



**PhD in Information Technology and Electrical Engineering**  
**Università degli Studi di Napoli Federico II**

**PhD Student: Andrea Capuozzo**

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**Cycle: XXXIX**

**Training and Research Activities Report**

**Academic year: 2024-25 - PhD Year: Second**

**Tutor: prof. Vincenzo Lippiello**

**Date: October 29, 2025**

# Training and Research Activities Report

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## 1. Information:

- **PhD student:** Andrea Capuozzo **PhD Cycle:** XXXIX
- **DR number:** DR997189
- **Date of birth:** 19/12/1998
- **Master Science degree:** Automation and Robotics Engineering **University:** Federico II
- **Scholarship type:** PNRR – Centro Nazionale CN5 – National Biodiversity Future Center
- **Tutor:** Vincenzo Lippiello
- **Co-tutor:**
- **Period abroad:**

## 2. Study and training activities:

| Activity                                                                                                                                                                                       | Type <sup>1</sup> | Hours | Credits | Dates                     | Organizer                             | Certificate <sup>2</sup> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|-------|---------|---------------------------|---------------------------------------|--------------------------|
| Miniaturization of Optical Spectrometers                                                                                                                                                       | Seminar           | 2     | 0.4     | 14/11/24                  | Prof. Giovanni Breglio                | Y                        |
| IEEE Photonics Society Seminars: “Monolithic, Heterogeneous and Hybrid Photonic Integration – There is a role for all” & “Life at a Photonic Startup: A very personal account”                 | Seminar           | 4     | 0.8     | 18/11/24                  | Prof. Giovanni Breglio                | Y                        |
| Perché l’intelligenza artificiale crede di fare a meno della teoria linguistica, ma in realtà non potrà farlo                                                                                  | Seminar           | 2     | 0.4     | 20/11/24                  | Prof. Francesco Cotugno               | Y                        |
| Machine Learning and AI for the Sciences: toward understanding, organizer                                                                                                                      | Seminar           | 1     | 0.2     | 21/11/24                  | MOX Laboratory, Politecnico di Milano | Y                        |
| - Study on how to apply the anisotropic diffusion model to improve the quality of wave measurements<br>- Study on Nav2 stack and SLAM Toolbox, buildup of a simulated differential drive robot | Research          |       | 7.2     | From 01/11/24 to 31/12/24 |                                       |                          |

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| capable of autonomous navigation in an unknown environment<br>- Implementation of ground truth detection algorithm to verify the quality of measurements (in simulated environment)<br>-Implementation of measurement algorithm for sea waves |           |    |     |                           |                                       |   |
| Teaching assistant for Robotics Lab course, a.y. 2024/2025, Professor Mario Selvaggio                                                                                                                                                         | Tutorship | 10 | 1   |                           |                                       |   |
| How to Boost Your PhD                                                                                                                                                                                                                         | Course    | 12 | 5   | From 08/01/25 to 12/02/25 | Prof. Antigone Marino                 | Y |
| Wave engineering in programmable piezoelectric metamaterials with digital shunts by Alpert Ertuk                                                                                                                                              | Seminar   | 1  | 0.2 | 14/01/25                  | MetaMAT Weekly Seminars               | Y |
| Isogeometric Analysis: Some recent advances with applications to complex and coupled problems by Alessandro Reali                                                                                                                             | Seminar   | 1  | 0.2 | 16/01/25                  | MOX Laboratory, Politecnico di Milano | Y |
| Limits to the Hall effect and other nonreciprocal effects in 3D composites by Christian Kern                                                                                                                                                  | Seminar   | 1  | 0.2 | 21/01/25                  | MetaMAT Weekly Seminars               | Y |
| A quasi-optimal space-time finite element method for parabolic equations by Rob Stevenson                                                                                                                                                     | Seminar   | 1  | 0.2 | 23/01/25                  | MOX Laboratory, Politecnico di Milano | Y |
| (Numerical) homogenization for wave propagation in time-varying media by Barbara Verfürth                                                                                                                                                     | Seminar   | 1  | 0.2 | 28/01/25                  | MetaMAT Weekly Seminars               | Y |

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|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|---|-----|---------------------------|-------------------------|---|
| Guided elastic waves in soft elastomers: from topology to space-time interfaces by Fabrice Lemoult                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Seminar   | 1 | 0.2 | 04/02/25                  | MetaMAT Weekly Seminars | Y |
| Taming Waves through Non-Hermiticity: From Invisible Tunneling to Unidirectional Nonlinear Pulses by Sayan Jana                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Seminar   | 1 | 0.2 | 25/02/25                  | MetaMAT Weekly Seminars | Y |
| -Completion of measurement and prediction algorithm for sea waves and heave motion<br>-Implementation of horizontal take-off window prediction for amphibious drones<br>-Submission to ICUAS 2025 of paper titled “Heave Motion Estimation from IMU measurement in Hybrid Aerial-Amphibious Drones and Horizontal Take-Off Window Prediction”<br>-Completion of collaboration with Marine Biology Department of University Federico II to produce a systematic review of “Technologies for biodiversity monitoring and conservation”<br>-Researching software architecture for amphibious drones and modeling | Research  |   | 7   | From 01/01/25 To 28/02/25 |                         |   |
| Participation to “Porte aperte” event for high school students’ orientation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Tutorship | 4 | 0.4 | From 11/02/25 to 13/02/25 |                         |   |

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| A quantum graph approach to metamaterial design by Gregor Tanner                                                                                                                                                                    | Seminar  | 1 | 0.2 | 04/03/25                  | MetaMAT Weekly Seminars               | Y |
| Lattice Boltzmann for solid mechanics: elastostatics and elastodynamics by Laura De Lorenzis                                                                                                                                        | Seminar  | 1 | 0.2 | 06/03/25                  | MOX Laboratory, Politecnico di Milano | Y |
| Protective metamaterials by Oliver Duncan                                                                                                                                                                                           | Seminar  | 1 | 0.2 | 11/03/25                  | MetaMAT Weekly Seminars               | Y |
| Advancing Scientific Machine Learning in Industry by Wil Schilders                                                                                                                                                                  | Seminar  | 1 | 0.2 | 26/03/25                  | MOX Laboratory, Politecnico di Milano | Y |
| The Electromomentum Coupling by Gal Shmuel                                                                                                                                                                                          | Seminar  | 1 | 0.2 | 01/04/25                  | MetaMAT Weekly Seminars               | Y |
| Robot Autonomy among Decision-Making Agents                                                                                                                                                                                         | Seminar  | 1 | 0.2 | 15/04/25                  | Prof. Fabio Ruggiero                  | Y |
| Underwater invisibility: pushing pentamode cloaks into 3D by Sebastiano Cominelli                                                                                                                                                   | Seminar  | 1 | 0.2 | 22/04/25                  | MetaMAT Weekly Seminars               | Y |
| -Study on PX4 firmware<br>-Implementation of horizontal take-off window prediction for amphibious drones in presence of measurement noise<br>-Starting implementation of new flight mode on PX4 for hybrid aerial-amphibious drones | Research |   | 8.6 | From 01/03/25 to 30/04/25 |                                       |   |
| Analyzing the propagation of elastic waves in space-time modulated media through multiple scattering and mode coupling theory by Antonio Palermo                                                                                    | Seminar  | 1 | 0.2 | 06/05/25                  | MetaMAT Weekly Seminars               | Y |

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| Computation of material property fields in multi-material systems by Stefan Szyniszewski                                                                                                                                                        | Seminar  | 1 | 0.2 | 13/05/25                  | MetaMAT Weekly Seminars | Y |
| Tunability strategies for elastic metamaterials: waveguiding, tonotopy and topological localization by Federico Bosia                                                                                                                           | Seminar  | 1 | 0.2 | 20/05/25                  | MetaMAT Weekly Seminars | Y |
| Control over mechanical properties of magneto-mechanical metamaterials by Krzysztof Dudek                                                                                                                                                       | Seminar  | 1 | 0.2 | 27/05/25                  | MetaMAT Weekly Seminars | Y |
| Direct mapping of nonreciprocal discrete models using simple acoustic networks by Vassos Achilleos                                                                                                                                              | Seminar  | 1 | 0.2 | 17/06/25                  | MetaMAT Weekly Seminars | Y |
| Robotic Manipulation @ Vanvitelly Robotics Lab: A bird's eye view on the last 5 years by Prof. Ciro Natale                                                                                                                                      | Seminar  | 2 | 0.4 | 18/06/25                  | Prof. Mario Selvaggio   | Y |
| Scattering from a random thin coating of nanoparticles: the Dirichlet case by Laure Giovangigli                                                                                                                                                 | Seminar  | 1 | 0.2 | 24/06/25                  | MetaMAT Weekly Seminars | Y |
| -Study on PX4 firmware<br>-Completion of firmware modifications on PX4 to implement switch logic between aerial navigation mode and marine navigation mode<br>-Implementation of manual control algorithm for marine navigation in PX4 firmware | Research |   | 8.4 | From 01/05/25 to 30/06/25 |                         |   |
| Innovation and Entrepreneurship                                                                                                                                                                                                                 | Course   | 8 | 3   | From 05/06/25             | Prof. Pierluigi Rippa   | Y |

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|                                                                                                                                                                                                                                                                                                 |          |   |     | to<br>26/06/25                     |                                       |   |
| Acoustofluidics and Metamaterials by Steven Cummer                                                                                                                                                                                                                                              | Seminar  | 1 | 0.2 | 01/07/25                           | MetaMAT Weekly Seminars               | Y |
| -Mission in Porto Cesareo, in collaboration with Marine Biology Department of University Federico II, for photodetection (through the usage of a drone) of marine protected area properties<br>-Continuing the implementation of manual control algorithm for marine navigation on PX4 firmware | Research |   | 3   | From<br>01/07/25<br>to<br>31/08/25 |                                       |   |
| Multi-* mathematics and simulations of coupled processes the Arctic by Malgorzata Peszynska                                                                                                                                                                                                     | Seminar  | 1 | 0.2 | 18/09/25                           | MOX Laboratory, Politecnico di Milano | Y |
| -Completion of manual control algorithm for marine navigation on PX4 firmware<br>-Study on PX4 firmware<br>-Starting the implementation of an autonomous hybrid aerial-marine navigation algorithm and mission planner on PX4 firmware                                                          | Research |   | 9.8 | From<br>01/09/25<br>to<br>31/20/25 |                                       |   |

- 1) Courses, Seminar, Doctoral School, Research, Tutorship  
2) Choose: Y or N

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## 2.1. Study and training activities - credits earned

|                 | Courses        | Seminars       | Research        | Tutorship      | Total     |
|-----------------|----------------|----------------|-----------------|----------------|-----------|
| Bimonth 1       | 0              | 1.8            | 7.2             | 1              | 10        |
| Bimonth 2       | 5              | 1.4            | 7               | 0.4            | 13.8      |
| Bimonth 3       | 0              | 1.4            | 8.6             | 0              | 10        |
| Bimonth 4       | 0              | 1.6            | 8.4             | 0              | 10        |
| Bimonth 5       | 3              | 0.2            | 3               | 0              | 6.2       |
| Bimonth 6       | 0              | 0.2            | 9.8             | 0              | 10        |
| <b>Total</b>    | <b>8</b>       | <b>6.6</b>     | <b>44</b>       | <b>1.4</b>     | <b>60</b> |
| <b>Expected</b> | <b>30 - 70</b> | <b>10 - 30</b> | <b>80 - 140</b> | <b>0 - 4.8</b> |           |

## 3. Research activity:

The research activities, conducted in collaboration with the Marine Biology Department of the University of Naples Federico II, aim to develop new technologies for marine biodiversity mapping and monitoring. A new class of aerial–amphibious drone is being designed to navigate autonomously in both air and surface-water environments, with seamless transitions between the two that do not require operator intervention. Once operational, and equipped with dedicated sampling probes and tools, the platform will autonomously reach target sites and perform sampling and environmental analyses at different depths, making the resulting data readily available to marine biologists.

Building on work initiated in the previous year, attention has been devoted to the take-off phase from water, a critical step for hybrid aerial–amphibious drones. The main risk consists in wave impacts on the propellers, which may reduce thrust and jeopardize take-off, potentially leading to capsizing. Mitigation requires maximizing the propeller–water distance: empirical observations indicate that this occurs when the vehicle maintains a level attitude at the crest of a wave. To anticipate time windows in which these conditions are met, an FFT-based prediction algorithm has been developed that uses onboard IMU data to forecast short-term heave (vertical displacement) and attitude induced by incoming wave fronts. Simulations show promising results for up to three long-period incident waves. Performance degrades under short-period, high-amplitude irregular seas; however, parameter retuning yields improvements. Future work will address automated parameter adaptation and integration of the algorithm within the PX4 firmware, which will constitute the core of the new drone platform.

To enable both manual and autonomous navigation without reliance on external middleware (e.g., ROS 2) or companion computers, and to manage all functions within the autopilot, the PX4 firmware architecture was analyzed and extended. A new manual “marine” mode, implemented as a dedicated control module, was added to the firmware. When operating on the sea surface, this mode provides velocity control, allowing command of linear speed and yaw rate. Linear velocity control explicitly accounts for hydrodynamic effects, including water viscosity and damping, to achieve stable and responsive motion on the surface. Angular regulation is formulated using quaternions and closes the loop on the autopilot’s attitude estimates, thereby ensuring robust heading control.

Upon completing the manual-control functionality, attention shifted to implementing the firmware extensions required for fully autonomous hybrid aerial–marine missions. Ongoing work centers on a finite-state machine that, based on waypoint type (aerial vs. marine), selects the appropriate navigation mode and plans how to traverse the segments between waypoints. Waypoint-type detection and the

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management of water take-off and landing have been completed; current efforts focus on autonomous navigation between marine waypoints.

All newly introduced firmware components have been validated in simulation, demonstrating promising performance across representative scenarios.

In parallel with the main research line, two side projects initiated last year, and conducted in direct collaboration with the Marine Biology Department of the University of Naples Federico II, have continued.

The first concerns the completion of data analyses for the systematic review “Technologies for Marine Biodiversity Monitoring and Conservation,” which surveys existing technologies for biodiversity mapping and monitoring with reference to the Essential Ocean Variables (EOVs).

The second involves the ongoing aerial survey campaign in Porto Cesareo (Puglia), using a *DJI Matrice 300 RTK* and a *Parrot Sequoia* multispectral camera to detect the presence of *Gongolaria Barbata*, an endangered algal species affected by climate change and rising sea temperatures. Recent surveys indicate a marked decline in the species’ presence over the past year.

## 4. Research products:

**Conference paper:** “Heave Motion Estimation from IMU measurements in Hybrid Aerial-Amphibious Drones and Horizontal Take-Off Window Prediction”, **Andrea Capuozzo**, Fabio Ruggiero, Vincenzo Lippiello, *International Conference on Unmanned Aircraft Systems, ICUAS 25, Charlotte, NC, USA, May 14-17, 2025*

## 5. Conferences and seminars attended

**Conference attended:** International Conference on Unmanned Aircraft Systems – ICUAS 25, Charlotte, NC, USA, May 14-17, 2025

**Paper presented:** “Heave Motion Estimation from IMU measurements in Hybrid Aerial-Amphibious Drones and Horizontal Take-Off Window Prediction”, **Andrea Capuozzo**, Fabio Ruggiero, Vincenzo Lippiello

## 6. Periods abroad and/or in international research institutions

## 7. Tutorship

Teaching assistant for *Robotics Lab* course of M.Sc. in *Automation and Robotics Engineering*, held by Professor Mario Selvaggio during academic year 2024/2025

## 8. Plan for year three

During the third year of the PhD, ongoing activities will be brought to completion to obtain the required results. Following finalization of the PX4 firmware for autonomous navigation and its

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validation in simulation, testing will be conducted on real hardware, first in confined waters and subsequently in the open sea.

The period abroad will be carried out in France, from January till the end of June 2026, at IRISA/Inria institute, under the supervision of Dr. Paolo Robuffo Giordano, to develop a mission planner that computes optimal trajectories for marine survey missions. The planner will (i) decide when to fly or navigate on the water while accounting for environmental constraints, (ii) determine efficient strategies for traversing distances by balancing speed and energy consumption, and (iii) schedule where and when to collect high-altitude imagery and to land for probe deployment and sampling.

After completion of the PX4 firmware, on-platform testing on the new drone, and full development of the mission planner, trials will be performed in real-world scenario by extending the ongoing campaign in Porto Cesareo to include, alongside the aerial phase, a new marine sampling phase.

The thesis will focus on the research conducted at PRISMA Lab, integrated with the topics explored during the international stay. Hybrid aerial–amphibious drones will constitute the core theme, with emphasis on the custom firmware and control strategies, and on prospective applications of this emerging technology.