205087 - Nonlinear Time Series Analysis

Coordinating unit: 205 - ESEIAAT - Terrassa School of Industrial, Aerospace and Audiovisual Engineering
Teaching unit: 748 - FIS - Department of Physics
Academic year: 2019
Degree: MASTER'S DEGREE IN AERONAUTICAL ENGINEERING (Syllabus 2014). (Teaching unit Optional)
MASTER'S DEGREE IN INDUSTRIAL ENGINEERING (Syllabus 2013). (Teaching unit Optional)
ECTS credits: 3 Teaching languages: English

Teaching staff
Coordinator: Cristina Masoller
Others: Antonio Pons

Opening hours
Timetable: Apointments should be arranged by email.

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, 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

<table>
<thead>
<tr>
<th>Total learning time: 75h</th>
<th>Hours large group: 19h</th>
<th>25.33%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours medium group: 0h</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>Hours small group: 8h</td>
<td>10.67%</td>
</tr>
<tr>
<td></td>
<td>Guided activities: 0h</td>
<td>0.00%</td>
</tr>
<tr>
<td></td>
<td>Self study: 48h</td>
<td>64.00%</td>
</tr>
</tbody>
</table>
## 205087 - Nonlinear Time Series Analysis

### Content

<table>
<thead>
<tr>
<th>Lineal tools for time series analysis and their limitations</th>
<th>Learning time: 16h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Laboratory classes: 2h</td>
</tr>
<tr>
<td></td>
<td>Self study: 10h</td>
</tr>
</tbody>
</table>

**Description:**
Fourier analysis and Correlation analysis

<table>
<thead>
<tr>
<th>Characterization of deterministic and stochastic time series</th>
<th>Learning time: 16h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Laboratory classes: 2h</td>
</tr>
<tr>
<td></td>
<td>Self study: 10h</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Synchronization and causality measures</th>
<th>Learning time: 16h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Laboratory classes: 2h</td>
</tr>
<tr>
<td></td>
<td>Self study: 10h</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Machine Learning techniques and classification methods</th>
<th>Learning time: 16h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Laboratory classes: 2h</td>
</tr>
<tr>
<td></td>
<td>Self study: 10h</td>
</tr>
</tbody>
</table>

**Description:**
Supervised and unsupervised machine Learning techniques for classification and prediction.
Data assimilation techniques

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

<table>
<thead>
<tr>
<th>Learning time: 11h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 3h</td>
</tr>
<tr>
<td>Self study: 8h</td>
</tr>
</tbody>
</table>

Qualification 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.

Regulations for carrying out activities

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:**


**Complementary:**