COM-502 **Dynamical system theory for engineers**

Thiran Patrick

Cursus	Sem.	Type
Biocomputing minor	H	Opt.
Bioengineering	MA1, MA3	Opt.
Computational Neurosciences minor	H	Opt.
Computational science and Engineering	MA1, MA3	Opt.
Computer science	MA1, MA3	Opt.
Cybersecurity	MA1, MA3	Opt.
Life Sciences Engineering	MA1, MA3	Opt.
SC master EPFL	MA1, MA3	Opt.
Sciences du vivant	MA1, MA3	Opt.
Systems Engineering minor	H	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Written
Workload	120h
Weeks	14
Hours	**3 weekly**
Lecture	2 weekly
Exercises	1 weekly
Number of positions	

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. Introduction to structural stability, Bifurcation theory. Introduction to chaotic systems (Lyapunov exponents).
- 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.

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).

Recommended courses

- A first-year Probabilty class, such as MATH-232, MATH-231, MATH-234(b), MATH-234(c), or equivalent.
- Analysis IV (MATH 207 or equivalent)

Important concepts to start the course

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

Teaching methods

- Lectures (blackboard), 2h per week
- Exercise session, 1h per week.

Expected student activities

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

Assessment methods

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

Supervision

Office hours	Yes
Assistants	Yes
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

- http://moodle.epfl.ch/course/view.php?id=303

Prerequisite for

Classes using methods from dynamical systems.