I-RIM

PhD Course in

ROBOTICS AND INTELLIGENT MACHINES

Curriculum: Robotics and Intelligent Machines for Agrifood

Research themes

The main goal of the Agrifood curriculum is to train scientists and researchers capable of working in multidisciplinary teams on topics related to state-of-the-art solutions for a modern agriculture that is resilient to climate change and able to cope with the increase in demand. Specific research areas include:

1. Automation and integration of human and artificial intelligence with mechanical capabilities to reduce fatigue and health problems related to work and interaction with chemicals, counteracting the shortage of labor in the agricultural and food sectors.

2. Intuitive and natural interfaces that allow farmers, workers, and sellers to manage robots without advanced training.

3. Precision agriculture to provide sufficient agricultural goods to the growing population with clean, climate neutral, sustainable, and responsible techniques.

4. Greater stability and safety of robots in physical interaction with humans and the environment, in the production and sale of agri-food products.

5. Robotic systems capable of carrying out manipulations and locomotion in air, water and on various types of land in the cultivation, collection, and transport of agri-food products.

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

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

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

1. Autonomous Robot for Inspection in Unstructured Environments – Università di Padova

Curriculum: Agrifood

Hosting Institution
Università di Padova

Department:
Dipartimento di Ingegneria dell'Informazione

Tutor(s):
Nicola Bellotto

Description:
This project aims to develop an intelligent autonomous system for monitoring unstructured environments, such as plants and crops in agricultural settings, using a small robot. The platform will integrate various sensors into a low-power embedded system, facilitating exploration of remote or difficult-to-access places. New hardware and software solutions will optimise information collection from places of interest, advancing research in TinyML and embedded AI applied to robotics.

Requirements:
The ideal candidate has a Master degree in Control Systems or Computer Engineering, possibly with other relevant qualifications in electronics or mechatronics engineering. He/she should have demonstrable experience in developing computer vision and machine learning algorithms for embedded systems. The candidate should be fluent in English to present his/her research in international conferences and top-tier outlets. Some professional experience in relevant industrial sectors would be a plus.

References:

- S. M. Neuman et al., "Tiny Robot Learning: Challenges and Directions for Machine Learning in Resource-Constrained Robots," IEEE International Conference on Artificial Intelligence Circuits and Systems (AICAS), Incheon, Korea (2022) pp. 296-299.

Company name and link (for industrial projects):
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Number of positions available:
1

Main Research Site
Università di Padova

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2. Manipulation of fruits and vegetables – Università della Campania

Curriculum: Agrifood

Hosting Institution
Università degli Studi della Campania "Luigi Vanvitelli"

Department:
Dipartimento di Ingegneria

Tutor(s):
Prof. Salvatore Pirozzi

Description:
Within robotics community, the challenge to realize robots even more intelligent and autonomous mainly depends on the capability to pushing the limits of current methodologies and technologies. In the robotic manipulation field, a lot of researchers, inspired by the dexterity of human hand, tackled the development of technological solutions, optimized with the objective to mimic its functionalities. Our main objective is to develop a multi-modal sensing system for multi-fingered robotic grippers to be implemented on-board together with several data interpretation and control algorithms suitably developed. The idea is to develop a multi-modal sensing system, constituted by optoelectronic tactile sensors, Time-of-Flight proximity sensors, and 2D/3D cameras, to be integrated in compliant fingers or gripper case. For control design, will be developed controllers embedded in the manipulation device that can use multiple sensor types fusing the information to extract relevant object manipulation features.
Manipulation of fruits and vegetables. The harvesting and distribution of fruits and vegetables from farm to fork is an articulated task, involving different market sectors. The whole procedure can be divided in several phases and a lot of them imply the manipulation at high speed of fruits and vegetables very different (e.g., in terms of size, shape, weight) and without damaging the products, e.g., in the packaging phase immediately after fruit and vegetables harvest for shipment to distribution centres, and in the distribution centres themselves for the sorting to supermarkets. Only for the latter, a robotic system designed to tackle this task has to be able of picking a wide range of different objects in any orientation and of storing them in specific orientations, inside a crate with many other objects. Current commercial solutions are conceptually simple, and they are mainly conceived for a single product, and adaptation to other products is often not possible or, if possible, it may require long time, high costs and experts to redesign at least partially the system both from software and hardware point of view.
We aim at developing a multi-modal sensing system for multi-fingered robotic grippers, with the sensors' feedback required for the on-board integration of control modalities suitably designed to allow the manipulation of fruits and vegetables without causing damage to the product surface, and with the capability to adapt the grasp to a high number of possible product variant in terms of size, shape, weight, and surface properties. For example, the use of an anthropomorphic robotic hand during the grasping of a strawberry, without a force/tactile feedback makes very difficult the task execution without the fruit damage, and practically impossible its generalization to fruits of different shape and size. The introduction of feedback solution, such as the tactile sensors becomes fundamental. Additionally, the use of vision and proximity sensors directly on-board can be exploited to increase the gripper capabilities in the manipulation within the reduced space available in the crates and in cluttered scene constituted by products of different colours.

Challenge. Improving the robotic grasping capabilities during the pick and place of loose fragile items, such as delicate fruits and vegetables, by exploiting a multi-sensorized gripper developed during the PhD, by:

- picking from a dense environment understating relationship between objects and detecting feasibility;
- reduce the damage to delicate fruits and vegetables imposed during grasp;
- pack with a certain orientation depending on the task requirements;

Requirements:
We are looking for a highly motivated, creative, and ambitious student, able to work in a team as well as independently. The candidate should fulfill, at least partially, the following requirements:

- Successfully completed scientific university degree in Computer Science, Robotics, Automatic Controls, Mechatronics Engineering, or other closely-related discipline
- Experience in sensor development, mechatronic design, control techniques
- Good knowledge and experience in robotics and manipulation
- Experience in development of control algorithms and embedded platforms
- Experience with Matlab, Python, C++, Fusion360
- Experience in composing academic and technical writing pieces (papers, deliverables, etc.)

References:

- Cirillo, A., et al., Proximity Sensor for Thin Wire Recognition and Manipulation. Machines, MDPI, 9, 188, 2021.
- Cirillo, A., et al., Tactile Sensor Data Interpretation for Estimation of Wire Features. Electronics, MDPI, 10, 1458,2021
- De Gregorio, D. et al., Integration of robotic vision and tactile sensing for wire-terminal insertion tasks, IEEE T-ASE, 16(2), 2019.
- Costanzo M., et al.. Two-Fingered In-Hand Object Handling Based on Force/Tactile Feedback. IEEE T-RO, 36.1, 157-173, 2020.
- Costanzo M., et al.. Tactile Feedback Enabling In-Hand Pivoting and Internal Force Control for Dual-Arm Cooperative Object Carrying. IEEE RAL, 7(4), pp. 11466-11473, 2022.

Company name and link (for industrial projects):

Number of positions available:
1

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3. Robotic devices for horticulture fertilization and monitoring – Politecnico di Torino

Curriculum: Agrifood

Hosting Institution
Politecnico di Torino

Department:
Department of Mechanical and Aerospace Engineering

Tutor(s):
Carmen Visconte

Description:
The research program aims at developing robotic devices to be used in agriculture, to improve automation and to reduce the waste during the plant treatment phase, according to the precision agriculture paradigm. An applied and multidisciplinary research activity will be required.
Innovative robotic devices will be addressed to the following tasks:

- Autonomous motion through the plant rows.
- Remote monitoring of the plant, to detect the presence of pests and diseases.
- Transport and handling of liquid/solid fertilizers or specific treatments, to be applied only where and when it is necessary.

Requirements:
Applicants are expected to have a prominent interest in the field of design of innovative robotic applications, which by nature declines into complex mechatronic systems. Thus, he/she must confidently handle all the involved aspects:

- Mechanical design skills are of uttermost importance, in particular a marked proneness to strictly defined methodological design processes.
- Electrical, mechatronic and control basic skills are required.
- A good attitude to experimental work is expected. The ability to collect and critically observe numerical and phenomenological results is mandatory.

At last, it is worth remarking that such a transversal project requires a plurality of soft skills essential to guarantee an advantageous cooperation with the work team, as well as the dissemination of the research results.

References:

- Lars Grimstad, Pål Johan From. “The Thorvald II Agricultural Robotic System”. Robotics 6(4): 24, 2017.
- G. Bagagiolo, G. Matranga, E. Cavallo, N. Pampuro. "Greenhouse Robots: Ultimate Solutions to Improve Automation in Protected Cropping Systems—A Review". Sustainability 14 (11): 6436, 2022.

- G. Quaglia, C. Visconte, L. S. Scimmi, M. Melchiorre, P. Cavallone, S. Pastorelli. "Design of a UGV powered by solar energy for precision agriculture”".Robotics 9(1): 13, 2020.
- C. Cruz Ulloa, A. Krus, A. Barrientos, J. del Cerro, C. Valero. “Trend Technologies for Robotic Fertilization Process in Row Crops”. Frontiers in Robotics and AI 9, 2022.

Number of positions available:
1

Main Research Site
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