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

PhD Student: Andrea Capuozzo

Cycle: XXXIX

Training and Research Activities Report

Year: First

Tutor: prof. Vincenzo Lippiello

Date: October 31, 2024

1. Information:

- **PhD student: Andrea Capuozzo** **PhD Cycle: XXIX**
- **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 Centre**
- **Tutor: Vincenzo Lippiello**
- **Co-tutor:**
- **Period abroad:**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Introduction to Complex Networks	Seminar	5	1	6-7/11/23	Prof. Stefano Boccaletti - Scuola Superiore Meridionale	Y
Numerical Optimization	Course	20	4	From 20/11/23 to 15/12/23	Prof. Alberto Bemporad - IMT Lucca	Y
Multi-agent autonomous flight at Leonardo Labs	Seminar	1	0.2	21/12/2023	Prof. Vincenzo Lippiello	Y
-Analysis of the state of the art methods for Ocean waves estimation -Estimation of the effect of Ocean waves on floating UAVs -Study on PX4 firmware -Setting up wave simulator for testing	Research		4.8	From 01/11/23 to 31/12/23		

Neural Networks and Deep Learning: Theoretical Foundations	Course	30	3	From 09/01/24 to 21/02/24	Prof. Giorgio C. Buttazzo - Scuola Superiore Sant'Anna	Y
Lessons Learned from Superhuman Autonomous Drone Racing	Seminar	1	0.2	10/01/24	Prof. Bruno Siciliano	Y
-Creation of PLACE drone simulated mockup for testing - Research on how to model the interaction between a body floating in a fluid and the fluid itself -Study on mathematical ways to describe sea waves - Completion of wave simulator for testing - Research on mean height and period of sea waves in the Italian seas - Starting collaboration with Marine Biology Department of University Federico II to produce a systematic review on "Technologies for biodiversity monitoring and conservation"	Research		6.8	From 01/01/24 to 29/02/24		
I Pilastri della trasformazione digitale	Course	12	3	From 20/03/24 to 05/04/24	ITEE PhD	Y
Reinforcement Learning	Course	30	6	From 04/03/24 to 08/03/24	Prof. Mario Zanon - IMT Lucca	Y

Model Predictive Control	Course	20	4	From 03/04/24 to 22/04/24	Prof. Alberto Bemporad - IMT Lucca	Y
Analytic center selection of optimization-based controllers for robot ecology	Seminar	1	0.2	09/04/24	Prof. Bruno Siciliano	Y
Exploring the Frontiers of Modern Cryptography	Seminar	1.5	0.3	12/04/24	Prof. Simon Pietro Romano	Y
- Continuing collaboration with the Marine Biology Department for systematic review -Deepening knowledge about PX4 firmware and the combined use of ROS 2 and PX4 -Making experience with real drones and setting up the hardware of a small drone to gain technical expertise	Research		1	From 01/03/24 to 30/04/24		
Optimization-Bases Planning and Control for Multi-Limbed Walking Robots	Seminar	1.5	0.3	27/05/24	Prof. Bruno Siciliano	Y
Introduction to Large Language Models: Evolution and the current state	Seminar	2	0.4	10/06/24	Prof. Giancarlo Sperlì	Y
Simultaneous Perception and Manipulation	Seminar	1	0.2	21/06/24	Prof. Bruno Siciliano	Y
On the Single Allocation hub location problems: New formulations	Seminar	1	0.2	26/06/24	Prof. Maurizio Boccia, Prof. Claudio Sterle, Prof. Adriano Masone	Y

and Solving Methods						
- Continuing collaboration with the Marine Biology Department for systematic review - Manipulation of roll and pitch IMU measurements for easier prediction - Analysis on FFT prediction usage to calculate the best drone take-off time interval from water in presence of sea-waves, with MATLAB simulations - Setting up simulations to evaluate maximum roll and pitch intervals for good performances drone take-off	Research		7	From 01/05/24 to 30/06/24		
2024 IEEE RAS Summer School on Multi-Robot Systems	Doctoral School	50	2	From 29/07/24 to 02/08/24	Prof. Martin Saska – Czech Technical University, Prague	Y
- Continuing collaboration with the Marine Biology Department for systematic review - Mission in Porto Cesareo, in collaboration with the Marine Biology Department of University Federico II, for photodetection (through the usage of a drone) of	Research		5.4	From 01/07/24 to 31/08/24		

marine protected area properties. - Evaluation of drone roll and pitch errors during take-off from inclined platform						
From ACE Technologies to Sustainable, Accesible and Equitable Urban Mobility: An Optimization Journey	Seminar	2	0.4	16/09/24	Prof. Stefania Santini	Y
- Continuing collaboration with the Marine Biology Department for systematic review -Analysis of drone trust and torque during take-off from inclined platform -Testing for Leonardo Drone Contest at Leonardo spa, Turin -Participation in Leonardo Drone Contest 5th Edition in Bologna at Droneitaly - Second mission in Porto Cesareo, in collaboration with the Marine Biology Department of University Federico II, for photodetection (through the usage of a drone) of marine protected area properties.	Research		9.1	From 01/09/24 to 31/10/24		

Teaching assistant for Robotics Lab course, a.y. 2024/2025, M.Sc. in Automation and Robotics Engineering, Professor Mario Selvaggio	Tutorship	4	0.5	25/09/24 and 23/10/24		

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

2.1. Study and training activities - credits earned

	Courses	Seminars	Research	Tutorship	Total
Bimonth 1	**4**	**1.2**	**4.8**	**0**	**10**
Bimonth 2	**3**	**0.2**	**6.8**	**0**	**10**
Bimonth 3	**13**	**0.5**	**1**	**0**	**14.5**
Bimonth 4	**0**	**1.1**	**7**	**0**	**8.1**
Bimonth 5	**2**	**0**	**5.4**	**0**	**7.4**
Bimonth 6	**0**	**0.4**	**9.1**	**0.5**	**10**
Total	**22**	**3.4**	**34.6**	**0.5**	**60**
Expected	**20 - 40**	**5 - 10**	**10 - 35**	**0 - 1.6**	

3. Research activity:

The conducted research activities, which are part of a broader project that involves collaboration with the Marine Biology Department of the University of Naples Federico II, focus on developing new technologies for marine biodiversity mapping and monitoring. Specifically, the aim is the creation of a new type of aerial-amphibious drone capable of navigating autonomously both the air and water environments, managing the transition between the two without the need of intervention of an external operator. Once completed and fully operational the drone, thanks to a specific probe, will be able to autonomously reach sites where sampling and analysis of the marine environment, at different depths, will be conducted, making all the necessary data available to marine biologists.

The initial phase involved reviewing the current state of the art to identify similar approaches to the task and specifically if the autonomous transition between air and water, take-off and landing, had already been addressed. A primary challenge involves managing those environments in which the sea surface is not often flat with sea waves representing a danger for both the whole drone and the single propellers: the first could be capsized because of the wave impact, while the latter can be slowed down or even broken by the waves, hindering takeoff. At present no reviewed studies have tackled these specific issues, thus no solution exists yet.

At the same time several approaches have been explored to simulate the marine environment and generate different kind of wavefields: the choice fell on the Gazebo Garden simulation environment where an already existing simulator, originally designed to facilitate the design, development and evaluation of autonomous **U**nmanned **S**urface **V**ehicles (USVs), has been modified to account for **U**nmanned **A**erial **V**ehicles (UAVs) and their interaction with water especially during the takeoff and landing phases.
To develop the drone the PX4 firmware has been selected as flight controller along with ROS2 to manage all the autonomous tasks involved. Currently the drone used in simulation is a digital mockup of the existing amphibious drone PLACE jointly developed by the start-up *NEABOTICS* and *PRISMA Lab* at the University of Naples Federico II. Note that the digital mockup will be upgraded to the final drone version once the design is finalized by the external contractor which is handling the full hardware production process.
Once the simulation framework was established, efforts focused on understating how the presence of waves, of different intensity, impact the drone performance: different takeoff tests had been carried out both from water, with different wave conditions, and dry surfaces, tilted at different angles. The results suggest that the tilting angle at which the drone starts the takeoff slightly, though not significantly, influences the performance in terms of position/orientation error or energy consumption, compared to a flat surface takeoff. The matter of avoiding contact between propellers and water is under active investigation: a feasible solution is estimating, in the immediate future, the wave pattern and intensity applying the FFT on the data coming from the IMU onboard the drone; based on this, propellers could be adjusted individually with different trust levels to adjust the orientation of the drone anticipating the incoming wave front.
Parallelly to the main line of research two side projects have been brought on in direct collaboration with the Marine Biology Department of the University of Naples Federico II.
The first one, in which also the University of Genova is involved, concerns the production of a systematic review titled *Technologies for Marine Biodiversity Monitoring and Conservation* which examines the existing technologies to monitor and map marine biodiversity according to the **E**ssential **O**cean **V**ariables (EOV). This review, which began with a database of over a thousand articles/studies and narrowed down to just below two hundred, reveals an increased interest in AI usage, although cost data are prevalently omitted, complicating benchmarking efforts for future investments. The submission of the systematic review is expected next year.
The second project entails on-site missions to Porto Cesaro (Puglia) to conduct a campaign of aerial photo detection, using the *DJI Matrice 300 RTK* drone and the *Parrot Sequoia* multispectral camera, to search for the presence of Gongolaria Barbata, an endangered algae species affected by climate change and the subsequent rise in water temperature. Two missions have been carried out: the first to test capability and limits of the custom aerial photographic drone and to identify possible algae sites; the second to obtain exact GPS coordinates for scuba divers to confirm that what in the photos appear as possible algae spots are. Additional missions will be carried out to monitor how algae presence and distribution will change over time.

4. Research products:

Participation to *Leonardo Drone Contest 5th Edition* (*Dronitaly* fair, Bologna): in this contest seven Italian universities faced each other in managing different tasks, simultaneously with a drone and a rover, in a city-like scenario without GPS-signal.

5. Conferences and seminars attended

None.

6. Activity abroad

None.

7. Activity in partner companies

Not foreseen.

8. 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