



NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Platforms for optimization and control of Drone-as-a-service in logistics

Ph.D. candidate

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Cycle

XXXIX

Tutors

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1. Description of the research program

Drones, or UAVs, are pivotal in Industry 4.0, reshaping various industries with adaptability. They enhance efficiency, cut costs, and improve safety in logistics, offering versatile applications in diverse environments. Mission types range from military to civil, covering surveillance, deliveries, and more. Drones cover outdoor and indoor missions. Outdoors, they handle deliveries, surveys, and security. Indoors, they manage inventory, inspect tight spaces, and aid in manufacturing. Drones are also classified by "see," "sense," "move," and "transform" capabilities. The "see" function pertains to drones' visual data collection abilities using high-resolution cameras or sensors, providing valuable visual data. The "sense" capacity involves gathering data from various sources like sensors, GPS, or thermal imaging cameras, which is then processed into structured information for analysis. The "move" capability enables drones to transport objects or perform physical tasks. Drones transport payloads, like packages or medical supplies, and can also perform tasks with robotic arms. The "transform" capability combines "see," "sense," and "move" functions, enabling real-time decision-making. For instance, drones with advanced computer vision can detect anomalies during inspections and respond promptly. In summary, drones' versatility in diverse environments and missions classifies them in logistics. Their "see," "sense," "move," and "transform" capabilities are valuable assets, revolutionizing logistics by covering data collection, physical tasks, and real-time decision-making.

Nonetheless, the simultaneous implementation of these three functions raises considerable hurdles related to collaboration, analytics, information processing, and optimization. The current project endeavors to tackle these challenges by formulating solutions that facilitate the seamless integration of these capabilities. Such integration is paramount for ensuring the effective and efficient performance of drones across a spectrum of environments and mission types. In conclusion, the adaptability and versatility of drones have firmly established them as indispensable tools within the context of Industry 4.0. Their manifold applications in logistics and their capacity to operate across diverse environments and mission types underscore their significance. However, it is imperative to acknowledge that the harmonious integration of their "see," "sense," and "move" capabilities presents complex challenges that warrant thorough consideration and resolution to guarantee their optimal functionality. Moreover, the gap in the related literature will be investigated so that the most interesting problems and the proper methodologies and strategies will be defined and addressed.

Following are the few related references:

- Hassija, Vikas, et al. "Fast, reliable, and secure drone communication: A comprehensive survey." *IEEE*
- Shamshirgaran, Azin, Hamed Javidi, and Dan Simon. "Evolutionary algorithms for multi-objective optimization of drone controller parameters." *2021 IEEE Conference on Control Technology and Applications (CCTA)*. IEEE, 2021.
- Azar, Ahmad Taher, et al. "Drone deep reinforcement learning: A review." *Electronics* 10.9 (2021): 999.
- Proia, Silvia, et al. "Safe and Ergonomic Human-Drone Interaction in Warehouses." *2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. IEEE, 2022.

2. Schedule of the research activities

First academic year (planned)

	Description	Period (months)	Activity abroad
Literature review	Study and review on (meta)-heuristic optimization frameworks as well as mathematical optimization techniques such as linear programming used to optimize the design and operations of drones in warehouses	1-4	NO
	Study and review on different methods of autonomous control systems for drones in warehouses including but not limited to: model predictive control (MPC), optimized linear quadratic control (OLQC), digital control systems	5-8	NO
	Preparation of a review paper in international journals (e.g., IEEE Transactions on Automation Science and Engineering)	9-12	NO
Description and analysis of system requirements	Definition and analysis of the system concept of drone-as-a-service	1-2	NO
	Preparation of a contribution for international conferences (e.g., IEEE International Conference on Automation Science and Engineering 2024)	3-4	NO

Second academic year (planned)

	Description	Period (months)	Activity abroad
Definition of optimization and control algorithms	Formulation of the optimization and control problems over decision-making levels (strategical, tactical, and operational), system architectures (1 drone/fleet of drones, centralized/decentralized)	1-8	NO
Testing of algorithms numerical simulation	Identification of validation scenarios based on real warehouses: validation of algorithms in numerical environments simulating the identified scenarios	9-12	NO
Preparation of manuscripts	Preparing at least two manuscripts (one for international journals and one for international conferences)	3-12	NO

Third academic year (planned)

	Description	Period (months)	Activity abroad
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Data-driven control of drones	Definition of data-driven control techniques for drones at Illinois University - Prof. Malvandi's research group	1-6	Yes (hosting university to be confirmed)
	Preparing at least one manuscript for publication	1-6	
Preparation of manuscripts	Preparing manuscript(s) for international journals and conferences	7-9	NO
Final preparation for dissertation	Final preparation for the thesis	10-12	NO

3. Training and research activities plan

First academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Control for Optimization (DAUSY)	1st Semester	Yes	1
	Introduction to linear quadratic control (DAUSY)	1st semester	Yes	2
	Optimization via extremum seeking (DAUSY)	1st semester	Yes	1
	Optimization and control of complex multi-agent systems: theory and application (EECI-M01 Oxford)	1st semester	Yes	5
	Model Predictive Control (IMT Lucca, online)	2 nd semester	Yes	2
	Introduction to nonlinear systems & control (EECI-M12)	2 nd semester	Yes	5
	Data-driven fault diagnosis and fault prognosis (DAUSY)	2 nd semester	Yes	2
B. Master's degree courses	Mobile robotics (MSc-Poliba)	2 nd semester	Yes	6
C. Participation to seminars	Available seminars			10
D. Participation to international congresses or workshops	CASE (Conference on Automation Science and Engineering) 2024	28 August- 1 September 2024		5
E. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			39
F. Individual research activity	Conducting research activities under the supervision of the tutors			6
G. Supervision of students	Supervision and of bachelor and master students			5
H. Integrative teaching activities				
I. Preparation of manuscripts for conferences or journals	Preparation of a literature review paper for international journals and a contribution for international conferences			10

	TOTAL OF ECTS FOR RESEARCH ACTIVITIES	20
	TOTAL OF ECTS	60

Second academic year (planned)

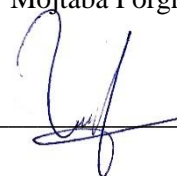
	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Multi-agent and multi-object estimation	1st semester	Yes	2
	Intelligent control systems	1st semester	Yes	2
	Game theory for controlling autonomous systems	1st semester	Yes	2
	Control and machine learning (M18-EECI)	2 nd semester	Yes	5
	Model predictive control	2 nd semester	Yes	5
	Summer school	2 nd semester	No	2.5
B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars	Available seminars			5
E. Participation to international congresses or workshops				
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			21
G. Individual research activity	Conduction research activities under the supervision of tutors			7.5
H. Supervision of students	Supervision of master and bachelor students			5
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Preparation of at least two manuscripts for international conferences and journals			24
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			36.5
	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			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			10
H. Supervision of students	Supervision of bachelor and master students			5
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Preparation of at least two manuscripts for international conferences and journals			35
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			50
	TOTAL OF ECTS			60

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