



UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

itee_{PhD}
information technology
electrical engineering



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Julien Mellet

Haptic Aerial Manipulation for Industrial Remote Operation

Tutor: Prof. Vincenzo Lippiello

Cycle: XXXVII

Year: 2024

Candidate's information

- **MSc degree**
 - Industrial Engineering (INSA, France) → **System**
 - Navigation, Guidance and Control (NPU, China) → **Control**
- **Experience**
 - Software Developer for **Ground Control** of drone swarm, Thales, France
- **Research group/laboratory**
 - PRISMA Lab → **Aerial Robotics Group**
- **PhD start date**
 - November 1st, 2021
- **Scholarship type**
 - Horizon 2020 Marie Skłodowska-Curie Innovative Training Network (ITN)
- **Periods abroad**
 - 5 months ETH Zürich, Switzerland (2022)
 - 2 months Inria, Rennes, France (2024)

Summary of study activities

- **Courses**

- Year 1
 - Field and Service Robotics, Prof. Fabio Ruggiero, ITEE
 - Robotics Lab, Dr. Jonathan Cacace, ITEE
 - Neural Networks and Deep Learning, Prof. Giorgio Buttazzo, Scuola Superiore Sant'Anna, Pisa
 - First Training School of AERO-TRAIN project, University of Seville, Spain
 - Training School on “Autonomous Systems with Uncertainties”, DTU, Denmark
 - Summer School on “Multi-Robot Systems”, Czech Technical University, Prague, Czech Republic
- Year 2
 - 3rd Training School of AERO-TRAIN project on “Field Experiment” , LTU, Sweden
 - 1st Integration Week of AERO-TRAIN project, Tampere University Finland
 - 2nd Integration Week of AERO-TRAIN project, Eurecat, Centre Tecnològic de Catalunya, Barcelona Spain
- Year 3
 - 3rd Integration Week of AERO-TRAIN project, CATEC, Seville, Spain
 - AERO-TRAIN Grand Challenge, DTU, Denmark

Summary of study activities

- **Seminars**

Year 1

- Data Management, IEEE Authorship, Using Delays to Control, On using simple optimization techniques for tuning UAVs, Intellectual Property Management, Service and companion robots in healthcare, Potential Challenges of next generation railway signalling systems: Moving Block and Virtual Coupling, Introduction to Deep Learning for Natural Language Processing & Explainable Natural Language Inference, Vine Robot: Design Challenges and unique opportunities, ...

Year 2

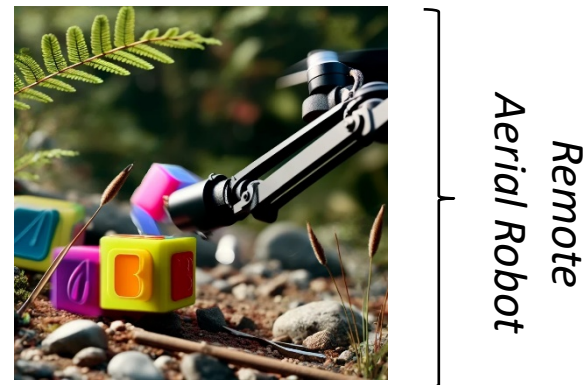
- Is control a solved problem for aerial robotics research?, AI, Robots and Society: Challenges and Opportunities for Social Innovation, Advanced Robotics, Authorship, Inspection-based robotics, Exploring Advanced Aerial Robotics: A Journey into Cutting-Edge Projects and Neural Control, Migration of IT, ...

Year 3

- Multi-agent autonomous flight at Leonardo Labs, Aerial Workers for infrastructure and asset maintenance: The journey from “Lab” to “Real-World”, Social Network Analysis: Methods and Applications, Introduction to Large Language Models: Evolution and the current state, Including elastic demand in the hub line location problem, The maximal covering location problem with edge downgrades, Agile motions, reinforcement learning and whole body model predictive control: results and prospects, Springer Nature & CARE CRUI: Research Integrity, ...

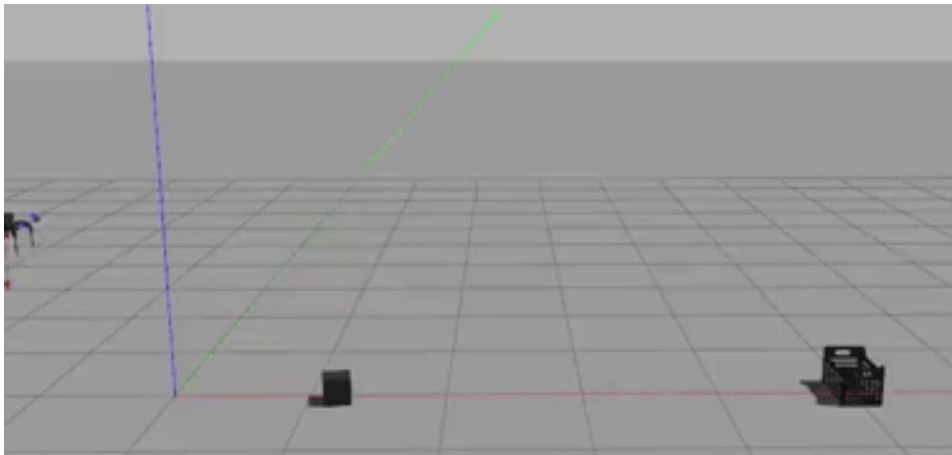
Research areas

- Need for **operations and maintenance** in industry and civil infrastructures, and use of aerial robots is already a reality
- It's fastidious to deploy autonomous robots while **humans have physical comprehension of the world** and incredible manipulation capabilities
- A carefully designed teleoperation system has to **be transparent for the operator** and allow **full control** of the robot in the remote environment
- Bridge gap between research and industry, innovative **aerial robotic** solutions
 - **Reduce risks and costs** associated to field operations by humans
 - Increase efficiency while **reducing workload** of operators



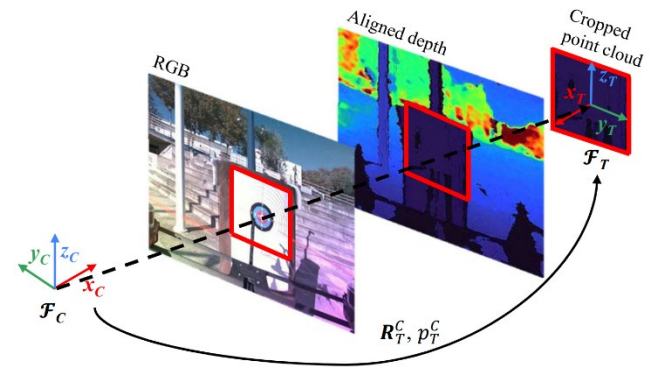
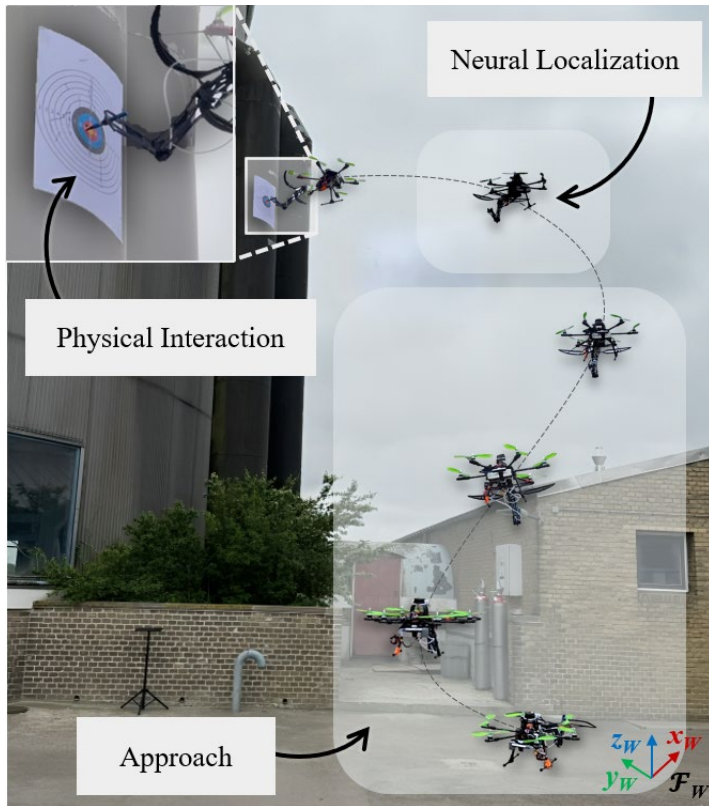
Research results

- **Neural estimation** for cable suspended transportation on minimal quadrotor sensing configuration with **design of the robot**



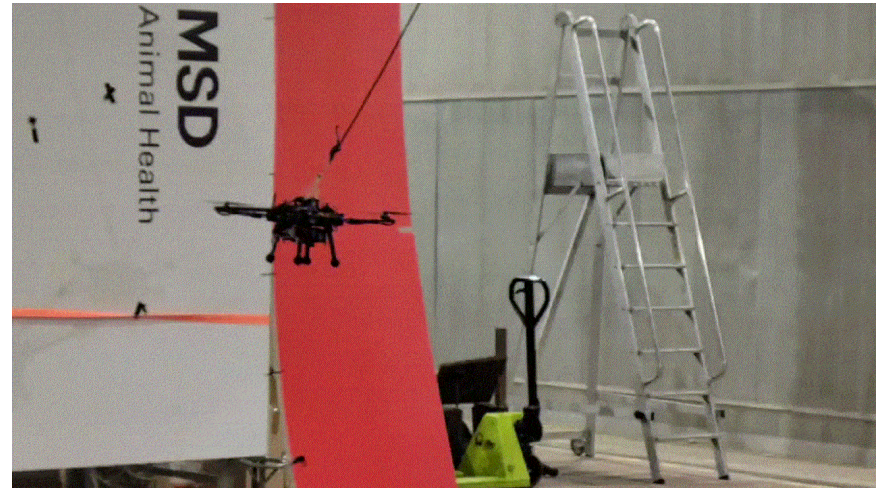
Research results

- **Semi-autonomous** aerial manipulator for physical interaction mission in industrial environment



Research results

- **Haptic finger control of a simplified design OMAV**



Research products

[C1]	<p>J. Mellet, J. Cacace, F. Ruggiero, and V. Lippiello <i>Neural-Network for Position Estimation of a Cable-Suspended Payload Using Inertial Quadrotor Sensing.</i> International Conference on Informatics in Control, Automation, and Robotics (ICINCO), Rome, Italy, 2023, pp 80-87, Scitepress (<i>Best paper candidate</i>)</p>
[C2]	<p>J. Mellet, A. Berra, A.S. Seisa, V.N. Sankaranarayanan, U.G.W.K.N. Gamage, S.G. Satpute, F. Ruggiero, V. Lippiello, G. Nikolakopoulos, M.A. Trujillo Soto, and G. Heredia <i>Design of a Flexible Robot Arm for Safe Aerial Physical Interaction.</i> International Conference on Soft Robotics (RoboSoft), San Diego, CA, USA, 2024, pp. 1048-1053, IEEE</p>
[C3]	<p>A. Berra, A.S. Seisa, V.N. Sankaranarayanan, J. Mellet, U.G.W.K.N. Gamage, S.G. Satpute, F. Ruggiero, V. Lippiello, M. Fumagalli, G. Nikolakopoulos, M.A. Trujillo Soto, and G. Heredia <i>Design of a Flexible Robot Arm for Safe Aerial Physical Interaction.</i> International Conference on Unmanned Aircraft Systems (ICUAS), Chania - Crete, Greece, 2024, pp. 1354-1361, IEEE</p>
[C4]	<p>J. Mellet, A. Berra, S. Marcellini, , M.A. Trujillo Soto, G. Heredia, F. Ruggiero and V. Lippiello <i>Design and Control of an Omnidirectional Aerial Robot with a Miniaturized Haptic Joystick for Physical Interaction.</i> ICRA, Submitted</p>

Research products

[C5]	J. Mellet , F. Pagano, F. Ruggiero and V. Lippiello <i>Simplifying Quadrotor Frame Design: Toward Scalability with a Modular Robot.</i> Italian Robotics and Intelligent Machines (I-RIM) , Accepted
[C6]	J. Mellet , F. Ruggiero and V. Lippiello <i>HATPIC: An Open-Source Single Axis Haptic Joystick for Robotic Development.</i> Italian Robotics and Intelligent Machines (I-RIM) , Accepted
[J7]	J. Mellet , M. Allenspach, E. Cuniato, C. Pacchierotti, R. Siegwart and M. Tognon <i>Evaluation of Human-Robot Interfaces based on 2D/3D Visual and Haptic Feedback for Aerial Manipulation.</i> T-ASE , Submitted
[J8]	A. Berra, J. Mellet , A.S. Seisa, V.N. Sankaranarayanan, U.G.W.K.N. Gamage, S.G. Satpute, F. Ruggiero, V. Lippiello, M. Fumagalli, G. Nikolakopoulos, M.A. Trujillo Soto, and G. Heredia <i>Target Localization and Manipulator Design for Safe Aerial Physical Inspection Mission.</i> T-FR , Submitted



PhD thesis overview

- **Problem statement** *with state-of-the-art*

*No commercial haptic aerial system for telemanipulation
& No evaluation to assess benefit on operator dexterity*

- **Objective**

*Propose models to control a set of teleoperation systems
with different characteristics and evaluate them*

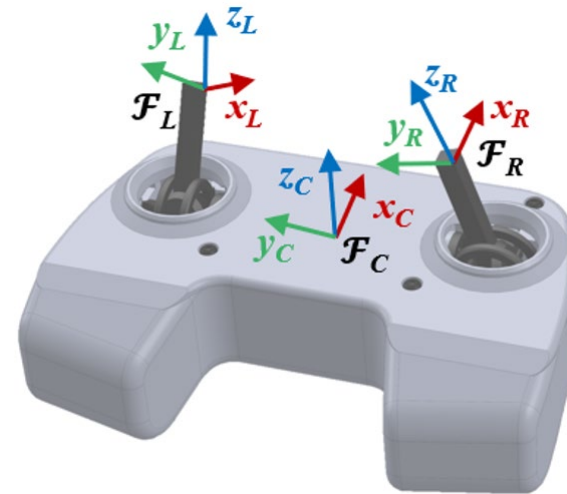
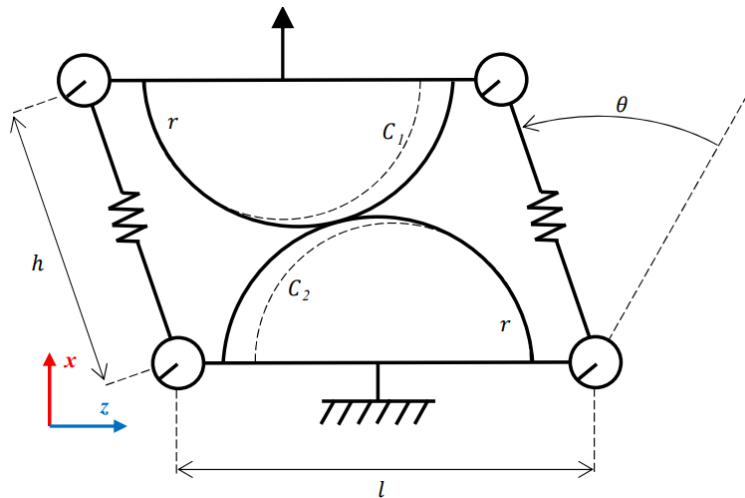
- **Methodology** *only with contributions*

Modelling → Control → Design → Experiments

PhD thesis

- **Modelling**

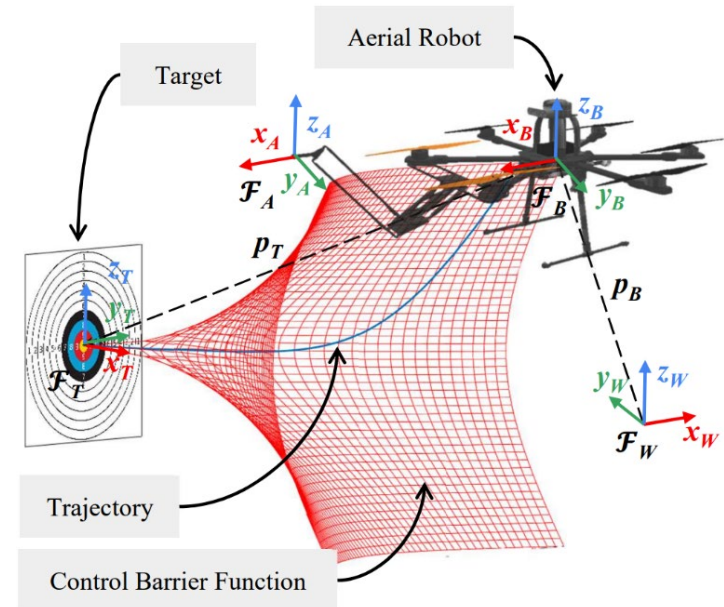
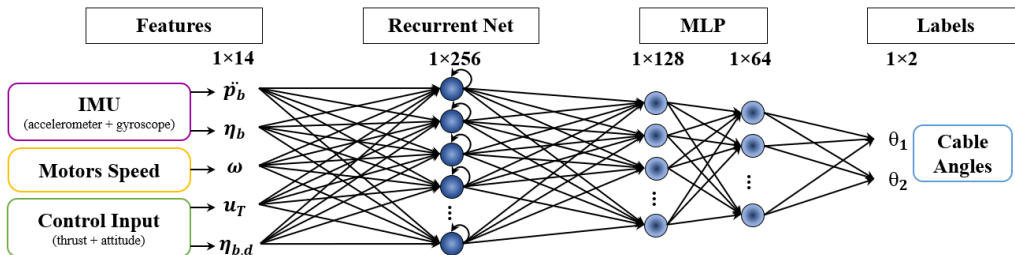
- *Elasto-mechanical description of passive dissipator [P2]*
- *Modelling of a local multimodal interface for remote 6-DoF teleoperation including 6-DoF haptic bilateral interface and a local virtual environment [P7]*
- *Formulation of 6-DoF bimanual haptic finger joystick with 4-DoF force feedback [P4]*



PhD thesis

- **Robot Control**

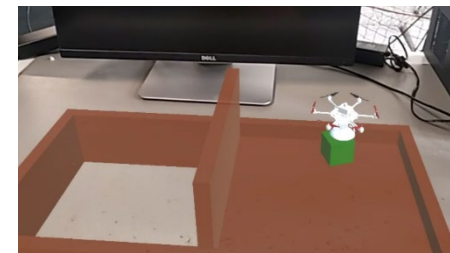
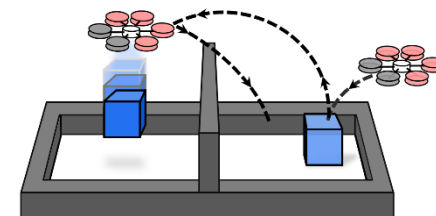
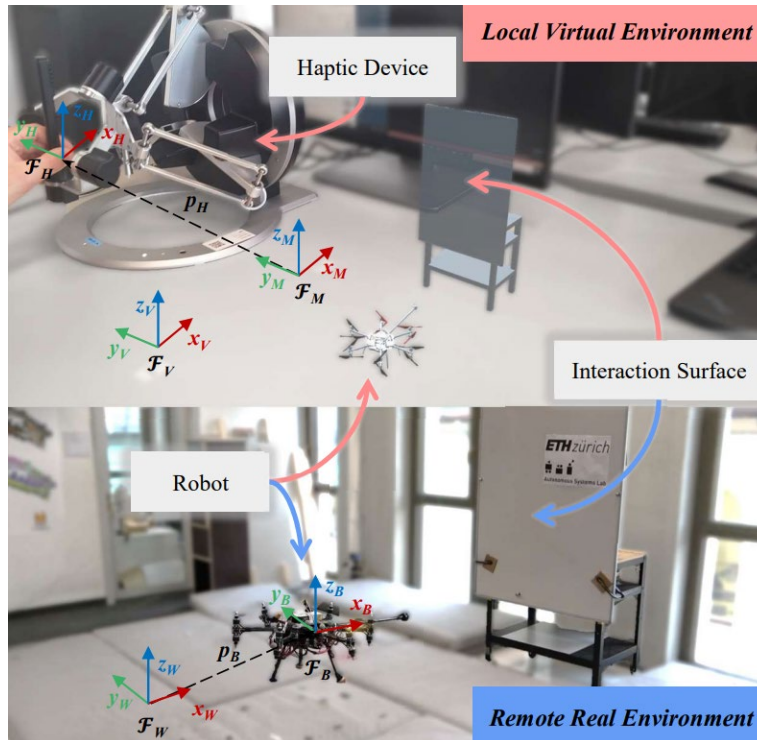
- *Neural estimator for cable suspended load [P1]*
- *Inverse kinematic control of quasi-serial manipulator [P2]*
- *Neural-based custom target localization with safe CBF for accurate and safe navigation before contact inspection [P3]*
- *Control allocation of tilting OMAV with actuation uncertainty [P4]*



PhD thesis

- **Operator Interface**

- 6-DoF haptic bilateral control of fully actuated aerial vehicle [P4] [P7]
- Multi-modal interface with haptic and 3D-MR goggle for remote telemanipulation [P7]
- DOE to evaluate operator dexterity with ABBT [P7]



PhD thesis

- **Prototype Design**

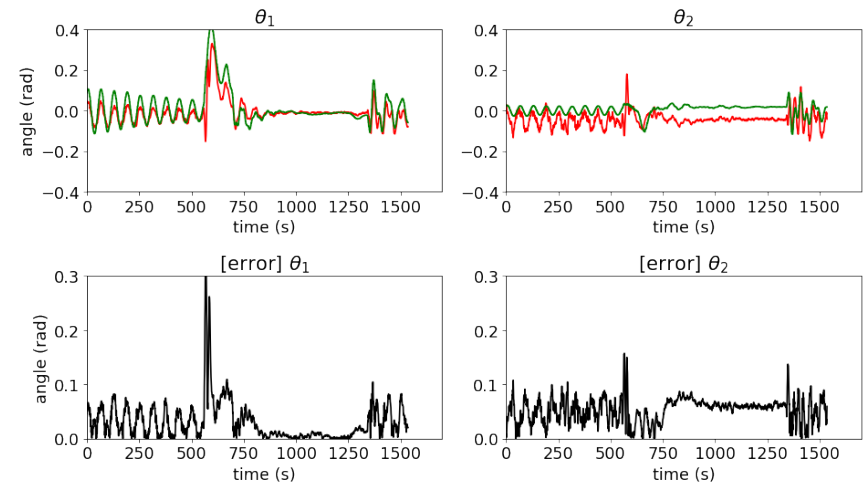
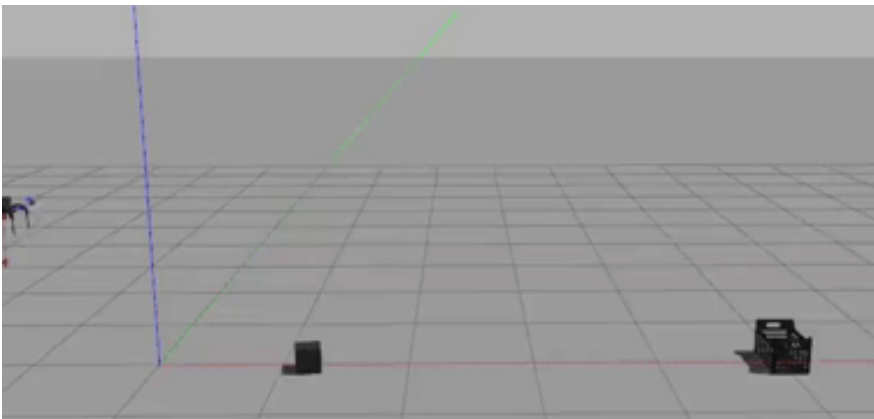
- *Modification of a commercial hexarotor for GPS-denied localization, and design of a low inertia flexible manipulator [P2] [P3] [P8]*
- *Design of a modular quadrotor for cable suspended transportation [P1] [P5]*
- *Design of a simplified OMAV [P4]*
- *Design of miniaturized haptic finger joystick with gamepad form factor [P4]*
- *Mechanical and electronic design of a 1-DoF haptic finger joystick for education [P6]*



PhD thesis

- **Experimental Application**

- *Evaluation and application of neural estimation of cable suspended load under a minimal sensing quadrotor [P1]*



PhD thesis

- **Experimental Application**

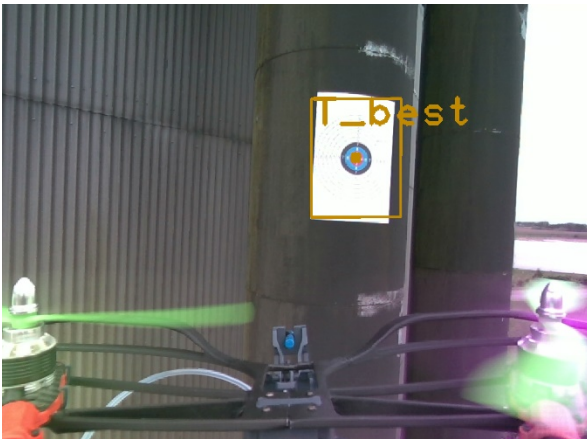
- *Evaluation and application of neural estimation of cable suspended load under a minimal sensing quadrotor [P1]*
- *Experimental evaluation of low impact of compliant robot arm on the aerial platform in physical interaction [P2] [P8]*



PhD thesis

- **Experimental Application**

- *Evaluation and application of neural estimation of cable suspended load under a minimal sensing quadrotor [P1]*
- *Experimental evaluation of low impact of compliant robot arm on the aerial platform in physical interaction [P2] [P8]*
- *Experimental application of custom target detection in industrial mission with aerial physical contact [P3] [P8]*



PhD thesis

- **Experimental Application**

- *Evaluation and application of neural estimation of cable suspended load under a minimal sensing quadrotor [P1]*
- *Experimental evaluation of low impact of compliant robot arm on the aerial platform in physical interaction [P2] [P8]*
- *Experimental application of custom target detection in industrial mission with aerial physical contact [P3] [P8]*
- *Evaluation of operator dexterity based on 2D/3D visual and haptic feedback [P7]*

**Analysis of Human-Robot Interfaces based on
2D/3D Visual and Haptic Feedback
for Aerial Manipulation**

Julien Mellet, Mike Allenspach, Eugenio Cuniato, Roland Siegwart and Marco Tognon



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PhD thesis

- **Experimental Application**

- *Evaluation and application of neural estimation of cable suspended load under a minimal sensing quadrotor [P1]*
- *Experimental evaluation of low impact of compliant robot arm on the aerial platform in physical interaction [P2] [P8]*
- *Experimental application of custom target detection in industrial mission with aerial physical contact [P3] [P8]*
- *Evaluation of operator dexterity based on 2D/3D visual and haptic feedback [P7]*
- *Evaluation on haptic finger joystick to perform single axis generation [P4]*



Thank you