



# Course guide

## 295121 - 295II331 - Biomedical Signal Analysis

Last modified: 27/05/2024

**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).

**Academic year:** 2024    **ECTS Credits:** 6.0    **Languages:** English

### LECTURER

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**Coordinating lecturer:** Torres Cebrian, Abel

**Others:** Primer quadrimestre:  
BEATRIZ FABIOLA GIRALDO GIRALDO - Grup: T10  
JORDI SOLA SOLER - Grup: T10  
ABEL TORRES CEBRIAN - Grup: T10

### PRIOR SKILLS

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Students must have taken the subject "Data analysis & Pattern Recognition"

Basic knowledge of Signals and Systems Analysis, Statistics, Matlab

### REQUIREMENTS

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None

### DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

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**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.

## 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 interpret 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	21,0	14.00
Hours small group	21,0	14.00
Self study	108,0	72.00

**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: 4h

Theory classes: 2h

Self study : 2h



### 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:** 8h

Theory classes: 4h

Self study : 4h

### 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:** 4h

Theory classes: 2h

Self study : 2h



### 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:** 8h

Theory classes: 4h

Self study : 4h

### 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:** 8h

Theory classes: 4h

Self study : 4h



### 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:** 6h

Theory classes: 3h

Self study : 3h

### 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:** 6h

Theory classes: 3h

Self study : 3h

## GRADING SYSTEM

Laboratory Reports: 6x5%

Technical report of the first project: 15 %

Oral presentation of the first project: 15 %

Individual test 1: 10 %

Technical report of the second project: 10 %

Oral presentation of the second project: 10 %

Individual test 2: 10 %

## 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

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### 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

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### Other resources:

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