Modeling and simulation of complex systems

Academic Year: (2020 / 2021) **Review date: 09-07-2020**

Department assigned to the subject:

Coordinating teacher: CUERNO REJADO, RODOLFO

Type: Electives ECTS Credits : 6.0

Year : 2 Semester : 1

OBJECTIVES

* Global vision over complex systems and emergent behavior.
* Ability to model complex phenomena in simple terms which allow to capture their main qualitative aspects.
* Become acquainted with standard tools employed in interdisciplinar research.
* Understand the relation between a system complexity and that of the models employed to study it.
* Understand basic concepts of thermodynamics and statistical mechanics as a framework of choice to study systems composed by a large numbers of agents.
* Understand the concept of emergent properties or global behavior which can not be directly inferred from single agent properties.
* Familiarity with basic notions and tools on critical phenomena as a paradigm of transitions among different emergent behaviors.
* Familiarity with basic phenomenology of nonlinear systems, in particular with the ideas of stability and bifurcation.
* Understand the implications of deterministic chaos as long-term umpredictability, different from stochasticity.
* Employ fractal dimensions as set-characterizing tools.
* Familiarity with the use of basic numerical tools for simulation.

DESCRIPTION OF CONTENTS: PROGRAMME

Part I: Large number of agents in equilibrium

1. Introduction: Thermodynamicas and Statistical Mechanics
   1.1. Thermodynamics
   1.2. Phase transitions

2. Critical phenomena
   2.1. Ising model and related systems.
   2.2. Continuum descriptions
   2.3. Mean-field and Gaussian approximations
   2.4. Scaling theories and the renormalization group

3. Heterogeneity
   3.1. Percolation
   3.2. Critical properties
   3.3. Related models

Part II: Nonlinear dynamics

4. Introduction
   4.1. Paradigmatic models

5. Finite number of degrees of freedom
   5.1. Phase portrait
   5.2. Linerized stability
   5.3. Non-linear behavior: bifurcations

6. Infinite number of degrees of freedom
   6.1. Pattern formation
   6.2. Reaction-diffusion systems

6.3. Bifurcation analysis

7. Chaotic dynamics
   7.1. Recurrences in one dimension
   7.2. Routes to chaos
   7.3. Probabilistic descriptions

LEARNING ACTIVITIES AND METHODOLOGY

Lecture hours (1.4 ECTS)

* Theory sessions.
* Practical sessions: hands-on demonstrations, exercise solving, etc.

Tutoring, mentoring, etc. (1.4 ECTS)

Autonomous student work (3.2 ECTS)

ASSESSMENT SYSTEM

Assignment resolution (including simulation-oriented assignments) (40%). Project ellaboration and public presentation (60%). On the second round an extraordinary exam may be offered (60%).

% end-of-term-examination:	60
% of continuous assessment (assigments, laboratory, practicals…):	50

BASIC BIBLIOGRAPHY

- G. Nicolis Introduction to Nonlinear Science, Cambridge University Press, 1995
- K. Christensen, N. R. Moloney Complexity and Criticality , World Scientific, 2005

ADDITIONAL BIBLIOGRAPHY

- D. Stauffer, A. Aharony Introduction to Percolation Theory, Taylor and Francis, 1994
- G. Nicolis, C. Nicolis Foundations of Complex Systems, World Scientific, 2007
- J. H. Holland Complexity: A Very Short Introduction, Oxford University Press, 2014
- N. Goldenfeld Lectures on Phase Transitions and the Renormalization Group, Addison Wesley, 1993
- S. Strogatz Nonlinear Dynamics and Chaos , Perseus Books, 1994
- S. Thurner, R. Hanel, P. Klimek Introduction to the Theory of Complex Systems, Oxford University Press, 2018
- Y. Bar-Yam Dynamics of Complex Systems, Addison-Wesley, 1997