I-RIM

PhD Course in

ROBOTICS AND INTELLIGENT MACHINES

Curriculum: Robotics and Intelligent Machines for Industry 4.0

Research themes

Sommario

For larger companies, robotics has been a key productivity factor for many years; nowadays, thanks to the development of the new enabling technologies of Industry 4.0, such as collaborative robotics and artificial intelligence, robotics is also becoming increasingly relevant for smaller industries, which are crucial for Italy's production and employment capacity. Many drivers are pushing the adoption of robotic technology in industry, such as the need of products customization, the increase in competitiveness in the global market and the progressive penetration of cobots in human-centred manufacturing scenarios.

The introduction and spread of the Industry 4.0 production paradigm has given more boost to the use of robots, since they are interconnected, highly digitized autonomous agents, equipped with a digital twin, able to improve their performance based on the analysis of data collected in production systems. On the other hand, as also highlighted by the European Economic and Social Committee (EESC), the next transition to Industry 5.0 will be characterized by the shift from coexistence to full cooperation, physical and social, between machines and people.

All these topics are addressed with an integrated and multidisciplinary approach by the projects proposed in this curriculum; they represent cutting-edge technological challenges

that can certainly be tackled due to the scientific and technological background of the proposing institutions and the experience of the involved researchers.

The main goals of the Industry 4.0 curriculum are:

- Encourage technology transfer from research to industry, particularly in the industrial sectors that can best exploit the use of robotics.
- Give industry the opportunity to help direct the research of PhD students, as demonstrated by the high number of scholarships in the curriculum funded or co-funded by companies
- Give PhD students the opportunity to spend some time within the companies participating in the training project

The ideal candidates are students with a Master (or equivalent/higher) degree in a STEM field: a specific background in Robotics or Mechatronics will be appreciated.

The students will perform their research project at the hosting institution (as described in the research project sheet). Interested students can contact the tutors and/or the Unit's Principal Investigators for clarifications before submitting their documentation.

International applications are encouraged, and the participants will receive logistic support with visa issues, relocation, etc.

1. Reinforcement Learning and Foundational Models for Adaptive Control of Robots in Unpredictable Environments – Istituto Italiano di Tecnologia

Curriculum:
Industry 4.0

Hosting Institution
Istituto Italiano di Tecnologia

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

Tutor(s):
Arash Ajoudani

ISTITUTO ITALIANO DI TECNOLOGIA

Description:
The advent of foundation models, particularly large language models (LLMs) and vision-language models (VLMs), has revolutionized the field of artificial intelligence, enabling unprecedented levels of understanding and interaction. This PhD research theme explores the integration of these cutting-edge technologies into the control systems of collaborative robots (cobots), focusing on achieving full autonomy and enhancing human-robot collaboration.
By leveraging foundation models, this research aims to develop innovative frameworks that allow cobots to understand and respond to human commands in natural language, interpret visual cues, and make autonomous decisions based on real-time data.
Students will investigate the application of LLMs to enable natural language understanding, allowing cobots to interact seamlessly with human operators. This includes designing systems that can interpret context, engage in multi-turn dialogues, and provide actionable feedback. In parallel, the use of VLMs will be explored to enhance the robots' visual perception capabilities, enabling them to comprehend and react to visual stimuli in their surroundings.
The proposed research will involve developing hybrid control architectures that combine the strengths of LLMs and VLMs with advanced control strategies, such as model predictive control (MPC) and reinforcement learning (RL). Students will have the opportunity to create adaptive algorithms that empower cobots to learn from their interactions, improving their performance and safety in real-world applications.
This theme not only promises to advance the theoretical understanding of AI in robotics but also emphasizes practical implementation, targeting industries such as healthcare, logistics, and manufacturing. By participating in this research, students will contribute to pioneering work that bridges the gap between AI and robotics, ultimately leading to the next generation of intelligent, collaborative systems.
We are seeking motivated and innovative students who are passionate about robotics and AI. Join us in shaping the future of human-robot interaction, where cobots will work alongside humans, enhancing productivity and safety in various environments. With guidance from leading experts in the field, you will gain hands-on experience and contribute to cutting-edge research that has the potential to transform industries.

Requirements:
The successful candidate must have an MSc degree with a strong background in Robotics, Machine Learning and/or human-robot interaction.
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:

- Zhang H, Solak G, Lahr GJ, Ajoudani A. SRL-VIC: A Variable Stiffness-based Safe Reinforcement Learning for Contact-rich Robotic Tasks. IEEE Robotics and Automation Letters. 2024.
- Zhao, Jianzhuang, et al. "A hybrid learning and optimization framework to achieve physically interactive tasks with mobile manipulators." IEEE Robotics and Automation Letters 7.3 (2022): 8036-8043.

Company name and link (for industrial projects):

Number of positions available:
2

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

Contacts:

Arash.ajoudani@iit.it

Funding Scheme: This doctorate grant is funded by the Horizon Europe Project Tornado (GA # 101189557)

Scholarship Amount:
- Fascia 4: 19,500 €/year

2. Soft Robotics for Archeology – Istituto Italiano di Tecnologia

Curriculum:

Industry 4.0

Hosting Institution
Istituto Italiano di Tecnologia

Department:
Soft Robotics for Human Cooperation and Rehabilitation

Tutors
Antonio Bicchi, Manuel G. Catalano, Giorgio Grioli

Description
The AUTOMATA project means to facilitate large-scale, rich, low-cost digitisation campaigns for archaeological finds (pottery and lithics) through an AI-augmented robotic system equipped with sensors. It will quickly and efficiently create 3D models of archaeological finds, enriched with archaeometric data, made freely available online, allowing effective data reuse by researchers and citizens. Our ambition is to create an open-source robotic infrastructure, encompassing both hardware and software components, that is modular, cost-effective, straightforward to deploy, and designed to automate the digitisation and analysis of small-sized artefacts, that can deployed in different archaeological contexts by non-experts.
The successful candidate will apply the paradigms of soft robotics to the development of Human-Robot Cooperation solution for the automatic digitisation and analysis of archaeological artefacts.

Requirements

- An MSc degree in Robotic Engineering, Mechatronic Engineering or closely related fields.
- Good communication skills.
- Ability and willingness to integrate in a multidisciplinary international research group.
- Good knowledge of written and spoken English.
- Knowledge of Matlab, Simulink and ROS is welcome.

References

- Catalano, Manuel G., et al. "Adaptive synergies for the design and control of the Pisa/IIT SoftHand." The International Journal of Robotics Research 33.5 (2014): 768-782.
- Mura, D., Barbarossa, M., Dinuzzi, G., Grioli, G., Caiti, A., & Catalano, M. G. (2018). A soft modular end effector for underwater manipulation: A gentle, adaptable grasp for the ocean depths. IEEE Robotics & Automation Magazine, 25(4), 45-56.
- Angelini, F., Petrocelli, C., Catalano, M. G., Garabini, M., Grioli, G., & Bicchi, A. (2020). SoftHandler: An integrated soft robotic system for handling heterogeneous objects. IEEE Robotics & Automation Magazine, 27(3), 55-72.

Number of positions available: 1

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

Contacts
Email: giorgio.grioli@iit.it

Funding Scheme
This doctorate grant is funded by the Italian Institute of Technology from fundings coming from the EU project AUTOMATA CUP J53C24000960006

Scholarship Amount:

- Fascia 4: 19,500 €/year

3. Advanced integration of perception and navigation systems for unstructured environments in coordination with human beings – Leonardo s.p.a. and University of Genova.

Curriculum:

Industry 4.0

Hosting Institution
University of Genoa

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

Tutor(s):
Fulvio Mastrogiovanni
Navvab Kashiri (Leonardo s.p.a.)

Description:

The core focus of this thesis lies on achieving tight integration between perception and navigation functionalities, while also leveraging human-robot collaboration. Current robotic navigation systems primarily rely on localization techniques to determine the robot's position within a pre-mapped environment. This thesis proposes a novel approach that goes beyond simple localization using LiDAR. By integrating perception systems encompassing sensors and cameras, the robot will actively build and maintain a dynamic map of the environment, including both static elements and mobile objects. This real-time map will not only enable self-navigation but also empower the robot to understand and react to its surroundings.

The human element plays a crucial role in this framework. The thesis explores methods for seamless human-robot interaction, allowing humans to guide the robot and provide context about the environment and desired tasks. This collaborative approach can be particularly advantageous when searching for specific objects within the unstructured environment. By leveraging the human's ability to recognize and categorize objects, the robot can refine its search strategy based on real-time data and human input, ultimately achieving faster and more accurate object retrieval.

This research will contribute significantly to the field of human-robot collaboration by:

1. Enhancing robot autonomy and adaptability: Robots will be able to operate effectively in dynamic environments without constant pre-programming.
2. Improving human-robot teamwork: Seamless interaction will enable humans to effectively guide robots and leverage their capabilities.
3. Facilitating real-world applications: The proposed system can be applied in various domains like search and rescue, industrial automation, and assistive technologies.

The successful implementation of this thesis will pave the way for a future where robots seamlessly integrate into our lives, functioning as intelligent collaborators in complex and ever-changing environments.

Requirements:
Applicants are expected to have a background in robotics, mechatronics, computer science and engineering, and related disciplines. They are also expected to be proficient in software design, software development, and control theory. Outstanding candidates have experience in software frameworks for robots, machine learning, knowledge representation and planning for robots, as well as robot motion control. Exceptional candidates have carried out research activities related to task-motion planning.

References:

- E. Merlo, E. Lamon, F. Fusaro, M. Lorenzini, A. Carfì, F. Mastrogiovanni, A. Ajoudani. An ergonomic role allocation framework for dynamic human-robot collaborative tasks. Journa of Manufacturing Systems 67:111-121, April 2023.
- K. Darvish, E. Simetti, F. Mastrogiovanni, G. Casalino. A hierarchical architecture for human robot collaboration processes. IEEE Transactions on Robotics 37(2):567-586, April 2021.

Company name and link (for industrial projects):
Leonardo S.p.A. (www.leonardo.com)

Number of positions available:
1

Main Research Site
Department of Informatics, Bioengineering, Robotics, and Systems Engineering, University of Genoa, Italy.

Contacts:

Prof. Fulvio Mastrogiovanni, email: fulvio.mastrogiovanni@unige.it

Funding Scheme: This doctorate grant is co-funded by **PROGRAMMA REGIONALE FONDO SOCIALE EUROPEO+ 2021-2027 PRIORITÀ 2 - ISTRUZIONE E FORMAZIONE - ESO 4.6 (OS-f) and Leonardo s.p.a..**

Scholarship Amount:
- Fascia 4: 19,500 €/year

4. Human/Robot collaboration in cooperative assembly tasks – Leonardo s.p.a. and University of Genova

Curriculum: Industry 4.0	
Hosting Institution University of Genova	
Department: DIBRIS	
Tutor(s): Giorgio Cannata Navvab Kashiri (Leonardo s.p.a.)	

Description:

The framework integrates the four key control methods:

1. Position Control: Ensures precise robot movement for tasks requiring high accuracy.
2. Force Control: Enables robots to interact with the environment and human partners with controlled forces.
3. Impedance Control: Combines position and force control, allowing robots to adapt to varying contact forces during assembly.
4. Admittance Control: Focuses on the robot's dynamic response to external forces, ideal for tasks requiring compliance.

Requirements:

Applicants are expected to have a background in robotics, mechatronics, computer science and engineering, and related disciplines. They are also expected to be proficient in software design, software development, and dynamic control.

References:

- Romiti, E., Malzahn, J., Kashiri, N., Iacobelli, F., Ruzzon, M., Laurenzi, A., Hoffman, E.M., Muratore, L., Margan, A., Baccelliere, L., Cordasco, S., Tsagarakis, N. "Toward a Plug-and-Work Reconfigurable Cobot (2022) IEEE/ASME Transactions on Mechatronics, 27 (5), pp. 3219-3231.
- Muratore, L., Laurenzi, A., Hoffman, E.M., Baccelliere, L., Kashiri, N., Caldwell, D.G., Tsagarakis, N.G. "Enhanced Tele-interaction in Unknown Environments Using Semi-Autonomous Motion and Impedance Regulation Principles", (2018) Proceedings - IEEE International Conference on Robotics and Automation, art. no. 8460559, pp. 5813-5820.

Company name and link (for industrial projects):

Leonardo S.p.A. (www.leonardo.com)

Number of positions available:

1

Main Research Site

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

Contacts:

Prof. Giorgio Cannata, email: giorgio.cannata@unige.it Dr. Navvab Kashiri, email: navvab.kashiri@leonardo.com
Funding Scheme: This doctorate grant is co-funded by **PROGRAMMA REGIONALE FONDO SOCIALE EUROPEO+ 2021-2027 PRIORITÀ 2 - ISTRUZIONE E FORMAZIONE - ESO 4.6 (OS-f) and Leonardo s.p.a..**
Scolarship Amount: ● Fascia 4: 19,500 €/year

5. Robust and Efficient Robotic Platforms For Versatile Applications - Leonardo s.p.a. and C.N.R. STIIMA

Curriculum:

Industry 4.0

Hosting Institution
Leonardo s.p.a.

Department:
N/A

Tutor(s):
Nicola Gallo (LEONARDO) nicola.gallo@leonardo.com
Vito Renò (CNR STIIMA) vito.reno@stiima.cnr.it

Description:
Production processes for aircraft manufacturing, although strictly supervised and inspected, can in some cases create defects in the final product that could impact quality, safety, and performance. Unexpected events could further damage or break some components of the aircraft. Therefore, it is mandatory to research for cutting-edge quality control and support systems for enhancing the aerospace production line support, for example integrating AI-empowered techniques as well as computer vision ones.
As an example, in order to improve sustainability in manufacturing (e.g. reduction of material waste; reduction of energy consumption; increase of quality levels) in combination with business productivity, costs reduction and quality assurance, AI-based models to support the monitoring of drilling operation and visual inspection of fuselage defects can be investigated and developed. Moreover, for increased lifetime of machinery and improved product quality, monitoring of critical machine and product parameters and developing AI-based models to support the monitoring of operations and visual inspection need to be investigated, designed and developed.

The objective of this PhD will span from the requirements definitions and applications for new sensors to the development of AI models. The sensors that will be installed into manufacturing processes, in accordance to the principles of not duplicating information (one variable will be measured by one type of sensor), considering possible redundancies for better accuracy, and will be designed in order to acquire data in the most straightforward possible way. LEONARDO will share its experience with CNR STIIMA to have a standard and cross-sectional work approach. In particular, the evaluation of proper devices for sensing and perception to be integrated to capture 2D and 3D quality data (stereo cameras, lidar, etc…) considering possible inputs from the field and the application (e.g. resolution, accuracy, framerate, synchronisation, calibration and context constraints).

Particular attention will be devoted to the design and development of the tools/setups for acquiring data from the manufacturing line from a technological point of view focused on vision hardware (2D, 3D) and processing algorithms. Among them, both AI/ML techniques will be evaluated, as well as standard computer vision approaches for collecting data and extracting meaningful features.

The development of AI-driven systems acting as serving systems in the real world—e.g., addressing industrial needs—requires following a rigorous strategy and development methodology. Many different aspects such as proper translation of the system requirements to ML requirements, assuring the quality of the data as well as a proper deployment setup, considering adequate measures for addressing data and model drift and finally assuring trustworthiness and handling ethical aspects in relation to processing individuals' data are all to be satisfied and managed decently.

The approach will be highly multidisciplinary as it will span across different disciplines: computer vision, software engineering, data science, AI and machine learning, optimization, simulation and quality control under the common reference application scenario of aerospace production line support.

Requirements:
Applicants are expected to have a background in computer science, computer engineering or information engineering (or equivalent). Applicants are expected to know programming languages (e.g. python) and object-oriented programming. Applicants should preferably have studied and applied machine learning or deep learning models. Applicants should preferably be familiar with popular libraries such as opencv, pytorch, pandas, scikit-image or scikit-learn

References:

- Cheng, X., Ma, G., Wu, Z., Zu, H., & Hu, X. (2023). Automatic defect depth estimation for ultrasonic testing in carbon fiber reinforced composites using deep learning. NDT & E International, 135, 102804.
- Renò, V., Nitti, M., di Summa, M., Maglietta, R., & Stella, E. (2020, June). Comparative analysis of multimodal feature-based 3D point cloud stitching techniques for aeronautic applications. In 2020 IEEE 7th International Workshop on Metrology for AeroSpace (MetroAeroSpace) (pp. 398-402). IEEE.
- Saeed, N., King, N., Said, Z., & Omar, M. A. (2019). Automatic defects detection in CFRP thermograms, using convolutional neural networks and transfer learning. Infrared Physics & Technology, 102, 103048.

Company name and link (for industrial projects):
LEONARDO (https://www.leonardo.com/it/home)

Number of positions available:
1

Main Research Site
LEONARDO RESEARCH SITE, Grottaglie (TA)

Contacts:

Nicola Gallo (LEONARDO) nicola.gallo@leonardo.com
Vito Renò (CNR STIIMA) vito.reno@stiima.cnr.it

Funding Scheme:
This doctorate grant is [fully] funded by LEONARDO s.p.a..

Scolarship Amount:
- Fascia 4: 19,500 €/year

6. Autonomous Interaction Control for High Fidelity Surface Treatment Tasks - Istituto Italiano di Tecnologia

Curriculum:

Industry 4.0

Hosting Institution
Istituto Italiano di Tecnologia

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

Tutor(s):
Nikos Tsagarakis, nikos.tsagarakis@iit.it

Description:
Surface treatment operations such as wall sanding and grinding require careful control of the motion trajectories and forces applied by the robotic end-effector tools on the surface, imposing a high level challenge for achieving consistent surface polishing quality.
At the same time, visual perception of imperfection features on the surface to be treated and the closed-loop use of this information during the sanding task execution is vital for enabling the autonomous execution of these operation through the continuous regulation of the robot -surface interaction achieved by the modulation of the motion and force profiles.
This research topic will develop control and perception strategies that allow robots to safely perform sanding and polishing operation on surface imperfections, exploiting customized end-effector tools used by human to perform these operations manually. The robot controller will have to track the desired motion, impedance and force trajectories that are modulated on the basis of an off-line-set of parameters as well as through online guidance using visual perception cues. To this aim, impedance control and hybrid motion-force control will be investigated. For the tuning of the off-line set of parameters data driven methods will be explored from data collected during the operation. If needed to collect data for learning the surface polishing interaction (force & motion parameters) , the possibility of asking human operators to directly operate the robotic manipulation system in kinesthetic teaching mode will be considered. At the interaction control level the developed tools shall permit the autonomous regulation of the motion/velocity profile, the regulation of the applied force on the surface to be treated as well as enable the reasoning and replanning when additional cycles of the process are needed to achieve the desired quality of surface. The developed tools will be demonstrated in tangible industrial use-cases scenarios related to wall sanding and car body grinding operations relevant to the EU project MAGICIAN (https://www.magician-project.eu/).

Requirements:
This topic lies in the intersection of Robot control and visual perception. Ideal applicants should have excellent C++ and Python programming competences. Strong competences in robot control and computer/robotic vision skills are required. Knowledge of motion planning tools and Robot Operating System (ROS) will be a plus. The applicants should be fluent in English and team players.

References:

- Yingxin Huo et al, Model-Free Adaptive Impedance Control for Autonomous Robotic Sanding, IEEE Trans. On Automation Science and Engineering, Vol. 19, No. 4, 2022.
- B. Maric et al, "Collaborative human-robot framework for delicate sanding of complex shape surfaces," IEEE RAL, vol. 5, no. 2, pp. 2848–2855, 2020.
- Y. Dong et al, "Contact force detection and control for robotic polishing based on joint torque sensors," Int. J. Adv. Manuf. Technol., vol. 107, pp. 2745–2756, Mar. 2020.

Number of positions available:
1

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

Contacts:
Email: nikos.tsagarakis@iit.it

Funding Scheme: This doctorate positions are funded by Horizon Europe Programme project MAGICIAN (https://www.magician-project.eu/) CUP: J53C23002180006

Scolarship Amount:
- Fascia 4: 19,500 €/year

7. AI-augmented Control for Robots and Humans Teaming in Manufacturing - National Research Council

Curriculum: Industry 4.0	
Hosting Institution National Research Council of Italy	
Department: STIIMA	
Tutor(s): Researcher Vito Renò Senior Researcher Nicola Pedrocchi	

Description:

Achieving a substantial next step in the ability of robots to perform non-repetitive functional tasks in realistic settings with mandatory robustness and quality requirements is a challenge, especially in manufacturing. Mobile manipulators raised the bar of requirements for safe, trustworthy, and effective collaboration, and their control needs a change in thinking to reach the point where the robot systems operating in dynamic manufacturing environments can carry out sequences of complex tasks to achieve a given production goal. In such a context, the PhD will focus on the integration of advanced perception solutions for advanced mobile manipulation.

The perception will be focused on the advancement of navigation methodologies in industrial scenarios. Federated learning has recently been applied to SLAM, which exploits various mobile robots as environmental sensors to increase scene knowledge. The PhD student will investigate the promising unsupervised approach (deep autoencoder, convolutional, LSTM, or variational). The studies will aim to increase dramatically the localization precision and the docking performance of mobile manipulators, by integrating semantic recognition of the scene.

The control of the mobile robot will also require the development of innovative methodologies for the motion plan of mobile manipulators, integrating navigation and dexterity of the robot arm. The research context for such methodologies consists of informed sampling-based evolutionary algorithms that optimize the mobile base and manipulator coordination during the planning phase. An external layer will optimize the mobile platform and robotic arm separately and feed an internal layer that considers the complete model of the mobile manipulator.

Requirements:

Applicants must have a good knowledge of robotics fundamentals and robot programming. Applicants are also expected to have programming skills (including Python, C/C++, ROS/2), be capable of conducting experiments, and have a strong attitude to problem-solving.

References:

- Li, S., et al. (2023). FedUTN: Federated self-supervised learning by updating the target network. Applied Intelligence, 53(9), 10879-10892.
- P. Franceschi, S. Mutti, N. Pedrocchi. Optimal design of robotic work-cell through hierarchical manipulability maximization. Robotics and CIM, 78, 2022
- M Faroni, N Pedrocchi, M Beschi. Accelerating sampling-based optimal path planning via adaptive informed sampling. Autonomous Robots, 2024

Company name and link (for industrial projects): -
Number of positions available: 1
Main Research Site CNR-STIIMA – Milano and/or Bari site
Contacts: Email: vito.reno@stiima.cnr.it, nicola.pedrocchi@stiima.cnr.it
Funding Scheme This doctorate grant is funded by the National Research Council of Italy
Scholarship Amount • Fascia 4: 19,500 €/year

8. Knowledge Engineering for Collaborative Robotics – CNR-ISTC

Curriculum:

Industry 4.0

Hosting Institution
Consiglio Nazionale delle Ricerche

Department:
Istituto di Scienze e Tecnologie della Cognizione

Tutor(s):
Andrea Orlandini

Description:
The PhD program is aimed at investigating the challenges related to knowledge engineering issues when dealing with the design of automated planning solutions for collaborative robotic applications in manufacturing. The main goal is to investigate the connection between knowledge representation and task planning techniques in order to support the design process of robotic applications. The PhD candidate should investigate new modeling approaches for representing production processes and tasks as well as considering operator characteristics, identify new techniques to facilitate the generation of task planning specification to design and implement robot control for safe and effective collaborative cells.

Requirements:
Applicants are expected to have the following expertise:

- Master Thesis in Computer Science, Computer Science Engineering, Artificial Intelligence and Robotics, etc.;
- Knowledge Engineering and modeling for automated planning and robot control;
- Good programming skills in common languages (e.g., Python, Java, C++, etc);
- Development of robot applications with ROS;
- Experience in automated planning for Collaborative Robots in industrial applications will be considered as a plus;
- Mastering of English (spoken and written);

References:

- Knowledge-based adaptive agents for manufacturing domains. S Borgo, A Cesta, A Orlandini, A Umbrico. Engineering with Computers 35, 755-779. 2019.
- Knowledge based modules for adaptive distributed control systems. A Ballarino, A Brusaferri, A Cesta, G Chizzoli, IC Bertolotti, L Durante, et al. Factories of the Future: The Italian Flagship Initiative, 83-108. 2019
- Simplifying the AI planning modeling for human-robot collaboration. E Foderaro, A Cesta, A Umbrico, A Orlandini. 30th IEEE International Conference on Robot & Human Interactive Communication (RO-MAN). 2021.

Company name and link (for industrial projects):
N/A

Number of positions available:

1
Main Research Site Via Gian Domenico Romagnosi 18A, 00196, Roma
Contacts: Email: andrea.orlandini@istc.cnr.it
Funding Scheme: This doctorate grant is funded by Consiglio Nazionale delle Ricerche.
Scholarship Amount: • Fascia 1: 16,500 €/year

9. Generating Whole-Body Avoidance Motion through Localized Proximity Sensing for Human-Robot Cooperative Operations – Università di Genova

Curriculum:

Industry 4.0

Hosting Institution
Universita' di Genova

Department:
DIBRIS

Tutor(s):
Prof. Giorgio Cannata

Description:
Collaborative robots (COBOTS) are used in industrial and service applications to accomplish tasks where human-robot cooperation (i.e. sharing a common space) or collaboration (i.e. physically interacting to complete a common action) is required. Among the various approaches for enabling Human-Robot Cooperation, an interesting way to provide the robot with environmental perception and obstacle detection is through the use of proximity sensors. Proximity-based whole-body control enables the development of advanced obstacle avoidance behaviors that can respond dynamically to unexpected collisions.

Unlike other sensor-based algorithms, such as those relying on cameras or tactile perception, this approach mitigates limitations related to field of view or environmental conditions, ensuring continuous and responsive interaction with the surroundings.

The PhD project aims to develop an advanced perception system for Human-Robot Collaboration, focusing on the ability of the robot to recognize and distinguish the presence and movements of a human operator within shared environments, primarily through proximity sensors. The perception system will enable the robot to adopt adaptive avoidance strategies, ensuring safe and efficient interaction by dynamically responding to the operator's actions and positioning. A promising aspect of the research involves investigating alternative robot representation methods beyond traditional point clouds, such as Signed Distance Fields (SDFs).
The experimental scenario is based on a 6 DOF manipulator (partially sensorized using tactile and proximity sensors) for industrial applications, sharing the space with a human operator to complete a series of operations involving contact of the robot with the environment.
This PhD research theme is part of the activities of the European project *HE Sestosenso* (www.sestosenso.eu)

Requirements:
Applicants must have a good knowledge of robotics fundamentals and robot programming. Applicants are also expected to have good programming skills (possibly including Python, C/C++, Matlab/Simulink), confidence with electronic hardware and be capable to conduct experiments, and a strong attitude to problem solving.

References:

- S. Tsuji and T. Kohama, "Proximity Skin Sensor Using Time-of-Flight Sensor for Human Collaborative Robot," *IEEE Sensors Journal*, vol. 19, no. 14, pp. 5859–5864, jul 2019.
- Y. Ding and U. Thomas, "Collision avoidance with proximity servoing for redundant serial robot manipulators," in 2020 *IEEE International Conference on Robotics and Automation* (ICRA), 2020, pp. 10249–10255.
- S. Kumar, S. Arora, and F. Sahin, "Speed and separation monitoring using on-robot time-of-flight laser-ranging sensor arrays," in 2019 *IEEE 15th International Conference on Automation Science and Engineering* (CASE), 2019, pp. 1684–1691.
- Yiming Li, Yan Zhang, Amirreza Razmjoo and Sylvain Calinon, "Representing Robot Geometry as Distance Fields: Applications to Whole-body Manipulation," in 2024 *IEEE International Conference on Robotics and Automation* (ICRA), 2024.

Company name and link (for industrial projects):

-

Number of positions available:

1

Main Research Site

DIBRIS – Universita' di Genova

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Email: giorgio.cannata@unige.it

Funding Scheme: This doctorate grant is co-funded by Universita' di Genova and European project *HE Sestosenso* CUP D37F22000070006.