NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Algorithms for management and control of mobile agent fleets

Ph.D. candidate

Federico SIGNORILE

Cycle

XL

Tutors

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1. Description of the research program

In the context of Logistics 4.0, mobile agent fleets refer to autonomous vehicle groups, including Automated Guided Vehicles (AGVs) and manual or automated trolleys, used to transport goods and materials in advanced logistics environments such as warehouses, industrial plants, and distribution centers. These mobile agents may include AGVs equipped with advanced navigation technologies such as laser sensors, cameras, or floor magnets, as well as trolleys operated manually or driven by automated systems. In Logistics 4.0, these mobile agent fleets are instrumental in making logistics processes smarter, more efficient, and increasingly autonomous. Their ability to operate independently and communicate with each other and other systems enhances the efficiency of goods handling and transport in dynamic environments.

The design and control of mobile agent fleets present several challenges, including path planning, deadlock resolution, fleet sizing, vehicle scheduling, inactive vehicle positioning, battery management, and vehicle routing.

This research program will focus on calculating paths to complete required tasks effectively while ensuring conflict avoidance and deadlock prevention. In particular, the proposed research project aims at defining advanced, reliable, innovative, and scalable methodologies to address the Multi-Agent Path Finding (MAPF) problem for fleets of mobile robots operating in a shared environment, avoiding collisions with both static and dynamic obstacles (agent-agent or agent-human). The primary goal is to develop scalable solutions for managing fleets of mobile agents in highly customized environments, particularly in internal logistics and autonomous vehicles, which often face bottlenecks and complex operating conditions, including potential disconnection of robots from the network.

The literature review will encompass both single and multi-agent approaches, examining methods such as Cooperative A*, CBS, and decentralized models to improve scalability.

Additionally, the project will also conduct a comprehensive assessment of the operational environment of the co-financing company, to align algorithmic development with the company's objectives and challenges to tailor solutions to meet real-world requirements.

A virtual simulation environment will be developed to reflect realistic operational variables - agent number, speed, and size, among others - allowing for controlled testing of algorithm performance across scenarios of increasing complexity.

The experimental phase will validate the algorithms' reliability in simulated environments by progressively increasing task difficulty, agent count, and the number of dynamic obstacles. Data collected from these simulations will inform iterative improvements to optimize pathfinding and collision-avoidance strategies. Upon successful virtual validation, algorithms will transition to real-world applications, using the co-financing company's case study as a testbed. This phase will assess the practical impact and effectiveness of the algorithms, ensuring that solutions meet industry standards and can be adapted for deployment in live operations.

The research activities will be conducted in close collaboration between the Decision and Control Laboratory (http://dclab.poliba.it/) of Polytechnic of Bari and E80 Group SpA (https://www.e80group.com/it/), an Italian company specialized in automated solutions for Logistics 4.0.

2. Schedule of the research activities

First academic year (planned)

	Description	Period	Activity abroad or at the reference company
Literature review	Analysis of gaps, limitations, and challenges in the state-of-the-art: The literature review will start with the analysis of the main single-agent planning techniques. Then, mathematical models for multi-agent path finding (MAPF) problem will be explored, evaluating both continuous-time and discrete-time approaches, with a focus on makespan minimization and collision avoidance constraints. Centralized and decentralized algorithms will be analyzed, to balance optimality and scalability in autonomous fleet management. Finally, the combination strategies of task allocation, task sequencing and MAPF problem solution approaches for multi-goal and repetitive applications will be analyzed.	11/2024-05/2025	NO
Description and analysis of system requirements	Study and analysis of operational processes and key challenges in managing autonomous fleets within real-world context. This phase ensures that the developed solutions align with business expectations from the co-funding company, effectively addressing practical issues of operational efficiency and safety.	04/2025-05/2025	YES-COMPANY
Model development and simulation / 1	Mathematical formalization of the MAPF problem's solution proposed and development of a high-level control algorithm implemented in a simulation environment.	06/2025 – 10/2025	NO

Second academic year (planned)

	Description	Period	Activity abroad or at the reference company
Model development and simulation / 2	Continues from the previous year	11/2025-01/2026	NO
Model validation – case study's context	Testing the developed solution in a laboratory setting of a company case study. Comparative analyses will be conducted between the simulated model and the real operations of the company, to ensure that the algorithm works in a practical context.	02/2026 – 03/2026	YES - COMPANY

Model refinement for complex scenarios	After initial validation, the model will be further refined to address complex operational scenarios, such as bottlenecks and variations in traffic conditions. A specific strategy for managing network disconnections will also be integrated, ensuring operational continuity even in unstable connectivity conditions. Optimization of the algorithm for scalability, resilience and reliability in dynamic environments, with simulations. In this phase, two solutions will be evaluated: one in which the job sequencing, job allocation, path planning and traffic management problems will be optimized individually and independently, and another in which the problem will be remodeled into a integrated solution.	04/2026-10/2026	NO

Third academic year (planned)

	Description	**Period**	**Activity abroad or at the reference company**
In-Company model testing and optimization	New test of the model in business settings with the aim of evaluating its performance in real-world situations and identifying any areas for improvement. Data will be collected on the performance and impact of the new algorithm on business operations, to ensure that it meets the objectives set.	11/2026-12/2026	YES - COMPANY
Extension and validation of the methodology in diversified application fields	Validation of the effectiveness of the proposed methodology in different contexts. By collaborating with an international research group (Prof. S. Koenig's research group, University of California, Irvine), other multi-agent applications areas will be investigated. The goal is to demonstrate the versatility and effectiveness of the algorithm in different application scenarios.	01/2027 – 06/2027	YES (hosting university to be confirmed)
Preparation of manuscripts	Preparing manuscripts for international journals and conferences	07/2027-08/2027	NO
Final preparation for dissertation	Final preparation for the thesis	07/2027 – 10/2027	NO

3. Training and research activities plan

First academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Research methodology	11/2024 – 12/2024	YES	2
	Introduction to probability and statistical inference	03/2025 – 05/2025	NO	1
	Model Predictive Control (IMT Lucca, online)	2nd semester	YES	2
	Simulation Systems for Engineering Applications	05/2025	YES	1
	Mathematical methods in deep learning	01/2025 – 02/2025	NO	1
	Distributed/Decentralized Control and Optimization of Large-Scale Systems	01/2025 – 02/2025	YES	1
	Game Theory for Controlling Autonomous Systems	06/2025	YES	1
	Introduction to autonomous systems	06/2025	YES	1
	Non-integer order systems and controllers	04/2025	YES	1
	Machine learning	01/2025 – 02/2025	YES	2
	Deep learning	02/2025	NO	1
B. Master's degree courses	Optimization and control	02/2025 – 06/2025	YES	6
	Estimation and control of dynamical systems	2nd semester	NO	3
C. Soft skill courses				
D. Participation to seminars	Automatica.it 2025 workshop	09/2025		3
E. Participation to international congresses or workshops	2025 IEEE 21st International Conference on Automation Science and Engineering (CASE) - At Millennium Biltmore, Downtown Los Angeles	17/08/25 - 21/08/25		5
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			31
G. Individual research activity	Conduction research activities under the supervision of tutors	TBD		20
H. Supervision of students	Supervision of bachelor and master students	TBD		3
I. Integrative teaching activities				0
J. Preparation of manuscripts for conferences or journals	Preparation of manuscripts for international conferences	TBD		6
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			29
	TOTAL OF ECTS			**60**

Second academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Numerical methods for big data	01/2026	YES	2
	Non – linear control	06/2026	YES	2
	Linear algebra for control applications	02/2026 – 03/2026	YES	2
	Optimization Theory		YES	2
	Data-driven fault diagnosis and fault prognosis	07/2026	YES	1
B. Master's degree courses	Machine learning and artificial intelligence	09/2025 – 06/2026	NO	6
	Big data analytics	09/2025 - 01/2026	NO	3
C. Soft skill courses				
D. Participation to seminars				
E. Participation to international congresses or workshops	2026 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)	TBD		5
	2026 IEEE International Conference on Robotics and Automation (ICRA) - Vienna, Austria	TBD		5
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			**28**
G. Individual research activity	Conduction research activities under the supervision of tutors	TBD		19
H. Supervision of students	Supervision of bachelor and master students	TBD		3
I. Integrative teaching activities	Lectures or tutoring activities	TBD		4
J. Preparation of manuscripts for conferences or journals	Preparation of manuscripts for international conferences and journals	TBD		6
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			**32**
	TOTAL OF ECTS			**60**

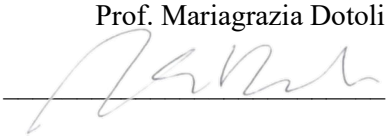
Third academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses				
B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars	Available seminars	TBD		10
E. Participation to international congresses or workshops				

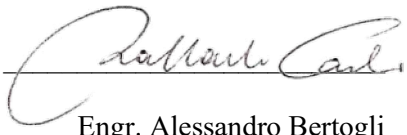
F.	**Presentation of research products at international congresses or workshops**				
		TOTAL OF ECTS FOR TRAINING ACTIVITIES			**10**
G.	**Individual research activity**	Conduction research activities under the supervision of tutors	TBD		16
H.	**Supervision of students**	Supervision of bachelor and master students	TBD		5
I.	**Integrative teaching activities**				
J.	**Preparation of manuscripts for conferences or journals**	Preparation of manuscripts for international conferences and journals	TBD		29
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES			**50**
		TOTAL OF ECTS			**60**

Federico Signorile

Prof. Mariagrazia Dotoli



Dr. Raffaele Carli



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