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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Adaptation in Cognitive Architectures for Human Robot Interaction

Tutors: Francesco Rea, Alessandra Sciutti, Giulio Sandini

Tutors affiliation: Istituto Italiano di Tecnologia IIT Research Units: CONTACT (https://contact.iit.it/) & RBCS (https://rbcs.iit.it/)

Description: To live independently, to interact with others and with daily life environments humans rely on their ability to adapt and to tune body and mind to contingent situations and goals. In humans, adaptation manifests both as a conscious change in our behaviors to adapt to changing environmental and social conditions and as an automatic regulation of chemically-mediated bodily reactions to external stimuli (or to maintain homeostatic conditions). Adaptability thus represents one of the desiderata for a cognitive agent, enabling it to fit in easily in changing environmental conditions and providing the foundation for rich, human-like personalized interaction with other agents.
The candidate interested in this research project will investigate the cognitive bases of human adaptation abilities by designing, implementing and testing elements of a cognitive architecture for an artificial cognitive agent, such as the iCub humanoid platform. This Ph.D. project advances the topics of the iCog Cognitive Architecture scientific initiative (https://www.icog.eu/scope), at the convergence of many relevant disciplines, such as computer science, artificial intelligence, neuro- & cognitive sciences, robotics, and social sciences. The successful candidate will collaborate with an international network of researchers and partake to the sharing and convergence of multidisciplinary knowledge.
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:

- Sandini, G., Sciutti, A., & Morasso, P. (2024). Artificial cognition vs. artificial intelligence for next-generation autonomous robotic agents. Frontiers in Computational Neuroscience, 18, 1349408.
- 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 prospective tutors before they submit their application: Francesco.Rea@iit.it, Alessandra.Sciutti@iit.it, Giulio.Sandini@iit.it

Cognitive-inspired architectural approach for AI in human-robot interaction

Tutors: Alessandra Sciutti, Francesco Rea, Giulio Sandini

Tutors affiliation: Istituto Italiano di Tecnologia IIT Research Units: CONTACT (https://contact.iit.it/) & RBCS (https://rbcs.iit.it/)

Description:

Cognitive-based computer vision refers to models that can achieve the classical computer vision functionalities — detection, localization, recognition, and understanding — with goal-directed behaviour, the ability to adapt to unforeseen changes in the environment and anticipate the presence of objects and the occurrence of events and actions. The integration of vision with multisensory information (including auditory, haptic and tactile perception) and a proactive approach to the acquisition of novel experiences supported by a cognitive architecture, endows a cognitive robot with the awareness of the physical and social environment. The multisensory and sensory-motor integration necessary to this aim can benefit from AI components that improve the capability of the artificial intelligent system to understand and interact with the world and others.
The general goal of this project will be to develop the AI components of a cognitive architecture (such as action generation, memory, internal motivation, perception) endowing the humanoid robot iCub with the ability to interact with human partners, with a focus on multisensory perception for action understanding in dyadic or small groups interactions. Using machine learning techniques, the student will start from existing computational models in order to enable a robot to decode the interaction partners' action, intention, or internal states (mood or feeling) and to generate appropriate behaviours. The successful candidate will collaborate with an international network of researchers and partake to the sharing and convergence of multidisciplinary knowledge.

Requirements: Degree in robotics, bioengineering, computer science, computer engineering, or related disciplines, attitude toward problem-solving, basic skills in C++ programming. A background in computer vision and machine learning is a relevant asset.

References:

- Belgiovine, G., Gonzalez-Billandon, J., Sciutti, A., Sandini, G., & Rea, F. (2022, October). HRI Framework for Continual Learning in Face Recognition. In 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) (pp. 8226-8233). IEEE.
- Garello, L., Lastrico, L., Rea, F., Mastrogiovanni, F., Noceti, N., & Sciutti, A. (2021, August). Property-aware robot object manipulation: a generative approach. In 2021 IEEE International Conference on Development and Learning (ICDL) (pp. 1-7). IEEE.
- 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.;

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Affective communication in human robot interaction: behavioral and neural perspectives.

Tutor: Giuseppe Di Cesare, Radoslaw Niewiadomski, Alessandra Sciutti

Tutors affiliation: Istituto Italiano di Tecnologia IIT Research Units: CONTACT (https://contact.iit.it/) & RBCS (https://rbcs.iit.it/)

Description:

During social interactions, the observation of actions allows us to understand the attitudes of others. Humans perform actions with different forms expressing their positive or negative mood/internal state. For example, observing a person that greets us, we may understand if that person is happy or not, or if he/she feels good or not. The perception and the generation of these forms of communication could be a valuable property for future robots allowing them to assume the right attitude in different scenarios, such as an authoritative role in the security contexts or a polite behavior in clinical ones, influencing human behavior. The aim of the present project is to study the kinematic features characterizing different human actions performed with different forms (i.e., gentle, enthusiastic, annoyed, rude) and to enable the iCub humanoid robot to express them with its own behaviour and detect them from visual observation of human actions. To quantitatively evaluate the impact on humans from behavioral and neural point of view, the project will leverage Real Time functional Magnetic Resonance Imaging technique (fMRI). Several robotic actions will be presented to healthy participants in order to study, in real time, the neural activity involved in the processing of these robotic actions. The research project will be carried out in collaboration with the University of Parma that is equipped with an advanced 3 Tesla MR scanner endowed with Real Time fMRI technology. The work will take advantage of an existing software module available on the iCub robot supporting the generation and detection of actions with different properties and will potentially improve it. The successful candidate will: 1) participate in the generation of iCub robot's actions characterized by different kinematic features and forms; 2) participate in the development of algorithms to detect action forms; 3) develop and test cognitive paradigms coupled with cortical and subcortical Real Time fMRI recordings; 4) compute brain activity maps from fMRI data.

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:

- Di Cesare G., Gerbella M., Rizzolatti G., (2020). The neural bases of vitality forms. National Science Review; 7, (1) 202–213.
- Vannucci F., Di Cesare G., Rea F., Sandini G., Sciutti A. (2019). A Robot with Style: Can Robotic Attitudes Influence Human Actions? IEEE-RAS International Conference on Humanoid Robots, doi: 10.1109/HUMANOIDS.2018.8625004.
- Lombardi, G., Sciutti, A., Rea, F., Vannucci, F., & Di Cesare, G. (2024). Humanoid facial expressions as a tool to study human behaviour. Scientific Reports, 14(1), 133.

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Development of novel user experience metrics to evaluate lower and upper limbs exoskeletons for rehabilitation

Tutor: Boccardo Nicolò (nicolo.boccardo@iit.it)

Tutors affiliation: IIT (Istituto Italiano di Tecnologia), Research Lab: Rehab Technologies Laboratory (Center for Convergent Technologies). https://rehab.iit.it/

Description

The candidate will contribute to developing assessment strategies on lower and upper limbs exoskeleton to evaluate patient's user experience when exoskeletons are used as rehabilitation devices in the context of the IIT-INAIL project ClinicExo. To develop a specific methodology for assessing the user experience of exoskeleton devices in rehabilitation, the first step is to evaluate state-of-art methodologies by understanding pro and cons and adapt them to the context of this project. Technical development will help in improving the human-device interaction therefore promoting user experience. This will help to develop novel user experience metrics derived from correlations between human-machine system movements and physiological measurements. These metrics would quantify the user's actual effort during usage, motor performance, mental and cognitive load. This comprehensive assessment framework can optimize exoskeleton device design and usability for improved rehabilitation outcomes. To this end, the Candidate will benefit from a lively network of collaborations with hospitals and research institutions. This project requires broad expertise in biomechanics (i.e. motion capture system, EMG signals, GSR equipment) and a demonstrated expertise in biomedical engineering and attitude to interact with patients. The ideal candidate should hold a degree in Biomedical Engineering or related disciplines, be a highly motivated and creative individual who wants to work in a dynamic, multi-disciplinary research environment. Former lab experience and previous technical and scientific results will be highly considered.

Requirements:

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

Contacts: https://rehab.iit.it/