PhD Program in Bioengineering and Robotics

**Curriculum:** Advanced and Humanoid Robotics

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In the spirit of the doctoral School on Bioengineering and Robotics, the goal of the “Advanced and Humanoid Robotics” curriculum is to study the design, realization, programming and control of anthropomorphic and legged robots. Students will work at the forefront of mechatronics and computer science research jointly covering the full development cycle from software to mechanical design and from machine learning to realization of sensors, actuators and electronics. We address the development of the technologies for the next generation of robots for sensing, actuation and computation. The goal is to develop robots that can adaptively interact with their environment, learn from their mistakes, and succeed in performing safely and reliably in real-world environments. Foreseen applications for anthropomorphic robots range from real-world practical scenarios - e.g., at home, as personal assistants- to industry as co-workers, to natural or man-made disaster scenarios. Humanoid robot software deals with vision, audition and tactile perception as well as the ability to look, reach and manipulate the world while walking freely to reach their targets, interacting naturally with the environment and their human “teachers”.

International applicants are encouraged and will receive logistic support with visa issues, relocation, etc.
Locomotion planning and control of a hybrid legged/wheeled robot platform

Tutors: Arturo Laurenzi, Luca Rossini, Nikos Tsagarakis,


Project Description
Emerging robots operating within man-made real-world workspaces will have to walk, reach, physically interact, pick up, retrieve and manipulate a variety of objects, tools and interfaces designed for human use. This research theme will focus on the development of hybrid locomotion planning strategies for the existing CENTAURO robot, which is equipped with wheeled and legged mobility (https://www.youtube.com/watch?v=F8F7aOxqZ6Y&t=13s, https://www.iit.it/web/humanoids-human-centered-mechatronics/robot-control) as well the new version of the platform that will be available during the duration of the PhD study. On flat terrains directly driven wheels will move the robot quickly and efficiently in an omnidirectional way by independently adjusting their speed and orientation. When driving over uneven ground, the legs will adapt to the surface, such that the posture of the main body is stabilized. Different principles and combinations of leg gaits and wheel mobility mechanisms will be developed and evaluated in simulation and finally implemented and validated on the CENTAURO prototype.

Requirements: We are seeking for highly motivated candidates with a background in Electrical, Mechanical or Control engineering, Physical Sciences or Robotics. Candidates should have strong competencies in robot dynamics, control and excellent programming skills in Matlab and C++. (Programming and Simulation 30%, Dynamics/Control %70). The experience on dynamic simulators (e.g. Gazebo) and ROS would be plus. The applicants should be fluent in English and team players.

Note: It is compulsory to prepare a research proposal on this topic.

References:


Contacts: arturo.laurenzi@iit.it, luca.rossini@iit.it, nikos.tsagarakis@iit.it
Intelligent end-effector embodiment principles

**Tutors**: Nikos Tsagarakis, Lorenzo Baccelliere

**Tutors Affiliation**: Humanoid and Human Centred Mechatronics Research line, https://www.iit.it/research/lines/humanoids-human-centered-mechatronics

**Project Description**

The realization of effective manipulation skills has strong dependencies on the robot end-effector mechatronics including the articulated kinematics, the actuation and the sensing principles of the end-effector module. This research topic targets to develop kinematically minimalistic end-effector modules that are equipped with intrinsic adaptation as well as multi-modal sensing capabilities to facilitate the manipulation robustness as well as the realization of low level autonomous grasping and manipulation skills. The mechatronic design and the engineering of the end-effector modules will explore the instrumentation of the grippers with integration of visual and haptic sensing that will provide the cues for implementing autonomous grasping and manipulation functionalities. Control methodologies and a set of autonomous manipulation skills will be explored and implemented to enable the execution and adaptation of grasping actions. Proprioceptive feedback will be employed for the regulation of the grasping forces and for their adaptation through reflex controllers. Two families of end-effector devices will be developed with different articulation topologies to serve the grasping and manipulation requirements of an assistive robotic arm developed within HARIA project (http://haria-project.eu/) and needs of the manipulation system developed within the REPAIR project (https://www.repairproject.eu/). In the first case the end-effector requirements will also include intrinsic features to favour safe human-robot interaction while in the second use-case of the RePair project the specifications of the end-effector device will prioritized high payload capacity and inherent adaptation to arbitrary shape objects.

**Requirements**: We are seeking for highly motivated candidates with a background in Mechanical and Control engineering, Physical Sciences or Robotics. Candidates should have competencies in CAD mechanical design and/or robot dynamics and control. (Mechanical design 60%, Control %40). The applicants should be fluent in English and team players.

**References**:


**Contacts**: nikos.tsagarakis@iit.it
Agile and efficient legged robot design and actuation principles

Tutors: Nikos Tsagarakis, Lorenzo Baccelliere, Yifang Zhang


Project Description

The Humanoid and Human Centred Mechatronics research line is one of the world leading research labs in the development and new actuation and robotic systems (https://www.iit.it/web/humanoids-human-centered-mechatronics/robot-hardware) powered by advanced actuation technologies. The aim of this topic is to develop and demonstrate break-through robot design and actuation principles targeting to achieve agile and efficient motion performance and resilient interaction capacity that goes far beyond the current state of art. Towards this progress, this project will exploit advancements in robotic actuation and energy recycling techniques, investigate state-of-the-art transmission units and research limb/structure design aspects including lightweight structural materials integrated with customized high power density actuation and transmission systems. Energy storage and recuperation will be also explored to increase the robot efficiency as well as agility during explosive motions. The developed robot design concepts and controllers will be applied to realize novel legged robot prototypes of bipedal/quadruped embodiment capable of performing high power bursts such as kicking and jumping while demonstrate improved efficiency performance.

Requirements: We are seeking for highly motivated candidates with a background in Mechanical engineering, Physical Sciences or Robotics. Candidates should have competencies in CAD mechanical design and/or robot dynamics and control. (Mechanical design 70%, Dynamics/Control %30). The applicants should be fluent in English and team players.

References:


Contacts: nikos.tsagarakis@iit.it
Locomotion planning and control of a hybrid legged/wheeled robot platform

Tutors: Nikos Tsagarakis, Luca Muratore


Project Description

The problem of mobility planning on cluttered, uneven and eventually dynamic terrains for navigation is the key aspect for completing locomotion in unknown environments. Similarly performing manipulation actions in an autonomous manner and enabling robots interact more richly with the world around them, requires a deeper understanding of the world in which they operate. The aim of this topic is to develop new geometric or machine learning methods for terrain/environment reconstruction and semantics that permit mobile wheeled or legged manipulation platforms to navigate around in unstructured terrains and environments and perform autonomous loco-manipulation actions. Such semantics information will be explored for autonomous mobility planning (path planning, wheeled/leg motion planning, foot placement) and autonomous manipulation (object and environment feature and interfaces recognition and manipulation strategy selection). Several exteroceptive (stereo/event/RGB cameras, RGB-D sensors, 2D/3D Lidar scanners) will be used to acquire RGB images and dense 3D point cloud while geometric simplifications for reasoning will be explored. Moreover, mobility and manipulation planning methods need to be developed to select and modulate suitable primitives for loco-manipulation. The development and testing will take place on a range of mobile platforms available in IIT including the CENTAURO hybrid legged-wheeled mobility robot (https://www.youtube.com/watch?v=F8F7aOxqZ6Y&t=13s, https://www.iit.it/web/humanoids-human-centered-mechatronics/robot-control, https://www.youtube.com/watch?v=tr5gCxs78vg) and the CONCERT mobile manipulation platform (https://concertproject.eu/) developed to operate within unstructured building construction sites.

Requirements: This topic lies in the intersection of Vision and Robotics. Ideal applicants should have strong C++ (Python and Matlab is a plus) programming skills. Machine learning and computer vision skills are required. A background in any of Robotics, Computer/Robotic Vision, Path Planning, and Robot Learning is desirable, while knowledge of the Robot Operating System (ROS) and the Point Cloud Library (PCL) is a plus (Programming and Simulation 30%, Perception/Learning %70). The applicants should be fluent in English and team players.

References:


Contacts: nikos.tsagarakis@iit.it, luca.muratore@iit.it
Optimal configuration synthesis and control of a reconfigurable mobile manipulation platform

Tutors: Edoardo Romiti, Arturo Laurenzi, Nikos Tsagarakis


Project Description

The robots are coming out of the cage, and getting closely involved into human life and physically interacting with them to execute tasks in a collaborative manner. This research theme will focus on the development of optimal configuration synthesis and control components for a fully reconfigurable mobile manipulation platform developed to operate within a construction site environment and execute tasks in collaboration with human workers. This platform, which has been developed within the EU CONCERT project (https://concertproject.eu/, https://alberobotics.it/), permits to adapt the physical embodiment of the robot given a set of manipulation requirements relevant to the task that the robot has to execute. In particular, it targets to assist humans within the construction environment in executing heavy or repetitive manipulation tasks in a supervised, semi-autonomous or fully autonomous manner. The project will look on the development of tools to assist the derivation of the robot configuration given a task, as well as control and interaction components that take into account the human inputs and intentions and combine them with autonomous modules driven by the robot perception to command the reconfigurable mobile manipulation platform in order to execute a range of constructions tasks related to interior finishing tasks within a construction site. Autonomous mobility and navigation, precise localization and robust high power physical interaction are some the required autonomous skills to be developed within this project in order to assist the human partner in commanding effectively and collaborating effectively with the reconfigurable mobile manipulation platform in the envisioned construction task scenarios.

Requirements: We are seeking for highly motivated candidates with a background in Electrical, Mechanical or Control engineering, Physical Sciences or Robotics. Candidates should have strong competencies in robot dynamics, control and excellent programming skills in Matlab and C++. (Programing and Simulation 30%, Dynamics 30%, Control %40). The experience on dynamic simulators (e.g. Gazebo) and ROS would be plus. The applicants should be fluent in English and team players.

References:

Contacts: edoardo.romiti@iit.it, arturo.laurenzi@iit.it, nikos.tsagarakis@iit.it
Design and development of mechatronic systems for human-robot interaction

Tutors: Arash Ajoudani

Tutors Affiliation: Human-Robot Interfaces and Interaction, Istituto Italiano di Tecnologia and Università di Genova

Project Description
This theme will aim to develop mechatronic systems that facilitate human-robot interaction and collaboration. It includes sensory-feedback systems for measurement and situational awareness, hardware interfaces to be used by humans or mounted on robots, and the design and development of new actuation systems (e.g., hybrid soft and rigid).

Requirements: The successful candidate must have an MSc degree with a strong background in Robotics, Embedded Systems, Mechatronics, and/or physical human-robot interaction. The successful candidate should have:

- Good skills on C++ and Python
- Experience with ROS
- Confidence with version control tools (specifically git)
- Good communication skills and ability/willingness to integrate within a multidisciplinary international research group
- Good knowledge of written and spoken English.

References:


Contacts: Arash@Ajoudani@iit.it
Design of the Next Generation of Quadruped Robots

Tutors: Claudio Semini and Matteo Villa

Tutors Affiliation: Dynamic Legged Systems (DLS), Istituto Italiano di Tecnologia – IIT, Genova [http://dls.iit.it](http://dls.iit.it)

Project Description

The DLS research line performs cutting-edge research and development of legged robots for challenging environments [1,2,3]. Our projects address disaster response, space exploration, precision agriculture, inspection and other applications.

Besides perception and control, the hardware design is crucial for robust and high-performance quadrupeds for real-world applications. This PhD theme will explore, build and test novel designs and special features for the next generation of quadruped robots. In particular, the student will explore different materials, actuators, sensors, geometries, as well as task-oriented design features.

Requirements: We are looking for a highly motivated and creative student, very committed to research and eager to explore new paradigms. An excellent Masters degree is expected in one of the following areas (or related): mechanical, mechatronics, or robotics engineering. As technical skills, the student must have solid knowledge of mechanical design, GD&T, robotics (kinematics and dynamics), systems modelling and simulation, as well as some basics in control theory. The candidate must have proven experience with CAD software packages, FEA software, Matlab, some experience with ROS as well as hands-on experience in machine development and testing. Experience with the design and testing of legged robots are a big plus.

References:


Contacts: claudio.semini@iit.it or matteo.villa@iit.it
Vision-Based Terrain Classification for Quadruped Robots

Tutors: Claudio Semini, Giulio Turrisi, Victor Barasuol, Giulia Pasquale, Lorenzo Natale


Project Description

The DLS research line performs cutting-edge research and development of legged robots for challenging environments. Our projects address disaster response, space exploration, precision agriculture, inspection and other applications.

In all these scenarios, perception is considered a core component of a robust and precise locomotion controller. Still, human-level capabilities in this sector are far from being achieved by robots. This PhD theme will explore the use of machine learning techniques for vision-based locomotion ([1], [2], [3]). In particular, the PhD candidate will explore different network architectures and learning modalities to perform precise terrain classification or segmentation, discerning dangerous areas which cannot be traversed by the robot. This information will then be exploited to perform safe path-planning and reactive foothold placements.

This project will be carried out in collaboration with IIT’s HSP research line, which has extensive expertise in machine learning and artificial perception for robotics.

Requirements: We are looking for a highly motivated and creative student, very committed to research and eager to explore new paradigms. An excellent Master’s degree is expected in one of the following areas (or related): artificial intelligence, computer vision, or robotics engineering. As technical skills, the student must have solid knowledge of machine learning, robotics (kinematics and dynamics), as well as some basics in control theory. The candidate must have proven experience with machine learning libraries, e.g. Pytorch or Tensorflow. Experience with ROS is considered a big plus.

References:


Contacts: claudio.semini@iit.it, giulio.turrisi@iit.it, victor.barasuol@iit.it
Human-robot Collaboration with Quadruped Robots on Rough Terrain

Tutors: Claudio Semini and Victor Barasuol

Tutors Affiliation: Dynamic Legged Systems (DLS), Istituto Italiano di Tecnologia – IIT, Genova [http://dls.iit.it](http://dls.iit.it)

Project Description

The DLS research line performs cutting-edge research and development of legged robots for challenging environments [1,2,3] ([https://www.youtube.com/watch?v=pLSNs1ZS_TI](https://www.youtube.com/watch?v=pLSNs1ZS_TI)). Our projects address inspection, space exploration, precision agriculture ([https://www.youtube.com/watch?v=nEyHafcRE_g](https://www.youtube.com/watch?v=nEyHafcRE_g)), disaster response ([https://www.youtube.com/watch?v=66ZMUaBLjaM](https://www.youtube.com/watch?v=66ZMUaBLjaM)), and other applications.

Quadruped robots are increasingly becoming the first choice when a mobile platform must be selected to perform tasks in unstructured environment or on irregular terrains. Although quadruped locomotion has reached noticeable robustness in challenging scenarios, quadruped loco-manipulation for human-robot collaboration must still be exploited. Therefore, the focus of this PhD theme lies on robust locomotion on rough terrain with quadruped manipulators when performing human-robot collaboration and other challenging manipulation tasks. The PhD student will explore aspects related to motion planning, static and dynamic locomotion stability, and human–robot interaction efforts.

Requirements: We are looking for a highly motivated and creative student, very committed to research and eager to explore new paradigms. An excellent Masters degree is expected in one of the following areas (or related): robotics engineering, control engineering, or mechanical engineering. As technical skills, the student must have solid knowledge of control theory, dynamic systems modelling, robotics, control of robot manipulators, and C++ programming. The candidate must have proven experience with physical engines (e.g., Matlab/Simulink or Gazebo). Strong experience with real robots, ROS and Gazebo is very welcome.

References:


Contacts: claudio.semini@iit.it or victor.barasuol@iit.it
Vision based control of prosthetic hands

Tutors: Lorenzo Natale, Elisa Maiettini

Tutors Affiliation: Humanoid Sensing and Perception, Istituto Italiano di Tecnologia (https://hsp.iit.it)

Project Description

Recent work has investigated the application of computer vision and machine learning techniques to the control of prosthetic arm devices for grasping objects (Vasile et al 2022, Starke et al 2022). These approaches implement shared-autonomy (or shared control) systems, where most of the control is delegated to an automatic system based on visual input, while the user decides only when to activate or stop the grasping, for example, through electromyography (EMG). Such an approach is particularly important for controlling prosthetic devices that have several degrees of freedom (DoFs) and that are difficult to control with EMGs alone. Moving from simple grasping to more complex actions (e.g., Activities of Daily Living, ADL) is, however, still an open challenge.

This project seeks to develop shared control strategies for prosthetic arm devices, based on AI methods and visual feedback, with the goal of increasing usability while reducing user effort. The focus will be to study how to provide the AI system knowledge about the target object and the action the user is about to accomplish, to identify, reliably, the motion of the hand and wrist degrees of freedom needed for the task. We will consider different sources of visual information, such as information gathered from a camera embedded in the prosthetic devices, or head-mounted cameras. The former provides information on the object and how it is approached, while the latter provides relevant contextual cues about the environment and the attention of the user. Inspired by recent Computer Vision literature (Grauman et al. 2022), we will investigate how visual information from head-mounted camera can be used to infer or anticipate the action the user is about to perform and control the prosthetic arm accordingly.

This project will be carried out in collaboration with the group Rehab Technologies Lab (https://rehab.iit.it/) using the Hannes hand prosthesis (https://rehab.iit.it/hannes).

Requirements: Applicants are expected to have an MSc degree in computer science, engineering or related fields, background in Computer Vision and AI methods, and experience with programming languages like C++ and Python and deep learning frameworks. In addition, the candidate is required to have a strong interest working with real robotic systems.

References:


Contacts: lorenzo.natale@iit.it, elisa.maiettini@iit.it