



NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Title of the research

AI-based Image Fusion for Agricultural Robot Navigation in Adverse Weather:
Fusing RGB and Infrared Sensing for Improved Obstacle Detection

Ph.D. candidate

Jaleh Farmani

Cycle

XL

Tutors

Prof. Daniele Carnevale

Prof. Sergio Galeani

Prof. Corrado Possieri

Dott. Federico Pallottino

1. Description of the research program

The development of automation and robotics has significantly transformed precision agriculture. Many research centers are working on autonomous machines for various agricultural tasks to reduce reliance on traditional machinery, enable precise and continuous monitoring, and minimize the use of pesticides and herbicides, ultimately improving overall efficiency. However, designing agricultural robots presents several challenges, particularly when it comes to navigation in adverse weather conditions.

The primary goal of this research is to enhance agricultural robot navigation using AI techniques, specifically addressing the challenges of obstacle avoidance in unpredictable and harsh environments. Agricultural robots must function effectively in dynamic conditions, including weather extremes that can degrade the performance of traditional sensors.

This research aims to fuse visible (RGB) and infrared images using advanced AI algorithms, such as target-aware dual adversarial learning, to generate high-quality, fused images that preserve both the structural information from infrared and the textural details from RGB images. This fusion will improve object detection and identifying plants, obstacles, roads, and pests by creating a more reliable navigation system that can function even in poor visibility conditions, such as fog, rain, or dust.

Additionally, to ensure accurate localization and mapping in agricultural fields, the study will explore sensor fusion and Visual Simultaneous Localization and Mapping (VSLAM) approaches. These will combine data from multiple sources, including LiDAR, GPS, IMU, and cameras. A prototype agricultural rover, developed by CREA and the University of Tor Vergata, will be used in experiments, and the system will be tested in real-world conditions using a control framework based on ROS2.

In parallel, a secondary research project will focus on applying AI in the medical field, particularly for analyzing long noncoding RNAs (lncRNAs) to aid early diagnosis of thyroid cancer. This interdisciplinary collaboration with Policlinico Universitario A. Gemelli and the University of Tor Vergata aims to develop cutting-edge diagnostic tools.

2. Schedule of the research activities

First academic year (planned)

	Description	Period	Activity abroad
State-of-the-art review and defining research problems	Conduct a comprehensive literature review on AI-based agricultural navigation systems, image fusion methods, and current challenges in adverse weather conditions. Define the key research problems to address. Simultaneously, explore medical AI applications and finalize research problems.	1/11/2024-1/3/2025	NO
Data collection	Agricultural focus: Collect data in collaboration with CREA using RGB and infrared cameras in various weather conditions to understand and	1/3/2025-1/5/2025	NO

	analyze the challenges in image fusion and obstacle detection. Medical focus: Collect data in collaboration with Policlinico Universitario A. Gemelli, focusing on the early detection of thyroid cancer.		
Initial Design & implementation of algorithms	Agricultural focus: Begin developing and implementing deep learning models for fusing RGB and infrared images for enhanced obstacle detection. Implement detection-oriented fusion to maintain visual quality and structural information. Medical focus: Start working on molecular analysis and AI applications for thyroid cancer diagnostics.	1/5/2025-31/10/2025	NO

Second academic year (planned)

	Description	Period	Activity abroad
Image fusion refinement & medical research integration	Continue optimizing agricultural image fusion methods and thyroid cancer early detection methods.	1/11/2025-1/2/2026	NO
Paper writing	Agricultural focus: Write and submit a paper on agricultural AI image fusion techniques. Begin integrating work on AI-based diagnostics in medical research. Medical focus: Write and submit a paper on diagnostics for thyroid cancer, focusing on enhancing early detection methods.	1/2/2026-1/5/2026	NO
Cooperation with a foreign company or university	Design and implementation of new image fusion techniques, with application to precision farming	1/5/2026-31/10/2026	YES – To Be Defined

Third academic year (planned)

	Description	Period	Activity abroad
Experimental validation on agricultural rover	Conduct experimental trials with CREA's agricultural rover, assessing the AI systems in field conditions and real-world scenarios.	1/11/2026-1/5/2027	NO
Medical research & write paper	Continue interdisciplinary research in medical diagnostics, focusing on publishing findings.	1/5/2027-1/9/2027	NO
PhD Thesis	Writing of the PhD Thesis	1/11/2026-31/10/2027	NO

3. Training and research activities plan

First academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Learning in multi-agent systems (DAUSY course)	25/11/24-17/1/25	Yes	2
	Modeling and simulation of biosystems (DAUSY course)	13/1/25-24/1/25	Yes	2
	Intelligent Supervisory Systems (DAUSY course)	8/1/25-30/1/25	Yes	2
	Machine learning (ScuDo Poliba)	29/1/25-6/2/25	Yes	2
	Deep learning (ScuDo Poliba)	11/2/25-20/2/25	Yes	2
	Research Methodology (ScuDo Poliba)	-	Yes	3
	Human Autonomous System Interaction (DAUSY course)	28/2/25-28/3/25	Yes	1
	Analysis and representation techniques for building research (ScuDo Poliba)	17/3/2205-24/3/2025	Yes	1
	Simulation Systems for Engineering Applications (DAUSY course)	19/5/25-28/5/25	Yes	1
	Introduction to autonomous systems (DAUSY course)	23/6/25-30/6/25	Yes	1
B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars	Innovations in Sustainable Energy Conversion Technologies	3/12/24-4/12/24		1.5
E. Participation to international congresses or workshops	Participation to at least two workshops according to availability.	TBD		2
F. Presentation of research products at international congresses or workshops	Presentation of research products to at least one international congress or workshop	TBD		2
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			22.5
G. Individual research activity	Research activity in the topics of precision farming, VSLAM, enhancing robot navigation using AI. And writing the PhD thesis			21.5
H. Supervision of students				
I. Integrative teaching activities	Integrative didactic activities will be carried out under the supervision of the tutor			2
J. Preparation of manuscripts for conferences or journals	Writing of conference/journal papers describing the obtained research results.			14
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			37.5
	TOTAL OF ECTS			60

Second academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Some courses to be defined according to the syllabus of academic year 2025/2026	TBD	Yes/No	10

B. Master's degree courses			Yes/No	
C. Soft skill courses	Italian Language course (Poliba/ Language School)	TBD	Yes	3
D. Participation to seminars	Participation to at least two seminars according to availability	TBD		3
E. Participation to international congresses or workshops	Participation to at least two workshops according to availability.	TBD		2
F. Presentation of research products at international congresses or workshops	Presentation of research products to at least one international congress or workshop	TBD		2
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			20
G. Individual research activity	Research activity in the topics of precision farming, VSLAM, enhancing robot navigation using AI. And writing the PhD thesis			24
H. Supervision of students				
I. Integrative teaching activities	Integrative didactic activities will be carried out under the supervision of the tutor			2
J. Preparation of manuscripts for conferences or journals				14
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			40
	TOTAL OF ECTS			60

Third academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses			Yes/No	
			Yes/No	
			Yes/No	
B. Master's degree courses			Yes/No	
			Yes/No	
C. Soft skill courses			Yes/No	
D. Participation to seminars	Participation to at least two seminars according to availability.	TBD		3
E. Participation to international congresses or workshops				
F. Presentation of research products at international congresses or workshops	Presentation of research products at international congresses or workshops	TBD		4
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			7
G. Individual research activity	Research activity in the topics of precision farming, VSLAM, enhancing robot navigation using AI. And writing the PhD thesis			40

H. Supervision of students				
I. Integrative teaching activities	Integrative didactic activities will be carried out under the supervision of the tutor			3
J. Preparation of manuscripts for conferences or journals	Writing of conference/journal papers describing the obtained research results.			10
TOTAL OF ECTS FOR RESEARCH ACTIVITIES				53
TOTAL OF ECTS				60

Insert Ph.D. candidate name

Jaleh Farmani

Tutor 1 name and title

Prof. Daniele Carnevale

Tutor 2 name and title

Prof. Sergio Galeani

Tutor 3 name and title

Prof. Corrado Possieri

Tutor 4 name and title

Dott. Federico Pallottino