Curriculum: Bioengineering

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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 nanotechnologies, 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.
Sleep maturation in preterm infants

Tutors: Gabriele Arnulfo, Lino Nobili

Tutors Affiliation: DIBRIS, DINOGMI

Project Description

Background: Sleep could be defined as a complex neuroendocrine function in common with many living beings. Among the mysterious functions that sleep absolve, there is its involvement in processes of neuronal plasticity both for nREM (non-Rapid Eye Movement) and REM sleep; in particular, REM stages allow acquisition of adaptive behavioural skills. Sleep is also involved in the reciprocal regulation with both innate immunity and the whole immune response; sleep loss has been related to a systemic proinflammatory state and to brain microglial activation in absence of other neuroinflammatory process.

Moreover, sleep regulates many subcortical signals, including communication between the central (CNS) and autonomic (ANS) nervous systems; a dysregulation of such a coupling has been recognized as marker of negative outcome in different diseases.

Sleep undergoes changes from foetal to adult life, with specific pattern of sleep states typical for age, which are associated with the development, maturation, and connectivity within neural networks. In particular, newborns and infants spend most of their time sleeping an immature REM sleep, conventionally named Active Sleep (AS).

Preterm birth is associated to alterations in sleep patterns and abnormal brain development through a poorly understood mechanism involving neuroinflammation. Future neurodevelopmental problems, including psychiatric illness and sleep alteration itself have to be considered as an outcome of prematurity.

Many questions still remain unanswered about sleep and prematurity, first of all about which impact can have prematurity itself on sleep (and so on brain) architecture in early life, which kind of outcome its alteration can lead and which kind of interventions could be done to prevent unfavourable outcome.

Objective: To relate in Very Low Birth Weight (VLBW) preterm infants ultradian sleep architecture (studied with Polysomnography (PSG) with a particular focus on CNS-ANS coupling) to brain microstructure at term of equivalent age (TEA) and to emotional, executive functional and temperamental outcome at 2 years of age.

Requirements: skills required for the project development.

References:

1. Frank MG, Heller HC. The Function(s) of Sleep. Handb Exp Pharmacol. 2019 Apr 20

Contacts: gabriele.arnulfo@unige.it, lino.nobili@unige.it
Translational neurosensory engineering

Tutors: Andrea Canessa

Tutors Affiliation: DIBRIS, University of Genoa

Project Description

Vision, audition, and touch all code the space around us, or rather the things that are located in the space around us, in a different way. Yet together our senses form a coherent spatial representation of our environment. Information from the different senses is then to be integrated in the central nervous system to build a unified perceptual representation of the world. This process of multisensory integration has been shown to result in a panoply of behavioral benefits, such as faster and more sensitive perceptual discrimination, as well as more accurate and precise localization of stimuli in space. Multisensory function is likely to play a key role in circumstances of sensory loss, in which large-scale brain reorganization typically takes place. In such circumstances, the nonimpaired senses provide redundant information that can supplement the absent or weak cues from the impaired sense. Such benefits provide an important foundation from which to explore the possibility of neurosensory rehabilitation based in multisensory training.

Virtual reality (VR) is an emerging technology which allows for the presentation of immersive and realistic yet tightly controlled audiovisual scenes. In comparison to conventional displays, the VR system can include depth, 3D virtual spatialized audio, fully integrated eye, head, and hand tracking, all over a much larger field of view than a desktop monitor provides. These properties demonstrate great potential for use in neurosensory experiments, especially those that can benefit from more naturalistic stimuli, particularly in the case of neurosensory rehabilitation. Prior work using conventional displays has demonstrated that that visual loss due to stroke can be partially rehabilitated through laboratory based tasks designed to promote long-lasting changes to visual sensitivity. Possible research topics are:

1) to explore how VR can provide a platform for new, more complex, naturalistic, interactive training paradigms which leverage multisensory stimuli.
2) to provides the foundation for future work in rehabilitating sensory deficits, by both improving the hardware and software systems used to present the training paradigm as well as validating new techniques which use multisensory training not previously accessible with conventional desktop displays.
3) to explore how the current technologies and the knowledge about the sensory mechanisms could educate the correct development of sensory faculties, rehabilitate sensory deficits, and assist the diagnosis of sensory disfunctions.
4) to understand the neural mechanisms of multisensory perception and rehabilitation based on a combination of computational models of multisensory interactions with high-density neuroimaging and naturalistic VR-based multisensory perceptual tasks.

Requirements: The successful candidate should have a Master's degree in biomedical science, neuroscience, computer science, mathematics, physics or a related field. In particular, the applicant should demonstrate the ability to acquire relevant skills reasonably fast. They should be willing to perform experiments with human participants. Desirable qualities in candidates include intellectual curiosity, a strong background in maths, skills in programming (e.g., C#, C/C++, Python, Matlab) and signal processing and analysis. Further assets are a creative mind, good problem-solving skills and a collaborative and collegial attitude.

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Rehabilitation for people with Multiple Sclerosis in the era of digital health

Tutors: Andrea Tacchino, Maura Casadio
Tutors Affiliation: Scientific Research Area, Italian Multiple Sclerosis Foundation, www.aism.it; DIBRIS, University of Genoa, www.unige.it

Project Description
Multiple sclerosis (MS) rehabilitation programs should start as soon as possible, be intensive and prolonged, and continue during the different phases of the disease [1]. The advancement of telehealth applications allowed easier achieving long-distance communication, especially in the field of rehabilitation. Indeed, telerehabilitation allows for disease treatment and clinical evaluation by integrating the traditional in-presence patient-rehabilitator interactive approach, covering situations in which it is complicated for patients to reach traditional rehabilitation infrastructures located far away from where they live, and, finally, reducing hospitalization times and costs to both patients and healthcare providers. Overall, numerous MS studies have proven the telerehabilitation effectiveness, especially during Covid-19 pandemic. Internet and teleconferences formats, virtual reality (VR), and gamification seem to be effective, tolerated and safe tools for MS treatment aimed at improving both motor and cognitive functions. Thus, remote communication technologies are options to be considered for people with MS as traditional rehabilitation is less accessible or inaccessible. However, despite the positive effects unveiled by the scientific literature, there are some aspects that need to be addressed in MS telerehabilitation. One main challenge is the definition of a tailored treatment due to the diverse disability levels and personal needs that could be better defined through approaches based on synchronous (i.e. real-time health information delivery during a remote live discussion) supervised individualized interventions. Indeed, most of MS telerehabilitation experiences are asynchronously (i.e. store-and-forward of medical information to a specialist) delivered. The major advantage of a synchronous approach is the efficiency gained by having the opportunity to refine details pertinent to the care episode during the session, by seeking additional information, and in many cases providing a clinical decision or advice within the session, a crucial aspect in MS rehabilitation. The effectiveness of synchronous telerehabilitation services is under debate [2].

The project aims at implementing technologies for the telerehabilitation of the cognitive function in people with MS, specifically, for the assessment of the effectiveness of a synchronous tele- vs. conventional rehabilitation program for the cognitive domain. Moreover, by looking to the future, it will explore the feasibility of new immersive VR tools as an option for cognitive-motor dual-task telerehabilitation [3]. Finally, it will be devoted to design and develop a survey aimed at mapping the telerehabilitation use in the Italian rehabilitation services.

Requirements: administration of cognitive and motor tests; administration of cognitive rehabilitative exercises; abilities to use devices for rehabilitation.

References:
1. European network for Rehabilitation in Multiple Sclerosis. Recommendations on Rehabilitation for Persons with MS.

Contacts: andrea.tacchino@aism.it, maura.casadio@unige.it
Assessment and treatment of fatigability in people with Multiple Sclerosis

Tutors: Andrea Tacchino, Maura Casadio

Tutors Affiliation: Scientific Research Area, Italian Multiple Sclerosis Foundation, www.aism.it; DIBRIS, University of Genova, www.unige.it

Project Description
Multiple Sclerosis (MS) is characterized by a wide spectrum of symptoms including cognitive decline, muscle weakness, spasticity, and excessive fatigue. It seems that the fatigue experienced by people with MS (PwMS) is distinct from the fatigue seen in unimpaired people and clearly carries a major physical and psychological burden, especially when completing everyday tasks.

Fatigability is one of the most prevalent disorder in MS followed by walking, balance and cognitive disorders [1]. However, there are few experimental studies on the effects of fatigability on balance and gait hampering the knowledge of causal fatigue-related changes of walking, balance and cognition.

Nowadays, instrumented systems such as wearable devices and optoelectronic systems are available and can be used to provide quantitative and objective indexes useful to monitor the changes of gait parameters during a fatiguing performance. Moreover, instrumented assessment of patients' performances in dual task paradigms can reveal the possible impact of fatigability on cognitive functions [2].

So far, high intensity functional training has been already used in MS to reduce fatigability. However, the true impact of reduced fatigability on walking, balance and cognition has not been assessed after a fatiguing task making impossible to understand the real impact of treatments focusing on fatigability on these functions.

The project aims: 1) to assess the acute effect of experimentally induced motor fatigability on walking, balance and cognitive functions using an objective instrumented assessment before, during, and after an overground fatiguing walking test [3]; 2) to investigate the effect of high intensity multimodal functional training to improve motor and cognitive disorders.

Requirements: administration of cognitive and motor tests; administration of motor rehabilitation exercises; abilities to use devices for rehabilitation.

References:

Contacts: andrea.tacchino@aism.it; maura.casadio@unige.it
Modeling dialogue between human and digital agents for the personalized stimulation of mnemonic abilities and the support for the evaluation of the progress and assistance of neurocognitive problems

Tutors: Maura Casadio, Luca Brayda

Tutors Affiliation: DIBRIS, University of Genova, www.unige.it, Nextage S.r.l.

Project Description
Large Language Models (LLMs) are attracting more and more attention because they allow digital agents to interact with humans by means of natural language. In the health sector, the topic is of interest because LLMs are well suited for novel approaches that target personalized medicine. For example, people with neurodegenerative conditions often present unique combinations of phenotypes [1], which are difficult to model even during diagnosis; for these persons communication and social interaction are the first means to be irreparably compromised. Recent studies have shown promising results in which textual communication supported by LLMs improves the degree of empathy between two people, one of whom has cognitive problems [2].

The main hypothesis of this project is that the use of conversational artificial intelligence techniques to stimulate a person’s autobiographical memory in a personalized way, provided through a platform usable on mobile terminals, can improve his/her psychological state, measured on anxiety, depression and neuropsychological scales, also digitized and measured via the platform.

The second hypothesis is that it is possible to analyze the type, frequency, style of conversation of the person, on a relatively large amount of data and derived from a regular interaction with a digital agent, to model the type of dialogue between person and agent that more likely leads to improvements in the classic scales related to depression or more generally to self-assessment of quality of life (eg GDS, CES-D, QOL-AD, LSI), used as a gold standard.

If the project is successfully completed, the platform developed and the dialogue models connected to it will allow for a better understanding of how to stimulate a person’s autobiographical memory with the ultimate goal of improving the quality of life. Furthermore, the software and algorithms derived from the experimentation could be made available in the research field and part of these could become an application available on the market.

Requirements:

References:

Contacts: maura.casadio@unige.it, luca.brayda@nextage-on.com
Technologies for assistance and rehabilitation of people with spinal cord injury

**Tutors:** Dr. Antonino Massone¹, Prof. Maura Casadio², Camilla Pierella²

**Tutors Affiliation:** ¹ Spinal Cord Unit, Santa Corona Hospital, ASL2 Savonese, Pietra Ligure, Italy; ² DIBRIS, University of Genoa, website: https://spinalcord-italianlab.it/

**Project Description**

Spinal cord injury (SCI) is a devastating condition that affects millions of people worldwide. It can result in a range of physical, sensory, and cognitive impairments, which can severely impact an individual's quality of life. Advancements in technology have enabled the development of various assistive and rehabilitative technologies that can help individuals with SCI overcome these challenges and regain their independence. Each individual's injury and resulting impairments are unique, and a one-size-fits-all approach to technology is unlikely to provide optimal outcomes. Personalization allows for the customization of technology to an individual's specific needs and preferences, which can improve their overall effectiveness and user satisfaction. It is therefore imperative to identify treatments that can effectively maximize and optimize the recovery of each specific patients' motor functions while considering the limitations of available resources in healthcare facilities and the unique needs of each individual. At the same time it is essential to have complete and objective assessment protocols to deeply characterize motor/sensory impairment following the injury and the relative rehabilitative intervention. Therefore the two main aims of such project will consist in:

**AIM 1** - To identify, validate and adopt functional assessment approaches to thoroughly and precisely evaluate the neuromotor impairments induced by the injury

**AIM 2** – To design, develop, and implement new effective, personalized, and feasible rehabilitation protocols specifically tailored to the personal needs of SCI individuals.

The candidate will spend most of the time working at the SCILab, the joint lab between DIBRIS and Santa Corona Hospital of Pietra Ligure, inside the hospital.

**Requirements:** We are seeking applicants who hold a Master's degree in Bioengineering or a related field, with a strong background in robot programming. Candidates should be strongly motivated to work in a multidisciplinary environment, and should have good social skills to interact with people with a disability. The ability to adapt to new challenges and collaborate effectively with colleagues from diverse backgrounds will also be highly valued.


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Software Architectures for Optimizing Upper Limb Rehabilitation with Robotics

Tutors: Maura Casadio¹, Jacopo Zenzeri²

Tutors Affiliation: ¹ DIBRIS, University of Genova; ² ReWing s.r.

Project Description
People with neurological and/or orthopedic conditions often experience motor dysfunctions and sensory impairments at the upper limbs that have high impact on their quality of life. Robots are promising tools to be used to recover from the abovementioned impairments.

This PhD project aims to exploit these technologies by developing software architectures that permits to optimize rehabilitation protocols and fasten the recovery both in clinical and home settings.

Moreover, the project will involve developing and testing robots for home use and comparing their effectiveness and the engagement of the users without human supervision to traditional in-clinic rehabilitation programs.

Requirements
We are seeking applicants who hold a Master's degree in Bioengineering or a related field, with a strong background in robot programming. Candidates should possess an exceptional problem-solving skills, and a strong motivation to work in a multidisciplinary environment. The ability to adapt to new challenges and collaborate effectively with colleagues from diverse backgrounds will also be highly valued.

References

Contacts
Email: maura.casadio@unige.it; jacopo.zenzeri@rewingtech.com
Closed-loop neuroengineering for electroceutical therapy

**Tutors:** Michela Chiappalone, Federico Barban

**Tutors Affiliation:** DIBRIS, University of Genova, [www.dibris.unige.it](http://www.dibris.unige.it)

**Project Description:** Research institutions and medical companies are investing on neuroengineering to design and develop electroceutical therapies based on neurostimulation to treat brain disorders. Currently, the easiest and most adopted way to stimulate the brain is in open-loop, with no respect of the actual brain state and therefore with suboptimal results. Differently, closed-loop systems, depending on the actual brain state, may improve the efficacy of the therapy and reduce the number of side effects. Nowadays, given the recent advances in recording and stimulation techniques, there is a big demand for high-performance signal processing techniques in both clinical practice and basic research. This PhD project aims at providing the building blocks of novel closed loop systems for neuroengineering applications to deliver electroceutical therapies, also relying on neuromorphic technology. The main objectives of the PhD work include the following topics: (1) Implementing algorithms for real-time processing of multichannel LFP/MUA for in vitro/in vivo experimental models; (2) Developing computational models able to reproduce the electrophysiological activity of in vitro/in vivo systems, to be configured into an FPGA for biohybrid experiments (both open and closed-loop); (3) Contributing to the development of a unified pipeline for offline analysis of neural data, evaluating their performance and interpreting experimental results. All the above activities are part of collaborative work, with the unique opportunity to be involved in experimental sessions, either in partners’ Labs (Mondino, IIT) or in the framework of both national and international collaborations (Un. Bordeaux, Un. Kansas) and funded projects (Galileo, MSCA-IF MorPHEUS, PNNR-RAISE).

**Requirements:** Applicants are expected to possess a proficient knowledge of programming languages such as Matlab, Simulink, Python, and/or C. Experience in FPGA programming, Machine Learning, former lab experience and scientific and technical results will be considered a plus. The ideal candidate should hold a degree in electronic/biomedical engineering or related disciplines, be a highly motivated and creative individual who wants to work in a dynamic, multi-disciplinary research environment.

**References**


**Contacts:** michela.chiappalone@unige.it; federico.barban@unige.it
Intracortical Microstimulation techniques for stroke recovery: a Comparative Study on Neural Dynamics

**Tutors:** Michela Chiappalone, Federico Barban

**Tutors Affiliation:** DIBRIS, University of Genova, [www.dibris.unige.it](http://www.dibris.unige.it)

**Project Description**

**Introduction:** Activity Dependent Stimulation (ADS), a type of closed loop stimulation, has shown promise in the restoration of function after brain damage (Guggenmos et al., 2013). However, the underlying neural mechanisms of ADS therapy in lesioned animals have been studied only during deep anesthesia and are not well understood (Averna, Barban et al., 2023).

Recently, Neural Dynamics analysis techniques have been shown to be a powerful technique to investigate event related neural activity, especially during highly repetitive and stereotyped tasks (Vyas et al., 2020). By extracting task related neural dynamics this project aims to further our understanding of ADS therapy, especially when compared to Open Loop stimulation therapy and controls.

**Methods:** The starting point of the study will involve the analysis of a pre-existing dataset describing 4-week therapy sessions with stroke animal models undergoing ADS therapy. Neural data will be analyzed to study the neural dynamics during the therapy. The results will be compared to those from animals undergoing Open Loop stimulation therapy and controls. Other data acquisition campaigns with rodents and/or non-human primates will be initiated/provided to further evaluate the impact of different stimulation-based therapeutic solutions, also in collaboration with the Kansas University Medical Center. The candidate will have the chance to develop new algorithms for neural data processing interpretation by capitalizing on Neural Dynamics approach but also exploiting new state-of-the art tools such as machine learning and focusing not only on spike but also on Local Field Potentials.

**Expected Outcomes:** This study is expected to provide insights into how neural dynamics evolve during ADS therapy, possibly informing new stimulation strategies. The results will have implications for the development of more effective neural prostheses for the restoration of function after brain damage. The feasibility of translation for human experiments will also be evaluated.

**Requirements:** Applicants are expected to have a background in neural data analysis and basic programming skills (MATLAB/Python).

**References:**

2. Averna, Barban et al., 2023. LFP Analysis of Brain Injured Anesthetized Animals Undergoing Closed-Loop Intracortical Stimulation

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**Correlation of multimodal $^{18}$F-DOPA PET and conventional MRI with treatment response and survival in pediatric-type diffuse high-grade gliomas**

**Tutors:** Marco Fato¹, Giovanni Morana², Arnaldo Piccardo³, Francesco Fiz³

**Tutors Affiliation:** 1 Department: DIBRIS (University of Genova), 2 University of Torino, 3 Galliera Hospital, Genova.

**Description**

Despite recent remarkable genomic discoveries, chemotherapy (CT) and radiotherapy (RT) remain the current standard of care in pediatric-type diffuse high-grade gliomas (PDHGG), providing transient clinical improvement and a limited survival benefit. Positron Emission Tomography (PET) imaging with amino-acid tracers, such as $^{18}$F-dihydroxyphenylalanine (DOPA), is a promising diagnostic tool able to provide non-invasive information of brain tumours, including prediction of disease evolution. Recent studies conducted in collaboration between Giannina Gaslini Children’s Institute and Ospedale Galliera have evaluated diagnostic and prognostic information obtained by $^{18}$F-DOPA PET in children with diffuse high-grade gliomas (both midline and hemispheric), revealing the potential of this imaging modality in providing crucial information for evaluating the metabolism of PDHGG [1-3]. Aforementioned works showed good correlation with $^{18}$F-DOPA PET uptake intensity and extent (PET tumour volume and uniformity) with clinical scores for treatment response and survival.

Along with static parameters measured in such studies, dynamic $^{18}$F-DOPA PET analysis can be exploited to improve even further PET imaging performance in grading assessment and survival prediction of PDHGG[4]. However, in such studies and, more generally, in clinical routine, quantitative markers extracted from PET scans are measured manually by clinicians with limited computer support. This process is time consuming and potentially subjected to inaccuracy and individual variability in measurements. The proposed work aims to apply the principles of radiomics to provide radiologists with a user-friendly computer-aid tool specifically conceived for pediatric PET images. Radiomics refers to the extraction of mineable data from medical imaging and has been applied within oncology to improve diagnosis, prognostication, and clinical decision support, with the goal of delivering precision medicine. Long-term relapses of this work may contribute to the establishment of well-timed, personalized and more effective therapies, aiming to improve overall survival and quality of life of PDHGG patients.

**Requirements:** background in bioengineering, physics, computational neuroscience, computer science. Attitude for problem solving. Interests in understanding/learning basic biology.

**Contacts:** marco.fato@unige.it

**References:**


Advanced computational approaches to preclinical imaging

Tutors: Caterina Montani¹, Antonio Uccelli¹, Marco Fato²

Tutors Affiliation: (1) IRCCS Ospedale Policlinico San Martino, 16132 Genova, Italy; (2) Department: DIBRIS (University of Genova)

Project Description

This Research project aims at developing novel methods of analysis and computational modeling applied to preclinical 7T MRI imaging. MRI technology is largely used in clinics for the diagnosis, prognosis, and monitoring of therapeutic approaches in many fields of medicine, including neuropsychiatric, neuromuscular diseases and oncology¹². The great translational value of MRI data and the low invasiveness favor the use of this technique also at the preclinical level, with the aim of identifying biomarkers and pathological phenotypes in solid, controlled, perturbable and reproducible experimental conditions³. The great variety of data and the complexity of the information they contain require a multidisciplinary and multidimensional approach to the analysis of the results, which includes considerable computational support. Specifically, this project aims to develop advanced techniques for the analysis and processing of anatomical and functional scans, to create predictive models of short and long-term outcomes, to develop simulations and computational tools to improve the interpretation of physiological and pathological mechanisms. Improving our expertise around this technological platform will greatly increase the competitiveness and versatility of our scientific results and will facilitate the translatability of the information obtained to basic and clinical research.

Requirements: background in bioengineering, biophysics and computational neuroscience. Interests in developing new methods and understanding/learning basic biology related to preclinical models. Previous experience on MRI data analysis would be a plus.

References:


Contacts: caterina.montani@hsanmartino.it, marco.fato@unige.it
Development of "Organ-on-Chip" semi-automatic platforms using pumping systems and robotics

Tutors: Maurizio Aiello¹, Silvia Scaglione¹, Marco Fato²

Tutors Affiliation: (1) React4life SpA (www.react4life.com), (2) DIBRIS (University of Genova)

Project Description

The project is about novel organ on chip to be used for drug testing and human disease modeling in vitro. This project includes a period of study and research divided into three phases, in which the candidate, supported by academic and company tutors, will achieve the following objectives:

(I) development and testing of new pumping solutions able to manage 12-24 independent lines of OOC for high-throughput purposes, to maintain a controlled laminar flow connecting multiple organs (1) having flexible distance between them, to manage a new fluid flow pumping system for cell circulation (2). Different types of pumping can be tested including syringe, peristaltic, pressure pumps.

(ii) development and testing of new OOC solutions with micro/macro braiding to manage different technical needs (flows, flow rates, different volumes); in this phase there is also a careful analysis and testing of the components (e.g. pipes, connectors)

(iii) software development to realize the user interface of the pumping system, computational fluid dynamics modeling, CAD modeling of the OOC, as well as software (e.g. python) and electronics (integration, firmware) skills for mechanical and electronic interface of the pump.

Requirements: Degree in Engineering, Maths, Physics or similar.

Contacts: management@react4life.com

References:


Development of advanced clinical data protection techniques to ensure the security and privacy of sensitive information in medical field

Tutor: Mauro Giacomini – Jaime Delgado (Polytechnic University of Catalonia)

Department: DIBRIS (University of Genova)
https://www.dibris.unige.it

Description:
Over the years, the digitalization of clinical and healthcare data has allowed the development and adoption of technological tools, such as the Electronic Health Record (EHR), which allows the patient's clinical information to be consulted, updated and shared, but also to carry out searches in healthcare field. Such data must be managed in a secure and efficient manner, and, for this reason, the protection of patient privacy is essential.

The PhD work will focus on the design and implementation of a clinical data security and privacy system that will consider all elements of the health information system (operating system, computer network, involved software) to improve the efficiency, accuracy, security, and privacy of data management. The system will need to ensure controlled access to sensitive patient data, protecting them from external and internal threats, and ensure compliance with multinational privacy regulations.

Specific objectives of this research will be: 1) examine the security of computer networks and operating systems used for the management of clinical data, trying to identify any weak points and proposing effective solutions to limit the risk of cyber-attacks. 2) Design and development of automatic systems for checking scientific and technical literature to identify possible security risks relating to the world of medical information technology. Tools for the automatic information extraction starting from natural language will be considered. 3) Analyse the impact of EHR on the privacy and security of clinical data, examining the challenges and opportunities offered by this technology and proposing solutions to ensure maximum security of sensitive data.

Requirements:
The ideal candidate holds a Master degree in Bioengineering and has some knowledge in one or more of the following areas: healthcare informatic standards, operating systems, computer networks.

References:


Contacts: Mauro.Giacomini@dibris.unige.it
Application of AI algorithms to bioimaging and medical history data for personalization of diagnostics

Tutor: Mauro Giacomini – Andrea Colombo (EL.CO. S.r.l.)

Department: DIBRIS (University of Genova) - https://www.dibris.unige.it
EL.CO. S.r.l. - https://www.elco.it/

Description:

The ever-increasing availability of large quantities of properly stored medical images closely correlated with the various patient files makes it possible to hypothesize the possibility of applying artificial intelligence algorithms to these medical images and related clinical data in order to develop medical decision support systems based on appropriate quantitative parameters.

Specific objectives of the PhD may be: identification of appropriate case studies; in-depth study with medical experts of these case studies to select appropriate sets of patients; identification on these patients of distinguishing features for differential diagnosis; development of pipelines with artificial intelligence tools to try to correlate the evidence identified in the previous point with the clinical picture; integration of the results obtained within the diagnostic workflow and evaluation of the improvement made to the diagnostic process.

Verification of the implemented algorithms on a dataset of past images for the identification of evidence not detected during the past diagnostic assessment but potentially related to the patient's current pathology.

Requirements:

- STEM Master Degree
- Knowledge of at least one major programming language and basic knowledge of related Artificial Intelligence frameworks;
- Excellent knowledge of Italian and English languages

References:


Contacts: Mauro.Giacomini@dibris.unige.it; andrea.colombo@elco.it
Optimization of the transition mechanisms from Client-Server systems to systems based on services for integration with the regional electronic health record infrastructure

Tutors: Mauro Giacomini, Dario Passi, Massimiliano Murialdo

Department: DIBRIS (University of Genova) - https://www.dibris.unige.it, Libra Sistemi S.r.l.

Project Description

L'evoluzione del fascicolo sanitario elettronico in Italia porterà tutti gli applicativi, anche quelli delle piccole realtà private sanitarie (accreditate SSN/SSR e non), a dover conferire i proprio dati al fascicolo in modalità standardizzata. Per questa ragione, si ritiene che nei prossimi anni molti degli applicativi utilizzati in sanità dovranno subire un'ampia ristrutturazione incentrata principalmente sul passaggio ad architetture a micro-servizi per renderli in grado di colloquiare con i sistemi esterni basato sugli standard HL7 e principalmente i servizi FHIR.

Attualmente molte aziende del settore informatico medico producono e distribuiscono gestionali modulari sviluppati con tecnologie piuttosto datate. Spesso questi applicativi sono volti alla gestione del dato amministrativo e clinico nelle strutture sanitarie private. L'architettura più diffusa in questi applicativi è quella Client-Server (vari applicativi installati sui client della struttura che colloquiano con un database posizionato su server locale). La necessità dell'integrazione con il fascicolo sanitario elettronico è un'occasione senza precedenti per poter effettuare una migrazione verso ambiente WebService per permettere un più agevolmente lavoro dell'utenza remota e per una futura migrazione ad interfaccia Web. A corredo dei precedenti moduli reingegnerizzati, risulta necessario identificare e costituire dei livelli di integrazione che permettano l'integrazione con sistemi terzi negli scenari nei quali, il gestionale software del Cliente, sia costituito da diversi applicativi verticali (es. PACS, di un fornitore, LIS di altro). Di particolare rilievo risultano le integrazioni necessarie con i sistemi esterni (PACS per la gestione immagini di diagnostica, apparecchiature medicali di laboratorio, etc.) e con i sistemi istituzionali quali i fascicoli sanitari regionali (FSR).

Data la localizzazione delle aziende possibilmente coinvolte, gli applicativi verranno testati con particolare riguardo verso i sistemi di fascicolo sanitario di Lombardia, Liguria, Piemonte e Valle d’Aosta.

Requirements: Conoscenza approfondita del linguaggio VB.NET, Esperienza con IIS, WebServices Soap e Rest. Conoscenze di HL7 in particolare in merito alla costituzione del CDA ed alla comunicazione con FHIR. Ottima conoscenza dell'Italiano scritto e parlato. Buona conoscenza dell'Inglese scritto.

References:


Contacts: d.passi@librasistemi.net, m.murialdo@librasistemi.net
Investigation of the interplay between connectivity and dynamics in large-scale hiPSC ensembles

Tutors: Sergio Martinoia, Paolo Massobrio

Tutors Affiliation: Department of Informatics Bioengineering Robotics and Systems Engineering (DIBRIS), University of Genova, https://dibris.unige.it/en

Project Description

Complex network topologies represent the necessary substrate to support complex brain functions. The present project aims at investigating the interplay between functional connectivity [1] of large-scale assemblies derived from human-induced pluripotent stem cells (hiPSC) [2] coupled to high density Micro-Electrode Arrays (MEAs) and the exhibited spontaneous dynamics, i.e., patterns of electrophysiological activity. In particular, the candidate should optimize already existent algorithms to infer functional connectivity and, at the same time, develop new possible computational strategies to characterize the topological properties of \textit{in vitro} network. The observed dynamics will be investigated by checking whether particular functional topologies may promote phenomena like synchronization, emergence of critical phenomena [3]. Exploiting the level of controllability of this kind of neuronal cultures, the expressed dynamics will be evaluated as a function of the excitatory/inhibitory balance as well as their spatial location.

Requirements: background in bioengineering, computational neuroscience, computer science. Interests in understanding/learning basic biology. High level of proficiency of Matlab and/or Python is required.

References:


Contacts: sergio.martinoia@unige.it; paolo.massobrio@unige.it
Brain-on-a-chip models to investigate new therapeutic approaches.

Tutors: Martina Brofiga, Paolo Massobrio

Tutors Affiliation: Department of Informatics Bioengineering Robotics and Systems Engineering (DIBRIS), University of Genova, https://dibris.unige.it/en

Project Description
The human brain is composed of about 86 billion neurons which originate rich and intricate networks. Moreover, neurons are organized in well-defined spatial locations that define clusters of neurons or modules. From a morphological and physiological point of view, each module is composed of specific neurons that differ in shape and function. Each cognitive and motor function is possible thanks to the correct interaction between the different modules. The disruption, loss, or alteration of these connections can produce pathological conditions. To understand how the information is transmitted and computed, we need to investigate the communication among the different modules [1-2]. Another essential feature to comprehend how the electrophysiological signals are transmitted and coded is the three-dimensional (3D) spatial organization of such modules [3]. The 3D microenvironment is fundamental for the correct expression of the neuronal cell phenotypes and for the modulation of the electrophysiological activity patterns. There are different approaches to investigate the transmission of the information: many studies use an in vivo approach but, in this case, it is very difficult to study a specific circuit. If the focus is understanding the effect of a specific module (e.g., the hippocampal one on the activity of the cortical one), we are unable to isolate this specific system in vivo as we cannot sever the connections of the cortex with other brain districts. In this perspective, in vitro engineered models could be a powerful tool: they reduce the complexity of the system, but at the same time they keep the key features of the in vivo environment of the brain, thus ensuring consistent results. The PhD project will combine recent advances in the field of neuroengineering to engineer neuronal networks with the aim to recreate more and more realistic in vitro brain-on-a-chip models to investigate the dynamical properties of complex neuronal circuits. As for future applications, they may be useful for therapeutics and diagnosis, to test new drug delivery protocol in a prolonged or targeted way, but also to identify the cells at the origin of a particular disease (such as cancer). During this 3-years project, the PhD student will be involved both in experimental (choice of the strategy to interconnect neuronal populations, experimental recordings) and computational (development of algorithms to explore the emergent dynamics and the functional topological properties) aspects.

Requirements: background in bioengineering, computational neuroscience, computer science. Interests in understanding/learning basic biology. High level of proficiency of Matlab and/or Python is required.

References:

Contacts: martina.brofiga@dibris.unige.it, paolo.massobrio@unige.it.
2D and 3D engineered neuronal networks

**Tutors:** Martina Brofiga, Paolo Massobrio

**Tutors Affiliation:** Department of Informatics Bioengineering Robotics and Systems Engineering (DIBRIS), University of Genova, https://dibris.unige.it/en

**Project Description**

The human brain is the most complex organ of our body, in which neurons are the interacting elements. These cells are coupled through physical connections and complex biochemical processes. They are able to self-organization and exhibit a rich repertoire of spatiotemporal patterns and dynamics states [1]. However, because of such high complexity, understanding human physiology as well as pathogenesis is not straightforward. Set-ups for *in vivo* studies are often very complicated, time consuming, and with low reproducibility. For this reason, there is the need to develop new *in vitro* systems capable of mimicking as much as possible the human brain. In addition, a successful model would minimize animal use for drug screening applications, deliver a highly reproducible system, and significantly lower costs in light of the current demand for pharmacological development [2].

Primary dissociated neuronal cultures are an elegant yet powerful experimental tool to investigate and describe both electrophysiological and morphological properties of neuronal networks, which guarantee a good trade-off between controllability/observability and similarity to the *in vivo* nervous system. The electrophysiological activity of such neuronal assemblies can be extracellularly recorded by means of Micro-Electrode Arrays (MEAs). Up to now, most of the works make use of homogeneous networks (cf., State of the Art), which do not fully mimic the complex organization as well as the functional and structural complexity of the human brain *in vivo* [3]. The goal of the research project will be to recreate *in vitro* 2D and 3D engineered neuronal networks made up of interacting sub-populations to recreate interconnected brain regions on a chip. During this 3-years project, the PhD student will be involved both in experimental (choice of the strategy to interconnect neuronal populations, experimental recordings) and computational (development of algorithms to explore the emergent dynamics and the functional topological properties) aspects.

**Requirements:** background in bioengineering, computational neuroscience, computer science. Interests in understanding/learning basic biology. High level of proficiency of Matlab and/or Python is required.

**References:**


**Contacts:** martina.brofiga@dibris.unige.it, paolo.massobrio@unige.it;
Large-scale models of neuronal ensembles to characterize the emerging patterns of electrophysiological activity

Tutors: Paolo Massobrio

Tutors Affiliation: Department of Informatics Bioengineering Robotics and Systems Engineering (DIBRIS), University of Genova, https://dibris.unige.it/en

Project Description
Behaviors require interaction with the environment and the contribution of different brain areas depending on the orchestrated activation of large neuronal assemblies. The present project aims at investigating how to effectively interact with neuronal systems by understating the role of the network connectivity in the computational properties of small/large/interacting neuronal networks. In particular, during the three-year research project, different computational network models will be developed and investigated, in order to: i) characterize the spontaneous activity of networks of neurons with different architectures. In particular, 2D uniform/homogeneous networks, 2D interconnected networks made up of few sub-populations (from 2 up to 4), and 3D structures will be taken into account. The observed dynamics will be investigated by checking whether particular configurations may promote phenomena like synchronization, emergence of critical phenomena, interplay between structural and functional connectivity; ii) characterize the stimulus-evoked activity induced by electrical stimulation in networks of neurons with different architectures. It will be investigated whether the evoked responses (i.e., the I/O function) can be modulated by structural connectivity.

Requirements: background in bioengineering, computational neuroscience, computer science. Interests in understanding/learning basic biology. High level of proficiency of one of the following sw (Matlab, C++, Python) is required.

Reference:


Contacts: paolo.massobrio@unige.it
3D in vitro model of Parkinson’s disease

Tutors: Laura Pastorino, Donatella Di Lisa

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

Project Description
The present project aim at developing a 3D in vitro model of PD for drug screening applications. To this aim, a biopolymeric hydrogel, mimicking the main characteristics of the extracellular matrix of the brain, will be developed and used to encapsulate neuronal cells differentiated from patient induced pluripotent stem cells. The developed model will be characterized morphologically by immunostaining techniques and functionally by microelectrode arrays for the recording of the electrophysiological activity. Moreover, important intracellular parameters, such as lysosomal pH, will be monitored in real time by using silica based-microsensors. The developed platform will be used for the screening of molecules candidate to reduce alfa-synuclein agglomerates.

Requirements: Applicants are expected possess a background in bioengineering/materials science/related disciplines. Attitude for problem solving. Interests in experimental work in the lab.

References:

Contacts:
laura.pastorino@unige.it
donatella.dilisa@edu.unige.it
3D bioprinting of living materials

Tutors: Laura Pastorino, Donatella Di Lisa

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

Project Description
The present project aim at developing 3D bioprinting strategies for the fabrication of living materials based on microalgae for environmental and biomedical applications. To this aim, bioinks specific for the encapsulation of plant, bacterial and mammalian cells will be developed to be used with commercial 3D bioprinters. For environmental applications 3D membranes encapsulating microalgae will be developed for the purification of wastewaters from heavy metals ions. For biomedical applications, 3D constructs encapsulating, in well-defined and separated areas, both mammalian and plant or bacterial cells will be developed for photosynthetic supported oxygenation of mammalian cells.

Requirements: Applicants are expected possess a background in bioengineering/materials science/related disciplines. Attitude for problem solving. Interests in experimental work in the lab.

References:

Contacts:
laura.pastorino@unige.it
donatella.dilisa@edu.unige.it
A computational analysis of early vision function in silico networks of LIF neurons

Tutor: Silvio P. Sabatini

Tutor Affiliation: DIBRIS, University of Genova

Project Description

One approach to understanding the implications of the initial stages of visual processing is ideal observer analysis, which evaluates the information available to support psychophysical discriminations at various stages of the early visual representation. Computational models of early processing typically rely on simple linear contrast-encoding assumptions, which do not account for many second-order phenomena. Accordingly, many details remain underrated, and their implications on functional vision not fully understood. By example, let’s think about asymmetries in the responses to brightness and darkness of the cells of ON and OFF pathways, which extend to neuronal spatial receptive fields and temporal properties. The project aims to implement neuromorphic multi-layer networks of leaky integrate and fire (LIF) neurons in cascade to a motorized event-based camera, as artificial replicas of the early stages of vision system for explaining and predicting visual performance in arbitrary natural and laboratory visual tasks. Models with be tested under multiple and varying parameters and in adaptive conditions. At functional level, the system will (1) consider the neural resources required to account for a range of linear/nonlinear early visual processes, and (2) provide the inference engines for relating the resulting visual representations to performance on psychophysical tasks. The visual performance of the resulting silicon model will be comparatively assessed with that of typical a human observer.

The objective is twofold: on the one hand, we contribute a deeper understanding of visual processes, especially about predicting how early computations may reverberate through the sensory pathways eventually contributing to functional vision. On the other hand, we contribute to a new generation of seeing machines which will bring about breakthroughs in AI systems and profound societal and economic changes.

Requirements: Applicants are expected to: (1) have a Master’s degree in Bioengineering, Computer Science, Physics or related disciplines, (2) have a keen interest in Vision Science and in Artificial Intelligence, (3) have good programming skills in at least one language (MATLAB, C/C++, Python, C#), (4) work well in group problem solving situations, (5) have intermediate communication skills (oral and written in English). Experience in neural modeling is a plus.

References:


Contact: silvio.sabatini@unige.it
Pass-through vision systems: continuous perceptual calibration strategies in augmented and impoverished reality

Tutors: Silvio P. Sabatini, Antonio Novellino

Tutors Affiliations: DIBRIS, University of Genova; ETT S.p.A.

Project Description

According to the implemented see-through paradigm, augmented reality (AR) head mounted displays (HMDs) can be classified as video pass-through (VPT) or HMD optical see-through (OST). In standard OST-HMD, direct vision of the real (3D) environment is augmented through the projection of artificially generated contents on semitransparent displays in front of the user’s eyes. Conversely, in VPT-HMD vision of the environment is mediated by one or two external cameras, which are anchored to the headset. The acquired images are coherently merged with additional VR contents and eventually rendered in the head mounted displays. Several psychophysical studies have analyzed the undesired perceptual effects of possible incoherencies in focus/accommodation cues, as well as of re-mapping of the different fields of view of real and virtual cameras, which might generate distorted perception of depth, visual fatigue and discomfort due to vergence-accommodation conflicts, and degradation in oculomotor response. The proposed research aims to develop perceptual calibration procedures derived from geometric models and from the characteristics of the human visual system to predict perceptual errors during the use of HMDs in pass-through mode and to determine perceptually correct visualization parameters. The research topic grounds on the results of a recent collaboration with ETT S.p.A., under the regional project REALTER (https://realter-project.eu/) that evidenced potentiality and limitations of the use of VPD-HMDs as medical assessment and assistive technologies.

The activity envisages: (1) the definition of a standard procedure for the functional characterization of a 3D viewer (in video see-through mode), (2) the development of automatic correction procedures which allow for the elimination of optical distortions and perceptual alterations with respect to an optical see-through theoretical model.

A training period abroad is foreseen at the School of Optometry of UC-Berkeley.

Requirements: Applicants are expected to: (1) have a Master’s degree in Bioengineering, Computer Science, Physics or related disciplines, (2) have a keen interest in Vision Science and in Augmented Reality, (3) have good programming skills in at least one language (MATLAB, C/C++, Python, C#), (4) work well in group problem solving situations, (5) have intermediate communication skills (oral and written in English). Experience in Unity 3D is a plus.

References:


[5] https://www.youtube.com/@realter2997/featured

Contacts: silvio.sabatini@unige.it, antonio.novellino@ettsolutions.com
Robotic agents and patient digital twins for personalized cognitive and neuromotor rehabilitation

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

Project Description:
Upper limb neurorehabilitation after a cerebrovascular accident (stroke) typically relies on high-dose, task-oriented training of the impaired arm. Robot-mediated interventions (eg weight support, assisted movements) have been moderately successful in facilitating recovery. Various processes have been implicated for recovery – among others, motor learning, increased strength, higher dose, increased motivation – but their mechanisms of action are largely unknown and likely depend on individual impairment [1].
The overall goal of this research is to develop and test in a clinically relevant scenario a novel concept of patient-adaptive robotic agent, with a built-in capability to play ‘rehabilitation games’, ie to understand the patient’s type and degree of impairment and its temporal evolution, and to establish forms of interaction which optimally facilitate recovery in a natural and intuitive way, also helping to unveil the underlying mechanisms.
The robot control architecture will build upon previous experimental and computational work on the development of interpersonal coordination [2] and human-robot coordination [3]. It will include a multi-level model of the patient’s actions and intentions and their temporal evolution – patient digital twin (PDT) and will be capable to establish collaborative or competitive forms of interaction. During a rehabilitation session, the robot will interact (visually and haptically) with the patient. Using optimal estimation and advanced machine learning, it will continuously monitor type and degree of impairment, and will facilitate recovery by engaging the patient in collaborative or competitive games that selectively promote the use of the impaired functions.
Research activities will specifically include PDT design and characterization, the development of techniques for continuous adaptation to individual impairments, and the selection mechanisms for the optimal interactive scenarios which best support recovery. In a series of feasibility studies involving subacute and chronic stroke survivors, the device will be tested with to demonstrate its capability to establish a stable and accurate PDT and to trigger an effective recovery.

Requirements: Background in biomedical engineering and/or robotics; Interest in neural control of movements, computational motor control and rehabilitation technologies.

References:

Contacts: vittorio.sanguineti@unige.it
Mobile applications for remote training to contrast cognitive decline

Tutors: ¹Vittorio Sanguineti, ²Maria Cristina Novello

Tutors Affiliation: ¹DIBRIS, University of Genova); ²Center of Cognitive Disorders and Dementia, Galliera Hospital (Genova)

Project Description: An estimated 15-20% of persons over 65 years exhibit signs of mild cognitive impairment (MCI). A person with MCI has a greater risk of developing Alzheimer’s disease or other forms of dementia [1]. Lifestyle, regular exercise and cognitive stimulation may reduce the risk of cognitive decline and dementia. Many standardized therapist-mediated tests and cognitive stimulation protocols exist, but remote monitoring based on mobile applications would allow a more timely detection of signs of impairment. The general objective of this research is to develop novel mobile solutions for monitoring and contrasting cognitive impairment – in particular, attention, executive functions, memory, language and executive functions – of persons with symptoms of cognitive decline [2]. A specifically designed smartphone application will be used to administer a variety of cognitive training exercises. The app will store performance information into a cloud-based repository. A therapists’ front-end, monitors users’ performance and allows to modify their training schedule to best fit the individual needs. The mobile application will enrich the professional relation between user and therapist, by adapting to the specific cognitive needs and by providing a tailored support based on clinical evidence. Research activities will include extending the app with new functionalities, and using machine learning and statistical models to characterize the relation between cognitive functions and exercise performance. A pilot trial involving outpatients from the center of cognitive disorders and dementia (CDCD) of the Galliera hospital, will test usability, user experience and acceptance of the solution. A later, more comprehensive clinical trial will look at whether and how app-based training affects the natural evolution of cognitive functions [3]. The final expected outcome is a general, comprehensive, clinically validated solution, which will be routinely offered to CDCD outpatients and integrated with electronic health records. The approach will be extended to other populations at risk of deteriorating cognitive conditions.

Requirements: Background in biomedical engineering; Interest in cognitive functions and probabilistic models. Expertise in development of mobile applications (Java) and network (cloud) services would be a plus.

References:

Contacts: vittorio.sanguineti@unige.it
Development of novel quantitative diagnostic methods to be applied in anatomic-pathology

Tutors: Roberto Raiteri (DIBRIS), Valerio Gaetano Vellone (DISC)


Project Description

The objective of this project is to develop novel techniques and methods to measure directly or indirectly quantitative biomarkers that can support the pathologist in the diagnostic/prognostic evaluation of tissue biopsies.

In particular, two research questions will be investigated: 1) can histological specimens recapitulate the mechanical properties of healthy and pathological fresh tissue? 2) do topographical and mechanical features of sample surface at the nanometer scale carry useful information to evaluate the pathological state of a tissue biopsy?

Research will be carried by means of atomic force microscopy and optical microscopy as well feature extraction techniques. Specific pathologies will be addressed as case studies to validate the proposed methods.

Requirements:

- degree in bioengineering or biophysics
- attitude toward experimental work
- interest in developing/implementing data analysis (feature extraction) algorithms

References:


Contacts: roberto.raiteri@unige.it valerio.vellone@unige.it
Advanced Clinical Evaluation of Lower Limb Prostheses

Tutor: Marco Freddolini, Marianna Semprini

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

Description: Learning how to effectively and confidently use a new prosthetic device is a process which might take considerable time and effort to lower limb users, especially if it comprises pattern actions that have yet to be learned [1, 2], which is a fundamental step for understanding the real potential of a new prosthesis. In addition to the standard biomechanical evaluation, which comprises motion analysis and muscular activity assessment [3], further parameters need to be included to measure other factors such as embodiment, confidence (trust), fatigue, cognitive effort, among others [1, 2, 4].

The ultimate goal of this PhD work consists of evaluating new lower limb prostheses developed by our group, which have been already validated in a pilot trial. For this, it will apply advanced measures for assessing mental aspects such as cognitive effort [2], embodiment and trust [1], and the level of physiological compliance in the use of the device, such as physical effort, motion and muscular activation patterns.

The PhD activities will include: (i) developing of a clinical protocol to evaluate lower-limb amputees; (ii) reviewing of methodology for mental and physiological aspects evaluation; (iii) data analysis; and (iv) close collaboration and interaction with our partners.

To this end, the Candidate will benefit from a lively network of collaborations with hospitals and research institutions, in particular with Centro Protesi INAIL in Budrio, national reference center for prosthetics. This project requires broad expertise in biomechanics (i.e. motion capture system, EMG signals) and a demonstrated expertise in biomedical engineering and attitude to interact with patients. 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 human acquisitions with EMG and/or motion capture system. Experience in clinical environment will be taken in high account.

Contacts: marco.freddolini@iit.it, marianna.semprini@iit.it

References:


Functional Electrical Stimulation for Neurorehabilitation

Tutor: Marianna Semprini

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

Description: Functional electrical stimulation (FES) consists in the stimulation of an intact lower motor neuron to activate plegic or paretic muscles in a precise sequence and magnitude so as to directly accomplish or support functional tasks [1]. The usefulness of this technique for the recovery of motor functions is now widely recognized, for example in case of accidental brain trauma and stroke, and specifically to enhance voluntary muscle strength and reduce spasticity. It has been shown that cortical re-organization takes place following FES intervention. FES has thus been clinically used to promote the recovery of voluntary motor production either as assistive device or as therapeutic intervention [2].

FES has been used in combination with robotic devices, such as exoskeletons [3] or in neuroprostheses where motor intentions extracted from central (i.e., EEG or intracortical neural activity) or peripheral (i.e., EMG) signals are translated into FES patterns, which actively move the limb.

The ultimate goal of this PhD work consists of investigating new neurorehabilitation scenarios based on the use of FES, in combination with robotic devices developed in the lab and/or with electrophysiological recordings.

The PhD activities will include: (i) the development of different neurorehabilitation protocols; (ii) the execution of pilot tests, including the collection of kinematic and electrophysiological data; (iii) data analysis for assessing the validity of the tested protocols; (iv) the execution of clinical trials with neurologic population.

To this end, the Candidate will benefit from a lively network of collaborations with hospitals and research institutions, in particular with Fondazione Don Carlo Gnocchi and Ospedale Valduce Villa Beretta. This project requires broad expertise in biomechanics (i.e., motion capture system), FES, electrophysiological recordings (i.e., EMG), and a demonstrated expertise in biomedical engineering and attitude to interact with patients.

Requirements: Background in bioengineering; proficient programming skills: experience with Matlab/Simulink, C and/or Python for data analysis. Experience with human acquisitions with EMG and/or motion capture system. Experience in clinical environment will be taken in high account.

Contacts: marianna.semprini@iit.it

References:


Neuromodulation for training of prosthetic users

Tutor: Marianna Semprini

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

Description: Myoelectric hand prostheses offer a promising solution for restoring hand functionality after upper limb amputation [1]. They use electromyographic (EMG) data from stump muscles to decode user’s motor intentions for device’s control [1]. However, the training process is time-consuming and requires large amount of data, impacting in device performance and user’s adoption.

It has been demonstrated the potential of non-invasive brain modulation techniques, such as transcranial electrical stimulation (tES), to enhance cognitive performance and motor learning. Implementing this technique during prosthetic user training could potentially improve the learning process, enhance embodiment, and reduce prosthesis abandonment for both traditional and machine learning-based control strategies.

This PhD project aims to enhance the learning process of prosthetic users by promoting neuroplasticity using non-invasive brain modulation. The project will focus on the Hannes hand, a poly-articulated myoelectric prosthesis developed jointly by IIT and INAIL.

The main objectives of this PhD projects are:

- To identify new training strategies for the HANNES hand applying tES, and utilizing neuroimaging techniques such as EEG and fMRI to investigate the modulation of body cortical representation. This will involve designing training protocols that incorporate brain cortex neuromodulation during specific training phases.
- To evaluate the effectiveness of these strategies in improving prosthetic use, acceptance, and facilitating the embodiment process. This evaluation will include comparing subjects’ performance in standardized tests with the prosthetic hand at different stages of training.
- To evaluate the effectiveness of these strategies in cortical representation changes. This evaluation will include the analysis of brain signals before and after training.

The candidate will collaborate closely with hospitals and research institutions, particularly Centro Protesi INAIL in Budrio, a renowned national center for prosthetics.

Requirements: Background in biomedical engineering, neuroscience or related disciplines and a demonstrated ability to interact with patients. The candidate should be highly motivated, creative, and thrive in a dynamic, multi-disciplinary research environment. Previous experience in neurophysiological signals, lab skills and scientific achievements will be highly valued in the selection process.

References:


Contacts: marianna.semprini@iit.it