Course guide
205087 - 205087 - Non-Linear Time Series Analysis

Last modified: 11/04/2025

Unit in charge: Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 748 - FIS - Department of Physics.

Degree: MASTER'S DEGREE IN INDUSTRIAL ENGINEERING (Syllabus 2013). (Optional subject).
MASTER'S DEGREE IN AERONAUTICAL ENGINEERING (Syllabus 2014). (Optional subject).

Academic year: 2025 **ECTS Credits:** 3.0 **Languages:** English

LECTURER

Coordinating lecturer: Cristina Masoller

Others: Antonio Pons

PRIOR SKILLS

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

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, stablish 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
Self study	48,0	64.00
Hours large group	19,0	25.33
Hours small group	8,0	10.67

Total learning time: 75 h

CONTENTS

Lineal tools for time series analysis and their limitations

Description:
Fourier analysis and Correlation analysis

Full-or-part-time: 16h
Theory classes: 4h
Laboratory classes: 2h
Self study : 10h

Characterization of deterministic and stochastic time series

Description:
Lyapunov exponents, phase space methods, symbolic analysis, surrogate data, entropy and complexity measures.

Full-or-part-time: 16h
Theory classes: 4h
Laboratory classes: 2h
Self study : 10h

Synchronization and causality measures

Description:
Hilbert analysis and bivariate methods to identify and quantify synchronization in time series. Mutual information, information transfer and Granger causality.

Full-or-part-time: 16h
Theory classes: 4h
Laboratory classes: 2h
Self study : 10h

Machine Learning techniques and classification methods

Description:
Supervised and unsupervised machine Learning techniques for classification and prediction

Full-or-part-time: 16h
Theory classes: 4h
Laboratory classes: 2h
Self study : 10h

Data assimilation techniques

Description:
Control techniques, data assimilation techniques, and Kalman Filters

Full-or-part-time: 11h
Theory classes: 3h
Self study : 8h

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 (5-10 minutes depending on the number of students) that will be followed by questions. The final grade will
be the average of the grades obtained in the reports.

EXAMINATION RULES.

The students will present a report for each module of the course, one of them can be a short oral presentation (5-10 minutes depending on the number of students) that will be followed by questions.
The grades obtained in the reports will take into account attendance and active participation in class. By the end of the course, a deadline will be established to present the reports. Reports received up to 48 hours after the deadline will be
penalized by 50% and will not be accepted after that.
If any student wants to improve the final grade, he or she will be given the opportunity of a second oral presentation, within the next 10 days of the first oral presentation.

BIBLIOGRAPHY

Basic:
- Bishop, Christopher M. Pattern recognition and machine learning. New York: Springer, cop. 2006. ISBN 9780387310732.
- Kantz, Holger; Schreiber, Thomas. Nonlinear time series analysis [on line]. 2nd ed. Cambridge [etc.]: Cambridge University Press, 2004 [Consultation: 04/07/2025]. Available on: https://doi-org.recursos.biblioteca.upc.edu/10.1017/CBO9780511755798. ISBN 0521529026.

Complementary:
- Pikovsky, Arkady; Rosenblum, Michael; Kurths, Jürgen. Synchronization : a universal concept in nonlinear sciences. Cambridge: Cambridge University Press, 2001. ISBN 9780521533522.