MASTER OF SCIENCE IN BIOMEDICAL ENGINEERING

BIONIC SYSTEMS AND NEUROENGINEERING

SSD ING-IND/34 – 6 CFU

Objectives

This course aims at giving to the students a direct insight into the emerging, interdisciplinary research area of Neural Engineering, which stand at the cross-intersection of Bioengineering, Neuroscience and Robotics.
Classes and laboratories will focus on providing the main theoretical, technological and experimental knowledge related to the following main topics: basis of neurophysiology, theoretical and experimental models of human motor control, neural interfaces, robotic and mechatronic technologies for research in neuroscience.
Moreover, at the end of the course students should be able to understand and replicate, working in small groups, a scientific experiment in the field of neural engineering, and to analyze and critically discuss the obtained results.

Expected Learning Outcomes

- Knowledge and understanding: Knowledge of the main anatomical and physiological characteristics of the neuro-muscular system and of the mathematical models that simulate its behaviours; Knowledge of the main technologies employed for the study of the neural system and for its interface with external artefacts.

- Applying knowledge and understanding: capability to apply the studied models to the experimental data acquired on healthy subjects or neurological patients; capability to use the main technologies, available for carrying out experiments on humans, for the study of the nervous system and for its interfacing with artificial components.

- Making judgements: capability to elaborate and evaluate autonomously the experimental data acquired during the scientific experiment replicated in lab, and to discuss the results with respect to the scientific hypotheses of the study; capability to assess and select the most appropriate neural interface for a specific application in the field of bionic systems.

- Communication skills: skills that allow students to clearly explain, using an appropriate technical/scientific terminology, the main concepts taught during the lectures and seminars; capability to present the results of the experimental study they have replicated during the laboratory hands-on sessions in a clear and exhaustive way.

- Learning skills: the scientific methodology provided during the lectures and the lab sessions should allow students to autonomously study and learn new topics in this field, that go beyond what they have been taught during the class lessons.

Prerequisites

None

Contents

Classes and laboratories will focus on the theoretical, technological and experimental aspects related to the following main topics:

• Neurophysiological models: Basis of Neurophysiology, with particular attention to the physiology of excitable cells. Computational models of the neural cells, theoretical description and MATLAB simulations of Hodgkin&Huxley model, open-source simulators (NEURON) of neural connectivity. Neuromuscular models and models of spinal reflexes. (around 14 hours)

• Theoretical and experimental models of human motor control: neurophysiological basis of human motor control, description of the anatomy and function of cortico-spinal pathways, basal ganglia and cerebellum, standard theories on human motor control (equilibrium point hypothesis, minimum jerk and minimum torque-change theories); internal models for learning multiple motor tasks. (around 10 hours)
• Anatomical and physiological bases of brain plasticity. Hebbian plasticity and neural networks. Involvements in learning, memory and recovery from injuries. Study of the methods for functional imaging of the activity and integrity of the brain and of sensorimotor pathways of peripheral nerves: EEG, MEG, fMRI, ENG, EMG, Evoked Potentials. Practice in the Clinical Neurophysiology laboratory. Robotic and mechatronic platforms for research on Neuroscience: Application of robotic systems for the validation of neuroscientific models. (around 6 hours)

• Neural interfaces: Invasive and Non-invasive neural interfaces to the peripheral and central nervous system. Neurophysiological requirements, classification and design criteria of invasive cortical and peripheral interfaces, bi-directional invasive interface and neural stimulation. Case studies of tf-LIFE and TIME systems and other examples of applications of invasive and non-invasive interfaces. Main techniques for the elaboration and data mining of neural signal, extraction of the useful features for the control of neuroprosthesis, computer or other technological devices. (around 6 hours)
• Hands-on sessions in laboratory with the aim of replicating, working in small groups, a scientific experiment in the field of neural engineering, and of analyzing and critically discussing the obtained results. (around 14 hours)

Teaching Methods

This class is composed by a set of 16-17 lectures on the main topics of the course (around 32 hours overall), followed by 1-2 seminars on hot topics by national and international experts of the field (around 4 hours). The last part of the class (1/3 of the total time, i.e. around 14 hours) is done in the NEXTlab at Campus Bio-Medico of Rome to allow students to perform the scientific experiments they have to replicate.

Verification of learning

Students' learning of the educational objectives of this class will be assessed in two steps: (i) first the students are required to present in groups their class project, i.e. the scientific experiment they have been assigned, and discuss the obtained results; (ii) then, an individual oral examination is used to assess students' knowledge about theoretical aspects of the class; the oral examination will be based on at least two different questions of increasing complexity, which will be done by two different examiners. The final grade of the student will be calculated as a weighted mean of the single grades, expressed out of 30 points, of the presentation of the scientific experiment and of the oral examination. For the calculation of the final grade the presentation of the scientific experiment will weight 1/3 of the final grade, while the oral examination will weight for the remaining 2/3.

Texts

Class notes and materials provided by the professor through the institutional e-learning platform: http://elearning.unicampus.it.

Other references:
• Akay M (Ed), Handbook of Neural Engineering, IEEE Press Series in Biomedical Engineering, Wiley/IEEE Press (Vol. I and Vol. II).
• Eric R. Kandel, James H. Schwartz, Thomas M. Jessel, Principi di Neuroscienze, III edizione, CEA Ed.
• Shadmehr R and Wise SP, "Computational Neurobiology of Reaching and Pointing. A Foundation for Motor Learning", MIT Press, Cambridge, MA, 2005.

• Schomer, D. L. and F. L. Da Silva (2012). Niedermeyer's electroencephalography: Basic principles, clinical applications, and related fields, Wolters Kluwer Health.