UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

DOTTORATO DI RICERCA / PHD PROGRAM IN
INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

Activities and Publications Report

PhD Student: Giancarlo D'Ago

Student DR number: DR996238

PhD Cycle: XXXVII
PhD Cycle Chairman: Prof. Stefano Russo

PhD Modality: Student enrolled supernumerary under the UNINA-CERN agreements and CERN Doctoral Student Programme

PhD program student's start date: 01/01/2022
PhD program student's end date: 31/12/2024

Supervisor: Prof. Fabio Ruggiero
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PhD scholarship funding entity: European Organization for Nuclear Research (CERN)

General information

Giancarlo D'Ago received in year 2021 the Master Science degree in Automation Engineering from the University of Napoli Federico II. He attended a curriculum in robotics within the PhD program in Information Technology and Electrical Engineering. He received a grant from European Organization for Nuclear Research (CERN).

Study activities

Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organization
1st	Matrix Analysis for Signal Processing with MATLAB examples	Ad hoc course	2.0	Prof. Carotenuto	UNINA
1st	Statistical Data Analysis for Science and Engineering	Ad hoc course	4.0	Prof. Pietrantuono	UNINA
1st	Scientific Writing	External course	3.0	Prof. Raymond L. Boxman	CERN
1st	General and Professional French	External course	6.0	Prof. Magalie Gontero	CERN
1st	Operational Research: Mathematical Modelling, Methods and Software Tools for Optimization Problems	Ad hoc course	4.0	Adriano Masone	UNINA
1st	Fast Forward: Productivity System for Researchers	External course	3.0	Dr. Nadine Sinclair	CERN
2nd	2023 Spring School on Transferable Skills	Ad hoc course	2.0	Various	UNINA
2nd	Convincing Scientific Presentations	External course	2.0	Prof. Sabine McCarthy	CERN
3rd	Python Programming	External course	2.5	Prof. Kevin Cunningham	CERN
3rd	Artificial Intelligence and Natural Language Processing	Ad hoc course	3.0	Prof. Cutugno	UNINA

Attended PhD Schools

Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organization
1st	Evento Enel	0.2	Lepore M.F., Calderone A., Francini A.	Various	UNINA
1st	Global and Cluster Synchronization in Complex Networks	0.2	Mattia Frasca	UNINA	UNINA
1st	IEEE Authorship and Open Access Symposium	0.3	Various	Various	IEEE
1st	MATLAB & Simulink Italian Academic Forum	0.8	Various	Various	MATLAB
1st	Service and Companion Robots in Healthcare	0.3	Andrea Ruggiero	UNINA	UNINA

1st	On Using Simple Optimization Techniques for Tuning UAVs	0.4	Prof. Dariusz Horla	Poznan University Technology	UNINA
1st	Using Delays for Control	0.4	Prof. Emilia Fridman	Tel Aviv University	UNINA
1st	IEEE 2022 ICRA Workshop: Shared Autonomy in Human-Robot Interaction	1.6	X. J. Yang, L. Peternel, C. O. Monreal, A. Kucukyilmaz, J. Mainprice, A. Kolling, B. Argall, E. K. Phillips, L. Riek, D. Hsu, D. Sadigh	Various	IEEE ICRA
1st	Vine Robots: Design Challenges and Opportunities	0.2	Nicholas Naclerio	Egypt-Japan University of Science and Technology	UNINA
1st	Stabilizer Renyi Entropy and Quantum Complexity	0.2	Prof. A. Hamma	UNINA	UNINA
1st	9th BE-CEM Students' Coffee Seminars	0.2	R. Cittadini, E. Galletti	CERN	CERN
2nd	Is Control a Solved Problem for Aerial Robotics?	0.2	Prof. Antonio Franchi		UNINA
2nd	10th BE-CEM Students' Coffee Seminars	0.2	Laura Rodrigo Perez	CERN	CERN
2nd	Astronauts-in-the-Loop Mobile Manipulation	0.2	Daniel Leidner	German Aerospace Center (DLR)	CERN
2nd	Multi-Robot Control of Heterogeneous Herds	0.2	Prof. Eduardo Montijano	Universidad de Zaragoza	UNINA
2nd	From Romeo & Juliet to Deep-Sea Exploration	0.2	Prof. Oussama Khatib	Stanford University	UNINA
2nd	ABP Alumni Forum	0.8	Stefania Papadopoulou, Veliko Dimov, Miriam Hahkala, Adriano Garonna, Androula Alekou	Various	CERN
2nd	How to Publish Under the CARE-CRUI Open Access Agreement with IEEE	0.4	Nino Grizzuti, Eszter Lukacs, Stefano Bianco	IEEE	CARE-CRUI and IEEE
2nd	ATS Seminar on IPAC 2023 oral contributions	0.4	Malika Meddahi,	CERN	CERN

			Giulia Papotti, Mario Di Castro, Oliver Bruning		
2nd	BE-CEM Technical Meeting: ML on crystal alignment	0.2	Gianmarco Ricci	CERN	CERN
2nd	UPM Collaboration on Robotics:	0.6	Manuel Ferre, Paloma De La Puente, Luca Rosario Buonocore, Alejandro Diaz Rosales, Chris Mcgreavy	UPM and CERN	CERN
2nd	Learn to Be Stable: Imitation Learning with Dynamical Systems	0.3	Prof. Matteo Saveriano		CERN
2nd	12th BE-CEM Student's Coffee	0.2	Elisa Bello, Cai Arcos Botias	CERN	CERN
2nd	ARCHE 2023: Advanced Robotic Capabilities for Hazardous Environments	0.4	ETH Zurich Researchers	ETH	ETH
2nd	Reconfigurable Robots for Real Intuitive Interactions	0.2	Prof. Jamie Park	EPFL	CERN
2nd	Design and validation of a safe mechatronic system for the handling of radioactive sources	0.2	Francesca Paola Nicoletti	CERN	CERN
2nd	Mixed Reality human-robot interface for remote operations in accelerator facilities	0.2	Krzysztof Adam Szczurek	CERN	CERN

Research activities

Giancarlo D'Ago participated in the research on long-reach robotic manipulation systems, focusing on dynamic modelling, system identification, and control strategies to address oscillations in cable-suspended articulated robotic systems. This work aims to enhance the safety and efficiency of tasks in challenging environments such as high-altitude maintenance and inspection of power lines and infrastructure.

During the first year, the research centered on developing dynamic models for cable-suspended manipulators using screw theory and Newton-Euler approaches. Two case studies were analysed: CERN's dual-arm system for particle accelerator maintenance (CRANEBot) and the University of Seville's drone-supported dual-arm platform (LiCAS A1). Realistic simulations were achieved by approximating the closed kinematic chain as an equivalent open chain. The study produced a

robust parameter identification methodology, validated through experiments and simulations, resulting in a journal publication.

In the second year, the dynamic models were refined to include arm motion and suspension couplings. Advanced simulations supported the testing of three control strategies: model-based partial feedback linearization, model-free energy-based control, and Model Predictive Control. Successful real-world implementation of these strategies marked a significant advancement, with outputs submitted to leading conferences.

The final year has focused on fully integrating sway damping control techniques for real-world applications and testing them in real case scenarios. These tasks resulted in two published conference papers on oscillation suppression controls. Improvements and refinement of the mechatronic setup of the CERN Robot (CRANEBot) have been performed, resulting in a conference publication. Finally, the exploration of algorithmic techniques to improve teleoperation efficiency has begun.

Tutoring and supplementary teaching activities

Credits summary

PhD Year	Courses	Seminars	Research	Tutoring / Supplementary Teaching
1st	22.0	5.0	33.0	0.0
2nd	4.0	5.9	45.0	0.0
3rd	5.5	0.0	54.5	0.0

Research periods in institutions abroad and/or in companies

The research has been supported by the PhD scholarship "CERN Doctoral Student Program" funded by the European Organization for Nuclear Research (CERN). The student has been enrolled supernumerary in the XXXVII cycle under UNINA-CERN agreements. The research activities have been conducted at CERN from to 01.03.2022 - 31.12.2024.

PhD Year	Institution / Company	Hosting tutor	Period	Activities
1st - 3st	CERN	Luca Rosario Buonocore	01.03.2022 - 31.12.2024	• Research on modelling identification and control of cable-suspended robot • Lab experiments on CRANEBot, cable-suspended robot in use at CERN.

				• Responsible of CRANEBot maintenance, upgrades and operational readiness. • C++ developer for CERN Robotic Framework • Collaboration in robotics interventions in accelerator facilities • Joint scientific papers preparation

PhD Thesis

In the PhD Thesis, Giancarlo D'Ago addresses the topic of cable-suspended robotic systems. Overhead robotic operations are vital in nuclear research, infrastructure inspection, and maintenance of challenging environments. Traditional solutions like long-reach manipulators often lack the flexibility for unstructured scenarios. Cable-suspended dual-arm robotic systems offer a promising alternative, providing extended workspaces and improved resilience to collisions. However, flexible cables introduce oscillatory dynamics that can compromise precision, safety, and operational efficiency during transportation and manipulation. This thesis addresses the challenges of modelling, simulation, and control of cable-suspended dual-arm systems. A novel methodology for dynamic modelling and parameter identification is presented, enabling realistic simulations that connect theoretical models with real-world applications. Utilizing these models, two innovative sway damping techniques are proposed: (i) a partial feedback linearization strategy to control cable oscillations directly, and (ii) a Nonlinear Model Predictive Control (NMPC) approach to minimize oscillations while adhering to constraints, such as joint limits and collision avoidance for dual-arm systems. Both methods uniquely leverage the motion of the manipulators to mitigate oscillations, eliminating the need to modify the suspension platform. The proposed methods were validated experimentally, demonstrating reduced oscillations and settling times, enabling safer and faster task execution. The results highlight the potential of cable-suspended robotic systems as efficient solutions for complex operations in constrained environments, paving the way for advancements in robust control and practical deployment.

Research products

Research results appear in **1** paper published in international journals, **4** contributions to international conferences (1 of them has been accepted, in press), and **1** under review to international conferences.

List of scientific publications

International journal papers

G. D'Ago, M. Selvaggio, A. Suarez, F. J. Gañán, L. R. Buonocore, M. Di Castro, V. Lippiello, A. Ollero, F. Ruggiero,
Modelling and identification methods for simulation of cable-suspended dual-arm robotic systems,
International Journal of Robotics and Autonomous Systems (RAS),
vol. 175, 104643, 2024, ISSN: 0921-8890, DOI: 10.1016/J.ROBOT.2024.104643.

International conference papers

G. D'Ago, M. Lefebvre, L. R. Buonocore, F. Ruggiero, M. Di Castro, V. Lippiello,
Modelling and control of a variable-length flexible beam on inspection ground robot,
2022 International Conference on Robotics and Automation (ICRA),
Philadelphia, PA, USA, May 2022, pp. 8224-8230, IEEE, DOI: 10.1109/ICRA46639.2022.9812444.

G. D'Ago, M. Selvaggio, C. Marzio, L. R. Buonocore, A. Suarez, A. Gonzalez-Morgado, J. Villanueva, A. Ollero, F. Ruggiero,
A Model-Based Oscillation Suppression Approach for a Cable-Suspended Dual-Arm Aerial Manipulator,
2024 International Conference on Unmanned Aircraft Systems (ICUAS),
Chania - Crete, Greece, June 2024, pp. 1140-1147, IEEE, DOI: 10.1109/ICUAS60882.2024.10557014.

G. D'Ago, S. Di Giovannantonio, L. R. Buonocore, M. Di Castro,
CRANEBot: Teleoperated Crane-Suspended Robotic System for Inspection and Manipulation in Harsh Environments,
21st International Conference on Informatics in Control, Automation and Robotics - Volume 2 (ICINCO),
Porto, Portugal, November 2024, pp. 101-108, ScitePress, DOI: 10.5220/0012892100003822.

M. Avagnale, **G. D'Ago**, M. Selvaggio, L. R. Buonocore, M. Di Castro, V. Lippiello, B. Siciliano, F. Ruggiero,
Oscillation Suppression in Cable-Suspended Robotic Manipulation Systems Using Nonlinear Model Predictive Control,
2024 International Symposium of Robotics Research (ISRR),
Long Beach, California, USA, December 2024 (Accepted, in press).

International conference papers (under review)

E. Matheson, L. R. Buonocore, S. Di Giovannantonio, G. D'Antuono, E. Romagnoli, C. Veiga Almagro, A. Garcia Gonzalez, **G. D'Ago**, C. McGreavy, R. Martinez Muniz, D. Forkel, J. Rodriguez-Nogueira, J. Playan Garai, A. Diaz Rosales, M. Di Castro,
Robotic Activities in Harsh Environments: Summary of 2024 Interventions at CERN,
2025 European Robotics Forum (ERF),
Stuttgard, Germany, Submitted 2024.

Patents and/or spin offs

Awards and Prizes

Date 03.12.2024

PhD student signature Giancarlo D'Ago

Supervisor signature Fabio Ruggiero