230685 - ASPTA - Advanced Signal Processing: Tools and Applications

Coordinating unit: 230 - ETSETB - Barcelona School of Telecommunications Engineering
Teaching unit: 739 - TSC - Department of Signal Theory and Communications
Academic year: 2020
Degree: MASTER'S DEGREE IN TELECOMMUNICATIONS ENGINEERING (Syllabus 2013). (Teaching unit Optional)
MASTER'S DEGREE IN ADVANCED TELECOMMUNICATION TECHNOLOGIES (Syllabus 2019). (Teaching unit Optional)
ECTS credits: 5
Teaching languages: English

Teaching staff
Coordinator: Pascual Iserte, Antonio
Others: Villares Piera, Nemesio Javier
Pascual Iserte, Antonio
Morros Rubio, Josep Ramon
Rey Micolau, Francesc
Pages Zamora, Alba Maria

Opening hours
Timetable: To be agreed with the lecturer.

Prior skills
The student must have skills on mathematics, and knowledge of probability, statistics and basic signal processing techniques.

Requirements
The student must have skills on mathematics and knowledge of probability, statistics and basic signal processing techniques.

Degree competences to which the subject contributes
Specific:
CE1. Ability to apply information theory methods, adaptive modulation and channel coding, as well as advanced techniques of digital signal processing to communication and audiovisual systems.

Transversal:
CT4. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.
CT5. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.
Learning objectives of the subject:
The course introduces the student to important statistical signal processing techniques and their application in digital communications, speech or computer vision. The course is organized into four modules covering the main aspects of the estimation, tracking and detection theories and their application to practical problems. For every module, classes are divided into classroom lectures, exercises and presentation of illustrative applications.

Learning results of the subject:
(i) To achieve a solid background on Statistical Signal Processing (estimation theory, detection theory and adaptive filtering) from the theoretical and applied perspectives.
(ii) Ability to design optimal and suboptimal estimators following classical and Bayesian approaches, as well as to evaluate the theoretical Cramér-Rao Lower Bound.
(iii) Ability to solve problems in which the unknown parameter (to estimate) evolves in time according to a dynamic or state model requiring the design of adaptive filters to track its value.
(iv) Ability to solve complex dynamical systems estimation problems using sequential Montecarlo methods.
(v) Ability to formulate simple binary and multiple hypothesis testing problems including the realistic situation in which there are some unknowns in the signal model (the pdf associated to the different hypotheses is not completely known).
(vi) Get familiarized with basic concepts of graph algebraic theory and ability to use these concepts to process data or signals lying on a graph.
(vii) Gain experience reading and understanding published journal and conference articles related with the topic.

Study load

<table>
<thead>
<tr>
<th>Total learning time: 125h</th>
<th>Hours large group:</th>
<th>39h</th>
<th>31.20%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Self study:</td>
<td>86h</td>
<td>68.80%</td>
</tr>
</tbody>
</table>
# Content

<table>
<thead>
<tr>
<th>Area</th>
<th>Learning time:</th>
<th>Description</th>
</tr>
</thead>
</table>
| **Estimation theory**         | 25h 30m        | **Learning time:** 25h 30m  
Theory classes: 12h  
Self study: 13h 30m  

**Description:**  
1.1. Minimum variance estimation, Crámer-Rao lower bound and sufficient statistics  
1.2. Maximum likelihood estimation and EM algorithm  
1.3. Bayesian estimation and application to robust filtering  
1.4. Applications in communications or computer vision |
| **Adaptive filtering and tracking** | 23h 30m | **Learning time:** 23h 30m  
Theory classes: 11h  
Self study: 12h 30m  

**Description:**  
2.1. Recursive least squares  
2.2. Kalman filter  
2.3. Monte Carlo methods and particle filters  
2.4. Applications in communications or computer vision |
| **Detection theory**          | 19h            | **Learning time:** 19h  
Theory classes: 9h  
Self study: 10h  

**Description:**  
3.1. Detection theory when the pdf is known  
3.2. Detection of deterministic signals  
3.3. Detection of random signals  
3.4. Detection theory when the pdf is not completely known  
3.5. Applications in communications or computer vision |
| **Graph signal processing**   | 13h            | **Learning time:** 13h  
Theory classes: 6h  
Self study: 7h  

**Description:**  
4.1. Algebraic graph theory  
4.2. Graph signals  
4.3. Graph systems  
4.4. Applications: spectral clustering and denoising signal graph |
### Project execution

<table>
<thead>
<tr>
<th>Learning time: 44h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 1h</td>
</tr>
<tr>
<td>Self study: 43h</td>
</tr>
</tbody>
</table>

**Description:**
- 5.1. General guidance on project execution and presentation
- 5.2. Summary of project status
- 5.3. Project execution and presentation

### Qualification system

Final exam: 50%
Individual assessments: 50%

### Regulations for carrying out activities

**Exercises:**
A set of exercises will be proposed in each chapter to strengthen the theoretical knowledge. The exercises will be solved in class or proposed as individual work.

**Individual project:**
Students will develop a supervised project consisting in programming, simulating and evaluating some of the signal processing algorithms presented in the course using some language such as C or MATLAB.

**Oral presentation:**
The project described above will be presented in class. This project (development and presentation) corresponds to the 50% of the qualification.

**Extended written exam (final examination):**
Final examination (written exam). The exam corresponds to the 50% of the qualification.
### Bibliography

#### Basic:


#### Complementary:


#### Others resources:

**Hyperlink**

**Slides and Exercices**

Resource in Atenea