Course guide
320164 - MCS - Modelling, Complexity and Sustainability

Last modified: 11/04/2025

Unit in charge: Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 724 - MMT - Department of Heat Engines.

Degree: BACHELOR'S DEGREE IN AUDIOVISUAL SYSTEMS ENGINEERING (Syllabus 2009). (Optional subject).
BACHELOR'S DEGREE IN CHEMICAL ENGINEERING (Syllabus 2009). (Optional subject).
BACHELOR'S DEGREE IN ELECTRICAL ENGINEERING (Syllabus 2009). (Optional subject).
BACHELOR'S DEGREE IN INDUSTRIAL ELECTRONICS AND AUTOMATIC CONTROL ENGINEERING (Syllabus 2009). (Optional subject).
BACHELOR'S DEGREE IN MECHANICAL ENGINEERING (Syllabus 2009). (Optional subject).
BACHELOR'S DEGREE IN TEXTILE TECHNOLOGY AND DESIGN ENGINEERING (Syllabus 2009). (Optional subject).
BACHELOR'S DEGREE IN AEROSPACE TECHNOLOGY ENGINEERING (Syllabus 2010). (Optional subject).
BACHELOR'S DEGREE IN AEROSPACE VEHICLE ENGINEERING (Syllabus 2010). (Optional subject).
BACHELOR'S DEGREE IN INDUSTRIAL DESIGN AND PRODUCT DEVELOPMENT ENGINEERING (Syllabus 2010). (Optional subject).
BACHELOR'S DEGREE IN INDUSTRIAL TECHNOLOGY ENGINEERING (Syllabus 2010). (Optional subject).

Academic year: 2025 **ECTS Credits:** 6.0 **Languages:** Catalan

LECTURER

Coordinating lecturer: Rosas Casals, Marti

Others:

TEACHING METHODOLOGY

Four types of activities:
a. Master class
b. Classroom sessions of practical work with a computer.
c. Self study study and accomplishment of tasks, exercises and questionnaires.
d. Preparation and completion of group activities.

LEARNING OBJECTIVES OF THE SUBJECT

This subject is part of the paradigm of sustainability and aims to provide ideas, criteria and instruments that facilitate the study of complex problems, related to the evolution and behavior of natural, social and technological systems. Therefore, tools and methodologies in the environment of system dynamics, network analysis and modeling with agents will be used. It is about developing criteria and skills that allow analyzing the behavior of the systems in a qualitative and quantitative way, and their response to certain actions, strategies, policies or action plans.

STUDY LOAD

Type	Hours	Percentage
Hours large group	30,0	20.00
Self study	90,0	60.00
Hours medium group	30,0	20.00

Total learning time: 150 h

CONTENTS

Unit 1: Fundamentals on complexity and systems thinking

Description:
1.1 From determinism to complexity. Historical summary
1.2 Characteristics of complex systems
1.3 Complexity in socio-ecological systems
1.4 Resilience, collapse and the paths towards unsustainability

Specific objectives:
Understand the evolution of science from the determinist paradigm to complexity.
Know how to define the characteristics of complex systems / problems.
Recognize the complexity of socio-ecological systems.
Recognize the causes of unsustainability in socio-ecological systems.

Related activities:
Readings
Practices with Excel
Practices with NetLogo

Full-or-part-time: 30h
Theory classes: 6h
Practical classes: 6h
Self study : 18h

Unit 2: Introduction to modelling

Description:
2.1 Computational models and complex systems
2.2 The modelling cycle
2.3 Abstractions vs. agents
2.4 NetLogo as a modelling tool

Specific objectives:
Describe the modeling cycle and identify individual tasks within this cycle
Describe and compare the main features of equation-based and agent-based modeling
Compare and describe bottom-up and top-down modelling approaches
Differentiate modeling and simulation
Apply the NetLogo programming language to import and export data in and from a computer and carry out basic operations of arithmetic and calculation in this environment
Solve mathematical problems by applying NetLogo encoding and procedures
Modify existing NetLogo codes

Related activities:
Readings
Practices with Excel
Practices with NetLogo

Full-or-part-time: 30h
Theory classes: 6h
Practical classes: 6h
Self study : 18h

Unit 3: Equation modeling

Description:
3.1 Regime and catastrophic shifts
3.2 Definitions and characteristics of dynamical systems
3.3 From conceptual maps to causal diagrams
3.4 From causal diagrams to stock and flow diagrams…and differential equations
3.5 Examples on equation modelling: social collapse, population growth and environmental damage
3.6 Stability analisis
3.7 The adaptive cycle and the concept of panarchy

Specific objectives:
Recognize the mathematical form of a differential equation
Explain the differences between iterated functions and differential equations
Classify iterated functions and differential equations into linear and non-linear
Calculate the trajectory of an iterated function (i.e., iterate a function)
Find and categorize fixed points in an iterated function
Translate conceptual maps into causal diagrams, stock and flow diagrams and differential equations
Employ NetLogo System Dynamics Modeller to implement stock and flow diagrams and numerically solve differential equations
Execute experiments with NetLogo System Dynamics Modeller to analyze the influence of the parameters in the temporal evolution of a dynamic system.
Use a spreadsheet (or similar tool) to analyze the results of iterating a function
Design and write a description of a model following the ODD protocol

Related activities:
Readings
Practices with Excel
Practices with NetLogo
Midterm Exam

Full-or-part-time: 30h
Theory classes: 6h
Practical classes: 6h
Self study : 18h

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Unit 4: Agent-based modeling

Description:
4.1 From equations to agents
4.2 Unbounded growth
4.3 Bounded growth
4.4 Consumption of non-renewable resources
4.5 Consumption of renewable resources
4.6 Interaction and emergence
4.7 Theory development, parameterization and calibration
4.8 Analysing and understanding agent-based modelling

Specific objectives:
Define the concept of probability as used in agent based modelling.
Define sensitivity experiment and emergency as used in agent based modelling.
Explain the differences between parameterization and calibration.
Edit an experiment using NetLogo's BehaviourSpace.
Perform sensitivity experiments in agent based models using NetLogo's BehaviourSpace.
Modify NetLogo procedures and codes.
Use a spreadsheet (or similar tool) to analyze the results of sensitivity experiments by means of pivot tables and graphs.

Related activities:
Readings
Practices with Excel
Practices with NetLogo

Full-or-part-time: 30h
Theory classes: 6h
Practical classes: 6h
Self study : 18h

Unit 5: Network modeling

Description:
5.1 Complexity and networks
5.2 Fundamentals of network theory
5.3 Introduction to computational algorithms
5.4 Network models and applications
5.5 Dynamic processes on networks

Specific objectives:
List and recognize examples of networked systems
Categorize networked systems by their space (i.e., topological vs. geographical), edge directionality (i.e., directed vs. undirected) and type of nodes (i.e., multipartite vs. unipartite)
Use a network analysis software package to calculate centrality measures of a network
Compare and contrast the structural features of different networks and models of networks
Perform sensitivity experiments to analyze different network models implemented in NetLogo

Related activities:
Readings
Practices with Excel
Practices with NodeXL
Final Exam

Full-or-part-time: 30h
Theory classes: 6h
Practical classes: 6h
Self study : 18h

GRADING SYSTEM

The weights in the evaluation are the following:
1st written exam (25%)
2nd written exam (25%) with option to reconduct the 1st written exam (*)
Tasks and questionnaires (50%)

(*) This reconduction can be accessed by students with a mark less than 4.0 points corresponding to the 1st exam. It will consist of a series of questions that will allow you to obtain 4.0 points if you respond correctly. The mark obtained by the application of the conversion will replace the initial qualification of the 1st exam whenever it is higher.

BIBLIOGRAPHY

Basic:

- Norberg, Jon; Cumming, Graeme S. Complexity theory for a sustainable future. New York: Columbia University Press, cop. 2008. ISBN 9780231134613.
- Berkes, Fikret; Colding, Johan; Folke, Carl. Navigating social-ecological systems: building resilience for complexity and change. Cambridge, U.K. ; New York: Cambridge University Press, cop. 2003. ISBN 0521815924.
- Berkes, Fikret; Folke, Carl; Colding, Johan. Linking social and ecological systems: management practices and social mechanisms for building resilience. Cambridge: Cambridge University Press, cop. 1998. ISBN 0521785626.
- Strogatz, Steven H. Nonlinear dynamics and chaos: with applications to physics, biology, chemistry, and engineering [on line]. 2nd ed. Philadelphia: Westview Press, cop. 2015 [Consultation: 11/05/2022]. Available on: https://ebookcentral-proquest-com.recursos.biblioteca.upc.edu/lib/upcatalunya-ebooks/detail.action?pq-origsite=primo&docID=1181622. ISBN 9780813349107.
- Solé Vicente, Ricard. Redes complejas: del genoma a internet. Barcelona: Tusquets, 2009. ISBN 9788483831175.

RESOURCES

Other resources:
Those suggested as the course goes on.
IMPORTANT: Students must have a laptop in the classroom during the course for a proper assessment and evaluation of the subject, as it is the fundamental tool for the exercise of modeling.