I-RIM

PhD Course in ROBOTICS AND INTELLIGENT MACHINES

Curriculum: Autonomous Systems

Research Themes

Automation, together with robotics and artificial intelligence, is a key enabling technology for the digital and sustainable transition. It enables the development of autonomous systems capable of operating without direct human intervention, through the acquisition of environmental information, data processing and interpretation, action planning, and performance optimization, while ensuring reliability and safety.

The "Autonomous Systems" curriculum aims to train PhD graduates with advanced expertise in the design, management, and development of autonomous systems to improve efficiency, safety, and sustainability across various application sectors, including industry, mobility, logistics, agriculture, energy, biomedicine, and the environment.
The program adopts an integrated and multidisciplinary approach, offering methodological and technological pathways organized into three distinct yet complementary areas:

- Automation: Particularly relevant for sectors such as automation, logistics, agriculture, and transportation, this area focuses on the design of next-generation industrial systems. Topics covered include the control and supervision of complex systems composed of networks of sensors, actuators, and collaborative robots. The approach incorporates advanced modeling methodologies, optimization techniques, and simulation based on digital twins, alongside modern mathematical tools. Special attention is devoted to sustainable and green automation.
- Smart Environment: Dedicated to intelligent environments and cyber-physical systems, with applications in smart cities, autonomous vehicles and mobile robots, smart grids, sustainable mobility, smart buildings, and smart homes. The focus is on advanced control problems using consensus algorithms, predictive control, distributed identification, and networked control. Key areas include distributed optimization and the integration of technologies for the intelligent and sustainable management of spaces and resources.
- Monitoring and Security: Focused on the design and management of autonomous systems to ensure reliability, resilience, and security, even under uncertain conditions. Topics include fault monitoring and prediction, privacy protection, resilience against physical and cyber-attacks, and the design of safe processes in environments where

humans and automated systems coexist. Security is considered a cross-cutting and priority issue across multiple domains, including environmental, cyber, clinical-healthcare, network, and public administration sectors.

The research theme offered by the University of Brescia and the Polytechnic University of Bari 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. Please consult the individual requirements for each research theme.

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

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

1. Machine-Learning Based Control of Robotics and Process Systems – University of Brescia

Curriculum:

Autonomous Systems

Hosting Institution:

University of Brescia (Università degli Studi di Brescia)

Department:

Department of Industrial and Mechanical Engineering

Tutor(s):

Prof. Antonio Visioli, Prof. Manuel Beschi

Description:

Advanced control strategies face significant bottlenecks in realizing their full potential in industrial robotics and process control. Machine learning offers promising solutions across the design, commissioning, and performance assessment phases. This research focuses on:

- Reinforcement learning for motion planning in human-robot collaboration, incorporating human-motion prediction and real-time trajectory replanning to enhance safety and efficiency.
- Cross-attention mechanisms for sensor fusion for predicting short-range human motion.
- Transfer learning for rapid commissioning of control systems in both robotic and process environments.
- Machine learning methods for performance evaluation, anomaly detection, and adaptive controller redesign.

Requirements:

An MSc degree in Control Engineering, Automation 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, Python and ROS(2) is welcome.

References:

[1] Franceschi P., Cassinelli D., Pedrocchi N., Beschi M., Rocco P.,Design of an Assistive Controller for Physical Human–Robot Interaction Based on Cooperative Game Theory and Human Intention Estimation (2024), IEEE Transactions on Automation Science and Engineering, DOI: 10.1109/TASE.2024.3429643

[2] Ferrari M., Sandrini S., Tonola C., Villagrossi E., Beschi M., Predicting Human Motion using the Unscented Kalman Filter for Safe and Efficient Human-Robot Collaboration (2024) IEEE International Conference on Emerging Technologies and Factory Automation, DOI: 10.1109/ETFA61755.2024.10710736

[3] Lingwei Zhu, Yunduan Cui, Go Takami, Hiroaki Kanokogi, Takamitsu Matsubara, Scalable reinforcement learning for plant-wide control of vinyl acetate monomer process, Control Engineering Practice (2020) DOI:10.1016/j.conengprac.2020.104331.

Number of positions available:

1

Main Research Site

Department of Industrial and Mechanical Engineering, University of Brescia, Via Branze 38, 25123 Brescia, Italy.

Contacts:

Email: antonio.visioli@unibs.it, manuel,beschi@unibs.it

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

Scholarship Amount:

- Fascia 1: 16,500 €/year

2. Wearable Soft Robotics Driven by Electrofluidic Muscles – Polytechnic University of Bari

Curriculum: Autonomous Systems	
Hosting Institution: Polytechnic University of Bari (Politecnico di Bari)	
Department: Department of Mechanics, Mathematics and Management.	
Tutor(s): Prof. Vito Cacucciolo, Dr. Yu Kuwajima	

Description:

Robotics is experiencing a revolution, with service robots becoming more advanced day by day. Soon legged robots will be sharing the space with humans. Though robots can do more for us. Flexible robots that could work in close contact with humans could support, compensate and even expand humans' abilities. For these robots to become a reality, a paradigm shift is required on their actuators. The servomotors that drive today's robots are rigid and bulky. Despite their reliability and high power density, they lack the versatility and integrability of biological muscles. This PhD project is focused on developing new robots and wearables with soft, flexible bodies driven by a new generation of artificial muscles in the form of fibers [1]. These artificial muscles are based on fluids pressurized by solid state soft pumps [2], such as fiber pumps [3]. Multiple artificial muscle fibers can be connected in bundles to scale up forces and provide unprecedented dexterity to robots and soft exosuits. Communication between robots and humans is also of critical importance and can happen on multiple levels, from physical touch to vision to neural activations.

Providing robotic designers with an incredibly vast design space, electro-fluidic artificial muscle fibers can pave the way for a new generation of human-centered robotic devices that can support and expand human abilities.

Requirements:

The ideal candidate would have a degree in Mechanical Enginnering, Electrical Engineering, Automation Engineering, Robotics, or related fields. Passion and curiosity for material-based robotics are great indicators that you could be a good match for this research topic. Hands-on experience with design, fabrication and testing of robotic devices is a great plus. Know-how in modeling multi-physics systems is also valuable.

References:

[1] V. Cacucciolo, H. Nabae, K. Suzumori, and H. Shea, "Electrically-Driven Soft Fluidic Actuators Combining Stretchable Pumps With Thin McKibben Muscles," *Front. Robot. AI*, vol. 6, 2020, doi: 10.3389/frobt.2019.00146.

[2] V. Cacucciolo, J. Shintake, Y. Kuwajima, S. Maeda, D. Floreano, and H. Shea, "Stretchable pumps for soft machines," *Nature*, vol. 572, no. 7770, pp. 516–519, Aug. 2019, doi: 10.1038/s41586-019-1479-6.

[3] M. Smith, V. Cacucciolo, and H. Shea, "Fiber pumps for wearable fluidic systems," *Science*, vol. 379, no. 6639, pp. 1327–1332, Mar. 2023, doi: 10.1126/science.ade8654.

Number of positions available:

1

Main Research Site

RoboPhysics Laboratory (RPL), Politecnico di Bari, Via Orabona 4, 70125 Bari, Italy.

Contacts:

Email: vito.cacucciolo@poliba.it

Funding Scheme: This doctorate grant is funded by the Polytechnic University of Bari, Project ROBOFLUID - Robotic Fluids for artificial muscles, wearable cooling, and active textiles" Project number 101116856 (ERC-2023-STG)

Scholarship Amount:

- Fascia 4: 19,500 €/year