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 biomedicine. The general objective of the program is to form scientists and research technologists capable of dealing with multidisciplinary projects involving aspects of engineering, technology and life-sciences.

The themes offered this year as part of this curriculum are supported by the Robotics, Brain and Cognitive Sciences Department of the Italian Institute of Technologies (RBCS – themes 1 to 13) and by the Department of Informatics, Bioengineering, Robotics and System Engineering (DIBRIS) of the University of Genova (theme 14).

In particular, the science of action and interaction is the research stream unifying the multidisciplinary environment of the “Robotics, Brain and Cognitive Sciences” (RBCS) department of IIT (www.iit.it/rbcs). After establishing iCub as one of the more successful humanoid robot, the focus of RBCS research has evolved toward the study of the embodied and cognitive interaction between humans and machines and its technological and social outcomes. In the spirit of the doctoral School on Bioengineering and Robotics, in RBCS we are merging top-level neuroscience research and top-level robotics research by sharing fundamental scientific objectives arising from the study of speech recognition and language, the foundations of physical and social interaction, the exploitation of sensory and motor rehabilitation. RBCS is where the iCub humanoid robot is used to investigate the language of embodied, human-human and human-robot communication and it is also the place where studies of how visual, haptic and tactile integration develops in normal as well as sensory-impaired children. RBCS is where technologies for robotic rehabilitation devices are developed and tested in joint labs established in clinical environments such as the “Giannina Galsini”pediatric hospital, and the “Istituto Chiossone” for blind and low vision children in Genova, and the National Institute for Insurance against Accidents at Work (INAIL) in Volterra.

DIBRIS (www.dibris.unige.it) has a long date tradition in investigating and applying embedded approaches to perception, cognition, and action to build autonomous and semi-autonomous intelligent systems operating in the real-world in close cooperation - or even in symbiosis -- with humans. In this general spirit, research at DIBRIS focuses on different problems, methodologies and application scenarios, ranging from visual perception and knowledge representation to the interpretation of social cues in living beings, from autonomous exploration in unstructured or crowded scenarios to assistive and interactive technologies for assessment and rehabilitation of sensorimotor and motor skills.

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. Some of the themes proposed offer the students the possibility of participating in international collaborations through EU supported exchange of researchers within dedicated Marie Skłodowska-Curie actions.

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

1. Assessment of assistive technologies to enhance residual sensory abilities

Tutors: Dr. Luca Brayda, Dr. Fabrizio Leo

Department: RBCS (Istituto Italiano di Tecnologia)
http://www.iit.it/rbcs

Description: Sensory impairments such as visual or hearing loss can have a devastating impact on physical, social and emotional well-being and represent also a major economic problem. In this framework, assistive technology can be used to enhance, maintain, or even enable functional capabilities of individuals with sensory disabilities. This can help with promoting their independence and, in addition to personal services, with improving the quality of care, as well as social inclusion. In this vein, assistive technology (AT) devices have to be effective and efficient in helping users to exploit their residual sensory modalities in specific contexts and environments. The aim of the current project is to assess the usability of several devices currently developed in IIT, with a specific focus on tactile and acoustic feedback. We will study qualitative single-user reported degrees of usability, as well as quantitative experimenter-defined criteria in different contexts and with users with different sensory disabilities. The project will also be investigating criteria valid for users with multiple sensory impairments. The end goal of the project is a software suite implementing serious games involving perception and understanding of environmental features, which allow to validate AT devices in a variety of settings.

Requirements: A degree in Computer Science Engineering, Bioengineering or equivalent, with high interests in human sciences. Expertise in Assistive Technologies, Acoustics and Haptics will constitute factors of preference.

International opportunity: The successful candidate will have the opportunity to spend part of his/her PhD at Osaka University and the University of Tokyo in the framework of the Marie Curie IRSES collaborative project CODEFROR (www.codefror.eu).

References: L. Brayda, C. Campus, M. Gori, *Predicting successful tactile mapping of virtual objects*, IEEE Transaction on Haptics, Vol. 6, No. 4, 2013

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2. Simultaneous multimodal force and motion estimation

Tutor: Dr. Francesco Nori

Department: RBCS (Istituto Italiano di Tecnologia)
http://www.iit.it/rbcs

Description: Human motion capture (MoCap) finds applications ranging from entertainment (movies and games) to rehabilitation and sport activity monitoring. Standard marker-based technologies (e.g. the Vicon http://www.vicon.com) have been recently replaced in several applications with innovative marker-less systems such as the Xsens MVN (http://www.xsens.com/products/xsens-mvn) and the Microsoft Kinect (http://www.xbox.com/kinect). The main limitation of these systems is that they provide only kinematic measurements, typically position, velocities and accelerations. Starting from a technology previously developed and tested on the iCub [1], this research proposal aims at developing a prototype of a force and motion capture system for humans. In order to overcome the limitations of available technologies, the system will be based on multiple sensor modalities (e.g. vision, touch, force, gyro, accelerometers, electromyography) fused in a Bayesian sense. The project is highly interdisciplinary and technological. As such, it will be conducted in collaboration with other departments such as PAVIS (sensor calibration and modeling, Alessio Del Bue and Vittorio Murino), iCub Facility (touch sensor, Lorenzo Natale and Giorgio Metta), IIT@POLITO (electromyography, Paolo Ariano e Marco Paleari) and ADVR (exoskeleton implementation, Jody Saglia).

Requirements: The candidate needs to have an engineering background with strong competences in computer science and basic statistics. Competences in robotics and control will be positively evaluated.

References:

1. M. Fumagalli, S. Ivaldi, M. Randazzo, L. Natale, G. Metta, G. Sandini, F. Nori, *Force feedback exploiting tactile and proximal force/torque sensing*, Autonomous Robots 33 (4), pp. 381-398
2. F. Nori, S. Traversaro, E. Jorhabib, F. Romano, A. Del Prete A., D. Pucci. *iCub Whole body Control through Force Regulation on Rigid Noncoplanar Contacts*, Frontiers in Robotics and AI.

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3. Fast and robust whole-body motion with variable stiffness actuators

Tutors: Dr. Francesco Nori, Dr. Luca Fiorio

Department: RBCS http://www.iit.it/rbcs and **iCub Facility** http://www.iit.it/iCub

Description: Humans are extremely efficient at planning movements and adapting their control actions to compensate for external disturbances (Mussa-Ivaldi, 1994). Recently, human behavioral studies have suggested that a crucial role in movement planning might be played by muscle co-contraction (Burdet, 2001), modeled as the capability of actively adjusting the passive musculoskeletal compliance. In the field of robotics, the capability of actively varying the system compliance is a very recent advancement (Wolf, 2008) and its potentialities are yet to be fully exploited.

The proposed research project focuses on designing an adaptive movement controller which relies on the simultaneous regulation of both force and system compliance (Yang, 2011). Specific care will be posed on understanding the role of active compliance regulation in whole-body motion planning and control. The considered framework will be general enough to be applicable to both humans and humanoid robots. Results of the theoretical studies will be implemented and validated on the iCub humanoid robot; this implementation might eventually result in novel principles for guiding the design of the next generation of robotic actuators. A possible outcome of the project will be a motion planner/controller capable of whole-body motions robust against unpredictable perturbations. The candidate will be required to collaborate with a multidisciplinary research group composed of roboticists, behavioral scientists and mechanical engineers.

Notes: In this theme a six-months visiting period in a foreigner university or research center is foreseen.

Requirements: Candidate is requested to have a background in control theory, mechanical engineering, computer science and/or robotics. Specific background in optimal control will be positively evaluated.

References:

1. E. Burdet, R. Osu, D. Franklin, T. Milner, M. Kawato, *The central nervous system stabilizes unstable dynamics by learning optimal impedance*. Nature, 2001
2. R. Shadmehr, FA. Mussa-Ivaldi, *Adaptive representation of dynamics during learning of a motor task,* Journal of Neuroscience, 14(5), pp. 3208-3224, 1 May 1994
3. S. Wolf, G. Hirzinger, *A new variable stiffness design: Matching requirements of the next robot generation*, 2008 IEEE International Conference on Robotics and Automation, Pasadena, CA, USA, May 2008
4. C. Yang, G. Gowrishankar, S. Haddadin, S. Parusel, A. Albu-Schäffer, and E. Burdet, *Human Like Adaptation of Force and Impedance in Stable and Unstable Interactions*, accepted for publication: IEEE Transactions on Robotics, 2011

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4. Second-person motor cognition: hands in interaction

Tutor: Prof. Cristina Becchio

Department: RBCS (Istituto Italiano di Tecnologia)
http://www.iit.it/rbcs

Description: A key component of social understanding is the ability to read intentions from movements. Observers are attuned to early differences in visual kinematics and can use these differences to discriminate between movements performed with different intentions (Ansuini et al., 2014, 2015). This has been investigated using psychophysical paradigms in which brief video clips were presented to passive observers. The advantage of this approach is the high degree of control and statistical power it ensures. However, it is not clear how far this type of paradigm accounts for real-time interactions in which two (or more) individuals co-act in a common social context. Social cognition has been proposed to be substantially different when we actively interact with others ('second-person' social cognition) rather than merely observe them ('third-person' social cognition; Schilbach et al., 2013). The present research theme focuses on the development of a 'second-person' approach to the study of intention understanding. The successful candidate will investigate how real-time interaction dynamics affect pick-up and use of advance kinematic information. This project will be carried out in the context of the ERC funded project I.MOVE.U (http://www.imoveuproject.eu/).

Requirements: The successful candidate should have a degree in Neuroscience or Psychology (or related disciplines). She/he should be highly motivated to work in a team and to collaborate across and beyond disciplines. Candidates with previous experience in using experimental techniques such as EEG, TMS, Kinematics, and Eye tracking are strongly encouraged to apply. Computer programming skills as well as a background in motor cognition are a plus.

International opportunity: The successful candidate will have the opportunity to spend part of his/her PhD at Osaka University and the University of Tokyo in the framework of the Marie Curie IRSES collaborative project CODEFROR (www.codefror.eu).

References:

1. C. Ansuini, A. Cavallo, C. Bertone, C. Becchio, *Intentions in the brain: The unveiling of Mister Hyde*, Neuroscientist 21, pp. 126-135, 2015
2. C. Ansuini, A. Cavallo, C. Bertone, C. Becchio, *The visible face of intention: why kinematics matters,* 2015, Frontiers in Psychology, 5, p. 815, 2014
3. L. Schilbach, B. Timmermann, V.Reddy, A. Costall, G. Bente, T. Schlicht, K. Vogeley, *Toward a second-person neuroscience,* Behavioral Brain Sciences, 36, pp. 393-414, 2013

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5. Neural and motor bases of social interaction

Tutors: Prof. Thierry Pozzo, Dr. Alberto Inuggi, Dr. Alessandro D'Ausilio

Department: RBCS (Istituto Italiano di Tecnologia)
http://www.iit.it/rbcs

Description: While progress has been made in the field of social neuroscience, the neural mechanisms underlying social interactions represent the 'dark matter' of cognition. We need to study real-time social encounters in a truly interactive manner, with the assumption that cognition is fundamentally different when we interact with others rather than merely observe them passively (Schilbach et al., 2013). In the classic motor control frame of reference, individuals can be conceived as proactively building models of their action and of their sensory consequence. During interaction, these sensorimotor models can be extended to the social space whereby the control signal becomes the negotiated behavior of other people (Wolpert et al., 2003). Here, we intend to map the brain activities responsible for the emergence of such a shared behavior. Recent research has employed the hyper-scanning technique consisting in the recording of brain activities from multiple participants engaged in artificial interactive tasks (Hasson et al., 2012).

The current projects will go beyond current approaches by recording multimodal data of real face-to-face interaction between two subjects/agents recorded simultaneously. Recording will include Electroencephalographic (EEG), Electromyographic (EMG) and body motion kinematics (MoCap) data. The neural metrics of group collaboration will be extrapolated by calculating cortical connectivity indexes (Directed Transfer Function, Partial Directed Coherence), coherence factors among EEG, EMG and MoCap data and whole body movement features (Berret et al. 2009). This approach will allow the study of the neural and motor bases of social non-verbal interaction within a group of participants engaged in a collaborative realistic task.

Requirements: The successful candidate will have a background in computer science or engineering, programming skills as well as a strong interest in cognitive neuroscience. Electroencephalographic and kinematic data analyses skills are a plus.

References:

1. D.M. Wolpert, K. Doya, M. Kawato, *A unifying computational framework for motor control and social interaction,* Phil Trans Roy al Soc Lond Series B: Biol Sci 358, pp. 593–602, 2013
2. U. Hasson, A.A. Ghazanfar, B. Galantucci, S. Garrod, C. Keysers C., *Brain-to-brain coupling: a mechanism for creating and sharing a social world.* Trends Cognitive Sciences 16(2), pp. 114-121, 2012
3. L. Schilbach, B. Timmermans, V. Reddy, A. Costall, G. Bente, T. Schlicht, K. Vogeley *Toward a second-person neuroscience*, Behav Brain Sci 36, pp. 393-414, 2013
4. B. Berret, F. Bonnetblanc, C. Papaxanthis, T. Pozzo, *Modular control of pointing beyond arm's length,* Journal of Neuroscience, 29, pp. 191-205, 2009

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6. Multisensory integration and cross-modal communication

Tutor: Dr. Monica Gori

Department: RBCS (Istituto Italiano di Tecnologia)
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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. We have recently demonstrated that the absence of one sensory modality (such as vision) impacts on the development of other sensory modalities (such as audition), resulting in a form of cross-modal impairment. Consequently, contrarily to what is widely believed, individuals with sensory and motor impairments do not always have enhanced skills in other non-impaired modalities. Starting from these premises the goal of this PhD theme are:

- study the communication and integration of sensory signals during development.

- study the audio-motor deficits in visually impaired individuals.

- investigate the neural mechanisms that subserve the cross-modal calibration process

Requirements: The PhD student will be involved in designing and performing psychophysical and neurophysiological experiments in adults with and without visual disability with the goal of create better understanding the neural processes that subtend the integration and calibration process. A background in biomedical engineering, psychology, basic neuroscience and programming skills are required.

International opportunity: The successful candidate will have the opportunity to spend part of his/her PhD at Osaka University and the University of Tokyo in the framework of the Marie Curie IRSES collaborative project CODEFROR (www.codefror.eu).
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7. Augmented sensorimotor interaction

Tutors: Dr. Alessandro D'Ausilio, Dr. Leonardo Badino, Prof. Luciano Fadiga

Department: RBCS (Istituto Italiano di Tecnologia)
http://www.iit.it/rbcs

Description: The project starts from the assumption that human cultural and moral evolution can only be based on the development of efficient cooperation, and coherence among people. In fact, human perception, action and cognition are geared to enable successful coordination with others. The MNIlab devises computational methods to quantify the information flow between human body movements in small group of participants (Badino et al. 2014). In fact, body movement is the key channel for non-verbal communication (D'Ausilio et al., 2015).
The successful candidate will work on the extension and consolidation of this methodology to different scenarios (i.e. small group behavior during meetings or sport activities) and the development of the analytical tools to extract in real-time the quantitative flow of sensorimotor communication (Granger Causality, Transfer Entropy, Cross-Recurrence Quantification Analysis). The research program will be complemented by basic motor neurophysiological research on behavioral coordination (D'Ausilio et al., 2015).
All these aspects will be critical to implement the next generation of biologically inspired automatic sensorimotor communication recognition systems. These automatic systems will be essential to augment natural human-human coordination and promote the future of efficient human-robot interaction.

Requirements: The successful candidate will have a background in computer science, engineering, computational neuroscience or experimental psychology. Programming skills as well as a strong motivation in bridging the gap between technology and neuroscience are necessary. Kinematic data analyses skills are a plus.

References:

1. L. Badino, A. D'Ausilio, D. Glowinski, A. Camurri, L. Fadiga, *Sensorimotor communication in professional quartets*, Neuropsychologia, 55(1), pp. 98-104, 2014
2. A. D'Ausilio, G. Novembre, L. Fadiga, P.E. Keller, *What can music tell us about social interaction?,* Trends Cognitive Sciences, 19(3), pp. 111-114, 2015
3. A. D'Ausilio, E. Bartoli, L. Maffongelli L., *Grasping Synergies: A motor-control approach to the mirror neuron mechanism,* Phys Life Rev. 12, pp. 91-103, 2015

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8. Mutual Understanding in Human Robot Interaction

Tutor: Dr. Alessandra Sciutti

Department: RBCS (Istituto Italiano di Tecnologia)
http://www.iit.it/rbcs

Description: As robots are making their way from factory floors into our everyday lives, the design of their interaction with humans is becoming more and more important and a key issue to address is how to transfer the excellent social skills exhibited by humans to human-robot interaction. Our approach to this challenge is based on leveraging on the neural and behavioral mechanisms naturally in place for human-human interaction to foster a seamless mutual understanding with humanoid robots. Hence, we use robots both as tools to stimulate human social interaction and as test beds for the derived models. In particular we focus on understanding in humans and implementing in a robotic platform the basic motor and perceptual skills supporting human collaboration, as gaze tracking [1], temporal coordination between partners [2], gesture and action understanding [3-4]. The activity we propose is twofold: on one side to further investigate how to establish efficient human robot collaboration by implementing models of social skills on the iCub robotic platform and on the other to assess these models in human-robot interactive scenarios by means of multiple techniques (e.g., eye-tracking, motion capture and force measurements).

Requirements: Background in computer sciences, robotics, engineering is required, as also willingness to make experiments with human participants and strong motivation to work and adapt to a multidisciplinary environment.

International opportunity: The successful candidate will have the opportunity to spend part of his/her PhD at Osaka University and the University of Tokyo in the framework of the Marie Curie IRSES collaborative project CODEFROR (www.codefror.eu).

References:

1. O. Palinko, A. Sciutti, F. Rea, G. Sandini, *Towards Better Eye Tracking in Human Robot Interaction Using an Affordable Active Vision System*, HAI 2014 A. Bisio, A. Sciutti, F. Nori, G. Metta, L. Fadiga, G. Sandini, T. Pozzo, *Motor Contagion during Human-Human and Human-Robot Interaction*, PloS one, vol. 9, no. 8, 2014
2. N. Noceti, A. Sciutti, F. Rea, F. Odone, G. Sandini, *Estimating human actions affinities across views*, VISAPP 2015
3. Sciutti, L. Patanè, F. Nori, G. Sandini G., *Understanding object weight from human and humanoid lifting actions*, IEEE Transactions on Autonomous Mental Development, vol. 6, no. 2, pp. 80-92, 2014
4. Sciutti, A. Bisio, F. Nori, G. Metta, L. Fadiga, G. Sandini, *Robots can be perceived as goal-oriented agents, Interaction Studies, 14:3 . xv, 179, pp. 329–350, 2013*

Contact: alessandra.sciutti@iit.it

9. Speaking in Concert

Tutors: Prof. Luciano Fadiga, Dr. Leonardo Badino, Dr. Alessandro D'Ausilio

Department: RBCS (Istituto Italiano di Tecnologia)
http://www.iit.it/rbcs

Description: While it is now undisputed that speakers engaged in a conversational interaction are perceived by external listeners as converging towards each other in how they speak, we do not know yet what exactly in their speech makes them sound more similar to each other. Both perceptual tests and detailed acoustic analyses have shown their limits, the former because they have failed to reveal along which acoustic/phonetic parameters convergence may occur between speakers, and the latter because we may not have looked at the right acoustic/phonetic parameters yet. In addition, little is known about the cerebral underpinnings of phonetic convergence in speech. The goal of this project is to better understand what makes speakers sound more like each other in a conversational interaction. We will achieve this by means of a set of simultaneous recordings at the neural, articulatory and acoustic levels, in order to identify the neural features that may control and modulate the articulatory movements that in turn are at the origin of convergence in speech. Another major issue will be to determine whether convergence is symmetrical or asymmetrical, i.e. whether one partner converges to a greater extent towards the other partner than the reverse. To address this issue, we will conduct a series of analyses based on methods such as Granger Causality and Transfer Entropy, which have already been successfully employed in studies on sensorimotor convergence (D'Ausilio et al., 2012).

Requirements: A degree in Computer Science, Engineering or equivalent, with interests in Neuroscience. A background in speech processing, statistical analysis and machine learning will be appreciated.

References: A. D'Ausilio, L. Badino, L. Yi, S. Tokay, L. Craighero, R. Canto, Y. Aloimonos, L. Fadiga, *Leadership in Orchestra Emerges from the Causal Relationships of Movement Kinematics*. PLoS ONE 7(5)

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10. The Control and Representation of Articulated Objects: Insights from Robots

Tutors: Dr. Francesco Nori, Prof. Gabriel Baud-Bovy

Department: RBCS (Istituto Italiano di Tecnologia)
http://www.iit.it/rbcs

Description: Because of their structural rigidity, most robots strain to manipulate kinematically-constrained objects without causing large interaction forces. Thanks to its unique tactile and force sensing, the iCub (www.icub.org) is an ideal platform to study physical interaction, especially when kinematically constrained. While progresses in robotics, ranging from elastic actuators to new control schemes, are useful in the manipulation of such objects, the robotic ability to develop models of the objects they manipulate is limited. The project aims at developing a computational framework that might endow robots with such capacity by modelling human physical interaction strategies. The PhD candidate will need (i) to get acquainted with current state-of-the-art in human motor control with focus on physical interaction, optimal motor control and active inference; (ii) investigate how these paradigms might model human capacity to identify and use kinematically constrained objects, (iii) leverage robot iCub's tactile sensing, series elastic actuation and force control abilities to endow iCub with the capacity to interact physically with articulated objects, (iv) validate the proposed approach on the iCub humanoid.

Requirements: Candidates must have a degree that allow them to enroll in PhD program and don't have a doctoral degree yet. They must be in the first four years of their research careers and not have resided or carried out their main activity in Italy for more than 12 months in the last 3 years. The position is associated with a considerably higher salary than a regular studentship and offers many opportunities to travel to the other European partners in the network. The position is well suited for a candidate with an engineering degree with a focus on either computer science, robotics, bioengineering or control theory and a strong interest in human cognition. The candidate should have good mathematical and programming skills and an interest toward applying these skills to model human sensory and motor processes.

International Opportunity: The position is funded by the Perception and Action in Complex Environments (PACE) network, an Innovative Training Network funded by the Marie Skodowska-Curie program of the European Union (http://www.int.univ-amu.fr/-ITN-Marie-Curie-network-PACE-), which aims at better understanding the dynamic link between the efficient processing of complex perceptual inputs and the adaptive control of motor behavior. We are looking for excellent students (early stage researchers, ESRs) willing to work in a multi-disciplinary environment and spend two periods (3-6 months) at the other PACE groups' locations.

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11. Control and representation of articulated objects: human behavior in sighted and blind adults and children

Tutors: Dr. Monica Gori, Prof. Gabriel Baud-Bovy

Department: RBCS (Istituto Italiano di Tecnologia)
http://www.iit.it/rbcs

Description: Many actions, from opening a door to using scissors, involve kinematically constrained objects. It has long been recognized in robotics that kinematic constraint is particularly challenging as it requires one to control the interaction at the kinematic and dynamical levels simultaneously. Despite its ubiquity in everyday action, only a few studies have investigated how humans manipulate kinematically constrained objects. The general objective of this PhD project is to study sensory and motor processes involved in the control of these objects. Starting from experimental data and acquaintance with current computational account of motor and sensory processes, the PhD candidate will need to develop a model of one from the visual observation of the movements of its parts and from the experience derived during its manipulation. During the PhD, the candidate will (i) measure the capacity to identify the object geometry from visual and/or proprioceptive cues (ii) identify motor control strategies when manipulating kinematically constrained objects (iii) map how the capacity to manipulate such objects and perceive their kinematic properties develop from childhood to adulthood in sighted individuals and (v) test blind children to assess how congenital blindness affects the manipulation and perception of these objects.

Requirements: Candidates must have a degree that allow them to enroll in PhD program and don't have a doctoral degree yet. They must be in the first four years of their research careers and not have resided or carried out their main activity in Italy for more than 12 months in the last 3 years. The position is associated with a considerably higher salary than a regular studentship and offers many opportunities to travel to the other European partners in the network. The position is well suited for a candidate with a degree in Computer Science Engineering, Bioengineering, Experimental Psychology or equivalent. The PhD candidate must have a strong interest toward understanding cognitive processes and doing experiments with human subjects. Good mathematical and/or statistical mathematical skills are needed to understand existing computational models of sensory and motor control processes.

International Opportunity: The position is funded by the Perception and Action in Complex Environments (PACE) network, an Innovative Training Network funded by the Marie Skodowska-Curie program of the European Union (http://www.int.univ-amu.fr/-ITN-Marie-Curie-network-PACE-), which aims at better understanding the dynamic link between the efficient processing of complex perceptual inputs and the adaptive control of motor behavior. We are looking for excellent students (early stage researchers, ESRs) willing to work in a multi-disciplinary environment and spend two periods (3-6 months) at the other PACE groups' locations.

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12. Modeling of the mechanisms underlying proprioception for rehabilitation

Tutors: Dr. Valentina Squeri, Dr. Jacopo Zenzeri

Department: RBCS (Istituto Italiano di Tecnologia)
http://www.iit.it/rbcs

Description: Proprioception has a critical role in promoting or hindering motor learning. A great majority of neurological patients present both motor dysfunctions and impairments in kinesthesia, but traditional robot and virtual reality training techniques focus either in recovering motor functions or in assessing proprioceptive deficits. An open challenge is to implement effective and reliable tests and training protocols for proprioception that go beyond the mere position sense evaluation and exploit the intrinsic bidirectionality of the kinesthetic sense, which refers to both sense of position and sense of movement. In order to do it the mechanisms underlying proprioception 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 (healthy and impaired) using haptic interfaces, analysis of movements and their neural correlates (using EMG, EEG, TMS). The knowledge gained from the experiments will be also used to design more effective haptic systems to be delivered potentially directly to clinicians.

Requirements: A degree in Computer Science Engineering, Bioengineering or equivalent, with high interests in human sciences. Attitude for experimental work, problem solving and computational modeling will constitute factors of preference.

Reference: D.De Santis, J. Zenzeri, M. Casadio, L. Masia, A. Riva, P. Morasso, V. Squeri, *Robot-assisted training of the kinesthetic sense: enhancing proprioception after stroke*, Front. Hum. Neurosci. 8:1037, 2015

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13. Development of a Research Infrastructure supporting Data Science in an Interdisciplinary Environment

Tutor: Marco Jacono, Dr. Elisa Molinari, Alessandro Bruchi

Department: RBCS (Istituto Italiano di Tecnologia)
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Description: One of the most challenging goals in scientific research is to create knowledge by analyzing datasets. *Data Science is a mash-up of several different disciplines that employs techniques and theories drawn from many fields within the broad areas of mathematics, statistics, information theory and information technology*. The task of a Data Scientist is to find replies to complex scientific questions using his/her abilities collect, manage and analyze data.

Due to the interdisciplinary research activities carried out in RBCS (spanning from Robotics to Human Perception) the data collection and the data analysis are highly heterogeneous.

The aim of the project is to create a standardized infrastructure that helps management and analysis of experimental data to improve the robustness and the repeatability of the results.

The project will also investigate how to best support the basic techniques of data science, including both SQL and NoSQL solutions for massive data management (e.g., MapReduce and contemporaries), algorithms for data mining (e.g., clustering and association rule mining), and basic statistical modeling (e.g., linear and non-linear regression).

The end goal of the project is to prove the architecture in real processes of data mining using the department datasets

Requirements: A degree in Computer Science with high interests in life sciences. Programming skills, familiarity with databases and statistics. Interest in process modeling and data mining.

References:
http://ieeexplore.ieee.org/xpl/articleDetails.jsp?reload=true&arnumber=6965184

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14. Integration of motion-in-depth multi-sensory information flows in the peripersonal space

Tutors: Silvio P. Sabatini

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

Description: While there is a growing evidence that the space immediately around the body (i.e., the *peripersonal space*) is coded in a distributed way across several coexisting reference frames, our knowledge of how different representations are aligned, adapt, and interact is still in its infancy. Where, when, and how does the brain implement the internal models underlying the sensorimotor transformations that guide both our actions and perceptions? Is the encoding of sensory information static, or does it change dynamically as the action unfolds? Looking for answers to these questions should help understanding how an agent should use sensing and proprioception-like signals dynamically to build sensorimotor representations of peripersonal space and self-calibrate.

Within the research framework developed in the PSPC lab at DIBRIS (see also www.eyeshots.it), the goal of the project is to investigate how different *cross-modal* information can enable arm and hand-related actions in the peripersonal space. Specifically, the focus will be on the development of a neuromorphic cognitive system for detecting/encoding motion-in-depth multimodal information flows relative to body parts. The underlying models, besides advancing experimental predictions about neuronal activity, are expected to drive learning of meaningful interactions with the environment thus achieving fluid multi-dimensional motor control in the presence of multiple sensory channels, and with minimal *a priori* knowledge.

Requirements: Background in bioengineering, computer science, physics or related disciplines, strong interest in computational and theoretical neuroscience.

Reference: Antonelli M., Gibaldi A., Beuth F., Duran A.J., Canessa A., Chessa M., Solari F., del Pobil A.P., Hamker F., Chinellato E. and Sabatini S.P. (2014) *A hierarchical system for a distributed representation of the peripersonal space of a humanoid robot*. IEEE Trans. on Autonomous Mental Development, Vol. 6(4):259-273.

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