DRIEI
PhD Program in Electronic and Computer Engineering
University of Cagliari, Italy

Course:	Nonlinear Systems and Chaos
Instructor:	Fabio Pisano
SSD:	IIET-01/A - Electrical Engineering
Credits / hours:	2.5 credits / 20 hours
Language:	English or Italian
Scheduling:	II semester, Sep
Final Exam:	Written essay with oral discussion

Goal of the Course

This course aims to provide advanced understanding and analytical skills in the qualitative analysis of dynamical systems and in the bifurcation analysis. Through lectures and practical applications, students will develop the theoretical knowledge and analytical skills necessary to understand and analyse complex dynamical systems. This course will equip students with the tools to contribute to various fields, including physics, biology, engineering, and economics, where the dynamics of complex systems play a crucial role.

Prerequisites

The prerequisites for this course would typically include:

- Proficiency in calculus, including differential equations and multivariable calculus.
- Understanding of linear algebra, including matrices, vectors, and eigenvalues/eigenvectors.
- Basic knowledge of dynamical systems theory, including concepts like phase space, trajectories, and stability analysis.

Programming Skills (optional but beneficial):

- Proficiency in a programming language such as MATLAB or Python for numerical simulations and analysis of dynamical systems.

Intersection with other courses at the University of Cagliari

Some of the topics of the course, in particular those related to the analysis of the qualitative behaviour of dynamical systems, are provided in the course [IA/0114] - DESIGN OF SIGNAL PROCESSING CIRCUITS for the master’s degree in electrical engineering.

Course Outline

1. Qualitative analysis of dynamical systems: Continuous-time and discrete-time dynamical systems; predictability and determinism; conservative and dissipative systems; attractor and attraction basin; stability. 1D flows: geometrical approach; fixed points and stability; linearization. 2D flows: phase plane; existence and unicity of solutions; linearization; fixed points and stability in 2D; limit cycles. ND

flows: torus; deterministic chaos; volumes contraction; strange attractors; Lyapunov Exponents; attractors dimension. 1D maps.

2. Structural stability and bifurcations: topological equivalence of dynamical systems; bifurcation curve. Bifurcations in 1D flows: saddle-node, transcritical and pitchfork. Imperfect bifurcations and catastrophes. Bifurcations of fixed points in 2D flows: saddle-node, transcritical and pitchfork; zero–eigenvalue bifurcations. Bifurcations of cycles in 2D flows: Hopf; global bifurcations of cycles; fold bifurcation; infinite-period bifurcation; homoclinic and heteroclinic bifurcations. Bifurcations in 1D maps: bifurcations of fixed points; flip bifurcation; period-doubling and Feigenbaum cascade. Numerical Methods for Bifurcation Analysis.