



UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

itee^{PhD}
information technology
electrical engineering



Giancarlo D'Ago

Dynamic compensation algorithms
for manipulation and transport of
non-rigid robotic platforms

Tutor:

Prof. Fabio Ruggiero

co-Tutors:

Dr. Eng. Luca Buonocore

Prof. Vincenzo Lippiello

Cycle: XXXVII

Year: 2023 (Second)

My background

- **MSc degree** in Automation Engineering (University of Naples “Federico II”)
- **PhD start date:** 01/01/2022
- **Partner:** European Organization for Nuclear Research (CERN)
- **Scholarship type:** CERN Doctoral Student Program
- **Research groups:**
 - CERN Mechatronics, Robotics and Operation Section (BE-CEM-MRO)
 - PRISMA Lab, UNINA



Research field of interest



- Control of non-rigid robotic systems
 - Long-reach cable-suspended robotic systems
 - Ultra-redundant and underactuated articulated systems



- Long-reach cable-suspended robots
 - Operation in high-altitude areas
 - Enlarged end-effector workspace



- Development of dynamic model-based compensation control strategies for manipulation and transport



(CERN CRANEBot)

Inspection and maintenance of accelerators infrastructures

Summary of study activities

- Ad hoc PhD courses:
 - **“2023 Spring School on Transferable Skills”** – 2 days course on Developing Skills in grant and CV writing for getting a faculty position.
 - **[ON GOING] “Ethics and AI”** – Prof. Guido Boella: This online course aims to provide a brief overview of the main ethical issues concerning AI from an interdisciplinary perspective. In particular, issues relating to the impact that AI has and will increasingly have on society are examined.
 - **[ON GOING] “Artificial Intelligence and Natural Language Processing”** – The course introduces the new vision of Natural Language Processing (NLP) considering the recent revolutions in the field. The course is organized as a series of lectures on the foundations of modern NLP and aspects related to AI.
- Other Courses (CERN Learning Courses):
 - **“Convincing Scientific Presentations ”** – Prof. Boxman: The course teaches the student how to (i) Structure and prepare clear and concise content required for scientific presentations (ii) Develop and design visual aids which convey key messages (iii) Gain practical experience on how to deliver your message whilst maintaining audience attention and engagement.

Summary of study activities

- Seminars, conferences and events attended:
 - Is control a solved problem for aerial robotics research?
 - 10th BE-CEM Student's Coffee
 - Astronauts-in-the-loop mobile manipulation for planetary surface infrastructure maintenance
 - Multi-robot control of heterogeneous herds
 - From Romeo & Juliet to OceanOneK Deep-Sea Robotic Exploration
 - ABP Alumni Forum
 - Academic training lecture series "Open Source"
 - Using Delays for Control
 - How to Publish Under the CARE-CRUI Open Access Agreement with IEEE
 - ATS Seminar on IPAC 2023 oral contributions
 - 9TH BE-CEM Students' Coffee
 - UPM Collaboration on Robotics
 - Learn To Be Stable: Imitation Learning With Dynamical Systems
 - 12th BE-CEM Student's Coffee
 - ARCHE 2023: Advanced Robotic Capabilities for Hazardous Environments
 - Reconfigurable Robots for Real Intuitive Interactions
 - Design and validation of a safe mechatronic system for the handling of radioactive sources
 - Mixed Reality human-robot interface for remote operations in accelerator facilities
 - 20th BE-CEM Student's Coffee
 - Optimal control and learning for legged locomotion

Research activity: Overview

TRANSPORTATION



**TIME
EFFICIENCY**



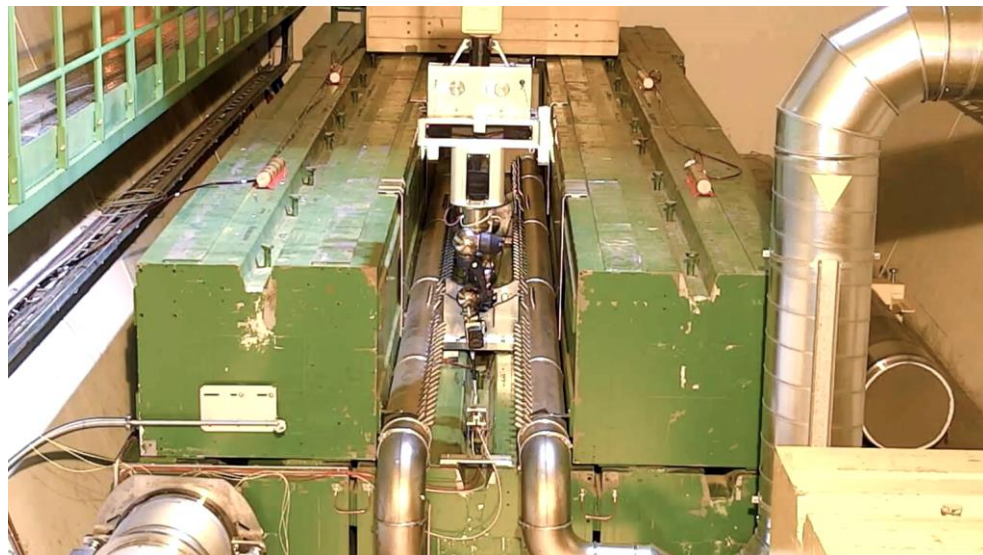
TELEOPERATION



ACCURACY



SAFETY



Research activity: Overview



TIME EFFICIENCY



ACCURACY

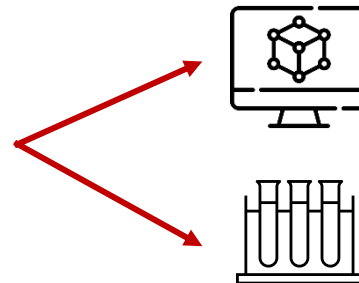


SAFETY

TRANSPORTATION

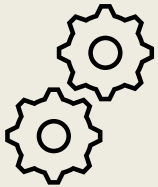
Use the arms themselves to reduce oscillations

Modeling
Identification
Control



Simulation

Real experiments



Modeling and Identification

IDENTIFICATION

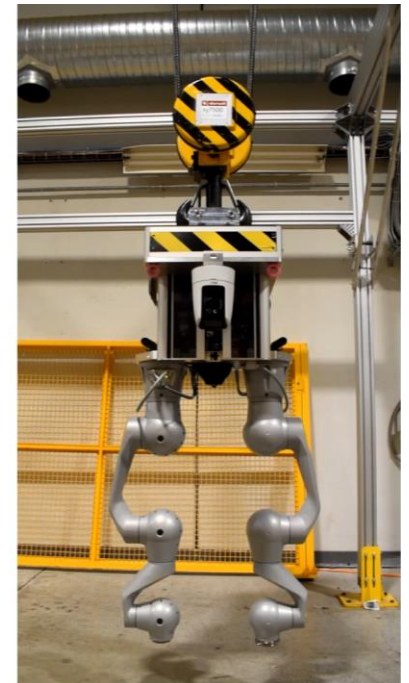
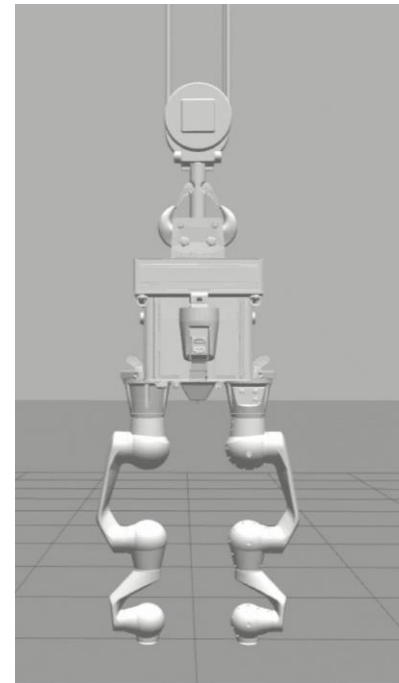
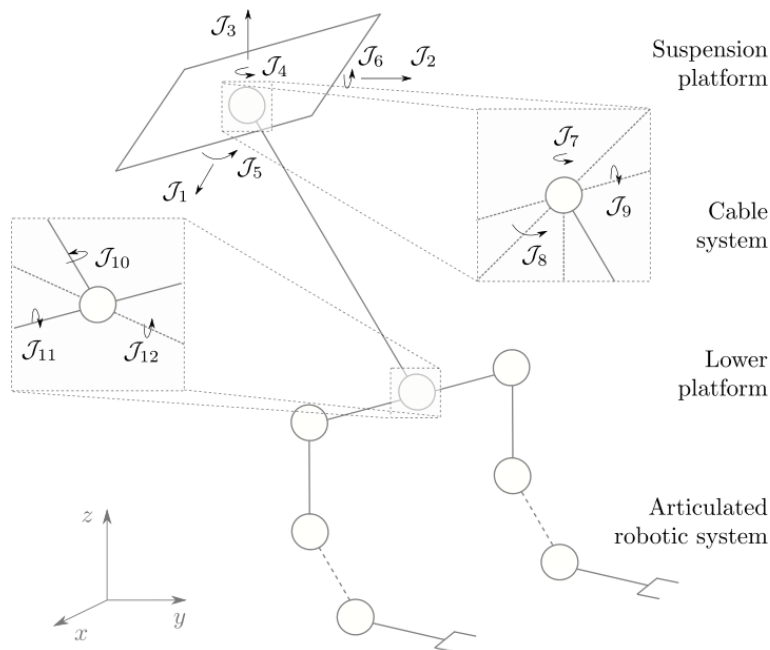
$$\hat{\mathbf{p}} = \arg \max_{\mathbf{p}} \frac{1}{N_e} \sum_{i=1}^{N_e} R(\mathbf{x}_m^i, \mathbf{x}_m^i(\mathbf{p}))$$

$$s. t. \quad \underline{\mathbf{p}} \leq \mathbf{p} \leq \bar{\mathbf{p}}$$

MODEL

REALISTIC SIMULATION

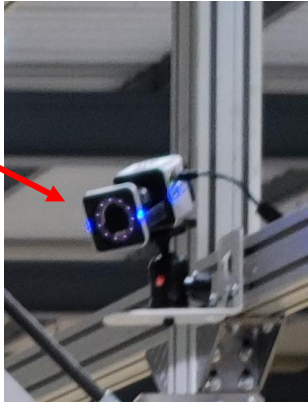
TIME EFFICIENCY



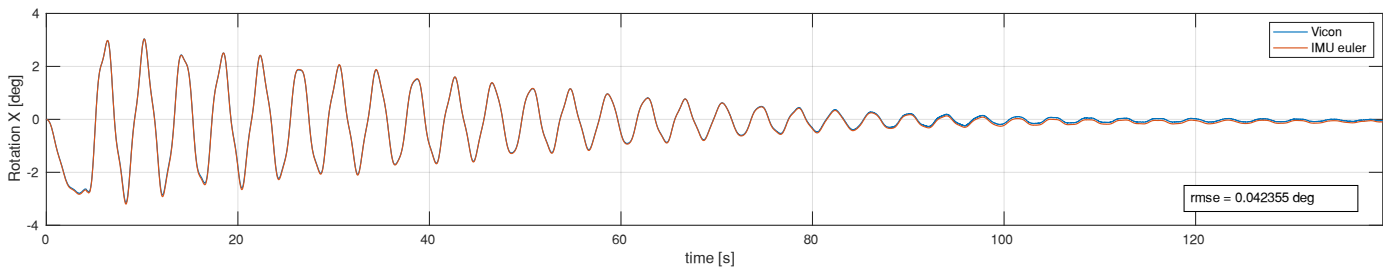
Sensing

POSE ESTIMATION

Measure of passive joints motion

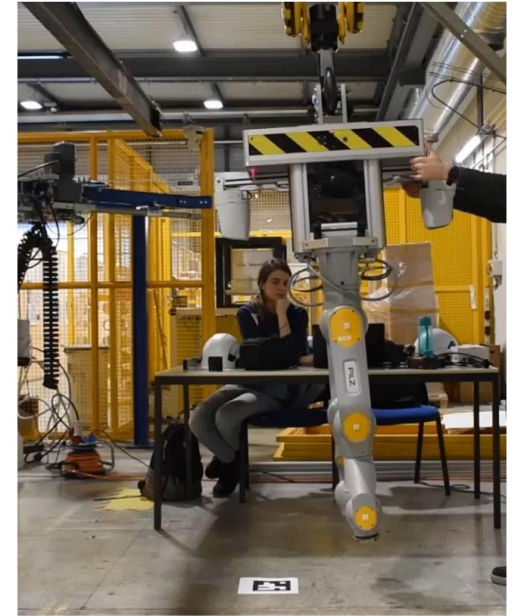
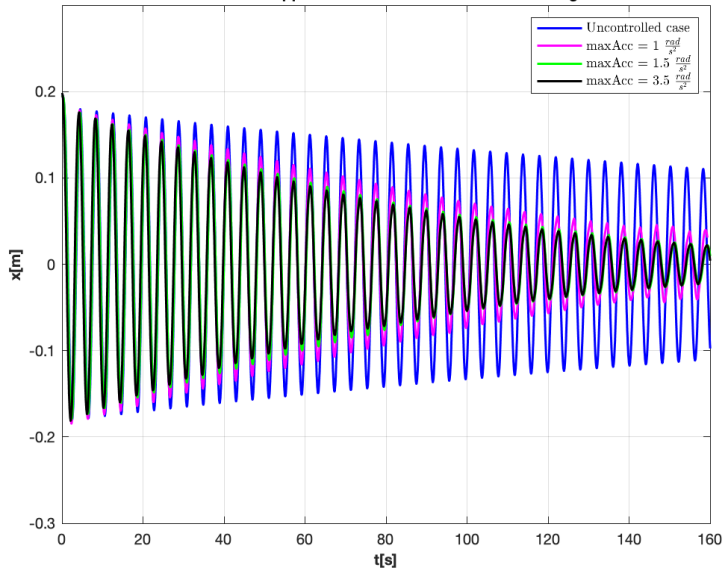


Validation IMU vs Vicon: Rotation Around X

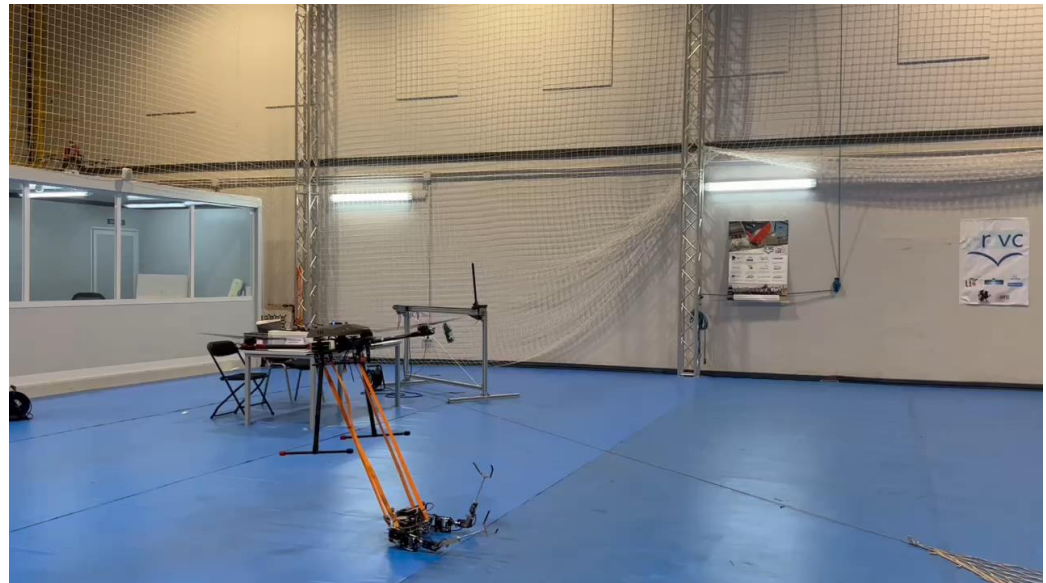
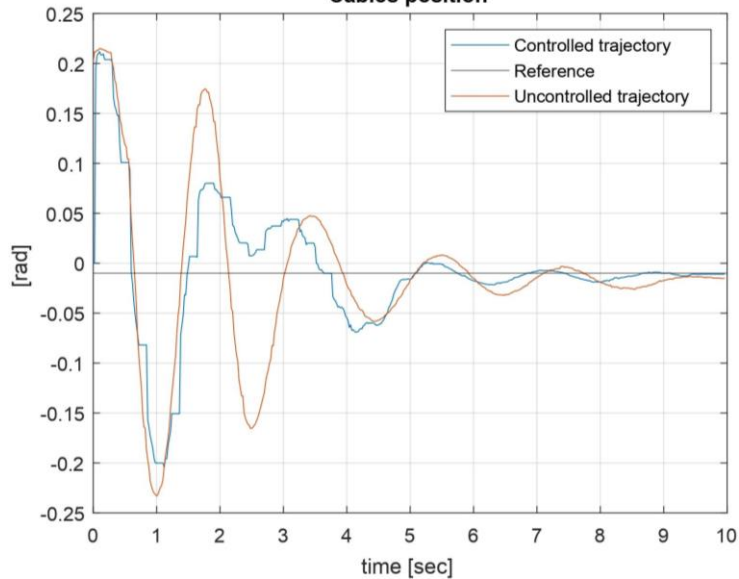


Control: simulation & experiments

Oscillation Suppression - maximum acceleration change



Cables position



Products

[P1]	G. D'Ago, M. Lefebvre, L. R. Buonocore, F. Ruggiero, M. Di Castro, V. Lippiello, <i>Modelling and control of a variable-length flexible beam on inspection ground robot</i> , published on IEEE International Conference on Robotics and Automation, 2022.
[P2]	G. D'Ago, M. Selvaggio, A. Suarez, F. J. Ganán Onieva, L. R. Buonocore, V. Lippiello, A. Ollero, F. Ruggiero, <i>Modelling and identification methods for simulation of cable-suspended dual-arm robotic systems</i> , submitted to Elsevier Robotics and Autonomous Systems, 2023.

Research activity: Next steps



1. Fully integrate oscillation suppression control for transportation
2. Theoretical study:
 - Performance evaluation
 - Improvements and corrections
3. Experimental tests in real operations
 - First tests scheduled in February
4. Reactionless manipulation solutions for teleoperation

Thanks
for your kind
attention