

## Course guide

# 200244 - ASTNL - Nonlinear Time Series Analysis

**Last modified:** 19/05/2024

**Unit in charge:** School of Mathematics and Statistics  
**Teaching unit:** 748 - FIS - Department of Physics.

**Degree:** BACHELOR'S DEGREE IN MATHEMATICS (Syllabus 2009). (Optional subject).

**Academic year:** 2024    **ECTS Credits:** 6.0    **Languages:** English

### LECTURER

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**Coordinating lecturer:** ANTONIO JAVIER PONS RIVERO

**Others:** Segon quadrimestre:  
CRISTINA MASOLLER - M-A  
ANTONIO JAVIER PONS RIVERO - M-A

### REQUIREMENTS

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The student will need good computational skills and will need to be familiar with Matlab or other programming language (C, fortran, python, R, etc)

### DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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#### Specific:

GM-CE2. CE-2. Solve problems in Mathematics, through basic calculation skills, taking in account tools availability and the constraints of time and resources.

GM-CE1. CE-1. Propose, analyze, validate and interpret simple models of real situations, using the mathematical tools most appropriate to the goals to be achieved.

GM-CE3. CE-3. Have the knowledge of specific programming languages and software.

GM-CE4. CE-4. Have the ability to use computational tools as an aid to mathematical processes.

GM-CE6. Ability to solve problems from academic, technical, financial and social fields through mathematical methods.

#### Generical:

GM-CB5. To have developed those learning skills necessary to undertake further interdisciplinary studies with a high degree of autonomy in scientific disciplines in which Mathematics have a significant role.

GM-CG1. CG-1. Show knowledge and proficiency in the use of mathematical language.

GM-CB4. CB-4. Have the ability to communicate their conclusions, and the knowledge and rationale underpinning these to specialist and non-specialist audiences clearly and unambiguously.

GM-CG2. CG-2. Construct rigorous proofs of some classical theorems in a variety of fields of Mathematics.

GM-CG3. CG-3. Have the ability to define new mathematical objects in terms of others already know and ability to use these objects in different contexts.

GM-CG4. CG-4. Translate into mathematical terms problems stated in non-mathematical language, and take advantage of this translation to solve them.

GM-CG6. CG-6 Detect deficiencies in their own knowledge and pass them through critical reflection and choice of the best action to extend this knowledge.

#### Transversal:

04 COE. EFFICIENT ORAL AND WRITTEN COMMUNICATION. Communicating verbally and in writing about learning outcomes, thought-building and decision-making. Taking part in debates about issues related to the own field of specialization.

07 AAT. SELF-DIRECTED LEARNING. Detecting gaps in one's knowledge and overcoming them through critical self-appraisal. Choosing the best path for broadening one's knowledge.

## TEACHING METHODOLOGY

Theory classes: The course is divided into different parts where mathematical concepts will be gradually introduced. Emphasis will be given to specific examples and analysis of real data that will facilitate the understanding of the concepts and their practical applications.

Practical classes: hands-on computer sessions.

Self-study for doing exercises and activities: The students will work in small groups (2-3 students) or individually the problems proposed by the professors.

## LEARNING OBJECTIVES OF THE SUBJECT

The study of complex dynamical systems is also the study of the tools used to characterize them. Nonlinear analysis techniques help to unveil the underlying dynamics of time series which are everywhere nowadays. These techniques address the distinction between deterministic and stochastic behavior, they allow to define complexity measures to characterize dynamical systems, establish synchronization relations between different time series or classify efficiently different systems. They are also involved in the efficient control of many systems. This type of analysis results in a wide arrangement of mathematical techniques which are developed with the assistance of computer algorithms. The objective of the course is to provide a broad overview of main concepts and methods, which include nonlinear dynamics, mathematical tools, computer skills and interdisciplinary applications.

As a result, the student will acquire a good general understanding of various techniques required to characterize nonlinear time series. The course will be formal but, at the same time, it will emphasize on the practical applications the techniques discussed.

## STUDY LOAD

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

**Total learning time:** 150 h

## CONTENTS

### Lineal Methods and their limitations

#### Description:

Dynamical Systems. Univariate time series. Review of Fourier analysis and Correlation analysis.

#### Full-or-part-time: 15h

Theory classes: 3h

Laboratory classes: 3h

Self study : 9h

### Characterization of deterministic and stochastic time series

#### Description:

Numerical computation of Lyapunov exponent, phase space methods, symbolic analysis, surrogate data, entropy and complexity measures.

#### Full-or-part-time: 30h

Theory classes: 6h

Laboratory classes: 6h

Self study : 18h



### Synchronization and causality measures

**Description:**

Bivariate and multivariate time series. Hilbert phase analysis and methods to identify and quantify synchronization in time series. Mutual information, information transfer and causality measures.

**Full-or-part-time:** 30h

Theory classes: 6h

Laboratory classes: 6h

Self study : 18h

### Control and Data assimilation techniques

**Description:**

Data assimilation. Linear Kalman filters. Nonlinear Kalman filters. Applications.

**Full-or-part-time:** 30h

Theory classes: 6h

Laboratory classes: 6h

Self study : 18h

### Machine Learning and Classification methods

**Description:**

Classification and Regression Trees. Kernel Methods. Artificial Neural Networks: Perceptron, Multilayer Perceptron. Deep Neural Networks. Convolutional Neural Networks. Recurrent Neural Networks. Other Network Methods. Applications and Numerical Implementations. Open Ethical Debates.

**Full-or-part-time:** 45h

Theory classes: 9h

Laboratory classes: 9h

Self study : 27h

## GRADING SYSTEM

The students will have to present a report for each module of the course. One of the reports can be a short oral presentation that will be followed by questions. The final grade will be the average of the grades obtained in the reports.

## EXAMINATION RULES.

Students will present a report for each module of the course. One of them can be a short oral presentation that will be followed by questions.

The grades obtained in the reports will take into account attendance and active participation in class. At the end of the course, a deadline will be established for submitting the reports. Reports received up to 48 hours after the deadline will be penalized by 50%.

If any student wants to improve their final grade, they will be given the opportunity to make an additional oral test.

## BIBLIOGRAPHY

**Basic:**

- Kantz, Holger; Schreiber, Thomas. Nonlinear time series analysis [on line]. 2nd ed. Cambridge [etc.]: Cambridge University Press, 2004 [Consultation: 03/03/2021]. Available on: <https://doi.org/10.1017/CBO9780511755798>. ISBN 978-0521529020.

- Bishop, Christopher M. Pattern recognition and machine learning. New York: Springer, cop. 2006. ISBN 978-0387-31073-2.



**Complementary:**

- Kutz, Jose Nathan. Data-driven modeling & scientific computation : methods for complex systems & big data [on line]. Oxford, United Kingdom: Oxford University Press, [2013] [Consultation: 13/07/2022]. Available on: <https://web-p-ebshost-com.recursos.biblioteca.upc.edu/ehost/ebookviewer/ebook?sid=cce84553-b0da-4fca-b8ad-6307d8abc913%40redis&vid=0&format=EB>. ISBN 9780199660346.
- Pikovsky, Arkady; Rosenblum, Michael; Kurths, Jürgen. Synchronization : a universal concept in nonlinear sciences. Cambridge: Cambridge University Press, 2001. ISBN 9780521533522.
- Press, William H. Numerical recipes : the art of scientific computing. 3rd ed. Cambridge [etc.]: Cambridge University Press, cop. 2007. ISBN 978-0521880688.