I-RIM

PhD Course in

ROBOTICS AND INTELLIGENT MACHINES

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

Research themes

The main goal of the 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. In this context, the main research objectives of the "Inspection and Maintenance of Infrastructures" curriculum (articulation 3) of the PhD are:

1. Innovative robotic solutions for the inspection processes of tanks, exchangers, refining towers, turbines, offshore platforms, underwater infrastructures and plants.

2. The inspection of turbines in the energy production and aeronautical sectors.

3. Inspection of power lines, aqueducts, dams, wind energy systems.

4. The inspection of railway infrastructures and of their subsystems (rails, sleepers, ballast, quay, platform, armaments, junctions, catenary, bearing wire, insulators, pylons, etc).

5. Inspection of viaducts and tunnels with IoT and service robotics technologies.

6. Inspection of air and naval infrastructures (vehicles, airports, ports etc.).

7. Innovative robotic solutions for remote-controlled robotic inspection and manipulation (immersive and multisensory interfaces and specialized robotic solutions for carrying out inspection and maintenance tasks).

8. Inspection and monitoring of the historical and architectural heritage.

The ideal candidates are students with a Master (or equivalent/higher) STEM (Science, Technology, Engineering, and Mathematics) degree and possibly a specific background in Robotics.

The students will perform their research project at the hosting institution (as described in the research project sheet). Interested applicants are encouraged to contact the tutors and/or the Unit's PI for clarifications before submitting their application.

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

1. Robotic based underwater shallow water infrastructure inspection - Univ. Genova

Curriculum: Inspection and Maintenance of Infrastructures

Hosting Institution: University of Genova (ISME node)

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

Tutor(s): Giovanni Indiveri

Description: The objective of the Ph.D. program is to study how underwater robotic technologies can be used to support the inspection of underwater infrastructure in support of predictive, preventive, and corrective maintenance. In particular, target applications are robot based underwater pipe and cable inspection. Among the many application scenarios, proper monitoring of underwater cables has the potential of drastically reducing maintenance costs of offshore wind farms. Europe is currently at the forefront of offshore wind energy production, and it is estimated that in ten years it will be responsible for more than 50% of global installations. One of the most expensive breakdowns to be detected and repaired is failure of the cable that carries electricity to shore. In most cases the fault occurs at the section of the cable closest to the coast, in very shallow water, where the action of the waves is more intense. Unfortunately, this is the most difficult stretch to locate and map with traditional means, because the low depth makes it virtually impossible for a work ship to operate under such stringent constraints.
Research topics will focus on one of the following broad areas: 1) underwater robot mission management, navigation, guidance and control in shallow waters; 2) sensor based underwater cables and/or pipeline detection and tracking. For both topics outlier robust filtering and estimation techniques are needed. Such techniques may eventually be the principal topic of investigation.

Requirements: Master (or equivalent/higher) STEM (Science, Technology, Engineering, and Mathematics) degree with a specific background in at least one of the following: Robotics, Systems Engineering, Automatic Control, Computer Science, Data analysis, Filtering and Estimation.

References:

1. Enrico Simetti, Giovanni Indiveri and Antonio Pascoal, WiMUST: A Cooperative Ma- rine Robotic System for Autonomous Geotechnical Surveys, Journal of Field Robotics, Volume 38, Issue 2, March 2021, Pages 268 - 288, DOI: 10.1002/rob.21986
2. Daniela De Palma and Giovanni Indiveri, Output outlier robust state estimation, Int. Journal Adapt. Control Signal Process, Volume 31, Issue 4, Special Issue: Adaptive Control and Signal Processing in Marine Systems, April 2017, Pages 581-607, DOI: 10.1002/acs.2673

Number of positions available:

1

Main Research Site: DIBRIS - Department of Informatics, Bioengineering, Robotics, and Systems Engineering, University of Genova, Genova (Italy)

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

2. Autonomous quadrupeds to improve public infrastructures resilience - Univ. Genova

Curriculum: Inspection and maintenance of infrastructures

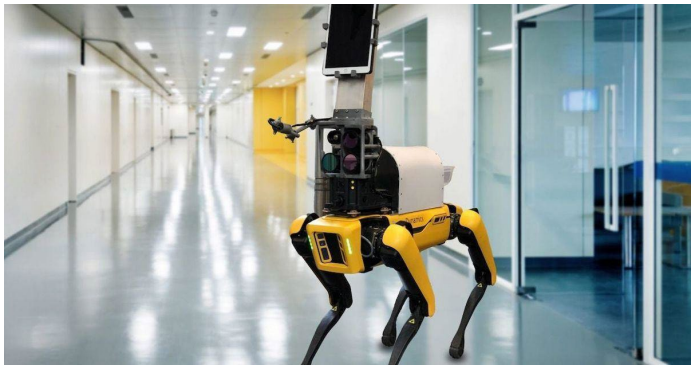
Hosting Institution
University of Genova, Genova

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

Tutor(s):
Antonio Sgorbissa, Carmine Recchiuto

Description:

Resilience is defined as "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events." In case of catastrophic events, such as severe earthquakes or floods, improving the resilience of public buildings such as the headquarters of national and local public administrations, fire and police stations, hospitals, or schools is key to improving the safety of people and the functioning of infrastructures.



Under these conditions, robotic technologies can play a key role. In particular, legged robots are an attractive solution thanks to their capability to move on non-planar surfaces to climb stairs, obstacles, and debris. Therefore, they offer many advantages compared to wheeled robots. We are getting used to seeing quadruped (and biped) robots everywhere: at the cinema, on the Internet, on television. They are characterized by outstanding mechanical design and control capabilities, making them capable of doing remarkable things. However, at a deeper look, it turns out that they still lack fully autonomous behavior: robotic research has not yet made them capable of making autonomous decisions to achieve their goals.

As an example, think about a severe earthquake. Despite the considerable cost of quadruped robots that makes them not easily affordable for private use, public administration buildings, fire and police stations, hospitals, schools, etc., could reasonably own one of them, ready to enter the action. If a catastrophic event occurs, the robot might start exploring the building autonomously: for example, it might check escape routes, recognize emergencies and find people needing help, give them instructions on how to behave, and build a map of the collapsed environment to improve the awareness of rescuers before they enter the area. Unfortunately, given the current state of the art, this is not possible, as no robot of this kind is capable of performing these tasks in complete autonomy.

To achieve the general objective of designing an intelligent quadruped robot, the Ph.D. student will have to address some of the "hottest" research topics in AI&Robotics. For example, what are the most appropriate planning models and strategies for mapping exploration, considering a complex building with multiple floors whose topology was possibly altered by the event [1]? How to model the actions that the robot must plan and execute to physically interact with the

environment and help people cope with the event [2]? How can the robot recognize relevant situations by acquiring and processing sensor data, including videos and other data received by smart devices carried or worn by people, fed to Deep Learning algorithms to classify them [3]? How can the robot autonomously extract the most relevant information and encode it in a suitable formalism for human rescuers [4]? Finally, how can the robot give people instructions on coping with the event and be "trusted" while considering their diversity in terms of age, physical skills, and culture [5]?

From an implementation perspective, these issues will be addressed by exploring the most recent AI technologies in autonomous navigation and planning, sensor fusion, trustworthy AI, learning, conversation, affecting computation, context- and cultural awareness. **The robot Spot by Boston Dynamics**, a popular quadruped equipped with cameras and lidar for mapmaking and obstacle avoidance, will be integrated with the Robot Operating System (ROS) to benefit from the vast amount of existing solutions developed by the robotic community.

Requirements:

Applicants must have good programming skills (C++, Java, or Python) and a profound interest in cutting-edge research in autonomous robotics. Previous experience with Artificial Intelligence solutions and ROS will be considered.

When applying for the Ph.D. scholarship, the student will be encouraged to propose solutions to address one or more of the abovementioned aspects.

References:

[1] Cadena, C., Carlone, L., …, Leonard, J.J. Past, present, and future of simultaneous localization and mapping: Toward the robust-perception age (2016) IEEE Transactions on Robotics, 32 (6), pp. 1309-1332.
[2] Gerevini, A.E., Haslum, P., Long, D., Saetti, A., Dimopoulos, Y. Deterministic planning in the fifth international planning competition: PDDL3 and experimental evaluation of the planners (2009) Artificial Intelligence, 173 (5-6), pp. 619-668.
[3] Wang, J., Chen, Y., Hao, S., Peng, X., Hu, L. Deep learning for sensor-based activity recognition: A survey (2019) Pattern Recognition Letters, 119, pp. 3-11.
[4] Riazuelo, L., Tenorth, …, Montiel, J.M.M. RoboEarth Semantic Mapping: A Cloud Enabled Knowledge-Based Approach (2015) IEEE Transactions on Automation Science and Engineering, 12 (2), pp. 432-443.
[5] Bruno, B., Recchiuto, C.T., …, R., Sgorbissa, A. Knowledge Representation for Culturally Competent Personal Robots: Requirements, Design Principles, Implementation, and Assessment (2019) International Journal of Social Robotics, 11 (3), pp. 515-538.

Number of positions available:

1

Main Research Site

The work will be performed at the DIBRIS department, Via Opera Pia 13, 16145, Genova, Italy. The "Laboratorium/Social Robotics Lab" is a fully equipped facility with aerial and ground robots (quadruped and wheeled), and humanoid robots for socially assistive applications

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Funding Scheme: This doctorate grant is co-funded by the proponent research institution and by the Italian Ministry of Research, under law D.M. 351/2022 (PA).

3. Development and experimentation of a Reconfigurable Underwater Vehicle for Inspection, Free-floating Intervention and Survey Tasks –Univ. Firenze

Curriculum: Inspection and maintenance of infrastructures

Hosting Institution
University of Florence

Department:
Department of Industrial Engineering

Tutor(s):
Prof. Benedetto Allotta, Dr. Alessandro Ridolfi

Description:
Development and experimentation of a Reconfigurable Underwater Vehicle for Inspection, Free-floating Intervention and Survey Tasks (RUVIFIST).

Requirements:
Applicants are expected to have very good skills in at least two of the following areas: software development, robot control, robot programming, mechatronics, mechanical design, sea trials. Furthermore, good attitude for experimental work and a strong motivation for team working are mandatory. Good programming skills with different languages and environments (including C/C++, Python, Matlab/Simulink, ROS), confidence with electronic hardware, attitude to problem solving, are desirable features.

References:

- Topini E., Pagliai M., Allotta B. (2021). Dynamic maneuverability analysis: A preliminary application on an autonomous underwater reconfigurable vehicle. APPLIED SCIENCES, vol. 11, p. 1-20, ISSN: 2076-3417, doi: 10.3390/app11104469
- Pagliai M., Ridolfi A., Gelli J., Meschini A., Allotta B. (2018). Design of a Reconfigurable Autonomous Underwater Vehicle for Offshore Platform Monitoring and Intervention. In: AUV 2018 - 2018 IEEE/OES Autonomous Underwater Vehicle Workshop, Proceedings. p. 1-6, Institute of Electrical and Electronics Engineers Inc., ISBN: 978-1-7281-0253-5, Porto, Portugal, 6-9 November 2018, doi: 10.1109/AUV.2018.8729776
- Allotta B., Gelli J., Pagliai M., Ridolfi A. (2020). "Underwater Vehicle with Variable Configuration," International Patent Application, International Publication Number WO 2020/021442 A1 (granted, 9th March 2022 EP 19 766 094.7).

Company name and link (for industrial projects): N/A

Number of positions available:

1

Main Research Site
Dept. of Industrial Engineering, Mechatronics and Dynamic Modelling Laboratory (MDM Lab), Pistoia facility

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Funding Scheme: This doctorate grant is co-funded by the proponent research institution and by the Italian Ministry of Research, under law D.M. 351/2022 (TD).

4. Human-centric, interactive, personal robotics - Univ. Pisa

Curriculum: Robotica e Macchine Intelligenti per l'ispezione e la manutenzione di infrastrutture

Hosting Institution
Centro di Ricerca "E. Piaggio" dell'Università di Pisa

Department:
Dipartimento di Ingegneria dell'Informazione

Tutor(s):
Antonio Bicchi, Giorgio Grioli, Manuel Catalano

Description:
The candidate will be trained to apply advanced robotic technologies in applications where interaction with humans is central. He will learn to consider human factors when developing new interfaces for programming robots, which are intuitive and allow people with skills other than those of computer code writers, to use robots as personal assistants in their home or as avatars at a remote physical workstation. The candidate will investigate this possibility both in collaborative robots applied in industrial scenarios and in the ALTER-EGO service robot platform.
ALTER-EGO is an open-source mobile soft manipulation platform with two arms, developed to operate in different environments and equipped with soft robotic technologies to enable safe physical interactions with humans and the environment, guarantee robustness and allow versatility. The candidate will investigate different communication channels that can be exploited to make robots in co-workers and companions.

Requirements:
Applicants are expected to possess a master's degree in engineering or other tightly connected field, with a background in robotics and control theory, and to be able to communicate in English. Applicants should also show good disposition toward team-work, willingness to travel, attitude for continuous education and commitment to results. Previous experiences in collaborative robotics, tele-operation, and/or motion capture are welcome but not required.

References:

- Lentini, Gianluca, et al. "Robot programming without coding." 2020 IEEE International Conference on Robotics and Automation (ICRA). IEEE, 2020.
- Lentini, Gianluca, et al. "Alter-ego: a mobile robot with a functionally anthropomorphic upper body designed for physical interaction." IEEE Robotics & Automation Magazine 26.4 (2019): 94-107.
- Zambella, Grazia, et al. "Dynamic whole-body control of unstable wheeled humanoid robots." IEEE Robotics and Automation Letters 4.4 (2019): 3489-3496.
- Mura, Domenico, et al. "On the role of stiffness and synchronization in human–robot handshaking." The International Journal of Robotics Research 39.14 (2020): 1796-1811.

Number of positions available:

1

Main Research Site
Research Center “E.Piaggio”, School of Engineering, University of Pisa, Largo Lucio Lazzarino 1, 56122 Pisa, Italy

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Funding Scheme: This doctorate grant is co-funded by the proponent research institution and by the Italian Ministry of Research, under law D.M. 351/2022 (PNRR).

5. Deep learning models for quality control and anomaly detection in Industry 4.0 - CNR STIIMA

Curriculum: Inspection

Hosting Institution
National Research Council of Italy (CNR)

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

Tutor(s):
Vito Renò

Description:
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, two 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.

Anomalies detection is a process that requires a machine to build a model to detect data - for example images - that deviate significantly from most of the information provided in input for training. In practice, the anomalies cannot be easily predicted in all their cases and therefore it becomes difficult to build suitable datasets that cover the entire variability of the observed phenomenon. Furthermore, anomalies depend on many unknown variables and can be generated by sudden and unknown phenomena until actually verified.

Deep learning techniques (or classification in general), used in a classical (or canonical) way, require a model to be retrained every time a new case study has to be added to be considered. This procedure is difficult if not impossible to apply in real practice for many reasons. In fact, the datasets that can be created are generally very unbalanced because they contain few examples of anomalies compared to the so-called good cases and each anomaly can be particular and represent a subclass itself. Finally, the detection of complex anomalies must be as robust as possible to noise and to the high data variability, considering the problems presented so far. We are therefore looking for a process capable of making quality control carried out with deep learning techniques more effective and robust.

Requirements:
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 such as opencv, pytorch, pandas, scikit-image or scikit-learn.

References:

- Pang, G., Shen, C., Cao, L., & Hengel, A. V. D. (2021). Deep learning for anomaly detection: A review. ACM Computing Surveys (CSUR), 54(2), 1-38
- Jiang, W. (2022). A Machine Vision Anomaly Detection System to Industry 4.0 Based on Variational Fuzzy Autoencoder. Computational Intelligence and Neuroscience, 2022.
- Jiang, Y., Wang, W., & Zhao, C. (2019, November). A machine vision-based realtime anomaly detection method for industrial products using deep learning. In 2019 Chinese Automation Congress (CAC) (pp. 4842-4847). IEEE.

Number of positions available:

1

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