



NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Control, coordination and monitoring of autonomous agents, with application to the agrifood field

Ph.D. candidate

Bushra SHAIKH

Cycle

XXXVIII

Tutors

Prof. Elena De Santis

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1. Description of the research program

The advancement in the robotics technology have benefited agricultural industry in many ways. However, more complex systems utilizing multiple agents (drones), can raise the production cycle efficiency to its next level. This research work will develop algorithms to implement Multi-agent drone network for agricultural processes. The proposed system will also address other issues related to agricultural operations, included but not limited to precision farming, safe interaction of drone with environment and Human-robot collaboration.

The applicability of robotics has been exponentially increasing in almost every field. However, due to the increasing complexity of tasks and working environments, a single robot cannot accomplish the required efficiency level; this has led the researchers towards the control and synchronization of the large robotic group, i.e., swarm network, multi-agent system, etc. Besides their individual potential, UGVs and UAVs can tackle more difficult tasks when used in co-operation.

The advantages of such automation in agriculture in terms of production cycle efficiency are unquestionable. However, the problem becomes more complicated when one thinks of actions more complex than those required for tilling a flat, unobstructed field. Indeed, the morphology and the particular task to be performed may require the coordination of different agents cooperating to achieve a common goal. Unmanned Aerial Vehicles (UAVs) systems will be considered, with the joint use of Unmanned Ground Vehicles (UGVs) and their related technologies for data collection and subsequent field action. In general, the term "drones" identifies both UAVs and UGVs. The proposed research activity aims to:

1. develop control systems, also integrating artificial intelligence methods, for the coordination of drones engaged in the realization of complex collective actions, in general not achievable by a single drone;
2. analyze and guarantee system's safety with respect to possible interactions with the environment, with particular reference to the relationship with human operators, including collaborative efforts;
3. study the interaction between automation systems for agricultural operations and data analysis algorithms for precision farming in order to achieve systems for control and optimization of crops and their maintenance.

Achieving the above goals requires the innovative development of methodologies in the control domain, in different modeling contexts, such as nonlinear systems, finite-state automata, and hybrid systems. In some cases, it will also be important to be able to represent the behavior of the system based on the availability of data gained from experience. A period of activity in the partner company is planned to acquire knowledge specific to the agrifood application area.

2. Schedule of the research activities

First academic year (Planned)

	Description	Period	Activity abroad
Literature Review	Thorough study about the state of art technology being used in agricultural applications; specific with the use of Multi agent drone networks. Learning about the requirements and challenges of using drone network in agricultural applications	November-June 2023 at UNIVAQ	NO
Industrial Training	Learning about the specific requirements of autonomous agents used in agricultural applications. Determining the challenges faced by current technology and proposing prospective solutions. This phase is based on the training at the partner Industry; Blu Hub	July-October 2023 at BluHub	NO

Second academic year (Planned)

	Description	Period	Activity abroad
Distributed positioning and Mapping system	Localization and mapping is the key to achieve collision free autonomous navigation for any type of mobile robot. During this phase various techniques will be analyzed to identify the location of drones. And based on the analysis an algorithm/techniques will be developed to estimate the accurate position of all drones in the working region.	November 2023- October 2024	NO
Multi Robot Motion Planning	Without efficient Multi-robot motion planning, it is impossible to operate aerial or ground robots in a shared environment. In this phase, optimal path planning algorithm will be developed to ensure collision free navigation.	May - October 2024 (To be Confirmed)	YES (University Polytechnic Hauts-de-France)

Third academic year (Planned)

	Description	Period	Activity abroad
Coordination and Controlling of Drones for Collective operation (Industrial training)	This phase will deal with the task allocation in Multi agent Drone Network. Various techniques will be studied and analyzed to control and synchronize independent groups (aerial and ground) of robots.	November 2024- February 2025 at BluHub	NO
Final Testing of the complete system	This final phase will ensure the satisfactory performance of overall developed system	November 2024- October 2025	NO

3. Training and research activities plan

First academic year (Planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Navigation systems for autonomous systems Instructor: Lorenzo Pollini (Pisa) Mode: Hybrid	JAN-FEB 2023	Yes	1.5
	Modeling, filtering and controlling aerospace systems. Instructor: Martina Mammarella (CNR Torino) Mode: Hybrid	APR-MAY	Yes	2
	Poliba scudo courses: Optimization and Control of Complex Systems	JAN-FEB 2023	Yes	2
	International Graduate School on Control: Multi-Agent Control under Spatiotemporal Logic Constraints Location: DELFT Mode: In Presence	22/5/23 – 26/5/23		
	International EECI Graduate School on Control: “Stability and Stabilisation of Time-varying Systems, Focus on Formation and Consensus Control” Location: L’AQUILA Mode: In Presence	20/3/23 – 24/3/23	yes	3
	International Graduate School on Control: “Distributed optimization for cooperative robotics and decision making: theory, numerical methods and toolboxes” Location: Bologna Mode: In Presence	12/6/23 – 16/6/23		
B. Master’s degree courses				
C. Soft skill courses				
D. Participation to seminars	Complex Systems Modeling Instructor: Chiara Mocenni (Siena) Mode: Hybrid	To be defined		1.5
	Introduction to dynamic control allocation Instructor: Sergio Galeani, Mario Sassano (Roma Tor Vergata) Mode: Hybrid	March 2023		3
E. Participation to international congresses or workshops	Participation to at least two seminars/workshops according to availability.			6
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			19
G. Individual research activity	Literature Review and Industrial Training Period			25
H. Supervision of students	Supervision of Students under the guidance of the tutor			06
I. Integrative teaching activities	Integrative didactic activities will be carried out under the supervision of the tutor			05
J. Preparation of manuscripts for	Preparation of manuscript for one Conference paper			05

conferences or journals				
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			41
	TOTAL OF ECTS			60

Second academic year (Planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Two or Three relevant PhD Courses		Yes	4
B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars	Participation to at least two seminars/workshops according to availability.			4
E. Participation to international congresses or workshops	Participation to international congresses or workshops according to availability			4
F. Presentation of research products at international congresses or workshops	Presentation of the results obtained to atleast one international congresses or workshops associated to a high impact factor			3
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			15
G. Individual research activity	Research work as mentioned in Second academic year including the training period abroad			20
H. Supervision of students	Supervision of Students under the guidance of the tutor			5
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Preparation of Manuscript for two conference and one journal Paper			20
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			45
	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	Participation to at least one seminar/workshop according to availability.			3
E. Participation to international congresses or workshops	Participation to international congresses or workshops according to availability			4

F. Presentation of research products at international congresses or workshops	Presentation of the results obtained to two international congresses or workshops associated to a high impact factor.			4
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			11
G. Individual research activity	Research activities mentioned in the last academic year.			30
H. Supervision of students				
I. Integrative teaching activities	Relevant teaching activities under the supervision of tutor			09
J. Preparation of manuscripts for conferences or journals	Manuscript Preparation for One Journal Paper and Thesis			10
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			49
	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.).

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