I-RIM

PhD Course in

ROBOTICS AND INTELLIGENT MACHINES

Curriculum: Robotics and Intelligent Machines for Inspection and Maintenance of Infrastructure

Research themes

The main goal of the Robotics and Intelligent Machines Inspection and Maintenance of Infrastructures curriculum is to train scientists and researchers capable of working in multidisciplinary teams on topics related to state-of-the-art solutions for Inspection and Maintenance of Infrastructures tasks. Robotics has a high potential in the technological innovation process of inspection and maintenance processes to reduce costs, improve the quality of services, as well as safety and environmental impact. The impossibility of adapting existing plants and infrastructures to the capabilities of common industrial robots, combined with the growing autonomy of the most advanced technological solutions, has created the right conditions for the development of specific service robotics solutions for civil and industrial inspection and maintenance applications.

The 5 fellowships offered in the first call of this year by Università degli Studi di Genova, University of Florence and CNR as part of this curriculum will be assigned to the best applicants to each of the 3 themes offered

Theme 1 addresses the design of a novel underwater reconfigurable vehicle for underwater intervention, and its control.

Theme 2 explores the use of Augmented Reality, Mixed Reality, and Virtual Reality technologies to support operators in their working activities (e.g., maintenance, assembly) through virtual instructions.

(*) This grant is co-funded by Regione Liguria.

Theme 3 focuses on non-gaited locomotion for quadrupedal systems in particularly challenging terrains, combining sensory information of various types with motion planning and control.

Theme 4 deals with the use of unmanned aerial vehicles to perform industrial inspections operations, such as, for example, the inspection of photovoltaic and wind installations.

Theme 5 will explore the use of marine robots for the inspection and maintenance operations of underwater infrastructures.

The students will perform their research project at the Hosting Institution (described in the research project sheet).

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

(*) This grant is co-funded by Regione Liguria.

1. Control of underwater vehicle-manipulator systems for inspection, maintenance, and repair tasks – University of Florence

Curriculum: Robots and Intelligent Machines for Inspection and Maintenance of Infrastructures

Hosting Institution
University of Florence

Department:
Dept. of Industrial Engineering

Tutors:
Benedetto Allotta, Alessandro Ridolfi

Description:
Robotic intervention systems aimed at ordinary management as well as inspection, repair and maintenance of plants represent an essential technology for a sustainable future, for example systems for the generation of energy from renewable sources in sea (waves, tides, wind).
Specifically, the candidate will contribute to the integration of a robotic arm on the underwater vehicle called RUVIFIST, an innovative reconfigurable vehicle developed and manufactured by the UNIFI DIEF research group. Subsequently, the PhD student will study the state of the art of control techniques for vehicle-manipulator systems, developing new ones that exploit the reconfigurability of the vehicle and dealing with their implementation. Finally, the doctoral activity involves experimentation in the tank and in the sea of the entire robotic system.
The PhD activity is perfectly aligned with the aims and objectives of the PNRR by bringing innovation in the field of technological innovation and digital transition. In particular, the goal of the PhD will be the creation of a system suitable for the inspection and protection of submerged critical infrastructures. The same robotic systems can be used for ecosystem monitoring (water column, seabed, coastal environment) to protect and conserve the environment and/or remediation of contaminated sites.

Requirements:
Applicants are expected to join the UNIFI Robotics Team and contribute with a leading role to the integration of manipulation capabilities on AUV assets available in the Lab. The PhD student will use the operational and scientific structures of UNIFI DIEF to carry out their study and research activities.

References:

- E. Topini, M. Pagliai and B. Allotta. “Dynamic maneuverability analysis: A preliminary application on an autonomous underwater reconfigurable vehicle”. MDPI Applied Sciences 11(10), 4469, 2021.
- E. Topini, […], A. Ridolfi. B. Allotta. “Development and Control of an Autonomous Reconfigurable Underwater Vehicle”. Proceedings of the 2022 IEEE OCEANS Hampton Roads Conference, Hampton Roads, USA, October 2022.

Company name and link (for industrial projects):
None

Number of positions available:

(*) This grant is co-funded by Regione Liguria.

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Main Research Site
UNIFI-DIEF MDM Lab facilities in:

- Via di Santa Marta3, Firenze;
- Via Vittorio Emanuele 32, Calenzano (FI);
- Via Panconi 12, Pistoia.

Contacts:
Email: benedetto.allotta@unifi.it, alessandro.ridolfi@unifi.it

Funding Scheme: PNRR funding scheme.
This doctorate grant is funded by PNRR program DM-118 (action 4.1 – Ricerca PNRR)

(*) This grant is co-funded by Regione Liguria.

2. Interaction and wellbeing in Extended Reality world using deep learning models in multiple industrial contexts - CNR-STIIMA

Department:
Institute of Intelligent Industrial Technologies and Systems for Advanced Manufacturing (STIIMA)

Tutor(s):
Maria di Summa, Vito Renò

Description:
Extended Reality (XR) is an umbrella term for any technology that alters reality by adding virtual elements to the real-world environment. It includes but is not limited to, Augmented Reality (AR), Mixed Reality (MR), and Virtual Reality (VR). Over the last twenty years, numerous studies confirmed that XR is powerful in assisting industrial operators, helping them in procedural tasks such as assembly and maintenance or for the training of novice operators. Nowadays, the technological maturity achieved by XR technologies allows applying more advanced design paradigms beyond the basic users' needs and goals toward higher-level human needs. Consequently, it is possible to develop XR applications that foster positive emotions, promote personal growth and support creativity, thereby contributing to social advancement. Also, recent advances on computer vision and artificial intelligence in the last years, with particular attention to the problems of quality control, suggest an in-depth study of the issues connected to the study, design and development of new AI models based on deep learning. In fact, in recent years, these techniques have been applied in numerous application contexts for the resolution of classification and regression problems or, more generally, of supervision and predictions for quality control. To deepen these concepts, the following research objectives will be pursued:

- the research for increasingly high-performance and specific models for Industry 4.0 application contexts through the design and development of innovative deep learning models (such as autoencoders or convolutional neural networks) for classification or regression purposes, with the aim of performing quality control;
- characterization and evaluation of models aimed to anomaly detection, with particular attention to unbalanced datasets;
- the research for better performing the interaction and wellbeing of the user in the virtual world, focusing on the understanding of how to reveal and measure the effect on human wellbeing of different designs of virtual environments;
- new data visualizing paradigms using extended reality, with the aim of supporting for the mental load of the user and evaluate the expression of how a synergistic approach between different technologies can contribute to innovation.

XR technologies can support operators in their working activities (e.g., maintenance, assembly), through virtual instructions that reduce the mental effort in the understanding of the task to accomplish. With the additional introduction of specific Virtual Elements (e.g. biophilic ones) in the industrial XR applications, it would be possible to further contribute to create health-promoting and sustainable working environments as already happens with real biophilic elements.

Requirements:

(*) This grant is co-funded by Regione Liguria.

Applicants are expected to have a background in computer science, computer engineering or information engineering (or equivalent). Applicants are expected to know programming languages (e.g. python) and object-oriented programming. Applicants should preferably have studied and applied machine learning or deep learning models. Applicants should preferably be familiar with popular libraries/platforms such as unity, vuforia for XR applications and opencv, pytorch, pandas, scikit-image or scikit-learn for computer vision and AI purposes.

References:

- Rocca, R., Santacruz, R. F. B., Sassanelli, C., Rosa, P., Fumagalli, L., & Negri, E. (2023). Digital Twin and Extended Reality: Strategic Approach and Practical Implementation. In Springer Handbook of Augmented Reality (pp. 853-880). Cham: Springer International Publishing.
- di Summa, M., Renò, V., Dibari, P., Pernisco, G., Sacco, M., & Stella, E. (2022). Extended reality and artificial intelligence: Synergic approaches in real world applications. Roadmapping Extended Reality: Fundamentals and Applications, 183-192..
- Pereira, F. (2022, October). Deep Learning-based Extended Reality: Making Humans and Machines Speak the Same Visual Language. In Proceedings of the 1st Workshop on Interactive eXtended Reality (pp. 1-2).
- Werbińska-Wojciechowska, S., & Winiarska, K. (2023). Maintenance Performance in the Age of Industry 4.0: A Bibliometric Performance Analysis and a Systematic Literature Review. Sensors, 23(3), 1409.

Number of positions available:
1

Main Research Site
CNR STIIMA, via G. Amendola 122 D/O, 70126 Bari, Italy

Contacts:

Email: maria.disumma@stiima.cnr.it – vito.reno@stiima.cnr.it

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

(*) This grant is co-funded by Regione Liguria.

3. Quadrupedal Locomotion and Navigation on Unstructured Scenarios – Leonardo s.p.a. and Università di Genova

Curriculum: Robots and Intelligent Machines for Inspection and Maintenance of Infrastructures

Hosting Institution
University of Genova

Department:
DIBRIS, Department of Informatics, Bioengineering, Robotics and Systems Engineering

Tutor(s):
Prof. Antonio Sgorbissa (UNIGE)
Dr. Enrico Mingo Hoffman (LEONARDO)

Description:

Quadrupedal robots are becoming increasingly attractive for inspection tasks due to their superior capability to traverse structured non-planar spaces, such as stairs and cluttered uneven terrains. However, existing systems still encounter difficulties when traversing particularly disrupted environments, as well as scenarios where non-gaited locomotion is required. In these cases, it is essential to have a good understanding of the environment and possess adequate motion skills to perform the necessary actions, such as being able to jump over gaps or precisely place the foot on stepping areas.

The research will focus on the area of non-gaited locomotion for quadrupedal systems in particularly challenging terrains, combining sensory information of various types with motion planning and control.

Requirements:

Applicants are expected to have good programming skills (possibly including Python, C/C++), confidence with electronic hardware and be capable to conduct experiments, and a strong attitude to problem solving.

References:

[1] Bazeille S., Barasuol V., Focchi M., Havoutis I., Frigerio M., Buchli J., Caldwell D.G., Semini C., Quadruped robot trotting over irregular terrain assisted by stereo-vision (2014) Intelligent Service Robotics, 7 (2), pp. 67 – 77
[2] Wellhausen, L., Dosovitskiy, A., Ranftl, R., Walas, K., Cadena, C., Hutter, M. Where should i walk(Predicting terrain properties from images via self-upervised learning (2019) IEEE Robotics and Automation Letters, 4 (2)

Company name and link (for industrial projects):

Leonardo S.p.a. – Genova (Innovazione e sviluppo tecnologie Leonardo Labs | Leonardo)

Number of positions available: 1

Main Research Sites

(*) This grant is co-funded by Regione Liguria.

DIBRIS Department, RICE lab (Robots and Intelligent systems for Citizens and the Environment), Via Opera Pia 13, Genova, Italy.

Leonardo Labs - Genova

Contacts:
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Email: enrico.mingohoffman@leonardo.com

Funding Scheme: This doctorate grant is co-funded by PNRR program DM-117

(*) This grant is co-funded by Regione Liguria.

4. Autonomous multirotor aerial drones for the inspection of industrial facilities – JPDroni s.p.a. and Università di Genova (*)

Curriculum: Robots and Intelligent Machines for Inspection and Maintenance of Infrastructures

Hosting Institution

University of Genova

Department:

DIBRIS, Department of Informatics, Bioengineering, Robotics and Systems Engineering

Tutor(s):

Prof. Antonio Sgorbissa (UNIGE)
Mr. Jacopo Calla (JPDRONI)

Description:

The research activity will address various topics related to the use of aerial drones for industrial inspection. Starting from an analysis of the international literature in this field, some case studies will be selected among those of particular interest internationally and on which the company carries out research and development activities, such as the inspection of photovoltaic and wind installations.

Based on these case studies, innovative solutions for autonomous flight, data acquisition, and their processing for issue recognition and/or the creation of maps and other representations in near real-time will be explored (taking into account constraints related to navigation speed, altitude, accuracy, resolution, etc.)

The research activity will include both phases of searching for innovative solutions supported by simulation and experimental development activities, with extensive data acquisition campaigns in the field made possible by the availability of areas that can be used for this purpose throughout Italy.

Requirements:

Applicants are expected to have strong programming skills (including Python, C/C++), a strong desire to acquire new theoretical knowledge and learn new technologies, and a strong problem-solving aptitude.

References:

[1] Morando L, Recchiuto CT, Calla J, Scuteri P, Sgorbissa A. Thermal and Visual Tracking of Photovoltaic Plants for Autonomous UAV Inspection. *Drones*. 2022; 6(11):347

[2] Zormpas, A.; Moirogiorgou, K.; Kalaitzakis, K.; Plokamakis, G.A.; Partsinevelos, P.; Giakos, G.; Zervakis, M. Power Transmission Lines Inspection using Properly Equipped Unmanned Aerial Vehicle (UAV). In Proceedings of the 2018 IEEE International Conference on Imaging Systems and Techniques (IST), Krakow, Poland, 16–18 October 2018; pp. 1–5.

Company name and link (for industrial projects):

JPDroni s.r.l. – Genova (https://www.jpdroni.it/)

(*) This grant is co-funded by Regione Liguria.

Number of positions available: 1

Main Research Sites

DIBRIS Department, RICE lab (Robots and Intelligent systems for Citizens and the Environment), Via Opera Pia 13, Genova, Italy.

JPDroni s.r.l. – Genova

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Funding Scheme: This doctorate grant is co-funded by Jp Droni and by Regione Liguria.

(*) This grant is co-funded by Regione Liguria.

5. Underwater Inspection and Maintenance with Marine Robots - Università di Genova

Curriculum: Robots and Intelligent Machines for Inspection and Maintenance of Infrastructures

Hosting Institution
University of Genova

Department:
Department of Informatics, Bioengineering, Robotics, and Systems Engineering - DIBRIS

Tutor(s):
Giovanni Indiveri and Enrico Simetti

Description:
Systems composed by heterogeneous robotic platforms are increasingly studied for their use in the marine environment. The robotic team can be composed of underwater vehicles (carrying sensors, e.g., water quality sensors, hydrophones, magnetometers, etc.) and surface vehicles (typically with a support role, for example for the localization of underwater vehicles, or carrying large payloads such as sparkers). In certain cases, an underwater vehicle can be physically connected to a surface through a tether cable, to exploit the extended communication range of the surface vessel, and possibly power from it.
The applications of such systems are diverse, and range from water quality monitoring, to offshore aquaculture inspection, to geotechnical exploration [1]. 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 [2]. In the above reference scenarios, different research challenges emerge, including low-level 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 low-level control strategies, reliable navigation and guidance in real-world conditions of each of the team members. The second one relates to the possible integration of acoustic sensor payload modules (eg. multibeam, forward looking, sidescan sonars) and the exploitation of the related acquired data for mission (re)planning.

Requirements:
Very good knowledge of Matlab and C++ is required.

References:

- Simetti, E., Indiveri, G., & Pascoal, A. M. (2021). WiMUST: A cooperative marine robotic system for autonomous geotechnical surveys. Journal of Field Robotics, 38(2), 268-288.
- Campos, D. F., Matos, A., & Pinto, A. M. (2021). Multi-domain inspection of offshore wind farms using an autonomous surface vehicle. SN Applied Sciences, 3(4), 1-19.

(*) This grant is co-funded by Regione Liguria.

Number of positions available:
1

Main Research Site
Department of Informatics, Bioengineering, Robotics, and Systems Engineering - DIBRIS, via all'Opera Pia, 13 - 16145 Genova (ISME node)

Contacts:
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Funding Scheme: This doctorate grant is funded by the proponent research institution.

(*) This grant is co-funded by Regione Liguria.