Activities and Publications Report

PhD Student: Julien Mellet

Student DR number: DR155251

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

PhD program student's start date: November 1st, 2021
PhD program student's end date: October 31st, 2024

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Co-supervisor: /

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PhD scholarship funding entity:
Early-Stage Researcher - AERO-TRAIN Marie S. Curie European Training Network

General information

Julien Mellet received in year 2018 the Master Science degree in Aerospace: Navigation, Guidance and Control from the Northwestern Polytechnical University, Xi'an, China. He attended a curriculum in Aerial Robotics within the PhD program in Information Technology and Electrical Engineering. He received a grant from AERO-TRAIN Marie S. Curie European Training Network.

Study activities

Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organization
1st	Field and Service Robotics	Course	6.0	Prof. Fabio Ruggiero	ITEE
1st	Robotics Lab	Course	6.0	Dr. Jonathan Cacace	ITEE
1st	Neural Networks and Deep Learning	External Course	8.0	Prof. Giorgio Buttazzo	Scuola Superiore Sant'Anna, Pisa

Attended PhD Schools

Year	School title	Location	Credits	Dates	Organization
1st	First Training School of AERO-TRAIN project	Seville, Spain	2	7-11 March 2022	University of Seville, Spain
1st	Training School on Autonomous systems working in uncertain environments	DTU Denmark	2.0	13th -17th June, 2022	DTU, Denmark
1st	Summer School on "Multi-Robot Systems"	Prague, Czech Republic	2.0	1st -5th Aug, 2022	Czech Technical University, Prague, Czech Republic
2nd	3rd Training School (TS3) of AERO-TRAIN project | "Training School on Field experimentation"	Lulea, Sweden	2.0	5th – 9th December, 2022	Lulea University of Technology, Sweden
2nd	1st Integration Week (IW-1) of AERO-TRAIN project	Tampere, finland	2.0	20th – 24th March, 2023	Tampere University Finland
2nd	2nd Integration Week (IW-2) of AERO-TRAIN project	Barcelona Spain	2.0	3rd – 7th July 2023	Eurecat, Centre Tecnològic de Catalunya, Barcelona Spain
3rd	3nd Integration Week (IW-3) of AERO-TRAIN project	Seville, Spain	2.0	20th –24th November 2024	CATEC (Advanced Center for Aerospace Technologies), in Seville, Spain
3rd	AERO-TRAIN Grand Challenge	Roskildi, Denmark	2.0	6th –10th May 2024	Technical University of Denmark

Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organization
1st	AERO-TRAIN PhD Data Management Plan webinar - part 1	0.2	Jitlka Stilund Hansen	DTU, Denmark	AERO-TRAIN at DTU, Denmark
1st	AERO-TRAIN PhD Data Management Plan webinar - part 2	0.2	Jitlka Stilund Hansen, and Signe Gudegaard	DTU, Denmark	AERO-TRAIN at DTU, Denmark
1st	IEEE Authorship and Open Access Symposium: Tips and Best Practices to Get Published from IEEE Editors	0.3	Rachel Berrington	IEEE Editor, Education: Colorado College	IEEE
1st	Using Delays for Control	0.2	Prof. Emilia Fridman	Tel Aviv University	University of Napoli Federico II
1st	Using Delays for Control (part 2)	0.2	Prof. Emilia Fridman	Tel Aviv University	University of Napoli Federico II
1st	On using simple optimization techniques for tuning of UAVs	0.4	Prof. Dariusz Horla	Poznan University of Technology - Poland	ITEE
1st	AERO-TRAIN 1st Exploitation Workshop: Intellectual Property Management	0.4	Julian Cayero Becerra	Eurecat	AERO-TRAIN
1st	Service and companion robots in healthcare	0.3	Pasquale Arpaia	University of Naples Federico II, Italy	ITEE
1st	Potential and challenges of next generation railway signaling systems: Moving Block and Virtual Coupling	0.2	Eng. Joelle Aoun	TU Delf, Netherlands	ITEE
1st	Introduction to Deep Learning for Natural Language Processing & Explainable Natural Language Inference	0.5	Dr. Marco	University of Manchester, United Kingdom.	ITEE
1st	5G Networks in Action – The PrivateMobileEra	0.3	Ing. Marco Centenaro Ing. Nicola Di Pietro. Ing. Daniele Munaretto	University of Naples Federico II, Italy	University of Naples Federico II, Italy
1st	Vine Robot: Design Challenges and unique opportunities	0.2	Mario Selvaggio	University of Naples Federico II, Italy	ITEE
1st	Shared Autonomy in	1.6	Mario	University of Naples	ICRA 2022

	Physical Human-Robot Interaction: Adaptability and Trust		Selvaggio	Federico II, Italy	
2nd	Is control a solved problem for aerial robotics research?	0.2	Prof. Antonio Franchi	University of Twente	ITEE
2nd	AI, Robots and Society: Challenges and Opportunities for Social Innovation	0.2	DR. AMIT KUMAR PANDEY	Chief Robotics and AI Officer	ITEE
2nd	Exploring Advanced Aerial Robotics: A Journey into Cutting-Edge Projects and Neural Control	0.2	Engr. Eugenio Cuniato	ETH Zürich	ITEE
2nd	Inspection-based robotics for society - Advanced Center for Aerospace Technologies (CATEC)	0.5	Dr. Antidio Viguria Jiménez	Advanced Center for Aerospace Technologies (CATEC)	CATEC
2nd	Migration of legacy IT infrastructures into the cloud: approaches and strategies	0.4	Ing. Claudio Perrotta	CTO Epsilon S.r.l.	ITEE
2nd	IEEE Authorship and Open Access Symposium: Tips and Best Practices to Get Published from IEEE Editors	0.3	IEEE Editors	IEEE	IEEE
3rd	Multi-agent autonomous flight at Leonardo Labs	0.2	DR. FABRIZIO SCHIANO	Leonardo Labs	ITEE
3rd	Aerial Workers for infrastructure and asset maintenance: The journey from "Lab" to "Real-World", Full Day Workshop at ICUAS	1.4	AEROTRAIN	AEROTRAIN	ICUAS 2024
3rd	Social Network Analysis: Methods and Applications,	0.4	Prof. Tanmoy Chakraborty	Indian Institute of Technology Delhi (IIT Delhi), India	Prof. Giancarlo Sperlì - DIETI - Unina
3rd	Introduction to Large Language Models: Evolution and the current state	0.4	Prof. Tanmoy Chakraborty	Indian Institute of Technology Delhi (IIT Delhi), India	Prof. Giancarlo Sperlì - DIETI - Unina
3rd	Including elastic demand in the hub line location problem	0.2	Prof. A.M. Rodríguez-Chía	Universidad de Cádiz, Cadiz, Spain	ITEE
3rd	The maximal covering location problem with edge downgrades	0.2	Prof. Marta Baldomero-Naranjo	Universidad de Cádiz, Cadiz, Spain	ITEE
3rd	Agile motions,	0.2	Dr. Olivier	CNRS	Dr. Paolo Robuffo

	reinforcement learning and whole body model predictive control: results and prospects		Stasse	– LAAS, Toulouse	Giordano, CNRS- Irisa, Rennes, France
3rd	TA Springer Nature & CARE CRUI_How to write a scientific paper	0.2	Elisa Magistrelli	Springer Nature	Online Springer Nature
3rd	TA Sprenger Nature & CARE CRUI: Research Integrity	0.2	Elisa Magistrelli	Springer Nature	Online Springer Nature
3rd	Author Journey – Transformative Agreement Springer Nature & Care CRUI	0.2	Elisa Magistrelli	Springer Nature	Online Springer Nature

Research activitiess

Julien Mellet participated in the research about multi-robot aerial manipulation for industrial teleoperation. The European project AERO-TRAIN he has been involved in tries to bridge the gap between research and industrial application. It presents a multimodal control framework for aerial manipulators, enabling a single operator to control one or multiple drones with haptic feedback. The primary objective is to simplify operator input and reduce control complexity, particularly for semi-autonomous systems performing aerial physical interaction. The study integrates haptic and visual augmentation to enhance operator performance, addressing challenges such as lifting larger payloads and interacting with complex environments. The research also evaluates the impact of haptic feedback on user control accuracy and performance, focusing on safe bilateral control for both single and multi-robot systems.

Key advancements include the development of a fully actuated, open-source omni-directional aerial platform with reduced components for improved aerial physical interaction. A miniaturized haptic joystick, designed for a standard remote control form factor, was introduced to enable intuitive force rendering. Furthermore, robust localization system combining neural networks and RGB-D cameras was proposed for custom target detection, and a flexible robot arm with passive impact absorption was developed for safe contact during interaction. Preliminary flight tests demonstrated the effectiveness of the proposed system. The haptic joystick successfully decoupled axis generation for the aerial vehicle, while the robot arm showcased reliable control using inverse kinematics with minimal impact in free flight. The system proved its reliability in industrial inspections, and user studies were designed to further assess the system's performance in aerial manipulation.

Tutoring and supplementary teaching activities

- *Seminar organization about Exploring Advanced Aerial Robotics: A Journey into Cutting-Edge Projects and Neural Control* with speaker Eng. Eugenio Cuniato, Thursday, 29 June 2023, 11:00–12:00
- *Summer-School organization for AERO-TRAIN* in Crete, Greece. From June 8th to 10th 2024. Summer School covered three main aspects: (1) Planning and perception methods to navigate into an industrial environment and detect possible damages to the infrastructure; (2) Control algorithms used to guarantee the performance and safety of such systems; (3) Human-Robot Interaction methods to pilot and obtain real-time feedback from the deployed *aerial robots.*

Credits summary

PhD Year	Courses	Seminars	Research	Tutoring / Supplementary Teaching
1st	26	5	35	0
2nd	6	1.8	52.2	0
3rd	0	3.6	52.8	0

Research periods in institutions abroad and/or in companies

PhD Year	Institution / Company	Hosting tutor	Period	Activities
2nd	ASL-ETH Zürich, Switzerland	Prof. Roland Siegwart, Head of the ASL	5-month 1-week	Research on augmentation for operator remotely controlling a fully actuated aerial manipulator. Lab experiments on validation of the system and 2 months user study. Joint scientific paper preparation about evaluation of MR-3D visions and haptics for aerial manipulation dexterity.
3rd	Rainbow Team, Inria, Rennes, France	Dr. Marco Tognon, permanent researcher	2-month 2-week	Research on safe control of multi-robot system for aerial bilateral manipulation. Lab experiment on controllability of the system by a single operator in simulation with haptic hardware in the loop.

PhD Thesis

In this PhD thesis, Julien Mellet focuses on developing a control framework for aerial manipulators to enable telemanipulation with haptic feedback and visual augmentation. Through advancements in modelling, control design, hardware prototyping, and experimental validation, this research aims to improve operator intuition for physical inspection while maintaining high precision in aerial physical interactions. The work advances aerial manipulation by combining semi-

autonomous control frameworks with intuitive interfaces, reducing the complexity of controlling fully actuated platforms in industrial physical interactions.

A key contribution is the development of a cable state estimation system for a flat multirotor with an attached load, enhancing stability and control in suspended load operations. This system estimates cable dynamics in real-time, enabling more precise manipulation of the payload and improving the overall control of aerial manipulators during physical interactions.

Recent developments in haptic technology and vision-based control have demonstrated the potential for enhanced operator immersion and control accuracy in aerial telemanipulation tasks. By leveraging force feedback and visual augmentation, this research seeks to improve operator performance in complex environments, particularly during interaction with external objects. A fully actuated omni-directional aerial platform was developed as an open-source system to accelerate research in aerial physical interaction. A haptic finger joystick design has been proposed to simplify robot control by decoupling axis generation, while localization methods using neural networks and RGB-D cameras were integrated to enhance custom target detection before interaction.

The flexible robot arm developed for this system, featuring passive impact absorption, further extends its capabilities in physical interaction tasks. The proposed control algorithms ensure reliable teleoperation, and flight tests demonstrated the effectiveness of the system in real-world industrial applications. The quantitative evaluation of operator dexterity was conducted through a user study involving two months of training on the multimodal setup, showing significant improvements in task performance and control accuracy. The macro-micro manipulation concept was validated, highlighting the system's ability to absorb physical impacts and maintain control accuracy in free flight. These results provide insights into future improvements in human-robot interaction for industrial applications.

Research products

Several prototypes have been developed for the research.

    a. _3DoF Robot Arm for Safe Aerial Physical Interaction (prototype):_ Design of quasi-serial robot arm with safe exergy dissipation. It increases the workspace of the previous compliant version and allows robots to compensate for natural oscillations of the robots. This lightweight robot arm has shown a low influence on the platform at actuation in free flight and energy improved stabilization in contact.
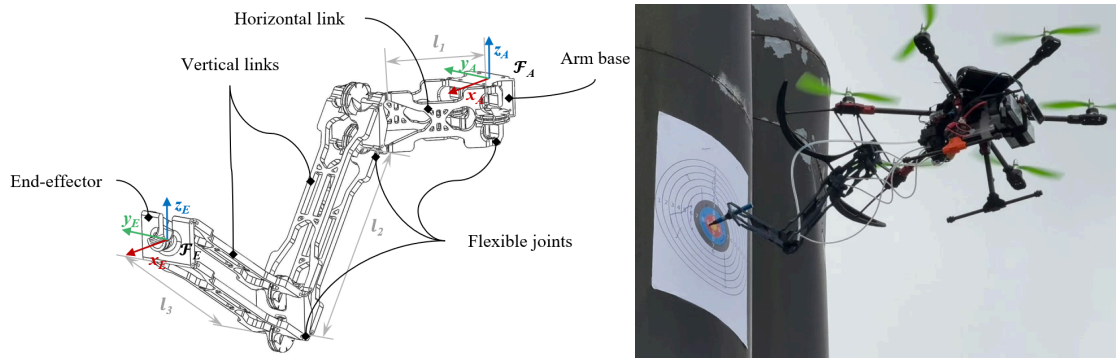
*Figure 1: Prototype of the robot arm for safe interaction with components description (left)
and in flight during industrial contact mission (right).*

b. <u>*Omni-Directional Aerial Vehicle (prototype):*</u> Design of a fully actuated/omnidirectional aerial vehicle with simplified maintenance. This open-source platform wants to ease accessibility of aerial physical interactions proposing an aerial robot with tilting mechanism. Preliminary flight tests showed its potential to handle contact inspection with force estimation. A simulation with SITL has also been developed.

Figure 2: Prototype of the omnidirectional quadrotor with model description (left) and exploded version with components (right).

c. <u>*Haptic RC (prototype):*</u> The need for haptic feedback for telemanipulation gives the sense of touch with extra information for the operator. Nevertheless, commercial joystick are not adapted for operator. A haptic finger joystick with standard RC form factor have thus been developed. Giving the operator 6DoF inputs, if has 4DoF miniaturized force feedback on the sticks.
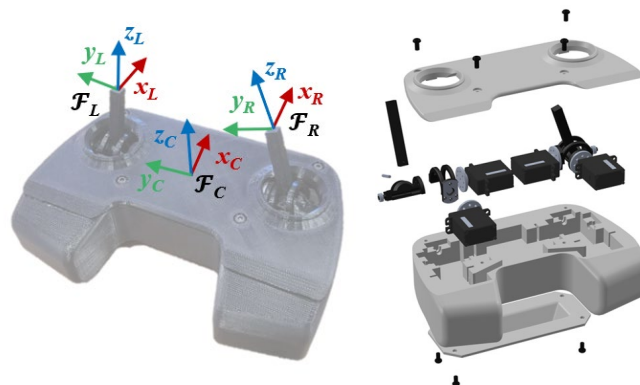

*Figure 3: Prototype of the miniaturized haptic finger joystick with model description (left)
and exploded version with components (right).*

Research results appear in *3* contributions to international conferences, and *2* contributions to national conferences.

List of scientific publications

International conference papers

J.Mellet, J.Cacace, F. Ruggiero, V. Lippiello,

Neural-Network for Position Estimation of a Cable-Suspended Payload Using Inertial Quadrotor Sensing,

20th International Conference on Informatics in Control, Automation and Robotics (ICINCO),

Rome, Italy, Nov 13-15. 2024

J. Mellet et al.,

Design of a Flexible Robot Arm for Safe Aerial Physical Interaction,

2024 IEEE 7th International Conference on Soft Robotics (RoboSoft),

San Diego, CA, USA, 2024, pp. 1048-1053, doi: 10.1109/RoboSoft60065.2024.10522019.

A. Berra, V. N. Sankaranarayanan, A. S. Seisa, **J. Mellet** et al.,

Assisted Physical Interaction: Autonomous Aerial Robots with Neural Network Detection, Navigation, and Safety Layers,

2024 International Conference on Unmanned Aircraft Systems (ICUAS),

Chania - Crete, Greece, 2024, pp. 1354-1361, doi: 10.1109/ICUAS60882.2024.10557050.

National conference papers

J.Mellet, F. Ruggiero, V. Lippiello,

HATPIC: An Open-Source Single Axis Haptic Joystick for Robotic Development,

IRIM-3D 2024: 6th Italian Conference on Robotics and Intelligent Machines,

Rome, Italy, Oct 25-27. 2024

J.Mellet, F. Pagano, F. Ruggiero, V. Lippiello,

Simplifying Quadrotor Frame Design: Toward Scalability with a Modular Robot

IRIM-3D 2024: 6th Italian Conference on Robotics and Intelligent Machines,

Rome, Italy, Oct 25-27. 2024

Awards and Prizes

Best paper overall candidate at ICINCO23

Date __14/10/2024__

PhD student signature _____Julien Mellet_____

Supervisor signature __Prof. Vincenzo Lippiello__