NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Satellite technologies for autonomous systems and decision support

Ph.D. candidate

Antonio DI PAOLA

Cycle

XXXIX

Tutors

Giuseppe Tomasicchio

Alessandro Giuseppi

1. Description of the research program

My Ph.D. journey, co-founded by La Sapienza University of Rome and Telespazio, is dedicated to exploring and advancing cutting-edge satellite technologies for autonomous systems and the primary objective of my work is practical applications of these technologies to enhance autonomy and decision support in space and military (defense) contexts. In collaboration with Telespazio, I will focus on developing a "digital twin" for lunar missions using virtual/augmented reality, the work belongs to the ESA project "Moonlight". This simulator's purpose is to faithfully replicate the conditions and challenges faced by a lunar lander during the mission. The goal is to improve the understanding, the awareness and control capability of lunar missions through virtual reality. In particular, the activity concerns the development and integration of AR/VR scenarios for the Interactive Mission Modeling and Visualization for GNC (Guidance Navigation and Control) validation for autonomous systems both terrestrial (i.e., UAV) and lunar (landers, rovers). For what concerning the activity with University of Rome La Sapienza, it will be focused on the control of a drone swarm defending in a military scenario. This project's goal is to use data-driven Deep Reinforcement Learning (RL) to train a defensive drone's swarm to contrast the attacks of drones in complex situations. This work will have a significant impact on security and defense in critical applications. My research work also aims to explore and develop innovative satellite technologies to face up challenges arising from climate change like wildfires prediction. Thus, the implementation of Deep Learning algorithms starting from satellite and terrestrial data in order to predict and avoid the evolution of such dangerous phenomena and the adoption of autonomous drones for the surveillance of critical areas. In summary, my Ph.D. journey focuses on the synergy between advanced space technology, the use of virtual reality for training and simulation, and the application of innovative deep reinforcement learning approaches for the control of autonomous systems, with an emphasis on defense applications. Through this research, we aim to enhance the safety, efficiency, and autonomy of space and military operations.

2. Schedule of the research activities

First academic year (planned)

	Description	Period	Activity at the company
"Moonlight" ESA project	The activity concerns lunar autonomous systems GNC validation via the study and integration of AR/VR scenarios for the Interactive Mission Modeling and Visualization.	First - second semester	YES
UAVs defense strategies	New Deep RL algorithms for the development of defense strategies for autonomous drone's swarm against attacking drones.	First - second semester	NO

Second academic year (planned)

	Description	Period	Activity abroad
Satellite technologies for wildfire predictions	Wildfire predictions via Deep Learning techniques starting from satellite data and autonomous UAVs patrolling.	First semester	NO
UAVs defense strategies	cont'd	First semester	NO

"Moonlight" ESA project	cont'd	Second semester	YES (c/o TELESPAZIO IBERICA, Madrid)

Third academic year (planned)

	Description	Period	Activity abroad
Satellite technologies for wildfire predictions	cont'd	First - second semester	NO
UAVs defense strategies	cont'd	First - second semester	NO

3. Training and research activities plan

First academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Introduction to Optimal Linear Quadratic Control	February 2024	Yes	2
	Control for Optimization	November 2023	Yes	1
	Intelligent Control Systems	January 2024	Yes	2
	From Least Squares to Subspace Identification	February-March 2024	No	1
	EECI International Graduate School on Control: "Control and Machine Learning" Location: Dubrovnik Mode: In presence	01/07/24 – 05/07/24	Yes	3
	EECI International Graduate School on Control: "Dissipation Inequalities and Quadratic Constraints for Control, Optimization, and Learning" Location: Stuttgart Mode: In presence	13/05/24 – 17/05/24	Yes	3
	Data-Driven fault diagnosis and fault prognosis	June 2024	Yes	1
B. Master's degree courses	Robotics I	First semester	No	3
	Robotics II	Second semester	No	3
	Reinforcement Learning	First semester	No	3
C. Participation to seminars				
D. Presentation of research products at international	Presentation at Sidra - automatica.it conference	September 2024		2

	congresses or workshops			
		TOTAL OF ECTS FOR TRAINING ACTIVITIES		24
E.	**Individual research activity**	Lunar mission "digital twin" development in VR/AR, GNC simulations and validation	2023/2024	25
		Underactuated aerial vehicles control: a benchmark between IDA-PBC methodology and Deep RL (deterministic policy gradient)	2023/2024	6
F.	**Supervision of students**			
G.	**Integrative teaching activities**			
H.	**Preparation of manuscripts for conferences or journals**	Preparation of manuscript for ECC 2025	2023/2024	5
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES		36
		TOTAL OF ECTS		**60**

Second academic year (planned)

		Description	Period	Final Exam	ECTS
A.	**Ph.D. courses**	Corso di 24 ore di "scrittura tecnico-scientifica"	February 2025	Yes	4
B.	**Master's degree courses**	Robot Programming	First semester	Yes	3
		Probabilistic Robotics	First semester	No	3
C.	**Participation to seminars**	GNC seminars of Aerospace Commission	2025		3
D.	**Participation to international congresses or workshops**	Participation to the European Control Conference (ECC)	2024/2025		4
		Joint Ka and Broadband Communications Conference and the International Communications Satellite Systems Conference (ICSSC)	2024/2025		4
E.	**Presentation of research products at international congresses or workshops**	Presentation at ECC 25	2024/2025		2
		TOTAL OF ECTS FOR TRAINING ACTIVITIES			23
F.	**Individual research activity**	New Deep RL algorithms development to get optimal defense strategies for a drone's swarm	2024/2025		22
		Lunar mission "digital twin" development in VR/AR, GNC simulations and validation (cont'd)			
G.	**Supervision of students**	Supervision of student's bachelor thesis on Automatic Control	2024/2025		5
H.	**Integrative teaching activities**	Control of autonomous multi-agent systems seminars	2024/2025		5
I.	**Preparation of manuscripts for conferences or journals**	Preparation of manuscript for ECC25	2024/2025		5
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES			37

	TOTAL OF ECTS			**60**

Third academic year (planned)

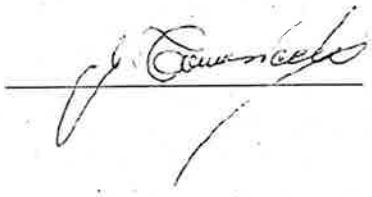
		Description	Period	Final Exam	ECTS
A.	**Ph.D. courses**				
B.	**Master's degree courses**				
C.	**Soft skill courses**				
D.	**Participation to seminars**				
E.	**Participation to international congresses or workshops**	International Technical Meeting of the Satellite Division of the Institute of Navigation (ION GNSS+)	2025/2026		5
		Participation to IEEE CDC	2025/2026		3
F.	**Presentation of research products at international congresses or workshops**	Presentation at CDC	2025/2026		2
		TOTAL OF ECTS FOR TRAINING ACTIVITIES			10
G.	**Individual research activity**	Deep Learning techniques for predicting landscapes/wildfires and UAVs patrolling over critical areas	2025/2026		30
H.	**Supervision of students**	Supervision of student's master thesis on autonomous systems	2025/2026		5
I.	**Integrative teaching activities**	Seminars of Deep Reinforcement Learning methods for controlling autonomous systems	2025/2026		5
J.	**Preparation of manuscripts for conferences or journals**	Preparation of manuscript for CDC26	2025/2026		15
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES			55
		TOTAL OF ECTS			**60**

4. List of the publications written by the candidate in the triennium

Insert the list of papers written during the Ph.D. program. If the paper is still not published indicate its status (e.g., submitted, under review, under 2nd review round, accepted to appear, etc.).

Di Paola Antonio

Tomasicchio Giuseppe



Giuseppi Alessandro