COURSE DATA

Data Subject	
Code	44277
Name	Signal processing
Cycle	Master's degree
ECTS Credits	3.0
Academic year	2020 - 2021

Study (s)

Degree	Center	Acad. year	Period
2199 - M.D. in Electronic Engineering	School of Engineering	1	First term

Subject-matter

Degree	Subject-matter	Character
2199 - M.D. in Electronic Engineering	1 - Digital signal processing	Obligatory

Coordination

Name	Department
CAMPS VALLS, GUSTAU ADOLF	242 - Electronic Engineering

SUMMARY

This course provides students with notions of various essential aspects in advanced statistical signal processing. The course covers four sections: 1) introduction to probability theory and random variables; 2) study of stochastic processes (describing types of processes and properties); 3) the standard statistical methods for spectral estimation (both parametric and non-parametric spectral densities so as to frequency detection), and finally; 4) signal transforms for multi-scale signal analysis: departing from Fourier analysis we move on to more complex signal transforms, such as multiresolution, wavelets and time-frequency transformations. The theoretical part is complemented with a number of practical applications in real problems in engineering.

PREVIOUS KNOWLEDGE

Relationship to other subjects of the same degree

There are no specified enrollment restrictions with other subjects of the curriculum.

Other requirements

The student should have a solid background on digital signal processing, and some notions on statistics and probability theory. Otherwise, basic material and tutorials will be provided to achieve the needed level to follow the course.

OUTCOMES

2199 - M.D. in Electronic Engineering

- Students should apply acquired knowledge to solve problems in unfamiliar contexts within their field of study, including multidisciplinary scenarios.
- Students should be able to integrate knowledge and address the complexity of making informed judgments based on incomplete or limited information, including reflections on the social and ethical responsibilities associated with the application of their knowledge and judgments.
- Students should communicate conclusions and underlying knowledge clearly and unambiguously to both specialized and non-specialized audiences.
- Students should demonstrate self-directed learning skills for continued academic growth.
- Take into account the economic and social context in engineering solutions, be aware of diversity and multiculturalism and ensure sustainability and respect for human rights and equality between men and women.
- Diseñar un sistema, componente o proceso que cumpla unas especificaciones desde diferentes puntos de vista: electrónico, económico, social, ético y medioambiental.
- Demostrar una comprensión sistemática de un campo de estudio y el dominio de las habilidades.
- Realizar un análisis crítico, evaluación y síntesis de ideas nuevas y complejas.
- Ser capaz de fomentar, en contextos académicos y profesionales, el avance tecnológico, social o cultural dentro de una sociedad basada en el conocimiento.
- Capacidad para proyectar, calcular y diseñar productos, procesos e instalaciones en todos los ámbitos de la Ingeniería Electrónica y en particular los de tratamiento de la señal, sistemas digitales y de comunicaciones y electrónica industrial.
- Capacidad para el modelado matemático, cálculo y simulación en todos los ámbitos relacionados con la Ingeniería Electrónica y campos multidisciplinares afines. En especial los de tratamiento de la señal, sistemas digitales y de comunicaciones y electrónica industrial.
- Conocer las técnicas avanzadas de análisis de datos.
- Capacidad de analizar, especificar y diseñar sistemas de tratamiento digital de señales desde su concepción hasta su implementación en sistemas hardware de tiempo real..

LEARNING OUTCOMES

The student should be able to select the most appropriate methodology for statistical signal processing over the wide range of introduced alternatives. He/she should be able to choose and apply signal decomposition schemes, time-frequency or wavelet transforms adapted to the signal characteristics at hand.

DESCRIPTION OF CONTENTS

1. Introduction to probability theory and random variables

1.1. Introduction
Probability theory
Independent events and experiments
Random variable and random process
Probability distributions
1.2. Continuous and discrete time processes
1.3. Moments of a random variable
Expectation and expected value
Correlation, dependence, orthogonality and higher order moments
Conditional expectation
Multiple and i.i.d. random variables
1.4. Convergence of random variables
Definition of convergence
Central limit theorem
Law of large numbers
1.5. Conclusions

2. Discrete time stochastic processes

2.1. Introduction
2.2. (Generalized) Harmonic Analysis
2.3. Mean and autocorrelation
2.4. Classes of random processes
Discrete time linear models
Sums of iid random variables
Independent stationary increments
Gaussian-Markov processes
Gaussian random processes
2.5. Wiener, Bernoulli, and Poisson processes
2.6. Composite processes: uncorrelated, colored, thermal
2.7. Autorregressive and moving average processes
Wold classification of signals
Pegels taxonomy of signal decomposition

AR, MA and ARMA processes
Box-Jenkins system identification
2.8. Implications of Stationarity and Ergodicity
2.9. Conclusions

3. Spectral estimation

3.1. Introduction and definition
3.2. Taxonomy: Parametric vs. non-parametric estimation
3.3. Fourier analysis
3.4. Autocorrelation function
3.5. Spectrogram using short-time Fourier transform
3.6. Nonparametric density estimation
Periodogram (Welch, Bartlett)
Blackman-Tukey correlogram
3.7. Parametric density estimation methods
Yule-Walker
Burg
Covariance methods
3.8. Multiple Signal Classification (MUSIC)
3.9. Conclusions

4. Signal decomposition and transforms

4.1. Introduction
4.2. Basis functions, eigenvectors and eigenvalues: SVD and PCA
4.3. Discrete time filters and the Fourier transform
4.4. Gabor filter and the Heisenberg uncertainty principle
4.5. Filter banks in time (Haar) and frequency (half-band) domains
4.6. Time-frequency transforms and wavelets
4.7. Orthogonal Wavelet Bases
4.8. Mallat Pyramid algorithms
4.9. Applications: biosignal, speech and image processing
4.10. Conclusions

5. Laboratory

Lab class 1: Random variables and processes. Stationarity and ergodicity. Spectral density estimation, filtering random signals.

Lab class 2: Spectral estimation, both parametric and non-parametric. Signal detection with MUSIC.

Lab class 3: Time frequency representations. Problems of the DFT. Windowing, and window types and impact. Applications.

Lab class 4: Wavelets. Multiresolution analysis of signals. Filter banks. Applications on denoising and compression of signals and images.

WORKLOAD

ACTIVITY	Hours	% To be attended
Theory classes	15,00	100
Laboratory practices	15,00	100
Study and independent work	10,00	0
Readings supplementary material	5,00	0
Preparation of evaluation activities	5,00	0
Preparing lectures	5,00	0
Preparation of practical classes and problem	10,00	0
Resolution of case studies	10,00	0
TOTAL	**75,00**	

TEACHING METHODOLOGY

The teaching methods employed in the development of the course are:

a) Theoretical activities.

Expository development of matter with the student's participation in the resolution of specific issues.

b) Practical activities.

Solving practical problems

c) Student's personal work.

Description: Performing outside the classroom to issues and problems as well as the preparation of classes and exams (study). This task will be performed individually and try to promote self-employment.

We will use e-learning platforms (LMS) to support communication with students. Through it the student will have access to course materials used in class, as well as solving problems and exercises.

EVALUATION

The evaluation of the course will be conducted by performing a test that will take the form of an individual examination or group work about the contents of the subject.

REFERENCES

Basic

- Statistical and Adaptive Signal Processing: Spectral Estimation, Signal Modelling, Adaptive Filtering & Array Processing. D. Manolakis, V.K. Ingle, S.M. Kogon. Artech House 2005.
- An Introduction To Statistical Signal Processing / Robert M. Gray, Lee D. Davisson, Cambridge University Press, 2004.
- Probability and Random Processes with Applications to Signal Processing. Henry Stark, John W. Woods, Prentice Hall, 2002.
- Introduction to random processes, William A. Gardner, 2nd Ed. McGraw-Hill, 1990.
- H. Stark and J.W. Woods. Probability and random processes with applications to Signal Processing. Prentices Hall
- A Wavelet Tour of Signal Processing, Stephane Mallat, Academic Press, 1999.

Additional

- Fundamentals of Statistical Signal Processing, Steven M. Kay, Prentice Hall, 1998.
- P. Billingsley. Probability and Measure. Wiley & Sons, 1995. 3rd Edition.
- Advanced Digital Signal Processing, John G. Proakis, MacMillan 1992.

ADDENDUM COVID-19

This addendum will only be activated if the health situation requires so and with the prior agreement of the Governing Council

In the event of a closure of the facilities due to the health situation that totally or partially affects the classes of the subject, these will be replaced by non-face-to-face sessions following the established schedules. If the closure affects any face-to-face assessment test of the subject, it will be replaced by a test of a similar nature that will be carried out in virtual mode through the tools with institutional support from the University of Valencia. The percentages of each evaluation test will remain unchanged, as established by this guide.