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 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. AI for Maritime Sensing, Perception, and Decision Support – University of Pisa

Curriculum: Autonomous Systems	
Hosting Institution: Department of Information Engineering, University of Pisa	
Department: Department of Information Engineering	
Tutor(s): Andrea Munafo and Andrea Caiti	

Description:

The proposed research lies in the area of artificial intelligence for maritime sensing, perception, and data-driven decision support, with particular focus on the analysis of heterogeneous data, the interpretation of acoustic events, and the deployment of AI methods under operational and computational constraints.

The overall objective is to develop methods and models capable of extracting meaningful information from incomplete, indirect, or complex data in order to improve situational understanding, monitoring, and intelligent support for maritime applications. Within this framework, one research direction concerns the detection of anomalies in the motion behaviour of objects from partial observations or bearing-only data, including the possible use of publicly available AIS data to generate representative scenarios. A second direction concerns the application of advanced AI models, including foundation models, to sonar spectrograms for the detection and classification of acoustic events of interest (e.g., marine mammals).

A further line of research addresses low-power and computationally efficient AI approaches, suitable for embedded systems or sensor platforms with limited processing capabilities. This part of the work will investigate what level of performance can realistically be achieved under strict hardware, energy, and complexity constraints, and will explore the trade-offs between accuracy, robustness, latency, and deployability. It may also include system-level considerations, combining algorithm design with awareness of hardware and implementation requirements.

From a methodological perspective, the research may involve modelling, simulation, data analysis, algorithm development, and experimental validation. Comparisons may be carried out between data-driven approaches, compact models for edge AI, and more computationally demanding models used as references. Particular attention will be given to robustness under uncertainty, limited observability, transferability from simulated to real-world data, and the practical feasibility of the proposed solutions.

Overall, the project aims to contribute to the development of intelligent tools for maritime perception, acoustic monitoring, and data-informed decision support, with potential applications in environmental monitoring, vessel traffic analysis, and autonomous marine systems.

Requirements:

The ideal candidate would have a degree in Robotics Engineering or Computer Science. Applicants are expected to...

References:

- Goodfellow, I., Bengio, Y., and Courville, A. (2016). Deep Learning. MIT Press.
- Gianluca Antonelli, Alessia Biondi, Andrea Caiti, Stefano Chiaverini, Riccardo Costanzi, Paolo Di Lillo, Alessandro Gentili, Andrea Munafò, Towards a multi-robot architecture for bearing-only tracking of underwater acoustic sources using vector sensors, Ocean Engineering, Volume 353, Part 2, 2026

Number of positions available:

1

Main Research Site

Department of Information Engineering, University of Pisa

Contacts:

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Funding Scheme: This doctorate grant is funded by University of Pisa with financial support by ATLAS Elektronik

Scholarship Amount:

- Fascia 4: 19,500 €/year

2. Data-driven approaches for identification and control of hybrid dynamical systems – University of Sannio

Curriculum: Autonomous Systems

Hosting Institution: Università degli Studi del Sannio di Benevento (UNISANNIO)

Department: Dipartimento di Ingegneria

Tutor(s): Luigi Iannelli, Francesco Vasca

Description:

Hybrid dynamical systems combine continuous-time dynamics with discrete-mode switching governed either by external events, internal state thresholds, or control logic. Canonical examples include power converters, mechanical systems with contacts/impacts, autonomous vehicles, and cyber-physical systems.
Standard identification and control methods assume a fixed smooth model structure. Hybrid systems deviate from this assumption since the system switches among multiple dynamical modes and, moreover, the switching logic itself is often unknown or uncertain. That makes the problem qualitatively harder than standard system identification or switching control.
Classical approaches to hybrid systems require strong a priori knowledge related to the number of modes, the switching surfaces, and the form of each mode dynamics. In many engineering contexts such knowledge is generally difficult to obtain. Data-driven methods address this gap by extracting both the continuous dynamics and the discrete switching structure directly from observed input-output trajectories. Availability of high-quality data, theoretical advancements on learning-based control and technological innovations on power computational resources are all converging factors that allow to pursue the specified research direction.
Within this general framework, the PhD candidate will be expected to propose and develop a research project focused on one of the following themes.

a) **Data-driven control of power converters**. This research direction aims to develop data-driven techniques within modeling frameworks that have been shown to be effective in describing the complex dynamics of power converters. One of such frameworks is, for instance, the one denoted by complementarity systems. The objective will be to exploit the structure and properties of the specific model (e.g., linear complementarity systems) for solving control problems of power converters through modern data-driven approaches.
b) **Data-driven approaches for co-estimation of battery models**. This research directions aims at applying data-driven techniques for the co-estimation problem of battery models, i.e., the simultaneous estimation of state of the dynamical system (in particular the state-of-charge) and parameters of the model (e.g., parameters instantiating the open circuit voltage—state-of-charge relation). Since monotonicity of some physical relations is a key property and, moreover, switched models are usually employed for modeling hysteresis phenomena in batteries, this engineering problem is definitely suitable to be investigated within the proposed theme.

Requirements:
The ideal candidate would have a degree in electronics or automation or computer engineering with competencies in switched dynamical systems and, more generally, hybrid dynamical systems. Candidates are expected to have knowledge of applications of systems and control theory to engineering fields that are suitable to be investigated within the hybrid systems framework. Digital skills like coding and making are desirable.

References:

Theme a)

- M.K. Camlibel, L. Iannelli, and F. Vasca. "Passivity and complementarity". *Mathematical Programming* 145.1-2 (June 2014). pp. 531–563. DOI: 10.1007/s10107-013-0678-4.
- V. Sessa, L. Iannelli, and F. Vasca. "A Complementarity Model for Closed-Loop Power Converters". *IEEE Transactions on Power Electronics* 29.12 (Dec. 2014). pp. 6821–6835. DOI: 10.1109/TPEL.2014.2306975
- F. Vasca, L. Iannelli, M.K. Camlibel, and R. Frasca. "A New Perspective for Modeling Power Electronics Converters: Complementarity Framework". *IEEE Transactions on Power Electronics* 24.2 (Feb. 2009). pp. 456–468. DOI: 10.1109/TPEL.2008.2007420

Theme b)

- K. Camlibel, L. Iannelli, and A. Tanwani. "Convergence of proximal solutions for evolution inclusions with time-dependent maximal monotone operators". *Mathematical Programming* 194.1–2 (July 2022). pp. 1017–1059. ISSN: 0025-5610. DOI: 10.1007/s10107-021-01666-7.
- E. Mostacciuolo, S. Baccari, L. Iannelli, and F. Vasca. "Processor-in-the-loop for the interlaced estimation of states and parameters in a LiFePo4 battery model". In: Proceedings of the *10th 2024 International Conference on Control, Decision and Information Technologies* (CoDIT 2024). 2024, pp. 354–359. DOI: 10.1109/CoDIT62066.2024.10708084.
- E. Mostacciuolo, L. Iannelli, S. Baccari, and F. Vasca. "An interlaced co-estimation technique for batteries". In: 2023 31st *Mediterranean Conference on Control and Automation* (MED). June 2023, pp. 73–78. ISBN: 979-835031543-1. DOI: 10.1109/MED59994.2023.10185840.

Number of positions available:
1

Main Research Site
Department of Engineering, Univeristy of Sannio in Benevento

Contacts:

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Funding Scheme: This doctorate grant is funded by University of Sannio in Benevento

Scholarship Amount:
- Fascia 1: 16,500 €/year

3. Control of Distributed Network Systems – Università degli Studi di Napoli Federico II

Curriculum: Autonomous Systems

Hosting Institution

Università degli Studi di Napoli Federico II

Department:

Department of Electrical Engineering and Information Technologies

Tutor(s):

Prof. Pietro De Lellis and Prof. Mario di Bernardo

Description:

The project focuses on the analysis and control of distributed dynamical systems interconnected through communication networks. Examples include multi-agent systems, robotic teams, smart grids, sensor and actuator networks, traffic and mobility systems, and cyber-physical infrastructures in which global coordination must emerge from local information exchange. The main objective is to design scalable control strategies that exploit the structure of the underlying network while guaranteeing stability, robustness, and performance in the presence of uncertainty, disturbances, delays, switching topologies, and limited communication bandwidth.

The research will investigate distributed feedback, consensus and synchronization protocols, formation and containment control, distributed optimization, event-triggered and self-triggered control, and data-driven or learning-based approaches for networked systems. Particular attention will be devoted to the co-design of control laws and communication policies, with the aim of reducing information exchange while preserving collective performance. The project may also address resilience to faults and cyber-attacks, observability and controllability of complex networks, and the integration of model-based and data-driven methods for large-scale systems.

The expected outcomes include theoretical results, algorithms with formal guarantees, numerical validation, and, where appropriate, experimental demonstrations on networked robotic or cyber-physical testbeds. The project is suitable for candidates interested in control theory, nonlinear dynamics, complex networks, and their applications to engineered and socio-technical systems.

Requirements:

Applicants are expected to have a master's degree or equivalent in Automation Engineering, Electrical Engineering, Computer Engineering, Applied Mathematics, Physics, or related areas. A solid background in systems and control, linear algebra, optimization, and programming is required. Previous experience with networked control systems, multi-agent systems, nonlinear dynamics, graph theory, robotics, or Python/MATLAB simulation is preferential.

References:

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

[2] Mesbahi, M., & Egerstedt, M. Graph Theoretic Methods in Multiagent Networks. Princeton University Press (2010).

[3] Bullo, F., Cortés, J., & Martínez, S. Distributed Control of Robotic Networks. Princeton University Press (2009).

[4] di Bernardo, M., Salvi, A., & Santini, S. Distributed consensus strategy for platooning of vehicles in the presence of time-varying heterogeneous communication delays. IEEE Transactions on Intelligent Transportation Systems 16(1), 102-112 (2015).

Number of positions available:

1

Main Research Site

Department of Electrical Engineering and Information Technologies, Università degli Studi di Napoli Federico II, Via Claudio 21, 80125 Napoli

Contacts:

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Funding Scheme: This doctorate grant is funded by University of Naples Federico II.

Scholarship Amount:

- Fascia 1: 16,500 €/year