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.

Interested applicants are encouraged to contact the perspective tutors for clarifications before submitting their application.

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.

Multisensory development: cortical and behavioral mechanisms

Tutors: Monica Gori

Tutors Affiliation: Istituto Italiano di Tecnologia

Project Description

We live in a multisensory world—continually bombarded with stimuli from multiple sensory modalities. As such, one of the significant activities of the human brain is to make sense of this sensory signals, integrating information that belongs together and segregating information that does not. Indeed, having information from multiple senses can dramatically improve performance in various domains, including detecting, discriminating, and localizing objects and events. While the benefits are known in adults, there is far less awareness of how the human brain develops multisensory processes. Although several studies have looked at multisensory development, they have been limited by numerous factors, including highly simplistic stimuli, differing tasks, various modality combinations, and a range of ages in cross-sectional designs. The project will investigate human development by combining psychophysics, neurophysiology computational modeling, and new technology. To move forward more systematically, the project will design studies using classical and more naturalistic stimuli across a consistent battery of tasks and modality combinations, and this will be done considering different children or the same children during development. Brain-behavior relations are evaluated.

Requirements: A background in cognitive neuroscience or neurophysiology is requested. Computational modeling skills, programming, experience with children, and haptic and VR skills are appreciated.

References:

Young children do not integrate visual and haptic form information, Current Biology 2008 M Gori, M Del Viva, G Sandini, DC Burr.

Multisensory spatial perception in visually impaired infants Current Biology 2021 M Gori, C Campus, S Signorini, E Rivara, AJ Bremner

Multisensory integration and calibration in children and adults with and without sensory and motor disabilities M Gori Multisensory Research 2015

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Memory-based Cognitive Architecture for Human Robot Interaction

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

Tutors affiliation: CONTACT (https://contact.iit.it/) & RBCS (https://rbcs.iit.it/)

Description: This project is part of the Brain and Machines IIT Flagship (https://www.iit.it/en/web/guest/our-research) and stems from 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. This research is planned to investigate which research pathway lays beyond the current prevailing Generative Artificial Intelligence approach to escape from the slavery of big-data to move toward a more human-like intelligence. For this reason, we anticipate 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. During their PhD, the successful candidate will have the opportunity to collaborate and visit international research institutes and universities, both in Europe, e.g. FIAS - Frankfurt Institute of Advanced Studies and outside, e.g. such as the University of Tokyo, within a framework of existing collaborations.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 as well as the implementation of the memory processes in the software architecture of the iCub humanoid. The goal of this project is to model and implement the computational processes of memory and experience building in a cognitive framework supporting human-robot interaction (HRI). This work will focus on the recall of **long-term memory** in interaction-based learning processes and on the **autonomous adaptation** to the human partner's memory during interactive tasks. The candidate will work on the proposed modular functional architecture to replicate from the perception of the environment, to the reuse of consolidated memory in HRI with human partners.

Requirements: Degree in Robotics, Bioengineering, Computer science, Computer engineering, Cognitive Sciences or related disciplines; attitude for problem-solving; C++ programming skills preferable.

References:

- Sandini, G. et al., (2024). Front. in Comp. Neurosci. https://doi.org/10.3389/fncom.2024.1349408
- Pasquali, D. et al. (2024). IEEE ICRA40 DOI: 10.5281/zenodo.12770885
- Kotseruba, I., & Tsotsos, J. K. (2020). Artificial Intelligence Review, 53(1), 17-94.

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Adaptation in Cognitive Architectures for Human Robot Interaction

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

Tutors affiliation: CONTACT (https://contact.iit.it/) & RBCS (https://rbcs.iit.it/)

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 behavioral and physiological level. Humans experience adaptation constantly in a multitude of ways - a conscious, social change in our behaviors 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. We want robots that can adapt to the individual needs and preferences of each partner. We interact differently with a child, an adult or an elderly person and we modulate our behavior even in multiple encounter with the same person, dependently on how she feels (e.g. agitated because in a hurry vs. relaxed or bored) and on our previous experiences with her. 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 Brain and Machines IIT Flagship (https://www.iit.it/en/web/guest/our-research) and stems from 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.

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:

- Berto, L., Tanevska, A., Cirne, A., Costa, P., Simões, A., Gudwin, R., ... & Sciutti, A. (2025). Curiosity and Affect-Driven Cognitive Architecture for HRI. IEEE Transactions on Affective Computing. DOI: 10.1109/TAFFC.2025.3551512
- 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.
- Sandini, G., Sciutti, A., & Morasso, P. (2024). Artificial cognition vs. artificial intelligence for next-generation autonomous robotic agents. Frontiers in Computational Neuroscience, 18, 1349408. https://doi.org/10.3389/fncom.2024.1349408

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A robot with style: implementing new robotic actions to promote human-robot interactions.

Tutors: Dr. Giuseppe Di Cesare, Dr. Francesco Rea, Dr. Alessandra Sciutti

Tutors affiliation: CONTACT (https://contact.iit.it/)

Description: During social interactions, observing others' actions enables us to infer their underlying attitudes and affective states. Humans naturally perform actions with varying forms—such as gentle, enthusiastic, annoyed, or rude reflecting their internal mood. For example, by observing how someone greets us, we can often discern whether they are happy, unwell, or experiencing discomfort. The ability to perceive and generate such forms of communication could be a valuable tool for future robots, allowing them to adapt their behavior appropriately across different contexts. For instance, a robot might adopt an authoritative role in security settings or exhibit polite behavior in clinical environments, thereby positively influencing human responses. In this view, the aim of this project is twofold: to study the kinematic features that characterize human actions expressed with different affective forms (e.g., gentle, enthusiastic, annoyed, rude), and to map these features onto the iCub humanoid robot in order to reproduce them through its own behavior. The candidate will research how to evaluate the behavioral impact of these expressive robotic actions on human users using physiological measures (e.g., electromyography, heart rate) and motion capture and how to develop comparable novel expressive robotic actions based on generative models (e.g., Generative Adversarial Networks). The project will be conducted in collaboration with the University of Parma, which will be equipped with a new iCub robot. The successful candidate will be involved in the following research activities: 1) contributing to the generation of expressive actions in the iCub robot based on distinct kinematic patterns; 2) designing and implementing novel Human-Robot Interaction (HRI) tasks; 3) analysing human kinematic data to guide the generation of robotic actions; 4) sharing responsibility, together with the supervisor, for managing the iCub robot in Parma.

Requirements:

Degree in Bioengineering, Computer Science, Computer Engineering, Robotics, or related disciplines, attitude for problem solving, C++ programming. We expect the candidate to develop skills in signal processing, and computational modelling. Excellent analytical skills (MATLAB) will also be required.

References:

- Lombardi G, et al., Sci Rep. 2024. doi: 10.1038/s41598-023-45825-6.
- F. Vannucci, et al., IEEE Access, 2024, doi: 10.1109/ACCESS.2024.3442863 .
- Di Cesare, et al., Natl Sci Rev. 2020, doi: 10.1093/nsr/nwz187.

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Lifelong Sensorimotor Health: Assessing and Rehabilitating Manipulation Skills with Haptic Devices

Tutors: Dr. Alessandra Sciutti, Dr. Dario Pasquali, Prof. Giulio Sandini

Tutors affiliation: CONTACT (https://contact.iit.it/) & RBCS (https://rbcs.iit.it/)

Description: The ability to manipulate objects is a fundamental aspect of human interaction with the environment, engaging cognitive and sensorimotor systems across the lifespan. In children, it fosters the development of fine motor skills, spatial awareness, problem-solving, and hand-eye coordination—capacities that are especially critical in the presence of impairments such as unilateral or bilateral Cerebral Palsy. In adults recovering from brain surgery, neurological events such as strokes or workplace accidents, restoring manipulation skills is key to regaining autonomy. Similarly, in older adults, maintaining these abilities is closely linked to cognitive health and the prevention of decline, including in neurodegenerative conditions such as Alzheimer's disease. Manipulation tasks require not only motor precision, but also sustained attention and the integration of visual, tactile, and proprioceptive information. Hand-eye coordination plays a central role in supporting both physical interaction and focused, goal-directed actions. Together, these integrated mechanisms form the foundation for learning, independence, and quality of life at all ages. This PhD project is part of the *Technologies for Healthy Living* IIT Flagship (https://www.iit.it/our-research) and the ERC Proof of Concept project *ARIEL* (https://cordis.europa.eu/project/id/101189387). The candidate will work with custom sensing technologies such as *myCube*, a sensorized object developed within ARIEL to quantitatively assess manipulation skills, along with commercial eye-tracking devices (e.g., Tobii, Pupil Labs) and custom Deep Learning models. The goal is to assess and support the assessment of development or recovery of cognitive and sensorimotor functions in children, adults, and elderly individuals. The candidate will join a multidisciplinary team and is expected to: (i) design assessment protocols for cognitive and/or sensorimotor skills; (ii) validate them with relevant populations, leveraging established collaborations across Italy and Europe; and (iii) develop and train Machine Learning models to support the evaluation of the enhancement or rehabilitation of these skills.

Requirements: Degree in Bioengineering, Computer Science and Engineering, Cognitive Sciences, Robotics or related disciplines; attitude for problem-solving; Python programming. We expect the candidate to develop skills in signal processing, data fusion, and statistical analysis.
References:

- F. Leo, et al., IEEE Trans. Haptics (2022).
- A. Sciutti and G. Sandini, IEEE Trans. Cogn. Dev. Syst. 14, 366–374 (2022).
- Pasquali, et al. Int J of Soc Robotics (2023).

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