PhD Program in Bioengineering and Robotics

Curriculum Bioengineering

Research themes

Bioengineering is a discipline that integrates physical, chemical, mathematical, computational sciences and engineering principles to study biology, medicine, behavior, and health.

Bioengineering advances fundamental concepts, creates knowledge from the molecular to the organ systems levels, and develops innovative biologics, materials, processes, implants, devices, and informatics approaches for the prevention, diagnosis, and treatment of disease, for patient rehabilitation, and for improving health and well-being (NIH Working Definition of Bioengineering—July 24, 1997).

The PhD curriculum in Bioengineering implements the evolution of a long-standing tradition of the Bioengineering School of the University of Genova, characterized by a marked *experimental* and *technological* vocation, providing advanced training and research experience for graduate students interested in: *in vitro* electrophysiology, cellular mechanobiology, microscopy, tissue engineering, neural control of the movements, motor learning and neuromotor recovery, as well as neuroengineering, micro- and nano-technologies, assistive and rehabilitation technologies, integrated perceptual systems.

The research activities, mainly conducted at the Department of Informatics, Bioengineering, Robotics and System Engineering (DIBRIS), cover a variety of areas and offers potential collaborations with other departments at the University of Genova, as well as with leading national and international research institutions. This will ensure a unique scientific environment to the students to carry out international research projects.

The main research interests lie within the following broad themes:

- Neuroengineering
- Molecular and cellular engineering
- Interaction and rehabilitation engineering
- Health informatics

The training will start with plans tailored to the need and interests of each individual student and aimed at bringing all students to a common understanding of the key scientific aspects and investigation tools of the different research themes. This will be obtained also by planning exchange of students for 6 to 12 months with national and international laboratories where particularly interesting experimental techniques and/or strategic scientific approaches are well established.

The ideal candidates are students with a higher level university degree willing to be involved in multidisciplinary studies and to work in a team of scientists coming from different background but sharing common objectives. The proposed themes are presented in details in the following indicating tutors and place where the research activity will be developed.

International applicants are encouraged and will receive logistic support with visa issues, relocation, etc.

Mechanobiology of cardiac muscle cells

Tutors: Roberto Raiteri

Department: DIBRIS (University of Genova)
www.dibris.unige.it
Description:
The project aims at investigating electoral and mechanical properties of cells *in vitro*, how such properties influence each other and how they are associated with disease or dysfunction. This would allow a better understanding of the mechanisms of pathogenesis or dysfunction progression, as well as novel disease treatment strategies.
The candidate will focus on the relation between cytoskeleton structure/function of cardiac muscle cells and arrhythmia, a set of heart dysfunctions that can cause sudden cardiac arrest and stroke. The study will be conducted experimentally at the single cell level by integrating different experimental techniques, including atomic force microscopy, optical microscopy, and electrophysiology recording. The candidate is expected to develop new *in vitro* experimental methods and data analysis techniques for the electromechanical characterization of cardiac myocites.

Requirements:
The ideal candidate holds a Master degree in electronic engineering, bioengineering or biophysics and has some practical experience in one or more of the following areas: design of analog electronic circuits, electrophysiology, soft matter mechanical testing. She/he should also be interested in the development of new experimental set-ups.

References:
JF. Saenz Cogollo *et al.* "A new integrated system combining atomic force microscopy and micro-electrode array for measuring the mechanical properties of living cardiac myocytes" *Biomed. Microdevices*, **2011** 13(4), 613-21

J.P. Kerr *et al.* "Detyrosinated microtubules modulate mechanotransduction in heart and skeletal muscle" *Nature Communications* **2015** 6: 8526 doi:10.1038/ncomms9526

G. Caluori *et al.* "Non-invasive electromechanical cell-based biosensors for improved investigation of 3D cardiac models Biosensors and Bioelectronics", *Biosensors and Bioelectronics* **2019** 124, 129-135

Contacts: roberto.raiteri@unige.it

Neuromuscular characterization of human motor behavior

Tutor: Marianna Semprini

Department: Rehab Technologies (Istituto Italiano di Tecnologia), http://rehab.iit.it/

Description: Electromyographic (EMG) recordings enable the characterization of voluntary motor production. Indeed, modular architectures based on muscle synergies have been proposed [1], as well as techniques to infer motor unit recruitment underlying muscular contraction [2]. These methods have been used also for assessing the motor impairment in case of neurologic damage [3] and EMG-derived metrics have been proposed as control signals in robotic based neurorehabilitative treatment [4] and in upper limb prosthetics [5]. However, despite the great amount of proposed EMG-based techniques to describe motor impairment and/or guide neurorehabilitation, none of them is currently employed in the clinical settings. The ultimate goal of this PhD work thus consists in integrating different EMG-based methods in order to provide a unified description of voluntary motor production, both in the healthy and pathological condition, which can be exploited to obtain new biomarkers or to design novel rehabilitation solutions [6]. The PhD activities will include: (i) experiments with healthy subjects, upper-limb amputees and neurologic patients during motor production with and without the support of a robotic device; (ii) software development and data analysis; and (iii) strong collaboration and interaction with our partners. To this end, the Candidate will benefit from a lively network of collaborations with hospitals and research institutions, such as Fondazione Mondino in Pavia, Ospedale Valduce - Villa Beretta in Lecco, Centro Protesi INAIL in Budrio, and Fondazione Don Gnocchi in Milan.
This project requires broad expertise in electrophysiology (i.e. EMG acquisitions and analysis) and a demonstrated expertise in biomedical engineering and software development. The ideal candidate should hold a degree in biomedical engineering or related disciplines, be a highly motivated and creative individual who wants to work in a dynamic, multi-disciplinary research environment. Former lab experience and previous technical and scientific results will be highly considered.

Requirements: Background in bioengineering; proficient programming skills: experience with Matlab/Simulink, C and/or Python for data analysis. Experience with acquisitions of electrophysiological signals from humans. Experience in clinical environment will be taken in high account.

References:

[1] D'Avella, A., Bizzi, E. Shared and specific muscle synergies in naturalmotor behaviors. PNAS, 2005.
[2] Farina, D. et al. The extraction of neural strategies from the surface EMG. Journal of applied Physiology, 2004.
[3] Cheung V.C.K. et al. Muscle synergy patterns as physiological markers of motor cortical damage. PNAS, 2012.
[4] Irastorza-Landa N. et al. Functional synergy recruitment index as a reliable biomarker of motor function and recovery in chronic stroke patients. Journal of Neural Engineering, 2021.
[5] Farina D. et al. The extraction of neural information from the surface EMG for the control of upper-limb prostheses: emerging avenues and challenges. IEEE Transactions in Neural Systems and Rehabilitation Engineering, 2014.

[6] Garro F. et al. Neuromechanical Biomarkers for Robotic Neurorehabilitation. Frontiers in Neurorobotics, 2021.
Contacts: marianna.semprini@iit.it