PhD Program in Bioengineering and Robotics

Curriculum Bioengineering

Research themes

1. Sleep maturation in preterm infants ................................................................. 3
2. Translational neurosensory engineering ......................................................... 4
3. Decoding the neurophysiology of locomotor control in Parkinson’s disease .................................................................................................................. 5
4. Bi-directional body machine interface for assistance and rehabilitation .................................................................................................................. 7
5. New Technologies in medical simulation .......................................................... 8
6. Anthropomorphic technology for regaining motor or cognitive abilities: relationship between form and function from prosthetics to humanoid robotics .................................................................................................................. 9
7. Closed-loop technologies for neuroengineering applications .................................. 10
8. Dynamic 3D tissue models .................................................................................. 11
9. Development of a standardized Natural Language Processing platform to support clinical researches ........................................................................ 12
10. Design and realization of an inkjet printed Micro-Electrode Array for neurophysiological applications.......................................................... 13
11. Brain-on-a-chip for precision medicine ............................................................ 14
12. *In vitro* interconnected brain regions coupled to Multi-Electrode Arrays: towards a brain-on-a-chip .................................................................................. 15
13. Development and characterization of biopolymeric nanoformulations having antibacterial properties ........................................................................ 16
14. Atomic force microscopy based techniques in medical diagnostics: new tools for translational medicine .......................................................... 17
15. Perceptual and motor issues in the development of interactive intelligence .................................................................................................................. 18
16. Joint action in humans and robots ..................................................................... 20
17. Unobtrusive wearable sensors for advanced biomedical applications ..................... 21

In the spirit of the doctoral School on Bioengineering and Robotics, the goal of the “advanced and humanoid robotics” curriculum is to study the design, realization, programming and control of anthropomorphic and legged robots. Students will work at the forefront of mechatronics and computer science research jointly covering the full development cycle from software to mechanical design and from machine learning to realization of sensors, actuators and electronics. We address the development of the technologies for the next generation of robots for sensing, actuation and computation. The goal is to develop robots that can adaptively interact with their environment, learn from their mistakes, and succeed in performing safely and reliably in real-world environments. Foreseen applications for anthropomorphic robots range from real-world practical scenarios - e.g., at home, as personal assistants- to industry as co-workers, to natural or man-made disaster scenarios. Humanoid robot software deals with vision, audition and tactile perception as well as the ability to look, reach and manipulate the world while walking freely to reach their targets, interacting naturally with the environment and their human “teachers”.

The PhD themes in this curriculum are offered by research lines that are part of the Robotics research domain and whose laboratories are located in Genova at the Center for Convergent Technologies and Center for Robotics and Intelligent Systems of the Istituto Italiano di Tecnologia (IIT). IIT’s laboratories are equipped with state-of-the-art robotic platforms which include collaborative robots (e.g. Panda from Franka Emika, Kuka LBR iiwa), fully-legged humanoid robots (e.g. iCub, R1, Walkman) as well as legged systems (e.g. CENTAURO, HyQ).
International applicants are encouraged and will receive logistic support with visa issues, relocation, etc.
1. Sleep maturation in preterm infants

Tutor: Gabriele Arnulfo, Lino Nobili

Department: DIBRIS, University of Genova [www.dibris.unige.it] DINOGMI, University of Genova

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: The successful candidate should have a Master’s degree in biomedical science, neuroscience, computer science, mathematics, physics or a related field.

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

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

Tutor: Andrea Canessa

Department: DIBRIS, University of Genova, www.dibris.unige.it

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 (MSI) 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.

Possible research questions are:

- how we create a full perception of space (at 360° and in depth) thanks of a space variant (3D) multisensory integration;
- how our senses differently interact one each other;
- how multisensory interactions between vision, audition, and touch are affected by the region of space in which information happens to be presented.
- 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;
- how to understand the neural mechanisms of multisensory perception based on a combination of computational models of multisensory interactions with high-density neuroimaging and 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.

Contacts:
Email: andrea.canessa@unige.it
3. Decoding the neurophysiology of locomotor control in Parkinson’s disease

Tutor: Andrea Canessa

Department:
https://www.dibris.unige.it/
https://www.hci.uni-wuerzburg.de/
https://www.wurzburg-neuroscience.de/isaias
https://www.parkinson.it/centro-parkinson.html

Description: Gait disturbances are a common and severe problem of Parkinson’s disease (PD) poorly responsive also to advanced treatments, like deep brain stimulation (DBS). Freezing of gait (FOG) is a peculiar gait derangement in PD and it is characterized by the inability to produce effective stepping causing falls, mobility restrictions, and poor quality of life. The pathophysiology of FOG is still unclear also because of the episodic and unpredictable nature that greatly challenges its recording and evaluation. Virtual Reality (VR) can overcome this limitation by replicating real-life situations triggering FOG in a controlled environment.

The study proposed [eventually also as Joint-PhD program with the University of Würzburg] aims to investigate the supraspinal locomotor control in patients with PD and FOG through a novel and integrated multimodal approach. In particular, we will collect detailed neurophysiological recordings of corticosubcortical dynamics (with hdEEG and implanted electrodes for DBS), biomechanics measurements, including surface electromyography, and functional and molecular brain imaging data (i.e. fMRI and FDG PET). Gait analysis will be performed in several VR environments recreating the situation of real-life usually triggering gait freezing. A computational model of the pathological dynamics of the locomotor circuits will merge all these complementary results for future personalized treatments. In the context of neurorehabilitation and neuromodulation, VR technology will foster the delivery of meaningful and patient tailored therapies promoting motor functional recovery.

Requirements: The successful candidate should have a Master’s degree in biomedical science, neuroscience, computer science, mathematics, physics or a related field. 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.

Selected references:
Contacts: andrea.canessa@unige.it
4. Bi-directional body machine interface for assistance and rehabilitation

**Tutor:** Maura Casadio

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

**Description:** People with a neurological disease or amputation must learn to operate assistive or rehabilitative devices—such as a computer, a prosthesis or a robotic system—by mapping the available body abilities, as residual movements or muscle activations, onto device control signals. The neuromotor system offers different signals and degrees of freedom to attain specific motor goals in a variety of different ways. This is a resource, providing for a high level of dexterity. But at the same time, it is also a computational challenge to overcome for achieving efficient control of devices or prostheses. In addition to motor dysfunction, absence or alteration of somatosensory feedback induce specific and identifiable motor and neural alterations, influencing the ability to perform daily living activities by controlling assistive technologies. This research project aims at generating the knowledge necessary for developing a new class of customized body machine interfaces (BMIs) based on the user's sensorimotor abilities.

The work will pursue three general objectives:

(i) To develop new technology and algorithms to record and translate body-derived signals into BMI commands, based on the individual characteristic of each subject.

(ii) To design and implement adaptive BMI algorithms, accounting for the evolving abilities of the user and the actual assistive/rehabilitative goals to attain or tasks to perform.

(iii) To develop and test new sensory stimulation technologies and techniques to encode feedback information on the subject’s state of motion and on the interactions with the environment, enabling also training or enhancement (i.e. 'sensory enhancement or substitution') of somatosensory abilities.

Based on their background and preference, candidates can focus on any combination of these specific objectives.

**Contacts:** maura.casadio@unige.it
5. New Technologies in medical simulation

Tutor: Maura Casadio

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

Description: Simulation in medicine is a field growing and changing over time. This is mainly due to the technological innovation affecting medicine. Furthermore, medical procedures update frequently, and professionals need to follow such renovation. Also, the application of disruptive technologies as 3D printing, Artificial Intelligence, Internet of Things, Augmented and Virtual Reality (AR, VR) are changing medical training and practice, and require new technical figures in simulation.

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

SO1: Build new medical simulators. Starting from educational needs of medical students, instructors and healthcare providers, it will be required to build new physical prototypes of medical simulators, both from a hardware and a software perspective. This may include modelling; 3D printing; electronic components placement; software implementation (spanning from code to collect data from sensors, up to graphic user interfaces and VR); synchronization of hardware and software.

SO2: Definition of metrics and experimental protocols to assess the usability and efficacy of different prototypes. Specifically, subjective feedback on the user experience will be evaluated and combined with behavioral (e.g., performance scores, movements) and biological (e.g., electromyography, electroencephalography) data to:

(i) validate the new systems;
(ii) compare new prototypes with existing tools;
(iii) investigate the learning processes underlying medical learning.

Currently, the joint lab for emerging technology in simulation is carrying out research studies on: low-cost gynecological trainers; VR-based basic and advanced life support training; surgical training by using haptic devices; development of an open-source, realistic, customizable and accessible driving simulator to train and assess driving ability of people with sensorimotor disability. According to the candidate’s interest different field can be investigated.

References


Contacts: [maura.casadio@unige.it](mailto:maura.casadio@unige.it)
6. **Anthropomorphic technology for regaining motor or cognitive abilities: relationship between form and function from prosthetics to humanoid robotics**

**Description**
The main objective of this project is to investigate and develop solutions for anthropomorphic systems promoting the recovery of impaired or lost motor and cognitive functions. The project aims at analysing the relationship between form and function of these solutions with a particular focus on for two different applications:

- Humanoid robotics for assistance and rehabilitation of people with sensorimotor and cognitive disabilities due to specific pathologies or aging.
- Prosthetics, focusing on low cost solutions.

Info & tutor aziendale: Emanuele Micheli micheli@scuoladirobotica.it
7. Closed-loop technologies for neuroengineering applications

Tutor: Michela Chiappalone

Department: DIBRIS, University of Genova [www.dibris.unige.it]

Description: Research institutions and medical companies are investing on neural engineering technologies to design and develop bioelectronic therapies based on neurostimulation to treat brain disorders. The easier 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, by means of the following sub-objectives: (1) Implementing algorithms for real-time processing of LFP/MUA for in vitro/in vivo; (2) Providing a rapid-prototyping, model-based design architecture for closed-loop on hardware-based devices, also in commercial systems; (3) Developing innovative data analysis tools 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 international collaborations (Un. Bordeaux, Un. Kansas) and funded projects (MathWorks, Galileo, MSCA-IF MorPHEUS).

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: Email: michela.chiappalone@unige.it
8. Dynamic 3D tissue models

**Tutors:** Marco Fato, Silvia Scaglione

**Department:** DIBRIS, University of Genova

**Description:** The goal besides this research work is to investigate the healthy/pathological cells response to different 3D matrix-based microenvironments cultured either in static condition or under fluid dynamic stimuli, better resembling the in vivo scenario.

The effects of different bioactive stimuli (e.g. mineral components, proteins functionalization) will be modeled and experimentally studied to identify the optimal matrix where cells may growth in vitro with high reliability and effectiveness. These engineered cell-based tissues will be then adopted to recapitulate disease models in vitro, by using bioreactors, where the systemic administration of traditional or immune-based therapies against specific disease models will be implemented.

The student will focus on i) the computational fluid-dynamic simulations (CFD) of the fluid motion within the bioreactor and the drug/mass transport kinetic within the circuit and the 3D tissue model, respectively, ii) the design and realization of 3D tissue realization (gel manufacturing and cells culture), iii) the analysis of cells crosstalk and response to specific chemo-physical stimuli. The work will be constituted also by microscopy analysis (optical microscopy and fluorescence confocal microscopy) and consequent images post-production and data analysis.

**Requirements:** The ideal candidate holds a Master degree in bioengineering, chemical engineering, biotechnology and has some practical experience in one or more of the following areas: CFD, material science, cell biology.

**References:**


**Contacts:**
Email: marco.fato@unige.it
9. Development of a standardized Natural Language Processing platform to support clinical researches

Tutor: Mauro Giacomini

Department: DIBRIS, University of Genova, Genova, www.dibris.unige.it

Description: Over the years Electronic Health Records have become a key source of important information for both patient care and biomedical research. It mainly contains structured data, which can be easily accessed and queried, but that is not the only way to collect them. Clinical texts such as discharge summaries and progress reports, that contain rich clinical information of patients, are entered by medical staff in free texts fields. For this reason, developing systems that automatically extract relevant information from clinical narratives is essential.

In this context Natural Language Processing (NPL) becomes an enabling technology to support clinical research and application, it allows not only to pull out specific information of interest, but it can also automatically extract relations between important clinical entities such as diseases, drugs and laboratory tests.

On the other hand, another key instrument in clinical data collection is the use of standardized vocabularies that support the semantic interoperability between hospital information systems and all the informatic instruments used for research. An example of this is the conduction of multicenter studies that need to coherently compare clinical trials’ data from different hospitals. The overall aim of this proposed research is to design and develop a standard terminology management service that, using NLP, extracts important information from clinical narratives. The research will be applied to several medical branches, such as infectious diseases, oncology, microbiology, and neurology. Specific objectives of this research will be:

- Design and development of specific interfaces for terminology systems jointly based on the definition of Common Terminology Service by HL7 and OMG (Release 2, CTS2) and FHIR resources and their application in the above cited fields.
- Recognition of all the most important NLP tools for the biomedical scenario taking into consideration both the English-speaking context and the other Indo-European languages.
- Design and development of specific NLP tools for the above cited applications.
- Integration of these tools in standardized data management platforms in order to develop decision support systems for the mentioned clinical fields.

Requirements: Applicants are expected to have good skills in data management and in coding with managed languages. Knowledge of the main standards at format level and at semantic level in the medical informatic field is also welcome.

References:

Contacts: Email: mauro.giacomini@dibris.unige.it
Design and realization of an inkjet printed Micro-Electrode Array for neurophysiological applications

Tutors: Sergio Martinoia, Andrea Spanu

Department: DIBRIS (University of Genova) [http://www.dibris.unige.it](http://www.dibris.unige.it)

Department: DIEE (University of Cagliari), [http://dipartimenti.unica.it/ingegneriaelettricaedelettronica](http://dipartimenti.unica.it/ingegneriaelettricaedelettronica)

Description: Organic Electronics has attracted considerable attention during the past years, thanks to the possibility of developing advanced electronic systems on highly flexible plastic substrates using cost-efficient fabrication technologies. In particular, organic devices and materials can be properly tailored in order to develop highly specific sensing tools that, to date, have been widely employed for the realization of different kinds of bioelectronics devices and systems.

The main idea behind this project is to employ an ink-jet device to realize an innovative, low-cost and multi-parametric organic-based sensing array. The sensors will be fabricated by using solution processable materials and possibly by inkjet or other printing approaches, with the aim of obtaining a highly flexible and low cost lab-on-chip device capable of detecting at the same time different bio-chemical cell-related inputs such as electrical activity, pH variations, temperature and other stimuli that could be of interest in the neurophysiological field.

Requirements: background on bioelectronics and material science. Interest in understanding and study the physics of devices.

References:


Contacts: sergio.martinoia@unige.it; andrea.spanu@unica.it;
11. Brain-on-a-chip for precision medicine

**Tutor:** Sergio Martinoia

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

**Description:** We are interested, in general, in investigating how computational properties emerge in 2D and 3D neuronal populations in a human model in which iPSC (induced Pluripotent Stem Cells) derived neurons are used. The final aim is to develop a brain-on-a-chip platform to study how information processing and transmission is related to the properties of neuronal networks. In this project we propose to develop a systematic and controlled experimental approach for investigating the dynamics of 2D (as a control) and 3D neuronal networks coupled to innovative high-density devices by means of advanced analysis tools. We plan to extensively characterize and compare 2D and 3D neuronal cultures by means of electrical and chemical stimulation. In addition, we will also characterize the 3D structure by means of optical (confocal) microscopy and immunofluorescence techniques. Within this framework we seek at developing a new in-vitro and automated system for neuropharmacology tests and on a long-term perspective a tool for precision medicine. In the last part of the project we foresee to challenge our experimental models with chemical substances and to study the electrophysiological response with respect to specific parameters (biomarkers).

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

**References:**

**Contacts:** [sergio.martinoia@unige.it](mailto:sergio.martinoia@unige.it)
12. **In vitro** interconnected brain regions coupled to Multi-Electrode Arrays: towards a brain-on-a-chip

**Tutor:** Paolo Massobrio

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

**Description:** The brain is a complex system characterized by the presence of different neuronal populations (e.g., cortical, hippocampal, thalamic neurons) which interact following well-defined principles of connectivity [1, 2]. Nonetheless, brain is truly three-dimensional (3D), and such a spatial organization deeply influences the emergent electrophysiological activity [3]. This PhD project will combine Multi-Electrode Array (MEA) technology with *ad hoc* techniques (patterning, microfluidics) to engineer neuronal networks for coupling different neuronal populations (in a 3D fashion) to a MEA with the aim to recreate interconnected brain-regions-on-a-chip. Since the complexity of the brain, the use of simplified *in vitro* experimental models is a strategic choice to understand more in details the relationships between connectivity and dynamics, as well as to provide insights to understand pathologies which damage the interactions among neuronal populations (e.g., Parkinson disease which involves the cortical-thalamic circuit). 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. Part of the activities will be in collaboration with the spin-off ScreenNeuroPharm ([www.screenneuropharm.com](http://www.screenneuropharm.com)) and with the Swiss company 3Brain ([www.3brain.com](http://www.3brain.com)).

**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:** paolo.massobrio@unige.it
**13. Development and characterization of biopolymeric nanoformulations having antibacterial properties**

**Tutor:** Laura Pastorino

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

**Description:** The hospital environment represents an important source of pathogens responsible for infections with high transmission risk. In addition, the formation of biofilms on surfaces allows microorganisms to multiply, to exchange antibiotic resistance genes with other bacteria and increases their survival. In this context, nano-engineered green formulations will be developed. The nanoformulations will be based on biodegradable and biocompatible polymeric nanoparticles functionalized with enzymes, having antibiofilm activity and antibacterial plant extracts. To this purpose biopolymeric nanoparticles will be produced, functionalized and characterized.

**Requirements:**  
Background in bioengineering, materials science, chemistry, physics or related disciplines. Attitude for problem solving. Interests in experimental work in the lab.

**References:**  

**Contacts:**  
Email: laura.pastorino@unige.it
14. Atomic force microscopy based techniques in medical diagnostics: new tools for translational medicine

Tutor: Roberto Raiteri

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

Description: Anatomical pathology is a branch of medicine that studies microscopic changes caused by diseases in cells and tissues of the human body. This is routinely done in hospitals using well consolidated microscopy techniques in order to provide a diagnosis for many pathologies. We want to develop novel methods and techniques to investigate the effects of selected diseases on human tissue and cells at the nanometer scale. The rationale is that by scaling down the investigation to the nanometer (i.e. molecular) scale, where the biochemical reactions responsible for the disease happens, it will be “easier” (i.e. more evident) to understand the mechanisms responsible for the development of the pathology and detect it at an early stage. The goal of the project is to provide novel quantitative methods and techniques that can complement existing ones in anatomical-pathology and support the anatomopathologist in the formulation of the diagnosis. Such methods and techniques will be based on state of the art atomic force microscopy instrumentation and will provide a topographical, mechanical, and biochemical characterization of tissue biopsies at the nanometer scale. Having a translational medicine target, the procedures and methods will have to be compatible with the clinical practice. Indeed the work will be conducted in close and continuous collaboration with the medical doctors of the “Unità Operativa” in anatomical pathology of the San Martino hospital in Genova. With whom the pathologies to focus during the project will be selected and who will provide the samples and the fundamental clinical feedback of the work of the PhD candidate.

Requirements:
Applicants are expected to hold a degree in engineering or physics and some practical experience in one or more of the following areas: laboratory work using measuring instruments, image and data analysis, mechanical properties of soft materials. She/he should also be interested in the development of new experimental methods and instruments.

References:
2. L. Peñuela et al. *Experimental Dermatology* 27(2): 150-155, 2018

Contacts:
Roberto.raiteri@unige.it
15. Perceptual and motor issues in the development of interactive intelligence

Tutor: Silvio P. Sabatini and Vittorio Sanguineti

Department: DIBRIS (University of Genova)

Description: Interaction is essential not only to understand the purpose of an intelligent system (in a closed loop with the external environment), but also to formalize and solve, from a computational point of view, the problem of the collection and organization of sensory information, according to efficiency and efficacy criteria. Human perception originates from (physical) interaction with the external environment. Interaction allows us to gain sensations about the world’s physical properties and enables a flexible development of specific brain functionalities.

Within this framework, a PhD research project is available on the following specific theme:

Functional models of blindsight
While in classical AI-based autonomous systems sensing is usually ancillary to the control of the action, in humans the conscious perception of objects and situations develops as an important and independent component of cognition. Experimental findings of blindsight studies [Goodale and Milner, 1992] suggested the existence of two parallel vision systems (“vision-for-action” and “vision-for-perception”), postulating dedicated and specialized cortical streams of visual processing originating in striate (V1) cortex: a dorsal, action-related “unconscious” stream and a ventral, perception-related “conscious” stream. The two streams must interact at some level as we are capable of deciding a course of action on the basis of what we consciously see. A reciprocal interstream interaction, i.e., adapting and modulating how we see the world on the basis of action, is more elusive and might subtend an interaction between conscious and unconscious sensory processing, which also includes information on the agent’s state.

In this project, the goal is to elucidate this point by investigating how the non-semantic (body-related) information provided by the vision-for-action stream can be used to develop a semantic (i.e., abstract) interpretation of reality (world). Experimental, modeling, and theoretical approaches might be pursued with a different accent according to personal attitude. The role of blindsight will be eventually assessed to design and validate systems, tools, and procedures for the diagnosis, re-education, conditioning and therapy of disorders in the developmental age and in the elderly, or associated to pathologies or neurological damage.

Keywords: Plasticity of perception; Predictive coding; Sensory-sensory and sensory-motor expectations; Decision making.

Requirements: background in bioengineering, computer science, physics or related disciplines. Attitude for problem solving.

References:

Contacts: silvio.sabatini@unige.it, vittorio.sanguineti@unige.it
16. Joint action in humans and robots

Tutor: Vittorio Sanguineti

Department: DIBRIS (University of Genova)

Description: Coordinating our actions with others – joint action - is pervasive in our daily life (e.g., talking, dancing, singing, working, or playing sports). To establish a joint action, we need to understand (and to account for) our opponent’s actions and intentions. Personal traits, emotions, short- and long-term goals also contribute to shaping the interaction. The ability to interact with humans is also a key requirement of artificial agents and robotic devices. In many application domains, robots need to share their workspace and possibly establish physical contact with humans, but effective interaction requires more than ensuring safety or contact stability: truly interactive agents should understand the actions, intentions, and possibly emotions of their human counterparts, and to continuously modify their actions by accounting for both short-term goals, like completing a task, and long-term aspects, like promoting skill learning in their human counterpart.

The general objective of this research is to understand the mechanisms of motor cognition during interaction with other humans, and to transfer these skills to ‘artificial partners’. Specific objectives include, but are not limited to: (i) understanding how humans interpret their opponent’s intentions and use this information during joint action; (ii) unveiling the mechanisms through which an expert may transfer his/her skill to a naïve partner. These goals will be addressed through a combination of experiments, computational models and the development of novel robot devices. In newly designed experimental paradigms involving sensorimotor interaction between pairs of humans (dyads) - both healthy subjects and persons with sensorimotor or cognitive impairments (e.g., stroke, Parkinson, autism spectrum disorders, schizophrenia) will allow to characterize interaction in terms of movement kinematics, exchanged forces, muscle and neural activity. These studies will be complemented with computational models based on differential game theory, which will be used to predict interaction strategies and to capture the mechanisms through which they are achieved. Models will be used to design ‘artificial partners’ and to apply them to human-robot interaction scenarios like robot-assisted skill learning and rehabilitation.

Keywords: joint action, differential game theory, computational motor control, rehabilitation robotics.

Requirements: Background in bioengineering; Interest in neural control of movements and computational motor control. Experience with data analysis and robot control would be a plus.

References:

Contacts: vittorio.sanguineti@unige.it
17. Unobtrusive wearable sensors for advanced biomedical applications

Tutors: Danilo Pani, Annalisa Bonfiglio

Department: Dept. of Electrical and Electronic Engineering, University of Cagliari, http://dipartimenti.unica.it/ingegnerielettricaedelettronica/

Description: Wearable sensing is a growing research field. The advancements of the research on electroconductive polymers now allow the selective functionalization of a textile substrate to create electrodes, electrochemical and mechanical sensors. The lack of adhesion of these sensors to the skin, especially when used in dry conditions, and the nature of the substrate, limit the field of applications of textile sensors. More recently, ultra-conformable sensors based on nanofilms, usually referred to as “tattoo electrodes”, are entering the physiological sensing arena, opening hitherto unthinkable applications, thanks to their incomparable adhesion without electrolytes, conformability able to follow the skin wrinkles, transparency and light weight. The aim of the proposed research theme is to develop, study and characterize wearable sensors based on ultra-conformable substrates, for advanced biomedical applications where the unobtrusiveness of the monitoring, the substrate conformability, its comfort and/or its transparency are essential qualities. The impact on the personalized medicine will be also investigated. Main application areas of interest are high-density EMG, invasive and non-invasive ECG, biomechanical sensing. Specific applications will require the adoption of advanced signal processing and machine learning tools for the processing and automated analysis of the signals gathered from these sensors, e.g. for prosthetic and assistive devices.

Requirements: background on physiology, electrophysiology and bioengineering methods. Proficiency in the use of Matlab for signal processing, basic knowledge of machine learning and digital microarchitectures. Attitude for laboratory activity, including development of devices and their validation.

References:

Contacts: danilo.pani@unica.it; annalisa.bonfiglio@unica.it