UAB
Universitat Autònoma de Barcelona

Digital Signal Processing

Code: 102687
ECTS Credits: 12

2024/2025

Degree	Type	Year
2500898 Telecommunication Systems Engineering	OB	3

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Teachers

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Teaching groups languages

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Prerequisites

It is recommended to have passed the following courses: Calculus, Algebra, Statistics, Discrete Systems and Signals, Fundamentals of Communications.

Objectives and Contextualisation

Once completed the subject, the student will be able to:

- Use vector and matrix algebra normally.
- Operate with numerical series and stochastic processes.
- Rigorously use different probabilistic tools.
- Estimate the parameters of a model from the signal samples at its output.
- Estimate the power spectral density of a random process.
- Design optimal filters in the MMSE sense and implement them in an efficient manner using iterative/adaptive algorithms.
- Apply signal processing techniques to situations in real life.

Competences

- Apply deterministic and stochastic signal processing techniques to the design of communication subsystems and data analysis.
- Develop personal attitude.

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- Develop personal work habits.
- Develop thinking habits.
- Learn new methods and technologies, building on basic technological knowledge, to be able to adapt to new situations.
- Perform measurements, calculations, estimations, valuations, analyses, studies, reports, task-scheduling and other similar work in the field of telecommunication systems.

Learning Outcomes

1. Adapt the knowledge and techniques of the digital signal treatment in accordance with the characteristics of communication systems and services as well as fixed or mobile work scenario.
2. Adapt to unforeseen situations.
3. Analyse and specify the fundamental parameters of communication subsystems from the point of view of the transmission, reception and digital treatment of signals.
4. Analyse the advantages and disadvantages of different technological alternatives or the implementation of communication systems from the point of view of digital signal treatment.
5. Apply adaptive statistical filtering and control theory to the design of dynamic algorithms for the coding, processing and transmission of multimedia information. Apply multichannel signal processing to the design of fixed and mobile antenna grouping based communication systems.
6. Apply detection and estimation theory to the design of communication receivers.
7. Apply statistical signal processing to estimate synchronisation parameters in digital communication and radio-navigation receivers.
8. Autonomously learn new knowledge related with digital signal processing in order to conceive and develop communication systems.
9. Be able to analyse, encode, process and transmit multimedia information employing analogue and digital signal processing techniques.
10. Describe the operational principles of radio-navigation, its architecture and the techniques for dealing with its sources of error.
11. Develop critical thinking and reasoning.
12. Develop curiosity and creativity.
13. Develop independent learning strategies.
14. Develop mathematical models to simulate the behaviour of communication subsystems and to evaluate and predict features.
15. Develop scientific thinking.
16. Develop the capacity for analysis and synthesis.
17. Generate innovative and competitive proposals in professional activity.
18. Manage available time and resources.
19. Manage information by critically incorporating the innovations of one's professional field, and analysing future trends.
20. Propose innovative solutions for problems related with the transmission, reception and the digital treatment of signals.
21. Work in complex or uncertain surroundings and with limited resources.

Content

1. Introduction

- Discrete random processes, frequency representation.
- Fundamentals of matrix algebra.
- The autocorrelation matrix.

2. Estimation theory

- Fundamentals of model-based methodology.
- Classical vs. bayesian estimation.

- MVU criterion and properties of good estimators.
- Maximum likelihood estimation.
- Cramér-Rao lower bound.
- Suboptimal estimation methods.
- Applications in communication and positioning systems.

3. Spectral estimation

- Non-parametric methods.
- Capon or minimum variance method.
- Parametric methods.
- Super-resolution methods.
- Applications in voice coding and multi-antenna signal processing.

4. Wiener filtering and adaptive filtering

- Minimum mean square error (MMSE) estimation.
- Linear prediction.
- Steepest descent method.
- Convergence criteria.
- Least Mean Square (LMS) method.
- Applications in noise cancellation.

Activities and Methodology

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Exercise classes	15	0.6	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 15, 16, 20
Laboratory classes	25	1	3, 4, 5, 6, 7, 9, 10, 13, 14
Lectures	60	2.4	3, 4, 5, 6, 7, 9, 10, 12, 14, 15, 16
Type: Supervised			
Tutorials	15	0.6	5, 6, 7, 9, 10, 11
Type: Autonomous			
Prepare laboratory classes	30	1.2	1, 3, 4, 8, 11, 13, 14, 16, 17, 19, 20
Problem solving	40	1.6	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 14, 15, 16, 20
Study	100	4	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16, 19, 20

Directed activities:

- Lectures, which convey the theoretical contents of the course.
- Exercise classes, where exercises related to the theoretical contents of the course are solved by the lecturer with the participation of the students.
- Laboratory classes for the application of the contents conveyed during the lectures using Matlab.
- Written assessment tests.

Autonomous activities

- Study of the theoretical and practical contents of the course. Preparation of the problem solving. Exam preparation.
- Practical assignments: complete the laboratory reports and consolidate the knowledge acquired during the laboratory classes.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continous Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Exam 1	35%	2.5	0.1	1, 3, 4, 5, 6, 7, 8, 9, 10, 14, 16, 19, 20
Exam 2	35%	2.5	0.1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 14, 16, 19, 20
Laboratory: exam of practice knowledge	4%	1	0.04	1, 2, 3, 4, 18
Laboratory: practice reports	26%	9	0.36	1, 3, 4, 5, 6, 8, 9, 11, 12, 13, 15, 16, 17, 18, 19, 20, 21

Continuous evaluation

It consists of an exam at half the semester (Exam1) and another one at the end of the semester (Exam2). The average mark of these two exams leads to the continuous evaluation mark for the theory classes:

MarkTheory = [(0.35 x Mark Exam1) + (0.35 x Mark Exam2)] / 0.7

Additionally, the mark for the laboratory classes is given by the weighted average of the mark from the laboratory reports, the mark from the "in-situ" reports and the mark from the laboratory exam, as follows:

MarkLab = [(0.26 x MarkLabReports) + (0.04 x MarkLabExam)] / 0.3

With the theory and laboratory marks, the final mark of the course will be computed as:

If (MarkTheory >= 3.5) && (MarkLab >= 3.5) --> FinalMark = (0.7 x MarkTheory) + (0.3 x MarkLab)

If (MarkTheory < 3.5) || (MarkLab < 3.5) --> FinalMark = min{MarkTheory, MarkLab}

Therefore, the student should get a mark at both theory and laboratory classes equal or greater than 3.5 to be eligible to have its marks being averaged.

Single evaluation

This subject does not consider a single assessment system.

Re-assessment

Students who have failed the continuous evaluation will be eligible to attend the re-assesment exam. This exam will be carried out within the period of exams published by the School. In this exam, the student can re-assess the part corresponding to the Exam1, the part corresponding to the Exam2, or both. The mark obtained in each part of the re-assessment exam (mark ExamRA1, mark ExamRA2) supersedes the previous mark that the student had in the corresponding continuous evaluation exam. The re-assessment mark is computed as follows:

MarkTheoryRA = [(0.35 x Mark {Exam1 or ExamRA1}) + (0.35 x Mark {Exam2 or ExamRA2})]/ 0.7

The final mark of the course is then computed as follows:

If (MarkTheoryRA >= 3.5) && (MarkLab >= 3.5) --> FinalMark = (0.7 x MarkTheoryRA) + (0.3 x MarkLab)

If (MarkTheoryRA < 3.5) --> FinalMark = MarkTheoryRA

Laboratory rules

- The assistance to all laboratory classes is compulsory.
- The report of each laboratory session must be delivered at the end of the session. Any delay in the delivery of the report will be penalised in the corresponding mark. In addition, the laboratory professor will be "in-situ" evaluating the actual progress and usage of the session made by the student and this item will have an impact on the mark of the report itself.

Repeating students

If they had passed the laboratory part of the course in previous years, they will not need to do the laboratory classes again. By default, the marks that they obtained inthat part will be maintained. If a repeating student would like to repeat the laboratory classes this year, then he/she will need to informthe professor in charge of the course.

Consideration of "Not assessable"

Students not performing any examination (neither the two exams of the continuous evaluation nor the re-assessment exam) will be marked as "Not assessable".

Additional considerations

Without prejudice to other disciplinary measures that may deem necessary in accordanceto the academic regulation, any irregularity committed by the student that may alter the mark of an assessment activity will lead this activity to be marked with zero points. For instance, copying or letting copy a laboratory report or any another assessment activity will involve to fail it with a mark equal to zero. Furthermore, such activity will not be able to be re-assessed during the same academic course. If this activity has a minimum mark associated to it, then the subject will be graded as failed.

If the student commits irregularities in various assessment activities of the course, the final mark of the course will be 0 in virtue of point 10, article 116, of the Academic Regulation.

Bibliography

Basic:

- S. M. Kay, *Fundamentals of statistical signal processing. Estimation theory, vol. I*, Prentice-Hall, 1993.
- M. H. Hayes, *Statistical digital signal processing and modeling*, John Wiley and Sons, 1996.
- P. Stoica and R. Moses, *Spectral analysis of signals*, Prentice-Hall, 2005.
- S. Haykin, *Adaptive filter theory*, Pearson, 2013.

Supplementary:

- D. G. Manolakis, V. K. Ingle, S. M. Kogen, *Statistical and adaptive signal processing: spectral estimation, signal modeling, adaptive filtering and array processing*, Artech-House, 2005.
- S. M. Kay, *Fundamentals of statistical signal processing. Practical algorithm development, vol. III*, Pearson, 2013.
- S. Lawrence Marple, *Digital spectral analysis*, Dover Publications, 2019.
- B. Widrow and S. D. Stearns, *Adaptive signal processing*, Prentice-Hall, 2985.
- A. Hjorungnes, *Complex-Valued Matrix Derivatives: With Applications in Signal Processing and Communications*, Cambridge University Press, 2011.
- Fundamentals:
    S. M. Kay, *Intuitive probability and random processes using Matlab*, Springer, 2006.
    V. K. Ingle and J. G. ProakisManolakis, *Digital signal processing using Matlab*, Cengage Learning, 2012.

Software

- The laboratory sessions will be carried out using the software MATLAB.
- The laboratory reports are encouraged to be written using LaTeX, for instance, using the online editor Overleaf.

Language list

Name	Group	Language	Semester	Turn
(PAUL) Classroom practices	331	Catalan/Spanish	first semester	morning-mixed
(PAUL) Classroom practices	332	Catalan/Spanish	first semester	morning-mixed
(PLAB) Practical laboratories	331	Catalan/Spanish	first semester	morning-mixed
(PLAB) Practical laboratories	332	Catalan/Spanish	first semester	morning-mixed
(PLAB) Practical laboratories	333	Catalan/Spanish	first semester	morning-mixed
(TE) Theory	330	Catalan/Spanish	first semester	morning-mixed