Study, Development and Design of Intelligent Systems for automatic diagnostics in industrial and biomedical fields

Ph.D. candidate

Roberto Maria SCARDIGNO

Cycle

XXXVIII

Tutors

Prof. Engr. Vitoantonio Bevilacqua, Ph.D.

Prof. Engr. Mariagrazia Dotoli, Ph.D.

Co-Tutors

Prof. Engr. Domenico Buongiorno, Ph.D.

Prof. Engr. Raffaele Carli, Ph.D.

Engr. Nicola Longo

1. Description of the research program

The research project involves the study, design, development and validation of intelligent decision support systems based on signal, images and video streams processing using Deep Learning techniques. Specifically, the project stands within the context of advanced diagnostic techniques useful both for industry 4.0 and precision medicine, by using Convolutional Neural Networks supported by explainability and interpretability frameworks. In the industrial sector, the detection of product surface defects is traditionally carried out by human visual inspection and the results are often poor in terms of performance and standardization. There could be an improvement of the results by introducing autonomous and explainable systems, ensuring higher reliability and accuracy.

In the biomedical field, patients have the right to know the dynamics behind the evaluations performed by Deep Learning-based CDSS (Clinical Decision Support Systems). In particular, the EU General Data Protection Regulation (GDPR), with Articles 13 and 14, decree that, when data are used in an automated decision-making process, the data subject has the right to meaningful information about the logic involved. For such reason, the most recent algorithms of explainability, both perceptive and mathematical, will be studied and adopted to reveal any hidden pattern present in the data as well as in their temporal evolution. Precision medicine could benefit further from omics data processing and modelling, that allow 1) to study and propose sustainable personalized and optimized radiotherapy treatments thus minimizing collateral effects and increasing the lesion reduction efficacy, and 2) to more effectively monitor the radiotherapy effects over time for a better prognosis. In this context, explainability and visualization methods become crucial to understand what causes a better response compared to another. Finally, for both industrial and biomedical fields, the goal of this project will be the design and implementation of a general-purpose framework that will have the flexibility to be used across different domains, minimizing the adaptation efforts when changing area of interest. To accomplish that, the framework will be built starting from 3 different use cases, each of which coming from the local research group, from COMAU company and from the international colleagues of University Hospital Essen – IKIM.

2. Schedule of the research activities

First academic year (planned)

	Description	Period	Activity abroad
State of the Art Review on industrial eXplainable Artificial Intelligence (XAI)	Review writing on the most recent explainability techniques used for deep learning models explanation in the industrial defect detection.	6 months	NO
State of the Art Review of Machine Learning Decision Support Systems and CDSS development	Study of the state of the art, in the medical field, of the frontiers techniques used to develop Decision Support Systems. Design and development of CDSS.	3 months	NO
State of the Art Review and development of medical XAI	Study of the latest trends, in the medical field, of the explainable methods used to explain and optimize deep learning models. Design, development and integration of explainable methods in pre-existing CDSS.	3 months	NO

Second academic year (planned)

	Description	Period	Activity abroad
Study of omics sciences	Study of omics sciences, focusing on multimodal data management to build optimized and personalized models of a single anatomic region.	4 months	NO
Study of radiotherapy interactions	Study of radiotherapy interactions from cells till organs.	2 months	NO
Study and development of radiotherapy treatment predictions visualization methods	Study of the best explainable methods to visualize radiotherapy treatment predictions. Design and development of explainable methods for CDSS.	6 months	YES (University Hospital Essen - IKIM)

Third academic year (planned)

	Description	Period	Activity abroad
Systematization of the design approach of classification models	Systematization of the classification models workflow to use them in both industrial sector and electronic, computer and industrial bioengineering. The workflow will include: pre-processing, feature extraction and management, classification/segmentation, validation and testing, explainability.	12 months	NO

3. Training and research activities plan

First academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Applications of MATLAB (SCUDO - PoliBa)	Jun - Jul 2023	Yes	2
	Model Predictive Control (Scuola IMT Alti Studi Lucca)	Mar - Apr 2023	Yes	2
	Modeling and simulation of biological and medical systems (CNR Roma)	TBD	Yes	3
B. Master's degree courses	Data Model Identification and Intelligent Control (PoliBa)	First Semester	Yes	6
	Optimization and Control (PoliBa)	Second Semester	Yes	6
C. Soft skill courses	POLIBA SOFT SKILL - TRAINING ACADEMY	Dec 2022 - TBD		3
D. Participation to seminars	Cycle of seminars on Industry 4.0: Digital Twin – Siemens and Masmec	TBD		2
E. Participation to international congresses or workshops				
	eXplainable AI Summer School - XAISS	July 2023		5
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			29

					ECTS
F.	Individual research activity				18
G.	Supervision of students				
H.	Integrative teaching activities				
I.	Preparation of manuscripts for conferences or journals				13
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES			31
		TOTAL OF ECTS			**60**

Second academic year (planned)

		Description	Period	Final Exam	ECTS
A.	Ph.D. courses				
B.	Master's degree courses	Dynamical Systems Theory	First Semester	Yes	6
C.	Soft skill courses	C1 English Preparation	First Semester	No	2
D.	Participation to seminars				
E.	Participation to international congresses or workshops				
F.	Presentation of research products at international congresses or workshops				
		TOTAL OF ECTS FOR TRAINING ACTIVITIES			8
G.	Individual research activity				35
H.	Supervision of students				
I.	Integrative teaching activities				5
J.	Preparation of manuscripts for conferences or journals	Manuscript on eXplainable AI in medical field			12
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES			52
		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				
E. Participation to international congresses or workshops				
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			0
G. Individual research activity				39
H. Supervision of students				
I. Integrative teaching activities				5
J. Preparation of manuscripts for conferences or journals				16
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			60
	TOTAL OF ECTS			**60**

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