I-RIM

PhD Course in

ROBOTICS AND INTELLIGENT MACHINES

Curriculum: Robotics and Intelligent Machines for Hostile and unstructured environments

Research themes

The main goal of the curriculum “Robotics and Intelligent Machines for Hostile and unstructured environments” is to address problems related to the study and development of enabling technologies and complex systems that will allow robots and intelligent machines to work in situations where the environment is dynamic, partially or totally unknown, hard to predict in advance, and possibly very challenging. The general objective of the curriculum is to form scientists and research technologists capable of working in multidisciplinary teams on projects where the interaction with a complex environment plays a crucial role in technological development and design.

The 11 research themes offered in the second call of this year by the Italian Institute of Technology (IIT), Università Politecnica delle Marche (UNIVPM) and University of Genova with the support of ISME and the Graal Tech company will be assigned to the best applicants to each of the 11 themes offered.

The ideal candidates are students with a strong background in robotics and intelligent machines from different perspectives: please check individual requirements for each research theme.

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.

1. Neuromorphic embodied intelligence: from sensing to actuation – Istituto Italiano di Tecnologia

Curriculum: Hostile and unstructured environments

Hosting Institution
Istituto Italiano di Tecnologia

Department:
Event-Driven Perception for robotics https://edpr.iit.it

Tutor(s): C. Bartolozzi

Description:
Neuromorphic sensing and computation can be used to design low-latency perception for robots. To fully exploit the low-latency and low-power paradigm, we aim at designing end-to-end spiking robotic systems, relying on event-driven sensory encoding, neuromorphic computation, and spiking motor control, all implemented on neuromorphic hardware [1].
To this aim, we plan to develop a system that includes neuromorphic tactile and proprioceptive information for closed-loop control, using brain-inspired computational primitives that allow to generate robust behaviour with limited and noisy resources [2]. We will build upon the recent work demonstrating the learning of inverse kinematics with triplet spike-timing dependent plasticity, basal ganglia-inspired disinhibition, and cooperative-competitive networks [1] and expand it to generate stable trajectories using balanced chaotic dynamic attractors [3,4]. As toy problem, we will use the iCub robot and use the developed network for handwriting.

Requirements:
We are looking for talented and motivated candidates, with a degree in Computer Science, Engineering, or related disciplines, with a background in Circuit Design, Soft Materials, Neuromorphic Engineering, or Computational Neuroscience Computer programming skills with Python, teamworking, and passion are much appreciated.

References:
[1] Zhao et al. Learning Inverse Kinematics using Neural Computational Primitives on Neuromorphic Hardware DOI: https://doi.org/10.21203/rs.3.rs-2220673/v1
[2] Bartolozzi C., Indiveri G., Donati E., Embodied neuromorphic intelligence, Nature Communications, DOI: 10.1038/s41467-022-28487-2
[3] Sussillo D, Abbott LF. Generating coherent patterns of activity from chaotic neural networks. Neuron. 2009 DOI: 10.1016/j.neuron.2009.07.018
[4] Goudar and Buonomano. eLife 2018;7:e31134. DOI: 10.7554/eLife.31134

Company name and link (for industrial projects):
n/a

Number of positions available: 1

Main Research Site
Istituto Italiano di Tecnologia, Center for Robotics and Intelligent Systems, Genova

Contacts: chiara.bartolozzi@iit.it

Funding Scheme: This doctorate grant is fully funded by the Italian Institute of Technology.
Scholarship Amount: • Fascia 4: 19,500 €/year

2. Manipulation without tools inspired from the elephant trunk – Istituto Italiano di Tecnologia

Curriculum: Hostile and unstructured environments	
Hosting Institution: Istituto Italiano di Tecnologia	
Department: Soft BioRobotics Perception Lab	
Tutor(s): Lucia Beccai: lucia.beccai@iit.it	

Description:

The elephant-trunk is an amazing organ that inspires the design and development of totally new versatile manipulators capable of both strong and delicate tasks in different environments. By investigating the trunk/object interaction it is possible to shed light on the different behaviors adopted by this animal, like previously done by our team by exploiting sensorized objects [1]. The different morphologies of the African and Asian species dictate the different behaviors that the animals adopt for dexterous and precise manipulation of single and multiple objects, heavy or light matter without the use of additional tools, by orchestrating the specific movements of the distal trunk. In this project (from a collaboration with the University of Geneve) unique anatomical and morphological data [2] of Asian and African trunks will be used to design completely new robotic manipulators. Various technological approaches will be investigated (soft and soft/rigid) to develop the dexterous grippers, also based on architected materials as we previously demonstrated [3]. Cutting-edge fabrication technologies (e.g., soft 3D/4D printing) will be used to iteratively develop different mock-ups and prototypes that will be evaluated in the two environments. The final aim of the project will be to provide completely new solutions to grasp and manipulate single and multiple objects in two different environments, air and shallow water, and to explore different applications of this innovative approach.

Requirements:

The successful candidate is strongly motivated to perform research in soft robotics by defining new specifications from the available biological data and committed to think and create out of the box. The required background is an excellent MSc engineering degree in areas of robotics, bioengineering, biomedical engineering, mechatronics, or equivalent. The prospective candidate should have solid knowledge of CAD / FEM tools and soft robotics, and good knowledge of soft actuation, hyperelastic materials, 3D printing, casting/moulding methods. Proficiency in spoken and written English is required as well as the propension for working in team. Propension to study biological and animal behavior papers is a plus.

References:

1. M. Lo Preti, L. Beccai Sensorized objects used to quantitatively study distal grasping in the African elephant iScience 26(9) 107657.
2. P. Dagenais, S. Hensman, V. Haechler, and M. C. Milinkovitch, Elephants evolved strategies reducing the biomechanical complexity of their trunk, Current Biology, 31(21):4727–4737, 2021.
3. S. Joe, O. Bliah, S. Magdassi, L. Beccai Jointless Bioinspired Soft Robotics by Harnessing Micro and Macroporosity Advanced Science 2302080 (2023).

Company name and link (for industrial projects): n.a.
Number of position available: 1
Main research site: Istituto Italiano di Tecnologia, Genova
Contacts: Lucia Beccai: lucia.beccai@iit.it
Funding scheme: This PhD grant is funded by the Istituto Italiano di Tecnologia
Scholarship Amount: • Fascia 4: 19,500 €/year

3. Control of anthropomorphic hands for collaborative tasks – Istituto Italiano di Tecnologia

Curriculum: Hostile and unstructured environments

Hosting Institution
Istituto Italiano di Tecnologia

Department:
Humanoid Sensing and Perception https://hsp.iit.it

Tutor(s):
Lorenzo Natale

ISTITUTO ITALIANO DI TECNOLOGIA

Description:
The ability to manipulate objects is fundamental in robotics and it has received significant attention within the field. Recent advancements in this area have largely focused on robotic grippers and data-driven, deep learning methods leading to exceptional performance in pick-and-place operations. The use of anthropomorphic hands support more complex hand-object interactions and tool use, which are fundamental capabilities especially in human-robot collaboration scenarios. An important limitation of grasping pipelines is that they predominantly utilize visual feedback and open-loop strategies which do not allow adjustments to improve grasp stability, in presence of uncertainty in unstructured environments.
The project's objective is to design algorithms for object manipulation using anthropomorphic hands, incorporating both visual and tactile feedback within human-robot collaborative settings. The approach involves developing motion planning and control algorithms that use visual data to establish initial grasp configurations and employ tactile inputs to enhance grasp stability and execute manipulative tasks. Research methods will include model-based techniques, machine learning (i.e. multi-modal models) and their integration. This project will be developed on the ergoCub robot (https://ergocub.eu/), a humanoid platform designed to study collaborative robotics for risk prevention in work environments.

Requirements:
Applicants are expected to have an MSc degree in computer science, engineering or related fields, background in Robotics, control systems and AI, experience with programming languages like C++ and Python and deep learning frameworks. In addition, the candidate is required to have a strong interest working with real robotic systems.

References:

- Billard A, Kragic D., Trends and challenges in robot manipulation, Science 364 (6446), 2019
- Bütepage, J., Cruciani, S., Kokic, M., Welle, M., & Kragic, D., From visual understanding to complex object manipulation., Annual Review of Control Robotics, and Autonomous Systems Vol. 2, 2019.

Company name and link (for industrial projects):

Number of positions available: 1

Main Research Site Istituto Italiano di Tecnologia, via San Quirico 19D, 16148, Genova
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Funding Scheme: this project is funded by INAIL in the context of the ergoCub-2.0 project – CUP J53C2400054005
Scholarship Amount: • Fascia 4: 19,500 €/year

4. Space Exploration with Legged Robots: Learning for Locomotion and Perception – Istituto Italiano di Tecnologia

Curriculum: Hostile and unstructured environments

Hosting Institution
Istituto Italiano di Tecnologia

Department:
Dynamic Legged Systems https://dls.iit.it

Tutor(s):
Victor Barasuol, Joao Soares and Claudio Semini

ISTITUTO ITALIANO DI TECNOLOGIA

Description:
In the scenario of space exploration, perception is considered a core component of a robust and precise locomotion controller for legged robots. This PhD theme will explore the use of machine learning techniques for legged locomotion in planetary exploration scenarios. These scenarios include rough, highly-inclined, and collapsing terrains.
The PhD candidate will explore different network architectures, and learning modalities, to perform precise terrain exploration and classification, discerning dangerous areas which cannot be traversed by the robot. This includes learning the characteristics of the terrain (slope, grain size, friction, "terrain reaction force"), and understanding the safety of the terrain. This information will then be exploited to perform safe path-planning and reactive foothold placements.

Requirements:
We are looking for a highly motivated and creative student, very committed to research and eager to explore new paradigms. An excellent Master's degree is expected in one of the following areas (or related): artificial intelligence, computer vision, or robotics engineering.
As technical skills, the student must have solid knowledge of machine learning, robotics (kinematics and dynamics), as well as some basics in control theory. The candidate must have proven experience with C++, Python, ROS and machine learning libraries, e.g. PyTorch or JAX.

References:

- O. Villarreal Magaña et al., “Fast and Continuous Foothold Adaptation for Dynamic Locomotion Through CNNs," in IEEE Robotics and Automation Letters, vol. 4, no. 2, pp. 2140-2147, April 2019
- P. Arm et al. “Scientific Exploration of Challenging Planetary Analog Environments with a Team of Legged Robots,” Science Robotics, Vol. 8, Issue 80, 2023.
- M. Mattamala et al. “Wild Visual Navigation: Fast Traversability Learning via Pre-Trained Models and Online Self-Supervision,” Arxiv, 2024.

Company name and link (for industrial projects):
n.a.

Number of positions available: 1

Main Research Site

Istituto Italiano di Tecnologia, via San Quirico 19D, 16163, Genova
Contacts: **Email:** victor.barasuol@iit.it, joao.virgolino@iit.it, claudio.semini@iit.it
Funding Scheme: Istituto Italiano di Tecnologia
Scholarship Amount: • Fascia 4: 19,500 €/year

5. Learning loco-manipulation skills for agile quadruped robots – Istituto Italiano di Tecnologia

Curriculum: Hostile and unstructured environments

Hosting Institution
Istituto Italiano di Tecnologia

Department:
Dynamic Legged Systems https://dls.iit.it

Tutor(s):
Giulio Turrisi and Claudio Semini

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Description:
Nowadays, Reinforcement Learning (RL) has emerged as a powerful method for controlling legged robots. Its data-driven nature, coupled with the possibility of training a robot for thousands of simulated years in a variety of complex environments, has made it possible to solve challenging tasks, such as robot parkour [1] or ball balancing [2], that were difficult to achieve before with classical model-based approaches. The focus of this PhD topic is to enhance the applicability and robustness of these methods for real quadrupedal locomotion and manipulation tasks. Depending on the candidate's interest, model-based approaches can even be used in conjunction with RL methods to enhance the predictability of the final controller, similar to [3]. The student will have the chance to test his ideas on the multiple legged machines and arms that are present in the lab.

Requirements:
We are looking for a highly motivated and creative student, very committed to research and eager to explore new paradigms. An excellent Master's degree is expected in one of the following areas (or related): artificial intelligence, or robotics engineering.
As technical skills, prospective candidates should possess expertise in robot control, dynamics, and machine learning. Proficiency in coding languages such as Python and C++ is essential.

References:

[1] Xuxin Cheng, Kexin Shi, Ananye Agarwal, Deepak Pathak, “Extreme Parkour with Legged Robots,” IEEE International Conference on Robotics and Automation, 2024.

[2] Jason Ma, William Liang, Hungju Wang, Sam Wang, Yuke Zhu, Linxi Jim Fan, Osbert Bastani, Dinesh Jayaraman, “DrEureka: Language Model Guided Sim-To-Real Transfer,” arXiv, 2024.

[3] Shafeef Omar, Lorenzo Amatucci, Victor Barasuol, Giulio Turrisi, Claudio Semini, “SafeSteps: Learning safer footstep planning policies for legged robots via model-based priors,” IEEE-RAS International Conference on Humanoid Robots, 2023.

Company name and link (for industrial projects):
n.a.

Number of positions available: 1

Main Research Site
Istituto Italiano di Tecnologia, via San Quirico 19D, 16163, Genova

Contacts:

Email: giulio.turrisi@iit.it, claudio.semini@iit.it

Funding Scheme:

this theme is funded by INAIL in the context of the Robot Teleoperativo 3 project

Scholarship Amount:

- Fascia 4: 19,500 €/year

6. Autonomous Loco-manipulation Planning and Control for legged robots – Istituto Italiano di Tecnologia

Curriculum: Hostile and unstructured environments

Hosting Institution
Istituto Italiano di Tecnologia

Department:
Humanoid and Human Centered Mechatronics Research line (https://hhcm.iit.it/)

Tutor(s):
Nikos Tsagarakis, nikos.tsagarakis@iit.it

Description:
This research topic concentrates on the development of autonomous loco-manipulation capabilities of legged robots engaged in applications involving navigation in complex and challenging environments. Legged-wheeled robots such as CENTAURO and the under development new hybrid mobility quadruped platform at HHCM Lab of IIT will be explored to provide services in logistics scenarios where they will have to grasp, load and unload goods, navigate sidewalks and other pedestrian areas to deliver packages directly to customers' doors. To perform their mission effectively, these robots shall be equipped with the skills that allow them to operate safely and reliably in urban environments that can be cluttered including the presence of humans or other dynamic entities, negotiate terrain challenges and obstacles and eventually be able to transfer from indoor to outdoor environments and vice versa. To realize these functionalities, machine learning (reinforcement/deep learning) as well as geometric based techniques for terrain/environment semantics detection and recognition will be explored to realize autonomous navigation skills and permit these mobile wheeled or legged manipulation platforms to move around in unstructured terrains, perform loco-manipulation actions and reach the targeted locations to deliver the transported goods. This requires the ability to interpret semantics (e.g., zebra crossings, sidewalks, doors, etc.) and include dynamic obstacles such as humans. Perception data from various sensors (RGB-D sensors, 3D Lidar scanners, etc.) will be fused to acquire RGB images and dense 3D point cloud while geometric simplifications for reasoning will be explored. Such semantics information will be eventually explored for autonomous mobility planning (path planning, wheeled/leg motion planning, foot placement, etc.) and autonomous manipulation (object and environment feature and interfaces recognition and manipulation strategy selection) to permit the navigation and manipulation of the encountered environment

Requirements:
This topic lies in the intersection of Perception and Robotics. Ideal applicants should have excellent C++ and Python programming competences. Machine learning and computer vision skills are required. A background in any of Robotics, Computer/Robotic Vision, Path Planning, and Robot Learning is desirable, while knowledge of the Robot Operating System (ROS) is a plus. The applicants should be fluent in English and team players.

References:

- Wellhausen L., Hutter M., ArtPlanner: Robust Legged Robot Navigation in the Field, https://arxiv.org/abs/2303.01420

- De Luca A., Muratore A, Tsagarakis N.G., Autonomous Navigation with Online Replanning and Recovery Behaviors for Wheeled-Legged Robots using Behavior Trees, IEEE Robotics and Automation Letters, 2023.

Number of positions available: 1

Main Research Site
Center for Robotics and Intelligent Systems (CRIS), IIT, Genova

Contacts:
Email: nikos.tsagarakis@iit.it

Funding Scheme: This doctorate positions are funded by Horizon Europe Programme project euROBIN (https://www.eurobin-project.eu/)

Scholarship Amount:
- Fascia 4: 19,500 €/year

7. Intelligent end-effector embodiment and autonomous manipulation control principles – Istituto Italiano di Tecnologia

Curriculum: Hostile and unstructured environments

Hosting Institution
Istituto Italiano di Tecnologia

Department:
Humanoid and Human Centred Mechatronics Research line (https://hhcm.iit.it/)

Tutor(s):
Nikos Tsagarakis, nikos.tsagarakis@iit.it

ISTITUTO ITALIANO DI TECNOLOGIA

Description:

The realization of effective manipulation skills has strong dependencies on the robot end-effector mechatronics including the articulated kinematics, the actuation and the sensing principles of the end-effector module. This research topic targets to develop kinematically minimalistic end-effector modules that are equipped with intrinsic adaptation as well as multi-modal sensing capabilities to facilitate the manipulation robustness as well as the realization of autonomous grasping and manipulation skills. The mechatronic design and the engineering of the end-effector modules will explore the instrumentation of the grippers with integration of visual and haptic sensing that will provide the cues for implementing autonomous grasping and manipulation functionalities. Control methodologies and a set of autonomous manipulation skills will be explored and implemented to enable the execution and adaptation of grasping actions. Proprioceptive feedback will be employed for the regulation of the grasping forces and for their adaptation through reflex controllers tuned using model and machine learning based techniques. The end-effector device will be realized with different articulation topologies to serve the grasping requirements of various target manipulation tasks. The developed end-effector and grasping control tools will be integrated in various robotic platform ranging from fixed manipulators to robot arms installed on legged robots.

Requirements:

We are seeking for highly motivated candidates with a background in Mechanical and Control engineering, Physical Sciences or Robotics. Candidates should have competencies in mechanical design, robot dynamics, learning and control. (Mechanical design 40%, Control %60). The applicants should be fluent in English and team players.

References:

- Barrett E., Ren Z., Tsagarakis N.G., Grasping with Embedded Synergies through a Reconfigurable Electric Actuation Topology, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2021, pp6131-6138.
- Ren Z, Kashiri N., Zhou C., Tsagarakis N.G., Heri ii: A robust and flexible robotic hand based on modular finger design and under actuation principles, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2018, pp 1449-1455.
- A. Ajoudani, E. Hocaoglu, A. Altobelli, M. Rossi, E. Battaglia, N.G. Tsagarakis, A. Bicchi, Reflex control of the Pisa/IIT SoftHand during object slippage, IEEE International Conference on Robotics and Automation (ICRA), 2016.

- Y. Bekiroglu, J. Laaksonen, J. Alison Jorgensen, V. Kyrki, D. Kragic, Assessing Grasp Stability Based on Learning and Haptic Data, IEEE Transactions on Robotics, 2011, Vol. 27, Issue 3.

Number of positions available: 1

Main Research Site
Center for Robotics and Intelligent Systems (CRIS), IIT, Genova

Contacts:
Email: nikos.tsagarakis@iit.it

Funding Scheme: This doctorate positions are funded by Horizon Europe Programme project HARIA (http://haria-project.eu/)

Scholarship Amount:

- Fascia 4: 19,500 €/year

8. Marine Biomimetic Cyber-Physical System(s) for Ocean Documentation – Università Politecnica delle Marche

Curriculum: Hostile and unstructured environments

Hosting Institution
Università Politecnica delle Marche

Department:
Dipartimento di Ingegneria dell'Informazione

Tutor(s):
Prof. David Scaradozzi

Description:
Biomimetics or bio-inspiration is the transfer of natural models into innovative technical applications by analyzing the working principles of nature's best examples and transferring the core mechanisms into technical applications without necessarily copying them. Biomimetic Marine Technologies move these natural templates to create highly efficient and sustainable solutions, e.g. marine vehicle hulls, sailing boats and (autonomous) underwater vehicle actuation.
The PhD research's primary objective will be to design and build a new generation of bio-inspired robots capable of exploring and acting in extreme environments, e.g., underwater, for several applications, including archaeology, sport diving, or monitoring Marine Protected Areas. The candidate will design and develop robots to advance state-of-the-art performance by combining additive manufacturing techniques, functional materials, and control strategies. From a constructive and applied research point of view, there are many robotic "fish" models and locomotion studies for possible single-vehicle Navigation, Guidance and Control (NGC) strategies. In recent years, the scientific literature has started presenting communication and cooperation strategies for their use as a "swarm". Still, there persists more needs in formal multi-vehicle modelling at large and in prototype implementation, linked to survey and patrol purposes of a confined area. Few have hybrid propulsion capability (fin/propeller) as the LabMACS (UNIVPM) BRAVe (Biomimetic Research Autonomous Vehicle) class. The research will empower LabMACS's research in different ways with the Cyber-Physical System(s) paradigm:

- "Single Robot" will reconsider the Fossen model and its validity for hybrid vehicles (fin/propellers propulsion) with Body, Caudal Fin locomotion. This part will contribute to the design of single robots' Navigation, Guidance and Control systems.
- "Multi-Vehicles" shoal in free patrolling as Multi-Agents System (MAS) will present a formalism to face situations where robots with limited capacities and characteristics and intermittent communication must agree in actions during unstructured area coverage and distributed estimation.
- "Perception and cloud infrastructure" Machine Learning and Artificial Intelligence infrastructures will be investigated for better modelling the robot(s) explored environment in real-time.
- Geo-Informatics, Digital Cultural Heritage, Ambient Intelligence & Space Sensing, Artificial Intelligence for interpreting complex 2D/3D data and modelling it in a digital twin of the explored environment.

More Information about the research teams and technology:
https://mscamasterclass.univpm.it/wp-content/uploads/2023/05/Scaradozzi-1.pdf

Requirements:

The candidates are expected to have an attitude to problem-solving and experimental work and be strongly motivated for team working.

Applicants are expected to have basic knowledge of kinematics and dynamics of systems. Moreover, adequate skills in modelling, analysis, and control of dynamic systems will be appreciated. Demonstrated experience with optimal control theory and programming (ROS1/ROS2, python, C/C++, Matlab) and experience in controlling compliant actuators is a plus. For the reasons above, the successful candidate should ideally have an MSc in Computer and Automation Engineering or a related field.

References:

- P. Abreu et al. ‘’Widely scalable mobile underwater sonar technology: An overview of the H2020 WiMUST project’’ Marine Technology Society Journal 2016
- D. Animobono, D. Scaradozzi, E. Zattoni, A. M. Perdon, G. Conte, “The Model Matching Problem for Max-Plus Linear Systems: a Geometric Approach”, 2022
- G. Antonelli, F. Arrichiello, F. Caccavale and A. Marino, "A Decentralized Controller-Observer Scheme for Multi-Agent Weighted Centroid Tracking," in IEEE Transactions on Automatic Control, 2013
- G. Antonelli, “Underwater robots”, Springer Tracts in Advanced Robotics, 2003, 4th edition 2018
- Blake, R.W. The mechanics of labriform locomotion I. Labriform locomotion in the angelfish (Pterophyllum eimekei): An analysis of the power stroke. J. Exp. Biol. 1979
- G. Cohen, S. Gaubert, and J.P. Quadrat, “Max-plus algebra and system theory: where we are and where to go now,” Annual reviews in control, 1999
- Costa, D.; Palmieri, G.; Palpacelli, M.C.; Callegari, M.; Scaradozzi, D. Design of a bio-inspired underwater vehicle. 12th IEEE/ASME International Conference on Mechatronic and Embedded Systems and Applications (MESA), 2016
- Costa, D.; Palmieri, G.; Palpacelli, M.C.; Scaradozzi, D.; Callegari, M. Design of a Carangiform Swimming Robot through a Multiphysics Simulation Environment. Biomimetics 2020
- Costa, D.; Palmieri, G.; Scaradozzi, D.; Callegari, M. Experimental Validation of a Bio-Inspired Thruster. J. Dyn. Syst. Meas. Control 2021
- Fiori, S. (2019). Model formulation over Lie groups and numerical methods to simulate the motion of gyrostats and quadrotors. Mathematics, 7(10), 935
- P. Majdzik, “Feasible schedule under faults in the assembly system,” in: 16th IEEE International Conference on Control, Automation, Robotics and Vision (ICARCV), 2020
- Marino et al., “Distributed Fault Detection Isolation and Accommodation for Homogeneous Networked Discrete-Time Linear Systems” IEEE Trans. on Automatic Control, 2017
- Marino, G. Antonelli, A. P. Aguiar and A. Pascoal, "A new approach to multi-robot harbour patrolling: Theory and experiments," IEEE/RSJ International Conference on Intelligent Robots and Systems, 2012
- L. Paull et al. "AUV Navigation and Localization: A Review" IEEE Journal of Oceanic Eng., 2014
- Scaradozzi, D.; Palmieri, G.; Costa, D.; Pinelli, A. BCF swimming locomotion for autonomous underwater robots: A review and a novel solution to improve control and efficiency. Ocean Eng. 2017
- Caiti, A., Ciaramella, E., Conte, G., Cossu, G., Costa, D., Grechi, S., ... & Sturniolo, A. Optocomm: introducing a new optical underwater wireless communication modem. IEEE Third Underwater Communications and Networking Conference (UComms), 2016

Company name and link (for industrial projects):
ANcybernetics s.r.l., via Brecce Bianche, 12, 60131 Ancona, www.ancybernetics.it

Number of positions available: 1

Main Research Site
Dipartimento di Ingegneria dell'Informazione, UNIVPM, Ancona (I). Experiments will be conducted also at the premises of the LabMACS Laboratory in Ancona (II) and SeaLab, CSSN in La Spezia (III).

Contacts:
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Funding Scheme:
This doctorate grant is funded by PNRR program DM-630

Scholarship Amount:

- Fascia 1: 16,500 €/year

9. Autonomous quadruped robots: new challenges in hostile and unstructured environments – University of Genova

Curriculum: Robotics and Intelligent Machines for Hostile and unstructured environments	Università di Genova
Hosting Institution UNIGE	
Department: DIBRIS, Department of Informatics, Bioengineering, Robotics and Systems Engineering	
Tutor(s): Antonio Sgorbissa	

Description:

While wheeled robots were the predominant choice for outdoor navigation and exploration in the past, legged robots with varied kinematics and locomotion capabilities are now gaining popularity. These robots are increasingly favored for their ability to operate in complex environments where traditional wheeled robots are ineffective, for instance, in references [1, 2]. They are especially useful in scenarios such as emergency interventions in natural or environmental disasters and the inspection of industrial plants, with potential applications in other areas as well.

Consider, for example, a large solar plant that needs inspection for potential damage. Typically, this task is performed using flying drones. However, drones have limitations concerning the resolution of images taken from above and cannot inspect areas obscured beneath solar panels. In such cases, a quadruped robot equipped with a manipulator arm could efficiently explore the area and possibly take preliminary action before human operators are directly involved, such as removing vegetable residues that can clog the solar panels.

In light of this general scenario where autonomous navigation capabilities are crucial, the thesis will offer the student the freedom to explore one or both of the following options:

- Using the quadruped robot SPOT by Boston Dynamics, equipped with a custom manipulator.
- Using the lighter quadruped robot GO1 from Unitree.

In both cases, the thesis will explore strategies for managing all the necessary aspects that enable a quadruped to exhibit fully autonomous behavior aimed at locomotion, navigation,

and manipulation—from sensor acquisition to controlling the robot's kinematics and dynamics to perform observations and interact with the environment.

These aspects will require investigating the robot's capabilities in terms of perception and locomotion in various scenarios, including rocks, grass, sand, garbage, pipes, and steep slopes, both uphill and downhill. This, in turn, raises theoretical and technological issues that go beyond the typical problems faced by wheeled manipulators in indoor, office-like environments [3], including the possibility to "pedipulate" objects with legs [4,5]. The student will have the opportunity to address these challenges by proposing original solutions that advance beyond the current state of the art.

Requirements:
The ideal candidate is a robotic scientist with previous experience in legged robot locomotion, software architectures and simulation of legged robots, kinematics and dynamics control for manipulation.

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] Ylikorpi, Tomi J; Halme, Aarne J; Forsman, Pekka J (2017). "Dynamic modeling and obstacle-crossing capability of flexible pendulum-driven ball-shaped robots". Robotics and Autonomous Systems. Elsevier. 87: 269–280.

[3] Hooks J., Ahn M.S., Yu J., Zhang X., Zhu T., Chae H., Hong D. ALPHRED: A Multi-Modal Operations Quadruped Robot for Package Delivery Applications, (2020) IEEE Robotics and Automation Letters, 5 (4), art. no. 9134727, pp. 5409 - 5416

[4] Cheng X., Kumar A., Pathak D. Legs as Manipulator: Pushing Quadrupedal Agility beyond Locomotion (2023) Proceedings - IEEE International Conference on Robotics and Automation, 2023-May, pp. 5106 – 5112

[5] Philip Arm, Mayank Mittal, Hendrik Kolvenbach, Marco Hutter, Pedipulate: Enabling Manipulation Skills using a Quadruped Robot's Leg, arXiv:2402.10837

Number of positions available: 1

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

Contacts:

Email: antonio.sgorbissa@unige.it

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

Scholarship Amount:

- Fascia 4: 19,500 €/year

10. Aerial Drones for Monitoring Large Photovoltaic Plants – University of Genova

Curriculum: Robotics and Intelligent Machines for Hostile and unstructured environments

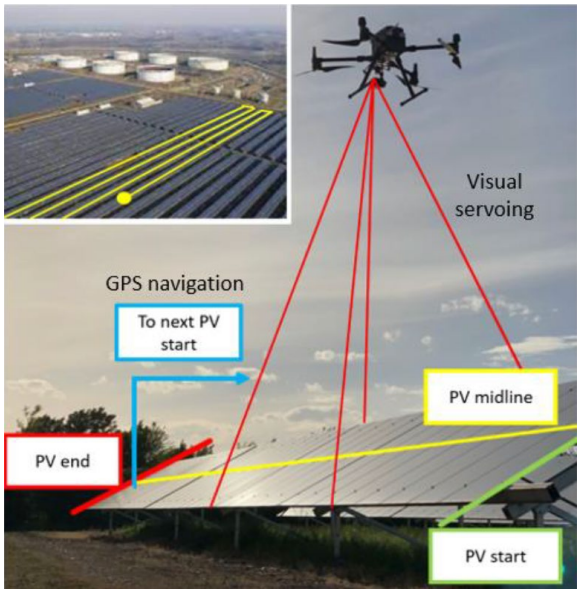
Hosting Institution
UNIGE

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

Tutor(s):
Antonio Sgorbissa

Description:

This PhD position is funded by the SOLARIS European project, which aims to foster the development and integration of PV systems in Europe and beyond. SOLARIS brings together 15 partners (6 research-oriented partners, 8 industrial partners including 2 start-ups & 3 SMEs, and a municipality) for a duration of 48 months. The project focuses on developing and demonstrating a comprehensive set of physical and digital tools for improved forecasting, operational performance, and maintenance, resulting in high-performance indices (90%) and availability (>98%) of PV plants.



Among other functionalities, SOLARIS will equip operators with automated multispectral PV inspection using drones. The University of Genoa, covered by this PhD position, will **develop strategies that enable drones to inspect PV plants more efficiently and reliably, operating in complete autonomy**. Please notice that the University of Genoa has gained relevant experience in this field from previous collaborations [1,2] To address these issues, the PhD candidate will explore GPS-based navigation as well as innovative real-time visual segmentation and servoing techniques for navigation and control, addressing current limitations in the state of the art [3,4]. This includes the capability to fly at variable heights from the ground (providing higher resolution images) and accommodating scenarios where PV panels may not be parallel to the terrain. Furthermore, the candidate will investigate path planning and optimization techniques [5,6] to ensure that the path taken by drones over PV panels maximizes the number of panels inspected on a single charge.

More specifically, for navigation and control, the candidate will explore solutions based on real-time visual segmentation and servoing, combined with GPS navigation for navigating between PV rows. The following steps are expected to be considered: 1) Real-time segmentation of PV panels from acquired images. 2) Utilization of filtering techniques (e.g., Extended Kalman Filter) to merge visual information obtained in successive steps, reducing

the impact of errors in image segmentation. 3) Visual servoing to maintain drone alignment along PV panel rows while maintaining a forward velocity. All these developments will first be validated using drone simulation and visualization software (NViz & Gazebo).

For path optimization, the candidate will explore innovative solutions, with the following steps expected to be considered: 1) Satellite image acquisition: obtaining georeferenced satellite images, such as those from Copernicus ; 2) PV panel and PV panel row segmentation through an ML tool, trained with a large dataset of satellite images (e.g., Detectron) to accurately segment PV panels and PV panel rows from the image background. 3) Subarea clustering: to simplify the subsequent optimization problem, subareas in the PV plant will be clustered by identifying subsets of PV panel rows and waypoints that can be inspected with a single battery charge. 4) Optimization: solving a Traveling Salesman Problem for each subarea.

Requirements:
The ideal candidate is a robotic scientist with a strong background in programming and control. Previous experience with aerial drones will be positively considered.

References:

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

[2] Iacono M., Sgorbissa A. Path following and obstacle avoidance for an autonomous UAV using a depth camera (2018) Robotics and Autonomous Systems, 106, pp. 38 - 46

[3] Aghaei, M.; Dolara, A.; Leva, S.; Grimaccia, F. Image resolution and defects detection in PV inspection by unmanned technologies. In Proceedings of the 2016 IEEE Power and Energy Society General Meeting (PESGM), Boston, MA, USA, 17–21 July 2016; pp. 1–5. 15.

[4] Zefri, Y.; Elkettani, A.; Sebari, I.; Lamallam, S. Thermal infrared and visual inspection of photovoltaic installations by uav photogrammetry—Application case: Morocco. Drones 2018, 2, 41.

[5] X. Luo, et al., "Optimal path planning for UAV based inspection system of large-scale photovoltaic farm," in Proc. of the CAC. Jinan, PRC: IEEE, Oct. 2017, pp. 4495–4500.

[6] A. M. M. Sizkouhi, S. M. Esmailifar, M. Aghaei, A. K. Vidal de Oliveira, and R. Rüther, "Autonomous path planning by unmanned aerial vehicle (UAV) for precise monitoring of large-scale PV plants," in Proc. of the 46th PVSC. Chicago, USA: IEEE, June 2019, pp. 1398–1402.

Number of positions available: 1

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

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Scholarship Amount:
- Fascia 4: 19,500 €/year

11. Optimizing AUV Teams through Heterogeneous Sensor Integration – Graal Tech s.r.l. and University of Genoa

Curriculum: Hostile and unstructured environments	GRAAL tech Robotics, from idea to the sea.
Hosting Institution University of Genoa	
Department: Interuniversity Research Center on Integrated Systems for the Marine Environment (ISME)	ISME Integrated Systems for Marine Environment
Tutor(s): Andrea Caffaz, Enrico Simetti, Giovanni Indiveri	

Description:

Autonomous Underwater Vehicles (AUVs) play a crucial role in oceanographic research, underwater exploration, and environmental monitoring. Recently, deployments of large teams of AUVs, ranging from ten to hundreds, have been undertaken for exploration and surveying tasks [1]. A significant challenge in deploying AUVs is achieving precise navigation and efficient task execution in the complex underwater environment. Understanding how the heterogeneity of sensors affects the performance of a team of vehicles is of particular interest. For instance, a Doppler Velocity Log (DVL) allows precise velocity measurement but is an expensive piece of equipment. Deploying hundreds of AUVs with DVLs on each could significantly increase costs.

This proposal focuses on leveraging the heterogeneity of sensors across a team of AUVs to enhance overall performance and optimize costs. The research aims to explore how distributed sensor data, ranging from Doppler Velocity Logs and Inertial Measurement Units (IMUs) to cameras and acoustic sensors, can be integrated and utilized to improve navigation accuracy and task efficiency.

The primary objective of this research is to develop a framework for the integration and utilization of heterogeneous sensor data within a team of AUVs. This includes designing algorithms that effectively fuse data from various sensors to enhance the situational awareness of the AUV team. Additionally, developing a distributed navigation system that allows AUVs to share and utilize each other's sensor data will improve both individual and collective navigation accuracy [2,3]. The research will also investigate how sensor data heterogeneity can be exploited to optimize task allocation and execution, ensuring that the unique capabilities of each AUV are maximized.

Requirements:

Applicants are expected to have strong programming skills (including Python, C/C++), and good background in control.

References:

1. Liu, G., Chen, L., Liu, K., & Luo, Y. (2023). A swarm of unmanned vehicles in the shallow ocean: A survey. Neurocomputing, 531, 74-86.
2. Li, Q., Ben, Y., Naqvi, S. M., Neasham, J. A., & Chambers, J. A. (2018). Robust Student's *t*-Based Cooperative Navigation for Autonomous Underwater Vehicles. IEEE Transactions on Instrumentation and Measurement, 67(8), 1762-1777.

3. Fischell, E. M., Kroo, A. R., & O'Neill, B. W. (2019). Single-hydrophone low-cost underwater vehicle swarming. IEEE Robotics and Automation Letters, 5(2), 354-361.
Company name and link (for industrial projects): Graal Tech s.r.l. (www.graaltech.com)
Number of positions available: 1
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Scholarship Amount: • Fascia 4: 19,500 €/year