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 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. Perception-Driven Task-Priority Control for Underwater Intervention Robotic Systems – University of Genova

Curriculum: Hostile and unstructured environments	Università di Genova
Hosting Institution: University of Genoa, Interuniversity Research Center of Integrated Systems for the Marine Environment	
Department: DIBRIS & ISME	
Tutor(s): Prof. Enrico Simetti, Prof. Giovanni Indiveri	

Description:

Marine robotic intervention is increasingly demanding robust and adaptable control strategies capable of operating in unstructured and challenging underwater environments. Single and cooperative robotic platforms, such as Autonomous Surface Vehicles (ASVs) paired with Remotely Operated or autonomous Underwater Vehicles (ROVs), must execute complex manipulation and interaction tasks under significant sensing uncertainty, limited communication, and time-varying environmental conditions.

This PhD project focuses on the development of an integrated perception and control framework for underwater intervention systems, structured along three progressive research directions.

The first direction concerns the design of a perception pipeline oriented toward manipulation-relevant feedback. Leveraging the 3D acoustic sensing and RGB camera systems available within the laboratory, the pipeline will extract task-relevant features — including object pose, proximity, and contact information — to close the control loop in real time. Acoustic sensing provides robust perception in turbid or low-visibility conditions, while RGB-based information can be exploited at close range to refine manipulation-relevant estimates. The emphasis is on the robust and efficient extraction of the information strictly necessary to guide intervention tasks, rather than on general-purpose scene reconstruction.

The second direction addresses the integration of this perceptual feedback within a task-priority control framework. Classical task-priority approaches will be extended to explicitly incorporate multimodal sensing feedback, enabling reactive and goal-directed behavior during manipulation and infrastructure interaction tasks. Learning and optimization techniques will be investigated to adapt task definitions, priority hierarchies, and control parameters online, improving robustness and efficiency in uncertain conditions.

The third direction extends the developed framework toward cooperative robotic systems, where manipulation and perception objectives are distributed among multiple heterogeneous agents. The task-priority structure naturally supports this generalization, allowing priorities and constraints to be dynamically reallocated across platforms according to mission requirements and system state.

Requirements:

The ideal candidate would have a degree in Robotics Engineering, Ocean Engineering, Computer Engineering or related fields, with good knowledge of robotics and C++ language.

References:

- López-Barajas, S., Solis, A., Marín-Prades, R., & Sanz, P. J. (2025). Towards Autonomous Coordination of Two I-AUVs in Submarine Pipeline Assembly. *Journal of Marine Science and Engineering*, *13*(8), 1490.
- d'Elia, E., Mouret, J. B., Kober, J., & Ivaldi, S. (2022, October). Automatic tuning and selection of whole-body controllers. In 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) (pp. 12935-12941). IEEE.
- Karimi, M., & Ahmadi, M. (2021). A reinforcement learning approach in assignment of task priorities in kinematic control of redundant robots. IEEE Robotics and Automation Letters, 7(2), 850-857.
- Penco, L., Hoffman, E. M., Modugno, V., Gomes, W., Mouret, J. B., & Ivaldi, S. (2020). Learning robust task priorities and gains for control of redundant robots. IEEE Robotics and Automation Letters, 5(2), 2626-2633

Number of positions available:

1

Main Research Site

DIBRIS, University of Genoa, via All'Opera Pia 13, 16145 Genoa, Italy

Contacts:

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

Scholarship Amount:

- Fascia 4: 19,500 €/year

2. Designing and developing humanoid robot companions – University of Genova

Curriculum: Hostile and unstructured environments
Hosting Institution: University of Genova
Department: DIBRIS
Tutor(s): Prof. Antonio Sgorbissa

Description:

Humanoid robot companions are increasingly expected to operate as intelligent partners in everyday human environments, supporting users through natural interaction, autonomous mobility, and meaningful engagement with domestic objects and spaces. Unlike industrial robots, humanoid companions must act in environments that are only partially structured, shared with humans, and characterized by dynamic objects, social conventions, and safety constraints. Platforms such as Pepper and Agibot X2 Ultra (the former already available at RICE lab and the latter currently in the process of being acquired), provide complementary opportunities to investigate how intelligent software architectures can enable humanoid robots to perceive, decide, navigate, and interact in human-centred contexts.

This PhD project focuses on the design and development of an integrated intelligent software framework for humanoid robot companions, structured along three progressive research directions.

The first direction concerns the development of a human-robot interaction framework enabling natural, context-aware, and socially appropriate communication. The system will integrate multimodal information, including speech, gestures, user position, facial cues, and interaction history, to support adaptive dialogue and personalized behaviour. Particular attention will be devoted to the robot's ability to interpret user intentions, manage interaction turns, and select actions that are understandable, acceptable, and useful in everyday scenarios.

The second direction addresses autonomous navigation in human environments. The robot will be required to move safely and efficiently in domestic or semi-domestic spaces, taking into account people, furniture, obstacles, and social constraints. Classical navigation and mapping techniques will be integrated with human-aware navigation strategies, allowing the robot to plan paths that are not only collision-free but also socially acceptable. The emphasis will be on robust mobility in environments that change over time and are not specifically designed for robotic operation.

The third direction extends the framework toward interaction with household objects and situated assistance tasks. The robot will learn to associate objects with their functions, locations, and possible uses within the home,

enabling behaviours such as finding, approaching, referring to, or supporting interaction with everyday items. Perception, navigation, and dialogue will be integrated so that the robot can understand object-related requests, reason about the surrounding environment, and coordinate its actions with the user's needs. This direction will progressively support richer forms of embodied assistance, where the humanoid companion is able to combine social interaction, spatial awareness, and object-centred reasoning within a unified intelligent architecture.

Requirements:

The ideal candidate would have a degree in Robotics Engineering or Computer Engineering, with a strong background in programming.

References:

- Grassi L., Recchiuto C.T., Sgorbissa A. Strategies for Controlling the Conversation Dynamics in Multi-Party Human-Robot Interaction (2025) International Journal of Social Robotics, 17 (8), pp. 1517 - 1539
- Nardelli A., Sgorbissa A., Recchiuto C.T.Designing Robot Companions: Exploring the Impact of Robot Personality on Perceived Empathy, Trust, Sociability, and Enjoyability (2026) IEEE Transactions on Affective Computing
- Singamaneni P.T., Bachiller-Burgos P., Manso L.J., Garrell A., Sanfeliu A., Spalanzani A., Alami R., A survey on socially aware robot navigation: Taxonomy and future challenges, (2024) International Journal of Robotics Research, 43 (10), pp. 1533 – 1572
- Kabir I.K., Mysorewala M.F. Socially aware navigation for mobile robots: a survey on deep reinforcement learning approaches (2026) Applied Intelligence, 56 (1)

Number of positions available:

1

Main Research Site

RICE lab, https://rice.dibris.unige.it/, DIBRIS, University of Genoa, via All'Opera Pia 13, 16145 Genoa, Italy

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

Scholarship Amount:

- Fascia 4: 19,500 €/year

3. Design and Control of Modular Robotic End-systems for Deformable Object Manipulation – Italian Institute of Technology

Curriculum: Hostile and unstructured environments

Hosting Institution: IIT JOiiNT LAB (Bergamo) and IIT CRISS (Genova)

Department: IIT NuBots (https://www.iit.it/it/people-profile/-/people/manuel-catalano)

Tutor(s): Manuel G. Catalano, Giorgio Grioli, Antonio Bicchi

ISTITUTO ITALIANO DI TECNOLOGIA

Description:

The PhD project focuses on the design and development of innovative robotic systems for the manipulation of flexible and deformable materials in advanced industrial environments. The research activities will include the study of bio-inspired, modular, and adaptive solutions, integrating principles of soft robotics, tactile sensing, and intelligent control to improve robustness, dexterity, and adaptability during the manipulation of complex objects such as electrical cables, membranes, technical textiles, and battery components. The candidate will contribute to the development of novel mechatronic architectures and control strategies validated in realistic application scenarios related to industrial automation, circular economy, and the factory of the future.

Requirements:

The ideal candidate would have a degree in Engineering.

References:

- G. Milazzo, G. Grioli, A. Bicchi and M. Giuseppe Catalano, "A Scalable, Durable, and Efficient Embodiment of Adaptive Synergies: The Pisa/IIT SoftHand Mark III," in *IEEE/ASME Transactions on Mechatronics*
- G. Milazzo, S. Lemerle, G. Grioli, A. Bicchi and M. G. Catalano, "Design, Characterization, and Validation of a Variable Stiffness Prosthetic Elbow," in *IEEE Transactions on Robotics*,
- Ude et al., "The Challenges of Using Robots to Automate the Recycling of Electronic Devices: A New Approach Incorporating AI, Modularity, and Soft Robotics," in IEEE Robotics & Automation Magazine

Number of positions available:

1

Main Research Site

IIT JOiiNT LAB (Bergamo) and IIT CRISS (Genova)

Contacts:

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Funding Scheme: This doctorate grant is funded by EU Project **Flexcycle** – **GA** 101189600 e

CUP: J53C25001280006
Scholarship Amount: • Fascia 4: 19,500 €/year

4. Highly integrated optical sensors in soft robotic manipulators - – Italian Institute of Technology

Curriculum: Hostile and unstructured environments	
Hosting Institution: Istituto Italiano di Tecnologia	
Department: Soft Perceptive BioRobotics lab https://www.iit.it/research/lines/soft-biorobotics-perception	
Tutor(s): Lucia Beccai	

Description:

Optical sensing is proven efficient in soft robotics [1,2}, and in the context of soft manipulators, our team has pioneered the monolithic approach to optical tactile skins, demonstrating how light-guiding structures can be co-fabricated with the robot body itself to yield seamlessly integrated perceptive systems[3,4]. This approach exploits the intrinsic compatibility of soft optical waveguides with compliant materials: they tolerate large deformations, are immune to electromagnetic interference, and can transduce multiple physical quantities: pressure, bending, and shear force, within a single, lightweight structure. Despite these developments, the field is still in its infancy and there is a need for: new components, to improve multimodality to simultaneously capture a richer set of mechanical stimuli, and to study the scalability of the approach in terms of sensor dimensions to obtain more highly resolved spatial information. Furthermore, the interaction of these sensing systems in different environments, both air and liquid, remains an open challenge. Moreover, the design of the gripper itself could benefit from bioinspired principles to better target different environments. A compelling example is the elephant trunk tip, which uses both pinching and suction in and out of shallow water; suction poses particular challenges for tactile sensing, since the deformable sensors must respond to touch events under gripper deformation caused by negative pressure. The goal of this research is to advance the optical sensing design and integration in soft manipulators, bioinspired and otherwise, in order to address the abovementioned aspects. The candidate will design, build and test individual new sensors and their integration in soft robotic artifacts. The fabrication techniques will span from advanced 3D printing to soft lithography, not excluding classic encapsulation/molding techniques. This research theme will focus on solid advances in soft transducers embedded in actuated soft systems and will build on the team's studies of bioinspired artificial trunks. It will also be possible to collaborate with materials scientists to identify appropriate materials and tune ad hoc technological processes.

Requirements:

Essential Expertise

- MSc degree in electrical or electronic engineering, nanotechnology, or equivalent.
- Engineering experience in the domain of soft robotics and soft sensing.
- Previous experience in tactile sensors.
- Previous experience in the design and test of electronic systems for sensing signal conditioning.

Desirable Expertise

- Programming skills (e.g. Python, MATLAB, or equivalent).
- Proven experience in CAD and FEM tools, particularly COMSOL Multiphysics.
- Knowledge of main prototyping techniques with soft materials for sensing applications.

References:

- [1] J. C. Yang, P. Trunin, B. Kamare, L. Beccai — The Elephant Trunk Skin Inspires a Highly Sensitive and Deformable, Yet Robust, Armor Skin. Advanced Science e74963 (2026). https://doi.org/10.1002/advs.74963
- [2] H. Wang, M. Totaro, L. Beccai — Toward Perceptive Soft Robots: Progress and Challenges. Advanced Science 5, 1800541 (2018). https://doi.org/10.1002/advs.201800541
- [3] P. Trunin, D. Cafiso, L. Beccai — Design and 3D Printing of Soft Optical Waveguides Towards Monolithic Perceptive Systems. Additive Manufacturing 104687 (2025). https://doi.org/10.1016/j.addma.2025.104687
- [4] P. Trunin, D. Cafiso, A. B. Nardin, T. Exley, L. Beccai — MELEGROS: Monolithic Elephant-Inspired Gripper with Optical Sensors. Advanced Science e18878 (2026). https://doi.org/10.1002/advs.202518878

Number of positions available:

1

Main Research Site

Istituto Italiano di Tecnologia, Genova

Contacts:

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Funding Scheme: This doctorate grant is funded by Istituto Italiano di Tecnologia.

Scholarship Amount:

- Fascia 4: 19,500 €/year

5. SLAM for Legged Robots in Dynamic and Changing Environments – – Italian Institute of Technology

Curriculum: Hostile and unstructured environments

Hosting Institution: Istituto Italiano di Tecnologia

Department: Dynamic Legged Systems https://dls.iit.it

Tutor(s): João Soares and Claudio Semini

Description:

The project will address robust SLAM for legged robots operating in real-world environments that change over multiple time scales: short-term dynamics such as people and movable objects, as well as long-term changes. The goal is to develop perception and mapping methods that allow legged robots to localize, navigate, and maintain useful maps over repeated deployments in complex, evolving environments.

The research will investigate how robots can distinguish persistent from transient scene elements, update maps over time, reason about environmental change, and maintain localization performance despite both dynamic objects and long-term map evolution. The project may involve visual, LiDAR, inertial, and proprioceptive sensing, with a particular emphasis on the challenges introduced by legged locomotion, such as motion blur, impacts, viewpoint changes, irregular trajectories, and operation in unstructured terrain.

The PhD student will work on topics such as dynamic-object-aware SLAM, long-term map maintenance, change detection, multi-session mapping, robust place recognition, and sensor fusion for legged robotic platforms. The research will combine algorithm development, experimental validation, and real-world deployment on legged robots.

Requirements:

We are looking for a motivated candidate with a Master's degree and a strong background in robotics, computer vision, machine learning, or related areas. The candidate should have solid programming skills, preferably in C++ and/or Python, and an interest in developing and testing perception algorithms on real robotic platforms. Prior experience with SLAM, state estimation, sensor fusion, ROS, 3D perception, or mobile robotics is highly desirable. Experience with legged robots is a plus, but not required. The candidate should be curious, independent, collaborative, and comfortable working on both theoretical and experimental aspects of robotic perception.

References:

- Schmid et al., "Khronos: A Unified Approach for Spatio-Temporal Metric-Semantic SLAM in Dynamic Environments", Robotics: Science and Systems 2024.
- Abati et al., "Panoptic-SLAM: Visual SLAM in Dynamic Environments using Panoptic Segmentation", Ubiquitous Robots, 2024
- Yugay et al., "Gaussian Mapping for Evolving Scenes", CVPR 2026

Number of positions available:

1
Main Research Site Istituto Italiano di Tecnologia, via San Quirico 19D, 16163, Genova
Contacts: Email: joao.virgolino@iit.it, claudio.semini@iit.it
Funding Scheme: This doctorate grant is funded by the Istituto Italiano di Tecnologia
Scholarship Amount: • Fascia 4: 19,500 €/year

6. Distributed autonomy and intelligent navigation for serious games with biomimetic robot swarms in GNSS-denied environments – Università Politecnica delle Marche

Curriculum: Hostile and unstructured environments	
Hosting Institution: Università Politecnica delle Marche	
Department: DII- Dipartimento di Ingegneria dell'Informazione	
Tutor(s): David Scaradozzi	

Description:

The PhD research will address distributed autonomy and intelligent navigation for biomimetic robot swarms operating in GNSS-denied and (partially) unstructured environments, with a specific focus on underwater exploration, environmental monitoring, digital heritage documentation and serious-game-based mission simulation.

Biomimetic and bio-inspired robotics transfer working principles observed in nature into innovative technical systems, without necessarily copying biological forms. In marine robotics, this approach can support highly efficient, maneuverable and environmentally compatible vehicles, especially for confined, fragile or sensor-challenging environments. The research will build on LabMACS (https://www.labmacs.university) experience in bio-inspired marine robotics and hybrid-propulsion vehicles, combining fin-based locomotion and conventional actuation to improve navigation, station keeping and adaptive maneuvering in underwater scenarios.

The primary objective of the PhD will be to develop a new generation of cooperative biomimetic robotic systems capable of exploring, mapping and monitoring complex environments where satellite positioning is unavailable, communication is intermittent and perception is affected by turbidity, occlusions, cluttered geometries or reduced visibility. Target applications include underwater archaeological sites, submerged coastal landscapes, Marine Protected Areas, harbor infrastructures and other environments where conventional survey strategies may be costly, invasive or operationally constrained.

The research will empower LabMACS activities through a cyber-physical and multi-agent systems paradigm, articulated along four main lines:

- **Single-robot autonomy and navigation.** The candidate will investigate Navigation, Guidance and Control strategies for hybrid biomimetic vehicles, extending classical marine craft models to account for fin/propeller actuation, body–caudal-fin locomotion, low-speed maneuvering and variable hydrodynamic conditions. This activity will support robust trajectory tracking, obstacle avoidance, adaptive station keeping and energy-aware navigation.
- **Distributed autonomy and swarm coordination.** The research will develop multi-agent coordination strategies for robot teams with limited onboard resources, partial observability and intermittent acoustic communication. Swarm behaviors will be designed for area coverage, cooperative exploration, distributed estimation and adaptive patrolling, with attention to resilience against communication dropouts, localization uncertainty and heterogeneous vehicle capabilities.

- **Serious games, simulation and human–robot interaction.** Serious-game and digital-twin environments will be used as research tools for mission design, operator training, validation and decision support. Game-based simulation will allow the candidate to reproduce realistic underwater and coastal scenarios, test cooperative behaviors before field deployment, evaluate operator decisions under uncertainty and compare alternative mission strategies in controlled but operationally meaningful conditions.
- **Perception, AI and digital representation of the explored environment.** The candidate will investigate AI-based methods for interpreting 2D/3D data acquired by the robots, including optical, acoustic and navigation data. Machine learning techniques will be explored for semantic mapping, anomaly detection, environmental reconstruction and integration of robotic observations into geospatial or digital-twin representations of the explored environment.

The expected outcome is a methodological and technological framework for biomimetic robot swarms that can operate autonomously or semi-autonomously in GNSS-denied environments, support human operators through serious-game-based simulation and decision tools, and contribute to the construction of dynamic digital representations of complex underwater and coastal systems.

The ideal candidate should have a background in robotics, automation, control, computer science, artificial intelligence, marine technologies or related engineering disciplines, and an interest in experimental validation, field robotics and interdisciplinary applications.

Requirements:

The candidates are expected to have an attitude towards 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:

- Scaradozzi, David, Bartolucci, Veronica, Gioiello, Flavia, Costa, Daniele, Castagna, Benedetta, Zattoni, Elena, Antonelli, Gianluca, Di Vito, Daniele, Marino, Alessandro, Arrichiello, Filippo, Di Lillo, Paolo, Chiaverini, Stefano, Gillini, Giuseppe (2025). Simulation and Coordination of Autonomous Bio-Inspired Underwater Agents. IEEE ACCESS, vol. 13, p. 175870-175883, ISSN: 2169-3536, doi: 10.1109/access.2025.3617767
- Bartolucci, Veronica, Scaradozzi, David, Zattoni, Elena (2026). A Solution to the Synchronization Problem for a Shoal of Fish Robots Via Max-Plus Algebra. JOURNAL OF DYNAMIC SYSTEMS, MEASUREMENT AND CONTROL, vol. 148, p. 1-11, ISSN: 0022-0434, doi: 10.1115/1.4070768
- Costa D., Scoccia C., Palpacelli M., Callegari M., Scaradozzi D. (2022). Design of a Labriform-Steering Underwater Robot Using a Multiphysics Simulation Environment. ROBOTICS, vol. 11, 11, ISSN: 2218-6581, doi: 10.3390/robotics11010011

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).

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Funding Scheme: This doctorate grant is co-funded by the proponent research institution and by the European Union.

Prog. AutoSTEM, CUP I33C25000780006, 2025-1-IT02-KA210-SCH-000358066

Prog. Edutainment4Care, CUP I33C25000760006, 2025-1-IT02-KA220-HED-000354183

Prog. RoboStellars, CUP I33C25000850006, 2025-1-IT02-KA220-SCH-000352313

Scholarship Amount:

- Fascia 1: 16,500 €/year