PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Francesca Pagano

Cycle: XXXVII

Training and Research Activities Report

Academic year: 2022-23 - PhD Year: Second

Francesca Pagano

Tutor: prof. Vincenzo Lippiello

Vincenzo Lippiello

Date: December 12, 2023

1. Information:

- **PhD student: Francesca Pagano**
- **PhD Cycle: XXXVII**
- **DR number: DR996115**
- **Date of birth: 18/03/1995**
- **Master Science degree: Automation Engineering**
  University: Università degli Studi di Napoli Federico II
- **Scholarship type: MUR PON (Green)**
- **Tutor: Vincenzo Lippiello**
- **Co-tutor:**

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Language course: C1 Cambridge	Course	12	0.0	27/01, 03/02, 07/02, 10/02, 14/02, 24/02/2023	CLA – Unina	N
Multi-robot Control of Heterogeneous Herds - Prof. Eduardo Montijano	Seminar	1	0.2	16/02/2023	SSM – Scuola Superiore Meridionale	Y
Model Predictive Control – Prof. Alberto Bemporad	Course	20	4.0	03/04/2023 – 05/05/2023	Scuola IMT Alti Studi Lucca	Y
From Romeo & Juliet to OceanOneK Deep-Sea Robotic Exploration – Prof. Oussama Khatib	Seminar	1.0	0.2	23/03/2023	Prof. Bruno Siciliano	Y
2023 Spring School on Transferable Skills	Course	9.5	2.0	24-25/05/2023	Department of Pharmacy University of Naples Federico II	Y
Exploring Advanced Aerial Robotics: A Journey into Cutting-Edge Projects and Neural Control	Seminar	1.0	0.2	29/06/2023	ITEE - Julien Mellet	Y

AI, Robots and Society: Challenges and Opportunities for Social Innovation	Seminar	1.0	0.2	25/05/2023	Prof. Bruno Siciliano	Y
Ethics and AI	Course	12	2.4	4/10/202, 11/10/2023, 18/10/2023, 25/10/2023, 8/11/2023, 15/11/2023	SIpEIA	Y
IEEE Authorship and Open Access Symposium: Tips and Best Practices to Get Published from IEEE Editors	Seminar	1.5	0.3	20/09/2023	IEEE Xplore	Y
Designing Cooperative Multi-Agent Teams and Socially-Aware Autonomy	Seminar	1.5	0.3	17/10/2023	ETHZ – Prof. Emilio Frazzoli	Y
Robotics Meets AI & 5G: The Future is Now!"	Seminar	1.5	0.3	30/10/2023	IIT DELHI	Y
Comfort Intelligence for Human-Robot Interaction (HRI)	Seminar	1.5	0.3	22/11/2023	INRIA - Dr. Anatole Lecuyer	Y
Learning to optimize dynamic behaviors	Seminar	1.5	0.3	20/11/2023	INRIA - Dr. Marco Tognon	Y
MAD Games - Multi-Agent Dynamic Games: What can you learn from Autonomous Racing?	Seminar	1.0	0.2	12/12/2023	ETHZ – Prof. Emilio Frazzoli	
Strategic Orientation for STEM Research & Writing	Course	8.0	0.0	07-15/12/2023 (to end in 2024)	DIETI-Unina	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**	**0.4**	**7.6**	**0.0**	**8.0**
Bimonth 2	**0.0**	**0.2**	**7.8**	**0.0**	**8.0**
Bimonth 3	**6.0**	**0.4**	**4.0**	**0.0**	**10.4**
Bimonth 4	**0.0**	**0.0**	**8.0**	**0.0**	**8.0**
Bimonth 5	**0.0**	**0.9**	**7.5**	**1.6**	**10.0**
Bimonth 6	**2.4**	**0.8**	**10.0**	**0.0**	**13.0**
Total	**8.4**	**2.7**	**44.9**	**1.6**	**57.6**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

3. Research activity:

Paper submission

During the first part of the second year, the research activity involved the writing and submission of the paper “Development of a Control Framework to Autonomously Install Clip
Bird Diverters on High-Voltage Lines” to the 2023 International Conference on Unmanned Aircraft Systems (ICUAS) [P1].

Multi-robot repetitive area reconnaissance

The research activity also focused on the multi-robot repetitive area reconnaissance problem in which multiple robots, eventually with heterogeneous locomotion or sensing capabilities, repeatedly visit some points of interest. This application is relevant in agriculture, where robots can be tasked to take multiple measurements or patrol a field to detect unwanted intruders like wild boars. The methodology employs the nonlinear model predictive control (NMPC) approach and extends to a multi-robot setting the work presented in [3]. The research activity focused on the problem definition, the coordination approach, and on different collision avoidance strategies [4][5]. Preliminary simulations were carried out in MATLAB and PX4/Gazebo employing the CasAdi and Ipopt libraries.

Drone autopilot and laboratory activities

The laboratory activities carried out during the first year of PhD underlined the limitations and the strengths of the PX4 open-source firmware in the scientific research, where it is often necessary to implement control laws for non-standard aerial platforms while ensuring safety functionalities for real drone on-field deployment. To address these limitations and provide a more versatile solution than the one employed in [P1][2], additional experiments were conducted during the second year of PhD, supervising a M.Sc. Student’s thesis work. A new customized version of the PX4 firmware that allows easy integration of new control laws in the standard architecture was successfully tested on multiple aerial platforms. The work will be soon prepared for submission to an international conference.

Extended set-based tasks execution and prioritization

This research activity was focused on the experimental validation of an approach to execute and prioritize a time-varying set of tasks. The work extends the framework presented in [1] and formalizes the definition of extended set-based tasks while proposing a way to dynamically insert, remove and prioritize them. The work employs an optimization-based approach, formulating a convex quadratic problem and encoding the tasks in the constraints through Control Barrier Functions (CBFs).
During the second year of PhD, the above approach, previously tested in MATLAB, was first validated in ROS/Gazebo simulations and then with real experiments on a Kuka manipulator.
The work was carried out in the context of an international collaboration and is currently being revised for submission to an international journal [P2].

Moreover, the above optimization framework was tested on a drone in a PX4/Gazebo simulation and MATLAB on a multi-robot application. Future work will employ the methodology developed in [P2] in a multi robot application where both safety tasks (i.e., collision avoidance), battery recharging and active sensing tasks will be considered.

4. Research products:

[P1]
Conference paper: Development of a Control Framework to Autonomously Install Clip Bird Diverters on High-Voltage Lines
Authors: S. D'Angelo, F. Pagano, F. Ruggiero, V. Lippiello
Conference: 2023 International Conference on Unmanned Aircraft Systems (ICUAS)
Status: published
Indexed: yes
Year of publication: 2023

[P2]
Journal paper: Beyond Jacobian-based tasks: Extended set-based tasks for multi-task execution and prioritization
Authors: G. Notomista, M. Selvaggio, M. Santos, M. Siddharth, F. Pagano, V. Lippiello, C. Secchi
Journal: International Journal of Robotics Research
Status: submitted

Student Contest: Leonardo Drone Contest – preliminary tests in Turin
Dates: 20-21/07/2023

5. Conferences and seminars attended

Conference: 2023 International Conference on Unmanned Aircraft Systems (ICUAS)
Place: Warsaw (Poland)
Dates: 6-9/06/2023
Presenting the paper: "Development of a Control Framework to Autonomously Install Clip Bird Diverters on High-Voltage Lines"

6. Periods abroad and/or in international research institutions

Period: 01/09/2023 – present

Hosting institution: IRISA/Inria Rennes (France)

Supervisior: Dr. Paolo Robuffo Giordano

Research Activity description

The research activity currently focuses on implementing a distributed control approach to execute a persistent multi-robot environmental monitoring task. The robots, seen as mobile sensors, estimate an unknown diffusive field (e.g., a gas leak) and thus reconstruct physical processes evolving in time.

This field of research is often denoted as active sensing as the robot motions can be optimized to plan informative trajectories, relying on a suitable information matrix, e.g. the Observability Gramian, the Fisher Information Matrix or the covariance matrix [10][11]. Employing a control theoretic approach based on the Observability Gramian, we plan to extend the approach proposed in [8] by considering a multi-robot setting and proposing a solution that does not rely on offline learned cost functions, as done in [9]. Similarly to [8][9], we plan to leverage the Control Barrier Functions (CBFs) approach to merge, in an optimization framework, both the active sensing task and the energy constraints but introducing new control approaches to take into account mobile recharging stations.
The research activity involved the study of the literature, the problem formulation, and MATLAB simulations.

Total number of months: 4
Expected total number of months abroad: 6.

7. Tutorship

- Teaching activities for the course Theory of Systems (ING-INF/04), Prof. Fabio Ruggiero.
- Co-supervisior of a student M.Sc. Thesis (P38 - INGEGNERIA DELL'AUTOMAZIONE E ROBOTICA)

8. Plan for year three

The activities planned for the third PhD include:

- End of the period abroad (29/02/2024) and finalization of the research activity with real experiments.
- Course “Strategic Orientation for STEM Research & Writing” attendance.
- 6 months company period (expected from 01/03/2024 to 01/09/2024).
- Draft topic of the thesis on multi-robot constraint driven task execution.

9. References

[1] Notomista, Gennaro et al. “A Set-Theoretic Approach to Multi-Task Execution and Prioritization.” 2020 IEEE International Conference on Robotics and Automation (ICRA) (2020): 9873-9879.

[2] S. Marcellini, J. Cacace and V. Lippiello, "A PX4 Integrated Framework for Modeling and Controlling Multicopters with Til table Rotors," 2023 International Conference on Unmanned Aircraft Systems (ICUAS), Warsaw, Poland, 2023, pp. 1089-1096, doi: 10.1109/ICUAS57906.2023.10156642.

[3] S. Marcellini, F. Ruggiero and V. Lippiello, "Nonlinear Model Predictive Control for Repetitive Area Reconnaissance with a Multirotor Drone," 2023 International Conference on Unmanned Aircraft Systems (ICUAS), Warsaw, Poland, 2023, pp. 515-522, doi: 10.1109/ICUAS57906.2023.10155895.

[4] M. Kamel, J. Alonso-Mora, R. Siegwart and J. Nieto, "Robust collision avoidance for multiple micro aerial vehicles using nonlinear model predictive control," 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Vancouver, BC, Canada, 2017, pp. 236-243, doi: 10.1109/IROS.2017.8202163.

[5] J. White, D. Jay, T. Wang and C. Hubicki, "Avoiding Dynamic Obstacles with Real-time Motion Planning using Quadratic Programming for Varied Locomotion Modes," 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Kyoto, Japan, 2022, pp. 13626-13633, doi: 10.1109/IROS47612.2022.9981268.

[6] G. Notomista, S. F. Ruf and M. Egerstedt, "Persistification of Robotic Tasks Using Control Barrier Functions," in IEEE Robotics and Automation Letters, vol. 3, no. 2, pp. 758-763, April 2018, doi:10.1109/LRA.2018.2789848.

[8] G. Notomista, C. Pacchierotti and P. R. Giordano, "Online Robot Trajectory Optimization for Persistent Environmental Monitoring," in IEEE Control Systems Letters, vol. 6, pp. 1472-1477, 2022, doi: 10.1109/LCSYS.2021.3110940.

[9] G. Notomista, C. Pacchierotti and P. R. Giordano, "Multi-Robot Persistent Environmental Monitoring Based on Constraint-Driven Execution of Learned Robot Tasks," 2022 International Conference on Robotics and Automation (ICRA), 2022, pp. 6853-6859, doi:10.1109/ICRA46639.2022.9811673.

[10] L. Balandi, N. De Carli and P. R. Giordano, "Persistent Monitoring of Multiple Moving Targets Using High Order Control Barrier Functions," in IEEE Robotics and Automation Letters, vol. 8, no. 8, pp. 5236-5243, Aug. 2023, doi: 10.1109/LRA.2023.3293312.

[11] P. Salaris, M. Cognetti, R. Spica and P. R. Giordano, "Online Optimal Perception-Aware Trajectory Generation," in IEEE Transactions on Robotics, vol. 35, no. 6, pp. 1307-1322, Dec. 2019, doi: 10.1109/TRO.2019.2931137.