I-RIM

PhD Course in ROBOTICS AND INTELLIGENT MACHINES

Curriculum: Autonomous Systems (CODE 11658)

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 AI4I, The Italian Institute of Artificial Intelligence for Industry, and the University of Cagliari 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. Safe generative models for control via differential geometry and control theory – AI4I

Curriculum: Autonomous Systems	
Hosting Institution: AI4I – The Italian Institute of Artificial Intelligence for Industry	
Department: PHI Lab	
Tutor(s): Dr. Leonel Rozo	

Description:

Control theory provides principled mechanisms such as stability certificates or control barriers that can be leveraged to control and guide the generalization behaviour of generative models. When trained, such models can capture the underlying geometry of the data, but they may also be trained on data that are intrinsically non-Euclidean or that belong to dynamical systems with specific geometric properties. The first goal will be to

integrate control-theoretic principles to guarantee safety, stability, and predictable generalization of generative models. The second objective will leverage differential geometry to understand what the models learn, how they generalize, and consequently design safety guarantees that leverage the geometry of the data and the generative model. The developed methods will be applied in robotic manipulation for contact-rich tasks, human-robot collaboration settings, control of physical systems, among others.

Requirements:

Must have skills:

- Excellent Masters degree in computer science, physics, mathematics, electrical or mechatronics engineering, or a related field
- Strong background in machine learning and robotics
- Good programming skills in Python
- Fluent in spoken and written English
- A team player, but also can work autonomously
- Experience with scientific writing

Good to have skills:

- Background on (applied) differential geometry
- Publication of peer-reviewed research papers

References:

1. J. Zhang, et al. “Learning Riemannian Stable Dynamical Systems via Diffeomorphisms”, CoRL, 2022.
2. H. Beik-Mohammadi, et al. “Neural Contractive Dynamical Systems”. ICLR, 2024.

3. H. Beik-Mohammadi, et al. “Extended Neural Contractive Dynamical Systems: On multiple tasks and Riemannian Safety Regions”. IJRR, 2025.

Number of positions available:

1

Main Research Site:

AI4I-THE ITALIAN INSTITUTE OF ARTIFICIAL INTELLIGENCE FOR INDUSTRY

Corso Castelfidardo 22, 10129 Torino

Contacts:

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Funding Scheme:

This doctorate grant is fully funded by the Italian Institute of Artificial Intelligence for Industry.

Scholarship Amount:

Fascia 4: 19,500 €/year

2. Geometric optimal control for generative models of physical systems– AI4I

Curriculum: Hostile and hazardous environments	
Hosting Institution: AI4I – The Italian Institute of Artificial Intelligence for Industry	
Department: PHI Lab	
Tutor(s): Dr. Leonel Rozo	

Description:

The interpretation of reinforcement learning (RL) as an approximated optimal control problem suggests that the differential geometry can offer a unifying framework for analyzing and formulating policy learning paths as geodesics flows on specific Riemannian manifolds. This geometric perspective opens the following research objectives to be explored during the PhD: (1) RL as latent geodesic flows, where stochastic Riemannian metrics estimated from learned generative models define and/or bias the policy optimization path; (2) Leverage the Riemannian geometry of the Wasserstein space for more stable and efficient policy optimization; and (3) Exploit contact Hamiltonian dynamics and its link to optimal control geodesics into a geometric framework to analyze and design novel and interpretable RL algorithms. The thesis will explore applications of the developed methods in the control of physical systems such as robots or quadrotors, as well as the fine-tuning of foundational models, among others.

Requirements:

Must have skills:

- Excellent Master's degree in computer science, physics, mathematics, electrical or mechatronics engineering, or a related field
- Strong background in machine learning and robotics
- Good programming skills in Python
- Fluent in spoken and written English
- A team player, but also can work autonomously
- Experience with scientific writing

Good to have skills:

- Background on (applied) differential geometry
- Publication of peer-reviewed research papers

References:

1. H. Ziesche and L. Rozo, "Wasserstein Gradient Flows for Optimizing Gaussian Mixture Policies", NeurIPS, 2023.

2. A. Testa et al. “Geometric Contact Flows: Contactomorphisms for Dynamics and Control”, ICML, 2025.

3. Y. Chen et al. “Optimal Transport in Systems and Control”, Annual Review of Contro, Robotics and Autonomous Systems. 2021

Number of positions available:

1

Main Research Site:

AI4I - The Italian Institute of Artificial Intelligence for Industry., Corso Castelfidardo 22, 10129 Torino

Contacts:

Email: leonel.rozo@ai4i.it

Funding Scheme:

This doctorate grant is fully funded by the Italian Institute of Artificial Intelligence for Industry.

Scholarship Amount:

Fascia 4: 19,500 €/year

3. Security and resilience of networked dynamical systems under adversarial conditions– University of Cagliari

Curriculum:

Autonomous Systems

Hosting Institution:

Università di Cagliari (UNICA)

Department:

DIEE: Dept. of Electrical and Electronic Engineering

Tutor(s):

Alessandro Giua, Carla Seatzu, Mauro Franceschelli

Modern technological and social infrastructures rely increasingly on networked dynamical systems, in which multiple agents exchange information to achieve global objectives. Examples include distributed control systems in smart grids and transportation networks, epidemic monitoring and containment, and information propagation in social media. In all these settings, the system's evolution depends critically on the integrity and reliability of shared information. When this information flow is partially observed or subject to malicious manipulation, the system's stability, performance, and trustworthiness can be severely compromised. Addressing these challenges requires a unified approach combining tools from automatic control, network theory, and cybersecurity.

Within this general framework, the PhD candidate will be expected to propose and develop a research project focused on one of the following three themes.

a) Security and privacy of cyber-physical systems. This theme aims to extend tools developed in the discrete event systems community -such as diagnosis, opacity, and attack detection- to hybrid dynamical systems combining discrete and continuous dynamics. The objective is to analyze how cyberattacks and partial observability affect security properties and to develop new methods for attack detection and mitigation in hybrid settings. Another approach of interest is based on machine learning models, such as spiking neural P-systems.

b) Resilient Control of Open Multi-Robot Systems. This direction focuses on the design of local interaction control laws between agents to achieve a desired collective behavior in multi-robot systems, including swarms of autonomous systems. This research will consider open multi-agent systems and multi-robot systems, i.e., network systems where robots can join and leave the swarm seamlessly and aim to develop formal tools for their analysis. Additionally, faults and adversarial behavior within the network of systems will be considered and this research will aim to develop local interactions with proven resiliency against a certain number of anonymous adversaries and faulty robots within the network.

c) Attack mitigation in social and information networks. This topic explores the dynamics of information and misinformation propagation in social networks. Using concepts from control theory, graph theory, diffusion model, and networked estimation, the research will study how malicious agents influence collective behavior and how control-inspired mechanisms can be employed to detect, contain, or mitigate the spread of false information.

The PhD will combine theoretical analysis, modeling, and algorithmic development, contributing to understanding of security and resilience in the selected subdomain of networked systems that span both technical and social domains.

Requirements:

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

References:

Theme a)

- 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.
- K. Peng, Y.F. Chen, C. Seatzu, Z.W. Li, A. Giua, "Concealability Analysis for Current-state Opacity Enforcement via Editing Functions," *IEEE Trans. on Automatic Control*, vol. 69, no. 10, pp. 7231-7238, Oct. 2024.

Theme b)

- D. Deplano, M. Franceschelli, A. Giua, "Distributed Tracking of Network Size, Diameter, Radius, and Node Eccentricities in Open Multi-Agent Systems," *IEEE Trans. on Automatic Contro*l, Vol. 71, no. 4, 2026. To appear.
- M. Santilli, M. Franceschelli, and A. Gasparri "Dynamic Resilient Containment Control in Multi-Robot Systems" *IEEE Transactions on Robotics*, Volume: 38, Issue: 1, Feb. 2022.

Theme c)

- L. Yang, Z.W. Li, A. Giua, "Rumor Containment by Blocking Nodes in Social Networks," *IEEE Trans. on Systems Man & Cybernetics*, Systems, Vol. 53, no. 7, pp. 3990-4002, 2023.
- L. Yang, Z.W. Li, A. Giua, "Containment of Rumor Spread in Complex Social Networks, "*Information Sciences*, Vol. 506, pp. 113-130, 2020.

Number of positions available: 1

Main Research Site Dept. of Electrical and Electronic Engineering, University of Cagliari,

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

Scholarship Amount:

Fascia 1: 16,500 €/year