Universitat Autònoma de Barcelona

2019/2020

Digital Signal Processing

Code: 102687
ECTS Credits: 12

Degree	Type	Year	Semester
2500898 Telecommunication Systems Engineering	OB	3	1

Contact

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Use of Languages

Principal working language: spanish (spa)
Some groups entirely in English: No
Some groups entirely in Catalan: No
Some groups entirely in Spanish: Yes

Teachers

Sergi Locubiche Serra

External teachers

Fran Fabra
Sergio Tomás

Prerequisites

This subject requires prior knowledge obtained through the following subjects: 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.

- 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 ones 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.

3. Spectral estimation

- Non-parametric methods.
- Capon or minimum variance method.
- Parametric methods.
- Super-resolution methods.

4. Wiener filtering and adaptive filtering

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

Methodology

Presential activities

- Lectures, which convey the theoretical contents of the subject.
- Exercise classes where exercises related to the theoretical contents of the subject are solved by the lecturer with the participation of the students.
- Laboratory classes for the application of the contents conveyed during the lectures and exercise classes, using simulation software and different models of real-life systems.
- Written assessment tests.

Autonomous activities

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

Activities

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

Study	100	4	1, 4, 3, 5, 7, 6, 8, 10, 15, 13, 16, 14, 11, 19, 20, 9

Assessment

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:

MarkTheoryCE = (Mark Exam1 + Mark Exam2) / 2

From this mark, the final mark of the subject is computed as follows:

If MarkTheoryCE >= 4 --> FinalMark = (0.7 x MarkTheoryCE) + (0.13 x MarkLabReport) + (0.13 x MarkLabReport "in-situ") + (0.04 x MarkLabExam)

If MarkTheoryCE < 4 --> FinalMark = MarkTheoryCE

Therefore, it is necessary that the student has a mark equal or greater than 4 to allow the laboratory marks to be averaged with the rest of the activities.

Re-assessment

Students who have been evaluated of at least two thirds of the global mark of the subject and who have obtained at least an average mark of 2.5 therein, can participate in the re-assessment exam that 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) substitutes the previous mark that the student had in the corresponding continuous evaluation exam. The re-assessment mark is computed as follows:

MarkTheoryRA = (Mark {Exam1 or ExamRA1} + Mark {Exam2 or ExamRA2}) / 2

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

If MarkTheoryRA >= 4--> FinalMark = (0.7 x MarkTheoryRA) + (0.13 x MarkLabReport) + (0.13 x MarkLabReport "in-situ") + (0.04 x MarkLabExam)

If MarkTheoryRA < 4 --> FinalMark = MarkTheoryRA

Laboratory rules

- The assistance to all laboratory classes is compulsory.
- Each laboratory workplace is composed of a group of two students.
- The pre-lab report must be done individually by each student and delivered when entering at the laboratory.
- The report of each laboratory experiment must be delivered one week after the end of the last laboratory session of that experiment. Any delay in the delivery of the report will be penalised in the corresponding mark.
- The laboratory professor may request the students to deliver a preliminary version of the laboratory report when finishing the classe ("in situ" report), in order to evaluate the progress of the student during the lab session.

Repeating students

In case the students may have failed the subject in previous years but had a "pass" mark for the laboratory activities, that is,

LaboratoryMark = ((0.13 x MarkLabReport) + (0.13 x MarkLabReport "in-situ") + (0.04 x MarkLabExam)) / 0.3 >=5

then by default, that laboratory mark will be kept and the student will not need to repeat the laboratory classes again when repeating the subject.

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 accordance to 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.

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Exam 1	35%	2.5	0.1	1, 4, 3, 5, 7, 6, 8, 10, 16, 14, 19, 20, 9
Exam 2	35%	2.5	0.1	1, 2, 4, 3, 5, 7, 6, 8, 10, 16, 14, 19, 20, 9
Laboratory: "in-situ" reports	13%	4	0.16	4, 8, 15, 13, 16, 12, 14, 11, 17, 19, 20, 21
Laboratory: exam of practice knowledge	4%	1	0.04	1, 4, 3
Laboratory: practice reports	13%	5	0.2	1, 4, 3, 5, 6, 8, 15, 13, 16, 12, 11, 18, 20, 9

Bibliography

Main bibliography:

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- P. Stoica and R. Moses, *Spectral analysis of signals*, Prentice-Hall, 2005.
- S. Haykin, *Adaptive filter theory*, Pearson, 2014.
- B. Widrow and S. D. Stearns, *Adaptive signal processing*, Prentice-Hall, 2985.

Additional bibliography:

- M. H. Hayes, *Statistical digital signal processing and modeling*, John Wiley and Sons, 1996.
- S. Lawrence Marple, *Digital spectral analysis*, Dover Publications, 2019.
- 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.

- Fundamental concepts:

  J. G. Proakis and D. G. Manolakis, *Digital signal processing: principles, algorithms and applications*, Prentice-Hall, 1996.

  A.V. Oppenheim, R.W. Schafer and J.R. Buck, *Discrete-time signal processing*, Prentice-Hall, 1999.

- Matrix algebra:

  J. R. Magnus, H. Neudecker, *Matrix differential calculus with applications in statistics and econometrics*, John-Wiley and Sons, 1999.

  R. A. Horn, C. R. Johnson, *Matrix analysis*, Cambridge University Press, 1985.