



UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

itee_{PhD}
information technology
electrical engineering



Francesca Pagano

Study of a multi-robot system in a shared autonomy
framework applied to precision agriculture

Tutor: Prof. Vincenzo Lippiello

Cycle: XXXVII

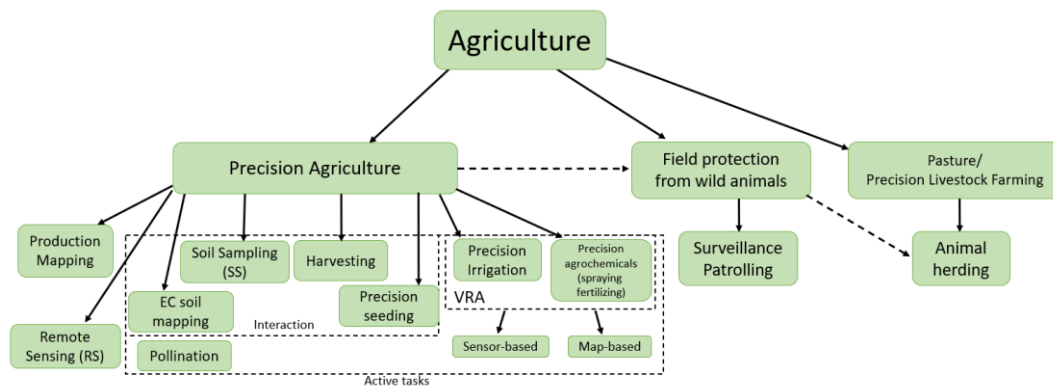
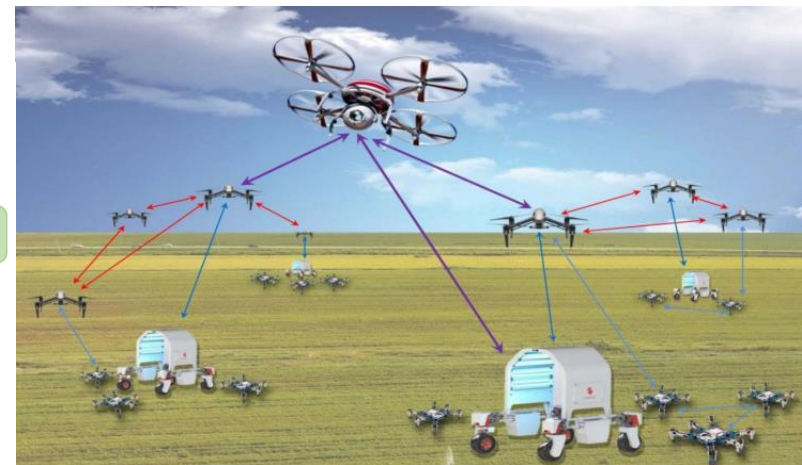
Year: First

My background

- M.Sc. in Automation Engineering, Università degli Studi di Napoli Federico II
- Research group: PRISMA Lab
- PhD start date: 01/01/2022
- Scholarship type: PON
- Partner company: Società Agricola “Lenza Lunga” dei F.lli Cacciapuoti

Research field of interest

- Research topic:
Study of a heterogeneous multi-robot system for precision agriculture.
- Possible applications:
 - coordinate remote sensing,
 - crop monitoring,
 - persistent surveillance.



Summary of study activities

- Ad hoc PhD courses:
 - Operational Research: Mathematical Modelling, Methods and Software Tools for Optimization Problems, *Prof. Adriano Masone*,
 - Probability calculus and elements of stochastic modelling, *Prof. Massimiliano Giorgio*,
 - Matrix Analysis for Signal Processing with MATLAB Examples, *Prof. A. De Maio, Prof. A. Aubry, Dr. V. Carotenuto*,
 - Theory and Applications of Contracting Dynamical Systems, *Prof. Francesco Bullo*.
- Courses borrowed from MSc curricula:
 - Control of Complex Systems and Networks, *Prof. Pietro De Lellis*,
 - Robotics Lab, *Prof. Jonathan Cacace*.
- Summer School:
 - IEEE RAS Summer School on Multi-Robot Systems 2022, *Czech Technical University of Prague*.



Summary of study activities

- Seminars:
 - Application of simultaneous block diagonalization of matrices to problems in Controls and Nonlinear Dynamics, *Prof. F. Sorrentino*,
 - IEEE Authorship and Open Access Symposium: Tips and Best Practises to Get Published from IEEE Editors,
 - Global and cluster synchronization in complex networks and beyond, *Prof. M. Frasca*,
 - An Introduction to Deep Learning for Natural Language Processing , Explainable Natural Language Inference, *Prof. F. Cutugno*,
 - On using simple optimization techniques for tuning of UAVs, *Prof. F. Ruggiero*.
- Workshops:
 - IEEE-ICRA 2022 workshop: Shared Autonomy in Physical Human-Robot Interaction: Adaptability and Trust,
 - IEEE-IROS 2022 Workshop: “Human-Multi-Robot Systems: Challenges for Real World Applications”.

Research activity: Overview

- Problem

- Use of multiple robots (mainly drones) in agriculture.
- Adoption of a “one-to-many” paradigm (one pilot/multiple drones) as it can reduce time, costs and improve efficiency in real world applications.

- Objective

- Development of control techniques to enable the coordinated execution of multiple prioritized tasks by a team of robots with human interaction and handling energy limitations.
- Target applications: remote sensing and intruder research.

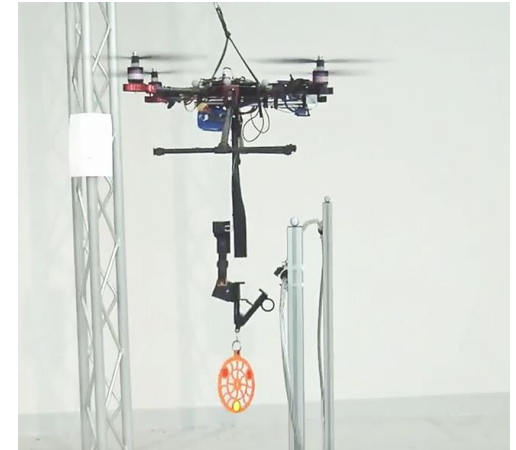
- Methodology

- Solution of Quadratic Problems (QP) with affine constraints and tasks encoded as Control Barrier Functions (CBFs),
- Nonlinear Model Predictive Control.

Research activity during first year

- Study of the State of Art in multi-drone application in agriculture.
- Laboratory activity:
 - Study of PX4 autopilot architecture.
 - Development of a custom flight controller for the insertion of a bird diverter device.
 - Simulation in ROS/Gazebo and flight arena tests.
 - **Future work:** paper writing for submission to a conference.

(work in collaboration with PhD student Simone D'Angelo)

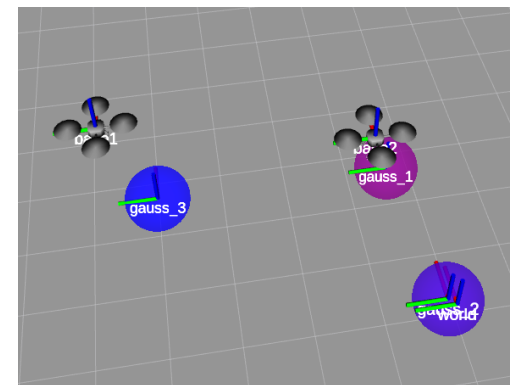


- Multi-drone Repetitive Area Reconnaissance with Nonlinear Model Predictive Control and global heatmap

(in collaboration with PhD Student S. Marcellini, Prof. F. Ruggiero).

Future work:

- Finalizing code implementation,
- experimental validation,
- paper submission.



Research activity during first year

- Study of the State of Art of CBFs in multi-robot systems.
- Implementation and simulation in MATLAB, using the Robotarium simulator, of:
 - Decentralized multirobot non uniform and time-variant coverage,
 - Task persistification with CBFs (energy recharging),
 - Energy-Aware Task Allocation and execution for Heterogeneous Multirobot System.

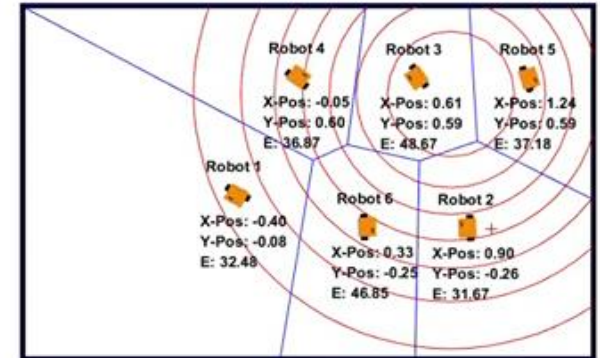
Future work:

- Multi-drone coordinate execution of an agriculture related task (e.g., visual coverage) using the CBFs methodology and considering battery limitations.
- Study on the execution and prioritization of set-based tasks, encoded by CBFs.

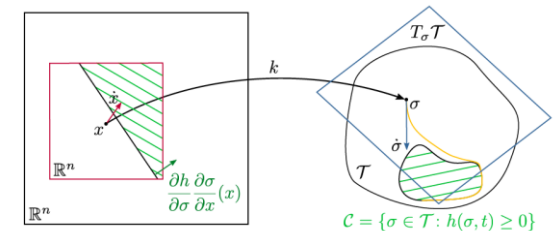
Simulations in MATLAB and preparation of experiments for a previous work extension (*G. Notomista, M. Selvaggio et al.*).

Future work:

- Introduction of human interaction and application to a multi-robot system.



Persistent non-uniform coverage



Thank you for your attention