PhD Program in Bioengineering and Robotics

Curriculum Cognitive Robotics, Interaction and Rehabilitation Technologies

Research themes

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 6 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 eight 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. 1 will be tutored jointly with colleagues of the Department of Informatics, Bioengineering, Robotics and System's Engineering (DIBRIS) of the University of Genova and Theme No. 7 is porposed as part of a EU Funded "Marie Sklodowska-Curie" Research Project.

Interested applicants are encouraged to contact the perspective tutors and/or the Unit's PI for clarifications before submitting their application.

All IIT units involved in this curriculum are located in the "Erzelli" site of the Italian Institute of Technology and share research facilities including, besided two iCub humanoid Robots, 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 , Dr. Francesco Rea – francesco.rea@iit.it and Prof. Pietro Morasso – pietro.morasso@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). Specifically RBCS addresses the study of sensorimotor and cognitive abilities in humans and robots with a focus on human-robot interaction and collaboration. A factor, common to all three streams is learning and development and, in general, the dynamics of knowledge acquisition and update.

A focus of this year's project is in the iCog open source scientific initiative started at IIT (www.icog.eu) with the goal of advancing our knowledge of human cognition by designing, building, and sharing a common cognitive architecture for an embodied artificial system such as iCub. The iCog initiative is planned to host and stimulate the convergence of many relevant disciplines such as computer science, artificial intelligence, neuro- & cognitive sciences, robotics, as well as social sciences.

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 child-hood and identify solutions (technologies and rehabilitation procedures)
ii. to enhance the sensorimotor abilities necessary to orient and move in space, to communi-cate, 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, Dr. Ana Tanevska – ana.tanevska@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 Enabling robots to understand and adapt to humans

Tutors: Dr. Francesco Rea, Dr. Alessandra Sciutti, Prof. Maura Casadio

Istituto Italiano di Tecnologia & University of Genova (UNIGE)
IIT Research Units: RBCS (https://www.iit.it/it/web/robotics-brain-and-cognitive-sciences)
& CONTACT (https://www.iit.it/it/web/cognitive-architecture-for-collaborative-technologies)
UNIGE Department: DIBRIS (https://www.dibris.unige.it)

Description: Effective human robot interaction depends on the ability of the robot to understand the needs and the internal state of its human partners and adapt to them. For instance, in the case of tutoring during motor learning, the tutor has to provide the appropriate physical assistance to the learner, but at the same time to assess and adapt to their affective and engagement state, to avoid frustration. Similarly, in a teaching or entertainment setting, the robot should be able to monitor both the behaviours and the engagement of the child or children it is tending to. The general aim of this project will be to provide the humanoid robot iCub with the ability to monitor both the motor behaviors and the affective and engagement responses of its human partner (or group of partners), to adapt its behavior accordingly and maintain the engagement in the interaction. The potential target group of users will be both adults and children. The work might take advantage of computational systems already available designed to process human movement and affective responses.

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:

- Vignolo, A., Sciutti, A., & Michael, J. (2020, November). Using Robot Adaptivity to Support Learning in Child-Robot Interaction. In International Conference on Social Robotics (pp. 428-439). Springer, Cham.
- Belgiovine, G., Rea, F., Barros, P., Zenzeri, J., & Sciutti, A. (2020, November). Sensing the Partner: Toward Effective Robot Tutoring in Motor Skill Learning. In International Conference on Social Robotics (pp. 296-307). Springer, Cham.
- Vignolo, A., Noceti, N., Rea, F., Sciutti, A., Odone, F., & Sandini, G. (2017). Detecting biological motion for human–robot interaction: A link between perception and action. Frontiers in Robotics and AI, 4, 14.

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

2 Assessing and training visuo-haptic exploration

Tutors: Dr. Alessandra Sciutti, Prof. Giulio Sandini

Istituto Italiano di Tecnologia
Research Units: RBCS (https://www.iit.it/it/web/robotics-brain-and-cognitive-sciences)
& CONTACT (https://www.iit.it/it/web/cognitive-architecture-for-collaborative-technologies)

Description:

When faced with a novel object, we explore it to understand its shape. This way, we combine information coming from different senses, as touch, proprioception and vision, together with the motor information embedded in our motor execution plan. How the exploration strategies are planned and how they change over the course of life is still an open question. Shedding light on how haptic exploration is connected with efficient perception of object properties could allow detecting the occurrence of abnormal exploratory behaviors, that emerge either due to developmental changes in childhood or to the set in of a disease, such as Mild Cognitive Impairment or dementia. We developed a series of sensorized objects, such as the iCube (Sciutti & Sandini, 2019), which allow to quantitatively measure the adopted exploratory procedures during short game-like tasks. This simple and non-invasive procedure could support the assessment and the quantitative evaluation of both perceptual-motor skills and memory processes, both in children and in elderly population. Additionally, it could provide fundamental insights on how successful haptic (and visuo-haptic) exploration is planned, fostering the development of a model of exploration for robotics manipulation. This is facilitated by the possibility of the iCube to directly communicate with the humanoid robotic platform iCub.

The successful candidate will conduct experimental investigation of human visuo-tactile exploration by means of multiple techniques, as eye-tracking, motion capture and force/touch measurements with ad hoc designed devices (e.g., the iCube). The target population will include children and elderly. If interested, the candidate will also participate in the modelling and porting of the haptic competences to the iCub robot.

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, Python).

References:

- Sciutti, A., & Sandini, G. (2020). To move or not to move: development of fine-tuning of object motion in haptic exploration. IEEE Transactions on Cognitive and Developmental Systems. https://ieeexplore.ieee.org/abstract/document/9246953
- Sciutti, A., Damonte, F., Alloisio, M., & Sandini, G. (2019). Visuo-haptic exploration for multimodal memory. Frontiers in integrative neuroscience, 13, 15. https://www.frontiersin.org/articles/10.3389/fnint.2019.00015/full

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

3 Trust and Shared Perception in cognitive robotics

ERS Position in the ERC Starting Grant "wHiSPER"

Tutors: Dr. Alessandra Sciutti, Dr. Francesco Rea

Istituto Italiano di Tecnologia

IIT Research Unit: CONTACT (https://www.iit.it/it/web/cognitive-architecture-for-collaborative-technologies) & RBCS (https://www.iit.it/it/web/robotics-brain-and-cognitive-sciences)

Description:

In everyday activities we often have to coordinate with our partner, whose perceptual and motor abilities might differ from ours. Aligning with the partners' perception implies understanding what will they sense and adapt our action accordingly. This is crucial in sports, where tight coordination in space and time is a requirement; but is also the backbone of every cooperative act in daily life – as for instance when we realize that the persons in front of us are not seeing what we are pointing at, and we rotate the screen to show them. The differences in individual perception also imply that cooperation requires a certain degree of trust, in particular to accept help and advice that might differ from our expectations. Taking this into account is necessary for the development of robots that can act as collaborative companions in contexts such as rehabilitation, elderly people assistance and education. The goal of the research is understanding the sensory-motor bases of the ability to align our perception to that of a partner and its implications for mutual trust. To this aim, we will use the humanoid robot iCub to investigate shared perception and mutual trust in human-robot interaction settings. Moreover, the robot will become the testbed of the models derived during the research and aimed at enabling it to adapt, trust and be trusted by the human partner. This research will have important impact in the field of Human-Robot Interaction, with potential implications for rehabilitative and assistive technology for the elderly.

The research for this position will involve the assessment of human perception and trust through behavioral measures and the development of methods and relative software to generate corresponding robot models of perception and trust. The models will be validated in human-robot interaction experiments.

During their PhD, the successful candidate will also have the opportunity to work with researchers from 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.

References:

- Mazzola, C., Aroyo, A. M., Rea, F., & Sciutti, A. (2020, March). Interacting with a social robot affects visual perception of space. In Proceedings of the 2020 ACM/IEEE International Conference on Human-Robot Interaction (pp. 549-557).
- Aroyo, A. M., Rea, F., Sandini, G., & Sciutti, A. (2018). Trust and social engineering in human robot interaction: Will a robot make you disclose sensitive information, conform to its recommendations or gamble?. IEEE Robotics and Automation Letters, 3(4), 3701-3708..

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

4 Proactive Memory in Cognitive Architectures for Human Robot Interaction

Tutors: Dr. Francesco Rea, Dr. Ana Tanevska, Dr. Vadim Tikhanoff

Istituto Italiano di Tecnologia (IT)
Research Unit: RBCS (https://www.iit.it/it/web/robotics-brain-and-cognitive-sciences), CONTACT (https://www.iit.it/it/web/cognitive-architecture-for-collaborative-technologies) & iCub Tech (https://icub.iit.it/)

Description:
This project is part of the iCog open source initiative started at IIT (www.icog.eu) with the goal of advancing our knowledge of human cognition by designing, building, and sharing a common cognitive architecture for an embodied artificial system such as iCub. The iCog initiative is planned to host and stimulate the convergence of many relevant disciplines such as computer science, artificial intelligence, neuro- & cognitive sciences, robotics, as well as social sciences.

Within this framework the focus of the project proposed is Memory which constitutes an important keystone to transform artificial systems from real-time executors of the action-perception loop to proactive, cognitive agents capable of reasoning about past experience and to anticipate the effect of actions. The project will involve both a contribution to the modelling of the Cognitive Architecture (the big picture) as well as the implementation of the memory processes in the software architecture of the iCub humanoids.

More specifically the goal of this project is to model and implement the computational processes of short-term and long-term memory in a cognitive framework supporting human-robot interaction (HRI) and human-robot collaboration (HRC). This work will address three specific memory aspects related to perception, action execution, and the closed loop between an artificial cognitive system and a human partner (interaction). In this way, the implemented cognitive functionalities will implement the elements of human cognition: 1) perceptual multimodal learning (**visual and auditory perception**) to recall the short-term memory in the operability of tasks (**context awareness**); 2) recall of long-term memory in interaction-based learning processes (**action planning**); and 3) autonomous adaptation to the human partner's memory during interactive tasks (**interaction**). The candidate will work on the proposed modular functional architecture to replicate the steps in memory autonomous development: from the perception of the environment, to the reuse of consolidated memory in HRI/HRC with human partners.

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

References:

- Rea, F., G. Sandini, and G. Metta. Motor biases in visual attention for a humanoid robot. in 2014 IEEE-RAS International Conference on Humanoid Robots. 2014. IEEE.
- Tata, M., A. Kothig, and F. Rea, A Bayesian System for Noise Robust Binaural Speaker Counting for Humanoid Robots.
- Tanevska, A., Rea, F., Sandini, G., Cañamero, L., & Sciutti, A. (2020). A Socially Adaptable Framework for Human-Robot Interaction. Frontiers in Robotics and AI, 7, 121.

Contacts: Applicants are strongly encouraged to contact the perspective tutors before they submit their application: Francesco.Rea@iit.it, Ana.Tanevska@iit.it, Vadim.Tikhanoff@iit.it

5 Adaptation in Cognitive Architectures for Human Robot Interaction

Tutors: Dr. Francesco Rea, Dr. Ana Tanevska, Prof. Giulio Sandini

Istituto Italiano di Tecnologia
IIT Research Unit: CONTACT (https://www.iit.it/it/web/cognitive-architecture-for-collaborative-technologies) & RBCS (https://www.iit.it/it/web/robotics-brain-and-cognitive-sciences)

Description:
In our everyday lives, we routinely engage in complex, adaptive and personalized interaction with our peers. In natural (biological) cognitive agents, adaptation is a fundamental ability, evident both at the behavioural and physiological level. Humans experience adaptation constantly in a multitude of ways - a conscious, social change in our behaviours and actions to accommodate interaction with other humans, an automatic adjustment of our hormones as a response to outside stimuli, etc. Adaptability thus represents one of the desiderata to implement an artificial cognitive agent, enabling it to fit in easily in new environments, to manage changes in its surroundings and to provide the foundation for a rich, human-like interaction with other agents.

The candidate interested in this research project will investigate how adaptation manifests in natural cognitive agents (i.e. humans) and will work on the design and implementation of adaptation mechanisms in a cognitive framework for an artificial cognitive agent (i.e. a social robot). This project is part of the iCog open source scientific initiative started at IIT (www.icog.eu) with the goal of advancing our knowledge of human cognition by designing, building, and sharing a common cognitive architecture for an embodied artificial system such as iCub. The iCog initiative is planned to host and stimulate the convergence of many relevant disciplines such as computer science, artificial intelligence, neuro- & cognitive sciences, robotics, as well as social sciences. Throughout this, the successful candidate will have a chance to collaborate and partake in the knowledge sharing with many other researchers in this converging networks of researchers.

Requirements: Degree in Robotics, Bioengineering, Computer science, Computer engineering, Cognitive Sciences or related disciplines; attitude for problem solving; C++ programming skills preferable (but not mandatory for candidates from non-CS backgrounds).

References:

- Vernon, D., Metta, G., & Sandini, G. (2007). A survey of artificial cognitive systems: Implications for the autonomous development of mental capabilities in computational agents. IEEE transactions on evolutionary computation, 11(2), 151-180.
- Tanevska, A., Rea, F., Sandini, G., Cañamero, L., & Sciutti, A. (2020). A Socially Adaptable Framework for Human-Robot Interaction. Frontiers in Robotics and AI, 7, 121.
- Kotseruba, I., & Tsotsos, J. K. (2020). 40 years of cognitive architectures: core cognitive abilities and practical applications. Artificial Intelligence Review, 53(1), 17-94.

Contacts: Applicants are strongly encouraged to contact the perspective tutors before they submit their application: Francesco.Rea@iit.it, Ana.Tanevska@iit.it, Giulio.Sandini@iit.it

6 ERC MySpace Position – Cortical mechanisms of spatial representation in children with and without visual impairment

Tutor: Dr. Monica Gori
Institute: IIT (Istituto Italiano di Tecnologia)
Research Unit: Unit for Visually Impaired People (https://www.iit.it/it/linee/unit-for-visually-impaired-people)

Description:

The human brain is highly plastic, able to modify its structure and functions to adapt to changes within the body or in the external environment. How spatial representation develops is still unclear. We have recently demonstrated that blind children have problems on many audio spatial processing. The goal of this Ph.D. theme are:

- studying spatial development from infancy to childhood.
- studying development of spatial representations with EEG technique.
- studying the relationship between spatial processing and sensory-motor skills.

The work of the Ph.D. will be within the ERC MySpace project (www.MySpaceproject.eu).

Requirements:
The Ph.D. student will be involved in doing psychophysical and EEG experiments with infants and children. A background in experimental psychology, EEG techniques and cognitive neuroscience. EEG skills are required.
The Ph.D. will be financed within the MySpace ERC project (G.A. N. 948349) .

Contacts: Applicants are strongly encouraged to contact the perspective tutors before they submit their application: Monica.gori@iit.it.

7 Predicting functional vision via multisensory interactions - Marie Sklodowska-Curie Fellow

ERS Position in the EU-Marie Sklodowska-Curie ETN "OPTIVIST"
Tutor: Dr. Monica Gori
Institute: IIT (Istituto Italiano di Tecnologia)
Department: Unit for Visually Impaired People (https://www.iit.it/it/linee/unit-for-visually-impaired-people)

Description:
The European MARIE SKŁODOWSKA-CURIE Innovative Training Network (ITN) OptiVisT (G.A. N. 955590) aims to resolve this by (1) gaining new Insights: i.e. a fundamental understanding of the visual demands of activities of daily living and sports; (2) developing Solutions: i.e. creating new objective, inclusive and engaging tools for testing, training and augmenting functional vision; and (3) the Application of 1 and 2: evaluating the effectiveness of our new tools in diagnostics, rehabilitation and classification in practice.

IIT participates to the project with an Early Stage Reserarcher (ERS 6).

The objective of the ESR6 is to study the cross-modal plasticity of visually impaired individuals to develop new tools for evaluation and screening. The project aims to find new solutions based on multisensory processing to quantify the level of impairment (e.g., kind of scotoma) and the deformations produced by it in the spatial and temporal domain. To do so, the ERS will use an interdisciplinary approach using psychophysics, Virtual Reality, Eye Tracking, and Motion Tracking systems combined with EEG. The work's expected results are defining better cortical plasticity associated with the impairment and developing a new tool based on cross-modal signals to obtain a quick evaluation of visual impairment and its potential impact on functional vision-based.

Research skills acquired:

Psychophysics evaluation of healthy controls and patients, EEG; programming and data analysis (MATLAB); eye and motion tracking analysis, modeling, development, and validation of new tools for screening and quantifying Visual impairment.

Requirements:
Applicants must be already selected by the OptiVist Consortium.

Contacts: Applicants are strongly encouraged to contact the perspective tutors before they submit their application: Monica.gori@iit.it.

8 Development of new SSD for visually impaired individuals

Tutor: Dr. Monica Gori,
Dr. Alessio Del Bue (co-supervisor)
Institute: IIT (Istituto Italiano di Tecnologia)
Department: Unit for Visually Impaired People (https://www.iit.it/it/linee/unit-for-visually-impaired-people)

Description:
Despite the massive improvement of technological devices specifically designed for visually impaired users, we find that many of these solutions are not widely accepted by adults and are not adaptable to children. This Ph.D. aims to develop and validate a new Sensory Substitution Device (SSD) for blind individuals to improve their interaction with the environment based on neuroscientific inputs and validation. The sensing abilities of the device will be enhanced by Computer Vision and Machine Learning approaches that will automatically understand the surrounding scene and support the blind individuals with their daily activities.

The goal of this Ph.D. theme are:

- studying spatial representations in blindness.
- develop a new SSD for orientation and interaction.
- validating the new device with a neuroscientific approach.

Requirements:
The Ph.D. student will be involved in doing psychophysical experiments and device/application development. A background in computer vision and biomedical or software engineering is required.

Contacts: Applicants are strongly encouraged to contact the perspective tutors before they submit their application: Monica.gori@iit.it.