ANNEX A-4

University of Genova – Italian Institute of Technology
Doctoral School on “*Life and Humanoid Technologies*”

Academic Year 2011-2012

Doctoral Course on

“*Robotics, Cognition and Interaction Technologies”*

30 positions available with scholarship

Research Themes

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1 ROBOTICS, BRAIN AND COGNITIVE SCIENCES – PROF. GIULIO SANDINI

The projects proposed under this heading will be developed within the multidisciplinary environment of the "Robotics, Brain and Cognitive Sciences" (RBCS) department of IIT (www.iit.it/rbcs) At RBCS we are merging top-level neuroscience research and top-level robotics research by sharing fundamental scientific objectives in the field of action execution and interpretation (see RBCS list of publications as well as our international collaborations).

The research team at RBCS is composed of neuroscientists, engineers, psychologists, physicists working together to investigate brain functions and realize intelligent machines and advanced prosthesis.

RBCS is where the iCub humanoid robot is developed in all its mechanical, electronic, software and cognitive components but 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 implanted, in-vivo brain machine interface are developed but it is also the place where electrophysiological experiments are performed to realize bi-directional direct communication between the brain and artificial systems.

This year's themes cover interdisciplinary areas of research and are grouped according to the scientific focus and not to the background of the applicants. Specifically we intend to foster interdisciplinary research activities in the areas of:

1. Grasping and Manipulation
2. Interfacing the brain
3. Motor Control and Robot Rehabilitation
4. Communication, Speech and Language
5. Reaching
6. Multimodal Sensing

1) <u>Grasping and Manipulation</u>

The topics addressed here are offered to students interested in studying how different aspects of manipulation and grasping can be investigated in humans and can be implemented in robots. Background span from degrees in Life science to Engineering. See the individual themes for details.

Theme 1.1: Learning to Act with Dexterity, Purpose and Commonsense: The DARWIN architecture
Tutor: Dr. Vishwanathan Mohan, Prof. Giorgio Metta
N. of available positions: 1

The most striking feature of any cognitive system is its ability to learn. Every human child plays, interacts with objects (and people) around it and 'continuously' learns from its actions and the resulting consequences of its actions. From learning to control our own bodies and knowing what we can do with different objects around us to understanding causal relations and simple facts of the way the world works, play gradually helps extending our cognitive horizons and prepares us to act with 'purpose' and 'reason' in a changing, dynamic world. What is the computational/neural substrate that can endow iCub with such a capability? The specific context in which the research goal will be addressed is the 4-year, EU funded project 'Darwin' (www.darwin-project.eu), in collaboration with a team of leading international experts. As a part of Darwin project (which will use iCub as the main platform), iCub will be playing and interacting with a range of toys generally used by 2-3 year old children (like make and break wooden blocks of different shapes and sizes, MECCANO 2+ assembly toy set, miniaturized versions of common tools, Lego bricks etc). We will investigate three specific goals: 1) Motor Skill learning (Dexterity): Teaching iCub a range of skilled actions (like use of common tools), through a combination of imitation, explorative play and motor imagery. This will further extend the existing action generation/learning system of iCub. 2) Learning simple causal relations (Commonsense): Create internal models that 'abstract' recurring patterns of 'sensorimotor' experience arising out of iCub's interactions with its world. (For example, learning that all objects fall when dropped, you cannot place a cube on top of a pyramid while making a stack, learning part-whole relationships, learning the effects of 'force' and 'directionality' when you push something, the effects of containment (in/out) with which you infer that if 'B' is inside 'A' and 'C' is inside 'B' then 'C' is inside 'A'). 3) Learning to act in a Goal directed fashion (Purpose): Create a general reasoning architecture that exploits the past experiences of the robot to generate 'purposeful' action sequences in the context of a goal. A wide range of scenarios arising from experimental studies on animal and infant cognition will be used to validate the cognitive architecture.

Requirements: Computer Science or Bioengineering background with experience in real-time systems, neural networks. Strong motivation to work with humanoid robots; good C++ programming skills.

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Theme 1.2: Learning affordances from and from manipulation

Tutor: Dr. Lorenzo Natale
N. of available positions: 1

The concept of affordances refers to the possible ways an observer can interact with a given object (Gibson, 1977). It has received a lot of attention by robotics researchers in recent years. For example, a computational, cognitive model for grasp learning in infants based on affordances was proposed by (Oztop et al., 2004). In the field of artificial cognitive systems, affordances have been used to relate actions to objects. Montesano and colleagues (Montesano et al., 2008) studied learning of affordances through the interaction of a robot with the environment. They developed a general model for learning affordances using Bayesian networks embedded within a general developmental architecture. Linking action and perception seems crucial to the developmental process that leads to that competence (Fitzpatrick and Metta, 2003). As the above and other research show, the integration of visoumotor processes aids the acquisition of object knowledge (Kraft et al., 2008; Ude et al., 2008; Modayil and Kuipers, 2004; Modayil and Kuipers, 2007, Modayil and Kuipers, 2007b). This project will be carried out in the context of the EU funded project Xperience (FP7-ICT2009-6, http://www.xperience.org/). The scenario is that of a robot interacting with objects to explore ways to interact with them. From the information gathered during exploration the robot learns a representation of objects that links sensory information to the motor actions performed on the objects. The scientific goals of the project are i) to develop a representation of affordances ii) to realize behaviors for autonomous generation of affordances and iii) to investigate the use of the representation of affordances in the context of planning and action understanding.

Requirements: the ideal candidate should have a degree in Engineering or Computer Science (or equivalent), be highly motivated to work on robotic platforms and have computer programming skills. In addition, some background on Computer Vision and/or Motor Control would be preferable.

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P. Fitzpatrick and G. Metta. Grounding Vision Through Experimental Manipulation. In Philosophical Transactions of the Royal Society: Mathematical, Physical, and Engineering Sciences, 361:1811, pp. 2165-2185. 2003.

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Ude, A., Omrčen, D., Cheng, G. (2008) Making object learning and recognition an active process, International Journal of Humanoid Robotics, 5 (2), pp. 267-286.

Modayil; J. and Kuipers, B. (2004). Bootstrap learning for object discovery, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), vol. 1, pp. 742-747.

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Theme 1.3: Electrophysiology of object grasping

Tutor: Prof. Luciano Fadiga
N. of available positions: 1

Electrophysiological studies of ventral premotor cortex in macaques have shown that this sector of the frontal cortex, and particularly area F5, contains an electrically excitable hand representation. The majority of F5 hand-related neurons discharge during goal-directed actions such as grasping, manipulating, tearing, holding. These functional properties suggest that area F5 stores a set of motor schemata or, as it was previously suggested by Rizzolatti and colleagues, a "vocabulary" of goal-directed actions. This property differentiates area F5 from the hand-related representation of the primary motor cortex (M1), where neurons code movements regardless of the action context in which they are performed (according to a "vocabulary of movements").

The topic we propose as PhD activity is to further investigate how areas F5 and M1 encode the various types of grasping (and thus the various objects) and to unveil the way by which is represented the so-called "opposition space", i.e. the force interface between the grasping fingerpads and the surface off the object. This will be achieved by measuring fingers force and position on a sensorized object, whose to-be-grasped surfaces could be changed in position and inclination by a computer-driven system. During this task, the activity of single neurons in ventral premotor (area F5) and primary motor (area M1) cortices of macaque monkeys will be recorded and correlated with grasping dynamics. The experiments will be performed in an electrophysiology lab coordinated by L. Fadiga at the University of Ferrara.

Requirements: The candidate should have some background in neurophysiology. As title of preference, previous experiences with behaving primates will be considered.

For further details concerning the research project, please contact: luciano.fadiga@iit.it

Theme 1.4: Kinetic analysis of object manipulation

Tutor: Prof. Gabriel Baud-Bovy
N. of available positions: 1

Many everyday tasks, such opening a door or a drawer, opening the cap of a bottle, involve the control of kinematically constrained objects. Surprisingly, very few studies have investigated how humans perform such tasks at the kinetic level, which involve the simultaneous control of force and motion – an outstanding issue in motor control and robotics. This project will investigate these issues at the behavioral level, studying how children and adults perform such tasks. In particular, this project will focus on the measure and analysis of the interaction and contact forces using customized tools and/or objects fitted with force sensors and motion capture systems. The information gained in this project will be used to design algorithms that help humanoid robots to perform these tasks.

Requirements: Engineering or experimental psychology background, a strong motivation to understand better how humans perform such tasks, willingness to make experiments with human participants, some statistical and programming skills.

For further details concerning the research project, please contact: gabriel.baud-bovy@iit.it

Theme 1.5: Human and robotic dexterous manipulation
Tutor: Prof. Gabriel Baud-Bovy, Dr. Francesco Nori
N. of available positions: 1

Robots are still unable to perform dexterous tasks such as buttoning a shirt or turning a coin with the fingertips. Considerable research on the way humans perform and learn such tasks is needed to provide the basic science necessary to endow humanoid robots with such capabilities.

The first objective of this project will be to identify and analyze how humans learn and exploit suitable hand synergies while performing multi-finger object manipulation. The second objective will be to understand how these principles can be ported into the context of robotic manipulation: implementations on the iCub humanoid robot are also foreseen. To that end, the project will rely on various technologies to measures motion of the object and fingers, the contact forces applied on the fingers as well as measure of the impedance of the fingering during the manipulation. The candidate will need to master relevant theoretical frameworks in human Motor Control and robotics.

Requirements: Engineering background, a strong motivation to understand better how humans perform such tasks, willingness to make experiments with human participants, knowledge of robotics and/or mechanics to model results and some programming skills.

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2) INTERFACING THE BRAIN

The focus here is to understand how information can be exchanged between a living brain and artificial devices to reach a meaningful goal (e.g. how to control an artificial limb or to exploit sensory information). This objective requires a coordinated, collaborative effort of researcher and students in biology, computational neuroscience, engineering and physics. See the individual themes for details

Theme 1.6: Bidirectional brain machine communication devices
Tutor: Dr. Alessandro Vato
N. of available positions: 1

In the last two decades many scientists focused their research in developing artificial systems able to communicate directly with the brain [1, 2]. The ultimate goal of this research field is to restore sensory or motor functionalities for people that, due to neurodegenerative diseases or after a stroke, have severe problems in the communication between the brain and the rest of the nervous system. Many theoretical (e.g. understanding and decoding the neural signal) and practical issues (i.e. reduction of the brain reaction to electrodes chronically implanted, design of low power multichannel amplifiers to record and wireless transmit the neural signal) are still unresolved before having reliable systems to be used by human subjects .
The main goal of this project is to study and develop bidirectional brain-machine communication devices by establishing motor and sensory artificial channels that permit the brain to exchange information with the external world in a bidirectional fashion. To achieve this goal we need to develop and test new decoding/encoding algorithms that permit to study how extract/inject information from/to the brain and how to interact with a dynamical artificial system in a closed-loop configuration. We are interested in using signal processing techniques as information theory to characterize and testing the performances of these bidirectional communication devices. Part of the project will be devoted to investigating the possibility of using patterns of intracortical microstimulation as artificial sensory [3]. The candidate will be also involved in developing a new family of bidirectional BMIs that emulate the functional properties of the vertebrate spinal cord [4].

[1] F. A. Mussa-Ivaldi and L. E. Miller, "Brain-machine interfaces: computational demands and clinical needs meet basic neuroscience," *Trends Neurosci,* vol. 26, pp. 329-34, Jun 2003.
[2] M. A. Lebedev and M. A. L. Nicolelis, "Brain-machine interfaces: past, present and future," *Trends Neurosci,* vol. 29, pp. 536-546, 2006.

[3] J. E. O'Doherty, M. A. Lebedev, T. L. Hanson, N. A. Fitzsimmons, and M. A. L. Nicolelis, "A brain-machine interface instructed by direct intracortical microstimulation," *Frontiers in Integrative Neuroscience,* vol. 3, 2009.

[4] F. A. Mussa-Ivaldi, S. T. Alford, M. Chiappalone, L. Fadiga, A. Karniel, M. Kositsky, E. Maggiolini, S. Panzeri, V. Sanguineti, M. Semprini, and A. Vato, "New Perspectives on the Dialogue between Brains and Machines," *Front Neurosci,* vol. 4, p. 44, 2010.

Requirements: the candidate for this PhD position will be required to have a background in computer science, electronics and basic neuroscience.

For further details concerning the research project, please contact: alessandro.vato@iit.it

Theme 1.7: Impact of carbon nanotubes composite coatings on long-term intracortical recording using metal microelectrodes

Tutor: Dr. Davide Ricci, Dr. Emma Maggiolini, Dr. Luciano Fadiga
N. of available positions: 1

A variety of clinical applications take advantage from neural signals recorded by extracellular microelectrodes that, for this purpose, are required to have a small tip to reduce tissue damage. Unfortunately, such small electrode size leads to an increase in electrical impedance, reducing the selectivity/sensitivity of the probe. For this reason, in recent years, the attention of researchers has been focused on the development of very low impedance probes via nanostructured coatings. Within this framework, we have tested several different carbon nanotubes based coatings on metal microelectrodes and have obtained, after coating, very small microelectrodes that exhibit high effective surface area and thus significantly decreased impedance values. When used in acute recording sessions, we found that such coated microelectrodes show interesting proprieties, like reduced low frequency interference and an improvement in signal power density in the high frequency band. The present project based on these results deals with a thorough testing of the behavior, in chronic application, of arrays of the same electrodes. The goals are two: first, to find out if the coated electrodes are able to maintain their superior recording quality in time and eventually optimize their properties to achieve this result and, second, to investigate the impact of the foreign nanomaterials on brain tissue, (in collaboration with Dott.ssa Teresa Pellegrino, Nanochemistry Facility-IIT).

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Theme 1.8: Understanding the cortical representation of sensory information by means of neural network models of cortical dynamics

Tutor: Dr. Stefano Panzeri, Dr. Alberto Mazzoni
N. of available positions: 1

Understanding how to extract information about external stimuli from neural activity is central for the understanding of brain function and for development of Brain Machine Interfaces. Recent results suggest that the cerebral cortex encodes information about the external environment in the time domain, by encoding different parameters of the external word in different frequency ranges of neural activity [1]. The candidate, building on previous work from the group [2,3], will construct biophysically plausible models of cortical neural networks which capture the basic features of the functional organization of cortex. The candidate will then use these models to investigate how neural networks can encode simultaneously both the sensory features and their time evolution on time scales relevant for perception and behaviour. The candidate, which we will be supervised by Stefano Panzeri and Alberto Mazzoni, should hold a degree in Physics, Mathematics, Engineering or Computer Science and have a keen interest in applying mathematical and numerical techniques to the study of brain function. Please contact Stefano Panzeri (stefano.panzeri@iit.it) for further information.

References

[1] Panzeri S, Brunel N, Logothetis NK, Kayser C (2010) Neural codes at multiple temporal scales in sensory cortex. Trends in Neuroscience 33: 111-120

[2] Mazzoni A, Whittingstall K, Brunel N, Logothetis NK, Panzeri S (2010) Understanding the relationships between spike rate and delta/gamma frequency bands of LFPs and EEGs using a local cortical network model. Neuroimage 52: 956–972
[3] Mazzoni A, Panzeri S, Logothetis NK, Brunel N (2008) Encoding of Naturalistic Stimuli by Local Field Potential Spectra in Networks of Excitatory and Inhibitory Neurons. PLOS Comput. Biol. 4: e1000239

For further details concerning the research project, please contact: stefano.panzeri@iit.it, alberto.mazzoni@iit.it

3) Motor Control, Robot Rehabilitation and Related Technologies

The focus here is on the theoretical and engineering aspects of motor control and motor learning with the two goals of implementing more intelligent robots and technologies for robot-based rehabilitation. The required background here span from mechanical and electronic engineering to real-time control, material science and manufacturing, electrophysiology of motor control, rehabilitation. See the individual themes for details

Theme 1.9: Antagonistic actuation for adaptive reaching tasks

Tutor: Dr. Francesco Nori, Dr. Alberto Parmiggiani
N. of available positions: 1

Most of the current robotic systems are inspired by the human body. However in most cases they resemble the human form rather than its function. State of the art robots have indeed very different characteristics compared to the remarkable capabilities of the human skeletomuscular system. The aim of this PhD program is to contribute to the transition from the traditional approach to robotic actuation to a new antagonistic, compliant and more robust principle. The proposed actuation principles will be implemented and tested in both reaching and grasping scenarios. The final goal of the project will be to develop a new antagonistic actuation system to be eventually integrated in the iCub humanoid robot (http://www.icub.org). As a complementary activity to the mechanical design, the candidate will be also required to develop a suitable control framework to understand to which extent compliance can be exploited for achieving stability with respect to external disturbances.

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Theme 1.10: Force and dynamic control (on the iCub)

Tutor: Dr. Francesco Nori
N. of available positions: 1

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 developing an adaptive movement controller which relies on the simultaneous regulation of both force and system compliance (Yang, 2011). Care will be devoted to understanding the role of active compliance regulation when learning novel dynamical contexts. 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 an autonomous motion planning controller capable of learning suitable system compliance in order to prevent the effects of an unpredictable perturbation. The candidate will be required to collaborate with a multidisciplinary research group composed of roboticists, behavioral scientists and mechanical engineers.

TOOLS:
optimal control, stochastic optimal control, Gaussian processes.

PREREQUISITES:
control theory, machine learning, basic robotic competences (kinematics and dynamics).

REFERENCES:
Burdet E, Osu R, Franklin D, Milner T, Kawato M (2001). The central nervous system stabilizes unstable dynamics by learning optimal impedance. Nature.

Shadmehr R, Mussa-Ivaldi FA. Adaptive representation of dynamics during learning of a motor task. Journal of Neuroscience, 1 May 1994, 14(5): 3208-3224.

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)

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

For further details concerning the research project, please contact: francesco.nori@iit.it and/or giorgio.metta@iit.it

Theme 1.11: Freeform fabrication technologies for humanoid robotics

Tutor: Dr. Alberto Parmiggiani, Prof. Giulio Sandini
N. of available positions: 1

Current humanoid robotic systems are inspired by the human body. However their structures are substantially different from those normally found in biological systems. Moreover these systems are increasingly complex and this characteristic reflects into high production costs. These limitations can however be addressed with new manufacturing technologies such as selective laser melting (SLM) and investment casting with rapid prototyping (RP) parts. The first goal of this PhD program is to transition from the traditional design approach of robotic systems to new design paradigms that exploit the freedom allowed by the SLM and investment casting processes. Ideally geometries will be recursively optimized with the help finite element analyses (FEA). A second and complementary goal will be to evaluate the effectiveness of low-volume manufacturing technologies for cutting the production costs of robots. The reference application will be the iCub robot (http://www.icub.org).

For further details concerning the research project, please contact: alberto.parmiggiani@iit.it and/or giulio.sandini@iit.it

Theme 1.12: Cortical Plasticity and Learning : Experimental and modeling approaches

Tutor: Prof. Thierry Pozzo, Prof. Luciano Fadiga
N. of available positions: 1

The idea that observation can activate motor representations opens innovative learning methods for humans and robots. Recently, we have shown that a brief period of hand immobilization in healthy subjects reduces the excitability of controlateral motor cortex (Avanzino et al., 2011) and cortical representation of the restricted muscles. These changes disappear when participants are instructed to observe hand human action during immobilization, but not when subjects mentally simulate those movements. Thus action observation blocks the cortical effect produced by immobilization, while motor imagery fails to ameliorate it, in contrast with previous studies recurrently demonstrating the efficiency of motor imagery in learning process.

In such a context the aims are:
- To better describe the mechanisms underlying action observation and motor imagery;
- To explore the role of other sensory input (haptic, proprioception, audition…) and their combination, in the cortical remapping;
- To built a computational model able to predict empirical data and to implement the experimental results performed on human in robot for learning by observing human movements.

Requirements: Backgrounds in computer sciences, robotic, computational or behavioural neurosciences are required. The candidate must be motivated and must show a strong interest for both building model and designing experiments.

For further details concerning the research project, please contact: thierry.pozzo@iit.it

Theme 1.13: Haptic Technology and Robotic Rehabilitation
Tutor: Dr. Lorenzo Masia, Prof. Pietro Morasso
N. of available positions: 1

In the last three decades technological advancement has contributed to outstanding innovations in the field of robotics and human-robot interaction (HRI) became the key feature of the robot design. Although far to reach performance compared with those of the biological counterpart, robots have been offering a wide range of applications in many different fields, from medicine to industry. Human-robot interaction (HRI) focuses on the study of interactions between people and robots with the basic goal to develop principles and algorithms to allow more natural and effective communication and interaction between humans and robots.
The present research theme aims to coordinate a multidisciplinary approach to the develop and use of robotic technology as the principal instrument to investigate how the central nervous system masters the interaction with the external environment or recovers motor functions after brain injury: having in mind the human nature as the main core of the study we propose to start two main subdivisions:

- **Human Recovery** (mechanical design of robotic system for motor restoration, control design for assistive algorithms, optimal control of human robot interaction, engineering of mechatronic system for biomechanics, quantification of human performance and ergonomics)

- **Human Enhancement** (haptic systems with interfaces optimized for human cognitive capabilities, combining interactive, perceptually-tuned haptic rendering to empower task performance, Tele-robotics with true human-assisted sensor fusion, exoskeletons for hands/arms with integrated force and tactile sensing, Hardware packaging for wearable systems)

One position is available: main goal is to design and characterize mechatronic devices for studying HRI in a variety of tasks and applications. We aim to develop new mechanical solutions (actuators, sensors) and control algorithms to build robotic systems in order to assist/empower human motor performance. The research will be broken down into the following steps: conceptual design and simulation of new hardware; mechanical design and assembly of the system; characterization and control of the device and experimental trials on humans.
Established collaborations with clinical institutions (Fondazione Maugeri Veruno, NO, and Gaslini Pediatric Hospital, Genoa) will be strongly encouraged and will involve the candidate to perform experiments and trials on site.
Requirements: We are preferably seeking candidates with a background in Mechanical engineering or Robotics.
Mechanical engineering background is essential (manual skills for hardware assembly, strong experience in CAD mechanical design, SolidWorks, Pro-E, Alibre), matlab/simulink programming skills and control engineering, (optional) confidence with mechanical measurement and instrumentation, (optional) background in biomechanics and neural control of movements.

For further details concerning the research project, please contact: lorenzo.masia@iit.it and pietro.morasso@iit.it or visit http://www.iit.it/en/rbcs/labs/motor-learning-and-rehab-lab.html

4) Communication, Speech & Language

The focus of this stream is on social interaction through natural communication channels for example through speech, gesture and by anticipating the outcome of goal directed actions (understanding of intentions). Background of potential applicants span from computer vision to human language understanding, to psychophysics of motor control and behavior, machine learning, cognition. See the individual themes for details.

Theme 1.14: Grounding language on the iCub
Tutor: Dr. Leonardo Badino, Dr. Vadim Tikhanoff
N. of available positions: 1

close integration of language and other cognitive capabilities [Barsalou, 1999]. One of the most important aspects in the integration of language and cognition is the grounding of language in perception and action. This is based on the principle that cognitive agents and robots learn to name entities, individuals and states in the external (and internal) world whilst they interact with their environment and build sensorimotor representations of it. When language is not grounded as in the case of search engines that only rely on text corpora lexical ambiguities that require consideration of contextual and extra linguistic knowledge cannot be solved. Grounded systems that have access to the cognitive and sensorimotor representations of words can, instead, succeed in solving these ambiguities [Roy et al., 2003]. Current grounded agent and robotic approaches have several limitations, in particular:

- they rely on strong prior phonological knowledge and therefore ignore the fundamental problem of segmenting speech into meaningful units (ranging from phonemes to words);
- the grounding of new words is a start-from-scratch process meaning that the knowledge acquired during the grounding of previous words is not exploited when grounding new words.

This project proposal tackles these two limitations by using an approach that may be regarded as a semi-supervised learning-based approach [Chapelle et al., 2006]. First the robot builds its own structured representation of the physical world it explores (which can consist of hundreds of different perceived objects) and of the acoustic space. The robot then uses these representations to perform language grounding. Both representations will be multiple-level hierarchical representations (starting from raw representations of the perceived space developing into more abstract representations of the same space) generated by deep-learning auto-encoders [Hinton and Salakhutdinov, 2006]. Thanks to the hierarchical representation of the physical world the robot will be able to identify properties/items of unlabeled objects (i.e., not-yet linked to automatically learned (sequences of sub-) words) that are shared with labeled objects. The knowledge of these shared properties/items will provide the robot with prior information that should lead to a large speed-up of the grounding process.

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Theme 1.15: Recognizing people and their behavior on the iCub
Tutor: Prof. Vittorio Murino, Prof. Luciano Fadiga, Dr. Yiannis Aloimonos
N. of available positions: 1

The theme deals with the study of how humans interact with the environment, and specifically it is aimed at focusing on the effect exerted by ambient affordances on full body motor behavior. The term object affordance is commonly used to refer to the set of possible actions that a specific object affords to a given agent. For example, a glass can be used to drink, or it can be grasped for washing it. The same applies to the environment. Stairs of a public building can be walked for reaching its entrance, or employed as chairs. During the PhD course, studies will be devoted to understand the affordances of particular architectural or natural elements of the environment. In particular, emphasis will be given in detecting and recognizing how the different classes of actions that can be performed with a given element are modulated by the surrounding space and objects. This course will be highly interdisciplinary: notions of Computer Vision and Pattern Recognition will be studied and explored, as so as notions of Robotics of grasping and de-ambulation will be necessary. Applications of this study can be found in domotics, surveillance, and social robotics to name a few.

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IMPORTANT: make explicit link to the nanotech call with same title/theme.

Theme 1.16: Understanding action and scene dynamics
Tutor: Prof. Francesca Odone, Prof. Giorgio Metta
N. of available positions: 1

Action understanding from medium or close-range observations has been long studied by the computer vision community, in particular with application to HMI. The general goal is to interact by means of key-gestures, mimicking a natural ability of human perception to understand the speaker intentions from his/her body language. The implementation of such general idea is often simplified by adopting visual markers or special gloves. In a more general setting, that is if there is no way to interfere with the environment, the problem is complex from both the image processing and the image understanding point of view. In this project we will set the basis for a benchmark system of action understanding on the iCub platform. Machine learning will be used to devise computational models able to learn new behaviors, classify different actions, possibly from partial observations. In particular, temporal continuity of visual observations will be used to learn spatio-temporal models of actions of interest. To address these issues we seek one candidate strongly motivated on studying both the theoretical and applied aspects of computer vision and machine learning for action recognition tasks in a humanoid robot perception model.

For further details concerning the research project, please contact Francesca Odone odone@disi.unige.it and/or giorgio.metta@iit.it

Theme 1.17: Action recognition

Tutor: Dr. Alessandro D'Ausilio, Prof. Luciano Fadiga, Prof. Thierry Pozzo
N. of available positions: 1

There are compelling evidences that there is a tight relationship between action and perception systems. However, the discovery of a class of visuo-motor neurons, the so-called mirror neurons have raised some some outstanding questions that still require further research. For instance, it is not clear whether the ultimate function of the mirror system is about representing other's action for (action) comprehension or for (social) interaction. Both functions may require very different descriptive details and may be affected differently by own action execution. Specifically, the successful candidate will investigate the problem of how far motor simulation granularity goes and if this is modulated by action goals. Moreover, a central aspect of the research will also revolve around action state-dependency since this may tell us whether action mirroring has an inherent social and thus communicative purpose or not.
The successful candidate will investigate these themes by using Transcranial Magnetic Stimulation, Electroencephalography as well as behavioral methods.

Requirements: Cognitive neuroscience background, experimental psychology methods, neurophysiology, programming in matlab (optional).

For further details concerning the research project, please contact: alessandro.dausilio@iit.it , luciano.fadiga@iit.it , thierry.pozzo@iit.it

Theme 1.18: Phonology and prosody in language recognition

Tutor: Dr. Alessandro D'Ausilio, Dr. Leonardo Badino
N. of available positions: 1

The central question in speech research is to understand the connections between the three basic components in the communication chain – the sender (speech production), the medium (acoustics) and the receiver (speech perception). Furthermore, certain attributes of speech are cross-linguistically universal: (1) the vocal tract as the uniform biological device for speech production; (2) the uniform auditory system for speech perception; (3) the physical acoustics in the form of complex waves, which show similar energy pulses in time; (4) such physical signals are encoded and decoded as linear combinations of discrete codes for language users. What, then, constitute the differences among different human languages? One can think of speech as combinations of codes which bear functional contrasts for linguistic usage. Such codes could be consonants, vowels, syllables or even words. In a tone language, pitch melodies are also one of the codes, but it occurs with consonants and vowels simultaneously. The decoding of pitch melodies depends on many phonetic cues, but the shape of the fundamental frequency (F0) is the most salient cue. Other cues for lexical tones include voice onset time of the onset consonant, duration of the syllable, vowel quality and the F0 pattern of the preceding syllable. Investigating F0 and its relationship with consonants, vowels, lexical tones and syllables provide an interesting platform for cognitive science.

The successful candidate will investigate if the production-perception link, as part of the domain-general mechanism, is innate in speech perception/production and if the bootstrapping of lexical tones is learned, language specific, and conforms to the probability theory of categorization. The candidate will use behavioral tests, electrophysiological (EMG, EEG) and computational methods.

Requirements: Cognitive neuroscience background, experimental psychology methods, programming in matlab (optional).

For further details concerning the research project, please contact: alessandro.dausilio@iit.it, leonardo.badino@iit.it

5) Reaching

The focus here is on "reaching" from a "whole body" perspective that is how the intention of reaching for an object (or a specific posture in space), is decomposed in a coordinated set of motor commands involving different levels of control (from reflexes to high level plans) and realized by complex motor synergies. The relevant background here are computational neuroscience, computer vision, machine learning, robot programming and engineering. **See the individual themes for details.**

Theme 1.19: Learning peripersonal space and visuo-tactile integration

Tutor: Prof. Giorgio Metta, Prof. Luciano Fadiga
N. of available positions: 1

Tantalizing evidence from neuroscience is showing that the control of reaching in humans and animals is correlated with the activation of several neural pathways, where touch, proprioception, and vision are intertwined with motor information in a multisensory representation of the space around the body (Fogassi, Gallese, di Pellegrino, Fadiga, et al. 1992). The goal of this PhD program is to model these multiple neural pathways in the form of a working controller for a humanoid robot. The robot in question is the iCub which is equipped with vision, proprioception and soon with a distributed sensorized skin. We will study how this multisensory representation can be acquired through learning and development during the interaction of the robot with the environment. We will formulate models that are in agreement with neuroscience (Rizzolatti, Fadiga, Fogassi, Gallese, 1997). We are seeking candidates with a strong motivation to implement biologically sound models in a humanoid robot, with a background in engineering or related disciplines, programming skills, and some machine learning or computer vision experience. The successful candidate is expected to work in a team and integrate with the existing development tools and methods.

Requirements: engineering or computer science background, some experience in one of more of the following disciplines: machine learning, computer vision, control systems, neuroscience.

For further details concerning the research project, please contact: giorgio.metta@iit.it and/or luciano.fadiga@iit.it

Theme 1.20: Whole body motion control on the iCub

Tutor: Dr. Francesco Nori
N. of available positions: 1

A number of everyday actions involve the coordination of the entire body structure. Even though whole body motion planning is a fundamental skill for robots designed to operate in human environments, very few research studies have extended their scope beyond restricted classes of movements, such as walking. The goal of this research project will be develop a whole body motion controller for the iCub humanoid robot (www.icub.org). The class of considered movements will include whole body reaching (e.g. leaning forward and exploiting multiple contacts to grasp a faraway object), whole body postural changes (e.g. standing up from a chair) and whole body interaction with the environment (e.g. opening a door while standing). The controller developed within this research project will be based on a number of hardware features (e.g. the artificial skin) and software tools (e.g. iDyn, a framework for computing the whole robot body dynamics) which make the iCub an ideal platform for implementing the aforementioned skills. Part of the project will be devoted to studying and understanding how humans perform and control similar whole body movements with the goal of porting this principle on the robotic implementation. In this sense the project candidate will be required to fully exploit the unique interdisciplinary environment available at the Robotics, Brain and Cognitive Science Department.

COMPETENCES
C++ programming, basic robotic competences (kinematics and dynamics), basic knowledge in control theory.

REFERENCES:
M. Stilman and J.J. Kuffner. Planning Among Movable Obstacles with Artificial Constraints. International Journal of Robotics Research,
27(12):1295-1307, November 2008.

L. Fautrelle, B. Berret, E. Chiovetto, T. Pozzo and F. Bonnetblanc. Equilibrium constraints do not affect the timing of muscular synergies during the initiation of a whole body reaching movement. Experimental Brain Research, 203(1): 147-158. Springer Berlin / Heidelberg.

http://www.roboskin.eu, http://www.icub.org/

For further details concerning the research project, please contact: francesco.nori@iit.it and/or giorgio.metta@iit.it

Theme 1.21: What to do next (and how)

Tutor: Prof. Thierry Pozzo
N. of available positions: 1

This research project is aimed at better understanding the interaction between movement planning and decision-making. Decision and motivational processes that drive our interaction with humans and non living objects range from those that are largely externally driven (e.g., stop when the light is red) to internally driven (e.g., fatigue or physiological state).
We recently developed an experimental paradigm called “manifold reaching” to investigate the behavior of subjects in presence of target redundancy. A number of questions arise when trying to understand the brain processes involved in such a task for which mainly subjective constraints contribute to the endpoint selection. For instance, **what is the role of gaze when no precise spatial cue is presented on the target** whereas subjects nevertheless make a particular choice of a preferred target? Is vision subordinated to the upcoming motor plan? **To which extent subjects know the endpoint before executing the movement**? What is the timing of these events? Also, a complementary question that will be investigated is **how do humans select a preferred movement duration when low accuracy constraints are required**? The processes motivating the natural movement duration are currently widely unknown (except for the speed/accuracy trade-off), while it is a fundamental parameter for motor control. Deciding the movement time may actually depend on both subjective and objective constraints. The candidate will investigate the above questions using smart experimental designs (e.g. combining 3D motion capture systems, eye-tracker, psychophysical protocols…) and mathematical models (e.g. optimal control, decision theory…).
Candidates with a background in computational sciences (bio-engineering, physics or mathematics) or experimental sciences (neurosciences, psychology) are desired. The candidate must be motivated and must show a strong interest for both building model and designing experiments.
For further details concerning the research project, please contact: thierry.pozzo@iit.it

Detailed Proposal
Processing time is crucial in both humans and robots. Understanding the timing of events, such as a motor act followed by a sensory consequence, is critical for moving and speaking for instance. In neuroscience, an extensive literature has grown up in recent years, showing that many diseases such as Parkinson may be essentially disorders of timing. Because movements involve changes in muscle lengths over time, motor control and timing are inextricably related. For instance, the coordinated activation of antagonist muscles requires accurate timing on the order of tens of ms. Cerebellar patients, for example, often display oscillating-like tremors during their movements as they make a series of overshoots and corrections. In the context of action/perception and mirror neurons theory, timing also reveals itself to be crucial. Physical and biological laws of motion being particularly linked to the time-courses of various variables such as positions, it is well-acknowledged that the processes of learning through observation depend on the perception of time. Some results in this direction have already been obtained.

Usually, the visuo-motor pathway is considered to be crucial to allow the generation of goal-directed movements. The retinal information of the target usually initiates the formation of a movement plan. In the manifold reaching task however, the gaze direction is free. Think of reaching to a long target bar: gaze could be directed to any point of the bar. The relative link and timing of the two events is a priori unclear. Movement planning could determine the gaze direction. On the other hand, a particular gaze direction could just enforce the use of a specific movement plan and change the preferred endpoint of the subjects. Using experiments and models, we could better determine the processes involved during manifold reaching. Adding a mass to the subjects hand and imposing the gaze direction might provide interesting insights.

Besides Fitts' law type paradigms focusing on the well-known speed/accuracy trade-off, little is known about the principles guiding the planning of movement time in unconstrained conditions. Only a few studies are addressed the problem from a computational point of view, and the existing models fail in providing a convincing explanation for the question: where does the "natural" movement time come from? For every task and action, humans selectively and implicitly adjust the movement duration suggesting that movement time is related to cost or reward functions. It is also likely that the natural movement time can be influenced by social interaction or other cognitive processes. Our goal is to provide a general computational model for predicting what should be the "natural" movement durations. The idea is to assume that our movements are not to slow nor too fast in order to optimize some cost functions (mechanical energy, amount of motor command, jerk etc.). We aim to provide simple principles that motivate the selection of particular movement duration rather than another. A formulation of the problem using free-time optimal control is expected. Usually, in robotics, the movement duration of a reaching movement is provided "by hand". In order to develop autonomous and adaptive robots, however, automatically determining the most human-like movement time seems to be important. This seems all the more relevant that human perception is especially efficient when confronted to biological motion. A robot moving too slowly for instance would probably be harder to interact with given that this should not be recognized as a biological behavior by the human brain. However, when working with elderly, that is to say in a low-speed environment, such movement times could be relevant. For an intuitive interaction with humanoid robots such as the iCub platform developed at IIT, some computational principles thus remain to be understood. As such, studies on humans to identify the rules underlying the timing of a motor plan will be performed. Using optimal control, possibly inverse optimal control methods, we will attempt to account for the essential features of what we call the natural movement time.

For further details concerning the research project, please contact: thierry.pozzo@iit.it

6) Multimodal Sensing

The focus of this stream of research is on understanding and implementing multisensory systems that can support goal directed actions. This goal requires the convergence of backgrounds spanning from human psychophysics, to computational neuroscience of sensory system, to the development and implementation of hardware for robot sensing. Special focus is on visual, tactile and haptic sensing and representation. **See the individual themes for details.**

Theme 1.22: ASIC design for tactile sensing
Tutor: Prof. Maurizio Valle, Prof. Giorgio Metta
N. of available positions: 1

Robotic skin systems are based on arrays of sensors which cover the robot body. The sensors measure many contact parameters at different locations i.e. force/pressure with different frequency bandwidths (up to 1 kHz), shear forces, deformation, temperature, etc. To be effectively integrated and used in the robot control loop, the high quantity of diverse sensors data must be efficiently acquired, locally processed and transmitted at high data rate on a serial bus. All these tasks must be accomplished in real time by ad-hoc electronics. This electronics must fulfill many contrasting requirements i.e. many readout channels, real time smart and complex data processing to extract meaningful information from the raw data, to dispatch the information on a high speed serial bus, etc. In addition, it has to be very small in order to allow integration on the robot body. An integrated circuit solution is foreseen. This Ph.D. research program involves the development of the electronic tactile sensing system, of the dedicated integrated module(s), of the integration of the module(s) on robot's body and subsequently their use in the robot control loop for exploration and manipulation tasks. The networking of the modules of tactile sensing arrays, so obtained, is expected to result in a scalable system. The idea applicant should have a strong background in electronics and integrated systems and in one or more of the following fields: computer science, sensors and/or robotics. The candidates must have good writing and communication skills and motivation to work in a highly competitive and multidisciplinary environment.

For further details concerning the research project, please contact: maurizio.valle@unige.it and/or giorgio.metta@iit.it

Theme 1.23: Emergence of invariance in a computational visual system: humanoid robots as a platform to understand the computations in the visual cortex

Tutor: Prof. Lorenzo Rosasco, Prof. Giorgio Metta
N. of available positions: 1

Learning is widely considered the key to understand human as well as artificial intelligence and a fundamental problem for learning is the representation of input data. While most data representation strategies are problem specific, there is a general class of recently proposed architecture for data representation, called HMAX, which was originally proposed as a model of the visual cortex and is applicable in a wide range of problems. Empirically the proposed representation is often robust to a wide range of transformations of the inputs while preserving the important semantic information. In this project we will analyze the emergence of robustness and invariance to transformations, in a visual system from a computational perspective. The proposed study will start from the current knowledge of the human visual system. The idea is to use the iCub platform to study different computational model to understand how an agent can learn invariant image representations from visual cues and interaction with the surrounding environment.

For further details concerning the research project, please contact: lrosasco@MIT.EDU and/or giorgio.metta@iit.it

Theme 1.24: Cross sensory calibration and multisensory integration in children with and without sensory disabilities

Tutor: Dr. Monica Gori
N. of available positions: 1

As no single information-processing system can perceive optimally under all conditions, integration of multiple sources of sensory information makes perception more robust. Many recent studies have demonstrated the capacity of human observers to integrate information across various senses in a statistically optimal fashion, where greater weight is given to the sense carrying the more reliable information under any particular condition. Importantly, performance in the multimodal condition is always better than in either single modality. In our laboratory we are studying development of multimodal integration. Our past studies have shown that prior to eight years of age, integration of visual and haptic spatial information is far from optimal, with either vision or touch dominating totally, even in conditions where the dominant sense is far less precise than the other. We extended the study in children with sensory disabilities and obtained important information for rehabilitation programs. This knowledge is fundamental to deepening our understanding of brain processing and will be important for reproducing human abilities in robotic systems. The PhD student will be involved in designing and performing psychophysical experiments in humans related to this research theme with the goal of understanding the rules that govern multisensory fusion and calibration during development. The information obtained will be then implemented in our robot and will be used to develop rehabilitation programs in people with sensory and motor disabilities.

Requirements: a background in experimental psychology or neuroscience, and basic programming skills (in particular Matlab).

For further details concerning the research project, please contact: monica.gori@iit.it

Theme 1.25: Visual perception and visual attention on the icub

Tutor: Prof. Giorgio Metta, Prof. Alessandro Verri
N. of available positions: 1

This research theme is about developing learning modules which can be useful to humanoid robots (and in particular the iCub) in order to perceive the environment and exhibit intelligent behaviors: the emphasis will be on approaches able to make effective use of weakly labeled data (like time sequences of images) in order to learn optimal representations over time. The role played by different learning principles and on-line algorithms will be investigated.

Requirements: the ideal candidate has a strong background in computer science, mathematics, engineering or related disciplines and possible some knowledge of machine learning methods.

For further details concerning the research project, please contact: giorgio.metta@iit.it or verri@disi.unige.it

Theme 1.26: Sensori-motor processing of tactile and kinesthetic signals
Tutor: Prof. Gabriel Baud-Bovy
N. of available positions: 1

Robots are still unable to perform dexterous tasks such as buttoning a shirt or turning a coin with the fingertips. Considerable research on the way humans perform and learn such tasks is needed to provide the basic science necessary to endow humanoid robots with such capabilities.

The first objective of this project will be to identify and analyze how humans learn and exploit suitable hand synergies while performing multi-finger object manipulation. The second objective will be to understand how these principles can be ported into the context of robotic manipulation: implementations on the iCub humanoid robot are also foreseen. To that end, the project will rely on various technologies to measures motion of the object and fingers, the contact forces applied on the fingers as well as measure of the impedance of the fingering during the manipulation. The candidate will need to master relevant theoretical frameworks in human Motor Control and robotics.

Requirements: Engineering background, a strong motivation to understand better how humans perform such tasks, willingness to make experiments with human participants, knowledge of robotics and/or mechanics to model results and some programming skills.

For further details concerning the research project, please contact: gabriel.baud-bovy@iit.it, francesco.nori@iit.it

Theme 1.27: Information theoretic study of efficient multiple-modality sensing in humanoid robots
Tutor: Prof. Stefano Panzeri, Dr. Chiara Bartolozzi
N. of available positions: 1

Successful interaction of a robot with the external world requires combining the information from different senses such as vision, touch, or hearing, and selecting and combining the information from each sense with efferent copies generated by the robot ongoing action. While current humanoid robots are being endowed with sensors providing information from artificial retinas and ears, and from touch sensors as well as from proprioception (including position and force), it is not clear how to optimally extract information from these data and use it to select the appropriate action for example in a sensorimotor coordination task. This project aims at developing and using analytical methods based on information theory (Quian Quiroga R, Panzeri S (2009) Nature Reviews Neuroscience 10: 173-185) to analyze the data collected by different arrays of sensors and to find out what combinations of multisensory parameters to extract information lend themselves to rapid and efficient extraction of relevant features of the external world. These algorithms have been used successfully to study how cortical neurons may transmit information about multisensory stimuli (Kayser C, Logothetis NK, Panzeri S (2010) Current Biology 20: 19-24). In the attempt to replicate biological perceptive skills, the robot platform used for the project is equipped with biologically inspired asynchronous event-driven visual sensors (P. Lichtsteiner, C. Posch and T. Delbruck (2008) IEEE J. Solid State Circuits,2:43, 566--576). The above approach based on information theory will be then used to characterize the information content of the event-driven vision sensors and design an efficient strategy for extracting relevant information from visual and then multisensory data. A longer term aim of the project is also the understanding of how these multisensory parameters may be used for learning sensorimotor coordination in a complex humanoid robot (www.icub.org). The candidate should hold a degree in Physics, Mathematics, Engineering or Computer Science, and have a keen interest in applying mathematical and numerical techniques to the study of robotics, as well as an interest in brain function.

For further details concerning the research project, please contact: stefano.panzeri@iit.it or chiara.bartolozzi@iit.it

Theme 1.28: Development of sensing technologies for multimodal large area robotic skin

Tutor: Prof. Massimo De Vittorio, Dr. Davide Ricci
N. of available positions: 1

Tactile sensing technologies, that may enable safer and enhanced interaction of robots with the environment and humans, are still in their infancy and significant progress is necessary both at the sensor level and at the system level for a more widespread application in robotics.
This project is focused on the full development of novel polymer supported Aluminium Nitride (AlN) piezoelectric sensors and their integration into a large area flexible and stretchable smart tactile system capable of covering surfaces like a skin. Based on the experience achieved during the development of a capacitive pressure sensing skin and polymer piezoelectric devices for the i-Cub robot, it has become apparent that it is necessary to improve the intrinsic properties of sensors in terms of sensitivity, thermal stability, mechanical sturdiness and also ease of fabrication and integration. AlN has a long standing history of success in MEMS applications and recently good preliminary results have been reported in making AlN sensing devices directly onto polymeric support, opening the route for soft-MEMS applications compatible with other polymer based technologies. The candidate's work will take place both at the Center for Biomolecular Nanotechnologies (IIT@Unile) and at the Robotics, Brain and Cognitive Sciences Department (IIT Genova) that are strongly collaborating on this project.

For further details concerning the research project, please contact: davide.ricci@iit.it

2 ADVANCED ROBOTICS – PROF. DARWIN CALDWELL

STREAM 1: Quadrupedal System, Design, Locomotion, Planning and Control

Theme 2.1: Control and planning of autonomous dynamic legged robot locomotion
Tutor: Dr Jonas Buchli, Dr Ioannis Havoutis, Dr Claudio Semini
Number of available positions: 2

Legged robots have an advantage over wheeled robots in difficult and unstructured environments (e.g. outdoors, accident and disaster sites, etc). While this is the motivation behind much of the research in legged robotics the actual solutions are still largely confined to rather simple 'laboratory conditions'. The reasons for this are many, ranging from mechanical and design aspects through software to challenges in control and theoretical difficulties. In the Dept of Advanced Robotics at IIT we are working on the technology to change this. We are developing legged robots and the required control, planning and navigation algorithms to enable fully autonomous, fast and reliable operation for in- and outdoor settings.
We are seeking two highly motivated PhD students to work on aspects of control and planning of dynamic locomotion through unstructured terrains (e.g. running through a forest, jumping, 'orienteering'). The students will be working in the framework of the HyQ project. This Hydraulic quadruped HyQ is a unique research platform. It is a fully torque controlled electric/hydraulic quadruped robot equipped with inertial measurement units, laser range finders and stereo cameras.
http://www.iit.it/en/advanced-robotics/hyq.html
The exact research program will be determined both based on the background and interests of the students and the need of the project. Possible research topics include but are not limited to: Control of floating base articulated robots, kino-dynamic planning, probabilistic planning & control, force & impedance control, learning and adaptive control of legged robots, dynamic terrain and obstacle perception and modeling, path planning.
The ideal candidate has an excellent background in Control Engineering, Robotics, Dynamical Systems or similar fields. Excellent programming skills are a prerequisite. It is furthermore desired that the student has a practical flair and a desire to do experimental work. The work will require elements of theoretical work, software implementation and field tests. The ability to collaborate across and beyond disciplines is a key to success in this research program.

For further details concerning the research project, please contact: jonas.buchli@iit.it or ioannis.havoutis@iit.it or claudio.semini@iit.it

Theme 2.2: Development of a Medium Sized Dynamic Quadruped Robot
Tutors: Dr Claudio Semini, Dr Nikos Tsagarakis
Number of Available Position: 1

A promising field of application of **legged robots** is their operation in areas that are **hard to access or dangerous** for humans. Most of the currently existing robots, however, lack the versatility of performing both precise navigation over **rough terrain** and strong and fast motions that are necessary for dynamic tasks such as jumping and running.
IIT's effort in developing truly versatile robots has recently resulted in the hydraulic quadruped HyQ, a fully torque-controlled legged robot.
http://www.iit.it/en/advanced-robotics/hyq.html
The HyQ robot is powered by a combination of electric and hydraulic actuators. Hydraulic cylinders are a crucial element of the robot design since they enable high joint speeds and torques and are robust against impact loads during running and jumping. HyQ's current dimensions are comparable to the size of a goat or a small horse.
The goal of this PhD proposal is the development and evaluation of a smaller sized version of the robot. The design of the new robot platform will be based on the experiences gained from HyQ and through modelling and simulation. The PhD student will evaluate different actuator technologies and construction materials, design and test prototype legs and finally build and experimentally evaluate the full quadruped robot.

Requirements: The successful candidate is able to both work in a team and independently. He/she has a top degree in mechanical, mechatronic or electric engineering, preferably with practical experience in robot design. (60% mechanical design, 20% hydraulics, 20% software).

For further details concerning the research project, please contact: claudio.semini@iit.it, nikos.tsagarakis@iit.it

Theme 2.3: Power transmission systems for autonomous robots

Tutors: David Branson, Dr Emanuele Guglielmino, Dr Claudio Semini and Industry Supervisor
N. of available positions: 1

The ability of a robot to operate autonomously in any environment is dependent upon its capacity to provide the necessary power. The design and testing of effective portable power supplies has therefore become increasingly important. Current robot designs show significant limitations in the duration, output, noise, weight, and environmental friendliness. What is needed is a powertrain system that addresses the need for adequate power output while maintaining a low weight and compact profile.
A Hydraulically Actuated Quadruped Robot (called HyQ) platform has been developed at IIT and provides the ideal working platform for the development and testing of such devices. The robot is able to perform highly dynamic tasks such as jumping, running and rough-terrain walking (http://www.iit.it/en/advanced-robotics/hydraulically-actuated-quadruped-hyq.html). The aim of the project is to develop a compact and light weight power transmission system for the HyQ robot to enhance power-autonomy. This will include investigating the energy storage medium (e.g. hydrogen gas, gasoline, H_20_2, propane, etc.), electrical and hydraulic power supply systems and components. The project will also look at optimizing power transmission efficiency, reducing noise output, and the need to consider environmental and health implications.
Work will involve design, modeling, simulation, prototyping and experimental work on a team based project at IIT and with industrial partners. The candidate should ideally have a top class master's degree in Mechanical Engineering or Mechatronics or similar. Experience with power transmission systems would be a benefit but is not essential. The candidates must also have good writing and communication skills (60% mechanical design, 20% hydraulics, 20% software).

For further details concerning the research project, please contact: david.branson@iit.it or **emanuele.guglielmino@iit.it** or **claudio.semini@iit.it**

Theme 2.4: Water hydraulic technology for robotics

Tutors: Dr Emanuele Guglielmino, Dr David Branson
Number of available positions: 1

There is an increasing trend in hydraulic power transmission to replace petroleum-based fluids with water in an effort to reduce dependence on petroleum products. Water is more environmentally friendly, easier to dispose of. However, water (as opposed to oil) is more prone to cavitation, its lubrication is poorer, and internal leakage of the components is higher. Hence research into appropriate component selection and system design is necessary to ensure proper application.
This project will look at the introduction of a water based fluid medium to achieve tasks such as walking, trotting, jumping, and rough-terrain walking on the HyQ quadruped hydraulically-actuated robotic platform developed at IIT. The project will be initially based on a system approach using off-the-shelf components to eliminate the need for component design at the initial stage.
The outcome of the project will be first a working leg using servovalve and digital hydraulic technology, and in the long term a full version of HyQ using water hydraulics. In particular research to improve powertrain efficiency through the use of digital hydraulics will be carried out. The project will involve some control, simulation work and mechanical system design to integrate hydraulic components into the robotic structure.
The candidate should ideally have a top class master's degree (or similar) in Mechanical Engineering, Mechatronics or a related domian. The candidates must have good writing and communication skills. Ideal candidates should have experience in fluid dynamics, and have programming skills in C. Experience with ProE, and/or AMESim would be a benefit but is not essential.

For further details concerning the research project, please contact: emanuele.guglielmino@iit.it or **david.branson@iit.it**

STREAM 2: Surgical Robotics

Theme 2.5: Cognitive Supervision for Robot-Assisted Minimally Invasive Laser Microsurgery

Tutor: Dr. Edward Grant and Dr. Leonardo Mattos
Number of available positions: 1

Surgical robotics is an increasingly active and successful area of development with challenges in both the engineering and medical aspects of the work. This research will be an integral part of a new EU project (µRALP) on micro-technologies and systems for robot-assisted laser microsurgeries. The focus here will be on the creation of a cognitive system capable of learning and predicting the continuous appearance changes of the surgical site observed during laser procedures. Once reliable performance is achieved, this system will be used to create a cognitive supervisory safety system to generate alarms when unexpected/unforeseen surgical situations are detected. This is expected to greatly increase the safety of laser surgeries and to generate knowledge beneficial to both the surgical robotics and the medical communities.
The ideal candidates for this research theme should have a top class degree in computer science or engineering and a strong interest in medical robotics.
Requirements: Experience in cognitive/AI/machine learning systems; Development experience using OOP approach in C, C++; Multithread programming; Software development in Windows and Linux; Fluency in English.
For further details concerning this research project, please contact: leonardo.demattos@iit.it

Theme 2.6: Novel User Interfaces for Robot-Assisted Minimally Invasive Laser Microsurgery

Tutor: Dr. Leonardo Mattos
Number of Positions: 1

This research will be part of an EU project (µRALP) on micro-technologies and systems for robot-assisted laser microsurgeries. The research focus will be on the analysis and development of novel user interfaces for intuitive, precise, safe and ergonomic teleoperation of a surgical robotic system. This will involve the creation of experimental setups to scientifically investigate critical factors that affect each of these characteristics, including their impact on the cognitive burden imposed on the system operator. In addition, a strong collaboration with partner surgeons will be essential as part of the new systems' evaluations. The results of this research will support the creation of an optimal teleoperation system for laser microsurgeries, advancing the state of the art in surgical laser control via new interface devices and operating environments.
The ideal candidates for this research theme should have top class degree in engineering (Mechanical, Electronic or Mechatronics) or computer science and a strong interest in medical robotics.
Requirements: Experience in the development of user interfaces, evaluation of human factors, development of computer games, software development using OOP approach in C++, and fluency in English are all bonuses.
For further details concerning this research project, please contact: leonardo.demattos@iit.it

STREAM 3: Machine Learning, Robot Control and Human- Robot Interaction

Theme 2.7: Machine learning for robot control of autonomous underwater vehicles

Tutor: Dr. Petar Kormushev, Dr. Sylvain Calinon, Prof. Darwin G. Caldwell
Number of available positions: 1

Learning and performing a skill in noisy and unstructured environment such as underwater is difficult for a robot. Doing this in a robust way to achieve persistent autonomy is even more challenging. The main problem is not only how to learn to generate the skill, but also how to recognize when something goes wrong. This is the key ingredient to achieving autonomy – the robot should be able to do fault detection and recovery simultaneously during the task execution.

Robot learning encompasses various research questions: how to learn optimally and in a user-friendly way new skills, such as what representations and what learning algorithms to use. Several skill encoding mechanisms have been proposed so far, such as Dynamic Movement Primitives (DMP), Gaussian Mixture Models (GMM) and Gaussian Mixture Regression (GMR), Hidden Markov Models (HMM), etc. Each of them possesses different encoding and generalization capabilities. Based on the representations, different learning algorithms are used, based on Expectation-Maximization algorithm, Optimal Control theory, reinforcement learning, imitation learning, apprenticeship learning, etc.

Underwater environment models are not usually known in advance with much detail, and might require iterative trial-and-error incremental learning approaches. Reinforcement learning is the general designation for methods and algorithms that learn Markov Decision Process (MDP) solutions, i.e., state-action maps (policies) that maximize the infinite horizon discounted cumulative rewards. Despite recent research progress, it is still challenging to apply reinforcement learning methods to large state and action spaces and various methods should be developed to meet the inherent complexity of the tasks.

To learn in noisy and uncertain underwater scenarios, the PhD candidate will explore new research directions in reinforcement learning that go beyond the search of a single solution through gradient computation. Some examples of promising approaches are the robust use of covariance information in the reward process, the use of multidimensional reward and adaptive exploration, and the consideration of adaptive policy parameterization. To handle the high dimensionality and large amount of data, the use of compact models that depend on task parameters (such as Parametric Hidden Markov Model) will be studied to learn parameter-dependent task models that provide better generalization capabilities.

The PhD student will be expected to develop and extend machine learning algorithms for robot control and skill learning. The research will be conducted especially targeting noisy and uncertain environments such as underwater scenarios. The target application will be AUV skill learning with abilities for persistent autonomy. Special focus will be put on allowing the skill representation to support both generation and recognition, in order to do fault detection using the same representation used for execution of the skill.

This PhD position is within a long-term European project in which IIT is a partner. AUVs and water tank equipment for conducting experiments will be provided by other partners in the project.

Requirements: The candidates should have top class degree and a background in Computer Science, Engineering, or Mathematics. Required technical skills: C/C++ and/or MATLAB

For further details please contact: petar.kormushev@iit.it and sylvain.calinon@iit.it

Theme 2.8: Machine learning for a soft robotic arm assisting in minimally invasive surgery
Tutor: Dr. Petar Kormushev, Dr. Sylvain Calinon, Prof. Darwin G. Caldwell
Number of available positions: 1

In minimally invasive surgery, tools go through narrow openings and manipulate soft organs that can move, deform, or change stiffness. There are limitations in current robot-assisted surgical systems due to the rigidity of robot tools. A soft robotic arm will be available within the project to manipulate objects while controlling the stiffness of selected body parts. This PhD theme will focus on the learning, human-robot interaction and variable compliance manipulation aspects.

The objective will be to use multiple demonstrations from the teleoperator to learn force/position control manoeuvres so that the operator will, over time, be able to concentrate on high level decisions while the robot takes care of low level reactive control manoeuvres in a semi-autonomous fashion. The PhD candidate will conduct experiments to answer a number of questions in the areas of learning to control the stiffness of selected parts of the robot, moving in a constrained space, and to exert desired forces on soft objects with uncertain impedance parameters.

Probabilistic encoding schemes based on Hidden Markov Models will be used to learn a policy that takes into account variability and correlation information collected during consecutive trials. The aim is to estimate an adequate level of compliance depending on the task requirements to leverage the operator with operations that are not directly relevant for the task. The use of novel control algorithms will be explored to arbitrate the degree of coupling of the flexible arm to best suit the statistics of the task (e.g., by stiffening the arm in task relevant dimensions).

A novel topic that will be investigated is the way humans account for uncertainties in the environment and how reinforcement learning algorithms can be used to map states to reward signals. In order for the proposed flexible manipulator to generalize from the motion patterns “taught” by the human operator, we will explore how an artificial cognitive system could use self-improving techniques during its interactions with the real world and build memory primitives that relate control actions to their consequences, which could in turn trigger de novo formation and memorization of complex patterns of motor sequences to maximize adaptability in uncertain environments.

We will consider several methodologies to bootstrap the robot’s control policy from the user’s demonstrations. Indeed, a broad spectrum of imitative behaviours exists in nature, continuously ranging from mimicry (the ability to reproduce an observed movement) to true imitation (the ability to understand the intended goal of an observed action). We will study the estimation of a critic from demonstrations to infer a reward function from the demonstrations instead of pre-specifying it in advance, which then allows the robot to find an adequate policy for the reproduction of the task. We will then consider an alternative use of the variations in the demonstrations, closer to mimicry than to true imitation, which allows the robot to build a model of the policy that takes into account this variability information to handle perturbation and to help it at exploring new solutions in an appropriate manner (e.g. by biasing the RL exploration process). As for their biological counterparts, these different mechanisms have advantages/disadvantages that we will analyze in relation with the situation and complexity of the skill.

Unlike conventional imitation based learning, where the learner tries to learn the exact kinematic profile of a movement, here we first plan to develop a method to enable the robot to learn the underlying objective of an action taken by the demonstrator. Once the robot learns these cost-functions, it will be able to develop its own behaviours in a reinforcement learning based paradigm. Ultimately, the robot will develop autonomous behaviours to respond to disturbances allowing the human operator to concentrate more on the high-level task.

Requirements: Technical skills required: C/C++ and/or Matlab

For further details please contact: petar.kormushev@iit.it and sylvain.calinon@iit.it

STREAM 4: Humanoids and Compliant Robotics

Theme 2.9: Building the next Humanoids: Exploring the Mechatronic Technological Limits and New Design Philosophies for the development of a Ultra High Performance Leg.

Tutor: Dr Nikos Tsagarakis
Number of available positions: 1

Although significant progress has been made during the past two decades in the mechatronic development of humanoid robots legs there are still significant barriers to be overcome before the legs (structure, actuation and sensing) of the humanoid systems approach the performance of the human body. When compared with human legs the engineered humanoid legs significantly lack performance, sensing capabilities and robustness during interactions with the environment either when they are self generated or accidentally imposed, e.g. falling down. High impact interactions which are required for example during the execution of highly dynamic tasks, e.g. running and jumping cannot be tolerated by any existing humanoid system. This is because the design approach of these systems is incompatible with those tasks. The existing humanoid legs consist of rigid structures and are actuated by highly geared stiff position servos which impose significant limitations both in the velocities/torque profiles that can be achieved at the joint level and in the capability of these systems to absorb the impacts. In addition the lack of compliance does not allow these robots to make use of the natural dynamics and storage of energy during the motion cycle. As a result these robots have higher energy demands since more effort is required by both the control system and the actuator. The aim of this research is to improve the performance of existing humanoid legs by exploring both the technological limits (structural materials, actuation and sensing) and through the development of new design and control philosophies. The outcome of these efforts will be verified though the development of a highly dynamic bipedal machine having the goal of achieving running speeds close to those achieved by humans while at the same time demonstrating robustness and tolerance to external disturbances.

Requirements: We are seeking a top class candidate with a background in Mechanical engineering or Robotics. This is a multidisciplinary project where the successful candidates should have strong competencies in CAD mechanism design and good knowledge of robot kinematics/dynamics. (Mechanical design 70%, Dynamics/Control 30%)
For further details concerning this research project, please contact: nikos.tsagarakis@iit.it

Theme 2.10: Development of a Variable Stiffness Actuated Humanoid Lower Body

Tutor: Dr Nikos Tsagarakis
Number of Positions: 2

The humanoid child robot iCub was constructed within the European consortium RobotCub. The legs have 12DOF and are powered by electrical motors and harmonic drives making the joints stiff. However, for energy efficient and natural walking, humans have compliant joints. At IIT different adaptably compliant actuators and their control architectures are under development. The goal of this research is to develop a new lower body to incorporate these compliant actuators. In the initial phase of the project simulation studies on the lower body will be used to identify the optimum position of the compliant elements across the leg kinematic chain. The compliant actuation sources will be designed and realized using electromechanical arrangements of mechanical elastic elements and motorized based units. The mechanical characteristics of these newly developed actuators will be determined through simulation analysis of the humanoid platform as well as from human biomechanical data. From these studies parameters such as joint stiffness range, energy storage capacity and actuator power will be determined and will be used for the fine tuning of the actuator electromechanical assembly. Following this the variable compliance solutions developed will be mechanically shaped to make them compatible with the mechanical morphology of the humanoid platform. The incorporation of the passive variable compliant actuation and the active compliance control will effectively result in the first humanoid platform which will exhibit a fully compliant lower body where compliance in the joints can be passively regulated. Following the mechatronic developments a second objective of the project will be to develop new control strategies making use of the intrinsic compliance in order to improve the energy efficiency and the adaptability of the robot to terrain variations.

This project is open to two different PhD candidates: one with more interest in control/software aspects and the other in mechanical/CAD design.
Requirements: We are ideally seeking for candidates with a background in Electronic/Mechanical engineering or Robotics. This is a multidisciplinary project where the successful candidates should have competencies in CAD mechanical design robot dynamics and good knowledge of MATLAB and C/C++ programming. (Mechanical design 50%, Control %30, MATLAB/Programming 20%)
For further details concerning this research project, please contact: nikos.tsagarakis@iit.it

Theme 2.11: Humanoid Walking and Motion Planning: From Flat Terrains through Uneven Terrains, to Particulate Surfaces and Terrains with different Stiffness properties.

Tutor: Dr Nikos Tsagarakis
Number of available positions: 2

Despite the significant progress made in Humanoid locomotion during the past decade most current humanoids still suffer from major problems related to dynamically equilibrated walking, stable walking and physical interaction with the environment. Looking at Humanoid locomotion developments it can be also observed that most of them have been performed on flat surfaces. This is a very ideal surface compared to those encountered in human environments where stairs, inclined surfaces, small obstacles and even rough surfaces are common. Up to now, there are a few effective demonstrations about walking and motion planning on these environments.
A new humanoid robot, CoMan, is under development in IIT under the European FP7 project AMARSI (htp://www.amarsi-project.eu/). This newly developed robot has compliant joint structures which will eventually enable us to obtain feasible jumping/running characteristics through the natural system dynamics. In addition, this robot has 6 axis Force/Torque sensors at the ankles and the soles of the feet are also equipped with 5 point 1-axis force sensors to detect contact with the ground. Such a sensory system created on the feet soles will permit an exploration of walking on:

a) Uneven terrains and stepping above obstacles
b) Particulate solid surfaces consisting of particles of different size and density
c) Surfaces of different stiffness.

Techniques will be developed to plan the motion and regulate both dynamic equilibrium and body/feet posture in order to achieve walking on uneven surfaces avoiding or passing above obstacles with variable inclinations, on particulate surfaces such as sand or to pass through surfaces of different stiffness properties. These methods will take into account different kinematics/dynamics or self collision constraints while detection of the terrain properties will be assisted by rich sensory feedback from the feet of the humanoid. In particular, we will explore how to detect rough terrain/obstacle properties such as inclination and stiffness using the contact force sensors located on the soles of the feet. Having determined the rough terrain characteristics, how the balance stability is affected when the robot is on this specific rough terrain will be evaluated and different control and trajectory planning methodologies will be developed to allow the humanoid passing through while maintaining stability and balance.
Requirements: The applicant should have a top class degree and ideally possess a strong background in physical system modeling and control, MATLAB and C/C++ programming. Knowledge on mechatronics hardware, fundamental robotics and rigid body dynamics is a plus.
For further details concerning this research project, please contact: nikos.tsagarakis@iit.it

Theme 2.12: Development and control of a Variable Damping/ Stiffness Actuated Humanoid Upper Body

Tutor: Matteo Laffranchi, Dr Nikos Tsagarakis
Number of available positions: 2

Compliant actuation systems enable safer human-robot interaction, make robots able to cope with unpredictable interactions within not well defined environments and improve the mechanical robustness of the structure. However, compliance induces also some drawbacks as the introduction of underdamped oscillatory modes and the reduction of the bandwidth which can be achieved in the controlled system. As a result, a number of different variable physical damping actuators (VPDA) to be used within SEA/VSA have been developed in IIT to facilitate the control and improve the performance of compliant actuation systems. Initially, this research will focus on the development of an upper body which incorporates the compliant actuators with variable physical damping developed at IIT: this will result into the first compliant robot design with adjustable physical damping. Lightweight composite material such as carbon fibre will be used in this design to enhance the safety and dynamic performances of the robot. In parallel to this, a model-based simulator of the upper body humanoid will be developed. The latter task will allow the design and validation of novel control strategies which will realize: optimal control of the elastic/kinetic energy for obtaining high motion speeds and dissipation techniques for damping of the induced oscillations, for improved human-robot interaction safety or simultaneous motion/impedance control of the robot.
The second main goal of this research is the development of novel modular actuation units with both variable stiffness and physical damping intended to be used for the development of multi-dof robots. As a consequence this will require the design of related control strategies for this enhanced actuator version with variable stiffness capability. This novel actuation unit will be used in the second version of the humanoid upper body with hybrid Variable Stiffness and Damping.
This project is open to two different PhD candidates: one with more interest in control/software aspects and the other in mechanical/CAD design.
Requirements: We are ideally seeking for candidates with a background in Electronic/Mechanical/Mechatronics engineering or Robotics. This is a multidisciplinary project where the successful candidates should have competencies in CAD mechanical design, robot dynamics and good knowledge of MATLAB and and C/C++ programming. (Mechanical design 40%, Control %40, MATLAB/Programming 20%)
For further details concerning this research project, please contact: matteo.laffranchi@iit.it

STREAM 5: Haptic Systems, Virtual and Augmented Reality

Theme 2.13: Dynamic Investigation Test-rig on hAptics (DITA) development and virtual fingertip model building by human perceptual performance measurement for the evaluation of touch sensitivity suitable for tactile display improvement.

Tutor: Ferdinando Cannella
Number of available positions: 1

Most sensory research has concentrated on the visual and audio aspects of the sensory systems but have largely ignored the three remaining senses - smell, taste and touch. Of these 'neglected' senses touch is now receiving attention with the advent of applications that require sensory fidelity beyond simply vision and audition. The neurophysiological and psychophysical mechanisms that underlie tactile perception have been a subject of much research. The structure and function of the low-level fibres innervating the skin is reasonably well understood, however the high-level mechanisms are still an area of speculation.
Interest in the sense of touch is increasing because it is crucial in many kinds of training or tele-operation procedures as these actions require the user to extensively engage his hand and fingers. In addition decreasing perceptual performance can be an effect of several illnesses (diabetes, multiple sclerosis, etc.) and careful observation and monitoring using haptic systems could help to identify the on-set and reduce the severity of the touch degeneration.
Improvements in hardware and software to provide effective force/touch feedback has led to the development of generic haptic devices that have been applied in various training simulators and tele-operation systems and have potential in medical diagnostics.
The first goal of this PhD will be to develop a virtual finger to replicate the function of the physical one to investigate the sensitivity of the human fingertip. A Dynamic Investigation Test-rig on hAptics (DITA) will be developed to measure the tactile sensitivity, followed by development of DITA software for acquiring data on subjects' touch sensitivity and for carrying out perceptual understanding trials. From these data the virtual finger will be tested and validated in comparison with the human finger. The evaluation process will quantify the effects of some hardware parameters (for instance tactile device spatial density and/or speed) on user haptic perception. The focus of this research will be to generate new knowledge on tactile sensitivity suitable for improving the tactile display.
The secondary goal is to develop DITA in order to make it suitable for clinical testing and investigations.
Requirements: The ideal applicant should have a good background in psychophysics with some experience in programming and in measurements (60% psychophysics, 20% software, 20% measurement).
For further details concerning this research project, please contact: ferdinando.cannella@iit.it

Theme 2.14: Cognitive and Behavioural Strategies in Human-Robot Interaction

Tutor: Eng. Andrea Brogni, Dr. Nick Tsagarakis
Number of available positions: 1

This project will involve the study and design of techniques exploiting the latest Virtual Reality and Human Robot Interaction technologies. The project will include the development of new interaction paradigms taking advantage of computer graphics, mobile systems and novel interfaces. The topic of the PhD will be the study of effective and affective interaction strategies between humans and robotics systems, both humanoid and manipulators.
The ideal candidate should have a background on psychology and cognition, as well as basic knowledge of computer science. He/she should also have a strong attitude to mix theory and practice, including design of experiments and programming. Experience with interfaces and robotics systems could be an advantage.

Requirements: Required technical skills:	Cognition/Psychology	50 %
	Software	30 %
	Presence/ Virtual Reality	20 %

For further details concerning this research project, please contact: Andrea.Brogni@iit.it

Theme 2.15: Enhancing Audiovisual Fruition through Virtual Reality Systems

Tutor: Eng. Andrea Brogni, Dr. Nick Tsagarakis
Number of available positions: 1

Study and design of techniques exploiting the latest Virtual Reality, Human Computer Interaction and Motion Capture technologies in expressive and artistic contexts. The project will include the development of new interaction paradigms taking advantage of computer graphics, audio and music manipulation possibilities.
The topic of the PhD will be mainly the design of stationary and portable platforms to be used within Virtual and Hybrid Environments, to help Virtual Reality fruition and to enhance audiovisual stage choreographies.
The ideal candidate should have a background on computer science or engineering and a strong attitude to mix theory and practice, including programming C++ libraries, interfaces for hardware and 3D OpenGL graphics. Experience with audio and tracking systems could be an advantage.

Requirements: Required technical skills:	Software	60 %
	Graphics	30 %
	Electronics	10 %

For further details concerning this research project, please contact: Andrea.Brogni@iit.it

Theme 2.16: Non-invasive Sensing System for Human Localization and Tracking in Virtual Environments

Tutor: Eng. Andrea Brogni, Dr. Nick Tsagarakis, Dr. Alessio Del Bue, Prof. Vittorio Murino
Number of Positions: 1 – shared with PLUS lab

Virtual Reality and Human Machine Interfaces are mostly restricted to a single subject or small group of individuals. The deployment of a VR system encompassing a large number of individuals, namely a crowd, brings the need of implementing a framework that automatically analyses the dynamics of a large group of people and their gestures, as a group or individuals.
The first part of the PhD will be studying the different possibility of non-invasive tracking allowed by the technology, in particular it would be necessary the definition of the possible interactions in different VR modalities. The second part will be design and implementation of a sensing system that may allow fine analysis of motion (kinematics and joint modelling) for the single/multi user interaction in 3D stereoscopic virtual environments. This work will be based on previous studies and in collaboration with other researchers.
The ideal candidate should have a background on computer science or engineering and a strong attitude to mix theory and practice, including programming C++ libraries, computer vision and 3D graphics.

Requirements: Required technical skills:	Software	50 %
	Graphics	40 %
	Electronics	10 %

For further details concerning this research project, please contact: Andrea.Brogni@iit.it

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