I-RIM

PhD Course in ROBOTICS AND INTELLIGENT MACHINES

Curriculum: Industry 4.0

Research Themes

For larger companies, robotics has been a key productivity factor for many years. Today, thanks to the development of new enabling technologies from Industry 4.0—such as collaborative robotics and artificial intelligence—robotics is also becoming increasingly relevant for smaller industries, which are crucial to Italy's production and employment capacity.

Several drivers are accelerating the adoption of robotic technologies in industry, including the need for product customization, the demand for increased competitiveness in the global market, and the progressive integration of collaborative robots (cobots) into human-centered manufacturing environments. The introduction and spread of the Industry 4.0 production paradigm has further accelerated the use of robots, which now function as interconnected, highly digitized autonomous agents equipped with digital twins. These systems continuously improve their performance through data analysis from production processes.

The transition to Industry 5.0 will be marked by a shift from simple coexistence to full physical and social cooperation between machines and humans.

All these topics are addressed through an integrated and multidisciplinary approach in the projects proposed within this curriculum. They represent cutting-edge technological challenges that can be effectively tackled thanks to the scientific and technological expertise of the proposing institutions and the experience of the participating researchers.

The main goals of the Industry 4.0 curriculum are to:

- Promote technology transfer from research to industry, particularly in industrial sectors that can most benefit from robotics.
- Provide industry with the opportunity to help shape the research conducted by PhD students, as demonstrated by the high number of scholarships in this curriculum that are funded or co-funded by companies.
- Offer PhD students the opportunity to spend time working within the companies participating in the training program.

The research theme offered will be awarded to the top applicants selected for this theme.

Ideal candidates are students with a Master's degree (or equivalent/higher qualification) in a STEM field; a background in Robotics or Mechatronics will be particularly valued.

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. Multi-agent cognitive architectures for heterogeneous robot coordination across different embodiments - Fusion AI Labs S.r.l.

Curriculum: Industry 4.0	
Hosting Institution: University of Genova, Fusion AI Labs	
Department: Department of Informatics, Bioengineering, Robotics, and Systems Engineering	
Tutor(s): Fulvio Mastrogiovanni, Antonello Scalmato	

Description:

Future robot "systems" will increasingly involve heterogeneous teams composed of different embodiments: wheeled or legged mobile manipulators, wheeled or legged humanoids, *ad hoc* robot arms, mobile bases, distributed (and wearable) sensors, and possibly *in-the-loop* human operators. However, current approaches to multi-robot team management still treat the "robot" as the fundamental unit of coordination. In this view, each robot is modelled as an autonomous entity with its own perception, reasoning, and motion pipeline, while coordination is achieved through task allocation, communication, and synchronization among robots.

This PhD thesis starts from a two-fold hypothesis:

1. we assume that future robot software architectures will be based on a collection of AI-based "cognitive agents" running on each robot of the team;
2. we posit that the fundamental unit of coordination should not be the robot, but the "cognitive agent".

A robot deployment should be understood as a distributed cognitive system in which multiple agents are scheduled, invoked, and coordinated across one or more physical embodiments. Some agents are embodiment-bound, whereas other agents are embodiment-independent. In this perspective, a heterogeneous robot team is not merely a fleet of robots, but a distributed graph of cognitive agents grounded in different bodies.

The goal of the PhD thesis is to design, formalize, and experimentally validate a multi-agent cognitive architecture for the coordination of non-homogeneous robots. The thesis will investigate:

1. how multiple cognitive agents can be orchestrated across heterogeneous embodiments,
2. how a robot body schema can support deployment on different robots, and
3. how "inner speech" mechanisms can support planning, reasoning, monitoring, and agent coordination.

Therefore, we can identify *three* main research questions that may be considered in this work.

The *first* is related to the architectural model. The proposed architecture will be fully multi-agent [1]. Instead of assuming a central controller that directly commands robots, the system will be composed of interacting agents with distinct roles: perception agents, reasoning

agents, memory agents, body-schema agents, execution agents, monitoring agents, communication agents, and possibly human-interaction agents. Coordination will take place at the level of agent scheduling, agent invocation, information exchange, and conflict resolution. The same robot will host multiple agents, and the same cognitive process may involve agents distributed across different embodiments. This allows the architecture to support heterogeneous robot teams in which capabilities are not rigidly assigned to individual robots but dynamically distributed across a cognitive substrate.

The *second* is how to decouple cognition from embodiment without losing physical grounding. Modern robot intelligence requires both general reasoning capabilities and precise embodiment-specific constraints [2]. A high-level planner may reason about transporting an object, opening a door, or assisting a person, but the feasibility of the corresponding action depends on the robot's morphology, reachability, payload, sensors, grippers, mobility, compliance, safety envelope, and available computational resources. The thesis will therefore investigate the notion of Body Schema as an explicit interface between cognitive agents and physical embodiments. The Body Schema will encode what each robot can perceive, reach, manipulate, carry, tolerate, compute, and safely execute. It will allow the architecture to reason about which agent should be deployed on which robot, which robot is best suited for a given subtask, and how the same cognitive architecture can be instantiated across different embodiments.

The *third* research direction concerns inner speech mechanisms [3]. In humans, inner speech is often associated with self-regulation, planning, task rehearsal, conflict resolution, and metacognitive monitoring. In robotics, inner speech can be interpreted as an internal linguistic or symbolic process through which agents make their intermediate reasoning states explicit to other agents. In the proposed thesis, inner speech will be investigated as a coordination mechanism for multi-agent cognitive architectures. It may allow agents to state hypotheses, ask for missing information, explain failures, propose subgoals, negotiate task decompositions, summarize perceptual evidence, or trigger replanning. Inner speech will be studied as an internal computational layer for orchestrating distributed reasoning.

Requirements:

Candidates should have a degree in Robotics Engineering, Computer Engineering, or related study programs. Applicants are expected to be proficient in software design and development (software architectures for robots, C/C++, Python), AI techniques for robots, perception, reasoning, and motion planning and execution. The ideal candidate is proficient computer vision, tactile sensing, knowledge representation, concurrent and recurrent processes.

References:

- [1] D. B. Acharya, K. Kuppan, B. Divya. Agentic AI: autonomous intelligence for complex goals – a comprehensive survey. IEEE Access, vol. 13, pages 18912-18936, 2025.
- [2] H. Karami, A. Thomas, F. Mastrogiovanni. A task and motion planning framework using iteratively deepened AND/OR graph networks. Robotics and Autonomous Systems 189, 104943, 2025.
- [3] V. Belcamino, M. Kilina, A. Carfì, V. Seidita, F. Mastrogiovanni, A. Chella. Factored reasoning with inner speech and persistent memory for evidence-grounded human-robot interaction. arXiv:2602.00675.

Company name and link (for industrial projects):

Fusion AI Labs

Number of positions available: 1
Main Research Site TheEngineRoom Lab, Department of Informatics, Bioengineering, Robotics, and Systems Engineering, University of Genoa. Fusion AI Labs, Genoa.
Contacts: fulvio.mastrogiovanni@unige.it, a.scalmato@fusionailabs.it
Funding Scheme: This doctorate grant is funded by Fusion AI Labs S.r.l
Scholarship Amount: • Fascia 4: 19,500 €/year

2. Task and motion planning models for cognitive robots - University of Genova

Curriculum: Industry 4.0	
Hosting Institution: University of Genova	
Department: Department of Informatics, Bioengineering, Robotics, and Systems Engineering	
Tutor(s): Fulvio Mastrogiovanni	

Description:

The ability of an autonomous robot to act proactively in its environment and while interacting with humans is essential for robust, flexible, and meaningful behaviour. However, providing robots with adequate knowledge for a wide range of scenarios remains extremely expensive, both in terms of the human effort required to encode such knowledge and in terms of the data and computational resources needed to train effective Artificial Intelligence (AI) models. Robots can often perform skilfully in *narrow tasks* when equipped with AI models trained on large-scale datasets, but they still struggle to generalize, reason recursively, adapt to unforeseen situations, and integrate high-level objectives with low-level geometric feasibility.

Recent Vision-Language-Action (VLA) models represent an important step towards more general robot intelligence [1]. These models integrate visual observations, linguistic task descriptions, and robot action representations to generate policies or action sequences tailored to a given task, embodiment, and perceptual context. Despite their impressive capabilities, current VLA models often remain limited by the distribution of their training data, by their difficulty in performing explicit long-horizon reasoning, and by the lack of transparent integration with symbolic planning, geometric reasoning, and execution monitoring.

Reasoning in Large Language Models (LLMs), with a specific emphasis on planning, has received an increasing attention in the past few months, especially with the release of the so-called *reasoning models* [2]. These AI models can structure reasoning processes into intermediate steps and provide (to a good extent) also explanations about their plans. However, due the limitation of their short-term memory (that is, the *context window*) these models struggle to generate very long plans, and in any case plans with the sufficient level of granularity to ground atomic robot actions.

Finally, classical Task and Motion Planning (TAMP) provide principled tools to combine discrete task-level reasoning with continuous motion feasibility, but it often requires strong domain modelling assumptions and may lack the adaptive, semantic, and perceptual flexibility offered by modern multimodal AI models [3].

This PhD thesis aims to investigate a new generation of cognitive architectures for autonomous robots based on the integration of VLA models, recursive planning with Large Language Models, and Task and Motion Planning. The central hypothesis is that robust robot behaviour can emerge from the recursive interaction between multimodal predictive models, language-based reasoning modules, and formal planning mechanisms. In this view:

- VLA models are not only action generators, but also predictive components that can be queried to simulate alternative courses of action;
- LLMs are not only linguistic interfaces, but recursive reasoning engines able to decompose, revise, and recompose plans;

- TAMP is not only a planning formalism, but the structural layer that constrains high-level reasoning through geometric, kinematic, and execution-level feasibility.

The thesis will therefore explore:

- how a robot can reason over its possible futures before acting; VLA models will operate on "world hypotheses" related to possible incoming future situations, and generate a set of courses of action; once the situation will be assessed via perception, all world hypotheses will "collapse" into one course of action;
- the adoption of recursive planning with LLMs; instead of assuming that a plan is generated once and then executed linearly, the thesis will investigate planning as a recursive process in which goals are decomposed into subgoals, subgoals are grounded into candidate actions, actions are checked against perceptual and geometric constraints, and failures trigger further decomposition, repair, or replanning;
- the integration of recursive reasoning with TAMP approaches; the thesis will investigate how high-level language-based planning can interact with TAMP representations in which symbolic actions, continuous parameters, object affordances, robot kinematics, and environmental constraints are jointly considered.

Requirements:

Candidates should have a degree in Robotics Engineering, Computer Engineering, or related study programs. Applicants are expected to be proficient in software design and development (software architectures for robots, C/C++, Python), AI techniques for robots, perception, reasoning, and motion planning and execution. The ideal candidate is proficient computer vision, tactile sensing, knowledge representation, concurrent and recurrent processes.

References:

- [1] Y. Ma, Z. Song, Y. Zhuang, J. Hao, I. King. A survey on Vision-Language-Action models for Embodied AI. IEEE Transactions on Neural Networks and Learning Systems, *accepted*.
- [2] G. Wang, J. Li, Y. Sun, X. Chen, C. Liu, Y. Wu, M. Lu, S. Song, Y. A. Yadkori. Hierarchical reasoning model. arXiv:2506.21734.
- [3] H. Karami, A. Thomas, F. Mastrogiovanni. A task and motion planning framework using iteratively deepened AND/OR graph networks. Robotics and Autonomous Systems 189, 104943, 2025.

Number of positions available:

1

Main Research Site

TheEngineRoom Lab, Department of Informatics, Bioengineering, Robotics, and Systems Engineering, University of Genoa.

Contacts: Emails: fulvio.mastrogiovanni@unige.it

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

Scholarship Amount:

- Fascia 4: 19,500 €/year

3. Sensing, Perception and Control for Human-Robot Physical Interaction - University of Genova

Curriculum: Industry 4.0	
Hosting Institution: Università di Genova	
Department: Department of Informatics, Bioengineering, Robotics, and Systems Engineering	
Tutor(s): Prof. Giorgio Cannata	

Description:

Human-robot interaction (HRI) is a key research topic in collaborative robotics, assistive systems, service robotics, and industrial automation. Robots are expected to operate in unstructured and shared environments where safe, adaptive, and intuitive interaction with humans is required. The proposed PhD activity aims to contribute to the development of next-generation collaborative robotic systems capable of natural, safe, and intelligent interaction with humans. The project is expected to generate scientific contributions in robotics sensing, AI-enhanced perception, and physical interaction control, leveraging the expertise developed at the University of Genoa (UNIGE) within the recent European projects *COLLABORATE* and *SESTOSENSO*.

The candidates can choose to focus one or more of the following research threads:

1. Design of Proximity and Tactile Sensors

- Large-area distributed tactile and proximity sensing skins for robot bodies.
- Miniaturized tactile sensors for robot hands and dexterous manipulation.
- Flexible and soft sensing technologies.
- Embedded electronics and real-time data acquisition systems.
- Sensor calibration, robustness, and reliability.

2. Physical Interaction Control

- Compliant and impedance/admittance control strategies.
- Human-robot collaborative manipulation.
- Robot-robot cooperative interaction.
- Sensor fusion for interaction-aware control.
- Safety and adaptive control in shared environments.

3. AI-Based Tactile and Proximity Perception

- AI methods for tactile and proximity gesture recognition.
- Touch-based object recognition and classification.
- Proximity-based exploration of the robot surrounding space.
- Deep learning and multimodal sensor fusion.
- Self-supervised and adaptive learning approaches for HRI.

Requirements:

The ideal candidate should possess:

- Strong background in robotics, control systems, embedded systems, or machine learning.
- Knowledge of programming languages such as C/C++, Python, and MATLAB/Simulink.
- Familiarity with robotic frameworks and middleware (e.g., ROS/ROS2).
- Basic knowledge of tactile sensing technologies, signal processing, or AI methods for perception is appreciated.
- Experience in experimental robotics and hardware/software integration is considered a plus.
- Good analytical skills, autonomy in research activities, and motivation for interdisciplinary research.
- Good written and spoken English.

References:

- Grella F., Albini A., Cannata G., Maiolino P. (2025) IEEE International Conference on Automation Science and Engineering, pp. 1998 - 2004.
- Borelli S., Giovinazzo F., Albini A., Grella F., Cannata G. "Generating Whole-Arm Avoidance Motion Through Localized Proximity Sensing" (2025) IEEE/ASME Transactions on Mechatronics, 30 (5), pp. 3988 - 3999.
- Giovinazzo F., Grella F., Sartore M., Adami M., Galletti R., Cannata G., "From CySkin to ProxySKIN: Design, Implementation and Testing of a Multi-Modal Robotic Skin for Human–Robot Interaction" (2024) Sensors, 24 (4).

Number of positions available:

1

Main Research Site

DIBRIS – Universita' di Genova

Contacts:

Email: giorgio.cannata@unige.it

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

Scholarship Amount:

- Fascia 4: 19,500 €/year

4. Design and Virtual Prototyping of Robot Hands for Humanoids - University of Genova

Curriculum: Robotics and Intelligent Machines for Industry 4.0	
Hosting Institution: University of Genova, Technical University of Munich	
Department: Department of Mechanical Energy Management and Transportation Engineering in Collaboration with TUM School of Computation, Information and Technology – Technical University od Munich	
Tutor(s): Giovanni Berselli, Cristina Piazza, Mario Baggetta	

Description:

The proposed research activity focuses on the design, modeling, development, and experimental validation of advanced robotic hands for humanoid robots. The objective is to create dexterous, lightweight, and energy-efficient robotic hands capable of performing complex manipulation tasks while closely replicating the kinematic and functional capabilities of the human hand.

Humanoid robotic hands represent one of the most challenging components in robotics due to the high number of degrees of freedom, the need for compliant interaction, and the integration of sensing, actuation, and intelligent control. The research aims to address these challenges through a multidisciplinary approach combining mechanical design, mechatronics, artificial intelligence, biomechanics, and advanced manufacturing technologies.

Expected Outcomes

The research is expected to produce:

- Novel anthropomorphic robotic hand architectures.
- Improved grasping and manipulation performance.
- Enhanced human-robot interaction capabilities.
- Scientific publications in high-impact robotics journals and conferences.
- Open-source datasets, control frameworks, or design methodologies.

Requirements:

The ideal candidate would have a degree in Mechatronics / Mechanical Engineering / Automation Engineering / Robotics Engineering. Also applicants from Biomedical Engineering are welcome to apply.

Applicants are expected to perform virtual and physical prototyping of innovative robotic hands for application on Humanoids.

Knowledge of CAD is a plus. Willingness to conduct also experimental activity is needed.

References:

- M. Baggetta, G. Pall, C. Melchiorri, and G. Berselli, Virtual and physical prototyping of a cable-driven compliant robotic wrist. IEEE/ASME Transactions on Mechatronics, vol. 30, pp. 4000–4010, 2025. IF: 5.867, CSI = 5.94, Q1.
- M. Baggetta, O. Pennacchio, S. Pirozzi, and G. Berselli, A reconfigurable four-finger gripper for versatile application in the agri-food industry," IEEE/ASME Transactions on Mechatronics, vol. 30, pp. 2999–3007, 2025. IF: 5.867, CSI = 5.94, Q1.
- G. Palli, C. Melchiorri, G. Vassura, U. Scarcia, G. Berselli, A. Cavallo, G. De Maria, C. Natale, S. Pirozzi, C. May, F. Ficuciello, B. Siciliano. The DEXMART Hand: Mechatronic Design and Experimental Evaluation of Synergy-Based Control for Human-Like grasping. SAGE International Journal of Robotic Research, DOI: 10.1177/0278364913519897, Vol. 33, No. 5, pp 799-824, 2014. IF: 6.887, CSI = 8.10, Q1.

Number of positions available:

1

Main Research Site

Department of Mechanical Energy Management and Transportation Engineering – University of Genova, Genova, Italy

Contacts:

Email: giovanni.berselli@unige.it

Funding Scheme: This doctorate grant is funded by FISA – Italian Fund on Applied Science - Companion - Ultra-low Cost COMPliANt Components for Human-Like Robotic ManipulatION: *Theoretical Foundation, Open-Source Design Tools and Manufacturing Methods*

Scholarship Amount:

- Fascia 2: 17,500 €/year

5. Multimodal AI for Generating Anticipatory Robot Behaviors that Adapt to Physical and Cognitive Ergonomics and Human Intentions – Italian Institute of Technology

Curriculum: Industry 4.0

Hosting Institution: Istituto Italiano di Tecnologia

Department:

Human-Robot Interfaces and Interaction https://hri.iit.it/

Tutor(s): Drs. Arash Ajoudani, Marta Lagomarsino

ISTITUTO ITALIANO DI TECNOLOGIA

Description:

This PhD research investigates the development of multimodal AI frameworks for generating anticipatory r**obot behaviors capable of adapting dynamically to human physical and cognitive ergonomics**, contextual task demands, and inferred human intentions in collaborative environments. The project focuses on the integration of computational ergonomics models with next-generation AI-driven robotic control architectures, enabling robots to proactively optimize interaction quality, safety, efficiency, and human comfort during shared activities. Advanced machine learning paradigms, including **Reinforcement Learning (RL), imitation learning, Vision-Language-Action (VLA) models, Vision-Language Models (VLMs), and multimodal foundation models,** will be employed to create adaptive control policies that can reason over visual, linguistic, biomechanical, physiological, and behavioral signals in real time. A key research objective is the development of embodied AI systems capable of understanding human motion, cognitive workload, fatigue, posture, and intent, while continuously adapting robot trajectories, force modulation, timing, and interaction strategies to ergonomic constraints and evolving human states. The project will explore hierarchical and uncertainty-aware control mechanisms, human-aware motion generation, and generative world models for anticipatory decision-making in complex and unstructured environments. Particular emphasis will be placed on **integrating ergonomic assessment metrics and markerless human motion capture technologies** into closed-loop robot control pipelines, enabling the creation of intelligent collaborative robotic systems that are not only autonomous and context-aware, but also ergonomically adaptive, cognitively aligned, and intrinsically human-centric.

Requirements:

The successful candidate must have an MSc degree with a strong background in Robotics, Machine Learning and/or computer vision.

The successful candidate should have:

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

- Good knowledge of written and spoken English.

References:

- Lagomarsino, Marta, et al. "Maximising coefficiency of human-robot handovers through reinforcement learning." *IEEE Robotics and Automation Letters* 8.8 (2023): 4378-4385.
- Merlo E, Lagomarsino M, Ajoudani A. Information-Theoretic Detection of Bimanual Interactions for Dual-Arm Robot Plan Generation. IEEE Robotics and Automation Letters. 2025 Mar 17.
- Kastritsi, Theodora, Marta Lagomarsino, and Arash Ajoudani. "Postural virtual fixtures for ergonomic physical interactions with supernumerary robotic bodies." The International Journal of Robotics Research (2026): 02783649261424269.

Number of positions available:

1

Main Research Site

Center for Robotics and Intelligent Systems (CRIS), IIT, Genova

Contacts:

Arash.ajoudani@iit.it

Funding Scheme: This open position is financed by Ministero dell'Università e della Ricerca (MUR) nell'ambito del "Bando FIS – Fondo Italiano per la Scienza – PROCEDURA COMPETITIVA PER LO SVILUPPO DELLE ATTIVITÀ DI RICERCA FONDAMENTALE, A VALERE SUL FONDO ITALIANO PER LA SCIENZA 2024–2025 (BANDO FIS 3)" – MACROSETTORE PE – Physical Sciences and Engineering, Decreto Direttoriale n. 1802 del 21/11/2024, e il Decreto "Approvazione delle Graduatorie Finali, Ammissione a Finanziamento – Disposizioni per l'avvio delle Attività Progettuali" prot. n. 18010 del 12/11/2025, within "The Ergonomics Embodied: Predictive and Inter-Causal Representation of Mind and Body in Robot-Assisted Occupational Ergonomics" project; Acronym: EPIC; Grant Agreement number: FIS-2024-026564; CUP: J53C25002230001.

Scholarship Amount:

- Fascia 4: 19,500 €/year

6. Physical AI and Humanoid Robotics for Adaptive Industrial Production Systems – Italian Institute of Technology (N. 2 positions)

Curriculum: Industry 4.0

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 research will address physical AI, embodied intelligence, advanced manipulation, autonomous inspection, industrial logistics, and human-robot collaboration in complex manufacturing environments.

The candidate will contribute to the design and integration of robotic technologies within a large-scale experimental ecosystem where humanoids, mobile robots, drones, and intelligent production systems cooperate to enable flexible, resilient, and remotely supervised industrial operations.

The project combines fundamental research, real-world industrial validation, and technology transfer activities in collaboration with research institutions, companies, and innovation stakeholders.

Requirements:

The ideal candidate would have a degree in Engineering

References:

- Zambella, G., Grioli, G., Cavaliere, A., Rosato, G., Petrocelli, C., Poggiani, M., ... & Catalano, M. G. (2025). Usability of a Robot Avatar Designed for the Real World: The Alter-Ego X Case Study. International Journal of Social Robotics, 17(3), 505-521.
- Duz, A., Negrello, F., Rucodainii, A., Lanzoni, D., Corsanici, M., Iapichino, A., ... & Catalano, M. G. (2025). From construction machines to remote construction robots: control, interfaces, and usability of the Cranebot. Frontiers in Robotics and AI, 11, 1504317.
- F. Kong, G. Zambella, S. Monteleone, G. Grioli, M. G. Catalano and A. Bicchi, "A Suspended Aerial Manipulation Avatar for Physical Interaction in Unstructured Environments," in *IEEE Access*, vol. 12, pp. 48108-48125, 2024

Number of positions available:

2

Main Research Site

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

Contacts: Email: manuel.catalano@iit.it

Funding Scheme: This doctorate grant is funded by IIT internal funding.
Scholarship Amount: • Fascia 4: 19,500 €/year

7. Vision-Language-Action Intelligence for Resilient Multi-Robot Construction – Italian Institute of Technology

Curriculum: Industry 4.0

Hosting Institution: Istituto Italiano di Tecnologia

Department: Human-Robot Interfaces and Interaction https://hri.iit.it/

Tutor(s): Drs. Arash Ajoudani

Description:

This PhD research is positioned within the broader vision of EIC BRICKS, a project that aims to redefine construction through autonomous, collaborative, and intelligent robotic systems. As the construction sector faces increasing pressure from labour shortages, safety concerns, and sustainability demands, BRICKS envisions future construction sites where humans and heterogeneous robot teams work together seamlessly to assemble modular buildings with high precision, resilience, and efficiency. Within this context, the PhD will focus on the development of embodied AI frameworks that combine Large Language Models (LLMs), Vision-Language-Action/Manipulation (VLA/VLM) architectures, and multi-agent robotic control to enable adaptive human-robot collaboration in dynamic construction environments. The research will investigate how robots can understand high-level human intentions through multimodal interaction, reason about complex assembly tasks, and autonomously coordinate manipulation, navigation, and task execution in collaboration with both humans and other robots. By Exploiting multi-agent reinforcement learning, distributed planning, graph-based coordination, and adaptive control, the work will develop resilient strategies for collaborative manipulation, task allocation, and fault recovery under uncertainty. By integrating cognitive reasoning with physical robotic capabilities, the PhD aims to contribute to the realization of intelligent robotic construction ecosystems capable of safe, explainable, and scalable autonomous assembly for future-ready infrastructure**.**

Requirements:

The successful candidate must have an MSc degree with a strong background in Robotics, Machine Learning and/or computer vision.

The successful candidate should have:

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

References:

- Merlo, Elena, Marta Lagomarsino, and Arash Ajoudani. "Information-theoretic detection of bimanual interactions for dual-arm robot plan generation." IEEE Robotics and Automation Letters (2025).
- Lagomarsino, Marta, et al. "Intuitive Programming, Adaptive Task Planning, and Dynamic Role Allocation in Human–Robot Collaboration." *Annual Review of Control, Robotics, and Autonomous Systems* 9 (2025).
- Merlo, Elena, et al. "Exploiting information theory for intuitive robot programming of manual activities." *IEEE Transactions on Robotics* 41 (2025): 1245-1262.

Number of positions available:

1

Main Research Site

Center for Robotics and Intelligent Systems (CRIS), IIT, Genova

Contacts: Arash.ajoudani@iit.it

Funding Scheme: This grant is funded by the IIT under the IC Pathfinder Challenges “BRICKS – Building Robotic Intelligence and Modular Construction Kit System“ project, awarded by the European Innovation Council (EIC) under the Horizon Europe Programme.

Scholarship Amount:

- Fascia 4: 19,500 €/year

8. Foundation Models for Human-Robot Collaboration and Tactile Manipulation – University of Campania "Luigi Vanvitelli"

Curriculum: Industry 4.0	
Hosting Institution: Università degli Studi della Campania "Luigi Vanvitelli"	
Department: Dipartimento di Ingegneria	
Tutor(s): Prof. Ciro Natale, Prof. Marco Costanzo	

Description:

Whereas traditional robotic systems operate in isolated and structured settings, collaborative robots are designed to interact directly with human operators while performing shared tasks, or to operate in scenarios where human safety must be guaranteed. However, the coexistence of humans and robots in the same workspace introduces significant challenges [1]. Safety in shared workspaces requires continuous monitoring of both the human operator and the surrounding environment through reliable perception and decision-making mechanisms. Conventional HRC systems typically rely on multimodal sensing technologies, such as cameras, LiDAR, force sensors, and proximity sensors, to detect human presence, recognize actions, and prevent collisions. By fusing information from multiple sensing modalities, these systems aim to maximize both production efficiency and operator safety. Nevertheless, traditional approaches are often limited by task-specific programming, poor adaptability to dynamic environments, and a restricted understanding of complex human behaviors and intentions. Foundation models offer new opportunities for robots to understand human intentions, interpret natural language instructions, reason about tasks, and adapt to changing environments. In particular, foundation models can fuse and align multimodal heterogeneous data gathered from various sensors into compact, homogeneous representations needed for robot understanding and reasoning, and can use these learned representations in any part of the autonomy stack, including perception, decision-making, and control. They can also generalize their learned knowledge to novel cases, enhancing adaptability and flexibility for robots in unstructured settings [2].

For example, Large Language Models (LLMs) can enhance communication between humans and robots by enabling robots to understand natural language instructions, or more broadly, Vision-Language-Action (VLA) models can integrate vision and language understanding to directly generate robot actions and motion commands, enabling robots to manipulate objects of different shapes and sizes. Incorporating force/tactile sensor might further expand these manipulation skills to include also fragile objects [3]. Another key aspect to consider is the integration of foundation models such as LLMs and VLMs into advanced robotic learning paradigms, including imitation learning and reinforcement learning, improving data efficiency, enhancing contextual understanding, and enabling synthetic data generation. In particular, these models could offer the possibility of creating large-scale and diverse synthetic datasets that complement the scarcity of real-world data, as well as assisting in the design of shaped reward functions. These features could enhance the performance of the learning-based force/pose controller, which can then be integrated in dual-arm cooperative manipulation framework [4], or in reconfigurable single-arm gripping devices for manipulating and grasping delicate objects [3].

Challenges:

Integrating foundation models into collaborative robotic systems brings numerous challenges, such as real-time performance constraints, safety evaluation, and the fine-tuning of pre-trained models. For the candidate, the following activities are foreseen:

- A thorough study of the general concepts related foundation models, transformers, large language models (LLMs), and VLMs
- Developing an innovative context-aware system for human robot interaction
- Integrate the foundation model in control system for safe human-robot collaboration

During the PhD, the student will exploit the numerous robotic arms and hands available in our lab together with RGB-D cameras, a thermal camera, force/torque sensors and tactile sensors, in order to experimentally test his/her studies.

Requirements:

We are looking for a highly motivated, creative, and ambitious student, able to work in a team as well as independently. The candidate should fulfill, at least partially, the following requirements:

- Successfully completed scientific university degree in Computer Science, Robotics, Automatic Control, or other closely-related discipline• Experience in real-time robot control techniques
- Experience in development of perception algorithms for vision and/or tactile sensors
- Experience with IsaacLab/IsaacSim, Groot, ROS2, C++, Matlab
- Experience in composing academic and technical writing pieces (papers, deliverables, technical reports)

References:

[1] M. Costanzo, G. De Maria, G. Lettera, C. Natale, “A multimodal approach to human safety in collaborative robotic workcells”, IEEE Trans. on Automation Science and Engineering 19.2 (2022),pp. 1202-1216.

[2] Roya Firoozi, Johnathan Tucker, Stephen Tian et al., “Foundation Models in Robotics: Applications, Challenges, and the Future”, The International Journal of Robotics Research. 2025;44(5):701-739.

[3] M. Baggetta, O. Pennacchio, S. Pirozzi and G. Berselli, ”A Reconfigurable Four-Finger Gripper for Versatile Application in the Agri-Food Industry,” in IEEE/ASME Transactions on Mechatronics, vol. 30, no. 4, pp. 2999-3007, Aug. 2025

[4] M. De Simone, M. Costanzo, G. De Maria and C. Natale, ”Cooperative Object Transport and Assembly: Pose/Force Control by Visual-Tactile Feedback,” in IEEE Robotics and Automation Letters, vol. 11, no. 4, pp. 4315-4322, April 2026

Number of positions available:

1

Main Research Site

Dipartimento di Ingegneria, Via Roma 29, 81031 – Aversa (CE), Italy

Contacts:

Email: salvatore.pirozzi@unicampania.it, Tel.: +39 081 5010433

Funding Scheme: This doctorate grant is funded by Università degli Studi della Campania

“Luigi Vanvitelli”
Scholarship Amount: • Fascia 1: 16,500 €/year

9. Development and integration of haptic devices for extended reality applications – University of Siena

Curriculum: Industry 4.0

Hosting Institution:

University of Siena, Via Banchi di Sotto, 55, 53100 Siena (SI), Italy

Department:
Department of Information Engineering and Mathematics

(Dipartimento Ingegneria dell'Informazione e Scienze Matematiche - DIISM)

Tutor(s):

Prof. Domenico Prattichizzo

UNIVERSITÀ DI SIENA 1240

Description:

The current state of the art in eXtended Reality (XR) interaction and remote collaboration is constrained by strong assumptions and highly specific, ad hoc scenarios. These limitations significantly hinder realism, scalability, and social acceptance. To address these challenges, we propose a novel approach to representing, processing, encoding, and interactively rendering XR content as a next-generation visuo-haptic medium. The objective is to enable a breakthrough multimodal immersion that is inclusive, realistic, and perceptually credible, ultimately enhancing interaction quality and user experience across virtual environments.

The candidate will be responsible for investigating the design and development of advanced haptic interfaces, including wearable devices such as armbands, headbands, rings, and thimbles. These systems should be capable of delivering rich tactile feedback through mechanisms such as gross skin deformation, vibrotactile stimulation, and thermal cues. In parallel, the research will explore new methods for haptic representation, with the aim of establishing haptics as a primary modality within XR systems. The work will focus both on refining control systems for haptic modules and on advancing the underlying hardware design. Additionally, the research will explore the integration of physical cutaneous and vibrotactile feedback with symbolic and affective haptics, where tactile signals can be used to convey emotions, intentions, or abstract information. This approach aims to expand the expressive capacity of haptic communication within immersive environments.

The candidate will conduct this research within the framework of a European Project (XR-SENSE – Next-Generation Visuohaptic Media Representation, Coding and Interactive Rendering for Immersive and Inclusive XR – GA n. 101297892) and will have the opportunity to collaborate and interact with academic partners, research centers, and companies involved in the project.

Requirements:

Applicants are expected to have a background in control, mechatronics, mechanical, robotics, and biomedical engineering or related fields

References:

- D'Aurizio, Nicole, et al. "On the correlation between tactile stimulation and pleasantness." IEEE Transactions on Haptics 16.4 (2023): 861–867
- Frisoli et al. (2024) “Wearable haptics for virtual reality and beyond”, Nature Reviews Electrical Engineering
- Safikhani, S. et al. (2024). “The influence of realism on the sense of presence in virtual reality: neurophysiological insights using EEG”, Multimodal Technologies and Interaction.

Number of positions available:

1

Main Research Site

Department of Information Engineering and Mathematics, University of Siena, Italy, Via Roma 56, 53100 Siena, Italy

Contacts:

Email: domenico.prattichizzo@unisi.it

Funding Scheme: This doctorate grant is funded by XR-SENSE (Next-Generation Visuohaptic Media Representation, Coding and Interactive Rendering for Immersive and Inclusive XR – GA n. 101297892).

Scholarship Amount:

- Fascia 1: 16,500 €/year

10. Generative Physical AI for humanoid robotics with differentiable computational models - Generative Bionics S.r.l.

Curriculum: Industry 4.0	GENERATIVE BIONICS
Hosting Institution: Generative Bionics	
Department: NA	
Tutor(s): Alessio Del Bue, Pietro Morerio, Stefano Dafarra	

Description:

The proposed research topic is positioned within Generative Physical AI and focuses on the development of differentiable computational models for humanoid robotics, integrating high-fidelity, physically consistent simulation with machine learning into a unified optimization framework. The goal is to overcome the traditional separation between mechanical design and control by enabling gradient-based optimization over both physical and computational parameters, turning simulation into a central component of the design process rather than a post-hoc validation tool.

The PhD will investigate methodologies for joint co-design of embodiment and control policies, allowing the simultaneous optimization of robot morphology, sensor configuration, actuation characteristics, and learning strategies. This approach aims to identify globally optimal system configurations for complex industrial tasks, significantly improving performance, robustness, and efficiency.

Requirements:

The ideal candidate would have a degree in Robotics, Machine Learning and related fields, Applicants are expected to have a strong knowledge of simulation environments for robotics and documented experience in working with humanoid platforms.

Company name and link (for industrial projects):

Generative Bionics - https://gbionics.ai/

Number of positions available:

1

Main Research Site

Great Campus Erzelli (GHT), Via Enrico Melen 83 -Tower B/11th Floor, 16152 Genova

Contacts:

Email: alessio.delbue@gbionics.ai, stefano.gianazzi@gbionics.ai

Funding Scheme: This doctorate grant is funded by Generative Bionics.

Scholarship Amount:

- **Fascia 4: 19,500 €/year**

11. Intelligent Loco-Manipulation Planning and Control of Mobile Robots – Leonardo S.p.A.

Curriculum: Industry 4.0

Hosting Institution:

Leonardo S.p.A.

University of Genoa (Università degli Studi di Genova)

Department:

Robotics Laboratory, Innovation Hub & Intellectual Property

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

Tutor(s): Navvab Kashiri, Giorgio Cannata

Description:

The integration of locomotion and manipulation capabilities in mobile robots holds transformative potential for applications such as industrial inspection, assistive robotics, disaster response, and autonomous construction, yet coordinating whole-body motion with dexterous manipulation in dynamic, unstructured environments remains a deeply complex problem. This PhD project aims to advance the field of mobile manipulation by developing intelligent planning and control frameworks that tightly couple legged or wheeled locomotion with robotic arm motion, enabling robots to interact with their environment in a purposeful and physically consistent manner. The inherent challenges of maintaining stability during manipulation, reasoning over contact interactions, and adapting to unpredictable terrains and objects demand a rethinking of traditional decoupled planning and control pipelines.

This research seeks to address these challenges through the development of unified, learning-augmented planning and control strategies capable of real-time whole-body coordination on physically capable robotic platforms. The work will focus on three key components:

- Whole-body motion planning, developing coupled locomotion-manipulation planners that reason jointly over robot stability, reachability, and task objectives in complex environments.
- Adaptive loco-manipulation control, leveraging model-based and learning-based control methods to handle contact-rich interactions, terrain disturbances, and dynamic object properties during task execution.
- Intelligent task and motion planning, integrating high-level task reasoning with low-level physical constraints to enable robots to autonomously decompose, sequence, and execute multi-step manipulation tasks while on the move.

Requirements:

Candidates should have a degree in Robotics Engineering, Computer Engineering, or related study programs. Applicants are expected to be proficient in software design and development (software architectures for robots, C/C++, Python), artificial intelligence techniques for robots, perception, reasoning, and motion planning and execution. The ideal candidate is proficient in the intersection of Robot control and visual perception.

References:

- Monguzzi, Andrea, Giuseppe Alfonso, Navvab Kashiri “Reactive Whole-Body Control of Mobile Manipulators for Dynamic Target Tracking via Adaptive-Predictive Visual Servoing.” 2026 IEEE International Conference on Robotics & Automation (ICRA), IEEE 2026.

Company name and link (for industrial projects):

Leonardo S.p.A.,

https://www.leonardo.com/en/innovation-technology/leonardo-labs/robotics

Number of positions available:

1

Main Research Site

Robotics Lab, Leonardo SpA, Via Raffaele Pieragostini, 80, 16151 - Genova, Italy.

Contacts:

Email: navvab.kashiri@leonardo.com, giorgio.cannata@unige.it

Funding Scheme: This doctorate grant is funded by Leonardo SpA.

Scholarship Amount:

- Fascia 4: 19,500 €/year

12. Optimization of flexible robotic work-cell for industrial handling – place reserved for Innova S.r.l. employee

Curriculum: Industry 4.0

Hosting Institution: Innova S.r.l. and University of Padova

Department: Department of Industrial Engineering

Tutor(s): Giovanni Boschetti

Description:

The project involves the development of methods and algorithms, also based on both 2D and 3D computer vision, for the optimization of end-effectors, work cycles, and the arrangement of semi-finished parts in industrial manipulation applications involving components of varying sizes with random arrival rates. The main goal consists in maximizing the utilization of available storage slots and the productivity of the work cell.

The methodologies will be validated both through virtualization of the robotic cell in simulation and through implementation in a prototype robotic cell equipped with robots, vision sensors, end-effectors, and part feeding systems.

Requirements:

The ideal candidate would have a degree in Computer Engineering / Control Systems Engineering

References:

- M.Bottin, G.Rosati, G.Boschetti, "Working Cycle Sequence Optimization for Industrial Robots" Mechanisms and Machine Science DOI: 10.1007/978-3-030-55807-9_26

Company name and link (for industrial projects): Innova s.r.l. (https://www.inn-group.it/)

Number of positions available:

1

Main Research Site

Innova s.r.l.

Contacts: Email: giovanni.boschetti@unipd.it

Funding Scheme: Place reserved for INNOVA S.r.l. employee