I-RIM

PhD Course in ROBOTICS AND INTELLIGENT MACHINES

Curriculum: Autonomous Systems

Research Themes

Sommario

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

3. Coordination and Control Techniques for Heterogeneous Multi-Agent Systems – Polytechnic University of Bari

Curriculum: Autonomous Systems	
Hosting Institution: Polytechnic University of Bari (Politecnico di Bari)	
Department: Department of Electrical and Information Engineering	
Tutor(s): Prof. Mariagrazia Dotoli	

Description:

The increasing complexity and interconnectivity of modern cyber-physical systems call for advanced coordination and control strategies capable of managing large-scale, heterogeneous multi-agent networks. This doctoral research focuses on the development of novel methodologies for the effective coordination and control of such systems, which may include autonomous mobile robots, unmanned aerial vehicles, intelligent machines, and, where applicable, human operators or software agents.

The research will investigate both centralized and non-centralized control architectures, addressing challenges such as real-time decision-making, resource allocation, cooperative and non-cooperative task execution, consensus protocols, and robustness to uncertainties and communication constraints. The proposed coordination and control strategies will integrate both formal methods and data-driven or learning-based approaches to enhance adaptability and generalization. Particular emphasis will be placed on the integration of agents with diverse dynamics, sensing capabilities, and levels of autonomy, enabling the emergence of flexible and scalable collective behaviors.

The proposed methodologies will be validated through theoretical analysis, numerical simulations, and experimental validation in representative scenarios such as digital industry, logistics, mobility, and surveillance.

Requirements:

The ideal candidate must hold a master's degree, preferably in Engineering, with a good background in relevant areas of interest (i.e., optimization, and control). Solid mathematical and coding skills are encouraged. Proficiency in both spoken and written English is required. The candidate should be highly motivated and interested in undertaking innovative and challenging research activities involving both theoretical analysis and experimental validation.

References:

Olfati-Saber, R., Fax, J. A., & Murray, R. M. (2007). Consensus and cooperation in networked multi-agent systems. *Proceedings of the IEEE*, *95*(1), 215-233.

Cortés, J., & Egerstedt, M. (2017). Coordinated control of multi-robot systems: A survey. *SICE Journal of Control, Measurement, and System Integration*, *10*(6), 495-503.

Dorri, A., Kanhere, S. S., & Jurdak, R. (2018). Multi-agent systems: A survey. *Ieee Access*, *6*, 28573-28593.

Number of positions available:

1

Main Research Site

Decision and Control Laboratory, Department of Electrical and Information Engineering, Polytechnic of Bari, via Orabona n. 4, 70125 Bari, Italy (http://dclab.poliba.it/)

Contacts:

Email: mariagrazia.dotoli@poliba.it

Funding Scheme:

This doctorate grant is funded by the Italian Ministry of University and Research - “Patti Territoriali dell’alta formazione per le imprese”.

Scholarship Amount:

- Fascia 3: 18,500 €/year

4. Artificial Intelligence for Disease Prediction, Prevention, and Management – Polytechnic University of Bari

Curriculum: Autonomous Systems	
Hosting Institution: Polytechnic University of Bari (Politecnico di Bari)	
Department: Department of Electrical and Information Engineering	
Tutor(s): Prof. Saverio Mascolo	

Description:

The integration of Artificial Intelligence (AI) into healthcare systems enables advanced capabilities in disease prediction, prevention, and management by leveraging multimodal biomedical data sources such as electronic health records (EHRs), medical imaging, genomics, wearable sensor streams, and population health datasets. Machine learning (ML) and deep learning (DL) techniques extract complex, non-linear associations and high-dimensional feature representations that enhance early diagnosis, risk stratification, and personalized screening protocols.

In preventive medicine, AI facilitates continuous patient monitoring, real-time behavioural interventions via digital health platforms, and epidemiological modelling to mitigate disease incidence. Within clinical management, AI-driven decision support systems enable dynamic treatment optimization, patient stratification, and outcome forecasting through data-driven policy adaptation.

AI methodologies have demonstrated efficacy in addressing non-communicable diseases (NCDs), including cardiovascular disease and diabetes, by enabling individualized risk scoring, longitudinal physiological monitoring via wearables, and algorithmically guided lifestyle modification interventions to slow disease progression and improve adherence.

Emerging paradigms integrate AI with digital twin models, reinforcement learning for adaptive treatment policies, and natural language processing (NLP) for clinical narrative extraction. Nonetheless, challenges remain in ensuring model interpretability, mitigating dataset bias, safeguarding patient privacy, and integrating AI solutions seamlessly into clinical workflows.

This research situates itself within this landscape, emphasizing multidisciplinary approaches encompassing computational science, clinical expertise, ethics, and regulatory frameworks to advance robust, equitable, and scalable AI-enabled healthcare systems.

Requirements:

The ideal candidate must hold a master's degree, preferably in Engineering, with a good background in relevant areas of interest (i.e., optimization and control, artificial intelligence). Solid mathematical and coding skills are encouraged. Proficiency in both spoken and written English is required. The candidate should be highly motivated and interested in undertaking innovative and challenging research activities involving both theoretical analysis and experimental validation.

References:

Alian, S., Li, J., & Pandey, V. (2018). A personalized recommendation system to support diabetes self-management for American Indians. *IEEE Access*, *PP*, 1–1.

Anisha, S. A., Sen, A., & Bain, C. (2024). Evaluating the potential and pitfalls of AI-powered conversational agents as humanlike virtual health carers in the remote management of noncommunicable diseases: Scoping review. *Journal of Medical Internet Research*, *26*, e56114.

Costa, O., & Gouveia, L. B. (2024). Artificial intelligence in primary care: Intelligent risk predicting platform for non-communicable chronic diseases. *Procedia Computer Science*, *239*, 2243–2250.

Di Molfetta, S., Laviola, L., Natalicchio, A., Leonardini, A., Cignarelli, A., Bonizzoni, E., Acmet, E., & Giorgino, F. (2023). Evaluation of a digital tool supporting therapeutic decision making for the personalized management of patients with type 2 diabetes not treated with insulin: A pilot study. *Diabetes Research and Clinical Practice*, *203*, 110836.

Giorgini, F., Di Dalmazi, G., & Diciotti, S. (2023). Artificial intelligence in endocrinology: A comprehensive review. *Journal of Endocrinological Investigation*, *47*, 1067–1082.

Gore, S., Meche, B., Shao, D., & et al. (2024). DiseaseNet: A transfer learning approach to noncommunicable disease classification. *BMC Bioinformatics*, *25*, 107.

Jørgensen, I. F., Haue, A. D., Placido, D., Hjaltelin, J. X., & Brunak, S. (2024). Disease trajectories from healthcare data: Methodologies, key results, and future perspectives. *Annual Review of Biomedical Data Science*, *7*(1), 251–276.

Leal Neto, O., & Von Wyl, V. (2024). Digital transformation of public health for noncommunicable diseases: Narrative viewpoint of challenges and opportunities. *JMIR Public Health and Surveillance*, *10*, e49575.

Ma, S., Lee, J., Serban, N., & Yang, S. (2023). Deep attention Q-network for personalized treatment recommendation. *Proceedings ... ICDM Workshops. IEEE International Conference on Data Mining*, 2023, 329–337.

Number of positions available:

1

Main Research Site

Control of computing and communication systems, Department of Electrical and Information Engineering, Polytechnic of Bari, Via Amendola 126/b - 70126 Bari, Italy (http://en.poliba.it/research/control-computing-and-communication-systems-lab)

Contacts: Email: saverio.mascolo@poliba.it
Funding Scheme: This doctorate grant is funded by the Italian Ministry of University and Research - "Patti Territoriali dell'alta formazione per le imprese".
Scholarship Amount: ● Fascia 3: 18,500 €/year

5. Higher-order estimation-based properties for the security of discrete event systems under attack – University of Cagliari

Curriculum:

Autonomous Systems

Hosting Institution:

University of Cagliari (Università degli Studi di Cagliari)

Department:

DIEE, Department of Electrical and Electronic Engineering

Tutor(s):

Alessandro Giua, Carla Seatzu

This project investigates the properties of discrete event systems (DES), a key class of dynamical systems with discrete-state spaces and event-triggered dynamics. Many complex engineering systems, such as manufacturing, industrial control, and logistics, can be effectively modeled as DES. Additionally, DES provide a formal framework for specifying high-level behaviors of cyber-physical systems involving both discrete and continuous spaces.

In many applications, DES are partially observed systems, meaning an external agent cannot directly access state information due to sensor limitations or partial data release. Instead, only system-generated information-flow is available for behavior estimation.

A key question is whether this information-flow contains enough data to solve decision problems. This leads to estimation-based properties related to security, such as control with partial observation in closed-loop systems (can safeness and liveness be enforced?), diagnosability in fault detection (can faults be detected?), or opacity in privacy analysis (can an intruder infer secret behaviors?).

By now, several approaches have been developed for verifying these properties. Most existing results assume a single agent who knows the system's structure, observes a subset of events, and estimates the state based on this information. The primary tool for state estimation and verifying estimation-based properties is the observer, a powerset construction originally proposed by Rabin and Scott (1959) to determinize a nondeterministic finite automaton with ε-transitions.

In recent years, a further issue has been addressed by the scientific community, namely how tampering with the information flow could affect these properties. Tampering could be caused by a malicious agent launching a cyberattack which can lead to a loss of controllability or diagnosability. The same approach can also be adopted by an agent which aims to enhance the privacy of the system, e.g., concealing secret behavior in a system which is not opaque.

However, in some applications, the system may be observed independently by multiple agents with different observations. In such a scenario, one may not only be interested in inferring the system's behavior directly but may also be interested in inferring the other agents' knowledge of the system to achieve its own goal. Such a setting requires defining higher-order estimation-based properties and has not received much attention in the DES literature, and the presence of attacks could further complicate the analysis.

Requirements:

The ideal candidate would have a degree in systems or computer engineering with competence in discrete-event and hybrid systems A theoretical and practical knowledge of algorithms related to opacity and security against cyberattacks in dynamical systems is desirable.

References:

- X. Yin, S. Lafortune, “A new approach for the verification of infinite-step and K-step opacity using two-way observers,” *Automatica*, Vol. 80 , 2017.
- D. Lefebvre , C.N. Hadjicostis, “Exposure and revelation times as a measure of opacity in timed stochastic discrete event systems,” *IEEE Trans. on Automatic Control*, Vol. 66, No. 12, 2021.
- T.L. Kang, C. Seatzu, Z.W. Li, A. Giua, "A joint diagnoser approach for diagnosability of discrete event systems under attack," *Automatica*, Vol. 172, 2025.

Number of positions available: 1

Main Research Site

DIEE, Department of Electrical and Electronic Engineering, Via Marengo, 2 - 09123 Cagliari, Italy.

Contacts: Email: giua@unica.it, carla.seatzu@unica.it

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

Scholarship Amount:

- Fascia 1: 16,500 €/year