UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH

Course guide
230685 - ASPTA - Advanced Signal Processing: Tools and Applications

Last modified: 25/05/2023

Unit in charge:	Barcelona School of Telecommunications Engineering
Teaching unit:	739 - TSC - Department of Signal Theory and Communications.

Degree: MASTER'S DEGREE IN TELECOMMUNICATIONS ENGINEERING (Syllabus 2013). (Optional subject).
MASTER'S DEGREE IN ADVANCED TELECOMMUNICATION TECHNOLOGIES (Syllabus 2019). (Optional subject).

Academic year: 2023   **ECTS Credits:** 5.0   **Languages:** English

LECTURER

Coordinating lecturer:	Consultar aquí / See here: https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/responsables-assignatura
Others:	Consultar aquí / See here: https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/professorat-assignat-idioma

PRIOR SKILLS

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.

TEACHING METHODOLOGY

Lectures
Application classes
Individual work (non presential)
Exercises
Oral presentations
Other activities (projects)
Written final exam

LEARNING OBJECTIVES OF THE SUBJECT

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

Type	Hours	Percentage
Hours large group	39,0	31.20
Self study	86,0	68.80

Total learning time: 125 h

CONTENTS

Estimation theory

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

Full-or-part-time: 25h 30m
Theory classes: 12h
Self study : 13h 30m

Adaptive filtering and tracking

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

Full-or-part-time: 23h 30m
Theory classes: 11h
Self study : 12h 30m

Detection theory

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

Full-or-part-time: 19h
Theory classes: 9h
Self study : 10h

Graph signal processing

Description:
4.1. Algebraic graph theory
4.2. Graph signals
4.3. Graph systems
4.4. Applications: spectral clustering and denoising signal graph

Full-or-part-time: 13h
Theory classes: 6h
Self study : 7h

Project execution

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

Full-or-part-time: 44h
Theory classes: 1h
Self study : 43h

GRADING SYSTEM

Final exam: 50%
Individual assessments: 50%

EXAMINATION RULES.

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:
- Haykin, S. S. Adaptive filter theory [on line]. Fifth ed. Harlow: Pearson Education Limited, 2013 [Consultation: 03/07/2020]. Available on: https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=5173892. ISBN 9780273775720.
- Anderson, B. D. O; Moore, J. B. Optimal filtering. Englewood Cliffs, NJ: Prentice-Hall, 1979. ISBN 0136381227.
- Kay, S.M. Fundamentals of statistical signal processing, v.1, Estimation theory. Englewood Cliffs: Prentice-Hall, cop. 1993-2013. ISBN 0130422681.
- Djuric, P.; Richard, C. Cooperative and graph signal processing: principles and applications [on line]. London: Academic Press, 2018 [Consultation: 28/04/2020]. Available on: https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=5448163. ISBN 9780128136782.
- Ristic, Branko; Arulampalam, Sanjeev; Gordon, Neil. Beyond the Kalman filter : particle filters for tracking applications. Boston: Artech House, 2004. ISBN 158053631X.
- Kay, S. M. Fundamentals of statistical signal processing, v.2, Detection theory. Englewood Cliffs: Prentice-Hall, cop. 1993-2013. ISBN 013504135X.

Complementary:
- Scharf, L.L. Statistical signal processing : detection, estimation, and time series analysis. Readig, MA: Addison-Wesley, 1990. ISBN 0201190389.
- Huang, X.; Acero, A.; Hon, H-W. Spoken language processing: a guide to theory, algorithm and system development. Upper Saddle River: Prentice Hall, 2001. ISBN 0130226165.

RESOURCES

Hyperlink:
- Slides and Exercices. Resource in Atenea