I-RIM

PhD Course in

ROBOTICS AND INTELLIGENT MACHINES

Curriculum: Curriculum: Robotics and Intelligent Machines for Hostile and unstructured environments

Research themes

The main goal of the curriculum "Robotics and Intelligent Machines for Hostile and unstructured environments" is to address problems related to the study and development of enabling technologies and complex systems that will allow robots and intelligent machines to work in situations where the environment is dynamic, partially or totally unknown, hard to predict in advance, and possibly very challenging. The general objective of the curriculum is to form scientists and research technologists capable of working in multidisciplinary teams on projects where the interaction with a complex environment play a crucial role in technological development and design.

The 13 research themes offered in the first call of this year by the Italian Institute of Technology (IIT), Università degli Studi di Genova, and Università Politecnica delle Marche as part of this curriculum will be assigned to the best applicants to each of the 13 themes offered (**please check the number of positions available for each theme**).

Theme 1 addresses perception and control algorithms that allow a humanoid robot to navigate safely in an environment populated by humans, and successfully engage in verbal interaction with them.

Theme 2 explores object grasping and manipulation with anthropomorphic hands, taking into account physical properties of the objects in relation to the task to be performed, as perceived through visual and tactile feedback.

Themes 3 and 4 explore the coupling of soft materials, sensory transduction, neuromorphic circuits for sensory encoding and computation, and soft actuation, towards the design of robots that can seamlessly and gently interact with their environment. However, theme 3 will specifically develop spiking neural networks for processing tactile signals from octopus's suckers during manipulation and guiding the movement of its arm in response to external stimulation. Theme 4 will focus on the design of neuromorphic circuits on flexible substrate for encoding tactile and proprioceptive sensory signals into spike trains and pre-process such signals in a distributed system.

Theme 5 aim at designing end-to-end spiking robotic systems, relying on event-driven sensory encoding, neuromorphic computation, and spiking motor control, all implemented on neuromorphic hardware. As a case study, solutions will be validated in robotic applications using the neuromorphic iCub.

Theme 6 will investigate miniaturizable solutions for embeddable valves and other suction cup actuation methods that can comply with soft bodies and enable controlled detachment of the grasping. The work will integrate with existing octopus-inspired robotic arms that have distributed sensing localized in the suction cups.

Theme 7 will investigate the principles and the fundamental nature of soft robotics, aiming at the proposition of functional devices that embody part of their control logic and expected behavior in the form of mechanical intelligence. The candidate will build upon the group's experience on the design, realization and application of Soft Synergetic hands and Variable Impedance Actuators.

Theme 8 will develop new geometric or machine learning methods for terrain/environment reconstruction and semantics that will be explored to realize autonomous navigation skills to permit mobile wheeled or legged manipulation platforms to move around in unstructured terrains and environments, performing loco-manipulation actions to reach the targeted locations and deliver the transported goods.

Theme 9 will study in inspection and search&rescue scenario, either by using off-the-shelf solution, i.e., using the quadruped robot SPOT by Boston Dynamics, or through custom-designed solution. This will include autonomous navigation on hazardous and unstructured environment, which will require perception and locomotion on rocks, grass, sand, rocks, garbage, pipes, steep slopes uphill and downhill, an immersive teleoperation and control, in which the robot and a human operator form a team that collaborates to tackle complex problems.

Theme 10 will investigate disaster management with heterogeneous teams including human operators and and aerial and quadrupedal robots, proposing a novel Human-Robot Interface (HRI) that merges Augmented Reality strategies with autonomous control, path planning, and Collaborative Localization and Mapping (CLAM) algorithms.

Theme 11 will explore easy-to-use models and tools for scalable verification of robotics deliberation. This will be done through the development of adequate integrated modeling concepts to specify a robot's software and deliberation mechanism as well as relevant

features and properties of the environment as foundation for the mentioned verification methods.

Theme 12 will explore solutions to detect, recognize and track different targets and obstacles in real-time to reliably operate in the complex and dynamic marine environment, where environmental disturbances (winds, waves, and currents), sea fog, lighting conditions, and water reflection, have a great impact on the performance of the perception system.

Theme 13 will focus on designing and building a new generation of bio-inspired robots capable of exploring and acting in extreme environments, e.g., underwater, for several applications, including archaeology, sport diving, or monitoring Marine Protected Areas. The candidate will design and develop robots to advance state-of-the-art performance by combining additive manufacturing techniques, functional materials, and control strategies.

Theme 14 will focus on the theoretical development and validation trough simulations and experiments of planning and control techniques for high level autonomy of robots that physically interact with unstructured environments.

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

1. Human-aware robot navigation – Istituto Italiano di Tecnologia

Curriculum: Hostile and unstructured environments

Hosting Institution

Istituto Italiano di Tecnologia

Department:

Humanoid Sensing and perception (https://hsp.iit.it)

Tutor(s):

Lorenzo Natale <lorenzo.natale@iit.it>

Description:

Service robots need to operate in dynamical, unstructured environments, and in close interaction with humans. Despite remarkable progress, robot navigation in dynamic environment is still challenging, as it requires robots to identify reliable features and landmarks for localization, detect humans and anticipate their motion for safe navigation. Robot navigation, often focuses on the problem of reaching a specific target on a map. However, in real applications, robots need to perform tasks that involve interaction with humans. The navigation system of the robot needs therefore to be specifically designed to take humans into account and perform differently when moving from one location to another, or, for example, when approaching a group of people. In this project, we seek to address the issues above, and study perception and control algorithms that allow a humanoid robot to navigate safely in an environment populated by humans, and successfully engage in verbal interaction with them. We consider the specific use case of a robotic museum guide, in which the robot is programmed to guide visitors inside a museum and interact verbally using speech and gestures. This project involves the following problems:

- detect visual landmarks that allow the robot to self-localize and navigate, when the presence of groups creates problems to the LIDAR;
- detect humans and anticipate their movement for safe navigation and to re-plan the tour in case a group of people obstructs the path;
- detect visitors to keep them engaged during the tour, maintain proper distance during the tour to ensure smooth interaction.

The system will be based on the technology developed during the 5GTOURS EU project, and the R1 robot developed at IIT. End-users from a museum will be involved during the design of the system and for field trials.

Requirements:

The ideal candidate would have a degree in Computer Science, Engineering or related disciplines, with a background in Robotics and/or Computer Vision. They would also be highly motivated to work on robotic platform and have computer programming skills with C++ and/or Python. Background in machine learning and deep learning would be considered a plus.

References:

- Colledanchise, Michele, Damiano Malafronte, and Lorenzo Natale. "Act, perceive, and plan in belief space for robot localization." *2020 IEEE International Conference on Robotics and Automation (ICRA)*. IEEE, 2020.

- Macenski, Steve, David Tsai, and Max Feinberg. "Spatio-temporal voxel layer: A view on robot perception for the dynamic world." *International Journal of Advanced Robotic Systems* 17.2 (2020): 1729881420910530.
- Holman, Blake, et al. "Watch where you're going! gaze and head orientation as predictors for social robot navigation." *2021 IEEE International Conference on Robotics and Automation (ICRA)*. IEEE, 2021.

Number of positions available: 1

Main Research Site

Istituto Italiano di Tecnologia, Center for Robotics and Intelligent Systems, Genova

Contacts:

Email: lorenzo.natale@iit.it

Funding Scheme: This doctorate grant is funded by Horizon Europe Programme under Grant Agreement No 101070227

2. Multi-modal object grasping and manipulation – Istituto Italiano di Tecnologia (2 positions)

Curriculum: Hostile and unstructured environments

Hosting Institution

Istituto Italiano di Tecnologia

Department:

Humanoid Sensing and perception (https://hsp.iit.it)

Tutor(s):

Lorenzo Natale <lorenzo.natale@iit.it>

ISTITUTO ITALIANO DI TECNOLOGIA

Description:

Object manipulation is a fundamental capability for robots and as such has been extensively studied in robotics. In recent research several data driven techniques based on deep learning have been proposed demonstrating remarkable performance especially in pick-and-place scenarios with robotic grippers (see for example Kleeberger et al. 2020). The majority of such approaches, however, rely on visual feedback alone to estimate and evaluate task-agnostic grasping candidates, and implement open-loop strategies that do not allow corrective actions to be performed after the initial grasp pose is evaluated.

In this project we seek to explore object grasping and manipulation with anthropomorphic hands, taking into account physical properties of the objects in relation to the task to be performed, as perceived through visual and tactile feedback. Topics of interests include:

- Methods for refining the position of the object, its global shape, and extract local shape information for grasping;
- Active methods to extract physical properties of objects in relation to the task at hand;
- Zero shot/few shot methods for learning object properties related to grasping;
- Learning based methods for computing grasp candidates with anthropomorphic hands, and controlling the hand in close loop using vision and tactile feedback;

We will consider an initial scenario in which objects are presented in isolation and move to a more challenging, cluttered scenario that involve groups of objects. For this work we will use the iCub humanoid robot and the Panda Arm from Franka Emika, both equipped with 3D tactile sensors (Holgado et al 2019).

Requirements:

The ideal candidate would have a degree in Computer Science, Engineering or related disciplines, with a background in Robotics and/or Computer Vision. They would also be highly motivated to work on robotic platform and have computer programming skills with C++ and/or Python. Background in machine learning and deep learning would be considered a plus.

References:

- K. Kleeberger, R. Bormann, W. Kraus, and M. F. Huber, “A survey on learning-based robotic grasping,” Current Robot. Rep., vol. 1, no. 4, pp. 239–249, Dec. 2020, doi: 10.1007/s43154-020-00021-6

- Holgado, A. C., Piga, N., Pradhono Tomo, T., Vezzani, G., Schmitz, A., Natale, L., and Sugano, S., Magnetic 3-axis Soft and Sensitive Fingertip Sensors Integration for the iCub Humanoid Robot, in Proc. IEEE-RAS International Conference on Humanoid Robotics, Toronto, Canada, 2019, pp. 1-8.
- A. Brohan et al., "RT-1: Robotics Transformer for Real-World Control at Scale", ArXiv preprint arXiv:2212.06817, 2022.

Number of positions available: 2

Main Research Site

Istituto Italiano di Tecnologia, Center for Robotics and Intelligent Systems, Genova

Contacts:

Email: lorenzo.natale@iit.it

Funding Scheme: This doctorate grant is funded by the Italian Institute of Technology.

3. Neuromorphic distributed intelligence for soft robots – computation with spiking neural networks for haptic perception and closed loop control of soft robots – Italian Institute of Technology

Curriculum: Hostile and unstructured environments

Hosting Institution

Istituto Italiano di Tecnologia

Department:

Event Driven Perception for Robotics https://edpr.iit.it

Tutor(s):

Chiara Bartolozzi, Barbara Mazzolai

ISTITUTO ITALIANO
DI TECNOLOGIA

Description:

Neuromorphic engineering exploits the physics of microelectronic circuits to implement efficient computation inspired on neural systems. In a similar fashion, biomimetic soft robotics exploits the physics of materials to implement intelligent sensors and actuators that can smoothly interact with the external world and express intelligent behaviour. We aim at coupling soft materials, sensory transduction, neuromorphic circuits for sensory encoding and computation, and soft actuation, towards the design of robots that can seamlessly and gently interact with their environment.

We will study the trade-off between local and distributed processing with materials and neuromorphic circuits for sensory acquisition [1,2,3] and pre-processing and centralised computation [4]. We will specifically develop spiking neural networks for processing tactile signals from octopus's suckers [5] during manipulation and guiding the movement of its arm in response to external stimulation.

This theme will be co-tutored with Prof. B. Mazzolai, head of the Bioinspired Soft Robotics lab in IIT.

Requirements:

We are looking for talented and motivated candidates, with a degree in Computer Science, Engineering, or related disciplines, with a background in Soft Robotics, Neuromorphic Engineering, or Computational Neuroscience

Computer programming skills with C++ and/or Python, teamworking, and passion are much appreciated.

References:

[1] Janotte E. et al., Neuromorphic capacitive tactile sensors inspired by slowly adaptive mechanoreceptors, NEWCAS 2022, DOI: 10.1109/NEWCAS52662.2022.9841988

[2] Muller-Cleve S.F. et al. Braille letter reading: A benchmark for spatio-temporal pattern recognition on neuromorphic hardware, Frontiers in Neuroscience, DOI: 10.3389/fnins.2022.951164

[3] Dabbous A. et al. Artificial bio-inspired tactile receptive fields for edge orientation classification, ISCAS 2021, DOI: 10.1109/ISCAS51556.2021.9401749

[4] Bartolozzi C., Indiveri G., Donati E., Embodied neuromorphic intelligence, Nature Communications, DOI: 10.1038/s41467-022-28487-2

[5] Shahabi, Ebrahim, et al. "Octopus-Inspired Suction Cups with Embedded Strain Sensors for Object Recognition." Advanced Intelligent Systems 5.2 (2023): 2200201.

Number of positions available: 1

Main Research Site

Istituto Italiano di Tecnologia, Center for Robotics and Intelligent Systems, Genova

Contacts:

chiara.bartolozzi@iit.it

Funding Scheme: This doctorate grant is funded by the Italian Institute of Technology

4. Neuromorphic distributed intelligence for soft robots – design of neuromorphic circuits on flexible substrates for sensing and computation – Italian Institute of Technology

Curriculum: Hostile and unstructured environments

Hosting Institution

Istituto Italiano di Tecnologia

Department:

Event Driven Perception for Robotics https://edpr.iit.it

Tutor(s):

Chiara Bartolozzi, Lucia Beccai

ISTITUTO ITALIANO DI TECNOLOGIA

Description:

Neuromorphic engineering exploits the physics of microelectronic circuits to implement efficient computation inspired on neural systems. In a similar fashion, biomimetic soft robotics exploits the physics of materials to implement intelligent sensors and actuators that can smoothly interact with the external world and express intelligent behaviour. We aim at coupling soft materials, sensory transduction, neuromorphic circuits for sensory encoding and computation, and soft actuation, towards the design of robots that can seamlessly and gently interact with their environment.

We will study the trade-off between local and distributed processing with materials and neuromorphic circuits for sensory acquisition [1,2,3] and pre-processing and centralised computation [4]. We will focus on the design of neuromorphic circuits on flexible substrate for encoding tactile and proprioceptive sensory signals into spike trains and pre-process such signals in a distributed system.

This theme will be co-tutored with Prof. L. Beccai, head of the Soft BioRobotics Perception lab in IIT.

Requirements:

We are looking for talented and motivated candidates, with a degree in Computer Science, Engineering, or related disciplines, with a background in Circuit Design, Soft Materials, Neuromorphic Engineering, or Computational Neuroscience

Computer programming skills with Python, teamworking, and passion are much appreciated.

References:

[1] Janotte E. et al., Neuromorphic capacitive tactile sensors inspired by slowly adaptive mechanoreceptors, NEWCAS 2022, DOI: 10.1109/NEWCAS52662.2022.9841988

[2] Muller-Cleve S.F. et al. Braille letter reading: A benchmark for spatio-temporal pattern recognition on neuromorphic hardware, Frontiers in Neuroscience, DOI: 10.3389/fnins.2022.951164

[3] Dabbous A. et al. Artificial bio-inspired tactile receptive fields for edge orientation classification, ISCAS 2021, DOI: 10.1109/ISCAS51556.2021.9401749

[4] Bartolozzi C., Indiveri G., Donati E., Embodied neuromorphic intelligence, Nature Communications, DOI: 10.1038/s41467-022-28487-2
Number of positions available: 1
Main Research Site Istituto Italiano di Tecnologia, Center for Robotics and Intelligent Systems, Genova
Contacts: chiara.bartolozzi@iit.it
Funding Scheme: This doctorate grant is funded by the Italian Institute of Technology

5. Online neuromorphic perception and actuation for robots – Italian Institute of Technology

Curriculum: Hostile and unstructured environments

Hosting Institution

Istituto Italiano di Tecnologia

Department:

Event Driven Perception for Robotics https://edpr.iit.it

Tutor(s):

Chiara Bartolozzi (IIT), Elisa Donati (UZH), Saray Soldado Magraner (UCLA)

Description:

Neuromorphic sensing and computation can be used to design low-latency perception for robots [1,2]. To fully exploit the low-latency and low-power paradigm, we aim at designing end-to-end spiking robotic systems, relying on event-driven sensory encoding, neuromorphic computation, and spiking motor control, all implemented on neuromorphic hardware [3].

To this aim, we propose two possible projects, one focussing on online, low-latency perception with event cameras for moving robots, one focussing on neuromorphic control.

- Theme 1. Event-cameras capture motion in their visual field by responding to local light changes. The perception of independently moving objects is greatly simplified when the camera is still, however, for most robotic applications, cameras are embedded and move while the robot acts. Robustly and efficiently separating the different sources of motion when event cameras are moving is therefore crucial in robotics but is still an open issue. While some work has been done taking inspiration from computer vision, focussing on stabilisation [2,4], statistical analysis [5], or optimisations [6], biological systems seem to still outperform artificial vision in robustness, latency, and efficiency. We will look at how biological sensory systems cope with moving sensors, studying sensory processing and its intrinsic relationship with ego-motion in the flow of information from the sensors to the brain. We will look at the mammalian visual system, and the computational models derived from this quest will be implemented with spiking neural networks, using neuromorphic hardware in the loop, and will be validated in robotic applications using the neuromorphic iCub.

- Theme 2. We study brain-inspired computational primitives that allow to generate robust behaviour using limited and noisy resources. We will build upon the recent work demonstrating the learning of inverse kinematics with triplet spike-timing dependent plasticity, basal ganglia-inspired disinhibition, and cooperative-competitive networks [7] and expand it to generate stable trajectories using balanced chaotic dynamic attractors [8,9]. As toy problem, we will use the iCub robot and use the developed network for handwriting.

This project will be developed in collaboration with Dr. E. Donati at the Institute of Neuroinformatics (University of Zurich) and Dr. S. Soldado Magraner at UCLA.

Requirements:

We are looking for talented and motivated candidates, with a degree in Computer Science, Engineering, or related disciplines, with a background in Neuromorphic Engineering, or Computational Neuroscience .

Computer programming skills with C++ and/or Python, teamworking, and passion are much appreciated.

References:

[1] D'Angelo G. et al., Event driven bio-inspired attentive system for the iCub humanoid robot on SpiNNaker, IOP Neuromorphic Computing and Engineering, DOI: 10.1088/2634-4386/ac6b50

[2] Gava L., et al. How Late is too Late? A Preliminary Event-based Latency Evaluation, EBCCSP 2022, DOI: 10.1109/EBCCSP56922.2022.9845622

[3] Bartolozzi C., Indiveri G., Donati E., Embodied neuromorphic intelligence, Nature Communications, DOI: 10.1038/s41467-022-28487-2

[4] Gallego G. et al. Event-Based Vision: A Survey, IEEE Transactions on Pattern Analysis and Machine Intelligence, DOI: 10.1109/TPAMI.2020.3008413

[5] Vasco V. et al., Independent motion detection with event-driven cameras, ICAR 2017, DOI: 10.1109/ICAR.2017.8023661

[6] Gallego, G. et al. A unifying contrast maximization framework for event cameras, with applications to motion, depth, and optical flow estimation, CVPR 2018.

[7] Zhao et al. Learning Inverse Kinematics using Neural Computational Primitives on Neuromorphic Hardware DOI: https://doi.org/10.21203/rs.3.rs-2220673/v1

[8] Sussillo D, Abbott LF. Generating coherent patterns of activity from chaotic neural networks. Neuron. 2009 DOI: 10.1016/j.neuron.2009.07.018

[9] Goudar and Buonomano. eLife 2018;7:e31134. DOI: 10.7554/eLife.31134

Number of positions available: 1

Main Research Site

Istituto Italiano di Tecnologia, Center for Robotics and Intelligent Systems, Genova

Contacts:

chiara.bartolozzi@iit.it

Funding Scheme: This doctorate grant is funded by the Italian Institute of Technology

6. Soft Robotics Technologies for Marine Environment – Istituto Italiano di Tecnologia

Curriculum: Hostile and unstructured environments

Hosting Institution

Istituto Italiano di Tecnologia

Department:

Bioinspired Soft Robotics (https://bsr.iit.it)

Tutor(s):

Barbara Mazzolai <barbara.mazzolai@iit.it>

Description:

Soft robotics aims to develop new devices that can actively interact with the real-world environment and undergo large deformations, relying on inherent or structural compliance [1]. Soft-bodied animals, such as the octopus, have often been used as a model for their ability to adapt and deform their bodies in unstructured environments [1],[2]. The octopus, with its eight soft arms endowed with suckers, is particularly interesting due to its unique biomechanical properties that enable it to exert considerable force, sense the environment, and manipulate objects [3]. The morphology and biomechanical properties of the suckers allow the octopus to adhere to all nonporous surfaces and generate high attachment forces [4]. Recently, soft, sensorized suction cups with the ability to recognize different object features have been developed [5].

This project aims to add actuation capabilities to the sensorized suction cups to implement local feedback control for object grasping and integrate them into an octopus-inspired soft arm. The project will investigate miniaturizable solutions for embeddable valves and other suction cup actuation methods that can comply with soft bodies and enable controlled detachment of the grasping. The work will integrate with existing octopus-inspired robotic arms that have distributed sensing localized in the suction cups.

Requirements:

The ideal candidate should have a degree in Mechanical Engineering, Mechatronics Engineering, Robotics, Bioengineering, or related disciplines. Additionally, they should be highly motivated to work on robotic platforms and have a strong interest in approaching bioinspired and biomimetic systems. Experience in fast prototyping, molding, 3D printing, casting, and Soft Robotics would be considered a plus.

References:

[1] S. Kim, C. Laschi, and B. Trimmer, “Soft robotics: a bioinspired evolution in robotics,” Trends in biotechnology, vol. 31, no. 5, pp. 287–294, 2013.

[2] C. Laschi, B. Mazzolai, and M. Cianchetti, “Soft robotics: Technologies and systems pushing the boundaries of robot abilities,” Science Robotics, vol. 1, no. 1, p. eaah3690, 2016.

[3] B. Mazzolai, A. Mondini, F. Tramacere, G. Riccomi, A. Sadeghi, G. Giordano, E. Del Dottore, M. Scaccia, M. Zampato, S. Carminati. Octopus-inspired soft arm with suction cups for enhanced grasping tasks in confined environments. Advanced Intelligent Systems. 2019 Oct;1(6):1900041.

[4] A. M. Smith, “Negative pressure generated by octopus suckers: a study of the tensile strength of water in nature,” Journal of Experimental Biology, no. 157, pp. 257–271, 1991.
[5] Shahabi, E., Visentin, F., Mondini, A., & Mazzolai, B. (2023). Octopus-Inspired Suction Cups with Embedded Strain Sensors for Object Recognition. Advanced Intelligent Systems, 5(2), 2200201.

Number of positions available: 1

Main Research Site

Istituto Italiano di Tecnologia, Center for Convergent Technologies, Genova

Contacts:

Email: barbara.mazzolai@iit.it

Funding Scheme: This doctorate grant is funded by the Italian Institute of Technology.

7. Soft Robotics for Human Cooperation and Rehabilitation – Istituto Italiano di Tecnologia

Curriculum: Hostile and unstructured environments

Hosting Institution

Istituto Italiano di Tecnologia

Department:

Soft Robotics for Human Cooperation and Rehabilitation (https://softbots.iit.it/it/)

Tutor(s):

Antonio Bicchi <antonio.bicchi@iit.it>
Manuel G. Catalano <manuel.catalano@iit.it>
Giorgio Grioli <giorgio.grioli@iit.it>

Description:

The Ph.D. student will investigate the design, modelling and control of robotic systems and of intelligent machines. The candidate will draw inspiration from the study of natural systems and from the application of the most modern and promising technologies, to develop a framework of human-centred devices and system that will find application in the widest range of fields, ranging from collaborative industrial robotics to prosthetics. In particular, the candidate results should apply to the emerging field of Bionics and bionic avatars. The student will investigate the principles and the fundamental nature of soft robotics, aiming at the proposition of functional devices that embody part of their control logic and expected behavior in the form of mechanical intelligence. This should facilitate interaction with different scenarios and with humans, and drastically reduce the complexity of the system control. In addition, the student will investigate problems bond to the technological limitations of producing, actuating and sensing soft robotic systems. The candidate will build upon the group's experience on the design, realization and application of Soft Synergetic hands and Variable Impedance Actuators.

Requirements:

Applicants are expected to possess a master's degree in engineering or other tightly connected field, with a background in robotics and control theory, and to be able to communicate in English. Applicants should also show good disposition toward team-work, willingness to travel, attitude for continuous education and commitment to results. Previous experiences in soft robotics design, modelling and control are welcome but not required.

References:

[1] G. Lentini,..., G. Grioli, M.G. Catalano, and A. Bicchi "Alter-Ego: A Mobile Robot With a Functionally Anthropomorphic Upper Body Designed for Physical Interaction," in IEEE Robotics & Automation Magazine, vol. 26, no. 4, pp. 94-107, Dec. 2019, doi: 10.1109/MRA.2019.2943846.
[2] Piazza, Cristina, et al. "Toward an adaptive foot for natural walking." 2016 IEEE-RAS 16th International Conference on Humanoid Robots (Humanoids). IEEE, 2016.
[3] Grioli, Giorgio, et al. "Variable stiffness actuators: The user's point of view." The International Journal of Robotics Research 34.6 (2015): 727-743.

[4] Della Santina, Cosimo, et al. "Toward dexterous manipulation with augmented adaptive synergies: The pisa/iit softhand 2." IEEE Transactions on Robotics 34.5 (2018): 1141-1156.
[5] Catalano, Manuel G., et al. "Adaptive synergies for the design and control of the Pisa/IIT SoftHand." The International Journal of Robotics Research 33.5 (2014): 768- 782.

Number of positions available: 1

Main Research Site

Istituto Italiano di Tecnologia, Center for Robotics and Intelligent Systems, Genova

Contacts:

Email: antonio.bicchi@iit.it

Funding Scheme: This doctorate grant is funded by the Italian Institute of Technology.

8. Autonomous Loco-manipulation planning for logistics mobile robots – Istituto Italiano di Tecnologia (2 positions)

Curriculum: Hostile and unstructured environments

Hosting Institution

Istituto Italiano di Tecnologia

Department:

Humanoid and Human Centred Mechatronics Research line (https://hhcm.iit.it/)

Tutor(s):

Nikos Tsagarakis <nikos.tsagarakis@iit.it>

Description:

This research topic concentrates on the development of autonomous loco-manipulation capabilities required to support the application of robotics in logistics scenarios and in particular in the delivery of objects directly to customers in urban or rural environments, involving navigation in complex environments, human-robot interaction and learning from the environment in order to make the delivery process more efficient and convenient. Legged-wheeled robots such as CENTAURO and COCERT platforms developed in IIT can permit to grasp, load and unload goods, navigate sidewalks and other pedestrian areas to deliver packages directly to customers' doors. To perform their mission effectively, these robots shall be equipped with the skills that allow them to operate safely and reliably in urban environments that can be cluttered including the presence of humans or other dynamic entities, negotiate terrain and obstacles and eventually be able to transfer from indoor to outdoor environments and vice versa.

The aim of this topic is to develop new geometric or machine learning methods for terrain/environment reconstruction and semantics that will be explored to realize autonomous navigation skills to permit these mobile wheeled or legged manipulation platforms to move around in unstructured terrains and environments, performing loco-manipulation actions to reach the targeted locations and deliver the transported goods. This will require the ability to interpret semantics (e.g., zebra crossings, sidewalks, doors, etc.) and include dynamic obstacles such as humans or cars. Such semantics information will be explored for autonomous mobility planning (path planning, wheeled/leg motion planning, foot placement, etc.) and eventually 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 fused to acquire RGB images and dense 3D point cloud while geometric simplifications for reasoning will be explored. Moreover, mobility and manipulation planning methods will be developed to select and modulate suitable primitives/strategies for the navigation and manipulation of the encountered environment and objects to manipulate.

Requirements:

This topic lies in the intersection of Vision and Robotics. Ideal applicants should have strong C++ and Python programming competences. 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) is a plus. The applicants should be fluent in English and team players.

References:

- Wellhausen L., Hutter M., ArtPlanner: Robust Legged Robot Navigation in the Field, https://arxiv.org/abs/2303.01420
- 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.

Number of positions available: 2

Main Research Site

Istituto Italiano di Tecnologia, Center for Robotics and Intelligent Systems, Genova

Contacts:

Email: Nikos.tsagarakis@iit.it

Funding Scheme: This doctorate positions are funded by Horizon Europe Programme project euROBIN (https://www.eurobin-project.eu/)under Grant Agreement No 101070596

9. Robot navigation anywhere: moving around autonomously in hostile and unstructured environments – University of Genova

Curriculum: Hostile and unstructured environments	UNIVERSITÀ DEGLI STUDI DI GENOVA
Hosting Institution University of Genova	
Department: DIBRIS, Department of Informatics, Bioengineering, Robotics and Systems Engineering	
Tutor(s): Antonio Sgorbissa, Carmine Tommaso Recchiuto	

Description:

While in the past wheeled robots were the most common solution for outdoor navigation and exploration, nowadays robots with different kinematics and locomotion capabilities are becoming increasingly popular due to their ability to operate in complex environments where more traditional wheeled robots are unusable, e.g., [1, 2]. Some of these contexts are emergency intervention in natural or environmental disasters or the inspection of industrial plants, but other scenarios can be foreseen as well. For example, consider an accident in a chemical plant or an earthquake. **The ability to explore the environment through a robot, capable of climbing obstacles on the ground or even stairs**, can play a key role in collecting information before planning a direct intervention of human operators, ensuring their safety and efficacy.

Given this general scenario in which autonomous navigation capabilities play a crucial role, the thesis will let the student free to explore one of the two options:

- an off-the-shelf solution, i.e., using the quadruped robot SPOT by Boston Dynamics that is available for research in the RICE lab at DIBRIS;
- *or* a custom-designed solution that a student with proved skills in mechatronics design may wish to propose and explore.

Custom solution

In both cases, either the student opts for the off-the-shelf solution (SPOT) or they propose a custom solution, the thesis will explore strategies for

- autonomous navigation on hazardous and unstructured environment, which will require investigating the robot's capabilities in terms of perception and locomotion on rocks, grass, sand, rocks, garbage, pipes, steep slopes uphill and downhill, etc.
- immersive teleoperation and control, in which the robot and a human operator form a team that collaborates to tackle complex problems [3, 4, 5], with the

human operators receiving feedback from the cameras on the robots through a virtual/augmented reality head-mounted display.

Both autonomous navigation and immersive teleoperation and control raise theoretical and technological issues that goes beyond the typical problems of wheeled robots in indoor, office-like environments, that the student will have the opportunity to address by proposing original solutions beyond the state-of-the-art.

For instance, concerning navigation, the robot should autonomously decide whether the best solution to avoid an obstacle is climbing it or turning around it along a safer path. Concerning self-localization, the robot shall take into account large errors in positioning due to the fact that legged motion on uneven terrain is not as reliable as a wheeled motion on a flat surface. Concerning immersive teleoperation, the robot should be able to mimic the person's movement, captured through the VR eyewear worn by the operator and embedded with Inertial Measurement Units, to provide an immersive teleoperation experience when the operator sees the world "through the robot's eyes."

Requirements:

Applicants are expected to have a background in at least one of the following, and a reasonable knowledge of all three:

- Programming (C++ or Python)
- Software architectures for robotics (e.g., ROS)
- Robot planning, navigation and control

Applicants should also show good disposition toward team-work, willingness to travel, attitude for continuous education and commitment to results.

References:

[1] Bazeille S., Barasuol V., Focchi M., Havoutis I., Frigerio M., Buchli J., Caldwell D.G., Semini C., Quadruped robot trotting over irregular terrain assisted by stereo-vision (2014) Intelligent Service Robotics, 7 (2), pp. 67 – 77

[2] Ylikorpi, Tomi J; Halme, Aarne J; Forsman, Pekka J (2017). "Dynamic modeling and obstacle-crossing capability of flexible pendulum-driven ball-shaped robots". Robotics and Autonomous Systems. Elsevier. 87: 269–280.

[3] Martins, H., Ventura, R. Immersive 3-D teleoperation of a search and rescue robot using a head-mounted display (2009) ETFA 2009 - 2009 IEEE Conference on Emerging Technologies and Factory Automation

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Number of positions available: 1

Main Research Site

DIBRIS Department, RICE lab (Robots and Intelligent systems for Citizens and the Environment), Via Opera Pia 13, Genova, Italy. The lab is a fully equipped facility for software development with ground robots (quadruped and wheeled), humanoid robots for socially assistive applications, and aerial robots.

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Funding Scheme: This doctorate grant is funded by PNRR program DM-118 (action 4.1 - Pubblica Amministrazione)

10. Augmented Reality Strategies for Teams of Robots – University of Genova

Curriculum: Hostile and unstructured environments
Hosting Institution University of Genova
Department: DIBRIS, Department of Informatics, Bioengineering, Robotics and Systems Engineering
Tutor(s): Carmine Tommaso Recchiuto, Antonio Sgorbissa

UNIVERSITÀ DEGLI STUDI DI GENOVA

Description:

Unmanned Aerial Vehicles (UAVs) can be effectively used in different phases of disaster management. For example, they can provide real-time images of inaccessible locations and produce accurate maps within a short time, which can be extremely helpful for first rescuers, identifying areas with more critical situations [1]. However, despite their vast potential, UAVs are still not widely used in disaster scenarios. Indeed, even if many studies have been focused on increasing their level of automation, they still need a trained pilot to operate them, and many pilots are required in order to control multiple UAVs exploring an unknown area. Indeed, flying a UAV after a disaster is hard work, with an elevated level of fatigue and mental workload. Moreover, UAVs are usually adopted in outdoor scenarios, where GPS signals help pilots control the drone's position. Still, they are rarely used in indoor contexts, where additional capabilities, i.e., autonomous localization and mapping, are needed.

On the other side, the usage of UAVs in this context may be of the utmost importance in case other robots (e.g., ground robots, legged robots, …) are also part of the team. In this scenario, aerial robots may be able to recognize objects, as well as create a collaborative map of the environment, providing useful information to the other component of the team. For example, the UAVs may help to define some specific regions of interest to be explored with quadrupedal robots, which may concurrently contribute to the exploration of the unknown environment [2],[3].

This work aims to investigate these aspects by proposing a novel Human-Robot Interface (HRI) for heterogeneous robots that merges Augmented Reality strategies with autonomous control, path planning, and Collaborative Localization and Mapping (CLAM) algorithms [4, 5]. The final output of the project will be an integrated framework for the management of UAVs/quadrupedal/ground robot teams that will allow pilots, by means of an AR-based Head Mounted Display, to assign tasks to specific subsets of the team, visualizing, at the same time, the map built by the robots and relevant information within the same (e.g., robots position, persons, relevant information, …).

The AR headset Microsoft Hololens and different types of robots (the UAVs DJI Mavic, DJI Tello, and Airvolute, the quadrupedal robot Spot, and ground robots Rosbots) will be used during the PhD work.

Requirements:

Applicants are expected to have good programming skills (C++, Java, or Python) and a profound interest in cutting-edge research in autonomous robotics. Previous experience with Augemented/Virtual reality applications and mobile robots will be considered.

When applying for the Ph.D. scholarship, the student will be encouraged to propose solutions to address one or more of the aspects described in the proposal.

References:

[1] Devo, A., Mao, J., Costante, G., & Loianno, G. (2022). Autonomous Single-Image Drone Exploration With Deep Reinforcement Learning and Mixed Reality. IEEE Robotics and Automation Letters, 7(2), 5031-5038

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[4] Agrawal, A., & Cleland-Huang, J. (2021). RescueAR: Augmented Reality Supported Collaboration for UAV Driven Emergency Response Systems. arXiv preprint arXiv:2110.00180.

[5] Recchiuto, C. T., & Sgorbissa, A. (2018). Post-disaster assessment with unmanned aerial vehicles: A survey on practical implementations and research approaches. Journal of Field Robotics, 35(4), 459-490.

Number of positions available: 1

Main Research Site

DIBRIS Department, RICE lab (Robots and Intelligent systems for Citizens and the Environment), Via Opera Pia 13, Genova, Italy. The lab is a fully equipped facility for software development with ground robots (quadruped and wheeled), humanoid robots for socially assistive applications, and aerial robots.

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Funding Scheme: This doctorate grant is funded by PNRR program DM-118 (action 4.1 – Ricerca PNRR)

11. Easy-to-use models and tools for scalable verification of robotics deliberation - Universita' di Genova/Bosch (**)

Curriculum: Hostile and unstructured environments	
Hosting Institution UniGe	
Department: DIBRIS, Department of Informatics, Bioengineering, Robotics and Systems Engineering	
Tutor(s): Armando Tacchella	

Description:

The main goal of the PhD work is the development of adequate integrated modeling concepts to specify a robot's software and deliberation mechanism as well as relevant features and properties of the environment as foundation for the mentioned verification methods.

This requires three submodels:

1. Software model: It shall specify the overall software system and the skills or capabilities of the robot as well as interdependencies between them and between the underlying algorithms (e.g., in terms of resources). There exist several suitable modeling languages that may serve as a starting point (e.g., GenoM). The challenge is to minimize the software model so that it allows for efficient verification over large numbers of scenarios but captures all relevant properties.
2. Deliberation model: This model specifies the deliberation mechanism itself. All technologies used for robotics deliberation (see list in very first paragraph) have a well-defined formal foundation that can be used directly. A crucial research question is how to streamline the underlying formalisms when combining different technologies such as integrated task and motion planning with partially specified behavior trees as it will be researched in CONVINCE.
3. Environment model: This model shall describe not only relevant elements and properties of the environment but also capture relationships (e.g., topological) as well as temporal processes. Relevant extensions of the Planning Domain Definition Language (PDDL) may serve as a starting point. A lot of research will have to be spent on suitable abstractions that allow describing the essence of an environment without the level of detail of a complete 3D model.

Special importance should be given to the concept of situations: These are intended to describe constellations in the environment that may differ greatly in their concrete properties (geometry, temporal processes), but raise similar challenges for the deliberation. As an example consider a vacuum robot getting entangled with flat obstacles on the floor such as cables, sox, or scarves.

The triad of models shall allow reasoning about situations from concrete executions to derive the root cause of certain contingencies or faults. Such understanding of situations is also the key for task-level learning.

While the software model and deliberation model both specify concrete implementations, the environment modeling language shall allow specifying concrete environments as well as meta-models that can be used to generate/simulate concrete environments.

This leads to the research questions on tooling. There exist many tools for software modeling (for CONVINCE the focus will be on Papyrus) and also for modeling of robotics deliberation (e.g., FlexBE and Groot). Questions about tool integration shall be addressed in CONVINCE but not in this thesis.

Focus of the thesis shall be on tooling for environment modeling. Such tooling shall enable to specify or generate environment models efficiently, using an adequate graphical UI. A promising path could be the use of 3D physics simulators and corresponding editors, which come with elaborate and mature UIs but require novel mechanisms to derive the essence of the 3D for the environment model.

Another important question is how to support robotics SW developers without a strong background in formal verification in specifying properties (e.g., liveness conditions) to be verified. A wizard-like approach with templates for typical use-cases is a first idea.

Finally, new algorithms for root cause analysis that support developers on a domain-level understanding of execution traces or counterexamples from verification shall be researched.

Requirements:
Applicants are expected to have a strong background in at least one of the following, and a reasonable knowledge of all three:

- Applications of formal methods to robotics and automation
- Model-based design for control software
- Software architectures for robotics

References:

- F. Ingrand, M. Ghallab: Deliberation for autonomous robots: A survey. In Artificial Intelligence, Elsevier, Vol. 247, pp. 10-44, 2017.
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- D. Long, M. Fox, R. Howey: Planning domains and plans: validation, verification and analysis. In Proc. Workshop on V&V of Planning and Scheduling Systems, 2009.
- F. Fourati, M. T. Bhiri, R. Robbana: Verification and validation of PDDL descriptions using Event-B formal method. In Proc. of ICMCS 2016.

Company name and link (for industrial projects):

Bosch Gmbh – Bosch Center for Artificial Intelligence - https://www.bosch-ai.com/

Number of positions available: 1

Main Research Site Bosch Center for AI – Renningen – Germany **Contacts:** Email: armando.tacchella@unige.it - ralph.lange@de.bosch.com
This doctorate grant is an executive scholarship reserved to Bosch employees.

12. Situational Awareness in Maritime Environments – Università di Genova

Curriculum: Robots and Intelligent Machines Robotics in hostile and unstructured environments

Hosting Institution

University of Genova

Department:

DIBRIS, Department of Informatics, Bioengineering, Robotics and Systems Engineering

Tutor(s):

Prof. Enrico Simetti (UNIGE)
Prof. Francesca Odone (UNIGE)

Description:

Recently, there has been considerable interest in the development of unmanned surface vehicles (USVs) due to their increasing demand in various maritime applications. One of the main capabilities that unmanned vehicle must be endowed with is a robust, reliable, effective and real-time guidance, navigation, and control (GNC) system. The ability to detect, recognize and track different targets and obstacles in real-time is strongly required in order to reliably operate in the complex and dynamic marine environment, where environmental disturbances (winds, waves, and currents), sea fog, lighting conditions, and water reflection, have a great impact on the performance of the perception system.

The research activity will involve the use of different sensors (LiDAR, Thermal Cameras, Electrooptical Cameras, IMU) to construct and update a world model of what is around the ASV. This model will be then used in the GNC scheme to allow the ASV to move safely in the area.

The research will exploit the ULISSE catamaran, made by UniGe.

Requirements:

Applicants are expected to have strong programming skills (including Python, C/C++), a good background in control, computer vision and machine learning.

References:

[1] Mina Sorial, Issa Mouawad, Enrico Simetti, Francesca Odone, Giuseppe Casalino, Towards a Real Time Obstacle Detection System for Unmanned Surface Vehicles, OCEANS 2019, Seattle
[2] Farahnakian, F., Poikonen, J., Laurinen, M., & Heikkonen, J. (2019, October). Deep convolutional neural network-based fusion of RGB and IR images in marine environment. In 2019 IEEE Intelligent Transportation Systems Conference (ITSC) (pp. 21-26). IEEE.

Number of positions available: 1

Main Research Sites

DIBRIS Department, GRAAL (Genoa Robotics and Automation Lab), Via all'Opera Pia 13, Genova, Italy.

Contacts:

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Funding Scheme: This doctorate grant is funded by Università di Genova.

13. Marine Biomimetic Cyber-Physical System(s) for Ocean Documentation – Università Politecnica delle Marche

Curriculum: Hostile and unstructured environments

Hosting Institution
Università Politecnica delle Marche

Department:
Dipartimento di Ingegneria dell'Informazione

Tutor(s):
Prof. David Scaradozzi

Description:

Biomimetics or bio-inspiration is the transfer of natural models into innovative technical applications by analyzing the working principles of nature's best examples and transferring the core mechanisms into technical applications without necessarily copying them. Biomimetic Marine Technologies move these natural templates to create highly efficient and sustainable solutions, e.g. marine vehicle hulls, sailing boats and (autonomous) underwater vehicle actuation.

The PhD research's primary objective will be to design and build a new generation of bio-inspired robots capable of exploring and acting in extreme environments, e.g., underwater, for several applications, including archaeology, sport diving, or monitoring Marine Protected Areas. The candidate will design and develop robots to advance state-of-the-art performance by combining additive manufacturing techniques, functional materials, and control strategies. From a constructive and applied research point of view, there are many robotic "fish" models and locomotion studies for possible single-vehicle Navigation, Guidance and Control (NGC) strategies. In recent years, the scientific literature has started presenting communication and cooperation strategies for their use as a "swarm". Still, more needs to be developed in formal multi-vehicle modelling at large and in prototype implementation linked to survey and patrol purposes of a confined area. Few have hybrid propulsion capability (fin/propeller) as the LabMACS (UNIVPM) BRAVe (Biomimetic Research Autonomous Vehicle) class. The research will empower LabMACS's research in different ways with the Cyber-Physical System(s) paradigm:

- "Single Robot" will reconsider the Fossen model and its validity for hybrid vehicles (fin/propellers propulsion) with Body, Caudal Fin locomotion. This part will contribute to the design of single robots' Navigation, Guidance and Control systems.
- "Multi-Vehicles" shoal in free patrolling as Multi-Agents System (MAS) will present a formalism to face situations where robots with limited capacities and characteristics and intermittent communication must agree in actions during unstructured area coverage and distributed estimation.
- "Perception and cloud infrastructure" Machine Learning and Artificial Intelligence infrastructures will be investigated for better modelling the robot(s) explored environment in real-time.
- Geo-Informatics, Digital Cultural Heritage, Ambient Intelligence & Space Sensing, and Artificial Intelligence for interpreting complex 2D/3D data and modelling it in a digital twin of the explored environment.

More Information about the research teams and technology:

https://mscamasterclass.univpm.it/wp-content/uploads/2023/05/Scaradozzi-1.pdf

Requirements:
The candidates are expected to have an attitude to problem-solving and experimental work and be strongly motivated for team working.
Applicants are expected to have basic knowledge of kinematics and dynamics of systems. Moreover, adequate skills in modelling, analysis, and control of dynamic systems will be appreciated. Demonstrated experience with optimal control theory and programming (ROS1/ROS2, python, C/C++, Matlab) and experience in controlling compliant actuators is a plus. For the reasons above, the successful candidate should ideally have an MSc in Computer and Automation Engineering or a related field.

References:

- P. Abreu et al. ''Widely scalable mobile underwater sonar technology: An overview of the H2020 WiMUST project'' Marine Technology Society Journal 2016
- D. Animobono, D. Scaradozzi, E. Zattoni, A. M. Perdon, G. Conte, "The Model Matching Problem for Max-Plus Linear Systems: a Geometric Approach", 2022
- G. Antonelli, F. Arrichiello, F. Caccavale and A. Marino, "A Decentralized Controller-Observer Scheme for Multi-Agent Weighted Centroid Tracking," in IEEE Transactions on Automatic Control, 2013
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- Fiori, S. (2019). Model formulation over Lie groups and numerical methods to simulate the motion of gyrostats and quadrotors. Mathematics, 7(10), 935
- P. Majdzik, "Feasible schedule under faults in the assembly system," in: 16th IEEE International Conference on Control, Automation, Robotics and Vision (ICARCV), 2020
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- L. Paull et al. "AUV Navigation and Localization: A Review" IEEE Journal of Oceanic Eng., 2014
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Number of positions available:
1

Main Research Site

Dipartimento di Ingegneria dell'Informazione, UNIVPM, Ancona (I). Experiments will be conducted also at the premises of the LabMACS Laboratory in Ancona (II) and SeaLab, CSSN in La Spezia (III).
Contacts: Email: d.scaradozzi@univpm.it
Funding Scheme: This doctorate grant is co-funded by the proponent research institution and by the Italian Ministry of Research, under law PNRR program DM-118 (action 4.1 – Ricerca PNRR)

14. Planning and Control Techniques for High-Level Autonomy of Robots – University of Pisa

Curriculum: Hostile and Unstructured Environments

Hosting Institution
University of Pisa

Department:
Information Engineering Department

Tutor(s):
Manolo Garabini
Franco Angelini
Lucia Pallottino

Description:

The main goals are the theoretical development and validation trough simulations and experiments of planning and control techniques for high level autonomy of robots that physically interact with unstructured environments.

Such techniques will be able to synthesize complex combinations of different dynamical phases of systems (including systems with the possibility to activate bi/mono lateral contacts) as well as reference trajectories. Given the generality of the problem to be addressed, the applications will encompass legged locomotion, multimodal robotics, manipulation, and combination thereof.

One of the main key aspects of the work is devoted to the robustness of the developed methods that should be tailored to work in unstructured scenarios as: environmental monitoring, manipulation of flexible objects, large scale autonomy.

The algorithms should be tested on the following robotic platforms: ANYmal [1], Alter-Ego [2], SOLO [4].

Requirements:

Applicants are expected to have a strong background in at least one of the following, and a reasonable knowledge of all three:

- Optimization techniques
- Model-based control design
- AI algorithms for robotics

References:

- [1] M. Hutter et al., ANYmal - a highly mobile and dynamic quadrupedal robot, 2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Daejeon, Korea (South), 2016, pp. 38-44
- [2] G Lentini, et al., Alter-ego: a mobile robot with a functionally anthropomorphic upper body designed for physical interaction, IEEE Robotics & Automation Magazine 26 (4), 94-107, 2019

- [3] F. Grimminger, et al., An Open Torque-Controlled Modular Robot Architecture for Legged Locomotion Research, IEEE Robotics and Automation Letters 5 (2), 3650-3657, 2020

Company name and link (for industrial projects):

Number of positions available:
1

Main Research Site
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Funding Scheme: This doctorate is partially funded by University of Pisa

In case of **PNRR funding scheme (if applicable):** This doctorate grant is funded by PNRR program DM-118 (action 3.4 – Transizione digitale e ecologica)