NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Autonomous Vehicles Fleet Management using Artificial Intelligence

Ph.D. candidate

Gabriele Gemignani

Cycle

XXXIX

Tutors

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1. Description of the research program

Deep Learning (*DL*) has revolutionized this era of marked interest and investments in several scientific sectors, robotics among all. Its potential in training arbitrarily complex systems, these often characterized by huge amount of data and unpredictable behavior's models, aspects generally difficult to handle with more classical methods, has already been widely highlighted by the worldwide research community and applied to different application domains. The majority of the state-of-the-art works in this regard consists of end-to-end control techniques, which means networks are trained to directly map raw sensor measurements to actuation commands. Despite achieving most of the times remarkable accuracy and cost metrics, such a way to use *DL* is limited to enhance the robot's efficiency in performing sophisticated tasks, while a major autonomy is desired for the future generations. Modern control strategies in fact typically behave optimally in specific nominal conditions, but don't adapt themselves following environmental changes, thus making the human intervention still a crucial part of the control loop scheme.

This 3-years PhD project aims at bringing contributions in this sense, as it tries to implement innovative *DL*-based techniques into robotic systems in order to enhance their autonomy in decision-making. Only the high-level mission-planning will be addressed, with the ultimate objective of enabling the robot to take the highest rewarded actions in response to various environmental inputs. In contrast, low-level control regarding the single steps inside the mission does not fall within the scopes of this study, given that this area has been covered by conventional estimation and control techniques with great success. Once dealt with the intrinsic issues connected to the use of *DL*, such as the high sensitivity to the choice of hyperparameters and the difficulty in faithfully modelling the real-world problem with a computationally inexpensive framework, the candidate will likely address how to handle the training process in presence of multiple cooperative agents; this would eventually be a notable contribution of the present PhD to the research related to robotic mission autonomy, given that deeper studies need to be carried out in the scientific literature and feasible solutions are still missing.

Schedule of the research activities

First academic year (~~completed~~/planned)

	Description	Period	Activity abroad
Preliminary study of scientific literature	• Intense bibliographic survey of advanced Deep Learning techniques (Reinforcement Learning among all) and research of their application to decision-making in robotic missions. • Attendance to didactic activities.	November 2023-April 2024	NO
First approach to application aspects	• Bibliographic study. • Attendance to didactic activities. • Choice of application scenario of interest, review of existing topic-related projects and/or software tools and merge into a unique simulation environment. • Possible participation to workshops and first publications.	April 2024-November 2024	NO

Second academic year (~~completed~~/planned)

	Description	Period	Activity abroad
Design of personalized Neural Network-based algorithms	• Coding of personalized innovative AI-based solutions for enhancing robots decision-making autonomy in the specific application scenario of interest. • Attendance to didactic activities. • Active tutoring to PhD-related thesis assigned to master's students.	November 2024-April 2025	NO
Training and Validation	• Validation of proposed methods through simulations and comparison with state-of-the-art most relevant results. • Study of modern techniques for handling multi-agents communication and cooperation in AI framework. • Report of the most significant outcomes in prestigious journals and conferences.	April 2025-November 2025	NO

	Description	Period	Activity abroad
Research deepening in a foreign fellowship	• Integration or extension of the research project within the foreign facility professional environment. • Implementation of multiple agents in AI simulation framework. • Active tutoring to PhD-related thesis assigned to master's students.	November 2025- April 2026	YES, in a foreign AI laboratory to be agreed with project tutor according to the trend of the research.
Publications and thesis dissertation	• Recap of all the sub-works carried out throughout the 3 years and refactoring in a complete well-documented re-usable environment. • Final publications and workshops attendances. • Thesis compilation.	April 2026- November 2026	NO

2. Training and research activities plan

Ph.D. students are required to carry out activities for an amount of 60 ECTS (CFU) per year, for a total of 180 ECTS throughout the academic course. The activities carried out by Ph.D. students are divided into:

- **Didactic activities:** min 36 – max 60 ECTS (of the total 180 ECTS), preferably in the first two years of the course.
- **Research activities:** min 120 – max 144 ECTS (of the 180 total ECTS)

The ECTS related to the **didactic activity** can be obtained, for instance, by attending courses and seminars from graduate schools or master's degree programs. The DAUSY teaching-course catalogue (http://dausy.poliba.it/Ph.D./teaching-course-catalogue/) comprehends a list of didactic activities that can be included in this plan. Didactive activities are divided into:

A. **Ph.D. courses:** these are courses offered at the Ph.D. level usually by doctoral schools (e.g., DAUSY Courses, Poliba ScuDo Courses, SIDRA Summer School Courses, EECI IGSC Courses, Partner Universities Ph.D. Courses, etc.).
B. **Master's degree courses**: maximum 18 ECTS can be obtained by master's degree courses or single-cycle degree courses if these have not been attended by the Ph.D. student during his/her second level education.
C. **Soft skills:** maximum 12 ECTS can be obtained by courses classified as "soft skills" after the authorization of the Academic Board.
D. **Participation to seminars**: participation to seminars related to the research program is considered as a didactic activity (5 hours of seminar = 1.5 ECTS).
E. **Participation to international congresses or workshops**: participation at international congresses and workshops is considered as a didactic activity (1 international congress/workshop day = 1 ECTS).
F. **Presentation of research products at international congresses or workshops:** presentation of a research product at international congresses and workshops is considered as a didactic activity (1 presentation = 2 ECTS).

Note that:

- **At least 18 ECTS (of the total 180 ECTS) of didactic activities (A) and (B) must be obtained by completing a final exam**.
- For all courses (A) and (B) the 50% of the total course ECTS is recognized in case the final exam is not completed.
- Didactic activities must be confirmed with attendance certificates.

Examples:

- A 6-ECTS course, given in a master's degree course, can be attended by the Ph.D. student who can receive 3 ECTS if he/she does not complete the final exam (in this case the attendance must be certified).
- If a Ph.D. student attends a 5-day conference presenting a scientific contribution, he/she will obtain 5 ECTS for the participation and additional 2 ECTS for the conference contribution (the certification is required for both the attendance and the presentation).

Please refer to the *"Educational regulations of the Doctoral School of Politecnico di Bari"* for more details
http://www.poliba.it/sites/default/files/dottorati/regscudopoliba.pdf

The ECTS related to the **research activities** are divided into:

G. **Individual research activity.**
H. **Supervision of students:** tutoring activities for students in undergraduate and master's degree programs.
I. **Integrative teaching activities:** supplementary teaching activity (e.g., seminars, courses, practical exercises, etc.) for students in undergraduate and master's degree programs within the limit of 40 hours per academic year.
J. **Preparation of manuscripts for conferences or journals.**

Note that each ECTS usually corresponds to 25 hours of research activity.

First academic year (~~completed~~/planned)

		Description	Period	Final Exam	ECTS
A.	**Ph.D. courses**	Dausy PhD course*: Optimization via extremum seeking*	November 2023	Yes	1
		Dausy PhD course: *Intelligent Control System*	January 2024	Yes	2
		Dausy PhD course: *Multi-Agent and Multi-Object Estimation*	January-February 2024	Yes	2
		Dausy PhD Course: *Game theory for controlling autonomous systems*	June-July 2024	Yes	2
		Dausy PhD Course: *Data-driven fault diagnosis and fault prognosis*	June-July 2024	Yes	1
		Unipi PhD Courses: *To be defined*	Still not known	Yes	5
		Poliba Scudo course: *Industry 4.0: Optimization, Control and Security* Or *Research Methodology*	Still not known	Yes	2
B.	**Master's degree courses**				
C.	**Soft skill courses**	German Course (4 ETCS)	Second semester	Yes	4
D.	**Participation to seminars**	Dausy seminars	To be defined	No	1.5
E.	**Participation to international congresses or workshops**				
F.	**Presentation of research products at international congresses or workshops**	Conference on AI or autonomous systems topics to be discussed with tutor	To be defined: (IROS,13-17 October 2024, Abu Dhabi)		7
		TOTAL OF ECTS FOR TRAINING ACTIVITIES			27.5
G.	**Individual research activity**	Bibliographic survey, choice of application scenario of interest and simulation environment set-up			28.5
H.	**Supervision of students**				
I.	**Integrative teaching activities**				

					4
J.	Preparation of manuscripts for conferences or journals	Preparation of a conference paper	Second half of first year		4
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES			32.5
		TOTAL OF ECTS			**60**

Second academic year (~~completed~~/planned)

		Description	Period	Final Exam	ECTS
A.	Ph.D. courses	Dausy or Poliba Scudo Courses	November 2024 – February 2025	Yes/No	4
		Unipi PhD courses	November 2024 – February 2025	Yes/No	4
B.	Master's degree courses				
C.	Soft skill courses				
D.	Participation to seminars	Dausy seminars	To be defined	No	3
E.	Participation to international congresses or workshops				
F.	Presentation of research products at international congresses or workshops	Conference on AI or autonomous systems topics to be discussed with tutor	June /July2025	No	7
		TOTAL OF ECTS FOR TRAINING ACTIVITIES			18
G.	Individual research activity	Design of innovative AI-based methods, validation through simulations and study of modern techniques for communication between multiple agents			34
H.	Supervision of students	Tutoring eventual Master thesis assigned to students			2
I.	Integrative teaching activities				
J.	Preparation of manuscripts for conferences or journals	Preparation of a conference paper and a Journal paper	Second half of second year		6
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES			42
		TOTAL OF ECTS			**60**

Third academic year (~~completed~~/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**			
F.	**Presentation of research products at international congresses or workshops**	Conference on AI or autonomous systems topics to be discussed with tutor	June/July 2026		7
		TOTAL OF ECTS FOR TRAINING ACTIVITIES			7
G.	**Individual research activity**	Implementation of multiple agents in the AI framework, research in the foreign institution with possible cooperation and integration of PhD project in that professional context	September 2025 – March 2026		32
H.	**Supervision of students**	Tutoring eventual Master thesis assigned to students			3
I.	**Integrative teaching activities**				
J.	**Preparation of manuscripts for conferences or journals**	Writing of journal and conference papers, final dissertation thesis	April – June 2026, July-October 2026		18
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES			53
		TOTAL OF ECTS			**60**

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

International Journal Articles

International Conference Proceedings

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