



NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

# **Multirobot planning and control for human-robot interaction and cooperation in the manufacturing sector**

## **Ph.D. candidate**

Giulia d'Addato

## **Cycle**

XXXIX

## **Tutors**

Professor Daniele Fontanelli

Professor Luigi Palopoli

# 1. Description of the research program

Trajectory control and planning are of great interest for the application of Cobots (collaborative robots) in all those application scenarios in which cooperation between robots and human beings is fundamental. In particular, the orchestration of multiple Cobots to solve tasks in robot-robot and/or human-robot cooperation is still a relevant and largely open problem. To be able to solve this problem it is necessary to have a correct interpretation of the operating context (perception) in order to guide the system towards the execution of the assigned task (control).

The main objective of the project is precisely to merge control and perception in a multirobot perspective for the execution of cooperative tasks. The control and planning of the trajectories must properly understand and represent the surrounding environment, i.e., the presence of the human operator and of the other robots, the requirements imposed by task to be performed and the achievement of an adequate level of accuracy in the estimation of the operating context and in the execution of the assigned task. Although the main target is the manufacturing industry, the developed solutions need to be general enough to be applied in different operational contexts. Distributed control and planning techniques will therefore be used, which are combined with model-based and data-driven approaches.

# 2. Schedule of the research activities

Insert the research activities that you plan, or you have completed for the three years, including any period abroad.

## First academic year (planned)

	Description	Period	Activity abroad
<b>Analysis of the state of the art</b>	Analysis of the existing solution for the cooperation of multiple Cobots (control and planning solutions) in different application domains and main focus in manufacturing	November 2023 - January 2024	NO
<b>Research challenges</b>	Identification of the main research questions and of the main technical tools to solve them	February 2024	NO
<b>First research results</b>	Development and design of preliminary model-based solutions, simulations and experiments. Possible submission of a first research paper	March 2024 - October 2024	NO

## Second academic year (planned)

	Description	Period	Activity abroad
<b>Model-based and data-driven</b>	Focus on planning and control using model-based and data-driven approaches for Cobots	November 2024 - January 2024	NO
<b>Experimental testing</b>	Model-based and data-driven approaches tests on Cobots and fusion with perception problems	December 2024 – April 2024	NO
<b>Experience in enterprise</b>	6 months – CRF, Torino – to collect field data and identification of the possible applications of the solutions provided	May 2024 - October 2024	NO

### Third academic year (planned)

	Description	Period	Activity abroad
<b>Human-robot cooperation</b>	Merge control and perception in a multirobot perspective for the execution of cooperative tasks also in presence of the human operator	November 2025 – February 2025	NO
<b>Environment perception</b>	Understand the surrounding environment, i.e., the presence of the human operator and of the other robots and achieve an adequate level of accuracy in the estimation of the operating context	March 2025 – August 2025	YES (6 months - FORTH, Creta - MAGICIAN project)
<b>Thesis work</b>	Finalization of the research project and writing of the Ph.D. thesis.	September 2025 - October 2025	NO

## 3. 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. Didactic activities are divided into:

- 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.).
- 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.
- Soft skills:** maximum 12 ECTS can be obtained by courses classified as "soft skills" after the authorization of the Academic Board.
- Participation to seminars:** participation to seminars related to the research program is considered as a didactic activity (5 hours of seminar = 1.5 ECTS).
- 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).
- 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:

- Individual research activity.**
- 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 (planned)

	Description	Period	Final Exam	ECTS
<b>A. Ph.D. courses</b>	Control for Optimization	Nov 2023 - Dec 2023	Yes	1
	Multi-agent and multi-object estimation	Jan 2024 - Feb 2024	Yes	2
	Intelligent Control Systems	Jan 2024 - Feb 2024	Yes	2
	Introduction to Optimal Linear Quadratic Control	Feb 2024 - Mar 2024	Yes	2
	Human autonomous systems interaction	Mar 2024 - Apr 2024	Yes	1
<b>B. Master's degree courses</b>				
<b>C. Soft skill courses</b>	Academic writing for sciences and engineering		Yes	2
	Entrepreneurship and Innovation		Yes	3
<b>D. Participation to seminars</b>	Safety VS security in risk-based vehicle routing		No	1.5
	Introduction to dynamic control allocation		No	3
	Complex systems modeling		No	1.5
<b>E. Participation to international congresses or workshops</b>	EECI modules	May 2024 - Jun 2024	No	3
<b>F. Presentation of research products at international congresses or workshops</b>				
	<b>TOTAL OF ECTS FOR TRAINING ACTIVITIES</b>			22
<b>G. Individual research activity</b>	Planning and control using model-based and data-driven approaches for Cobots	Nov 2023 – July 2024	No	30
<b>H. Supervision of students</b>	Tutoring activities for students	Mar 2024 – Jul 2024	No	4
<b>I. Integrative teaching activities</b>				
<b>J. Preparation of manuscripts for conferences or journals</b>	Manuscript related to the research activity	Mar 2024 – Jul 2024	No	4
	<b>TOTAL OF ECTS FOR RESEARCH ACTIVITIES</b>			38
	<b>TOTAL OF ECTS</b>			<b>60</b>

### Second academic year (planned)

	Description	Period	Final Exam	ECTS
<b>A. Ph.D. courses</b>	Courses related to robust control, non-linear control, trajectory planning	Nov 2024 – Jul 2025	Yes	8

<b>B. Master's degree courses</b>				
<b>C. Soft skill courses</b>			No	4
<b>D. Participation to seminars</b>	Seminars offered by DAUSY			
<b>E. Participation to international congresses or workshops</b>	SIDRA summer school		No	6
<b>F. Presentation of research products at international congresses or workshops</b>				
<b>TOTAL OF ECTS FOR TRAINING ACTIVITIES</b>				18
<b>G. Individual research activity</b>	Perception and control in multirobot contexts		No	34
<b>H. Supervision of students</b>	Tutoring activities for students		No	4
<b>I. Integrative teaching activities</b>				
<b>J. Preparation of manuscripts for conferences or journals</b>	Manuscript related to the research activity		No	4
<b>TOTAL OF ECTS FOR RESEARCH ACTIVITIES</b>				42
<b>TOTAL OF ECTS</b>				<b>60</b>

### Third academic year (planned)

	Description	Period	Final Exam	ECTS
<b>A. Ph.D. courses</b>				
<b>B. Master's degree courses</b>				
<b>C. Soft skill courses</b>				
<b>D. Participation to seminars</b>	Seminars offered by DAUSY		No	3
<b>E. Participation to international congresses or workshops</b>	Participation to workshops		No	2
<b>F. Presentation of research products at international congresses or workshops</b>	Presentation of works related to human-robot cooperation		No	3
<b>TOTAL OF ECTS FOR TRAINING ACTIVITIES</b>				8
<b>G. Individual research activity</b>	Human-robot cooperation Thesis work	Nov 2025 – Nov 2026	No	44
<b>H. Supervision of students</b>	Supervision of graduating students		No	4
<b>I. Integrative teaching activities</b>				
<b>J. Preparation of manuscripts for</b>	Manuscript related to human-robot cooperation		No	4

<b>conferences or journals</b>				
	<b>TOTAL OF ECTS FOR RESEARCH ACTIVITIES</b>			52
	<b>TOTAL OF ECTS</b>			<b>60</b>

#### 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.).

##### International Journal Articles

- [j1] A. Einstein, "On the movement of small particles suspended in stationary liquids required by the molecular kinetic theory of heat." *Ann. d. Phys.* (**under preparation**)
- [j2] G. Eason, B. Noble, and I. N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," *Phil. Trans. Roy. Soc. London*, (**submitted**)

##### International Conference Proceedings

- [c1] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," *IEEE Transl. J. Japan*, vol. 2, pp. 740–741, August 1987 [Digest 9th Annual Conf. Magnetics Japan, p. 301, 1982]. (**published**)
- [c2] J. Yamato, (2022, June). Recognizing human action in time-sequential images using hidden Markov model. In *CVPR*. (**accepted and to appear**)

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