UAB Universitat Autònoma de Barcelona	Dynamical Systems and Complexity Code: 45559 Credits: 6	2026/2027

Degree programme	Type	Course
Modelling for Science and Engineering	OP	1

Contact lecturer

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Teaching staff

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Group languages

You can consult this information at the end of the document.

Prerequisites

Students must have mathematical skills at a graduate level of a scientific degree.

Objectives

The course aims to develop the students' ability to systematically analyze deterministic nonlinear dynamical models and to elaborate mathematical models of real systems.

Learning outcomes

- CA09 (Devise models based on dynamical systems and complex systems to solve specific practical problems.) Devise models based on dynamical systems and complex systems to solve specific practical problems.
- CA10 (Communicate to an expert audience the results obtained from the analysis of models based on dynamic and complex systems incorporating ethical, sustainability and gender equality criteria.) Communicate to an expert audience the results obtained from the analysis of models based on dynamic and complex systems incorporating ethical, sustainability and gender equality criteria.
- CA11 (Assess, using specific metrics and mathematical tools, the level of complexity of a set of data obtained through experimentation and/or observations.) Assess, using specific metrics and mathematical tools, the level of complexity of a set of data obtained through experimentation and/or observations.
- KA09 (Recognise the main analysis techniques to study dynamical systems, as well as the theoretical scope of application of each of them.) Recognise the main analysis techniques to study dynamical systems, as well as the theoretical scope of application of each of them.
- KA10 (Recognise the different criteria that can be used to quantify and/or measure the complexity of a

system.) Recognise the different criteria that can be used to quantify and/or measure the complexity of a system.

- SA09 (Formulate dynamical systems and complex models capable of capturing essential dynamic features of specific applications.) Formulate dynamical systems and complex models capable of capturing essential dynamic features of specific applications.
- SA10 (Solve, either analytically or computationally, complex dynamic models using the appropriate mathematical tools for each situation.) Solve, either analytically or computationally, complex dynamic models using the appropriate mathematical tools for each situation.
- SA11 (Implement tools and methodologies to study emerging behaviours in reference models in the field of complex systems.) Implement tools and methodologies to study emerging behaviours in reference models in the field of complex systems.

Contents

1. Introduction to Dynamical Systems

Types and characteristic properties. Related concepts.

2. One-Dimensional Discrete Dynamical Systems

Graphical and analytical study. Fixed points. Linear stability. Bifurcations. The logistic map.

3. Two-Dimensional Dynamical Systems

Classification of linear systems. Phase portrait. Limit cycles. Bifurcations. Biological models.

4. Chaotic Dynamical Behavior

Deterministic chaos. Definition. Examples.

5. Quasilinear first order Partial Differential Equations

The traffic flow model. Shock waves. Reaction diffusion equations. Morphogenesis.

6. Complexity

Systems with novel organized topology. Basic elements of complex systems. Emergent behaviors. Case studies. Measures of complexity.

Learning activities and methodology

Title	Hours	ECTS	Learning outcomes
Problem sets and projects	30	1.2	CA09, CA10, CA11, KA09, KA10, SA09, SA10, SA11
Theory and problem-solving classes	48	1.92	CA09, CA10, CA11, KA09, KA10, SA09, SA10, SA11
Independent study	66	2.64	CA09, CA11, KA09, KA10, SA09, SA10, SA11

The methodology is based on lectures that include some practical exercises (either written or computational). Some of the exercises will be solved and submitted periodically by students through the Virtual Campus. Afterwards, any doubts regarding these exercises will be discussed in class.

Note: 15 minutes of one class session, within the schedule established by the department or degree program, will be reserved for students to complete surveys evaluating the teaching performance and the course/module.

Annotation: within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continuous assessment activities

Title	Weight	Hours	ECTS	Learning outcomes
Exam	70%	6	0.24	CA09, CA11, KA09, KA10, SA09, SA10
Projects and worked-out exercises	30%	0	0	CA09, CA10, CA11, KA09, KA10, SA09, SA10, SA11

Continuous Assessment

Grades will be based on:

- Submission of solved problems, simulations, reports, and presentations, which will account for 30% of the final grade.
- Written exams, which will account for 70% of the final grade.

To pass the course, the weighted average of both components must be greater than 5 (out of 10).

Single Assessment

Students who choose the single assessment modality must take a final exam, which will consist of problem-solving and some theoretical questions. After the exam, they must also submit all exercises and reports related to the coursework. The final grade and the passing threshold are the same as in the continuous assessment.

For both types of assessment (continuous and single), if the final grade is below 5, the student will have a second opportunity to pass the course through a resit exam (worth 70%) and the submission of exercises and reports (worth 30%).

NOTE: In this course, the use of Artificial Intelligence (AI) technologies is not permitted at any stage. Any work that includes AI-generated fragments will be considered a breach of academic honesty and may result in a partial or total penalty on the activity grade, or more serious sanctions in cases of severe misconduct.

Bibliography

- S.H. Strogatz. Nonlinear Dynamics and Chaos. Second Edition. Perseus Books, Westview Press, Boulder, 2014.

- R.V. Solé y S.C. Manrubia, Orden y caos en sistemas complejos, ediciones UPC, Barcelona, 2001.

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- S. Parker , Leon O. Chua. Practical Numerical Algorithms for Chaotic Systems (1989).

- B.C. Goodwin, How the Leopard Changed Its Spots: Evolution of Complexity. Prentice Hall, 1994.

– Hanski, I. Metapopulation Ecology Oxford University Press. 1999.

– J.D. Murray. Mathematical Biology I: An introduction. Interdisciplinary Applied Mathematics 2002

– W. A. Strauss, Partial Differential Equations: An Introduction, John Wiley & Sons, 1992.

– K. Kaneko. Theory and Applications of Coupled Map Lattices (Nonlinear Science: Theory and Applications) 1st Edition, 1993

– A. Ilachinski. Cellular Automata: A Discrete Universe, 2001

– U. Dieckmann, R. Law, J.A.J. Metz. The Geometry of Ecological Interactions: Simplifying Spatial Complexity: 1 (Cambridge Studies in Adaptive Dynamics, Series Number 1), 2000

- R. Clark Robinson, An introduction to Dynamical Systems: Continuous and Discrete, Pure and Applied undergraduate texts, American Mathematical Society, 2012

- Robert L. Devaney, An introduction to Chaotic Dynamical Systems, Westview Press, 2003

- Stefan Thurner, Peter Klimek, Rudolf Hanel, Introduction to the Theory of Complex Systems, Oxford University Press, 2018

- Introduction to Complexity (online). Complexity Explorer, Santa Fe (https://www.complexityexplorer.org/courses/185-introduction-to-complexity#gsc.tab=0)

Software

There is no specific software for the subject.

Course groups and languages

The information provided is provisional until November 30. After this date, you will be able to consult the language of each group through this link. To access the information, you will need to enter the course CODE

Type of teaching	Group	Language	Semester	Shift
(TEm) Theory (master)	1	English	first semester	morning-mixed