INTERUNIVERSITY PH.D. PROGRAM BETWEEN

POLITECNICO DI BARI AND UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

IN INDUSTRY 4.0

Innovative Methodologies in Agriculture for High-Throughput Plant Phenomics using Computer Vision and Artificial Intelligence

PhD candidate

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Cycle

XXXVII Cycle

Tutors

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Description of the research program

With rapid human population growth and consumption of agricultural products, high-quality plant phenotypes emerged to help cultivate high-yielding plants. Recently plant phenomics, which focuses on identifying patterns of organization and changes in plant phenomes, played a major role in precision crop monitoring, genetics, botany, agronomy, improving the efficiency of breeding programs, understanding plant-environment interactions, managing agricultural systems, and they are rapidly advancing. Although methods for phenotypic traits measurement have some limitations in aspects of cost, performance, and space-time coverage, it is necessary to improve the current approaches towards the automation of phenotyping activities, from dataset acquisition to data interpretation. Without doubt, this aim can only be achieved by appropriately integrating biological skills with those of computer science and engineering. In this automatic revolution, the skilful use of Computer Vision and Artificial Intelligence techniques will play a key role. Meantime, recently the computer vision, machine learning, and deep learning aspects of artificial intelligence successfully integrated into non-invasive imaging techniques that are fundamental in the automation, standardization, and quantitative analysis of huge amounts of plant phenomics data. With this increased amount of image data, it will become urgent to develop robust analytical tools able to extract phenotypic traits accurately and rapidly. Considering that the world population program to 2050 (by estimating population growth rate) will be mainly focused on more food production, my research proposal is positioned exactly in this context of precision crops monitoring and cultivating high-yielding plants. Therefore, this study aims at the analysis of two macro-categories (the aerial part of a plant and its root system) in plant phenomics for the specific study of operational hardware, and innovative experimental setups, as well as the most suitable algorithms to analyze the data produced by computer vision and artificial intelligence both in the laboratory (Phenolab platform at ALSIA) and open agricultural sites (open field).

The first research objective (RO1) is devoted to the high-throughput plant phenotyping problem definition, especially when the phenotyping activity is carried out using a huge amount of data coming from multiple sensors. In this scenario, it will be necessary to extensively study the current literature performing a complete literature review on the relevant aspects of automated plant phenotyping, with particular focus on: a) the most suitable hardware that can be used to carry out phenotyping experiments; b) data availability and data acquisition issues; c) automatic or semi-automatic approaches currently employed for phenotyping activities, involving computer vision and machine/deep learning; d) the main plant traits to focus on during a phenotyping experiment, such as particular geometrical measurements or relevant plant structures to be identified, specific colors or spectral bands to be analyzed and so on.

The second research objective (RO2) regards the development of innovative techniques for studying the aerial part of the plant as well as its root system using both state of the art models or defining custom data processing algorithms and architectures.

The third research objective (RO3) consists of the test of the developed models and algorithms using both datasets acquired in a controlled environment provided by the Phenolab platform at ALSIA or open-field tests directly acquired on the field.

Throughout the whole research project, regular reports about the progress will be performed, comprehending weekly and milestone updates. Furthermore, scientific publications and material useful for the final dissertation fulfilment will be prepared on time.

Schedule of the research activities

First academic year

	Description	Period	Activity abroad
first research activity	High-throughput plant phenotyping problem definition	1-12	NO
second research activity	Preparation of at least two manuscripts for publication	1-12	NO

Second academic year

	Description	Period	Activity abroad
first research activity	Design and development of innovative techniques for plant phenotyping	1-12	NO
second research activity	Test of the developed algorithms and models at ALSIA or in open-field	6-12	To Plan
third research activity	Preparation of at least two manuscripts for publication	1-12	NO

Third academic year

	Description	Period	Activity abroad
first research activity	Experimental tests at ALSIA or in open-field	1-12	NO
second research activity	Test of the developed algorithms and models at ALSIA or in open-field	1-12	NO
third research activity	Preparation of at least two manuscripts for publication	1-12	NO

Provisional training and research activities plan

First academic year

	Description	Period	Duration	CFU
PhD courses	Complex Networks: Big Data modelling and learning	Jun 2022	20 h	2
	Time-series databases for sensor data analysis	January 2022	20 h	2
	-	-	-	-
	-	-	-	-
Master's degree courses	Numerical Methods for IT	February 2022	60 h	6
	Image Processing and Artificial Vision	March 2022	-	12
Participation to seminars and international congresses or workshops	Online Winter School on Image Analysis for Plant Phenotyping	February 2022	21 h	2
	Seminars and Workshops	-	-	9
Presentation of research products at international congresses or workshops	least one paper	-	-	2
	-	-	-	-
	TOTAL OF CFU FOR TRAINING ACTIVITIES			**35**
Individual research activity	Research Activity and Tutoring Students		400 h	16
Students' supervision	-	-	-	-
Integrative didactive activities	-	-	-	-
Preparation of manuscripts for conferences or journals	Manuscripts		225 h	9
	TOTAL OF CFU FOR RESEARCH ACTIVITIES			**25**
	TOTAL OF CFU FOR YEAR I			**60**

Second academic year

	Description	Period	Duration	CFU
PhD courses	-	-	-	-
	-	-	-	-
	-	-	-	-
	-	-	-	-
Master's degree courses	-	-	-	-
	-	-	-	-
Participation to seminars and international congresses or workshops	Winter or Summer Schools	-	-	3
Presentation of research products at international congresses or workshops	Seminars and Workshops	-	-	3
	least one paper	-	-	2
	TOTAL OF CFU FOR TRAINING ACTIVITIES			**8**
Individual research activity	Research Activity and Tutoring Students	-	800 h	32
Students' supervision	-	-	-	-
Integrative didactive activities	-	-	-	-
Preparation of manuscripts for conferences or journals	manuscripts	-	500 h	20
	TOTAL OF CFU FOR RESEARCH ACTIVITIES			**52**
	TOTAL OF CFU FOR YEAR II			**60**

Third academic year

	Description	Period	Duration	CFU
PhD courses	-	-	-	-
	-	-	-	-
	-	-	-	-
	-	-	-	-
Master's degree courses	-	-	-	-
	-	-	-	-
Participation to seminars and international congresses or workshops	-	-	-	-
	-	-	-	-
Presentation of research products at international congresses or workshops	least one paper	-	-	2
	-	-	-	-
	TOTAL OF CFU FOR TRAINING ACTIVITIES			**2**
Individual research activity	Research Activity and Tutoring Students	-	750 h	30
Students' supervision	-	-	-	-
Integrative didactive activities	-	-	-	-
Preparation of manuscripts for conferences or journals	Manuscripts	-	500 h	20
Preparation of PhD Thesis	Thesis	-	200 h	8
	TOTAL OF CFU FOR RESEARCH ACTIVITIES			**58**
	TOTAL OF CFU FOR YEAR III			**60**
	TOTAL OF CFU FOR THE WHOLE PHD COURSE			**180**