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

Year: First

Tutor: prof. Vincenzo Lippiello

Co-Tutor:

Date: December 13, 2022

1. Information:

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

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Probability calculus and elements of stochastic modelling	PhD Course	24	4	10/01/2022 -16/02/ 2022	Prof. Massimiliano Giorgio – S.S.M.	Y
Matrix Analysis for Signal Processing with MATLAB Examples	PhD Course	8	2	22-23/03/ 5- 7/04/2022	Prof. Antonio De Maio, Augusto Aubry, Dr. Vincenzo Carotenuto - ITEE-DIETI	Y
Control of Complex Systems and Networks	MSc course	48	6	07/03/2022 - 07/06/2022	Prof. Pietro de Lellis - DIETI	Y
Robotics Lab	MSc course	48	6	07/03/2022 - 06/06/2022	Prof. Jonathan Cacace - DIETI	Y
Operational Research: Mathematical Modelling, Methods and Software Tools for Optimization Problems	PhD Course	10	4	14-21-28/09 - 05-12/10/2022	Prof. Adriano Masone - DIETI	Y
Theory and Applications of Contracting Dynamical Systems	PhD Course	10	2.5	18-21- 22-23/11/2022	Mario di Bernardo – S.S.M.	Y
IEEE RAS Summer School on Multi-Robot Systems 2022	Summer School	50	2	1-5/08/2022	Czech Technical University	Y
Application of simultaneous block diagonalization of matrices	Seminar	1	0.2	10/01/2022	Prof. Francesco Sorrentino	Y

to problems in Controls and Nonlinear Dynamics						
IEEE Authorship and Open Access Symposium: Tips and Best Practises to Get Published from IEEE Editors	Seminar	1.5	0.3	30/03/2022	Rachel Berrington Director, IEE Client Services	Y
Global and cluster synchronization in complex networks and beyond	Seminar	1	0.2	11/03/2022	Prof. Mattia Frasca – SSM Scuola Superiore Meridionale	Y
An Introduction to Deep Learning for Natural Language Processing	Seminar	1	0.2	13/04/2022	Prof. Francesco Cutugno	Y
Explainable Natural Language Inference	Seminar	1	0.2	13/04/2022	Prof. Francesco Cutugno	Y
On using simple optimization techniques for tuning of UAVs	Seminar	2	0.4	27/04/2022	Prof. Fabio Ruggiero	Y
IEEE-ICRA 2022 workshop: Shared Autonomy in Physical Human-Robot Interaction: Adaptability and Trust	Seminar	5	1.0	23/05/2022	Mario Selvaggio et al.	Y
Introduction to Intellectual Property Managment	Seminar	2	0.4	19/07/2022	5G Academy – Antonia Maria Tulino	Y
IROS 2022 Workshop: “Human-Multi-Robot Systems: Challenges for Real World Applications”	Seminar	6	1.2	27/10/2022	G. Notomista, R. Funada, J. Yamauchi, P. Robuffo Giordano	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**	**0.2**	**8.8**	**0.0**	**9.0**
Bimonth 2	**2.0**	**1.3**	**5.7**	**0.0**	**9.0**
Bimonth 3	**4.0**	**1.0**	**5.0**	**0.0**	**10.0**
Bimonth 4	**8.0**	**0.4**	**1.6**	**0.0**	**10.0**
Bimonth 5	**10.0**	**1.2**	**4.8**	**0.0**	**16.0**
Bimonth 6	**2.5**		**4.0**	**0.0**	**6.5**
Total	**26.5**	**4.1**	**29.4**	**0.0**	**60.5**
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

3. Research activity:

The research activity is focused on the control of a multi-robot system in agricultural applications. The system, mainly composed of drones, is seen as a team in which agents cooperate to achieve a joint mission based on their characteristics and operative conditions. In this framework, the eventual presence of a human operator or a piloted drone will be considered, and the interaction with the autonomous robots will be studied. The research topic is highly relevant for agriculture tasks like weed monitoring, remote sensing, spraying of chemicals, farming and wild animals' detection, which could benefit of the use of many aerial platforms embedded with different sensors. The study of the literature showed that the use of multiple heterogeneous drones is still limited in agriculture [1] and that the low flight autonomy, due to batteries depleting, could be mitigated if more robots were used and methods for autonomous recharging adopted.

The first months focused on the state of the art in multirobot systems applied to agriculture-related tasks and on the Pixhawk flight controller architecture. This last activity was carried out both in simulation with ROS/Gazebo and in the flight arena and led to the implementation of a custom flight controller for the autonomous insertion of a bird diverter device on a power line cable. The outcome of this work is now being prepared for possible submission to a conference.

The study also focused on using Control Barrier Functions (CBF) for the execution of multiple tasks by a team of heterogeneous robots in a coordinated fashion. In [2], a framework for an energy-aware task allocation is proposed and the tasks, encoded in CBFs, are executed by solving a quadratic problem with affine constraints and allocated to robots solving a Mixed Integer Quadratic Program. The use of CBFs has been widely adopted in literature for the execution of coverage tasks for both constant and time-varying densities [3], predefined or generated by a human user [4], and applied to visual coverage control for teams of quadcopters [5]. In [6], CBFs are proposed to achieve persistent task execution bringing the robots to recharging areas and preventing battery depletion. The latter approach has been used in [7] to achieve a persistent environmental monitoring based on learned robotic tasks. CBFs have also been used in defence and surveillance [8] and to encode Signal Temporal Logic Tasks.

Following the state of the art, the use of CBFs for multi-robot task allocation and execution, task persistification, and time-varying coverage have been implemented and simulated in MATLAB using the Robotarium simulator [9] and Gurobi solver. Future work will bring this approach to an agriculture-related application with drones.

Part of the research activity is currently focused on the study of execution and prioritization of extended set-based tasks encoded by CBFs, as an extension of the work in [10]. Simulations are being carried out in MATLAB, and first experiments will soon be executed on a manipulator arm. The same approach for prioritization, also introducing human presence, will then be brought to multi-robot control in future work since multi-robot task allocation can be interpreted as a prioritization, as done in [2].

Current activity also addresses the use of Nonlinear Model Predictive Control for multi-drone Repetitive Area Reconnaissance using a decentralized approach with a global map whose time evolution simulates the probability of finding an intruder. This work might be submitted to a conference soon.

[1] Panagiotis Radoglou-Grammatikis, Panagiotis Sarigiannidis, Thomas Lagkas, Ioannis Moscholios, “A compilation of UAV applications for precision agriculture,” Computer Networks, 2020, 172, 107148

[2] G. Notomista et al., "A Resilient and Energy-Aware Task Allocation Framework for Heterogeneous Multirobot Systems," in IEEE Transactions on Robotics, vol. 38, no. 1, pp. 159-179, Feb. 2022, doi: 10.1109/TRO.2021.3102379.

[3] S. G. Lee, Y. Diaz-Mercado and M. Egerstedt, "Multirobot Control Using Time-Varying Density Functions," in IEEE Transactions on Robotics, vol. 31, no. 2, pp. 489-493, April 2015, doi: 10.1109/TRO.2015.2397771.

[4] Diaz-Mercado, Y., Lee, S.G., Egerstedt, M. (2017). Human–Swarm Interactions via Coverage of Time-Varying Densities. In: Wang, Y., Zhang, F. (eds) Trends in Control and Decision-Making for Human–Robot Collaboration Systems. Springer, Cham. https://doi.org/10.1007/978-3-319-40533-9_15

[5] R. Funada, M. Santos, J. Yamauchi, T. Hatanaka, M. Fujita and M. Egerstedt, "Visual Coverage Control for Teams of Quadcopters via Control Barrier Functions," 2019 International Conference on Robotics and Automation (ICRA), 2019, pp. 3010-3016, doi: 10.1109/ICRA.2019.8793477.

[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.

[7] 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.

[8] L. Guerrero-Bonilla, M. Egerstedt and D. V. Dimarogonas, "Area Defense and Surveillance on Rectangular Regions Using Control Barrier Functions," 2021 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2021, pp. 8166-8172, doi: 10.1109/IROS51168.2021.9636379.

[9] https://www.robotarium.gatech.edu/

[10] 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.

4. Research products:

5. Conferences and seminars attended

- International Conference on Robotics and Automation, IEEE-ICRA 2022, Workshop: “Shared Autonomy in Physical Human- Robot Interaction: Adaptability and Trust”, Philadelphia, 23/05/2022. Online attendance, not presenting a paper.

- International Conference on Intelligent Robots and Systems, IROS 2022, Workshop: “Human-Multi-Robot Systems: Challenges for Real World Applications”, Tokyo, 27/10/2022. Online attendance, not presenting a paper.

6. Activity abroad:

None.

7. Tutorship

None.