



UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

itee_{PhD}
information technology
electrical engineering



PhD student: Simone D'Angelo

**Interaction control of Unmanned Aerial
Manipulators**

Tutor: Prof. Bruno Siciliano

Cycle: XXXVII

Year: 2022/2023

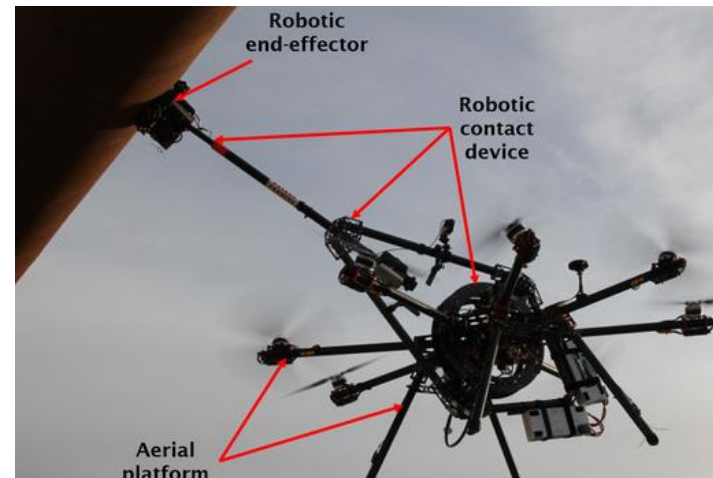
My background

- PhD Student: Simone D'Angelo
- M.Sc. in **Automation Engineering** – University of Naples “Federico II”
- Laboratory: **Prisma Lab (UNINA)** – **Aerial Robotics** Research group
- PhD start date: **01/11/2021**
- University Scholarship: “**Semi-autonomous Interaction Control of Robotics Systems**” – funded by **DIETI**
- Tutor: **Prof. Bruno Siciliano**



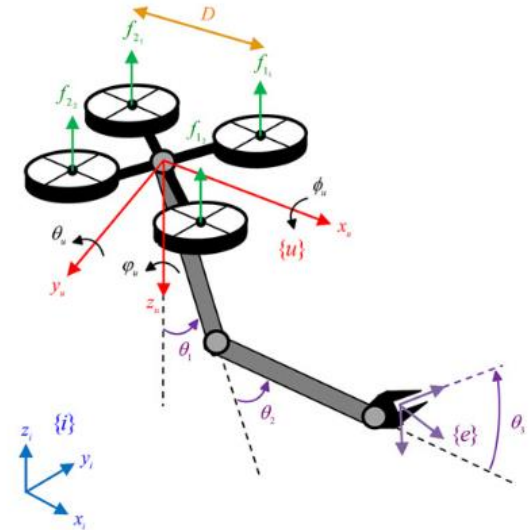
Research field of interest

- Interaction control of unmanned aerial manipulators (UAM)
 - Autonomous aerial vehicle equipped with robotic arms
- **Objective:** Develop UAM solutions to perform non-destructive tests (NDT) in industrial environment
- **Why drones:**
 - Thanks to their agility and dimensions, they can operate in various hard-to-reach environments improving human safety.



Research field of interest

- **UAM** are an efficient solution providing an aerial vehicle with the capability of performing dexterous manipulation tasks
- In addition, the motors **tilting mechanism** gives higher agility and maneuverability
- **NDT** measures prove the integrity of the material without compromising its internal structure



Summary of study activities

- Ad hoc PhD courses:
 - **“Using Deep Learning properly”** – Prof. Apicella: This course aims to provide a general pipeline for designing and validating a machine learning system, avoiding the most common errors that can easily be made. To this end, it will be shown how to implement the experimental evaluation of simple classification tasks, highlighting their peculiarities and points to pay attention to.
 - **“Model Predictive Control”** – Prof. Bemporad: General concepts of Model Predictive Control (MPC). MPC based on quadratic programming. General stability properties. MPC based on linear programming. Linear parameter-varying, time-varying, and nonlinear MPC. Models of hybrid systems: discrete hybrid automata, mixed logical dynamical systems, piecewise affine systems. MPC for hybrid systems based on on-line mixed-integer optimization. Multiparametric programming and explicit linear MPC, explicit solutions of hybrid MPC. Stochastic MPC: basic concepts, approaches based on scenario enumeration. Learning-based MPC. Selected applications of MPC in various domains, with practical demonstration of the MATLAB toolboxes.
 - **“2023 Spring School in Transferable Skills”**: We will give an overview of the breadth of interviews that can be expected on your interview journey and will provide a space to practise interview questions. We will discuss about team management, public engagement, gender equality and communication in academia and research.
 - **“Semantic artifacts and multimedia knowledge graphs for bio-data integration”** – Prof. Russo: The course provides an overview ontologies and OWL language. Knowledge graphs and models for KGRL are presented and implemented in the last practical lessons.
 - **“Formazione sulla progettazione europea offerta dalla Direzione Generale della Ricerca del Ministero dell’Università e della Ricerca nell’ambito del PON Ricerca e Innovazione”** - L'Ateneo Federico II ha aderito all'attività di formazione per il rafforzamento delle competenze del proprio personale docente e ricercatore e per i partecipanti ai corsi di dottorato di ricerca sulla progettazione europea, offerto dal Ministero dell'Università e della Ricerca, nell'ambito del PON Ricerca e Innovazione
- Conferences / events attended:
 - **“The 2023 Int’L Conference On Unmanned Aircraft Systems - ICUAS 23”**: conference attended in June 2023 in Warsaw, Poland. Presented paper: **Development of a Control Framework to Autonomously Install Clip Bird Diverters on High-Voltage Lines**
- Tutorship: Tutor of the course Field and Service Robotics, spring semester: University of Naples "Federico II". Master's Course in Automation Engineering (Second year, second semester 06/03/2023 – 09/06/2023)

Research activity: Overview

- **Main problems** in industrial facility inspections:
 - They are hard-to-reach place
 - Needed fast and safe movements avoiding obstacles
 - High battery consumption
 - Interaction can create perturbations on the drone
 - Known/unknown interaction surfaces
 - Sensor fusion and pose estimation problem



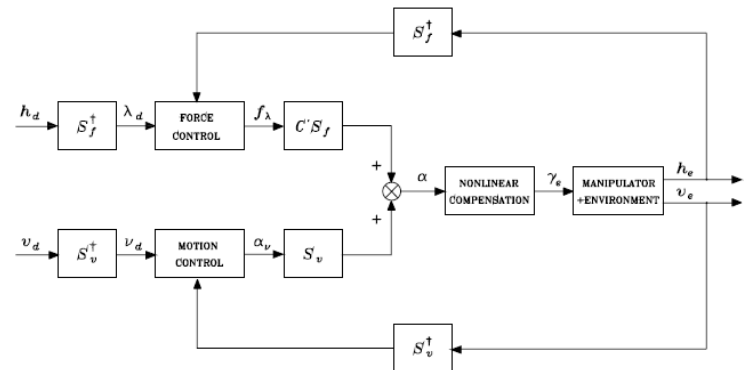
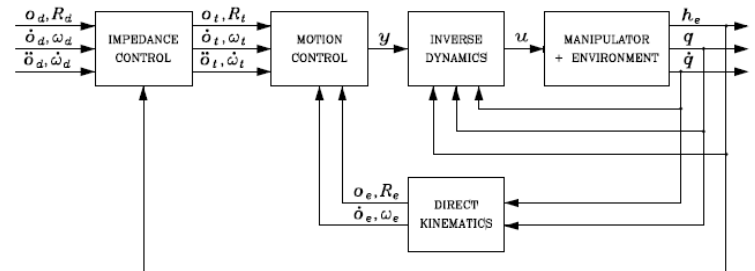
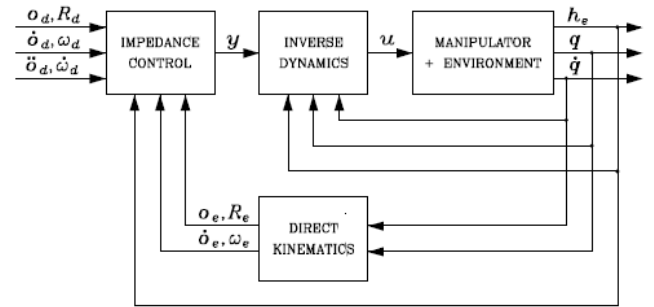
Research activity: Solutions

- **Interaction control laws:**

- Impedance Controller
- Admittance Controller
- Direct Force Control

- **Advanced control laws:**

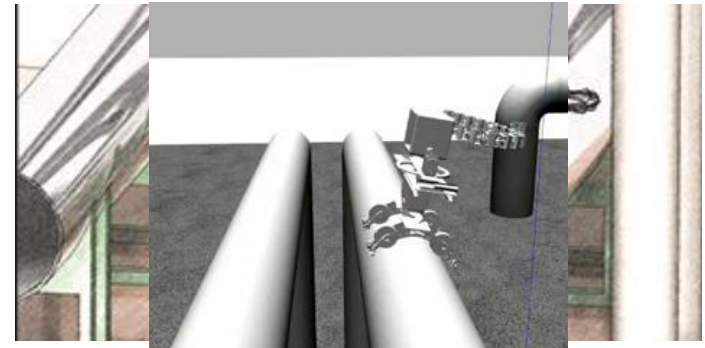
- Parallel force/motion Control
 - Force-impedance controller
 - Force-vision controller



Research activity: Results

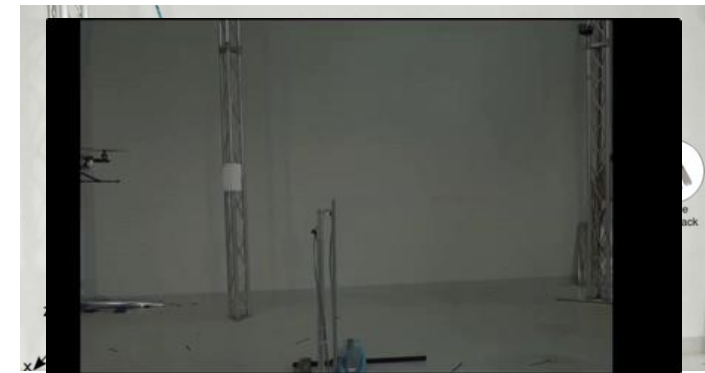
- **Pipe-rack inspection:**

- Controlling a wheeled mobile manipulator endowed with a **snake-like** arm to inspect the structures while stabilizing the supporting pipe.
- MPC + hierarchical force/motion controller with redundancy resolution



- **Power-Line interaction:**

- Preliminary control framework for the autonomous installation of clip **bird diverters** on high-voltage line
- Geometric tracking control + Admittance filter



- **NDT inspection:**

- Semi-autonomous operations
- Custom px4 firmware + parallel force/impedance controller
- Echometer + force sensor

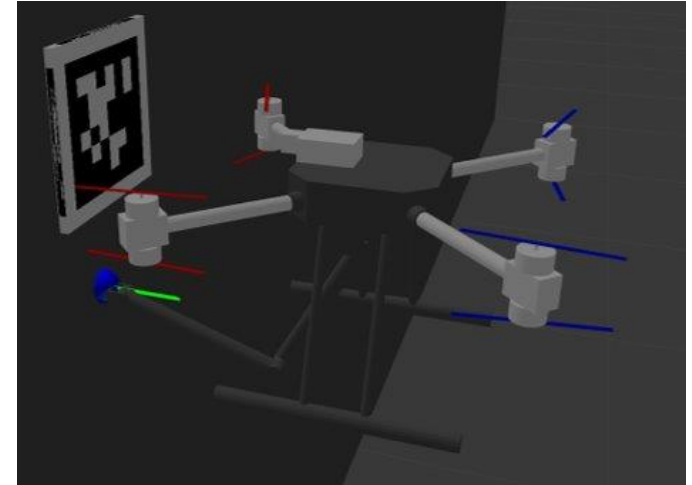


Research activity: Products

[J1]	<p>Stabilization and Control on a Pipe-Rack of a Wheeled Mobile Manipulator with a Snake-like Arm - <i>Simone D'Angelo, Antonio Corrado, Fabio Ruggiero, Jonathan Cacace, Vincenzo Lippiello</i></p> <p>Journal: Robotics and Autonomous Systems (RAS)</p> <p>Current state: published</p>
[C1]	<p>Development of a Control Framework to Autonomously Install Clip Bird Diverters on High-Voltage Lines - <i>Simone D'Angelo, Francesca Pagano, Fabio Ruggiero, Vincenzo Lippiello</i></p> <p>Conference: <i>The 2023 Int'L Conference On Unmanned Aircraft Systems - ICUAS 23</i></p> <p>Current state: published</p>
[C2]	<p>Development of a Semi-Autonomous Framework for NDT Inspection with a Tilting Aerial Platform - <i>Salvatore Marcellini, Simone D'Angelo, Alessandro De Crescenzo, Michele Marolla, Vincenzo Lippiello, and Bruno Siciliano</i></p> <p>Conference: <i>18th International Symposium on Experimental Robotics - ISER 2023</i></p> <p>Current state: accepted</p>

Current research activity

- Designing and building different drones for testing purposes
- Customization of the PX4 firmware
 - **Model-based** Controller implementation
- **Merged visual and force feedback** performing Push-&-Slide tasks:
 - Development of a **parallel vision/force controller** for aerial manipulators
 - The idea is to study the interaction with an **unknown** object using a force sensor on the end-effector; a camera sensor can detect an unknown object in the environment: its pose can be estimated though the **visual features** extracted.
- **Model Predictive Controller** implementation:
 - NL dynamic constraints
 - Contact's stability constraints
 - Coulomb friction model



Thank you
for your attention