I-RIM

PhD Course in

ROBOTICS AND INTELLIGENT MACHINES

Curriculum: 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 play a crucial role in technological development and design.

The 15 research themes offered in the second call of this year by the Italian Institute of Technology (IIT) and Università degli Studi di Genova as part of this curriculum will be assigned to the best applicants to each of the 14themes offered (**please check the number of positions available for each theme**).

Theme 1 addresses self-learning strategies where robots can autonomously learn and refine their perception models using diverse sensory data, including the use of large language models (LLMs) and multimodal models (LMMs) with zero-shot capabilities..

Themes 2 and 3 explore the coupling of soft materials, sensory transduction, neuromorphic circuits for sensory encoding and computation, and soft actuation, towards the design of robots that can seamlessly and gently interact with their environment. However, theme 2 will specifically develop spiking neural networks for processing tactile signals from octopus's suckers during manipulation and guiding the movement of its arm in response to external stimulation. Theme 3 will focus on the design of neuromorphic circuits on flexible substrate for encoding tactile and proprioceptive sensory signals into spike trains and pre-process such signals in a distributed system.

Theme 4 will investigate miniaturizable solutions for embeddable valves and other suction cup actuation methods that can comply with soft bodies and enable controlled detachment of the grasping. The work will integrate with existing octopus-inspired robotic arms that have distributed sensing localized in the suction cups.

Theme 5 will create control strategies for a multi-arm robotic system operating in marine environments. It involves coordinating the arms, determining the best way to grasp various objects, and handling delicate samples. One key aspect is exploring techniques for minimal object reconstruction to enable safe and secure object manipulation.

Theme 6 will investigate the principles and the fundamental nature of soft robotics, aiming at the proposition of functional devices that embody part of their control logic and expected behavior in the form of mechanical intelligence. The candidate will build upon the group's experience on the design, realization and application of Soft Synergetic hands and Variable Impedance Actuators.

Theme 7 (two positions available) will develop new geometric or machine learning methods for terrain/environment reconstruction and semantics that will be explored to realize autonomous navigation skills to permit mobile wheeled or legged manipulation platforms to move around in unstructured terrains and environments, performing loco-manipulation actions to reach the targeted locations and deliver the transported goods.

Theme 8 will explore solutions to detect, recognize and track different targets and obstacles in real-time to reliably operate in the complex and dynamic marine environment, where environmental disturbances (winds, waves, and currents), sea fog, lighting conditions, and water reflection, have a great impact on the performance of the perception system

Theme 9 will focus on developing software and algorithms for robotics in collaboration with INAIL Centro Protesi Vigorso di Budrio. The student will work on clinical validation with patients to improve the robot's control and sensory feedback. The research involves designing experiments to enhance the naturalness of robot control and sensory feedback for better user experience.

Theme 10 will focus on designing and developing advanced mechatronic solutions for a soft lower limb exoskeleton. This includes in-depth analysis, simulations, and optimization of the actuation design, control architecture, and integration of elastic elements like Series Elastic Actuators (SEAs). They will also explore sensor integration for functional control. The research

will involve testing the physical machine in real-world conditions to refine the design and gain valuable scientific insights.

Theme 11 will focus on robust locomotion on rough terrain with quadruped manipulators when performing Human-Robot and Robot-Robot collaborations and other challenging manipulation tasks. The thesis project will explore aspects related to quadruped robot motion planning, static and dynamic locomotion stability, and H-R and R-R interaction efforts.

Theme 12: will focus on machine-learning based perception for quadruped robot locomotion. The thesis project will explore different network architectures and learning modalities to perform precise terrain classification or segmentation, discerning dangerous areas which cannot be traversed by the robot.

Theme 13 aims to develop two grippers inspired by two elephant species, based on existing biological data and by potentially conducting safe interaction experiments with the animals. Advanced technologies will be used like soft 3D/4D printing and architected materials. These grippers will be tested in both air and water environments, with the goal of creating new solutions for grasping and manipulating objects in these settings.

Theme 14 aims to create advanced soft grippers driven by specific applications. Different approaches soft actuation solutions will be evaluated to adapt the gripper's mechanical response to object size and shape. Soft tactile sensors will be integrated for feedback. The goal is to develop a system capable of successfully grasping various objects without causing damage, with applications in agriculture, waste sorting, assisting in lifting heavy loads, and potential integration into mobile robotic platforms.

Theme 15 (position reserved for foreign state scholar) aims to develop and utilize real-time 3D reconstruction and tracking of dynamic remote scenes and objects; real-time rendering of complex remote information in an immersive MR interface; deep learning for semantic remote scene understanding.

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

1. Self-supervised learning and reinforcement learning using large multi-modal models (LMM) for active vision tasks – Italian Institute of Technology

Curriculum: Robotics and Intelligent Machines for Hostile and unstructured environments

Hosting Institution

Istituto Italiano di Tecnologia

Department:

Humanoid Sensing and perception (https://hsp.iit.it) and Pattern Analysis and Computer Vision (https://pavis.iit.it/)

Tutor(s):

Lorenzo Natale lorenzo.natale@iit.it
Alessio Del Bue alessio.delbue@iit.it
Pietro Morerio pietro.morerio@iit.it

Description:

Modern Deep Learning methods demonstrate impressive performance in various tasks, however, require large amount of training data. These methods are effective in those applications that can leverage Internet data, or training data acquired in simulated environment, but are less effective in those cases in which data is scarce, like robotics. In addition, standard closed-set models will likely fail in an open-world scenario, where robots encounter diverse and unpredictable environments (e.g., unknown objects or unpredictable human behaviours). Active vision and active learning methods have been proposed as a way to empower robots with the capability to actively explore the environment gather pertinent sensory information to solve a given task.
This Ph.D. topic investigates self-learning as a core strategy for an agent to autonomously learn and refine their perception models based on heterogeneous – possibly multimodal – observations. We leverage the zero-shot capabilities of LLMs and LMMs that can be exploited to boost robot skills and investigate methods that conveniently intertwine exploration and learning to complement pre-trained knowledge with information relevant to solve a given task. Possible applications include visual guided robot navigation and task oriented object manipulation.

Requirements:

The ideal candidate would have a degree in Computer Science, Engineering or related disciplines, with a background in Robotics and Computer Vision. They would also be highly motivated to work on robotic platform and have computer programming skills with C++ and/or Python. Background in machine learning and deep learning would be considered a plus.

References:

- D. S. Chaplot, M. Dalal, S. Gupta, J. Malik, and R. Salakhutdinov, “SEAL: Self-supervised embodied active learning using exploration and 3d consistency,” in Thirty-Fifth Conference on Neural Information Processing Systems, 2021.
- S. K. Ramakrishnan, D. Jayaraman, and K. Grauman, “An exploration of embodied visual exploration,” 2020.
- D. Gordon, A. Kembhavi, M. Rastegari, J. Redmon, D. Fox, and A. Farhadi, “Iqa: Visual question answering in interactive environments,” in Proceedings of the IEEE conference on computer vision and pattern recognition, 2018, pp. 4089–4098.

Number of positions available:

1

Main Research Site

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

Contacts:

Email: lorenzo.natale@iit.it, alessio.delbue@iit.it, pietro.morerio@iit.it

Funding Scheme:
This doctorate grant is funded by the Italian Institute of Technology

2. Neuromorphic distributed intelligence for soft robots – computation with spiking neural networks for haptic perception and closed loop control of soft robots – Italian Institute of Technology

Curriculum: Hostile and unstructured environments

Hosting Institution

Istituto Italiano di Tecnologia

Department:

Event Driven Perception for Robotics https://edpr.iit.it

Tutor(s):

Chiara Bartolozzi: chiara.bartolozzi@iit.it

Barbara Mazzolai; barbara.mazzolai@iit.it

ISTITUTO ITALIANO DI TECNOLOGIA

Description:

Neuromorphic engineering exploits the physics of microelectronic circuits to implement efficient computation inspired on neural systems. In a similar fashion, biomimetic soft robotics exploits the physics of materials to implement intelligent sensors and actuators that can smoothly interact with the external world and express intelligent behaviour. We aim at coupling soft materials, sensory transduction, neuromorphic circuits for sensory encoding and computation, and soft actuation, towards the design of robots that can seamlessly and gently interact with their environment.

We will study the trade-off between local and distributed processing with materials and neuromorphic circuits for sensory acquisition [1,2,3] and pre-processing and centralised computation [4]. We will specifically develop spiking neural networks for processing tactile signals from octopus's suckers [5] during manipulation and guiding the movement of its arm in response to external stimulation.

This theme will be co-tutored with Prof. B. Mazzolai, head of the Bioinspired Soft Robotics lab in IIT.

Requirements:

We are looking for talented and motivated candidates, with a degree in Computer Science, Engineering, or related disciplines, with a background in Soft Robotics, Neuromorphic Engineering, or Computational Neuroscience

Computer programming skills with C++ and/or Python, teamworking, and passion are much appreciated.

References:

[1] Janotte E. et al., Neuromorphic capacitive tactile sensors inspired by slowly adaptive mechanoreceptors, NEWCAS 2022, DOI: 10.1109/NEWCAS52662.2022.9841988

[2] Muller-Cleve S.F. et al. Braille letter reading: A benchmark for spatio-temporal pattern recognition on neuromorphic hardware, Frontiers in Neuroscience, DOI: 10.3389/fnins.2022.951164

[3] Dabbous A. et al. Artificial bio-inspired tactile receptive fields for edge orientation classification, ISCAS 2021, DOI: 10.1109/ISCAS51556.2021.9401749

[4] Bartolozzi C., Indiveri G., Donati E., Embodied neuromorphic intelligence, Nature Communications, DOI: 10.1038/s41467-022-28487-2

[5] Shahabi, Ebrahim, et al. "Octopus-Inspired Suction Cups with Embedded Strain Sensors for Object Recognition." Advanced Intelligent Systems 5.2 (2023): 2200201.

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 funded by the Italian Institute of Technology

3. Neuromorphic distributed intelligence for soft robots – design of neuromorphic circuits on flexible substrates for sensing and computation – Italian Institute of Technology

Curriculum: Hostile and unstructured environments

Hosting Institution

Istituto Italiano di Tecnologia

Department:

Event Driven Perception for Robotics https://edpr.iit.it

Tutor(s):

Chiara Bartolozzi: chiara.bartolozzi@iit.it
Lucia Beccai : lucia.beccai@iit.it

ISTITUTO ITALIANO DI TECNOLOGIA

Description:

Neuromorphic engineering exploits the physics of microelectronic circuits to implement efficient computation inspired on neural systems. In a similar fashion, biomimetic soft robotics exploits the physics of materials to implement intelligent sensors and actuators that can smoothly interact with the external world and express intelligent behaviour. We aim at coupling soft materials, sensory transduction, neuromorphic circuits for sensory encoding and computation, and soft actuation, towards the design of robots that can seamlessly and gently interact with their environment.

We will study the trade-off between local and distributed processing with materials and neuromorphic circuits for sensory acquisition [1,2,3] and pre-processing and centralised computation [4]. We will focus on the design of neuromorphic circuits on flexible substrate for encoding tactile and proprioceptive sensory signals into spike trains and pre-process such signals in a distributed system.

This theme will be co-tutored with Prof. L. Beccai, head of the Soft BioRobotics Perception lab in IIT.

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] Janotte E. et al., Neuromorphic capacitive tactile sensors inspired by slowly adaptive mechanoreceptors, NEWCAS 2022, DOI: 10.1109/NEWCAS52662.2022.9841988

[2] Muller-Cleve S.F. et al. Braille letter reading: A benchmark for spatio-temporal pattern recognition on neuromorphic hardware, Frontiers in Neuroscience, DOI: 10.3389/fnins.2022.951164

[3] Dabbous A. et al. Artificial bio-inspired tactile receptive fields for edge orientation classification, ISCAS 2021, DOI: 10.1109/ISCAS51556.2021.9401749

[4] Bartolozzi C., Indiveri G., Donati E., Embodied neuromorphic intelligence, Nature Communications, DOI: 10.1038/s41467-022-28487-2

Number of positions available: 1

Main Research Site

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

Contacts:

Chiara Bartolozzi: chiara.bartolozzi@iit.it

Funding Scheme: This doctorate grant is funded by the Italian Institute of Technology

4. Soft Robotics Technologies for Marine Environment – Italian Institute of Technology

Curriculum: Hostile and unstructured environments

Hosting Institution

Istituto Italiano di Tecnologia

Department:

Bioinspired Soft Robotics (https://bsr.iit.it)

Tutor(s):

Barbara Mazzolai <barbara.mazzolai@iit.it>

Description:

Soft robotics aims at developing new devices that can actively interact with real-world environments and can undergo large deformations relying on inherent or structural compliance [1]. In this view, soft-bodied animals have often been taken as a model for the capability to adapt and deform their bodies to unstructured environments [1],[2]. To this aim, the octopus, with its eight soft arms endowed with suckers, is particularly interesting for its unique biomechanical properties that combine the ability to exert considerable high force with the one to sense the environment and manipulate objects [3]. The morphology and biomechanical properties of suckers allow the octopus to adhere to all nonporous surfaces and generate very high attachment forces [4]. Soft, sensorized suction cups that can recognize different object features have recently been developed [5].

This project aims to add actuation capabilities to the sensorized suction cup for implementing local feedback control for object grasping and integrating it into an octopus-inspired soft arm. Activities of the project include investigating miniaturized solutions for embeddable valves and other suction cup actuation methods that can comply with soft bodies and enable controlled detachment of the grasping. The work will integrate with existing octopus-inspired robotic arms that have distributed sensing localized into the suction cups.

Requirements:

The ideal candidate would have a degree in Mechanical engineering, Mechatronic engineering, Robotics, Bioengineering, or related disciplines. They would also be highly motivated to work on robotic platforms and lean to approach bioinspired and biomimetic systems. Background in fast prototyping, molding, 3D printing, casting, and Soft Robotics would be considered a plus.

References:

[1] S. Kim, C. Laschi, and B. Trimmer, “Soft robotics: a bioinspired evolution in robotics,” Trends in biotechnology, vol. 31, no. 5, pp. 287–294, 2013.

[2] C. Laschi, B. Mazzolai, and M. Cianchetti, “Soft robotics: Technologies and systems pushing the boundaries of robot abilities,” Science Robotics, vol. 1, no. 1, p. eaah3690, 2016.

[3] B. Mazzolai, A. Mondini, F. Tramacere, G. Riccomi, A. Sadeghi, G. Giordano, E. Del Dottore, M. Scaccia, M. Zampato, S. Carminati. Octopus-inspired soft arm with suction cups for enhanced grasping tasks in confined environments. Advanced Intelligent Systems. 2019 Oct;1(6):1900041.
[4] A. M. Smith, "Negative pressure generated by octopus suckers: a study of the tensile strength of water in nature," Journal of Experimental Biology, no. 157, pp. 257–271, 1991.
[5] Shahabi, E., Visentin, F., Mondini, A., & Mazzolai, B. (2023). Octopus-Inspired Suction Cups with Embedded Strain Sensors for Object Recognition. Advanced Intelligent Systems, 5(2), 2200201.

Number of positions available: 1

Main Research Site

Istituto Italiano di Tecnologia, Center for Convergent Technologies, Genova

Contacts:

Email: barbara.mazzolai@iit.it

Funding Scheme: This doctorate grant is funded by the Italian Institute of Technology.

5. Multi-arm Control for Underwater Manipulation – Italian Institute of Technology

Curriculum: Hostile and Unstructured Environments

Hosting Institution
Istituto Italiano di Tecnologia

Department:
Bioinspired Soft Robotics (https://bsr.iit.it)

Tutor(s):
Barbara Mazzolai: barbara.mazzolai@iit.it

Description:
Soft robotics aims at developing new devices that can actively interact with real-world environments and can undergo large deformations relying on inherent or structural compliance [1]. In this view, soft-bodied animals have often been taken as a model for the capability to adapt and deform their bodies to unstructured environments [1],[2]. To this aim, the octopus, with its eight soft arms endowed with suckers, is particularly interesting for its unique biomechanical properties that combine the ability to exert considerable high force with the one to sense the environment and manipulate objects [3].
The manipulation capability of an individual robotic arm can be augmented by integrating multiple octopus-inspired robotic arms in a single end effector.
This project aims to develop control strategies for such a multi-arm robotic system to coordinate arms' movements, define the optimal grasping strategy given different objects, and manipulate delicate samples in marine environments. Activities of the project include investigating strategies for minimal object reconstruction to allow grasping and handling of the objects safely and firmly.

Requirements:
The ideal candidate would have a degree in Robotics, Mechatronic engineering, Software engineering, Computer science, or related disciplines. They would also be highly motivated to work on robotic platforms and lean to approach bioinspired and biomimetic systems.

References:

[1] S. Kim, C. Laschi, and B. Trimmer, "Soft robotics: a bioinspired evolution in robotics," Trends in biotechnology, vol. 31, no. 5, pp. 287–294, 2013.
[2] C. Laschi, B. Mazzolai, and M. Cianchetti, "Soft robotics: Technologies and systems pushing the boundaries of robot abilities," Science Robotics, vol. 1, no. 1, p. eaah3690, 2016.
[3] B. Mazzolai, A. Mondini, F. Tramacere, G. Riccomi, A. Sadeghi, G. Giordano, E. Del Dottore, M. Scaccia, M. Zampato, S. Carminati. Octopus-inspired soft arm with suction cups for enhanced grasping tasks in confined environments. Advanced Intelligent Systems. 2019 Oct;1(6):1900041.

Number of positions available:
1

Main Research Site
Istituto Italiano di Tecnologia, Center for Convergent Technologies, Genova

Contacts: Email: barbara.mazzolai@iit.it
Funding Scheme: This doctorate grant is funded by the Italian Institute of Technology.

6. Soft Robotics for Human Cooperation and Rehabilitation – Italian Institute of Technology

Curriculum: Hostile and unstructured environments

Hosting Institution:
Istituto Italiano di Tecnologia

Research Lab:
Soft Robotics for Human Cooperation and Rehabilitation (https://softbots.iit.it/it/)

Tutor(s):
Antonio Bicchi: antonio.bicchi@iit.it
Manuel G. Catalano: manuel.catalano@iit.it
Giorgio Grioli: giorgio.grioli@iit.it

Description:
The Ph.D. student will investigate the design, modelling and control of robotic systems and of intelligent machines. The candidate will draw inspiration from the study of natural systems and from the application of the most modern and promising technologies, to develop a framework of human-centred devices and system that will find application in the widest range of fields, ranging from collaborative industrial robotics to prosthetics. In particular, the candidate results should apply to the emerging field of Bionics and bionic avatars. The student will investigate the principles and the fundamental nature of soft robotics, aiming at the proposition of functional devices that embody part of their control logic and expected behavior in the form of mechanical intelligence. This should facilitate interaction with different scenarios and with humans, and drastically reduce the complexity of the system control. In addition, the student will investigate problems bond to the technological limitations of producing, actuating and sensing soft robotic systems. The candidate will build upon the group's experience on the design, realization and application of Soft Synergetic hands and Variable Impedance Actuators.

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 soft robotics design, modelling and control are welcome but not required

References:
[1] G. Lentini,..., G. Grioli, M.G. Catalano, and A. Bicchi "Alter-Ego: A Mobile Robot With a Functionally Anthropomorphic Upper Body Designed for Physical Interaction," in IEEE Robotics & Automation Magazine, vol. 26, no. 4, pp. 94-107, Dec. 2019, doi: 10.1109/MRA.2019.2943846.
[2] Piazza, Cristina, et al. "Toward an adaptive foot for natural walking." 2016 IEEE-RAS 16th International Conference on Humanoid Robots (Humanoids). IEEE, 2016.
[3] Grioli, Giorgio, et al. "Variable stiffness actuators: The user's point of view." The International Journal of Robotics Research 34.6 (2015): 727-743. 17

[4] Della Santina, Cosimo, et al. "Toward dexterous manipulation with augmented adaptive synergies: The pisa/iit softhand 2." IEEE Transactions on Robotics 34.5 (2018): 1141-1156.
[5] Catalano, Manuel G., et al. "Adaptive synergies for the design and control of the Pisa/IIT SoftHand." The International Journal of Robotics Research 33.5 (2014): 768- 782

Number of position available:
1

Main research site:
Istituto Italiano di Tecnologia, Center for Robotics and Intelligent Systems, Genova

Contacts:
Antonio Bicchi: antonio.bicchi@iit.it

Funding scheme:
This doctorate grant is funded by the Italian Institute of Technology.

7. Autonomous Loco-manipulation planning for logistics mobile robots – Italian Institute of Technology (2 positions)

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

Description:

This research topic concentrates on the development of autonomous loco-manipulation capabilities required to support the application of robotics in logistics scenarios and in particular in the delivery of objects directly to customers in urban or rural environments, involving navigation in complex environments, human-robot interaction and learning from the environment in order to make the delivery process more efficient and convenient. Legged-wheeled robots such as CENTAURO and COCERT platforms developed in IIT can permit 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 and obstacles and eventually be able to transfer from indoor to outdoor environments and vice versa.

The aim of this topic is to develop new geometric or machine learning methods for terrain/environment reconstruction and semantics that will be explored to realize autonomous navigation skills to permit these mobile wheeled or legged manipulation platforms to move around in unstructured terrains and environments, performing loco-manipulation actions to reach the targeted locations and deliver the transported goods. This will require the ability to interpret semantics (e.g., zebra crossings, sidewalks, doors, etc.) and include dynamic obstacles such as humans or cars. Such semantics information will be explored for autonomous mobility planning (path planning, wheeled/leg motion planning, foot placement, etc.) and eventually autonomous manipulation (object and environment feature and interfaces recognition and manipulation strategy selection).

Several exteroceptive (stereo/event/RGB cameras, RGB-D sensors, 2D/3D Lidar scanners) will be fused to acquire RGB images and dense 3D point cloud while geometric simplifications for reasoning will be explored. Moreover, mobility and manipulation planning methods will be developed to select and modulate suitable primitives/strategies for the navigation and manipulation of the encountered environment and objects to manipulate.

Requirements:

This topic lies in the intersection of Vision and Robotics. Ideal applicants should have strong 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., Raghavan V.S., Antonucci D., Tsagarakis N.G., Autonomous Obstacle Crossing Strategies for the Hybrid Wheeled-Legged Robot Centauro, Frontiers in Robotics and AI, Vol. 8, 2021.
- 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: 2

Main Research Site

Istituto Italiano di Tecnologia, Center for Robotics and Intelligent Systems, 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/)under Grant Agreement No 101070596

8. Situational Awareness in Maritime Environments – Università di Genova

Curriculum: Robots and Intelligent Machines Robotics in hostile and unstructured environments	
Hosting Institution University of Genova	
Department: DIBRIS, Department of Informatics, Bioengineering, Robotics and Systems Engineering	
Tutor(s): Prof. Enrico Simetti (UNIGE) Prof. Francesca Odone (UNIGE)	

Description:

Recently, there has been considerable interest in the development of unmanned surface vehicles (USVs) due to their increasing demand in various maritime applications. One of the main capabilities that unmanned vehicle must be endowed with is a robust, reliable, effective and real-time guidance, navigation, and control (GNC) system. The ability to detect, recognize and track different targets and obstacles in real-time is strongly required in order to reliably operate in the complex and dynamic marine environment, where environmental disturbances (winds, waves, and currents), sea fog, lighting conditions, and water reflection, have a great impact on the performance of the perception system.

The research activity will involve the use of different sensors (LiDAR, Thermal Cameras, Electrooptical Cameras, IMU) to construct and update a world model of what is around the ASV. This model will be then used in the GNC scheme to allow the ASV to move safely in the area.

The research will exploit the ULISSE catamaran, made by UniGe.

Requirements:

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

References:

[1] Mina Sorial, Issa Mouawad, Enrico Simetti, Francesca Odone, Giuseppe Casalino, Towards a Real Time Obstacle Detection System for Unmanned Surface Vehicles, OCEANS 2019, Seattle

[2] Farahnakian, F., Poikonen, J., Laurinen, M., & Heikkonen, J. (2019, October). Deep convolutional neural network-based fusion of RGB and IR images in marine environment. In 2019 IEEE Intelligent Transportation Systems Conference (ITSC) (pp. 21-26). IEEE.

Company name and link (for industrial projects): -
Number of positions available: 1
Main Research Sites DIBRIS Department, GRAAL (Genoa Robotics and Automation Lab), Via all'Opera Pia 13, Genova, Italy.
Contacts: Email: enrico.simetti@unige.it Email: francesca.odone@unige.it
Funding Scheme: This doctorate grant is funded by Università di Genova.

9. Multimodal Bidirectional Interfaces for Patient-in-the-loop Control of Assistive Robotic Devices - Italian Institute of Technology

Curriculum: Hostile and unstructured environments	
Hosting Institution: Istituto Italiano di Tecnologia	
Research Lab: Rehab Technologies Laboratory (https://rehab.iit.it/)	
Tutor(s): Boccardo Nicolò (nicolo.boccardo@iit.it) Canepa Michele (michele.canepa@iit.it) Matteo Laffranchi (matteo.laffranchi@iit.it)	

Description:
The Rehab Technologies Lab (IIT) is looking for a Ph.D. candidate with an M.Sc. inArtificial Intelligence, Computer Science, Computer Engineering, Robotics Engineering, Biomedical Engineering, or related fields.
The candidate will contribute to developing new software algorithms for bidirectionally interface prosthetics and orthotics devices to the patient. The developed platform will help in closing the loop among the patient sensorimotor system and the advanced robotic devices developed at Rehab Technologies.
Rehab Technologies Lab (Rehab Tech) is coordinated by Lorenzo De Michieli, who has extensive experience in the field of robotic assistive medical devices development, including prosthetics for upper-limb and lower-limb and assistive exoskeletons for upper and lower body districts.
The goal of the project (BioInterNect) is to study novel interfaces between a variety of sensor inputs (Electromyography, Electroneurography, Tactile, Kinematics) with the movement intention and the peripheral nervous system of the patient, in synergy with the control of the assistive robot. These interfaces will be integrated into a modular control platform, using advanced techniques such as Neuromorphic Encoding and Artificial Intelligence, for managing in real-time the bidirectional flow of information among patient and robot.
The PhD will be involved in doing software and algorithm development, as well as clinical validation of the control and feedback strategies with patients, in collaboration with INAIL Centro Protesi Vigorso di Budrio (BO). The PhD student will design experiments concerning the assessment of control and feedback strategies, with the purpose of enhance the naturalness of the robot control and the embodiment of the sensory feedback.

Requirements:
A M.Sc. in Artificial Intelligence, Computer Science, Computer Engineering, Robotics Engineering, Biomedical Engineering, or related fields.
Knowledge of C/C++, Python (strongly preferred for machine learning) and MATLAB environments.
General knowledge of Electronics, laboratory tools and debugging systems.

References:

[1] Laffranchi M., Boccardo N., Traverso S., Lombardi L., Canepa M., Lince A., Semprini M., Saglia J.A., Naceri A., Sacchetti R., Gruppioni E., De Michieli L. (2020). The Hannes hand prosthesis replicates the key biological properties of the human hand, ***Science Robotics***, 5.

[2] Marinelli A., Boccardo N., Canepa M., Domenico D.D., Semprini M., Chiappalone M., Laffranchi M., De Michieli L., Dosen S. (2023). A Novel Method for Vibrotactile Proprioceptive Feedback Using Spatial Encoding and Gaussian Interpolation, ***IEEE Transactions on Biomedical Engineering***.

[3] Marinelli A., Boccardo N., Tessari F., Di Domenico D., Caserta G., Canepa M., Gini G., Barresi G., Laffranchi M., De Michieli L., Semprini M. (2023). Active upper limb prostheses: a review on current state and upcoming breakthroughs, ***Progress in Biomedical Engineering***, 5.

Number of position available:

1

Main research site:

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Contacts:

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Matteo Laffranchi (matteo.laffranchi@iit.it)

Funding scheme:

This doctorate grant is funded by INAIL-IIT for the project BioInterNect

10. Advanced mechatronics for soft robotic lower limb exoskeleton device - Italian Institute of Technology

Curriculum: Hostile and unstructured environments	
Hosting Institution: Istituto Italiano di Tecnologia	
Research Lab: Rehab Technologies Laboratory (https://rehab.iit.it/)	
Tutor(s): Boccardo Nicolò (nicolo.boccardo@iit.it) Traverso Simone (simone.traverso@iit.it) Matteo Laffranchi (matteo.laffranchi@iit.it)	

Description:

The Rehab technologies Lab (IIT) is looking for a Ph.D. candidate with an M.Sc. in robotic engineering, mechatronic engineering, mechanical engineering, or related fields.

Rehab Technologies Lab (Rehab Tech) is coordinated by Lorenzo De Michieli, who has extensive experience in the field of robotic assistive medical devices development, including prosthetics for upper-limb and lower-limb and assistive exoskeletons for upper and lower body districts.

The candidate will contribute to developing new mechatronic actuation solutions for a soft robotic lower limb exoskeleton device, which is going to be designed and manufactured in Rehab Technologies, in collaboration with Heidelberg University and Politecnico di Milano, within the INAIL-IIT project FeatherEXO.

The FeatherEXO Project aims to provide new high-tech robotic tools specifically designed to assist the mobility of the lower limbs in individuals with motor limitations due to muscle weakness and/or partial loss of sensory or motor function, whether of orthopedic or neurological origin. A significant portion of the population, in fact, while not affected by a complete loss of lower limb motor function, requires personalized, modular, and minimally invasive solutions to increase their mobility and independence.

The Ph.D. will be involved in developing and implementing experimental mechatronic solutions on the exoskeleton, also regarding advanced control architectures and related simulations. Deep research for the high-end actuation and control strategies already existing for these kinds of devices is going to be made, getting into the field through the know-how present in both Rehab Technologies.

The Ph.D. student will design and develop high-end mechatronic solutions for a soft lower limb exoskeleton, with deep analysis and simulations regarding the actuation design and the overall control architecture. Elastic elements, like Series Elastic Actuator (SEA), and light structural elements, are going to be approached. There will be the chances to work also on the sensors of the device and their integration in the functional control of the prototype. The results of the Ph.D. design activity will converge into daily tests on the field of the physical machine, giving the opportunity to have direct feedback of the initial concept, to further improve the value of the design and the scientific experience.

Requirements:

A M.Sc. in robotic engineering, mechatronic engineering, mechanical engineering, or related fields. Knowledge of CAD softwares (Creo Parametric - 3D CAD is a plus) and MATLAB environments.

References:

[1] Float exoscheleton (https://rehab.iit.it/float)

[2] Twin exoscheleton (https://rehab.iit.it/twin)

[3] Bodo G., Di Bello P., Tessari F., Buccelli S., Boccardo N., De Michieli L., Laffranchi M. (2022). Comparative Analysis of Inverse Kinematics Methodologies to Improve the Controllability of Rehabilitative Robotic Devices, ***IEEE-RAS-EMBS International Conference on Rehabilitation Robotics (ICORR)***.

[4] Laffranchi M., D'Angella S., Vassallo C., Piezzo C., Canepa M., De Giuseppe S., Di Salvo M., Succi A., Cappa S., Cerruti G., Scarpetta S., Cavallaro L., Boccardo N., D'Angelo M., Marchese C., Saglia J.A., Guanziroli E., Barresi G., Semprini M., Traverso S., Maludrottu S., Molteni F., Sacchetti R., Gruppioni E., De Michieli L. (2021). User-Centered Design and Development of the Modular TWIN Lower Limb Exoskeleton, ***Frontiers in Neurorobotics***, 15.

Number of position available:
1

Main research site:
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Funding scheme:

This doctorate grant is funded by INAIL-IIT for the project FeatherEXO

11. Human-robot and Robot-robot Collaboration with Quadruped Manipulators on Rough Terrain - Italian Institute of Technology

Curriculum: Hostile and unstructured environments

Hosting Institution:
Istituto Italiano di Tecnologia

Department:
Dynamic Legged Systems Lab
http://dls.iit.it

Tutor(s):
Claudio Semini: claudio.semini@iit.it
Victor Barasuol: victor.barasuol@iit.it

Description:

DLS research line performs cutting-edge research and development of legged robots for challenging environments [1,2,3] (https://www.youtube.com/watch?v=pLsNs1ZS_TI). Our projects address inspection, space exploration, precision agriculture (https://www.youtube.com/watch?v=nEyHafcRE_g), disaster response (https://www.youtube.com/watch?v=66ZMUaBLjaM), and other applications.

Quadruped robots are increasingly becoming the first choice when a mobile platform must be selected to perform tasks in unstructured environment or on irregular terrains. Although quadruped locomotion has reached noticeable robustness in challenging scenarios, quadruped loco-manipulation for human-robot (HR) and robot-robot (RR) collaboration must still be exploited. Therefore, the focus of this PhD theme lies on robust locomotion on rough terrain with quadruped manipulators when performing HR and RR collaborations and other challenging manipulation tasks. The PhD student will explore aspects related to motion planning, static and dynamic locomotion stability, and HR and RR interaction efforts. The thesis project is expected to be developed using simulation tools alongside the DLS Locomotion Control Framework, with motion control and planning mostly implemented in C++, and validated experimentally on the quadruped robots of the DLS 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): robotics engineering, control engineering, or mechanical engineering. As technical skills, the student must have solid knowledge of control theory, dynamic systems modelling, robotics, control of robot manipulators, and C++ and Python programming. The candidate must have proven experience with simulation environments (e.g., Matlab/Simulink or Gazebo). Strong experience with real robots, ROS and Gazebo is very welcome.

References:

1. R. Parosi, M. Risiglione, D.G. Caldwell, C. Semini and V. Barasuol, Kinematically-Decoupled Impedance Control for Fast Object Visual Servoing and Grasping on

Quadruped Manipulators IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2023.
2. M. Risiglione, V. Barasuol, D. G. Caldwell, and C. Semini, “A Whole-Body Controller Based on a Simplified Template for Rendering Impedances in Quadruped Manipulators”, IEEE/RSJ Int. Conf. on Intelligent Robots and Systems (IROS), 2022.
3. S. Fahmi, V. Barasuol, D. Esteban, O. Villarreal, and C. Semini, "ViTAL: Vision-Based Terrain-Aware Locomotion for Legged Robots," IEEE Transactions on Robotics, 2023.

Number of position available:
1

Main research site:
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Contacts:
Claudio Semini: claudio.semini@iit.it

Funding scheme:
This doctorate grant is funded by the Italian Institute of Technology

12. Vision-Based Terrain Classification for Quadruped Robots - Italian Institute of Technology

Curriculum: Hostile and unstructured environments

Hosting Institution:
Istituto Italiano di Tecnologia

Department:
Dynamic Legged Systems Lab
http://dls.iit.it

Tutor(s):
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Victor Barasuol: victor.barasuol@iit.it
Giulia Pasquale: giulia.pasquale@iit.it
Lorenzo Natale: lorenzo.natale@iit.it

Description:
The DLS research line performs cutting-edge research and development of legged robots for challenging environments. Our projects address disaster response, space exploration, precision agriculture, inspection and other applications.
In all these scenarios, perception is considered a core component of a robust and precise locomotion controller. Still, human-level capabilities in this sector are far from being achieved by robots. This PhD theme will explore the use of machine learning techniques for vision-based locomotion ([1], [2], [3]). In particular, the PhD candidate will explore different network architectures and learning modalities to perform precise terrain classification or segmentation, discerning dangerous areas which cannot be traversed by the robot. This information will then be exploited to perform safe path-planning and reactive foothold placements.
This project will be carried out in collaboration with IIT's HSP research line, which has extensive expertise in machine learning and artificial perception for robotics.

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 machine learning libraries, e.g. Pytorch or Tensorflow. Experience with ROS is considered a big plus

References:
1. O. A. Villareal 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.

2. S. Fahmi, V. Barasuol, D. Esteban, O. Villarreal and C. Semini, "ViTAL: Vision-Based Terrain-Aware Locomotion for Legged Robots," in IEEE Transactions on Robotics, vol. 39, no. 2, pp. 885-904, April 2023.
3. D. Hoeller, N. Rudin, C. Choy, A. Anandkumar and M. Hutter, "Neural Scene Representation for Locomotion on Structured Terrain," in IEEE Robotics and Automation Letters, vol. 7, no. 4, pp. 8667-8674, Oct. 2022.

Number of position available:
1

Main research site:
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Funding scheme:
This doctorate grant is funded by the Italian Institute of Technology

13. Dexterous grippers inspired from Asian and African elephant distal trunk for dry and wet environment - Italian Institute of Technology

Curriculum: Hostile and unstructured environments

Hosting Institution:
Istituto Italiano di Tecnologia

Department:
Soft BioRobotics Perception Lab

Tutor(s):
Lucia Beccai: lucia.beccai@iit.it
Seonggun Joe: seonggun.joe@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, dry or wet. Investigating the capability to interact with objects through their trunk it is possible to shed light on the different behaviors adopted by this animal, like previously done by our team with 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 multiple objects [2], in air but also in water, by orchestrating the specific movements of the distal trunk. In this project unique anatomical and morphological data of the two kinds of animals will be used to derive the main specifications to design completely new grippers. The research activities will be based on previously gathered data on the biological models but, if needed, it will also be possible to perform experiments on the prehensile behavior with the animals in a safe manner at a specific experimental site, like in [1]. In a second phase, the different kinds of grippers will be developed based on the bioinspired designs. Various technological approaches will be investigated (soft and soft/rigid) to develop the dexterous grippers, also based on architected materials as we previously demonstrated [2]. 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 both in two different environments, air and in water.

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 understand 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).

Number of position available:
1

Main research site:
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Funding scheme:
This doctorate grant is funded by the Istituto Italiano di Tecnologia

14. Sensorized soft hybrid grippers for agricultural and environmental applications - Italian Institute of Technology

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

Description:
Soft grippers are an example of a highly mature branch of soft robotics, where deformable materials are used to safely grasp delicate objects and adapt to complex and variable shapes. Yet, soft materials alone are not sufficient to ensure successful grip and manipulation of a large variety of objects, and new design approaches to mechanics, sensing and control are required for grasping objects with wide different shape, size, weight, stiffness, and surface type. This research project addresses the design and development of grippers that can merge different kinds of materials having different stiffness or architectures with variable stiffness, which are simple to control and yet show versatility and dexterity. Grippers that replicate the hand functionality tend to be extremely complex, expensive, and hard to control. Following an alternative approach, in this project we will leverage architected materials, as well as advanced fabrication techniques to infuse the gripper dexterity into its mechanics and materials, starting from the results of our pioneering study in the field [1].
We will use cutting-edge fabrication technologies (e.g., Soft 3D/4D printing) and mechanical modelling to produce architected materials with fine-tuned mechanical behaviours. Both tendon-driven approach and artificial muscles will be evaluated for integration to operate the gripper and modify its mechanical response adapting it to the object size and shape. Soft tactile sensors [2] will be selected and integrated to provide feedback on the state of the gripper and on the grasped object, enabling a learning-based grasping approach. The final objective is the development of a system that can perform successful grasps of objects having different shape, dimension, and stiffness with enough force to lift and manipulate them at high speed but without damaging them.
Several practical applications will be targeted, such as agricultural robotics [3], to help monitor and harvesting crops of different kinds, sorting of medium/small garbage in difficult-to-reach places, helping humans in lifting heavy weights but also perform precise tasks. There will be also the option of integrating the developed soft grippers in mobile (land or air) robotic platforms to demonstrate some application scenarios.

Requirements:
The successful candidate is strongly motivated to perform research oriented to specific applications that dictate the requirements. The necessary background is an excellent MSc engineering degree in areas of robotics, mechatronics, or equivalent. The prospective

candidate should have solid knowledge of CAD / FEM tools and soft robotics, and good knowledge of soft actuation, soft tactile sensing, hyperelastic materials, 3D printing, casting/moulding methods. Proficiency in spoken and written English is required as well as the propension for working in team.

References:

1. S. Joe, O. Bliah, S. Magdassi, L. Beccai Jointless Bioinspired Soft Robotics by Harnessing Micro and Macroporosity Advanced Science 2302080 (2023).
2. H. Wang, M. Totaro, L. Beccai, Towards Perceptive Soft Robots: Progress and Challenges Advanced Science 5(9):1800541 (2018).
3. F. Bernabei, M. Lo Preti, S. Joe, L. Beccai, Development of a monolithic pneumatic soft actuator for fruit grasping 6th IEEE/RAL Int. Conf. Robosoft 2023 Singapore April 3-7, 2023.

Number of position available:

1

Main research site:

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Contacts:

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Funding scheme:

This doctorate grant is funded by the Istituto Italiano di Tecnologia

15. Real-time Scene Reconstruction and Mixed Reality Interfaces for Immersive Remote Telerobotics – Italian Institute of Technology

Curriculum: Robotics and Intelligent Machines for Hostile and unstructured environments

Hosting Institution

Istituto Italiano di Tecnologia (IIT)

Department:

Advanced Robotics (https://advr.iit.it/)

Tutor(s):

Nikhil Deshpande nikhil.deshpande@iit.it
Darwin G. Caldwell darwin.caldwell@iit.it

Description:

Robotics provides an advanced solution to mitigate risks in extreme work environments (e.g., nuclear, disaster response, etc.), through technologies such as remote telerobotics, advanced 3D perception, and smart sensing and visualization. This PhD research will develop new software systems for an immersive 3D user interaction experience for interfacing with robotic systems (e.g., robotic arms, mobile robots, etc.) The project will use, develop, and integrate advanced technologies in 3D scene reconstruction, robotic manipulation and locomotion, SLAM, and VR / AR / MR towards improving the situational awareness of the operator(s), providing an intuitive and intelligent user interface for robotic teleoperation and monitoring in high-risk environments. During this program, the student will develop and utilize their knowledge in:

- Real-time 3D reconstruction and tracking of dynamic remote scenes and objects;
- Real-time rendering of complex remote information in an immersive MR interface;
- Deep learning for semantic remote scene understanding;

This PhD project will benefit from a strong multidisciplinary approach at the interface of Computer Science and Robotics and will focus on evaluating the usability and user experience aspects for telerobotics using mixed reality.

Requirements:

The ideal candidate would have a degree in Computer Science, Engineering, or other related fields, and it would be beneficial to have relevant competencies in computer vision, coding (C/C++, Python), deep learning algorithms (YOLO, TensorFlow), VR software (Unity, Unreal Engine), and VR hardware devices (HTC Vive, Meta Quest), etc. Experience with robotic software (ROS, Gazebo) and hardware (manipulators, mobile robots) is a plus!

References:

- Y Kim, MCC Silva, S Anastasi, N Deshpande, “Towards Immersive Bilateral Teleoperation using Encountered-type Haptic Interface”, IEEE Systems, Man, and Cybernetics (SMC), 2023
- YT Tefera, D Mazzanti, S Anastasi, DG Caldwell, P Fiorini, N Deshpande, “Towards Gaze-contingent Visualization of Real-time 3D Reconstructed Remote Scenes in Mixed Reality”, Advances in Robotics (AIR), 2023
- YT Tefera, D Mazzanti, S Anastasi, DG Caldwell, P Fiorini, N Deshpande, “FoReCast: Real-time Foveated Rendering and Unicasting for Immersive Remote Telepresence”, ICAT-EGVE 2022

- A Naceri, D Mazzanti, J Bimbo, YT Tefera, D Prattichizzo, DG Caldwell, LS Mattos, N Deshpande, “The Vicarios Virtual Reality Interface for Remote Robotic Teleoperation: Teleporting for Intuitive Tele-manipulation”, Journal of Intelligent & Robotic Systems 101, 1-16, 2021

Number of positions available: 1

Main Research Site:

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Funding Scheme:
This doctorate position is reserved for student recipients of the CSC Scholarship.