PhD Program in Bioengineering and Robotics

Curriculum Cognitive Robotics, Interaction and Rehabilitation Technologies

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In the spirit of the doctoral School on Bioengineering and Robotics the PhD Program for the curriculum “Cognitive Robotics, Interaction and Rehabilitation Technologies” provides interdisciplinary training at the interface between technology and life-sciences. The general objective of the program is to form scientists and research technologists capable of working in multidisciplinary teams on projects where human factors play a crucial role in technological development and design.

The 7 fellowships offered this year by the Istituto Italiano di Tecnologia as part of this curriculum will be assigned to the best applicants to one of the 10 themes offered by three Units: i) the Robotics, Brain and Cognitive Sciences Unit (RBCS); ii) the Unit for Visually Impaired People (U-VIP), and iii) the Unit COgNiTive Architecture for Collaborative Technologies (CONTACT). Themes No. 7 and No. 8 will be tutored jointly with colleagues of the Department of Informatics, Bioengineering, Robotics and System’s Engineering (DIBRIS) of the University of Genova. Interested applicants are encouraged to contact the perspective tutors and/or the Unit’s PI for clarifications before submitting their application.
All units involved in this curriculum are located in the “Erzelli” site of the Italian Institute of Technology and share research facilities including a fully equipped motion capture room with simultaneous electromyography recording and force-platforms, a Transcranial Magnetic Stimulation Lab, an Electrophysiology Lab for EEG recording and meeting rooms.

The ideal candidates are students with a higher level university degree willing to invest extra time and effort in blending into a multidisciplinary team composed of neuroscientists, engineers, psychologists, physicists working together to investigate brain functions and realize intelligent machines, rehabilitation protocols and advanced prosthesis.

**International applications are encouraged and will receive logistic support with visa issues and relocation.**

A brief description of the Units Involved and their overall objectives are given below.

**RBCS Unit: Robotics, Brain and Cognitive Sciences**  
(Prof. Giulio Sandini – giulio.sandini@iit.it)

In RBCS we are merging top-level neuroscience research and top-level robotics research by sharing, as a fundamental scientific objective, the study of physical and social interaction in humans and machines [www.iit.it/rbcs](http://www.iit.it/rbcs). The research activity is articulated in three main streams:

i) The study of human sensorimotor and cognitive abilities with a focus on action execution and understanding;

ii) The implementation of sensorimotor and cognitive abilities in the humanoid robot iCub with a focus on human–robot cooperation and symbiosis;

iii) The exploitation of assistive technologies to alleviate sensory disabilities and the implementation of robotic rehabilitation devices with a special attention on user requirements and strict clinical assessment.

A factor, common to all three streams is learning and development and, in general, the dynamics of knowledge acquisition and update.

Besides the humanoid platform iCub and the support of professional electronic and mechanical design, RBCS research facilities include haptic devices for ergonomic measures of individual and dyadic interaction, haptic devices that exploit visuo-tactile sensory substitution, binaural acoustic feedback platforms, robot rehabilitation devices for the upper limbs including the wrist. This infrastructure supports our students’ research activities including the realization of ad-hoc experimental set-ups and mechatronic devices.

RBCS research activity is articulated into four Laboratories:

1. Motor Learning, Assistive and Rehabilitation Robotics (Jacopo Zenzeri, Pietro Morasso);
2. Cognitive Robotics and Human-Human Interaction (Francesco Rea)
3. Dynamic Touch and Interaction Lab (Gabriel Baud-Bovy)
4. Spatial Awareness and Multisensory Perception (Luca Brayda)
U-VIP: Unit for Visually Impaired People
(Dr. Monica Gori – monica.gori@iit.it)

The main aim of the unit is to identify spatial impairments possibly conditioning the life of children and adults with and without visual disability, with the ultimate goal to develop new technological solutions suitable since the first years of life to overcome impairments and enhance learning skills.

In particular the focus of the group is:

i) to investigate how integration between sensory and motor signals develops during childhood and identify solutions (technologies and rehabilitation procedures)

ii) to enhance the sensorimotor abilities necessary to orient and move in space, to communicate, to access everyday information and, therefore, to interact in social contexts

iii) testing and validating with human-centered techniques the devices (friendly and ergonomic) developed by considering social and clinical contexts.

CONTACT Unit: COgNiTive Architecture for Collaborative Technologies
(Dr. Alessandra Sciutti – alessandra.sciutti@iit.it)

The aim of this unit is to overcome the limitations of current human-machine co-working, where often machines and humans just work in the same space, to obtain a novel form of collaboration, in which the two partners can actually perform joint actions, establish mutual understanding and achieve real cooperation. To this aim, it is crucial to endow robots with the same degree of predictivity and intuition that characterizes humans, enabling them to understand and adapt to the other’s feelings, goals and needs. To achieve this goal, we focus on the investigation of the human perceptual, motor, and cognitive skills supporting efficient interaction. In particular, we also exploit robots as unique measurement tools for the systematic study of social interaction. The research is conducted within the framework of the ERC StG project wHiSPER – Investigating Human Shared Perception with Robots.

The research activity is articulated into two main streams

i. The investigation of the mechanisms supporting mutual understanding in human-human and human-robot interaction, with a focus on identifying the minimal verbal and non-verbal signals necessary to enable intuitive communication;

ii. The implementation on the iCub humanoid robot platform of the derived models, to validate the theories, and bring forward a new generation of adaptive technologies, able to support and assist non-expert users.
1. **Touching to interact and communicate**

**Tutors:** Dr. Alessandra Sciutti, Prof. Giulio Sandini

**Istituto Italiano di Tecnologia**

**Research Units: RBCS & CONTACT**

[http://www.iit.it/rbcs](http://www.iit.it/rbcs)

[https://www.iit.it/it/research/lcognitive-architecture-for-collaborative-technologies](https://www.iit.it/it/research/lcognitive-architecture-for-collaborative-technologies)

**Description:** Humans are very good at interacting and collaborating with each other. This ability is based on mutual understanding and is supported by a continuous exchange of information mediated only in minimal part by language. The majority of messages are covertly embedded in the way the two partners move when interacting. It is this silent, movement-based flow of information that enables a seamless coordination. Although extended research has been dedicated to the investigation of non-verbal communication mediated by vision, the domain of intuitive communication mediated by touch has been less explored. This research project focuses on the role of touch in interaction, both in human-human and in human-robot scenarios. Starting from an analysis of how active touch is exploited and controlled in the interaction with the environment, the investigation will then identify the properties specific to touch aimed to interaction with others. The potential differences between tactile interaction with humans and humanoid robots will be investigated. The collected data will be used to model the tactile interaction strategies, in order to enable a robot to understand and send appropriate tactile signals in interaction. The successful candidate will conduct experimental investigation of human (visuo-)tactile exploration and interaction by means of multiple techniques, as eye-tracking, motion capture and force measurements with ad hoc designed devices, and with the humanoid robot iCub.

**Requirements:** The candidate for this position must have either a degree in Computer Science Engineering, Bioengineering or equivalent, with high interests in human sciences, or alternatively a degree in Psychology, with proven background in programming toolboxes (Matlab, R).

**References:**


**Contacts:** Applicants are strongly encouraged to contact the perspective tutors before they submit their application: alessandra.sciutti@iit.it, giulio.sandini@iit.it
2. Innovative robotic rehabilitation protocols to improve recovery outcomes

Tutors: Dr. Jacopo Zenzeri, Prof. Pietro Morasso

Istituto Italiano di Tecnologia
Research Unit: RBCS
https://www.iit.it/rbcs

Description: A great majority of neurological and/or orthopedic patients present both motor dysfunctions and impairments in kinesthesia at the upper limbs, but traditional robot and virtual reality training techniques focus either in recovering motor functions or in assessing proprioceptive deficits. The big challenge is to implement effective and reliable assessment and training protocols for sensorimotor recovery that exploit the interaction capabilities of the robots. In order to do it the mechanisms underlying sensorimotor deficits have to be studied from a computational point of view and translated into control algorithms in rehabilitation robots. The research will involve experiments with human subjects (children and adults - healthy and impaired) using haptic interfaces, analysis of movements and their neural correlates (using EMG, EEG). The knowledge gained from the experiments will be also used to design more effective haptic systems to be delivered directly to clinicians. This will imply a real push of the prototypes improved during the research period toward products and the concrete transfer of them in the clinical environment. The clinical experimental activities will be carried out inside major hospitals where IIT has formalized collaborations.

Requirements: a master degree in Bioengineering, Computer Science or equivalent, with experience in the analysis and modeling of human movements and in robot programming. Attitude for experimental work, problem solving and computational modeling will constitute factors of preference.

References:


Contacts: jacopo.zenzeri@iit.it pietro.morasso@iit.it
3. Modeling human sensorimotor processes to optimize haptic interaction with robots

Tutors: Dr. Jacopo Zenzeri, Prof. Pietro Morasso

Istituto Italiano di Tecnologia  
Research Unit: RBCS  
https://www.iit.it/rbcs

Description: In the last decade there has been a growing interest in studying physical coupling between humans or humans and machines. Indeed, developing a machine capable of understanding the intention of a movement and interactively cooperate with a human is among the frontiers of the research in robotics as well as rehabilitation and training. In order to optimize the interaction between humans and robots it is needed to understand and model the human sensorimotor processes involved in the daily activity complex tasks. In particular the research will include the study of the sensorimotor organization related to challenging tasks involving unstable dynamics [1, 3] and will involve experiments with human subjects (healthy and impaired) using haptic interfaces, mathematical modeling of human control strategies and design of more effective robots able to effectively learn skills.

Requirements: a master degree in Bioengineering, Computer Science or equivalent, with experience in the analysis and modeling of human movements and in robot programming. Attitude for experimental work, problem solving and computational modeling will constitute factors of preference.

References:


Contacts: jacopo.zenzeri@iit.it pietro.morasso@iit.it
4. Multisensory integration for locomotion and orientation

Tutors: Dr. Monica Gori, Prof. Giulio Sandini,

Istituto Italiano di Tecnologia
Research Units: RBCS & U-VIP
http://www.iit.it/rbcs
https://www.iit.it/it/research/lines/unit-for-visually-impaired-people

Description: Advances in our understanding of how the brain processes mobility and locomotion skills have been attained by means of neurophysiological, psychophysical, neuropsychological, neuroimaging, and computational modelling studies. Robotics, Brain and Cognitive Sciences and Unit for Visually Impaired People (IIT) are looking for a PhD in the field of multisensory integration for locomotion and orientation.

The goal of the project is to:
- To understand the brain mechanisms associated with the development of mobility, orientation and locomotion abilities in adults and children (e.g. vestibular, visual, acoustic).
- To develop specific technologies to support the inclusion of with visual disabilities through natural sensory-motor associations.
- The demonstration and the validation of the technology through user, experimental and clinical studies.

Requirements: The PhD student will be involved in doing psychophysical and EEG experiments with adults and children and to help in the development of device from the electronic and software point of view. A background in biomedical engineering or cognitive neuroscience, and programming skills are required.

References:

Contacts: Applicants are strongly encouraged to contact the perspective tutors before they submit their application: monica.gori@iit.it, giulio.sandini@iit.it;
5. Cortical mechanisms of multisensory integration during development from infancy to childhood

Tutor: Dr. Monica Gori

Istituto Italiano di Tecnologia
Research Unit: U-VIP
[https://www.iit.it/it/research/lines/unit-for-visually-impaired-people](https://www.iit.it/it/research/lines/unit-for-visually-impaired-people)

Description: The human brain is highly plastic, able to modify its own structure and functions to adapt to changes within the body or in the external environment. How multisensory and sensory-motor abilities develop is still unclear. We have recently demonstrated that optimal multisensory integration develops after 8-10 years. The goal of this PhD theme are:

- studying multisensory and sensory-motor integration development from infancy to childhood.
- studying the cortical mechanisms associated with optimal integration with EEG technique.
- studying the relationship between lack of integration and other cognitive processing (e.g. memory; attention, cognitive skills).

Requirements: The PhD student will be involved in doing psychophysical and EEG experiments with children and adults. A background in experimental psychology or cognitive neuroscience. Programming skills are required.

References:


Contacts: Monica.gori@iit.it
6. **Computational neuroscience models for auditory aware robots**

**Tutors:** Dr. Francesco Rea, Prof. Giulio Sandini

**Istituto Italiano di Tecnologia**  
**Research Unit: RBCS**  
https://iit.it/RBCS

**Description:** Selective attention is fundamental to any living being. The ability is a prerequisite for action performance and social interaction in complex environment. In this context, the multisensory attention has been only partially exploited despite the evident advantages in attentional orienting and mutual understanding in social realistic contexts. The PhD program intends to develop and implement novel computational neuroscience models of audiovisual processing as a solution for cognitive robotics. The program is working toward the goal of endowing the humanoid robot iCub with audiovisual awareness in an unstructured acoustic world. In the RBCS group, the work on audiovisual cognitive neuroscience has begun to make substantial progress towards a truly auditory aware iCub [1], [2].

The activities carried out aim:

a) to consolidate audio attention system in the existing robotics setup iCub[3];
b) to enable experimentation involving ecological interaction with human subjects;
c) enhancing the existing multimodal attention system;
d) to provide deep-learning models of speech recognition;
e) to integrate the speech recognition system in existing cognitive framework of human robot interaction implemented for the iCub[4].

**Requirements:** degree in Robotics, Bioengineering, Computer science, Computer engineering, or related disciplines, attitude for problem solving, C++ programming. A background on Machine learning is an asset.

**References:**


**Contacts:** Applicants are strongly encouraged to contact the perspective tutors before they submit their application: francesco.rea@iit.it, giulio.sandini@iit.it
7. Cognitive-inspired models for motion understanding for human-robot interaction

**Tutors:** Dr. Alessandra Sciutti, Dr. Francesco Rea, Prof.ssa Nicoletta Noceti

**Istituto Italiano di Tecnologia & University of Genova (UNIGE)**
**IIT Research Units: RBCS and CONTACT**
**UNIGE Department: DIBRIS**
[https://www.iit.it/RBCS](https://www.iit.it/RBCS)
[https://www.iit.it/it/research/lines/cognitive-architecture-for-collaborative-technologies](https://www.iit.it/it/research/lines/cognitive-architecture-for-collaborative-technologies)
[https://www.dibris.unige.it](https://www.dibris.unige.it)

**Description:** Cognitive Computer Vision refers to models that can achieve the classical computer vision functionalities — detection, localization, recognition, and understanding — with a goal-directed behavior, the ability to adapt to unforeseen changes of the environment, and of anticipating the presence of objects and the occurrence of events and actions.

The general goal of this project will be to provide iCub with a human inspired computer vision abilities that will guarantee a more natural and proficient interaction with human users. In particular the focus will be on action and agent understanding. Starting from existing computational models supporting movement processing, the visual properties of the observed movements will be used by the robot to decode the action, the intention or the internal status (mood or feeling) of the interacting partner by using machine learning techniques.

View-invariance will be one of the crucial aspects of the system, together with the capability of inferring information about the 3D orientation of an agent.

**Requirements:** degree in Robotics, Bioengineering, Computer science, Computer engineering, or related disciplines, attitude for problem solving, basic skills on c++ programming. A background on Computer vision and Machine learning is an asset.

**References:**


**Contacts:** Applicants are strongly encouraged to contact the perspective tutors before they submit their application: alessandra.sciutti@iit.it, francesco.rea@iit.it, nicoletta.noceti@unige.it
8. Make humanoids understand and synthesize human actions

Tutors: Dr. Francesco Rea, Dr. Alessandra Sciutti, Prof. Fulvio Mastrogiavanni

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IIT Research Units: RBCS and CONTACT
UNIGE Department: DIBRIS
https://iit.it/RBCS
https://www.iit.it/it/research/lines/cognitive-architecture-for-collaborative-technologies
https://www.dibris.unige.it

Description: Action understanding is a fundamental ability at the basis of human interaction. Neurophysiological evidence indicates that such an understanding is supported by a visuo-motor matching process: action observation activates in the observer a motor representation of the same action learned through execution, which yields a rapid and automatic understanding of the action goal. Hence, visual action understanding requires a sensori-motor representation of the action, built by performing it and learning its motor and sensory consequences.

The general aim of this project will be to provide the humanoid robot iCub with a similar visuo-motor matching skill in order to endow it with a human-like ability to understand human actions and to synthesize movements that are intuitively readable by the human collaborator. In particular, the robot will have to learn the motor and sensory consequences of its own actions to build a complete action representation. The research should determine which multisensory information is needed to allow for the recall of this model, when the robot perceives the same action performed by someone else. The work might take advantage of a computational system already available on the robot addressing both the perception and synthesis of human actions.

During his/her PhD, the successful candidate will also have the opportunity to work with researchers from Osaka University and the University of Tokyo within a framework of existing collaborations.

Requirements: Degree in Robotics, Bioengineering, Computer Science, Computer Engineering, or related disciplines, attitude for problem solving, C++ programming. A background on Machine Learning is an asset.

References:

- Vannucci F., Di Cesare G., Rea F., Sandini G., Sciutti A. 2018 'A robot with style: can robotic attitudes influence human actions?', IEEE-RAS 18th International Conference on Humanoid Robots (Humanoids), Beijing, China, November 6-9, 2018

Contacts: Applicants are strongly encouraged to contact the perspective tutors before they submit their application: alessandra.sciutti@iit.it, francesco.rea@iit.it, fulvio.mastrogiavanni@unige.it

Tutors: Dr. Alessandra Sciutti, Dr. Francesco Rea, Prof. Giulio Sandini

Istituto Italiano di Tecnologia
IIT Research Units: RBCS and CONTACT
https://iit.it/RBCS
https://www.iit.it/it/research/lines/cognitive-architecture-for-collaborative-technologies

Description: When interacting with others toward a joint goal, it is often necessary that the two partners coordinate in space and time their behaviors, both with respect to each other and with respect to external stimuli. For instance, while dancing, the two partners have to perceive the correct timing from the musical input, while at the same time adjusting to the other’s moves. In everyday activities we often have to coordinate with spatio-temporal dynamic inputs deriving from the environment – e.g., to catch an object before it falls – and with the partner, whose perceptual and motor abilities might differ from ours. Aligning with the partner’s perception implies understanding what will he or she perceives (e.g. with respect to the timing and location of the falling objects) and adapt our action accordingly – as for instance accelerating to catch the object if we realize that the other has misperceived the actual time to fall.

The goal of the research is enabling the humanoid robot iCub to similarly adapt its perception and action to the human partner, in order to establish an efficient interaction, with potential implications for assistive technology for the elderly.

The research for this position will involve: (i) the assessment of human spatial and temporal perception skills through behavioral measures; (ii) the development of methods and relative software to generate corresponding robot behaviors and perception; (iii) the design and implementation of novel adaptation models; (iv) the analysis/validation in human-robot interaction experiments.

Requirements: Degree in Robotics, Bioengineering, Computer science, Computer engineering, or related disciplines; attitude for problem solving, c++ programming.

References:


Contacts: Applicants are strongly encouraged to contact the perspective tutors before they submit their application: alessandra.sciutti@iit.it, francesco.rea@iit.it, giulio.sandini@iit.it
10. Virtual Reality and mental health disorders

Tutor: Prof. Gabriel Baud-Bovy, Prof. Giulio Sandini

Istituto Italiano di Tecnologia
Research Unit: Robotics, Brain and Cognitive Sciences
https://www.iit.it/rbcs

Description: In the last decade, there has been considerable interest in using virtual technologies for therapy of cognitive and psychiatric disorders (Freeman et al. 2017). The objective of the project is to develop and evaluate virtual reality applications to assess body image in patients with eating disorders (anorexic, obese) in collaboration with experimental psychologists and clinicians (Risso et al., 2017; Galimberti et al., submitted). The contribution of the student will consist first and foremost in developing the application using virtual reality technologies (Unity, Blender) and haptic interfaces (Balzarotti & Baud-Bovy, 2019). The virtual reality application will implement rigorous psychophysical methods to assess not only psychiatric disturbances but also possible underlying sensory, motor and/or cognitive deficits.

Requirements: a master degree in Computer Science (or equivalent) with strong interest for Virtual Reality, Gaming and/or haptic technologies. The candidate should be able to demonstrate strong programming skills, a capacity to manage projects and solve problems autonomously and an interest for the applications in Cognitive Neurosciences.

References:


Contacts: gabriel.baud-bovy@iit.it
11. **The role of Social Signals in Human-Robot Communication**

**Tutors:** Dr. Francesco Rea, Prof. Giulio Sandini

**Istituto Italiano di Tecnologia**

**Research Unit: RBCS**

[https://www.iit.it/rbcs](https://www.iit.it/rbcs)

**Description:** The PhD program intends to address:

- the development of methods and relative software to generate robot behaviors for natural mutual understanding;
- the design and implementation of novel models of immediate perception of the human partner state;
- the design of experiments, testing and analysis/validation of human-robot interaction experiments.

The first goal of the research is modelling how the humanoid robot iCub could adapt its perception and behavior to the individual needs of the partner during an interaction, with potential implications for communicative technology in different robotics application areas such as automotive and personal. The second goal of the research is to exploit how these models can be transferred to minimalistic robotic designs exploiting social signals.

**Requirements:** degree in robotics, bioengineering, computer science, computer engineering, or related disciplines, attitude for problem solving, C++ programming. A background on machine learning is an asset.

**References:**

2. Vannucci F., Di Cesare G., Rea F., Sandini G., Sciutti A. 2018 'A robot with style: can robotic attitudes influence human actions?', IEEE-RAS 18th International Conference on Humanoid Robots (Humanoids), Beijing, China, November 6-9, 2018

**Contacts:** Applicants are strongly encouraged to contact the perspective tutors before they submit their application: francesco.rea@iit.it, giulio.sandini@iit.it