or equivalent.

Recommended courses

- Analysis IV (MATH 207 or equivalent)

Important concepts to start the course

- Linear Algebra (vector spaces, matrix operations, including matrix inversion and eigendecomposition).
- Calculus (linear ordinary differential equations; Fourier, Laplace and z-Transforms).
- Notions of topology.
- Notions of probability.

Learning Outcomes

By the end of the course, the student must be able to:

- Analyze a linear or nonlinear dynamical system.
- Anticipate the asymptotic behavior of a dynamical system.
- Assess / Evaluate the stability of a dynamical system.
- Identify the type of solutions of a dynamical sytem.
- Analyze a linear or nonlinear dynamical system
- Anticipate the asymptotic behavior of a dynamical system
- Assess / Evaluate the stability of a dynamical system
- Identify the type of solutions of a dynamical system

Teaching methods

- Lectures (blackboard, no video), 3h per week
- Exercise session, 1h per week

Expected student activities

Exercises in class and at home (paper and pencil, and Python)

Assessment methods

1. Mid-term 20%
2. Final exam 80%

Supervision

Office hours	No
Assistant.e.s	No
Forum	Yes

Resources

Bibliography
Course notes; textbooks given as reference on the moodle page of the course.

Notes/Handbook
Course notes, exercises and solutions provided on the moodle page of the course.

Moodle Link
- https://go.epfl.ch/COM-502

Prerequisite for
Classes using methods from linear and nonlinear dynamical systems.