I-RIM

PhD Course in

ROBOTICS AND INTELLIGENT MACHINES

Curriculum: Robotics and Intelligent Machines for Industry 4.0

Research themes

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 customisation, 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 digitised 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 characterised 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 objectives of the 3 proposed research themes are:

- Study, develop and test solutions for intelligent multi-agent systems based on innovative approaches such as artificial intelligence, deep reinforcement learning, iterative learning control. (theme 1)
- Investigate how to prevent disclosure of sensitive information applied to the areas where humans use interconnected technologies especially in the context of human

machine interactions (e.g.: robot companion, assistive robotics, home assistance, etc.). (theme 2)
- xxx (theme 3)

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 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 applicants are encouraged to contact the tutors and/or the Unit's Principal Investigators for clarifications before submitting their application.

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

1. Innovative distributed control approaches for intelligent multiagent cooperative systems- Politecnico di Bari

Curriculum: Industry 4.0

Hosting Institution
Politecnico di Bari

Department:
Department of Electrical and Information Engineering

Tutor(s):
Maria Pia Fanti

Description:
Intelligent multi-agent systems (MASs) can autonomously learn to solve problems or take decisions by means of each agent's intelligence and by collaborating and exploiting collective intelligence. The MASs become a promising and challenging paradigm in industrial application and robotics. Examples of MAS include autonomous cars, mobile robots, drones, autonomous vehicles in warehouses and manufacturing systems.
The goal of the PhD program is to study, develop and test intelligent solutions for MASs based on innovative approaches such as artificial intelligence, deep reinforcement learning, iterative learning control.
The research is part of the Horizon Europe project IN2CCAM "Enhancing Integration and Interoperability of Cooperative, Connected and Automated Mobility eco-system" that aims to accelerate the implementation of innovative technologies and systems for connected and autonomous driverless vehicles.

Requirements:
Applicants are expected to have very good skills in some of the following areas: software development, optimization, automation, simulation, programming with different languages such as C/C++, Python, Matlab/Simulink. Applicants have to have attitude to problem solving and be strongly motivated.

References:

- Difilippo, G., Fanti, M.P., Mangini, A.M. "Maximizing Convergence Speed for Second Order Consensus in Leaderless Multi-Agent Systems" IEEE/CAA Journal of Automatica Sinica, 2022, 9(2), pp. 259–269.
- L. Abbatecola, M.P. Fanti, G. Pedroncelli, W. Ukovich, "A Distributed Cluster-Based Approach for Pick-Up Services" IEEE Transactions on Automation Science and Engineering, Vol. 16, no. 2, pp. 960-971, 2019.
- M.P. Fanti, A.M. Mangini, G. Pedroncelli, W. Ukovich, "A decentralized control strategy for the coordination of AGV systems", Control Engineering Practice, Volume 70, January 2018, pp. 86–97.
- M. P. Fanti, A.M. Mangini, F. Mazzia, W. Ukovich, "A New Class of Consensus Protocols for Agent Networks with Discrete Time Dynamics", Automatica, vol. 54, n. 4, 2015, pp. 1-7.

Number of positions available:
1

Main Research Site
Ingegneria Elettrica e dell'informazione, Via Orabona 4, 70125 Bari, Italy

Contacts:
Email: mariapia.fanti@poliba.it

Funding scheme: This doctorate grant is fully funded by the proponent research institution.

2. Cyber-physical social security applied to emergent innovative technologies – Italian Institute of Technology & Univ. Genova

Curriculum: Industry 4.0

Hosting Institution
Istituto Italiano di Tecnologia and Università di Genova

Department:
IIT: Informatics and Communication Technology (ICT)
uniGE: Department of Computer Science, Bioenginering, Robotics and Systems Engineering (Dibris)

Tutor(s):
Dr. Francesco Rea, Dr. Alessandra Sciutti, Dr. Stefano Bencetti; Prof. Nicoletta Noceti

Description:
The field of cyber security is a fast-growing discipline that impacts on the interaction between people and technology. Even though the effectiveness of security measures to protect personal data is increasing, people remain susceptible to manipulation and thus the human element remains the weakest link: social engineering. Such weakness is often exploited by the use of various manipulation techniques aiming at the disclosure of sensitive information, namely social engineering. The field of social engineering is still in its early stages however the interaction between individuals and new technologies (assistive robotics, robot companion) and new ways of working (smart working) might be exposed to yet unknown risks associated with the misuse of protected data only partially addressed by traditional computer security. The overall aim of the project is to investigate how to prevent disclosure of sensitive information applied to the areas where humans use interconnected technologies (e.g. robotics, IOT, Big Data Analytics systems) especially in the context of human machine interactions (e.g.: robot companion, assistive robotics, home assistance, etc.). The aim unfolds into two goals for the candidate. First, the ideal candidate is required to develop algorithms of human machine interaction relying on cutting-edge machine learning techniques that allow the artificial intelligence to adapt to the person. For example, the assistive robot autonomously adapts the data acquisition strategy to the goal of improving the provided assistance without the acquisition of personal data, which is irrelevant to the assistance. The second goal is to improve the robustness and high integrity of system architectures (cyber-physical security) relying also on computer vision and adopted for above-mentioned cutting-edge technologies. The solutions defined by the candidate can also help the management of security risk and the analysis of social engineering threats.
As outcome of the project, such methodologies will be concretely applied to innovative applications especially involving robotics technologies designed at the Istituto Italiano di Tecnologia to make the applications socially aware and socially acceptable.

Requirements:
Applicants are expected to have very good skills in at least two of the following areas: software development, computer vision, robot programming, machine learning. Furthermore, good attitude for experimental work is mandatory. The candidates must have: very good programming skills with different languages (including C/C++, Python,

Matlab/Simulink); be capable to conduct experiments; attitude to problem solving, and be strongly motivated for team working.

References:

- Pasquali D., Gonzalez-Billandon J., Aroyo A.M., Sandini G., Sciutti A., Rea F. (2021). Detecting Lies is a Child (Robot)'s Play: Gaze-Based Lie Detection in HRI. International Journal of Social Robotics
- Pasquali D., Gonzalez-Billandon J., Rea F., Sandini G., Sciutti A. (2021). Magic iCub: A humanoid robot autonomously catching your lies in a card game. ACM/IEEE International Conference on Human-Robot Interaction
- Pasquali D., Sciutti A., Sandini G., Bencetti S., Rea F. (2022); Toward a Human-Oriented Social Engineering Defense System; Workshop: AI for Cybersecurity, Second CINI National Conference on Artificial Intelligence (Ital-IA)

Number of positions available:
1

Main Research Site
Istituto Italiano di Tecnologia, Via Morego, 30 16163 Genova - Italy
CONTACT - COgNiTive Architecture for Collaborative Technologies (IIT)
https://www.iit.it/it/web/cognitive-architecture-for-collaborative-technologies/home

Contacts:

Dr. Francesco Rea, Francesco.Rea@iit.it
Dr. Alessandra Sciutti, Alessandra.Sciutti@iit.it
Dr. Stefano Bencetti, Stefano.Bencetti@iit.it
Prof. Nicoletta Noceti, Nicoletta. Noceti@unige.i

Funding Scheme: this doctorate position is fully funded by the proponent research institution

3. Robotics and Autonomous Systems –University of Genova

Curriculum: Industry 4.0

Hosting Institution
Università di Genova

Department:
Department of Computer Science, Bioenginering, Robotics and Systems Engineering (DIBRIS)

Tutor(s):
M. Baglietto, G. Cannata, G. Indiveri, F. Mastrogiovanni, C. Recchiuto, A. Sgorbissa, E. Simetti.

Description:

Innovative robot systems are expected to play a major role in order to optimize the resources required to execute a wide number of types of operations leading to a greater efficiency in tasks performed in poorly structured environments, in presence or in contact with humans.

These new robot systems will play a fundamental role in industrial application making more efficient, safer, and lean manufacturing processes, as well as in service and logistics applications, etc.. Furthermore, robots will represent and major solution to problems of environment monitoring for both marine and terrestrial environment allowing to enforce safe management of the natural resources.

The Doctorate Program in Bioengineering and Robotics of the University of Genova is selecting PhD candidates to study robotic systems and technologies for the development of autonomous systems falling into the following research themes:

Each applicant must submit a research proposal addressing (only) one of the following 4 topics

Research theme 1

Systems composed by heterogeneous robotic platforms are increasingly studied for their use in the marine environment. The applications of such systems are diverse, and range from water quality monitoring, to offshore aquaculture inspection, to geotechnical exploration. Among the scenarios, the monitoring and inspection of underwater cables and pipelines with marine robots could drastically reduce costs of the maintenance of offshore wind farms. In the above reference scenarios, different research challenges emerge, including control strategies, reliable navigation and guidance in real-world conditions, limited communication ranges and bandwidths and coordination and distributed task allocation and monitoring. Within this PhD proposal, we want to investigate the use of such systems focusing on two main aspects. The first deals with the control, guidance and navigation of each of the team members. The second one relates to the motion planning of the team, including strategies to maximise the information gained based on pre-existing models (model-driven) or just on the data currently acquired (data-driven).

Research theme 2

The research will explore the problem of periodic monitoring of renewable power plants through Unmanned Aerial Vehicles, using multirotors equipped with different sensors including RGB and Thermal cameras. Specifically, it will investigate how the multirotor can compute and execute optimal paths in order to cover the whole area of interest, by using onboard sensors both for data acquisition aimed at periodic maintenance and for autonomous navigation.

Research Theme 3

This research theme aims at solving the problem of the robotic characterization and selection of electronic boards in WEEE disposal plants, currently performed manually, during the related de-manufacturing process. The proposal is organized into three complementary development lines and specifically in the following macro-activities: 1) Design and development of computer vision techniques to recognize and classify electronic boards as well as their components; 2) Develop an automatic sorting setup for electronic boards in which the a human operator supervises the behaviour of, collaborates with, and corrects the operations of one or more robotic manipulators; 3) Conduct an in-depth analysis of the currently operational manual processes involved in the disassembly of laptops and tablets, in order to formulate an overall evaluation of the benefits introduced by a system such the one envisaged here.

These lines will be integrated in a robot sensing and control architecture specifically designed for human-robot collaboration. While the use of collaborative robots in manufacturing scenarios have been proposed to be deployed alongside human operators to perform a series of tasks traditionally considered stressful, tiring or difficult, their use in de-manufacturing processes for WEEE waste management is still largely unexplored. Recently, we have proposed a comprehensive human-robot collaboration (HRC) framework called FlexHRC showing interesting results on the Baxter dual-arm robot and on cooperative mobile manipulators.

Research Theme 4

The project aims to develop new knowledge in the field of innovative robotic systems intended to operate both independently and in a joint human-robot collaboration for carrying out operations in conditions of uncertainty such as those that characterize the agricultural environment. The research concerns the development of new control techniques for robots and robotic machines capable of operating at ground, plant and fruit level. In addition, the research will develop in the field of AI technologies for the development of perceptual models based on both robotic and external sensors to the robot intended for the perception of the interaction of the robot with the environment and for monitoring.

The specific application context of the research is placed in the field of industrial cultivation systems (including vertical-farming) with the aim of transferring both autonomous and assisted robotic solutions (human-robot interaction) to an agricultural production context with industrial connotation.

Requirements:

Applicants are expected to have excellent skills in the following areas: programming and software engineering, robot control, robot programming. Furthermore, good attitude for experimental work is mandatory. The candidates must have excellent knowledge of different programming languages (including C/C++, Python, Matlab/Simulink) and robot frameworks like ROS; be capable to conduct experiments; attitude to problem solving, and be strongly

motivated for team working.

References:

- xxx
- xxx
- xxx)

Number of positions available: 1

Main Research Site
Dept. of Computer Science, Bioengineering, Robotics and Systems Engineering (DIBRIS), University of Genova.

Contacts:
Prof. Giorgio Cannata
giorgio.cannata@unige.it

Funding Scheme: this doctorate position is fully funded by the proponent research institution

4. Planning and control of robotics manipulation system for pharmaceutical manufacturing – University of Pisa

Curriculum: Industry 4.0
Hosting Institution
University of Pisa
Department:
Department of Information Engineering
Tutor(s):
Paolo Salaris, Manolo Garabini, Franco Angelini

Description:
Industry4.0 equivalent in the pharmaceutical processes focuses on methods to track products and to monitor in real-time interconnected processes to enable a truly agile and continuous delivery system where decisions are automatically planned based on collected data. Automation is then required to minimize errors and manual interventions while keeping the flexibility for adaptation to different manufacturing processes. Robots have already proved a fundamental impact in Industry4.0 and the possibility to reach the abovementioned requirements in pharmaceutical processes. Robots are highly flexible, cost- and energy-efficient, safe, and able to share environments with humans and work closely with them. The objective of this thesis is to adapt and integrate such robots in the pharmaceutical environment by further developing *wheeled or legged mobile dynamic manipulation capabilities* also while collaborating with humans. The proposed mobile manipulation systems will improve the process of drug manufacturing by handling both primary (e.g. syringes and infusion bags) and secondary packaging (e.g. folding boxes and cartons) and by supporting chemists' work in ensuring repeatability and lowering the risk of contamination in cell culture processes. The mobile manipulation system will have energy-efficient elastic actuators and will be able to work safely with humans in unknown, changing environments through advanced planning and control methodologies to improve efficiency while limiting associated risks. Dedicated end-effectors based on multi-synergistic, soft, and self-adaptive hands will be integrated to grasp and manipulate different objects in terms of weight, size, shape, softness, and texture. Activities that may be carried out include: the development and implementation of efficient risk-based planning and control algorithms for the mobile manipulation system in pharmaceutical environment, the integration of the manipulator with advanced end-effectors, development and validation of integrated manipulation system. Finally, proof-of-concepts and prototypes of the integrated system (with necessary perception, planning and control methodologies) will be tested in reproduced pharmaceutical scenarios (TRL 6/7). Exploitation of the developed system will be conducted in collaboration with qbRobotics srl that will also provide dedicated components.
Requirements:
For the reasons above, the successful candidate should ideally have a MSc in robotics and automation engineering, or a related field, with a strong background in control theory, planning, robotics and mathematics. Demonstrated experience with optimal control theory and programming (ROS1/ROS2, python, C/C++,

Matlab) as well as experience in controlling complect robots composed with compliant manipulators and soft gripper is a plus.

References:

- M. Garabini, A. Passaglia, F. A. W. Belo, P. Salaris, and A. Bicchi. *Optimality principles in variable stiffness control: the VSA hammer*. In IEEE/RSJ International Conference on Intelligent RObots and Systems (IROS), pages 3770 – 3775, 2011.
- A Palleschi, R Mengacci, F Angelini, D Caporale, L Pallottino, A De Luca, M Garabini. *Time-optimal trajectory planning for flexible joint robots*. IEEE Robotics and Automation Letters 5 (2), 938-945.
- F. Angelini et al., "*Decentralized Trajectory Tracking Control for Soft Robots Interacting With the Environment*", in IEEE Transactions on Robotics, vol. 34, no. 4, pp. 924-935, Aug. 2018.
- A. Velasco, G. M. Gasparri, M. Garabini, L. Malagia, P. Salaris, and A. Bicchi. *Soft actuators in cyclic motion: Analytical optimization of stiffness and pre-load*. In IEEE- RAS International Conference on Humanoid Robots (Humanoids), pages 354–361, 2013.
- A Palleschi, M Hamad, S Abdolshah, M Garabini, S Haddadin, L Pallottino. *Fast and safe trajectory planning: Solving the cobot performance/safety trade-off in human- robot shared environments*. IEEE Robotics and Automation Letters 6 (3), 5445-5452, 2021.

Number of positions available:

1

Main Research Site

Research Centre “E. Piaggio”: https://www.centropiaggio.unipi.it

Department of Information Engineering: https://www.dii.unipi.it/en/

Contacts:

Email: paolo.salaris@unipi.it, manolo.garabini@unipi.it, franco.angelini@unipi.it.

Funding Scheme: This doctorate grant is fully funded by the proponent research institution from PNRR ministerial funding (decreto n.3277/2021) “Avviso Ecosistemi dell’Innovazione”, project THE “Tuscany Health Ecosystem” (CUP: I53C22000780001), spoke 9 “Robotics and Automation for Health”.