Universitat Autònoma de Barcelona

**2022/2023**

**Deterministic Modelling**

Code: 43479
ECTS Credits: 6

| Degree | Type | Year | Semester |
|---|---|---|---|
| 4313136 Modelling for Science and Engineering | OT | 0 | 1 |

## Contact

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## Use of Languages

Principal working language: english (eng)

## Teachers

Anna Cima Mollet

Jose Sardañes Cayuela

## Prerequisites

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

## Objectives and Contextualisation

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

## Competences

- Analyse complex systems in different fields and determine the basic structures and parameters of their workings.
- Analyse, synthesise, organise and plan projects in the field of study.
- Apply logical/mathematical thinking: the analytic process that involves moving from general principles to particular cases, and the synthetic process that derives a general rule from different examples.
- Apply techniques for solving mathematical models and their real implementation problems.
- Conceive and design efficient solutions, applying computational techniques in order to solve mathematical models of complex systems.
- Continue the learning process, to a large extent autonomously.
- Formulate, analyse and validate mathematical models of practical problems in different fields.
- Isolate the main difficulty in a complex problem from other, less important issues.
- Solve complex problems by applying the knowledge acquired to areas that are different to the original ones.
- Use acquired knowledge as a basis for originality in the application of ideas, often in a research context.
- Use appropriate numerical methods to solve specific problems.

## Learning Outcomes

1. Analyse, synthesise, organise and plan projects in the field of study.

2. Apply logical/mathematical thinking: the analytic process that involves moving from general principles to particular cases, and the synthetic process that derives a general rule from different examples.
3. Choose the best description of a system on the basis of its particular characteristics
4. Construct and resolve models to describe the behaviour of a real system.
5. Continue the learning process, to a large extent autonomously.
6. Isolate the main difficulty in a complex problem from other, less important issues.
7. Solve and simulate models on the basis of numerical calculation methods and Monte Carlo methods.
8. Solve complex problems by applying the knowledge acquired to areas that are different to the original ones.
9. Solve mathematical models by using analytic and numerical methods
10. Use acquired knowledge as a basis for originality in the application of ideas, often in a research context.
11. Use numerical calculation methods to solve complex problems.

## Content

1.- Introduction to dynamical systems
Introduction.- Characteristic properties of nonlinear dynamical systems.- Examples of nonlinear dynamical behaviors.- Classification of dynamical systems.- Dynamical systems according to their dynamics.

2.- Discrete dynamical systems.
Maps.- Logistic map.- Fixed points. Stability.- Universality.

3.- Dynamical systems in one dimension.
Graphical Solution. Fixed-Points.- Analytical solution. Linear stability.- Numerical Solution.- Bifurcations.- Flows on the circle.- Synchronization of fireflies.

4.- Dynamical Systems in 2 dimensions. Oscillations.
Introduction. Dynamic Behaviors in 2 dimensions.- Linear stability.- Population dynamics.- Bifurcations.- Oscillations. Biological Rhythms.

5.- Dynamical Systems in 3 dimensions. Chaos.
Deterministic Chaos.- Lorenz Equations.- Rossler system.- Applications.- Chaos descriptors.- Epidemics.

6.- Introduction to numerical methods

Numerical integration of differential equations.- Methods and implementation.- Sources of error

7.- Spatio-temporal dynamics
Metapopulations.- Reaction-diffusion equation.- Linear diffusion.- Turing bifurcation.- Spatial patterning.- Diffusion-induced chaos.- Coupled map lattices.- Cellular automata.

## Methodology

The methodology is based on lectures that include some exercises. Most exercises will be solved by the students and delivered periodically through the Virtual Campus. After that, any doubt about them will be discussed in class.

If the sanitary situation derived from Covid-19 required teaching to be virtual, our intention is to keep as much presenciality as possible, especially for exams. However, if necessary, teaching will be given by electronic means, either uploading the registered class so that you can visualize it at your convenience, or by sinchronous classes through some videoconference platform (Teams,...). In addition, some hours would be reserved weekly for tutorials via videoconference to solve doubts.

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.

## Activities

| Title | Hours | ECTS | Learning Outcomes |
| --- | --- | --- | --- |
| Type: Directed | | | |
| Theory and exercise classes | 38 | 1.52 | 2, 1, 4, 6, 5, 7, 9, 8, 3, 10, 11 |
| Type: Supervised | | | |
| Assesments and projects | 40 | 1.6 | 2, 1, 4, 6, 5, 7, 9, 8, 3, 10, 11 |
| Type: Autonomous | | | |
| Personal study | 69 | 2.76 | 2, 1, 4, 5, 7, 9, 8, 3, 11 |

## Assessment

Grades will be obtained from:
1) deliveries of solved problems, simulations, reports and presentations.
2) at least two written exams, weighing around 50% of the final grade.

To pass the course:
- the average mark of the exams must be greater than 4 (on a scale of 10), and
- the final mark (exams and other evaluation tests) must be greater than 5.

## Assessment Activities

| Title | Weighting | Hours | ECTS | Learning Outcomes |
| --- | --- | --- | --- | --- |
| Exams | around 50% | 3 | 0.12 | 2, 4, 6, 9, 8 |
| Projects and solved exercises | around 50% | 0 | 0 | 2, 1, 4, 6, 5, 7, 9, 8, 3, 10, 11 |

## 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.

- S.H. Strogatz. SYNC. Rythms of nature, rythms of ourselves, Penguin, 2004.

- 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

## Software

There is no specific software for the subject