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 play a crucial role in technological development and design.

The three fellowships offered in the second call of this year by the Istituto Italiano di Tecnologia, Università degli Studi di Genova, ISME and Bosch as part of this curriculum will be assigned to the best applicants to each of the three themes offered.

Theme number 1 addresses the problem of developing models to specify a robot’s software and deliberation mechanisms as well as relevant features and properties of the environment as the basis for formal verification.

Theme number 2 investigate advantages and disadvantages of event-driven cameras with respect to frame-based cameras in object detection problems, and investigate methods that take advantage of the visual information that can be obtained from both type of sensors.

Theme number 3 explores the possibility of using sonar data underwater to detect, track and avoid obstacles with underwater autonomous vehicles.

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

1. Machine learning for mobile manipulation in dynamic environment

Curriculum: Hostile and unstructured environments

Hosting Institution
Istituto Italiano di Tecnologia

Department:
Humanoid Sensing and Perception

Tutor(s):
Lorenzo Natale

Description:
Humanoid robots are expected to successfully navigate and perform useful tasks like grasping, object manipulation in unstructured environments and in close interaction with humans. To be able to navigate in such situations robots need to be able to adapt online to cope with unexpected, dynamic, obstacles and the presence of humans. In addition the robot should be endowed with algorithms that allow to successfully interact with objects, grasping and manipulating them depending on the task to be performed (i.e. object affordances).
The goal of this project is to advance the capabilities of humanoid robots to interact with the environment, possible topics are:

- Detect humans and anticipate their movement, perform trajectory planning and re-planning for safe navigation;
- Learning how to grasp objects taking into account the task at hand (i.e. object affordances in relation to the task to be performed);
- Learning complex tasks which involve physical interaction with the environment (opening door or a drawer, operating a switch, pushing objects);

This work will be carried out on the humanoid robots available in the Humanoid Sensing and Perception group, the R1 robot, iCub and/or the Panda Arm from Franka Emika.

Requirements:
The ideal candidate would have a degree in Computer Science, Engineering, or related disciplines, with a background in Robotics. They would also be highly motivated to work on robotic platform and have computer programming skills.

Number of positions available:
1

Main Research Site
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Funding Scheme: This doctorate grant is fully funded by the Italian Institute of Technology

2. Scene perception with frame-based and event-driven visual sensors

Curriculum: Hostile and unstructured environments

Hosting Institution
Istituto Italiano di Tecnologia

Department:
Humanoid Sensing and Perception
Event-Driven Perception for Robotics

Tutor(s):
Lorenzo Natale
Chiara Bartolozzi

Description:

To effectively interact with the environment and adapt to different contexts and goals, robots need to be able to recognize, detect and estimate the pose of objects. Modern deep architectures provide great performance but at high computation cost. Especially with cost effective hardware, deep architectures provide inference at relatively slow frame rate, which is unsuitable in dynamic situations. Event-driven sensors have been proposed as an alternative paradigm to conventional frame-based cameras, because they provide efficient encoding and rich temporal information that can be exploited in those situations in which either the camera or the objects move at fast speed. The goal of this project is to investigate advantages and disadvantages of event-driven cameras with respect to frame-based cameras, and investigate methods that take advantage of the visual information that can be obtained from both type of sensors to solve perception tasks that involve camera or objects motion at high speed. We will investigate methods for multi-modal fusion based on machine learning as well as Bayesian frameworks. Methods will be validated on the iCub humanoid robot.

Requirements:
The ideal candidate would have a degree in Computer Science, Engineering, or related disciplines, with a background in Robotics. They would also be highly motivated to work on robotic platform and have computer programming skills.

References:

- Benosman, R.; Clercq, C.; Lagorce, X.; Sio-Hoi Ieng; Bartolozzi, C., "Event-Based Visual Flow," Neural Networks and Learning Systems, IEEE Transactions on, vol.25, no.2, pp.407,417, Feb. 2014, doi: 10.1109/TNNLS.2013.2273537
- Piga, N., Onyshchuk, Y., Pasquale, G., Pattacini, U., and Natale, L., ROFT: Real-time Optical Flow-aided 6D Object Pose and Velocity Tracking, IEEE Robotics & Automation Magazine, vol. 7, no. 1, pp. 159-166, 2022
- Vasco, V., Glover, A., Mueggler, E., Scaramuzza, D., Natale, L., and Bartolozzi, C., Independent Motion Detection with Event-driven Cameras, in Proc. IEEE International Conference on Advanced Robotics, Hong Kong, 2017, pp. 530-536

Number of positions available:
1

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

3. Underwater Obstacle Detection and Avoidance with Sonar Data

Curriculum: Hostile and unstructured environments

Hosting Institution
UniGe

Department:
ISME / DIBRIS

Tutor(s):
E. Simetti, F. Odone

Description:
The sea is a harsh and hostile environment, which makes the employment of robots very challenging. Despite this fact, there is an increasing interest in the development of marine robots both for civil and military purposes. One of the main challenges when underwater vehicles operate near shore is the development of a reliable obstacle detection and tracking capability. Below the surface, the visibility is often very limited and acoustic sensors such as forward-looking sonar needs to be employed [1].

The goal of this PhD proposal is twofold. On the one hand, the processing of forward-looking sonar data should be developed to develop a reliable detection and tracking of underwater obstacles should be carried out. On the other hand, once the tracking is performed, the vehicle should take this information into account to autonomously avoid the obstacle [2]. The proposal is framed within an on-going research project between ISME and the Italian Navy.

Requirements:
Applicants are expected to have good programming skills (Python and C++) and have good background knowledge in computer vision and machine learning.

References:

- [1] Galceran, E., Djapic, V., Carreras, M., & Williams, D. P. (2012). A real-time underwater object detection algorithm for multi-beam forward looking sonar. IFAC Proceedings Volumes, 45(5), 306-311.
- [2] Petillot, Y., Ruiz, I. T., & Lane, D. M. (2001). Underwater vehicle obstacle avoidance and path planning using a multi-beam forward looking sonar. IEEE journal of oceanic engineering, 26(2), 240-251.

Company name and link (for industrial projects):

Number of positions available:
1

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Funding Scheme: This doctorate grant is fully funded by ISME

4. Mobility Control of Legged and Wheeled Robots – Istituto Italiano di Tecnologia

Curriculum: : Hostile and unstructured environments

Hosting Institution
Istituto Italiano di Tecnologia

Department:
Center for Robotics and Intelligent Systems

Tutor(s):
Nikos Tsagarakis

Description:
The need of mobile manipulation has been tackled in the past with the development of a variety of mobile manipulation systems made by robotic arms installed on mobile bases with the mobility provided by wheel and leg mechanisms. On one hand, wheeled rovers provide optimal solutions for well-structured and relatively flat terrains environments, however, outside of these types of workspaces and terrains their mobility decreases significantly and usually they can only overcome obstacles smaller than the size of their wheels. Compared to wheeled robots, legged robots are more sophisticated to design, build and control but they have obvious mobility advantages when operating in unstructured terrains and environments. This research theme will focus on the development of hybrid locomotion planning strategies for legged/wheeled robotic platforms. Different principles and combinations of leg gaits and wheel mobility trajectories will be developed and evaluated in simulation and finally implemented and validated on different legged and wheeled mobility platforms available in IIT to advance the mobility of these platforms when they have to deal with a range of terrain constraints and disturbances.

Requirements:
We are seeking for highly motivated candidates with a background in Electrical, Control engineering, Physical Sciences or Robotics. Candidates should have strong competencies in robot dynamics, control and excellent programming skills in Matlab and C++. (Programing and Simulation 30%, Dynamics 30%, Control %40). The experience on dynamic simulators (e.g. Gazebo, Webot, RoboTran, etc.) and ROS would be plus.
NOTE: It is compulsory to prepare a research proposal on this topic

References:

- Laurenzi A., Mingo Hoffman E., Tsagarakis N. G., Quadrupedal walking motion and footstep placement through linear model predictive control, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pp 2267-2273, 2018.
- Kashiri et al, CENTAURO: A Hybrid Locomotion and High Power Resilient Manipulation Platform, IEEE Robotics and Automation Letters, Vol: 4, Issue: 2, pp 1595 – 1602, 2019.

Number of positions available:
1

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Funding Scheme: This doctorate grant is funded by EuROBIN .

5. Perception and semantics for Robot Loco-manipulation – Istituto Italiano di Tecnologia

Curriculum: : Hostile and unstructured environments

Hosting Institution
Istituto Italiano di Tecnologia

Department:
Center for Robotics and Intelligent Systems

Tutor(s):
Nikos Tsagarakis

Description:
The problem of mobility planning on cluttered, uneven and eventually dynamic terrains for navigation is the key aspect for completing locomotion in unknown environments. Similarly performing manipulation actions in an autonomous manner and enabling robots interact more richly with the world around them, requires a deeper understanding of the world in which they operate. The aim of this topic is to develop new geometric or machine learning (e.g. deep learning) methods for environment reconstruction and semantics that can enable autonomous loco-manipulation and permit mobile wheeled or legged manipulation platforms to move around in unstructured environments and perform loco-manipulation actions. Such semantics information semantics will be explored for autonomous mobility planning (path planning, wheeled/leg motion planning, foot placement) and 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 used to acquire RGB images and dense 3D point cloud while geometric simplifications for reasoning will be explored. Moreover, mobility and manipulation planning methods need to be developed to select and modulate suitable primitives for loco-manipulation. The development and testing will take place on a range of mobile platforms available in IIT

Requirements:
This topic lies in the intersection of Vision and Robotics. Ideal applicants should have strong C++ (Python and Matlab is a plus) programming skills. 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) and the Point Cloud Library (PCL) is a very big plus. The applicants should be fluent in English and team players.
NOTE: It is compulsory to prepare a research proposal on this topic

References:

- 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.
- Kanoulas et. al., Footstep Planning in Rough Terrain for Bipedal Robots using Curved Contact Patches, ICRA 2018.

Number of positions available:
1

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Funding Scheme: This doctorate grant is funded by EuROBIN .

6. Human-Robot Collaborative Control for Legged/Wheeled Mobile platforms – Istituto Italiano di Tecnologia

Curriculum: : Hostile and unstructured environments

Hosting Institution
Istituto Italiano di Tecnologia

Department:
Center for Robotics and Intelligent Systems

Tutor(s):
Nikos Tsagarakis

Description:
The robots are coming out of the cage, and getting closely involved into human life and physically interacting with them to execute tasks in a collaborative manner. This research theme will focus on the development of a collaboration control framework that will permit a human operator to control the mobility and manipulation systems of mobile manipulation platforms remotely. The project will look on the development of human intention estimation modules and supervised/interactive autonomous collaboration controllers that take into account the human high level intention inputs detected by multimodal interfaces to drive the execution of the robot mobility and manipulation actions. Autonomous motion and impedance regulation principles will be applied at the robot side to assist the human partner in commanding the collaborative behaviours of the robot assistant during physical interactions with the remote environment

Requirements:
We are seeking for highly motivated candidates with a background in Electrical, Control engineering, Physical Sciences or Robotics. Candidates should have strong competencies in robot dynamics, control and excellent programming skills in Matlab and C++. (Programing and Simulation 30%, Dynamics 30%, Control %40). The experience on dynamic simulators (e.g. Gazebo, Webot, etc.) and ROS would be plus.
NOTE: It is compulsory to prepare a research proposal on this topic

References:
L. Peternel, N.G. Tsagarakis, D.G. Caldwell, Darwin and A. Ajoudani", Adaptation of robot physical behaviour to human fatigue in human-robot co-manipulation", IEEE-RAS 16th International Conference on Humanoids, pp489-494, 2017

Number of positions available:
1

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