I-RIM

PhD Course in

ROBOTICS AND INTELLIGENT MACHINES

Curriculum: Hostile and Unstructured Environments

Research Themes

The main goal of the curriculum “Robotics and Intelligent Machines for Hostile and Unstructured Environments” is to address challenges related to the study and development of enabling technologies and complex systems that will allow robots and intelligent machines to operate in environments that are dynamic, partially or completely unknown, difficult to predict, and potentially very challenging.

The general objective of the curriculum is to train scientists and research technologists capable of working in multidisciplinary teams on projects where interaction with a complex environment plays a crucial role in technological development and design.

The research theme offered by the University of Genoa and the Italian Institute of Technology (IIT) will be awarded to the top applicants selected for this theme.

Ideal candidates are students with a strong background in robotics and intelligent machines, from various perspectives. Please consult the individual requirements for each research theme.

Students will conduct their research project at the hosting institution (as described in the research project sheet). Interested students are encouraged to contact the tutors and/or the Unit’s Principal Investigators for further information prior to submitting their application.

International applications are welcome, and participants will receive logistical support for visa issues, relocation, and related matters.

1. Scene representation and planning in hybrid robotic systems using large language models (LLMs) and Visual Language Models (VLMs) - University of Genoa

Curriculum:

Hostile and unstructured environments

Hosting Institution

University of Genoa (Università degli Studi di Genova)

Department:

DIBRIS, Department of Informatics, Bioengineering, Robotics and Systems Engineering (https://dibris.unige.it/)

Tutor(s):

Prof. Antonio Sgorbissa

Description:

This research will explore how advanced tools for analyzing language (i.e., Large Language Models, LLMs) and visual information (i.e., Visual Language Models, VLMs) can be used to produce representations of the external world. These representations will serve as input for one or more robots to plan and execute actions aimed at achieving their goals.

Traditionally, in standard PDDL (Planning Domain Definition Language) planners, both the domain and the problem are static: they are defined by programmers and provided to the planner as fixed inputs. This research will investigate the possibility of constructing and dynamically updating the domain based on sensor inputs and their interpretation by the system, through the use of LLMs and VLMs. This approach raises a set of novel and unprecedented challenges.

The research will focus on:

- Robot-agnostic solutions, i.e., approaches suitable for robots with varying sensors, mechanical characteristics, and application domains—ranging from quadrupeds for search & rescue to manipulators for industrial use and socially assistive robots.
- Alternative representations for scenes and action planning sequences, exploring formats beyond PDDL, such as scene graphs or other models for describing the robot's surroundings and reasoning about them.

- Novel methods for merging dynamic snapshots of the same scene captured by different robots or sensors, from varying viewpoints and at different times. This includes addressing the challenge of reconciling differing descriptions of the world that may use different terms or identify distinct relationships in each snapshot.

The research will include a theoretical investigation of possible solutions, their implementation in simulation, and validation on real robots in the RICE lab (Spot and Go1 quadruped robots; Pepper, NAO, and Navel humanoid robots; Gen3 Manipulators; and many others).

Requirements:

Applicants are expected to have good programming skills (C++, Java, or Python) and a profound interest in cutting-edge research in autonomous robotics and socially assistive robotics. Previous experience with Artificial Intelligence techniques and Human-Robot Interaction strategies 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. Qiao Gu et al., ConceptGraphs: Open-Vocabulary 3D Scene Graphs for Perception and Planning, arXiv:2309.16650, https://arxiv.org/abs/2309.16650
2. Xiaohan Zhang et al., Grounding Classical Task Planners via Vision-Language Models, arXiv:2304.08587, https://arxiv.org/abs/2304.08587
3. Rongjie Li et al., From Pixels to Graphs: Open-Vocabulary Scene Graph Generation with Vision-Language Models, https://arxiv.org/abs/2404.00906

Number of positions available:

1

Main Research Site

RICE lab (https://rice.dibris.unige.it/), DIBRIS Department, University of Genoa, Via all'Opera Pia 13, 16145, Genova, Italy.

Contacts:

Email: antonio.sgorbissa@unige.it

Funding Scheme: This doctorate grant is funded by the University of Genova.

Scholarship Amount:

- Fascia 4: 19,500 €/year

2. Advanced navigation and guidance systems for autonomous marine robots – University of Genoa

Curriculum:

Hostile and unstructured environments

Hosting Institution

University of Genoa (Università degli Studi di Genova)

Department:

DIBRIS, Department of Informatics, Bioengineering, Robotics and Systems Engineering https://dibris.unige.it/

Tutor(s):

Prof. Giovanni Indiveri

Description:

Autonomous marine robots are playing an increasingly critical role in underwater inspection and maintenance, environmental monitoring, and the exploration of unstructured and uninstrumented underwater environments. Ensuring precise and reliable navigation in such conditions—often characterized by limited or degraded access to external positioning systems (e.g., LBL, SBL, USBL), low-speed operations, complex maneuvers, and variable seafloor geometries—requires the development of advanced navigation and guidance strategies [1].

This PhD project aims to investigate, design, and implement next-generation navigation algorithms for underwater vehicles, with a particular emphasis on fusing sophisticated hydrodynamic modeling [2] with inertial navigation systems (INS). The modelling of underwater vehicles should account for many factors that are often neglected, such as the impact of the direction of the fluid with respect to the thruster. The research will explore both classical modeling approaches (e.g., rigid-body mechanics, lumped parameter models) and high-fidelity numerical techniques such as Computational Fluid Dynamics (CFD), seeking to combine them into hybrid estimation frameworks. These models will be used to augment the accuracy and robustness of navigation filters under uncertain and dynamically changing operating conditions. The use of AI-based estimation (e.g., neural networks, transformers, LSTM) to recover unmeasured quantities or compensate for faulty/missing data could also be envisaged.

Requirements:

Applicants are expected to have good programming skills (including Python, C/C++), a good background in control systems and software development.

References:

1. Zhang, B., Ji, D., Liu, S., Zhu, X., & Xu, W. (2023). Autonomous underwater vehicle navigation: A review. Ocean Engineering, 273, 113861.
2. Simetti, E., & Indiveri, G. (2022). Control oriented modeling of a twin thruster autonomous surface vehicle. Ocean Engineering, 243, 110260.

Number of positions available: 1
Main Research Sites GRAAL laboratory (https://graal.dibris.unige.it/), DIBRIS Department, University of Genoa, Via all'Opera Pia 13, Genova, Italy.
Contacts: Email: giovanni.indiveri@unige.it
Funding Scheme: This doctorate grant is funded by the DIBRIS Department (project INTERREG IF Marittimo00226 FABBISOGNI E SOLUZIONI PER L'INTEGRAZIONE DELLE COMPETENZE SUBACQUEE – FABIS)
Scholarship Amount: • Fascia 4: 19,500 €/year

3. Learning Adaptive Robotic Behavior in Unstructured Environments – Italian Institute of Technology (IIT)

Curriculum:

Hostile and unstructured environments

Hosting Institution:

Italian Institute of Technology (Istituto Italiano di Tecnologia)

Department:

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

Tutor(s):

Dr. Lorenzo Natale

ISTITUTO ITALIANO DI TECNOLOGIA

Description:

The deployment of robots in unstructured environments remains a central challenge in robotics and artificial intelligence. Recent advances — particularly the emergence of foundation models (LLMs and VLMs) – have enabled promising forms of robot programming through natural language and task planning. However, their utility is mostly limited to high-level instruction following, and an open problem remains how to ground pre-trained model to the robot action space. Imitation Learning (IL) and Reinforcement Learning (RL), on the other hand, have been widely used to train robots for complex tasks, yet they come with significant limitations: IL relies on human teleoperation and is labor-intensive, while RL demands extensive simulation and computational resources. Both approaches scale poorly and struggle to support autonomous adaptation in real-world deployment.

This PhD project aims to investigate learning frameworks that overcome these limitations and enable scalable, adaptive behavior in humanoid robots with a focus on generalization and physical interaction.

Several research directions may be pursued depending on the candidate's interest and background, including:

- Motion retargeting while inferring physical interactions from egocentric videos;
- Blending IL and RL techniques to enable robust policy transfer across embodiments and environments;
- Visuo-tactile sensor integration to solve contact-rich tasks with minimal supervision;
- Physics-aware particle based scene representation and simulation;
- Task learning and grounding through natural language interaction, including learning and adaptation of foundational multi-modal models.

The goal is to develop methods that enable robots to learn efficiently, adapt autonomously, and generalize across environments, embodiments, and tasks.

Requirements:

The ideal candidate would have a degree in Computer Science, Engineering or related disciplines, with a background in Robotics, Computer Vision and/or Machine Learning. They would also be highly motivated to work on robotic platforms and have computer programming skills.

References:

1. Ceola, F., Rosasco, L., and Natale, L., *RESPRECT: Speeding-up Multi-fingered Grasping with Residual Reinforcement Learning*, IEEE Robotics & Automation Letters, vol. 9, no. 4, 2024.
2. Puang, E.Y., Ceola, F., Pasquale, G. and Natale, L. PCHands: PCA-based Hand Pose Synergy Representation on Manipulators with N-DoF, under submission 2025.
3. Vasile, F., Qiu R., Natale, L., Wang X., CollidingGS: Gaussian-Augmented Physics Simulation and Identification with Complex Colliders, under submission 2025.

Number of positions available:

3

Main Research Site

Center for Robotics and Intelligent Systems (CRIS), Istituto Italiano di Tecnologia, via San Quirico 19D, 16163, Genova, Italy.

Contacts:

Email: lorenzo.natale@iit.it

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

Scholarship Amount:

- Fascia 4: 19,500 €/year

4. Soft Robotics for Human Cooperation – Italian Institute of Technology (IIT)

Curriculum:

Hostile and unstructured environments

Hosting Institution:

Italian Institute of Technology (Istituto Italiano di Tecnologia)

Department:

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

Tutor(s):

Prof. Antonio Bicchi, Dr. Manuel G. Catalano, Dr. Giorgio Grioli

ISTITUTO ITALIANO
DI TECNOLOGIA

Description:

This PhD project will focus on robotic automation for sustainable waste recycling of deformable and soft materials. The candidate will work on the development of adaptive robotic systems capable of autonomously disassembling end-of-life devices such as clothes, cables and membranes. Research will include robot learning, soft manipulation, vision-based perception, and task reconfiguration for unstructured and variable environments. The PhD student will also contribute to designing collaborative human-robot workflows to improve safety and efficiency. The project combines mechatronic design, AI-based control, and experimental validation in realistic recycling scenarios. Strong interdisciplinary collaboration with academic, industrial, and environmental stakeholders is expected. Opportunities for international mobility and research exchange within the EU will be provided.

Requirements:

The successful candidate must have an MSc degree with a strong background in Robotics, end/or Control.

The successful candidate should have:

- Good skills on C++ and Python
- Experience with ROS
- Excellent skills in control
- Good communication skills and ability/willingness to integrate within a multidisciplinary international research group
- Good knowledge of written and spoken English.

References:

1. Catalano, M. G., Grioli, G., Farnioli, E., Serio, A., Piazza, C., & Bicchi, A. (2014). International Journal of Robotics Research, 33(5), 768–782.
2. Bonilla, M., Farnioli, E., Piazza, C., Catalano, M. G., Grioli, G., Garabini, M., Gabiccini, M., & Bicchi, A. (2015). Grasping with Soft Hands. In 2014 IEEE-RAS International Conference on Humanoid Robots (pp. 581–587).

3. Franco Angelini, Cristiano Petrocelli, Manuel G. Catalano, Manolo Garabini, Giorgio Grioli, Antonio Bicchi *IEEE Robotics & Automation Magazine*, Volume 27, Issue 3, pp. 55–72, 2020. DOI: 10.1109/MRA.2019.2955952

Number of positions available:

2

Main Research Site

Center for Robotics and Intelligent Systems (CRIS), Istituto Italiano di Tecnologia, via San Quirico 19D, 16163, Genova, Italy.

Contacts:

Email: antonio.bicchi@iit.it

Funding Scheme: This doctorate grant is funded by the Italian Institute of Technology (Flexcycle EU project).

Scholarship Amount:

- Fascia 4: 19,500 €/year

5. Autonomous Mobility and Interaction for Mobile Robots in Dynamic Unstructured Environments – Italian Institute of Technology (IIT)

Curriculum:

Hostile and unstructured environments

Hosting Institution:

Italian Institute of Technology (Istituto Italiano di Tecnologia)

Department:

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

Tutor(s):

Dr. Nikos Tsagarakis

Description:

Robots operating in real-world environments must be capable of robust navigation, precise physical interaction, and human-aware behavior, all while adapting over time to dynamic surroundings and shifting operational demands. These challenges are magnified in environments that are unstructured and shared with humans such as active construction sites, logistics hubs, or in-orbit servicing (IOS) missions. This PhD research will focus on developing methods that enable robotic systems to operate persistently and safely in such conditions, by coupling perception, learning, and control in a unified adaptive framework.

A core objective is the blending of semantic navigation with real-time environment mapping. To this end, the robot should leverage multi-modal perception including lidar, stereo/depth cameras, and RGB vision to interpret complex scenes and extract semantic features. Through deep learning-based segmentation and object recognition, the robot should be able to identify and differentiate elements such as work zones, temporary structures, safety boundaries, human workers, and interaction points. Simultaneous In both terrestrial and orbital applications, precision alignment and docking are mission critical. The robot must also learn to recognize and localize physical features or fiducial markers with sub-centimeter accuracy, even under varying lighting, geometry, or motion. To achieve this, pose estimation networks and learning-based feature detectors will be explored and combined with visual servoing. Reinforcement learning may be employed to train robust docking behaviors that account for micro-motions, latency, and compliance in the physical interfaces, particularly in space or cluttered terrestrial environments. Ultimately, the robot's perception and control systems will be tightly coupled with a learning-enabled reasoning layer, capable of updating semantic world models, adapting navigation policies, and refining alignment routines based on experience.

Real-world deployment and testing will be conducted using state-of-the-art robotic systems (https://hhcm.iit.it/robots) developed in HHCM laboratory such as the CONCERT modular platform and the legged-wheeled quadrupedal robot CENTAURO, across extended missions in variable environment settings.

The developments within this PhD topic are linked to research projects obtained from the European commicion and industry.

Requirements:

This topic lies in the intersection of Robot model-based control and learning. Ideal applicants should have excellent C++ and Python programming competences. Strong competences in robot control and learning are required and experience in robot perception/vision is essential. Knowledge of motion planning tools and Robot Operating System (ROS/ROS2) is also necessary. The applicants should be fluent in English and team players.

References:

1. Choi, J et al, Self-Supervised Online Learning for Safety-Critical Control using Stereo Vision., In Proceedings of the IEEE International Conference on Robotics and Automation (ICRA), pp 11487-11493, 2022.
2. Rosinol, A. et al, Kimera: An open-source library for real-time metric-semantic localization and mapping, In IEEE Intl. Conf. on Robotics and Automation (ICRA), 1690-1696, 2020.

Number of positions available:

1

Main Research Site

Center for Robotics and Intelligent Systems (CRIS), Istituto Italiano di Tecnologia, via San Quirico 19D, 16163, Genova, Italy.

Contacts:

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Funding Scheme: This doctorate position is funded by the Italian Institute of Technology Technology (EU Project MAGICIAN – GA 101120731)

Scholarship Amount:

- Fascia 4: 19,500 €/year

6. Learning-based Manipulation Skills for Agricultural Robotics – Italian Institute of Technology (IIT)

Curriculum:

Hostile and unstructured environments

Hosting Institution:

Italian Institute of Technology (Istituto Italiano di Tecnologia)

Department:

Dynamic Legged Systems lab (https://dls.iit.it)

Tutor(s):

Dr. Giulio Turrisi, Dr. Victor Barasuol, Dr. Claudio Semini

Description:

Robot manipulation is an area still far from being solved by researchers today, given the amount of variability that exists in a real-word setting that challenges modern control methods. The primary goal of this PhD project is to work on the above topic, developing learning-based approaches — such as reinforcement learning [1], supervised learning [2], or hybrid methods— to enable effective and adaptive manipulation with one or two robotic arms, the latter in a bimanual setting scenario. The work will explore how state-of-the-art learning algorithms can be applied to complex, real-world agricultural scenarios. A key component of the project is the integration and optimal use of custom mechatronic end-effectors developed within the DLS group, including innovative grippers, shears, and other specialized tools. Expected platform for testing the approach are primarily fixed-base manipulator arms and mobile manipulators.

Requirements:

We are looking for a highly motivated and creative student, very committed to research and eager to explore new paradigms. The ideal candidate has an excellent Master's degree with a focus on Robotics and Machine Learning. As technical skills, prospective candidates should possess expertise in Python and ROS.

References:

1. J P Sleiman, M Mittal, M Hutter, "Guided Reinforcement Learning for Robust Multi-Contact Loco Manipulation," Proceedings of the 8th Conference on Robot Learning (CORL), 2025.
2. K Black et al. "π0: A Vision-Language-Action Flow Model for General Robot Control," arXiv, 2025.

Number of positions available:

1

Main Research Site

Center for Robotics and Intelligent Systems (CRIS), Istituto Italiano di Tecnologia, via San Quirico 19D, 16163, Genova, Italy.
Contacts: Email: giulio.turrisi@iit.it, victor.barasuol@iit.it, claudio.semini@iit.it
Funding Scheme: This doctorate grant is funded by the Italian Institute of Technology.
Scholarship Amount: • Fascia 4: 19,500 €/year

7. Quadruped Robot Control for Environmental Sustainability using Machine Learning – Italian Institute of Technology (IIT)

Curriculum:

Hostile and unstructured environments

Hosting Institution:

Italian Institute of Technology (Istituto Italiano di Tecnologia)

Department:

Dynamic Legged Systems lab (https://dls.iit.it)

Tutor(s):

Dr. Giulio Turrisi, Dr. Victor Barasuol, Dr. Claudio Semini, Dr. Barbara Mazzolai

Description:

Pollution presents a significant threat to the equilibrium of many ecosystems. In this sense, robotics can help reduce such a problem by automizing litter collection and disposal in urban and coastal areas [1] [2], soil measuring in agricultural terrain, or forest monitoring [3]. Still many challenges need to be solved to reach an autonomous and continuous interaction with the environments in a robust manner. This project will focus on the development of novel Reinforcement Learning methods focusing on the above topic and challenges, accounting for autonomous decision-making skills, navigation, perception and control in structured and unstructured scenarios. The main platform for this project will be a quadruped robot, with or without an additional extra manipulator arm.

Requirements:

We are looking for a highly motivated and creative student, very committed to research and eager to explore new paradigms. The ideal candidate has an excellent Master's degree with a focus on Robotics and Machine Learning. As technical skills, prospective candidates should possess expertise in Python and ROS.

References:

- L Amatucci et al., "VERO: A vacuum-cleaner-equipped quadruped robot for efficient litter removal," Journal of Field Robotics, 2024.
- VERO: a Vacuum-cleaner-Equipped Quadruped RObot for Efficient Litter Removal, youtube video, 2024. https://www.youtube.com/watch?v=O8BqvAe-moI
- M Mattamala et al. "Autonomous Forest Inventory with Legged Robots: System Design and Field Deployment," IEEE ICRA Workshop on Field Robotics, 2024.

Number of positions available:

1

Main Research Site Center for Robotics and Intelligent Systems (CRIS), Istituto Italiano di Tecnologia, via San Quirico 19D, 16163, Genova, Italy.
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Funding Scheme: This doctorate grant is funded by the Italian Institute of Technology.
Scholarship Amount: • Fascia 4: 19,500 €/year