295121 - 295II331 - Biomedical Signal Analysis

Coordinating unit: 295 - EEBE - Barcelona East School of Engineering
Teaching unit: 707 - ESAII - Department of Automatic Control
Academic year: 2019
Degree: MASTER'S DEGREE IN INTERDISCIPLINARY AND INNOVATIVE ENGINEERING (Syllabus 2019). (Teaching unit Optional)
ECTS credits: 6  Teaching languages: English

Teaching staff
Coordinator: Torres Cebrian, Abel
Others: Sola Soler, Jordi
Giraldo Giraldo, Beatriz Fabiola

Prior skills
Students must have taken the subject “Data analysis & Pattern Recognition”
Basic knowledge of Signals and Systems Analysis, Statistics, Matlab

Requirements
None

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).

General:
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

<table>
<thead>
<tr>
<th>Total learning time: 150h</th>
<th>Hours large group: 22h</th>
<th>14.67%</th>
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<tbody>
<tr>
<td></td>
<td>Hours medium group: 0h</td>
<td>0.00%</td>
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<tr>
<td></td>
<td>Hours small group: 22h</td>
<td>14.67%</td>
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<tr>
<td></td>
<td>Guided activities: 4h</td>
<td>2.67%</td>
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<tr>
<td></td>
<td>Self study: 102h</td>
<td>68.00%</td>
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# Introduction to Biomedical Signal Analysis

<table>
<thead>
<tr>
<th>Description:</th>
<th>Learning time: 4h</th>
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<tbody>
<tr>
<td>Objectives of biomedical signal analysis</td>
<td>Theory classes: 2h</td>
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<tr>
<td>Examples of biomedical signals: origins and characteristics</td>
<td>Self study: 2h</td>
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<tr>
<td>Basic signal categories: deterministic and stochastic signals. Stationary and non-stationary signals</td>
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<tr>
<td>Definitions: mean, covariance, correlation and power</td>
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<tr>
<td>Types of noise, interferences and artefacts in biomedical signals</td>
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<table>
<thead>
<tr>
<th>Related activities:</th>
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<tbody>
<tr>
<td>Individual project: Study of a public biomedical signal data base and evaluation of its research objective, signals and interferences/artefacts</td>
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<table>
<thead>
<tr>
<th>Specific objectives:</th>
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<tbody>
<tr>
<td>- To identify different types of biomedical signals, their origins and characteristics</td>
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<tr>
<td>- To understand the different categories of signals, and their types of noise, interferences and artefacts associated of them</td>
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# Filtering for removal artefacts

<table>
<thead>
<tr>
<th>Description:</th>
<th>Learning time: 8h</th>
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<tbody>
<tr>
<td>Digital signals: sampling, Shannon and the Nyquist frequency</td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td>Acquisition device: anti-aliasing filter</td>
<td>Self study: 4h</td>
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<tr>
<td>Z-transform</td>
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<tr>
<td>Time-domain filters</td>
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<tr>
<td>Frequency-domain filters</td>
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<tr>
<td>Filter design</td>
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<tr>
<td>Synchronized averaging and ensemble averaging</td>
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<tr>
<td>Optimal filtering</td>
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<tr>
<td>Adaptive filters</td>
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<table>
<thead>
<tr>
<th>Related activities:</th>
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<tbody>
<tr>
<td>Laboratory session 1: Time and frequency domain filters. Noise and artefact reduction in ECG</td>
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<tr>
<td>Laboratory session 2: Adaptive filtering and synchronized averaging. Maternal vs fetal ECG. ECG interference in trunk EMG signals</td>
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<tr>
<td>Laboratory session 3: Noise in event related potentials. Synchronized averaging of evoked potentials in EEG signals</td>
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<table>
<thead>
<tr>
<th>Specific objectives:</th>
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<tr>
<td>To know, identify and understand different methods for several biomedical signal filtering</td>
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### Detection of events and waves

**Learning time:** 4h  
Theory classes: 2h  
Self study: 2h

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

**Related activities:**  
- Laboratory session 4: QRS detection algorithms: matching filtering and Pan-Tompkins methods  
- Detection of dicrotic notch in arterial pulse signals  
- Laboratory session 5: Detection of first and second heart sounds  
- Detection of epileptic seizures in electroencephalographic (EEG) recordings

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

### Frequency-domain characterization

**Learning time:** 8h  
Theory classes: 4h  
Self study: 4h

**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

**Related activities:**  
- Laboratory session 6: Sleep analysis based on polysomnographic (PSG) data  
- Laboratory session 7: Testing for fatigue in EMG signals. Spectral analysis of heart rate variability

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

**Learning time:** 8h  
Theory classes: 4h  
Self study: 4h

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

### Related activities:
Laboratory session 8: Time-scale and time-frequency analysis of visual evoked potentials (VEP) and heart sounds (PCG)

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

## Coupled Processes, complexity and non-linear dynamical analysis

**Learning time:** 6h  
Theory classes: 3h  
Self study: 3h

### 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.

### Related activities:
Laboratory session 9: Analysis of cardiorespiratory interaction in patients in the weaning process

### 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
### Statistical Analysis of biomedical data

#### Learning time:
- **6h**
  - Theory classes: 3h
  - Self study: 3h

#### 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.

#### Related activities:
- Laboratory session 10 (4 h): Statistical analysis of biomedical data

#### 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.

### Qualification system

Laboratory Reports (pairs): 6x5%
Technical report of the midterm individual data analysis assignment (10 %)
Initial technical report of the small group (3-4) project (15 %)
Oral presentation of the small group project (20 %)
Final technical report of the small group (3-4) project (5 %)
Individual final test (20 %)

### Regulations for carrying out activities

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.
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Bibliography

Basic:


Complementary:


Others resources:

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