



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

PhD Student: Hameed Ullah

Cycle: XXXVII

Training and Research Activities Report

Academic year: 2022-23 - PhD Year: Second

Tutor: Fabio Ruggiero

tutor signature

Co-Tutor:

Date: October 22, 2023

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle:

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1. Information:

- ☐ **PhD student:** Hameed Ullah **PhD Cycle:** XXXVII
- ☐ **DR number:** 157880
- ☐ **Date of birth:** 08/05/1992
- ☐ **Master Science degree:** Electrical Engineering **University:** National University of Sciences and Technology Islamabad, Pakistan
- ☐ **Scholarship type:** AEROTRAIN Project under *Marie Curie Scholarship Funded by EU.*
- ☐ **Tutor:** Prof. Fabio Ruggiero
- ☐ **Co-tutor:**

2. Study and training activities:

Activity	Type ¹	Hours	Credits	Dates	Organizer	Certificate ²
Is control a solved problem for aerial robotics research?	Seminar	1	0.2	12/1/2023	Prof. Fabio Ruggiero, UNINA II	Y
3rd Training School (TS3) of AEROTRAIN project "Training School on Field experimentation" George Nikolakopoulos Luleå University of Technology (LTU), Sweden	Training School	28	2.0	5 th – 9 th December 2022	Lulea University of Technology Sweden	Y
1st Integration Week (IW-1) of AEROTRAIN project Erdem Sahin Tampere University, Finland	Integration Week	28	2.0	20 th – 24 th March 2023	Tampere University Finland	Y
AI, Robots and Society: Challenges and Opportunities for Social Innovation	Seminar	1	0.2	25 th May 2023	PROF. BRUNO SICILIANO, UNINA II	Y
Migration of legacy IT infrastructures into the	Seminar	2	0.4	23 rd May 2023	Prof. Roberto	Y

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle:

Author:

cloud: approaches and strategies					Canonico, UNINA II	
Inspection-based robotics for society	Seminar	2.5	0.5	15th June 2023	Dr. Antidio Viguria Jiménez	Y
Optimization of a mobile clinic routing and scheduling problem in equitable vaccination outreach	Seminar	1	0.2	21st June 2023	Maurizio Boccia	Y
Traffic Engineering with Segment Routing: optimally dealing with most popular use-cases	Seminar	1	0.2	23rd June 2023	Prof. Valerio Persico	Y
Quantum communications with continuous variables of light	Seminar	1	0.2	20th June 2023	QST Seminars, Procolo Lucignano, Domenico Montemurro, Davide Massarotti, Vincenzo D'Ambrosio, Filippo Cardano and Martina Esposito.	Y
Exploring Advanced Aerial Robotics: A Journey into Cutting-Edge Projects and Neural Control	Seminar	1	0.2	29th June 2023	Engr. Julien Mellet, Prisma Lab, ITEE, UNINA II	Y
2nd Integration Week (IW-2) of AERO-TRAIN project Julian Cayero Eurecat, Centre Tecnològic de Catalunya, Barcelona Spain	Integration Week	28	2.0	3rd – 7th July 2023	 Eurecat, Centre Tecnològic de Catalunya, Barcelona Spain	Y

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle:

Author:

BGP & Hot-Potato Routing: graceful and optimal convergence in case of IGP events	Seminar	1	0.2	30 June 2023	Prof. Valerio Persico	Y
IEEE Authorship and Open Access Symposium: Tips and Best Practices to Get Published from IEEE Editors	Symposium	1.5	0.3	20 th September 2023	IEEE	Y
Worked on learning Linux and ROS. Understanding and implementation Nonlinear Model Predictive Control (NMPC) for Quadrotor.	Research		10	1.11.2022 – 31.12.2022		N
Working on the Quadrotor in ROS and Gazebo. Start implementing controllers for Quadrotor.	Research		9.8	1.01.2023 – 28.02.2023		N
Implement a Hierarchical controller on Quadrotor in ROS Gazebo. Continue working on the ROS and Gazebo.	Research		6.0	1.03.2023 – 30.04.2023		N
Worked on the theoretical and Mathematical understanding of Geometrical Controller and its implementation on Quadrotor. Started working on Docker, PX4, GitHub, Gitkraken and related data. Worked on some push and slide operation with Quadrotor in Gazebo.	Research		8.1	1.05.2023 – 30.06.2023		N

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle:

Author:

Worked on Nonlinear Model Predictive Controller basic concept and detail mathematical understanding. Work on the Nonlinear Model Predictive Controller simulation for quadrotor on MATLAB simulation.	Research		9.8	1.07.2023 – 31.08.2023		N
Started working on MATLAB/Simulink interface with GAZEBO through ROS. Implemented the controller in MATLAB/Simulink and interfaced to GAZEBO through ROS. Perform some push and slides operations.	Research		7.7	1.09.2023 – 31.10.2023		N

- 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	0	0	10	0	10
Bimonth 2	0	0.2	9.8	0	10
Bimonth 3	4.0	0	6.0	0	10
Bimonth 4	0	1.9	8.1	0	10
Bimonth 5	0	0.2	9.8	0	10
Bimonth 6	2.0	0.3	7.7	0	10
Total	6.0	2.6	51.4	0	60
Expected	30 - 70	10 - 30	80 - 140	0 - 4.8	

3. Research activity:

The PhD scholarship is associated with the project **AERO-TRAIN** “AERial RObotic TRAINing for the next generation of European infrastructure and asset maintenance technologies”, which is a **Marie-Sklodowska-Curie** Innovative Training Network (ITN) - European Training Network (ETN) project. The main aim of the AERO-TRAIN project is to take a step further toward the research of aerial manipulators which face the challenges of the Operations & Maintenance industry of civil and industrial infrastructures by deploying

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle:

Author:

innovative aerial robotic solutions to reduce the risks and costs associated with field operations by humans. It is a Multi-disciplinary Research and with the aim to fill technological gaps of autonomous flying robots.

The PhD research activities mainly focus on stabilizing and controlling aerial manipulators (basically a drone with a stick or robotic arm) while physically interacting with the surrounding environment for on-site measurements. The main objectives of the PhD project are to design a model-based control for an aerial device or an aerial manipulator while in contact with the environment to perform some physical tasks. To design a force interaction controller and robust controller that can estimate external disturbance. The main goal is to perform push-and-slide operations of the aerial manipulator while interacting with the environment. Aerial manipulators present multiple scientific and technological gaps, and a need for real-life testing to enable a broader spectrum of new technological capabilities. The AERO-TRAIN project aims to fill the gap between scientific research and industrial needs, which is necessary for developing new markets and applications.

In the second year of the PhD, the PhD candidate did a comprehensive state-of-the-art on the recent research work on UAVs/quadrotors, aerial manipulators and the control techniques applied. UAVs/drone industrial applications have increased astoundingly in the last few decades, but drones mostly perform passive tasks and their limitation involves any kind of contact with the environment. UAVs have to migrate from passive tasks to active tasks that do require manipulation and physical interaction with the environment. Therefore, for physical interaction, we need Unmanned Aerial Manipulators (UAM) for physical interaction, but it is a challenging task to control it. The methodology included designing a robust controller to stabilize aerial manipulators while performing physical tasks. The PhD candidate worked on designing various model-based controllers that can stabilize the aerial manipulators while interacting with the surrounding environment to perform some physical tasks.

*During the second year of the PhD, the candidate worked on **ROS Toolbox** in MATLAB/Simulink, interfacing with Gazebo through ROS. Gazebo is an open-source 3D robotic simulator with dynamical joints. Gazebo offers the ability to accurately and efficiently simulate populations of robots in complex indoor and outdoor environments. It is a robust physical engine, with high-quality graphics, and convenient programmatic and graphical interfaces. MATLAB/Simulink are used which make it easier to connect the blocks to design the controller, planning and perception. Designed the controller in MATLAB/Simulink to control a device in the dynamic simulation environment. ROS (Robot Operating System) is a communication protocol (using rosnode) used to connect the MATLAB/Simulink to Gazebo. With this setup, some physical tasks are performed like push-and-slide operations. Furthermore, this year, the research focused on nonlinear model predictive control (NMPC), a powerful, robust nonlinear controller technique for complex nonlinear systems. Moreover, we started work on the state of the art of the NMPC, its understanding, and then implementation. In addition, we implemented NMPC on a quadrotor on MATLAB/Simulink and got the desired results. We are currently moving forward to implement NMPC on aerial manipulators while performing push and slide operations during physical tasks.*

*On the other hand, as a participant in the **AEROTRAIN** project, the PhD candidates participate in the “**AEROTRAIN challenge**”. It is a competition between 3 teams of project's PhDs to develop an aerial manipulator capable of performing non-destructive measurement tests. The project organized various international training schools and integration weeks to achieve these goals. This PhD candidate attended all training activities organized by AEROTRAIN to achieve the desired results towards the final grand challenge. This PhD candidate attended the Training School-3 (TS-3), the “Training School on Field experimentation” which was held at **Luleå University of Technology (LTU), Sweden**, organized by (George Nikolakopoulos) of the AERO-TRAIN project. The activities during the TS-3 focusing on field robotics were conducted in the*

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle:

Author:

Robotics and AI group's unique underground tunnel environment research facility. This training program exposed the project's PhDs (ESR's, Early-Stage Researchers) to conducting field experiments, such as designing and planning an experiment, sensor configurations, and data collection, processing, and analysis. This training program focused on various aspects of the project with the practical aspects of estimation, computer vision and perception algorithms. This TS3 aimed to prepare the project's PhDs (ESRs) for the upcoming integration weeks and grand challenge within the AERO-TRAIN project. Moreover, this PhD candidate attended the 1st Integration Week (IW-1) of AERO-TRAIN project, which was held at **Tampere University, Finland**, organized by (Erdem Sahin) AERO-TRAIN project. This integration week's main aim was for the project's PhDs to gain knowledge on the fundamentals of 3D scene capture, representation, processing, and visualization, along with the related algorithms and methods. During the IW-1, the team worked on the integration of the base platform, implementation of the simulation environment, the control for physical contact and the communication setup. Fly the aerial manipulator for the first time, flight without and with contact were tested successfully. Initially, the built-in position controller was used and that stabilized the system. In addition, the simulation environment was extended to allow for testing different components in the simulation. Finally, the integration of the aerial platforms with an indoor localization system has been performed.

Furthermore, this PhD candidate attended the 2nd Integration Week (IW-2) of the AERO-TRAIN project, which was held at **Eurecat, Centre Tecnològic de Catalunya, Barcelona Spain**, organized by (Julian Cayero) AERO-TRAIN project. The IW 2 proceeded further upon the achievements of the previous IW1, the implementation of the simulation environment. The focus of IW-2 was navigation, target detection and target contact in GNSS denied environments. This integration needed on-board sensors to feedback the localization to the control algorithms, not only on the target approach phase, but also to move the drone from point A to point B, avoiding obstacles. The goal was to enable drones with augmented navigation and contact capabilities, which was achieved comfortably. This event's main aim is to showcase the project's PhDs ability to enable drones with augmented navigation and contact capabilities, culminating in flight tests in two remarkable scenarios. The first one was a challenge inside the **parking lot**, this challenge involved navigating in a straight line and approaching the target. The second challenge entailed navigating inside the **train tunnel**, while identifying and approaching the target positioned on the wall. Both challenges were done successfully.

Working with other PhDs of the project, the team progressed very well and performed all the tasks successfully during these activities/project meetings towards the final grand challenge. Working in a team and as the PhD candidate responsibilities, worked on the designing of the controller for physical contact. All these activities not only helped to compete for the grand challenge, to share information and build strong research networks with other PhD students as a team, but also to deeply understand the inspection and maintenance of aerial systems working in uncertain environments for physical interaction.

4. Research products:

Not yet.

5. Conferences and seminars attended

Not Yet.

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle:

Author:

6. Periods abroad and/or in international research institutions

- **TS-3: Training School 3 of AERO-TRAIN project on Autonomous Aerial Field Robotics, Luleå, Sweden:** The “Training School on Field experimentation” was held at **Luleå University of Technology (LTU), Sweden**, organized by (George Nikolakopoulos) of the **AERO-TRAIN** project from 5th to 9th December 2022 for a period of one week. The activities carried out during the TS-3, focusing on field robotics, were conducted in the Robotics and AI group’s unique underground tunnel environment research facility. The training program also exposed the project’s ESRs (Early-Stage Researchers) to the practical aspects of estimation, computer vision and perception algorithms. This training program focused on conducting field experiments such as designing and planning an experiment, sensor configurations, and data collection, processing, and analysis.
- **IW1: First Integration Week of AERO-TRAIN project, Tampere University, Finland:** The first integration week of the **AERO-TRAIN** project was held at **Tampere University, Finland**, organized by (Erdem Sahin) **AERO-TRAIN** project from 20th to 24th March 2023. This IW-1 mainly focused on Human-Robot Interfaces (HRI). The integration week’s main aim was for the ESRs to gain knowledge on the fundamentals of 3D scene capture, representation, processing, and visualization, along with the related algorithms and methods. A presentation of these technologies has then followed. Finally, the integration of the aerial platforms with an indoor localization system has been performed. The program included theoretical lectures and technology demonstrations.
- **IW-2: Second Integration Week of AERO-TRAIN project, Eurecat, Cerdanyola:** The 2nd Integration Week (IW-2) of **AERO-TRAIN** project was held at **Eurecat, Centre Tecnològic de Catalunya, Barcelona Spain**, organized by (Julian Cayero) **AERO-TRAIN** project from 3rd to 7th July 2023. The focus of IW-2 was navigation, target detection and target contact in a GNSS-denied environment. This integration needed onboard sensors to provide feedback on the localization to the control algorithms, not only on the target approach phase but also to move the drone from point A to point B, avoiding obstacles. Further, the event’s main aim was to showcase our ESRs’ ability to enable drones with augmented navigation and contact capabilities to experiment inside the train tunnel and underground parking lot.

7. Tutorship

NO Tutorship.

8. Plan for year three

The activities for the third year will be planned as follows. In the final year of the PhD, the plan is to complete the Simulation in MATLAB/Simulink interfacing with Gazebo through ROS. In addition, the plan is the Implementation of the Nonlinear Model Predictive Control (NMPC) on the aerial manipulator in simulation and then on the practical hardware. To design a force interaction controller and robust controller that can estimate external disturbance. Implementation of the work on the real hardware experimental platform. The main goal is to complete the push-and-slide operation of the aerial manipulator while interacting with the environment.

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle:

Author:

Moreover, the activities for the third year are to prepare for the third integration week (IW-3), which will be held in CATEC (Advanced Center for Aerospace Technologies) and **University of Sevilla, Sevilla, Spain**, from 20th to 24th November 2023, to be organized by AEROTRAIN project. This third integration week aims to progress the experimentation and results of the previous integration week and to move towards the competition's Final Grand Challenge. Furthermore, in the third year of the PhD, the plan is to prepare for the **Final Grand Challenge**, which will be held in **Italy** in the middle of March 2024, to be organized UNINA through the AEROTRAIN project. The main aim of this Final Grand Challenge is to finalize the competition of the ESR's Groups/teams and announce the winner based on performance and good results throughout the competition and on the final competition day. The ESR/PhD candidate aims to play a critical role as an individual performer and team to win the competition as a group.

Moreover, in the final year of the PhD, the plan is to organize/plan the AERO-TRAIN Summer School (AERO-TRAIN Workshop) at ERF2024 (European Robotics Forum) in June 2024, at Chania, Crete, Greece. The main aim of the ERF2024 is to serve as a gathering place for researchers and industry professionals from various parts of Europe, providing a platform for discussing recent developments in robotics and their practical applications. The forum will explore the current technological maturity in aerial robotics for inspection missions while shedding light on the critical gaps still to be solved.

During the 3rd year, the PhD candidate will plan the Secondment (Abroad period) at the Technical University of Denmark - DTU, Denmark, probably from January 2024 to June 2024 for six months. Finally, the plan will be to start writing the PhD thesis.