Course guide
295121 - 295II331 - Biomedical Signal Analysis

Last modified: 02/10/2025

Unit in charge: Barcelona East School of Engineering
Teaching unit: 707 - ESAII - Department of Automatic Control.

Degree: MASTER'S DEGREE IN INTERDISCIPLINARY AND INNOVATIVE ENGINEERING (Syllabus 2019). (Optional subject).
ERASMUS MUNDUS MASTER'S DEGREE IN ADVANCED MATERIALS SCIENCE AND ENGINEERING (Syllabus 2021). (Optional subject).
MASTER'S DEGREE IN ADVANCED BIOMEDICAL TECHNOLOGIES (Syllabus 2025). (Compulsory subject).

Academic year: 2025 **ECTS Credits:** 6.0 **Languages:** English

LECTURER

Coordinating lecturer: ABEL TORRES CEBRIAN

Others: Primer quadrimestre:
BEATRIZ FABIOLA GIRALDO GIRALDO - Grup: T11
JORDI SOLA SOLER - Grup: T11
ABEL TORRES CEBRIAN - Grup: T11

PRIOR SKILLS

Basic knowledge of Signals and Systems Analysis, Statistics, Matlab

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CEMUEII-17. Apply advanced techniques of acquisition, processing, analysis and interpretation of biomedical signals for the identification and monitoring of physiological biomarkers applied to the diagnostic process (Specific competence of the Healthcare and Biomedical Applications specialty).

Generical:
CGMUEII-01. Participate in technological innovation projects in multidisciplinary problems, applying mathematical, analytical, scientific, instrumental, technological and management knowledge.
CGMUEII-05. To communicate hypotheses, procedures and results to specialized and non-specialized audiences in a clear and unambiguous way, both orally and through reports and diagrams, in the context of the development of technical solutions for problems of an interdisciplinary nature.

Transversal:
05 TEQ. TEAMWORK. Being able to work as a team player, either as a member or as a leader. Contributing to projects pragmatically and responsibly, by reaching commitments in accordance to the resources that are available.
06 URI. EFFECTIVE USE OF INFORMATION RESOURCES. Managing the acquisition, structure, analysis and display of information from the own field of specialization. Taking a critical stance with regard to the results obtained.
03 TLG. THIRD LANGUAGE. Learning a third language, preferably English, to a degree of oral and written fluency that fits in with the future needs of the graduates of each course.

LEARNING RESULTS

Knowledges:
K5. Describe advanced knowledge of analysis and interpretation of biomedical signals.
K2. Recognise advanced data analysis and modelling structures.
K7. Infer advanced knowledge of digital biomarkers and artificial intelligence techniques in health technologies.

Skills:
S10. Use common analysis tools in technological innovation to evaluate business opportunities and develop innovation proposals in the field of biomedical technologies.
S5. Propose digital biomarkers through advanced analysis of biomedical signals, artificial intelligence techniques and bioinformatics.
S6. Interpret biomedical data using data analysis, machine learning and deep learning techniques.
S8. Design digital and mobile health applications (mHealth).

Competences:
C3. Identify and analyse problems that require making autonomous, informed and reasoned decisions in order to act with social responsibility following ethical values and principles.
C6. Integrate the values of sustainability and understand the complexity of systems, with the aim of undertaking or promoting actions that restore and maintain the health of ecosystems and improve justice, thereby generating visions of sustainable futures.
C4. Use information resources effectively, manage the acquisition, structure, analysis and visualisation of data and information in the area of specialisation and critically assess the results.
C5. Use scientific and technical information to respond to any demand for modification, innovation or improvement of devices, products and processes linked to biomedical engineering for new scientific or technological applications.

TEACHING METHODOLOGY

The course will be practical and interactive in nature. In theory sessions students will learn about different advanced signal processing methods and its applications to several practical examples. In laboratory sessions students will be challenged to program their own algorithms, facilitating them to quickly apply the newfound knowledge. Finally, students will work in small groups on a global biomedical project. The results of this project will be evaluated in a session of oral presentations.

LEARNING OBJECTIVES OF THE SUBJECT

At the end of this course students should be able to:

- To apply and assess the appropriateness of different advanced signal processing techniques for several types of data, and to extract relevant information and interpretat it to obtain clinical conclusions
- To develop and understand advanced methods for removal of artefacts, to detect event, identify the optimum filters, time-frequency and time-scale representations, in biomedical signals
- To define methods for estimate and characterize the most relevant parameters, and linear and non-linear patterns of a biomedical system
- To design an appropriate statistical study for each case, and to be able to analyze and interpret their results

STUDY LOAD

Type	Hours	Percentage
Hours large group	27,0	18.00
Hours small group	27,0	18.00
Self study	96,0	64.00

Total learning time: 150 h

CONTENTS

Introduction to Biomedical Signal Analysis

Description:
Objectives of biomedical signal analysis
Examples of biomedical signals: origins and characteristics
Basic signal categories: deterministic and stochastic signals. Stationary and non-stationary signals
Definitions: mean, covariance, correlation and power
Types of noise, interferences and artefacts in biomedical signals

Specific objectives:
- To identify different types of biomedical signals, their origins and characteristics
- To understand the different categories of signals, and their types of noise, interferences and artefacts associated of them

Related activities:
Individual questionnaire related to the Individual Test 1

Full-or-part-time: 6h
Theory classes: 3h
Self study : 3h

Filtering for removal artefacts

Description:
Digital signals: sampling, Shannon and the Nyquist frequency
Acquisition device: anti-aliasing filter
Z-transform
Time-domain filters
Frequency-domain filters
Filter design
Synchronized averaging and ensemble averaging
Optimal filtering
Adaptive filters

Specific objectives:
To know, identify and understand different methods for several biomedical signal filtering

Related activities:
Laboratory session 1: Removing artefacts from biomedical signals

Full-or-part-time: 12h
Theory classes: 6h
Self study : 6h

Detection of events and waves

Description:
Envelope extraction
Analysis of activity
Temporal event detection
Correlation analysis and template matching

Specific objectives:
- To identify and apply different techniques to characterize each type of biomedical signal studied
- To define and apply methods for detection of different events and their analysis

Related activities:
Laboratory session 2: Detection algorithms for biomedical signals

Full-or-part-time: 12h
Theory classes: 6h
Self study : 6h

Frequency-domain characterization

Description:
Fourier spectrum
Power spectral density (PSD) function
Spectral resolution and leakage
Welch Periodogram
Lomb periodogram
AR spectral estimation
Measures derived from PSD's: moments and power ratios

Specific objectives:
To identify and analyze methods in frequency domain for the characterization of the biomedical signals studied

Related activities:
Laboratory session 3: Spectral analysis of biomedical signals

Full-or-part-time: 12h
Theory classes: 6h
Self study : 6h

Analysis of nonstationary signals

Description:
Nonstationary signals
Short-time Fourier transform
Continuous wavelet transform
Ambiguity Function
Wigner-Ville distribution
Cohen's class general time-frequency distributions

Specific objectives:
To know and understand several techniques used in the analysis of the nonstationary biomedical signals

Related activities:
Laboratory session 4: Time-scale and time-frequency analysis of biomedical signals

Full-or-part-time: 12h
Theory classes: 6h
Self study : 6h

Coupled Processes, complexity and non-linear dynamical analysis

Description:
Cardio-respiratory interaction
Cross-spectral and coherence analysis
Mathematical techniques and computational tools to study non-linear, chaotic dynamics and complexity of biomedical systems. Identification and characterization of their patterns.

Specific objectives:
-To define and know the relation between different biomedical systems
-To apply complexity techniques to characterize these interactions and the analysis of their dynamic

Related activities:
Laboratory session 5: Interaction analysis between biomedical signals (cardio-respiratory interaction)

Full-or-part-time: 12h
Theory classes: 6h
Self study : 6h

Statistical Analysis of biomedical data

Description:
Descriptive statistics: statistics used to describe the sample or summarize information about the sample (central tendency or location, dispersion or variability, kurtosis, skewness.)
Inferential statistics: statistics used to make inferences or generalizations about the broader population (hypothesis testing and statistical significance: parametric and non-parametric tests). Analysis of variance, regression and correlation analysis, classification techniques. Accuracy, sensitivity, specificity.

Specific objectives:
To identify, define and apply the appropriate statistical test in each case, according to the type of data, the type of biomedical signal to study, and the analysis (descriptive, classification, modelling, etc) to will be made

Related activities:
Laboratory session 6: Statistical analysis of biomedical data

Full-or-part-time: 12h
Theory classes: 6h
Self study : 6h

GRADING SYSTEM

Laboratory Reports: 4x7,5%
Technical report of the individual data analysis assignment (10 %)
Individual test: 25 %
Technical report of the project: 20 %
Oral presentation of the project: 15 %

EXAMINATION RULES.

Laboratory reports will be done in groups of 2 students.
The group project will be carried out in groups of 3-4 students.
Projects written presentation will be formatted as a conference proceedings paper (6-10 pages) and will be presented to the class during the last week of the course (15 min conference presentation + questions). After presentation, a reviewed more complete version of the written report should be submitted.

BIBLIOGRAPHY

Basic:
- Rangayyan, Rangaraj M. Biomedical signal analysis. 2nd ed. Piscataway [etc.]: IEEE press, 2015. ISBN 9780470911396.
- Sörnmo, Leif; Laguna, Pablo. Bioelectrical signal processing in cardiac and neurological applications [on line]. San Diego: Academic Press, 2005 [Consultation: 14/04/2020]. Available on: https://www.sciencedirect.com/science/book/9780124375529. ISBN 9780124375529.
- Bruce, Eugene N. Biomedical signal processing and signal modeling. New York: John Wiley & Sons, 2001. ISBN 0471345407.
- Tinsley, Howard E. A.; Brown, Steven D. (ed.). Handbook of applied multivariate statistics and mathematical modeling [on line]. San Diego: Academic Press, 2000 [Consultation: 14/04/2020]. Available on: https://www.sciencedirect.com/science/book/9780126913606.
- McLachlan, Goffrey J. Discriminant analysis and statistical pattern recognition. Wiley: New York, 2004. ISBN 0471691151.
- Rosner, Bernard. Fundamentals of biostatistics. 7th ed. Pacific Grove, Calif.: Brooks/Cole, Cengage Learning, 2011. ISBN 9780538733496.

Complementary:
- Pratt, John W.; Gibbons, Jean Dickinson. Concepts of nonparametric theory. Springer-Verlag: Springer, 1981. ISBN 0387905820.
- Weisberg, Sanford. Applied linear regression [on line]. 4th ed. New York: Wiley, 2016 [Consultation: 14/04/2020]. Available on: https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=1574352. ISBN 9781118594858.
- Riffenburgh, R. H. Statistics in medicine [on line]. 2nd ed. Burlington, MA: Elsevier Academic Press, 2006 [Consultation: 14/04/2020]. Available on: https://www.sciencedirect.com/science/book/9780120887705. ISBN 0120887703.

RESOURCES

Other resources:

Biopac system, Shimmer sensing devices
Biomedical databases
Biomedical engineering laboratory (A8.2)
Matlab, IBM SPSS Statistics, AcqKnowledge acquisition software