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.

Building Neuromorphic Brain Twins from Imaging and Electrophysiological Data to Test Electroceutical Strategies

Tutors: Marco Fato

Tutors Affiliation: Dipartimento di Informatica, Bioingegneria, Robotica e Ingegneria dei Sistemi (DIBRIS), Università degli Studi di Genova

Project Description

Stroke and traumatic brain injury (TBI) often result in persistent motor and sensory deficits, despite pharmacological and physical rehabilitation. This PhD project, embedded in a larger initiative on neurostimulation-based recovery, focuses on the creation of a neuromorphic twin, an in silico dynamical model grounded in multimodal brain data, to test electroceutical strategies prior to in vivo application. The twin will be constructed by integrating high-resolution imaging and electrophysiological recordings from rodent models undergoing stroke recovery. Structural and functional MRI will be used to map lesion extent and dynamic changes in brain connectivity. In parallel, high-density electrophysiological data, including local field potentials and spikes, will be recorded via a 512-channel CMOS-based SiNAPS probe [1] spanning cortical and subcortical regions such as the somatosensory cortex, thalamic nuclei, and hippocampus. Data will be acquired under control conditions and at multiple stages post-stroke (up to 4 weeks), enabling the characterization of evolving thalamo-cortical dynamics. Analytical pipelines will correlate neural signals with MRI-derived connectivity and kinematic features from behavior. The ultimate goal is to use these multimodal datasets to inform the development of biologically grounded, neuromorphic dynamical models that replicate architecture and function of the injured brain, providing a powerful platform to simulate, personalize, and refine electroceutical interventions.

Requirements: Applicants should have a background in bioengineering, neuroscience, computer science, or a related field. Proficiency in programming languages such as Python and Matlab is essential. Experience with electrophysiological data analysis, imaging dta analysis, modeling and neuromorphic engineering is highly desirable. Familiarity with machine learning techniques, and real-time computing is a plus.

References

[1] Angotzi, G. N., et al. (2019). SiNAPS: An implantable active pixel sensor CMOS-probe for simultaneous large-scale neural recordings. Biosensors and Bioelectronics, 126, 355-364.

Contacts: marco.fato@unige.it

Biological and digital twins for personalized disease mechanism identification and treatment prediction

Tutors: Monica Frega

Tutors Affiliation: DIBRIS, University of Genova, http://www.dibris.unige.it

Project Description

Human induced pluripotent stem cell (hiPSC)-derived neuronal networks provide a powerful platform to study patient-specific phenotypes and treatment responses. These models, referred to as biological twins, recapitulate key cellular and network-level properties of the patient *in vitro*[1]. However, linking these patient-specific phenotypes to underlying molecular mechanisms and predicting treatment outcomes remains a key challenge. To address this challenge, digital twins (i.e., computational models personalized using experimental data) are designed to reproduce neuronal network activity and link it to underlying molecular and cellular mechanisms[2,3].

This project aims to integrate biological and digital twins to investigate neuronal dysfunction in a patient-specific manner. Neuronal networks derived from patients with neurogenetic disorders will be cultured on micro-electrode arrays (MEAs) to characterize electrophysiological phenotypes and responses to pharmacological treatments. In parallel, digital twins will be developed to reproduce network activity, infer the molecular and cellular parameters underlying the observed phenotypes, and predict responses to pharmacological and/or stimulation-based interventions.

This integrated approach will enable the identification of mechanisms and candidate biomarkers associated with treatment response, supporting more targeted therapeutic strategies.

Requirements: background in bioengineering, physics, computational neuroscience. Attitude toward experimental and computational work. Attitude for problem solving. Interests in understanding/learning basic biology.

References:

1. Mossink, B. *et al*. Human neuronal networks on micro-electrode arrays are a highly robust tool to study disease-specific genotype-phenotype correlations *in vitro.* Stem Cell Reports, 16(9):2182–2196 (2021). https://doi.org/10.1016/j.stemcr.2021.07.001
2. Doorn, N. *et al*. Breaking the burst: Unveiling mechanisms behind fragmented network bursts in patient-derived neurons, Stem Cell Reports, 19, 1583-1597 (2024). https://doi.org/10.1016/j.stemcr.2024.09.001
3. Doorn, N. *et al*. Automated inference of disease mechanisms in patient-hiPSC-derived neuronal networks, Communications biology, **8**, 768 (2025). https://doi.org/10.1038/s42003-025-08209-2

Contacts: monica.frega@unige.it

Neuro AI: brain-organoids as adaptive biological CPUs

Tutors: Sergio Martinoia, Paolo Massobrio

Tutors Affiliation: DIBRIS, UNIGE, https://neuroengineering.unige.it/

Project Description

This project aims to explore the use of human-derived in vitro brain organoids as biohybrid computational systems capable of performing information processing tasks analogous to biological central processing units (CPUs). Brain organoids—three-dimensional neural tissues generated from pluripotent stem cells—exhibit spontaneous electrical activity, synaptic plasticity, and emergent network dynamics resembling early human brain development. By interfacing these living neural networks with microelectrode arrays and machine-learning frameworks, the project seeks to investigate whether organoids can execute adaptive computation, pattern recognition, and energy-efficient learning beyond the capabilities of conventional silicon-based hardware.

The research combines stem cell biology, neuroengineering, artificial intelligence, and bioelectronics to develop closed-loop systems in which neural organoids receive stimuli, process information, and generate measurable outputs. Potential applications include neuromorphic computing, adaptive robotics, drug discovery, and next-generation low-power artificial intelligence architectures. Ethical implications concerning consciousness, sentience, and responsible innovation will also constitute an integral component of the project.

Requirements: Applicants are expected to have a background in (bio)engineering or mathematics or computer science; proficient programming skills: experience with Matlab, C and/or Python for data analysis. Experience on data analysis of neural signals (MUA or LFP recordings) is recommended. Previous Lab experience is a plus.

References:

Smirnova, L., et al. (2023). *Organoid intelligence (OI): the new frontier in biocomputing and intelligence-in-a-dish.* Frontiers in Science, 1, 1017235.

Kagan, B. J., et al. (2022). *In vitro neurons learn and exhibit sentience when embodied in a simulated game-world.* Neuron, 110(23), 3952–3969.e8.

Trujillo, C. A., et al. (2019). *Complex oscillatory waves emerging from cortical organoids model early human brain network development.* Cell Stem Cell, 25(4), 558–569.e7.

Contacts: Sergio.martinoia@unige.it

Paolo.massobrio@unige.it

Adaptive sensory-motor assessment in healthy and clinical populations

Tutor:
Silvio P. Sabatini
Department:
DIBRIS, University of Genova www.dibris.unige.it
Description:
Binocular vision depends on the interaction between sensory mechanisms, which combine the two retinal images into a single percept, and oculomotor mechanisms, which coordinate fixation, saccades, smooth pursuit and vergence. Disruption of either component can lead to amblyopia, diplopia, suppression, strabismus, vergence insufficiency and broader deficits in visual exploration. Current clinical assessments usually rely on separate, repetitive and simplified tasks. Saccades, pursuit, vergence, contrast sensitivity and stereopsis are often tested independently, using artificial and predictable stimuli. Although useful, these protocols may lack ecological validity, be vulnerable to anticipatory strategies, and provide limited insight into the dynamic coupling between perception and eye movements. This also limits the development of coordinated sensory-motor therapies.
This project aims to develop a unified perceptual, oculomotor and computational framework for assessing visual function under dynamic and ecologically relevant conditions. The goal is to move from fragmented, static testing toward continuous, adaptive and integrated measurement of sensory-motor visual behavior. The framework will combine controlled laboratory stimuli with naturalistic and virtual three-dimensional environments. A continuous tracking task will be implemented in binocular space, using version and vergence coordinates. Target motion will be generated stochastically, allowing simultaneous assessment of fixation stability, reactive saccades, smooth pursuit and vergence control while reducing prediction-based strategies. Adaptive psychophysical procedures will modulate stimulus properties, such as contrast, spatial frequency and binocular disparity, according to real-time gaze behavior and perceptual performance. This closed-loop design will allow rapid estimation of contrast sensitivity, stereoacuity, fusional ranges, pursuit gain and latency, vergence stability, and saccadic accuracy and latency within a single experimental flow.
The project will provide efficient tools for quantifying sensory and motor visual deficits in an integrated way, while also clarifying how perceptual and oculomotor mechanisms interact during binocular vision. Although directly relevant to amblyopia, strabismus and vergence dysfunction, the framework may be extended to developmental, neurological, neurodegenerative and aging-related conditions, supporting future gamified and personalized assessment or rehabilitation.
Requirements:
Applicants are expected to have a background in bioengineering, computer science, physics or related disciplines. Attitude for problem solving. Interest in experimental work.
References:

- A. Gibaldi, A. Canessa, and S.P. Sabatini, “The active side of stereopsis: Fixation strategy and adaptation to natural environments,” Scientific Reports 7: 44800, 2017.
- Lesmes LA, Lu ZL, Baek J, Albright TD. “Bayesian adaptive estimation of the contrast sensitivity function: The quick CSF method”. J Vis. 2010 Mar 30;10(3):17.1-21. doi: 10.1167/10.3.17.

Contacts:
Email: silvio.sabatini@unige.it

Development and characterization of novel electro-mechanical stimulation strategies for *in vitro* applications

Tutors: Roberto Raiteri

Tutors Affiliation: DIBRIS, University of Genova, www.dibris.unige.it

Project Description

Recent advances in nanomaterials and biomedical ultrasound have enabled novel strategies for remote, non-invasive cellular stimulation [1]. This research proposes the development and characterization of innovative stimulation techniques based on the synergistic use of low-intensity ultrasound and piezoelectric nanoparticles (e.g., $BaTiO_3$). The core objective is to establish a platform capable of precise and tunable activation of cellular processes in vitro, exploiting the mechanical-to-electrical transduction properties of nanoparticles to convert acoustic waves into localized bioelectric stimuli.

The project will explore the application of this approach in four distinct yet interconnected areas: (a) neuromodulation of neuronal cultures, aiming at controlled excitation or inhibition of neural activity [2]; (b) modulation of neuroinflammatory responses through glial cell stimulation; (c) pacing of cardiomyocytes with spatiotemporal precision; and (d) guidance of stem cell differentiation via localized electromechanical cues. A multidisciplinary methodology will be adopted, integrating nanoparticle functionalization, acoustic field optimization, electrophysiological recordings, and molecular biology techniques.

This research holds promise for the development of non-invasive interfaces for tissue engineering and regenerative medicine, paving the way for next-generation bioelectronic systems and therapeutic platforms. The proposed study will also contribute to fundamental understanding of mechanoelectrical transduction at the cell-nanomaterial interface.

Requirements: attitude toward experimental work involving the development of new setups and procedures.

References:

[1] A. Cafarelli et al., "Piezoelectric Nanomaterials Activated by Ultrasound: The Pathway from Discovery to Future Clinical Adoption," *ACS Nano* (2021) doi: 10.1021/ACSNANO.1C03087

[2] C. Rojas et al. "Acoustic stimulation can induce a selective neural network response mediated by piezoelectric nanoparticles" *J Neural Eng*. (2018) doi: 10.1088/1741-2552/aaa140

Contacts: roberto.raiteri@unige.it

Extended Reality for training caregivers and healthcare professionals in the care of fragile individuals

Tutors: Serena Ricci, Maura Casadio

Tutors Affiliation: DIBRIS, University of Genoa

Project Description

This PhD project aims to develop and evaluate immersive Extended Reality (XR) training environments to support the acquisition of procedural knowledge and non-technical skills for healthcare professionals and caregivers involved in the care of fragile individuals. The project will focus on the design of realistic and interactive XR scenarios addressing complex clinical and relational situations, such as de-escalation of aggressive behaviors in different settings, management of ventilated individuals, palliative care communication, and management of people with neurodegenerative disorders. By combining immersive technologies, intelligent virtual avatars, conversational AI, and simulation-based methodologies, the project will deliver safe, repeatable, and emotionally engaging healthcare simulations to support the acquisition and assessment of procedural knowledge, communication, empathy, stress management, and clinical decision-making skills.

The project can be divided into two specific objectives (SO).

SO1: To design and develop immersive VR training scenarios for the care of fragile people. This SO includes the co-design of clinically relevant scenarios with healthcare professionals and caregivers, the development of virtual environments and interactive virtual avatars, the implementation of procedural and communication-based tasks, and the integration of performance assessment and feedback tools to support both technical and non-technical skill acquisition.

SO2: To evaluate the effectiveness of immersive VR for clinical and educational applications in different caregiving contexts. This SO includes: the validation of realism, usability, and emotional engagement of the developed simulations; the comparison with existing simulation-based methods; the study of their impact on procedural knowledge, communication skills, stress management, empathy, confidence, and clinical decision-making among healthcare professionals, students, and inexperienced caregivers involved in the care of fragile individuals.

The candidate will have the opportunity to work with different clinicians and healthcare institutions. The project will be carried out in collaboration with the THERAlab living lab https://theralab.unige.it/home and the JETS laboratory https://simav.unige.it/en/lab_dibris . THERAlab contributes expertise in rehabilitation technologies, human movement analysis, and assistive systems for fragile populations, while JETS provides expertise in immersive technologies, simulation environments, and interactive digital experiences for training and education.

Requirements: We are seeking applicants with a master's degree in Bioengineering or Computer Science. Candidates should possess programming skills and a strong motivation to work with healthcare providers, caregivers, and people with neurodegenerative disorders. Experience with immersive technologies, conversational AI, or human-centered healthcare technologies design and development would be appreciated.

References:

C.-H. Chou, H.-C. Tai, and S.-L. Chen. The effects of introducing virtual reality communication simulation in students' learning in a fundamentals of nursing practicum: A pragmatic randomized control trials. Nurse Education in Practice, 74:103837, 2024

H. Lee and J. Han. Development and evaluation of a virtual reality mechanical ventilation education program for nursing students. BMC medical education, 22(1):775, 2022.

M. Coduri, A. Calandrino, G. Addiego-Mobilio, M. Casadio, S. Ricci, "RiNeo MR: A mixed reality simulator for newborn life support training". Coduri M., Calandrino A., Addiego Mobilio G., Casadio M., Ricci S., PLOS one 18(12): e0294914, 2023

Contacts: serena.ricci@unige.it, maura.casadio@unige.it

Dynamic modelling of cortical folding through bioprinted 4D constructs: exploration of meccano-cellular interactions in neurodevelopment

Tutors: Laura Pastorino, Donatella Di Lisa

Tutors Affiliation: Department of Informatics, Bioengineering, Robotics and Systems Engineering (DIBRIS), University of Genoa

Project Description

Cortical folding is a distinctive feature of human brain development and is essential for the formation of functional neural circuits. Understanding the biomechanical and cellular dynamics underlying this process is crucial for uncovering the mechanisms of many neurodevelopmental and neurological disorders. Despite advances in computational models and biomaterial-based approaches, integrated knowledge of mechanical forces and cellular behaviors remains limited. Recent innovations, such as brain organoids-on-a-chip, have provided new insights but still fall short in replicating the full complexity and dynamism of cortical folding. In this context, 4D bioprinting and AI-guided smart material design offer unprecedented opportunities to recreate dynamic, physiologically relevant tissue environments. The proposed project will focus on the design and fabrication of multilayered 4D scaffolds that closely mimic the dynamic architecture of the developing human cortex. To achieve this, we will employ AI-guided design of smart materials, particularly thermo- and mechano-responsive hydrogels, capable of undergoing controlled, stimulus-induced deformations. These materials will be engineered into microscale architectures that replicate the laminar organization characteristic of cortical tissue, allowing for spatial patterning of mechanical properties and cellular distribution. External mechanical and chemical stimuli will be applied in a controlled manner to guide tissue development and induce morphogenetic processes, including cortical folding. To characterize and interpret the evolving tissue structures, a comprehensive dynamic and functional analysis will be performed. This will include real-time monitoring through advanced live-cell microscopy, 3D imaging modalities, and electrophysiological recordings to assess both structural and functional maturation of the constructs. Finally, automated data analysis will be conducted using machine learning algorithms to detect and quantify correlations between folding-related mechanical forces and cellular behaviors over time, enabling predictive modeling of neurodevelopmental trajectories.

Requirements: Applicants are expected possess a background in bioengineering/materials science/related disciplines. Attitude for experimental and computational.

References:

1. Gu, Qi, et al. "Functional 3D neural mini-tissues from printed gel-based bioink and human neural stem cells." *Advanced healthcare materials* 5.12 (2016): 1429-1438.
2. Esworthy, Timothy J., et al. "Advanced 4D-bioprinting technologies for brain tissue modeling and study." *International journal of smart and nano materials* 10.3 (2019): 177-204.
3. Soykan, Merve Nur, et al. "Four-Dimensional Printing Technology at the Frontier of Advanced Modeling and Applications in Brain Tissue Engineering." *Journal of Medical Innovation and Technology* 3.2 (2021): 46-57.

Contacts: laura.pastorino@unige.it, donatella.dilisa@edu.unige.it

Hybrid Body–Machine Interfaces for Adaptive Multi-DoF Control of External Devices

Tutors: Camilla Pierella, Maura Casadio

Tutors Affiliation: DIBRIS, University of Genoa

Project Description

Individuals with neurological conditions or limb loss often rely on assistive or rehabilitative technologies to perform functional tasks or engage in therapeutic activities. Their ability to interact with such systems depends on the quality and consistency of the residual motor signals they can generate, as well as on the availability of meaningful sensory feedback. The neuromotor system provides multiple potential control sources—such as kinematic information and electromyographic (EMG) activity — but these signals are frequently affected by weakness, abnormal synergies, fatigue, impaired proprioception, or altered sensory integration. As a result, designing interfaces that can interpret these signals in a stable, intuitive, and clinically meaningful way remains a significant challenge.

This PhD project aims to develop and validate a new class of Body–Machine Interfaces (BoMIs) capable of operating with EMG signals alone, kinematic signals alone, or a combination of the two, depending on the user's motor abilities. A central component of the project is the implementation of effective sensory feedback mechanisms, since feedback is essential for motor learning, error correction, and the stabilization of voluntary control. The overarching goal is to create interfaces that are technically robust and clinically relevant, able to adapt to heterogeneous motor profiles and support functional training even in the presence of fluctuating performance or sensory deficits.

SO1: Develop a hybrid BoMI integrating EMG and kinematic signals with adaptive, feedback-supported control

The first objective focuses on the development of a control interface that can flexibly rely on EMG, kinematics, or both, selecting the most reliable and accessible source of information for each user. The interface will adapt its control parameters based on the user 's performance and motor state, ensuring that the system remains usable even when motor output varies due to fatigue, abnormal synergies, or sensory impairments.

A key aspect of this objective is the integration of structured sensory feedback. Visual, haptic, vibrotactile, or multimodal feedback will be used to help users interpret the consequences of their actions, refine their control strategies, and maintain stable performance over time. The system will be implemented in real time and tested on multi-DoF external devices to evaluate its functional applicability and its potential to support rehabilitation in realistic scenarios.

SO2: Experimentally characterize motor learning and adaptation under different feedback and signal-integration conditions

The second objective investigates how users learn to operate the interface when the available control signals and feedback modalities are systematically varied. The study will examine how individuals adapt when using EMG alone, kinematics alone, or a hybrid configuration, and how different forms of feedback influence the acquisition, retention, and refinement of control. Experimental tasks may include reaching, tracking, navigation, object manipulation, or interactive rehabilitation-oriented activities, allowing for a comprehensive assessment of accuracy, smoothness, stability, efficiency, and compensatory behaviors.

This objective aims to clarify how users reorganize their motor strategies when transitioning between different signal sources, how feedback supports this adaptation process, and which configurations are most intuitive and clinically transferable. The resulting insights will guide the design of adaptive interfaces capable of supporting motor rehabilitation, enhancing engagement, and accommodating diverse motor profiles in both individual and group-based therapeutic contexts.

Requirements:

- Background in biomedical engineering, robotics, movement sciences, sport science, neuroscience, or related fields
- Programming experience (MATLAB, Python, C++ preferred)
- Interest in motor control, human–machine interaction, or rehabilitation
- Experience with EMG and/or kinematic signal processing
- Motivation to work with human participants (healthy, clinical)

References:

1. Pierella C. et al., *Linear vs nonlinear mapping in a body-machine interface based on electromyographic signals*, IEEE BioRob, 2018.
2. Rizzoglio F. et al., *A hybrid Body-Machine Interface integrating signals from muscles and motions.* Journal of Neural Engineering, 2020
3. Rizzoglio F. et al., *A non-linear body machine interface for controlling assistive robotic arms.* IEEE Transactions on Biomedical Engineering, 2023

Contacts: camilla.pierella@unige.it, maura.casadio@unige.it

Tools for connecting to health information systems for the reuse of clinical data for research purposes

Tutors: Prof. Mauro Giacomini

Tutors Affiliation: University of Genova

Project Description

The second-generation electronic health record is being developed throughout Italy, characterized by overcoming the purely documentary vision to make available analytically analyzable data. Similar efforts are being implemented at European level for the creation of the European Health Data Space.

Specific objectives of the doctorate could be:

- Design, implementation and testing of clinical data anonymization tools
- Design, implementation and testing of pipelines, based on natural language processing methods, for the extraction of analytical data from natural language texts, appropriately anonymized with the tools made available in the previous point.
- Identification, development and testing of methods based on artificial intelligence to answer questions of strong clinical interest.

During the doctorate, appropriate case studies will be identified within which the tools described in the previous points will be tested, the validity of which will be assessed with groups of doctors interested in the study.

Requirements:

- STEM master degree;
- Knowledge of at least one of the main programming languages and basic knowledge of the related frameworks for Artificial Intelligence;
- Languages: Italian and English.

References:

D. Stojanov, E. Lazarova, E. Veljkova, P. Rubartelli, M. Giacomini "Predicting the outcome of heart failure against chronicischemic heart disease in elderly population – machine learning approach based on logistic regression, case to Villa Scassi hospital Genoa, Italy" Journal of King Saud University – Science, 2023, vol. 35, Issue 3, pp, 1-12, Id. 102573, doi: https://doi.org/10.1016/j.jksus.2023.102573

S. Mora, D. R. Giacobbe, C. Bartalucci, G. Viglietti, M. Mikulska, A. Vena, L. Ball, C. Robba, A. Cappello, D. Battaglini, I. Brunetti, P. Pelosi, M. Bassetti, M. Giacomini "Towards the automatic calculation of the EQUAL Candida Score: extraction of CVC-related information from EMRs of critically ill patients with candidemia in Intensive Care Units" Journal of Biomedical Informatics, 2024 doi: https://doi.org/10.1016/j.jbi.2024.104667

Contacts: mauro.giacomini@unige.it

Closed-loop non-invasive Brain Stimulation for Motor Learning and Rehabilitation

Tutors: Marianna Semprini

Tutors Affiliation: Rehab Technologies Lab, Italian Institute of Technology www.rehab.iit.it

Project Description

Closed-loop non-invasive brain stimulation (NIBS) systems represent a significant advancement over traditional open-loop approaches, as they dynamically adapt stimulation parameters in real time based on ongoing neural activity. This state-dependent stimulation has been shown to enhance plasticity, reduce inter-individual variability, and improve outcomes compared to fixed-parameter stimulation (Zrenner & Ziemann, 2024).

In the context of motor rehabilitation, where timing-dependent plasticity plays a critical role, closed-loop EEG-NIBS offers a promising alternative to conventional therapies, with the potential to accelerate motor learning and promote functional recovery in neurological conditions such as stroke (Zrenner et al., 2018; Reis & Fritsch, 2011).

The PhD project will be conducted within the Rehab Technologies Lab of the Italian Institute of Technology (IIT), providing access to state-of-the-art facilities and a strong interdisciplinary environment. The candidate will also benefit from an established network of clinical and research collaborators, supporting both the scientific and translational aspects of the project.

Within this framework, the PhD candidate will design and conduct experimental studies in both healthy participants and clinical populations. The main objectives of the project are to:

- Develop and optimize closed-loop algorithms based on motor-related EEG biomarkers, including oscillatory phase, movement-related desynchronization, and error-related potentials.
- Quantify the behavioral and neurophysiological effects of closed-loop stimulation on motor learning dynamics, including learning rate, short-term retention, and EEG markers of plasticity.
- Design and implement rehabilitation scenarios (e.g., stroke, multiple sclerosis and/or upper-limb amputation) to evaluate the effectiveness and translational potential of the approach.

This project will provide rigorous scientific validation of a closed-loop EEG–NIBS framework for motor learning. Expected outcomes include quantitative performance benchmarks, optimized stimulation strategies, and practical guidelines to support the deployment of adaptive neuromodulation systems in both research and clinical rehabilitation settings.

Requirements:

The proposal is open for candidates from bioengineering engineering or computer science. Programming skills such as Matlab are required.

References:

Zrenner, C., & Ziemann, U. (2024). Closed-Loop Brain Stimulation. Biological psychiatry, 95(6), 545–552. https://doi.org/10.1016/j.biopsych.2023.09.014

Zrenner, C., Desideri, D., Belardinelli, P., & Ziemann, U. (2018). Real-time EEG-defined excitability states determine efficacy of TMS-induced plasticity in human motor cortex. Brain stimulation, 11(2), 374–389. https://doi.org/10.1016/j.brs.2017.11.016

Reis, J., & Fritsch, B. (2011). Modulation of motor performance and motor learning by transcranial direct current stimulation. Current opinion in neurology, 24(6), 590–596. https://doi.org/10.1097/WCO.0b013e32834c3db0

Contacts: marianna.semprini@iit.it

AI-Based Methods for the Development of Novel Digital Biomarkers and the Implementation of Precision Rehabilitation Interventions

Tutors: Paolo Bonato[1] and Maura Casadio[2]
Tutor affiliation
[1]Spaulding Rehabilitation Hospital, Harvard Medical School)
[2]Department of Informatics, Bioengineering, Robotics and Systems Engineering — DIBRIS, University of Genova, www.dibris.unige.it)

Company name and link: Spaulding Rehabilitation Hospital https://spauldingrehab.org/locations/spaulding-rehabilitation-hospital

Project Description

Neurological conditions such as stroke, Parkinson's disease, and other disorders affecting motor control require accurate, objective, and continuous assessment tools to support clinical decision-making and personalize rehabilitation. Current clinical evaluations rely heavily on episodic observations and standardized scales administered during hospital visits. However, these traditional methods often fail to capture subtle fluctuations in motor performance, recovery trajectories, or how patients perform functional activities in daily life [1].

To address these limitations, this PhD project aims to develop AI-based methods to extract novel digital biomarkers from multimodal movement data collected during rehabilitation exercises and functional motor tasks [2]. Data sources will encompass wearable sensors, markerless video-based analysis, optical motion capture, and clinical assessments. The research will target clinically meaningful tasks, including gait, upper-limb movements, and activities of daily living.

The core scientific objective is to design robust, interpretable machine learning models capable of continuously quantifying motor impairment, forecasting disease progression, and identifying multimodal movement features associated with functional recovery [3, 4]. Hence, the project will tackle key methodological challenges related to multimodal data fusion, automated movement segmentation, data feature extraction, model generalization across diverse cohorts and clinical settings, and validation against established clinical outcomes [2].

This research will be conducted in close collaboration with clinical and industrial partners to translate AI-driven movement analysis into tools for precision rehabilitation [5]. The long-term goal is to advance adaptive, data-driven rehabilitation technologies where assessment data is used to dynamically tailor intervention parameters to each patient thus leading to optimal clinical outcomes [6].

Requirements

Applicants are expected to have a background in Biomedical Engineering, BioRobotics, Computer Engineering, Data Science, or related studies.

The ideal candidate should have:

- good programming skills, preferably in Python and/or Matlab;
- knowledge of signal processing, biomechanics, movement analysis and machine learning;
- interest in neurorehabilitation, rehabilitation technologies and human movement assessment;
- motivation to work in a multidisciplinary environment including engineers, clinicians, patients and industrial partners.

Previous experience with wearable sensors, computer vision, markerless motion capture, deep learning, clinical data analysis and rehabilitation technologies will be considered a plus.

References

[1] E. R. Dorsey et al., "The First Frontier: Digital Biomarkers for Neurodegenerative Disorders," Digital Biomarkers, 2017. doi: 10.1159/000477383

[2] C. Kanzler et al., "A Data-Driven Framework for Selecting and Validating Digital Health Metrics: Use-Case in Neurological Sensorimotor Impairments," NPJ Digital Medicine, 2020. doi: 10.1038/s41746-020-0286-7

[3] R.Z.U. Rehman et al., "Selecting Clinically Relevant Gait Characteristics for Classification of Early Parkinson's Disease," Scientific Reports, 2019. doi: 10.1038/s41598-019-53656-7

[4] S.I. Lee et al., "Predicting and Monitoring Upper-Limb Rehabilitation Outcomes Using Clinical and Wearable Sensor Data in Brain Injury Survivors," IEEE Transactions on Biomedical Engineering, 2020. doi: 10.1109/TBME.2020.3027853

[5] C. Adans-Dester et al., "Enabling Precision Rehabilitation Interventions Using Wearable Sensors and Machine Learning to Track Motor Recovery," NPJ Digital Medicine, 2020. doi: 10.1038/s41746-020-00328-w

[6] Wang et al., "Closed-loop Rehabilitation of Upper-limb Dyskinesia After Stroke: From Natural Motion to Neuronal Microfluidics," Journal of NeuroEngineering and Rehabilitation, 2025. doi: 10.1186/s12984-025-01617-9

Contact: Email: pbonato@mgh.harvard.edu

Technology-enabled monitoring of people with multiple sclerosis: from clinical rehabilitation to daily life and home-based care

Tutor: Andrea Tacchino[1], Maura Casadio[2]

Tutors' Affiliation: 1NeuroBRITE Research Center, Italian Multiple Sclerosis Foundation (FISM), www.aism.it, 2Department of Informatics, Bioengineering, Robotics and Systems Engineering — DIBRIS, University of Genova, www.dibris.unige.it

Partner / Funding body: Italian Multiple Sclerosis Foundation (FISM).

Project Description

Multiple Sclerosis is a chronic neurological condition characterized by heterogeneous and fluctuating symptoms that may affect mobility, upper-limb function, balance, fatigue, coordination, sensory processing, and the ability to perform activities of daily living. Clinical assessments remain essential for evaluating functioning and rehabilitation outcomes, but they are often episodic and may not fully capture day-to-day variability, subtle functional changes, or the emergence of motor difficulties in real-life contexts.

This PhD project will develop technology-enabled methods for the assessment and longitudinal monitoring of people with Multiple Sclerosis, across the continuum from clinical rehabilitation to daily life and home-based care. The project will focus on the integration of wearable sensors, markerless video-based movement analysis, and digital tools to quantify motor function during clinically relevant tasks and activities of daily living, including reaching, grasping, object manipulation, and upper-limb functional actions.

A central objective of the research will be the identification of digital biomarkers able to describe motor performance, functional limitations, compensatory strategies, and changes over time. Particular attention will be devoted to robust and interpretable movement features that can be used outside highly controlled laboratory settings, supporting more ecological and continuous monitoring of people with MS.

The project will also explore the potential role of technology-mediated sensory feedback in supporting rehabilitation, motor awareness and self-management. Visual, auditory or haptic feedback may be used to guide movement execution, reinforce effective motor strategies, increase awareness of compensatory patterns, and promote engagement during exercises performed in clinical or home-based settings. In this perspective, monitoring is not only considered a passive measurement but also part of adaptive rehabilitation systems capable of providing personalized information to people with MS, clinicians, and caregivers.

The research will involve the design of data acquisition protocols, the development of algorithms for movement analysis and multimodal data fusion, and the validation of digital indicators against clinical scales, functional measures, self-reported outcomes and rehabilitation goals. The expected outcome is a set of technological and methodological tools to support objective assessment, personalized rehabilitation planning and continuity of care for people with Multiple Sclerosis.

Requirements

Applicants are expected to have a background in Bioengineering, Biomedical Engineering, Robotics, Computer Engineering, Data Science, Neuroscience or related study programs.

The ideal candidate should have good programming skills, preferably in Python and/or Matlab, and an interest in human movement analysis, neurorehabilitation and clinical technologies. Knowledge of signal processing, biomechanics, machine learning or computer vision will be considered relevant. Motivation to work in a multidisciplinary environment involving engineers, clinicians, people with MS, caregivers and associations is essential.

Previous experience with wearable sensors, markerless motion capture, video-based movement analysis, rehabilitation technologies, sensory feedback systems or clinical data analysis will be considered a plus.

References

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Contacts:
Email: andrea.tacchino@aism.it; maura.casadio@unige.it