ISTITUTO ITALIANO DI TECNOLOGIA | PhD@IIT

Research Topics for **Doctorate in Bioengineering and Robotics,** curriculum in **Advanced and Humanoid Robotics**

Research Topics

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1. Intelligent End-effector Embodiment Principles

Tutors
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Research Line
Humanoid and Human Centred Mechatronics, IIT, Genova

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 activity 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. Such low level autonomous principles will include automatic execution of end-effector opening/closing actions when approaching the object to grasp, adaptation of the manipulation forces on the basis of the perceived properties of the object to grasp or reflex control principles e.g. for accommodating autonomously slippage during grasping. We will leverage on visual and haptic stimuli generated by the end-effector proprioceptive sensing and visual perception modules

integrated on the robotic system. Proprioceptive feedback will be employed for the regulation of the grasping forces and for their adaptation through reflex controllers.

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%, Dynamics/Control %40).

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

References

- Barrett E., Mingo-Hoffman E., Baccelliere L., Tsagarakis N.G., Mechatronic Design and Control of a Light Weight Manipulator Arm for Mobile Platforms, IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM), 2021, pp 1255-1261.
- Ren Z, Kashiri N., Zhou C., Tsagarakis N.G., Heri ii: A robust and flexible robotic hand based on modular finger design and under actuation principles, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2018, pp 1449-1455.

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2. Semantics for Robot Locomanipulation

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Research Line
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Description
Enabling robots to deal autonomously with structured and eventually unstructured environments and replace humans in difficult tasks is an open challenge in robotics. Rapid advancements in robot design and control over the past few years enabled articulated legged robots to walk in uneven terrain. Still, the problem of mobility planning on uneven terrain 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 (e.g. deep learning) methods for environment reconstruction and semantics that can enable autonomous locomanipulation and permit wheeled or legged manipulation platforms, such CENTAURO (https://www.iit.it/web/humanoids-human-centered-mechatronics/robot-control) or

CONCERT (https://concertproject.eu/) to move around in unstructured environments and perform locomanipulation actions. Such semantics information semantics will be explored for autonomous mobility planning (foot placement, path planning) 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 locomanipulation. The development and testing will take place on our full-size quadrupedal and mobile robots in real-world environments.

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 very big plus. The applicants should be fluent in English and team players.

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

References

- De Luca A., Muratore A., Raghavan V.S., Antonucci D., Tsagarakis N.G., Autonomous Obstacle Crossing Strategies for the Hybrid Wheeled-Legged Robot Centauro, Frontiers in Robotics and AI, Vol. 8, 2021.
- Kanoulas et. al., Footstep Planning in Rough Terrain for Bipedal Robots using Curved Contact Patches, ICRA 2018.

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3. Wearable Interfaces for Teleoperation and Human Robot Interaction

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This theme focuses on the development of wearable kinesthetic input and feedback devices for the upper limp including systems for the hand and arm. One of the main objectives of the design of these systems is to move away from the traditional design paradigms of wearable devices that target to develop systems with many actuators following anthropomorphic exoskeleton structures attached to the upper limp segments using physical interfaces with multiple fixation points. With special attention on the systems ergonomics both a t the level of physical interface as well as at the level of the functionality this project will follow instead a different approach. At the implementation and physical interface level the project will attempt to minimize the complexity yet keeping the functionality of the device through the use of under-actuation and the employment of minimalistic physical interface principles that can resemble the interaction between the physiotherapist and the patients' upper limp. The activity of this project is strongly linked to the recently obtained EU project HARIA.

Requirements

The successful candidates will have a Master degree in Mechatronics, Robotics, Mechanical Engineering or equivalent and will be able to work both in a team and independently. Experience in CAD mechanical design, programming with C/C++ and Matlab is mandatory and knowledge of robot kinematics and dynamics is preferable. (50% mechanical design, 50% software and control).

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

References

- Brygo A., Sarakoglou I., Grioli G., Tsagarakis N.G., Synergy-based Bilateral Port: a Universal Control Module for Tele-manipulation Frameworks using Asymmetric Master-Slave Systems, Frontiers in Bioengineering and Biotechnology, Volume 5, 2017.
- Sarakoglou I., Brygo A., Mazzanti D., Garcia Hernandez N.V., Caldwell D.G., Tsagarakis N.G., HEXOTRAC: A Highly Under-Actuated Hand Exoskeleton for Finger Tracking and Force Feedback, IEEE/RSJ Int. Conf. Intelligent Robots and Systems (IROS), 2016.

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