Universitat Autònoma de Barcelona

**2022/2023**

## Modelling and Simulation

Code: 104410
ECTS Credits: 6

| Degree | Type | Year | Semester |
|---|---|---|---|
| 2503740 Computational Mathematics and Data Analytics | OB | 3 | 2 |

## Contact

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## Use of Languages

Principal working language: catalan (cat)

Some groups entirely in English: No

Some groups entirely in Catalan: Yes

Some groups entirely in Spanish: No

## Other comments on languages

In case of discrepancy, the only valid guide is the one in Catalan

## Teachers

Gabriel Jover Mañas

## External teachers

Aureli Alabert

## Prerequisites

The contents of calculus, probability and linear algebra given in the 1st year should be well known. It is appropriate to be familiarized with the programming language R. It is advised to have studied the subjects Ordinary Differential Equations (2nd year) and Partial Differential Equations (3rd year).

## Objectives and Contextualisation

In this course different alternatives related to the modelling of real world phenomena are presented. The goal is that the students learn how to formulate acurate models that fit the needs of the real problem and that they know how to analyse them formally or computationally as appropriate.

## Competences

- Apply a critical spirit and rigour for the validation or rejection of your own arguments and those of others.
- Demonstrate a high capacity for abstraction and translation of phenomena and behaviors to mathematical formulations.
- Formulate hypotheses and think up strategies to confirm or refute them.
- Make effective use of bibliographical resources and electronic resources to obtain information.

- Students must be capable of applying their knowledge to their work or vocation in a professional way and they should have building arguments and problem resolution skills within their area of study.
- Students must be capable of collecting and interpreting relevant data (usually within their area of study) in order to make statements that reflect social, scientific or ethical relevant issues.
- Students must be capable of communicating information, ideas, problems and solutions to both specialised and non-specialised audiences.
- Students must develop the necessary learning skills to undertake further training with a high degree of autonomy.
- Students must have and understand knowledge of an area of study built on the basis of general secondary education, and while it relies on some advanced textbooks it also includes some aspects coming from the forefront of its field of study.
- Use computer applications for statistical analysis, numerical and symbolic computation, graphic visualisation, optimisation and other to experiment and solve problems.
- Work cooperatively in a multidisciplinary context assuming and respecting the role of the different members of the team.

## Learning Outcomes

1. "Mathematically identify and describe a problem; structure available information; select a suitable model."
2. Apply a critical spirit and rigour for the validation or rejection of your own arguments and those of others.
3. Contrast the solution obtained, after resolving the model, in terms of its adjustment to real phenomenon.
4. Contrast, if possible, the use of calculation with the use of abstraction in solving a problem.
5. Distinguish when calculations of analytical probabilities can be carried out and when to use stochastic simulation.
6. Evaluate the advantages and disadvantages of using calculation and abstraction.
7. Evaluate the difficulty of calculating analytical probabilities in complex situations.
8. Extract appropriate conclusions from the model result.
9. Find models of scientific or technological reality relating to a decision-making problem and express this with the mathematical language of optimisation problems with dynamic programming or stochastic queues.
10. Handle specific scientific software to solve problems with real data and to carry out simulations.
11. Know how to generate and manipulate reality-simulation models to establish and verify hypotheses in the study of problems or more complex realities.
12. Make effective use of bibliographical resources and electronic resources to obtain information.
13. Master the basics of theory and be able to combine these and use them to solve problems.
14. Students must be capable of applying their knowledge to their work or vocation in a professional way and they should have building arguments and problem resolution skills within their area of study.
15. Students must be capable of collecting and interpreting relevant data (usually within their area of study) in order to make statements that reflect social, scientific or ethical relevant issues.
16. Students must be capable of communicating information, ideas, problems and solutions to both specialised and non-specialised audiences.
17. Students must develop the necessary learning skills to undertake further training with a high degree of autonomy.
18. Students must have and understand knowledge of an area of study built on the basis of general secondary education, and while it relies on some advanced textbooks it also includes some aspects coming from the forefront of its field of study.
19. Within a problem, distinguish what is important from what is not so as to construct the mathematical model and its resolution.
20. Work cooperatively in a multidisciplinary context, taking on and respecting the role of the distinct members in the team.

## Content

1. Types of models. Dynamics versus optimization.

2. Deterministic modelling. Introduction to bifurcation theory. Lyapunov exponents. Relation between microscopic and mesoscopic models.

3. Discrete time stochastic modelling. Introduction to stochastic processes. Markov chains. Invariant distributions.

4. Continuous time stochastic modelling. Simulation of random variables using the uniform distribution. Simulation of discrete events. Poisson process. Birth and death processes. Queueing theory.

5. Relation between stochastic and deterministic models.

## Methodology

Two hours of theory class per week correspond to this subject. In addition, 8 hours of seminar will be held where students will solve exercises raised by the teacher (4 seminars of 2 hours each). There will also be 14 hours of problem classes in which the formulation and analysis of concrete models will be treated. It is essential that students have at their disposal the software that teachers recommend during the course. The Virtual Campus of the subject will provide all the material and all the information related to this subject that is necessary for the student.

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 | | | |
| Problem lessons | 14 | 0.56 | 6, 7, 3, 4, 5, 19, 13, 8, 1, 10, 16, 14, 15, 11 |
| Theoretical lessons | 28 | 1.12 | 6, 7, 4, 5, 19, 1, 18, 16, 14, 15 |
| Type: Supervised | | | |
| Working seminars | 8 | 0.32 | 2, 3, 8, 1, 10, 18, 17, 14, 11, 9 |
| Type: Autonomous | | | |
| Solving problems and personal study | 96 | 3.84 | |

## Assessment

The assessment of the course will be carried out mainly from three activities:

Partial exam (EP): exam of part of the subject, with theoretical questions and problems. Final exam (EF): exam of the whole subject, with theoretical questions and problems. Seminars (S): deliveries of the proposed problems in the 4 seminars.

In addition, students will be able to submit to a ressiting exam (ER) with the same characteristics as the exam (EF). Practices will not be recoverable.

It is a requirement to pass the subject that max (0.35 * EP + 0.65 * EF, EF, ER)> = 3.5 and that S> = 3.5.

The final grade of the subject will be
0.7*max(0.35*EP+0.65*EF,EF,ER)+0.3*S.

The "matrícula de honor" will be awarded to the first complete evaluation of the subject. Later achievements will not be considered for this purpose.

## Assessment Activities

| Title | Weighting | Hours | ECTS | Learning Outcomes |
|---|---|---|---|---|
| Assignments Simulation | 15% | 0 | 0 | 2, 3, 4, 19, 8, 1, 10, 16, 15, 11, 20, 9, 12 |
| Exam Modelling | 35% | 2 | 0.08 | 6, 7, 5, 13, 8, 1, 18, 17, 16, 14 |
| Exam Simulation | 35% | 2 | 0.08 | 6, 7, 5, 13, 8, 1, 18, 16, 14 |
| Modelling Assignments | 15% | 0 | 0 | 2, 3, 4, 19, 8, 1, 10, 16, 15, 11, 20, 9, 12 |

## Bibliography

- Alligood, K. T. ; Sauer, T. ; Yorke, J.A. Chaos: an introduction to dynamical systems.

- Martínez, R. *Models amb Equacions Diferencials*, Materials de la UAB no. 149. Bellaterra, 2004

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

- Bardina, X. & Ferrante, M. An excursion into Markov chains. Springer, 2020.

- Ross, Sheldon (2013) Simulation. Elsevier (Recurs electrònic UAB).

- L.J.S. Allen, An Introduction to Stochastic Processes with Applications to Biology. Chapman & Hall/CRC, Boca Ratón. 2011

## Software

During the course, the software will be precised, and instructions to install it willbe given if necessary