PhD student: Simone D'Angelo
Unmanned Aerial Manipulators in interaction with the environment

Tutor: Prof. Bruno Siciliano

Cycle: XXXVII   Year: 2021/2022

My background

- PhD Student: Simone D'Angelo

- M.Sc. in **Automation Engineering** - Università degli Studi di Napoli "Federico II"

- Laboratory: **Prisma Lab (UNINA) – Aerial Robotics** Research group

- PhD start date: **01/11/2021**

- University Scholarship: "**Controllo dell'interazione semi-autonomo di sistemi robotici**" – funded by **DIETI**

- Tutor: **Prof. Bruno Siciliano**

Research field of interest

- Interaction control of unmanned aerial manipulators (UAM)
  - Aerial vehicle equipped with robotics arm
- **Objective:** Develop an aerial autonomous system for 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.
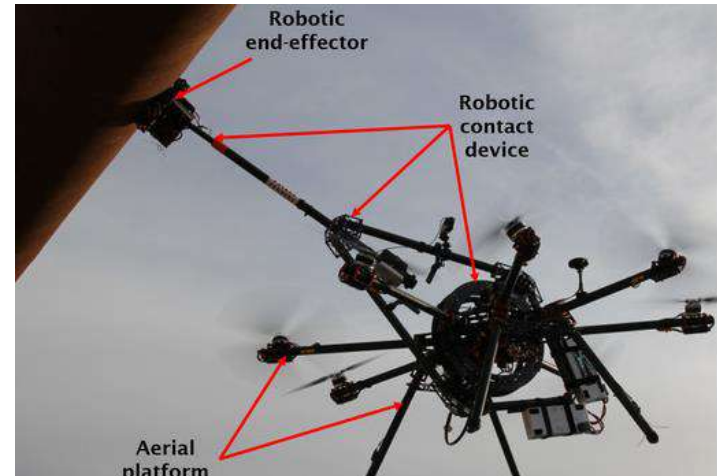
Research field of interest

- NDT measures prove the integrity of the material without compromising its internal structure

- UAM are an efficient solution providing an aerial vehicle with the capability of performing dexterous manipulation tasks

- In addiction, the motors **tilting mechanism** gives higher agility and maneuverability
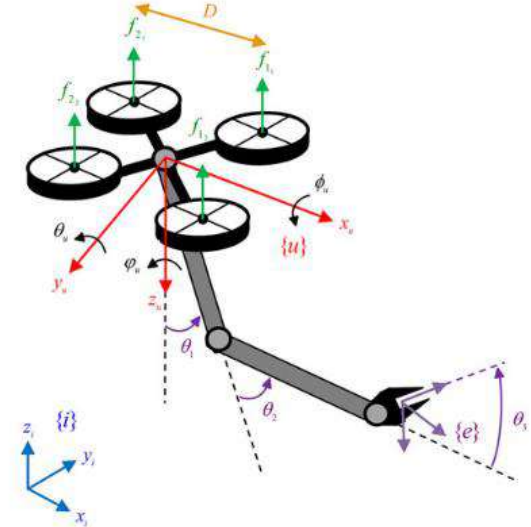
Summary of study activities

- Ad hoc PhD courses:
  - **"Matrix Analysis for Signal Processing with MATLAB examples"** – Prof. Carotenuto: The course provides an overview on some topics in matrix theory together with their intrinsic interaction with and application to signa processing.
  - **"Statistical data analysis for science and engineering research"** – Prof. Pietrantuono: The course provides an overview of the experimental design and data analysis and is intended for PhD students in science and engineering disciplines who need to use statistical methods and data analysis as part of their research.
  - **"Imprenditorialità Accademica"** – Prof. Rippa: The course provides an overview of the models of economic valorization of the scientific research results as well as of the instruments for the intellectual property protection of an academic matrix.
  - **"Operational Research: Mathematical Modelling, Methods and Software Tools for Optimization Problems"** – Prof. Masone: The course teaches how to build mathematical models of optimization problems, to be able to classify models and to know the mathematical foundations of algorithmic techniques that allow them to be solved.

- Courses borrowed from MSc curricula:
  - **Methods for Artificial Intelligence** – Prof. Rossi: The course provides an overview on the methods for AI with particular reference on problem solving, game theory, multi-agent theory and reinforcement learning.
  - **Control of Complex Systems and Networks** – Prof. De Lellis: The course provides a set of tools for the analysis and control of dynamic agent networks, with particular reference to the optimization, their safety, and their possible use during the design or management of network systems in different application domains of interest engineering.

- PhD School:
  - **"IEEE RAS Summer School on Multi Robot Systems in Prague"** – Prof. Saska: The main scope of the 2022 IEEE RAS Summer School on Multi-Robot Systems will be systems of cooperating aerial vehicles and swarms, including lectures by well-recognized experts in the field, and hands-on experience with real-world experiments using state-of-the-art aerial platforms developed for Multi-Robot research.
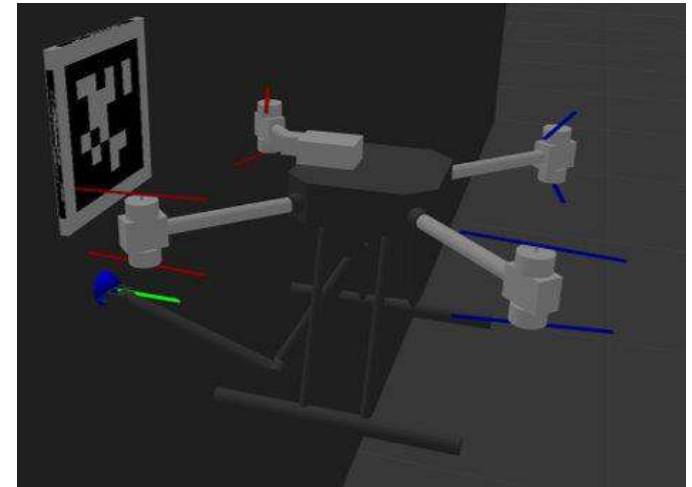
Research activity: Overview

- **Main problems** in inspections of pipe-rack environments**:**
  - 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
   - Pose estimation problem
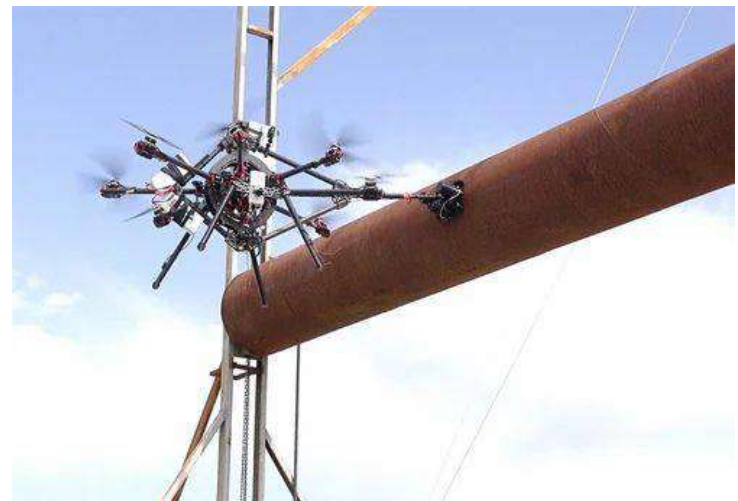
Research activity: Overview

- **Research activity during the First Year**

- Build and programming different drones for testing purposes.

- Search of the state of the art of UAVs **visual servoing** and control of **omnidirectional** drones.

- Studied the possibility to **merge visual** and **force feedback** to control the UAM:

  - Development of a **parallel vision/force controller** for aerial manipulators

  - UAM **mathematical model** computation

  - Study of different **image elaboration libraries**

  - 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.

  - The final goal is to complete **Push-&-Slide tasks**

itee **PhD**
information technology
electrical engineering

Research activity: Overview

- **Research activity during the First Year**

- Search of the state of the art of aerial manipulators in interaction with the environment.

- Enlarged and completed M.Sc. Thesis project studying the **interaction** of the hybrid platform with the environment.

- Modeling and control of a hybrid platform composed by an aerial vehicle, a **wheeled rover** and a **hyper-redundant arm**. The flight is not considered.

- Development of a parallel **force/motion hierarchical controller** for a snake-like arm to complete a pipe inspection task.

- Simulations in Gazebo physics engine

- The **stabilization** task leverages the resulting propagating force on the wheeled robot given by the snake-like arm's dynamics.
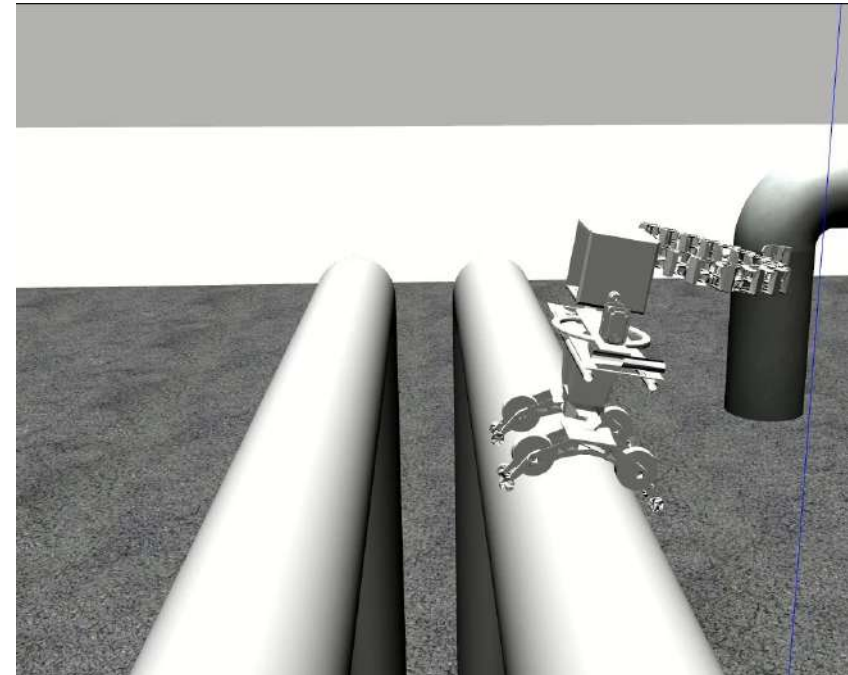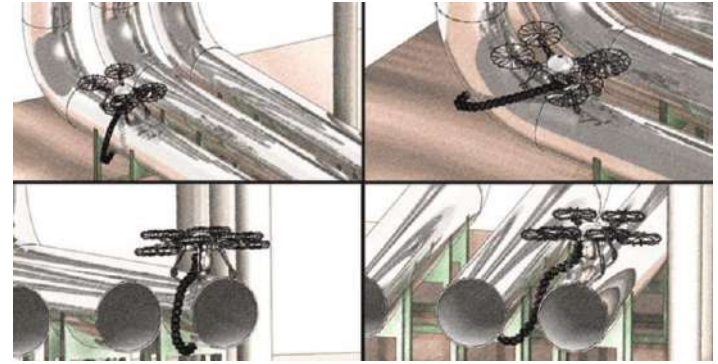
Products

[P1]	**S. D'Angelo**, A. Corrado, F. Ruggiero, J. Cacace, V. Lippiello, "**Stabilization and Control on a Pipe of a Wheeled Mobile Manipulator with a Snake-like Arm.**" submitted to: *IEEE Robotics and Automation Letters* (RA-L).