UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Ingegneria
ACADEMIC YEAR	2021/2022
BACHELOR'S DEGREE (BSC)	BIOMEDICAL ENGINEERING
SUBJECT	BIOMEDICAL DATA AND SIGNAL PROCESSING
TYPE OF EDUCATIONAL ACTIVITY	B
AMBIT	50296-Ingegneria biomedica
CODE	19354
SCIENTIFIC SECTOR(S)	ING-INF/06
HEAD PROFESSOR(S)	PERNICE RICCARDO Ricercatore a tempo determinato Univ. di PALERMO
OTHER PROFESSOR(S)	
CREDITS	9
INDIVIDUAL STUDY (Hrs)	144
COURSE ACTIVITY (Hrs)	81
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	
YEAR	3
TERM (SEMESTER)	1° semester
ATTENDANCE	Not mandatory
EVALUATION	Out of 30
TEACHER OFFICE HOURS	**PERNICE RICCARDO** Wednesday 08:00 10:00 Stanza 3001, terzo piano Ed. 9, oppure su Microsoft Teams, in entrambi i casi previa prenotazione tramite Portale Studenti Thursday 15:00 16:00 Stanza 3001, terzo piano Ed. 9, oppure su Microsoft Teams, in entrambi i casi previa prenotazione tramite Portale Studenti

DOCENTE: Prof. RICCARDO PERNICE

PREREQUISITES	Notions of Mathematics and Physics II. Basic knowledge of differential and integral calculus. Good knowledge of vector calculus and phasors.
LEARNING OUTCOMES	Knowledge and comprehension capacity: The student will acquire in-depth knowledge of deterministic signal representation and of the corresponding frequency analysis, of the impulse response, of the transfer function of discrete time linear systems, of the design of numerical filters, of the statistical and spectral analysis of random processes. Moreover, the student will acquire basic knowledge of statistical data analysis, in particular regarding descriptive inferential statistics, statistical hypothesis testing and decision theory. The topics of the course will be focused on biomedical data and signal representation. The course will include a substantial amount of laboratory activities employing the MATLAB environment for numerical computing, which will allow the student to fully understand data and signal analysis techniques, to evaluate their peculiarities through numerical exercises, and to exploit their potentialities to extract physiological, biological and clinical information starting from biomedical data and signals. Ability to apply the acquired knowledge: The student will be able to apply the acquired knowledge for the analysis and synthesis of simple continuous- or discrete-time signal processing systems, and will be able to represent a biomedical signal in both time and frequency domains, extracting descriptive indexes of physiological and medical interest. The student will be also able to design numerical filters to perform signal conditioning, to improve the signal-to-noise ratio or to emphasize the oscillations of interest in a biomedical signal. Finally, the student will be able to apply the basic statistical tools to characterize biomedical data and physiological signals, and also to execute the main statistical significance tests to assess physiological alterations and to aid clinical decision. The exercises will stimulate the student's skills to apply the acquired knowledge in the biomedical field, and will favor self-comprehension about the analytical tools studied in the theoretical part of the course. Ability to evaluate scenarios: The student will be able to identify the operational limits of the data information processing techniques studied during the course, and thus to assess their soundness. The student will be also able to estimate, both quantitatively and qualitatively, the performance of processing algorithms and of biomedical software, in order to devise the most suitable strategies and solutions in the application field taken into account. Communication skills: The student will be able to: communicate and express in group projects problems related to the topics covered during the course. The student will be able to sustain conversation on topics related to bioinformatics, he will be able to underline problems related to software operating limits and to offer solutions. Finally, the student will be able to sustain conversation on topics related to biomedical data and signal processing and to computer and IT tools employed in such field. Learning ability: The student will have learned the techniques to employ to process biomedical signals acquired by sensors, and will be able to provide a suitable representation of such signals in time and frequency domains, as well as to extract parameters of clinical and physiological interest. The student will also be able to represent and interpret, from a statistical point of view, biomedical signals of different typologies in the most common applications. This will allow the student to continue the engineering studies in the field of Biomedical Engineering with a greater autonomy and discernment.
ASSESSMENT METHODS	Written exam, Oral exam not compulsory Assessment of learning will be performed through a written exam after the course. The oral exam is not compulsory and does not replace the written exams; the student gains access to the oral exam if he passes the written one (minimum mark 18/30) and wants to improve the mark. All exams (written and/or oral) will be relevant to topics treated during the course. The main goal of the verification is to assess whether the student has a good knowledge of signals (especially biosignals), of the most widely used digital signal processing techniques, of data statistical analysis, and finally of MATLAB codes and algorithms. If the exam is passed the commission assigns a mark on the basis of the level of knowledge acquired (around 50% of the final mark), of the ability to elaborate and interpret the concepts (around 40% of the final mark), and of the capability

	to express concepts in a correct technical language (around 10% of the final mark). The verification of these levels will be favored including in the written exam both theoretical questions and practical exercises. The evaluation will be based on the following criteria: a) excellent (30 – 30 cum laude): the student has very good knowledge of the topics, very high ability to express concepts in technical language, and is fully able to apply independently the acquired knowledge to solve the problems posed; b) very good (27-29): the student has good knowledge of the topics, high ability to express concepts in technical language, and is able to apply the acquired knowledge to solve the problems posed; c) good (24-26): the student shows good knowledge of the main topics, ability to express concepts in technical language, and partial capability to apply independently the acquired knowledge to solve the problems posed; c) satisfying (21-23): the student shows knowledge of the main topics, sufficient ability to express concepts in technical language, and limited capability to apply independently the acquired knowledge to solve the problems posed; d) sufficient (18-20): the student shows minimal knowledge of the main topics and ability to express concepts in technical language, and very limited capability to apply independently the acquired knowledge to solve the problems posed; e) insufficient: the student does not show appreciable knowledge of the main topics, and has poor ability to express concepts in technical language.
EDUCATIONAL OBJECTIVES	The course aims to provide future engineers with the knowledge and the key enabling technologies to enter the Biomedical Engineer profession, with regard to numerical processing of data acquired from biomedical equipment and measurement systems. This course delivers knowledge with regard to: representation of time series obtained sampling continuous signals, and their spectral analysis; design and implementation of numerical filters for discrete time signal processing; statistical description of signals using the concept of stochastic process and its corresponding frequency-domain description using spectral analysis based on classic techniques based on Fourier transform and novel methods based on parametric models; data representation through statistical estimators, and utilization of the most common approaches for statistical hypothesis testing. The main objective of the course is to allow the student to exploit the acquired knowledge by developing and using algorithms within the MATLAB environment. At the end of the course, the student will be able to describe a signal in the time and frequency domains employing both deterministic and statistical approaches, to design a numerical filter and employ it for signal processing, and to extract parameters of interest from the different signal representations. Thanks to the acquired software skills, the student will be able to deal with the most common biomedical signals and to extract physiological information of medical interest from such signals.
TEACHING METHODS	Frontal lectures and tutorials; Laboratory tutorials
SUGGESTED BIBLIOGRAPHY	- Luigi Landini: Fondamenti di analisi di segnali biomedici. Pisa University Press, 2013 - Suresh R. Devasahayam: Signals and systems in biomedical engineering – Signal processing and physiological systems modeling. Springer, 2nd edition, 2013 - Rangaraj M. Rangayyan: Biomedical signal analysis – a case-study approach. IEEE Press Series on Biomedical Engineering – John Wiley & Sons, 2002

SYLLABUS

Hrs	Frontal teaching
3	Introduction to biomedical signals: definition, classification and examples.
2	Continuous and discrete time signals: features and representation. Energy and power of a signal.
6	Spectral signal analysis: Fourier series, discrete and continuous Fourier transform (FT, DFT, DTFT, FFT). Analog-to-digital conversion and sampling theorem.
4	Numerical processing of biomedical signals: convolution, z transform, transfer function
5	Digital filters: definitions, specifications, design methods. FIR and IIR filters.
6	Statistical analysis of biomedical data: probability, random variables, statistical independence; characteristics of a diagnostic test, contingency tables and ROC curves.
5	Statistical estimation: mean, variance, correlation, confidence intervals. Statistical tests and hypothesis testing
2	Time series analysis. Heart Rate Variability: introduction and measurements in time and frequency domain.
3	Statistical analysis of biomedical signals: stochastic processes and their characterization
9	Spectral analysis of stochastic processes: classic and parametric methods.
9	Principal component analysis. Independent Component Analysis

Hrs	Practice
3	Introduction to MATLAB. Graphical User Interface and workspace. Arrays and matrices. Operations with arrays. Files and scripts..

Hrs	Practice
2	Exercises on FFT and convolution.
2	Visualization of zeros and poles of a transfer function.
4	Design of filters and application to biomedical signals (electrocardiogram, photoplethysmogram).
2	Exercises on probability calculation and characteristics of a diagnostic test.
4	Statistical analysis of biomedical data: statistical estimation and tests – application to physiological and clinical data.
6	Spectral analysis of biomedical signals: EEG, heart rate, blood pressure, breath rate.

Hrs	Workshops
4	Experimental acquisition of biomedical signals in laboratory and their processing using MATLAB