NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Digital Driven Diagnostics, Prognostics and Therapeutics for sustainable Health care

Ph.D. candidate

Valeriana Mancazzo

Cycle

XXXIX

Tutor

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1. Description of the research program

"Digital Driven Diagnostics, Prognostics and Therapeutics for Sustainable Health care" project (D34H) is focused on the development of digital and biological twins for the management of five diseases through the collection of health data analyzed by artificial intelligence-based algorithms.

In this context, this PhD research project aims to study, design and develop a Digital Twin (DT) for modeling the Central Nervous System (CNS) areas affected by Multiple Sclerosis (MS) and brain tumors to improve the quality of diagnosis, monitoring and treatment. Both these two pathologies are from the five of interest of D34H and are characterized by heterogeneous course and complexity. Given the possibility of integrating multidimensional and longitudinal data, such as clinical data, neuroimaging, and laboratory data, DTs are specifically suitable for modeling such pathologies.

As for imaging, MRI, in combination with more invasive technologies, e.g., PET or SPECT, are the fundamental tools for the diagnosis and monitoring of MS and brain tumors, allowing the detection of the affected cerebral areas and their spread in space, as well as the monitoring of lesions over time. In addition, the analysis of brain signals, such as Evoked Potential (EPs), which measure the electrical activity of the brain in response to stimulation of specific nerve pathways, has been considered as a methodology for extracting biomarkers to study and evaluate possible cognitive and motor deficits due to brain tumors, brain surgery or MS. In fact, signals such as Visual Evoked Potentials (VEPs) and Motor Evoked Potentials (MEPs) can detect the reduction in electrical conduction caused by demyelination or the spread of tumor along these pathways even before it translates into clinical symptoms. Nonetheless, the precise prognostic potential of EPs for these diseases is still under discussion.

In general, the detection of both MS and brain tumor remains challenging, as the differential diagnosis from other neuroinflammations caused by demyelinating pathologies is complex, especially in the early stages, and the classification of brain tumors into their different types is demanding. Moreover, the current treatments used for MS are not personalized and can entail a series of side effects. Similarly, brain tumor therapies require individualized approaches to minimize radiotherapy and chemotherapy side effects and limit surgical damage to surrounding tissues.

Considering the limitations presented by current technologies, DT can represent an essential tool for the identification and characterization of patient-specific patterns. This can lead to an improved diagnostic capacity, distinguishing different types of lesions and providing patients with personalized and precise medical care, also alleviating the problems of current therapies by utilizing specific patient data and the ability to make predictions about their responses to treatment, maximizing effectiveness while reducing damages.

2. Schedule of the research activities

First academic year (planned)

	Description	Period	Activity abroad
Study and literature review	Understanding of the concept of the Digital Twin and its applications in the field of medicine, particularly for CNS diseases. Examine previous studies and research to identify existing gaps and challenges.	6 months	NO
Identification of specific needs and challenges related to the management of CNS diseases	Collaborate with medical experts and researchers to identify key areas where the Digital Twin could make a significant impact. Define key objectives and metrics to assess the project's success.	3 moths	NO
Data collection and analysis	Gathering of clinical, imaging and other relevant data related to patients with CNS diseases. Analyze the data comprehensively to identify significant patterns and relationships.	3 months	NO

Second academic year (planned)

	Description	Period	Activity abroad
Design and development of the Digital Twin model	Design and development of a virtual model that represents the physiological characteristics and dynamics of CNS diseases.	12 months	NO

Third academic year (planned)

	Description	Period	Activity abroad
Optimization and validation	Optimization and validation of the Digital Twin model to ensure an accurate match with clinical outcomes and real patient data.	6 months	NO
Abroad Project	TBD	6 months	YES

3. Training and research activities plan

First academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Control for optimization	Nov-Dec 2023	Yes	1
	Multi-agent and multi-object estimation	Jan-Feb 2024	Yes	2
	Data-driven fault diagnosis and fault prognosis	Jun-Jul 2024	Yes	1
	Game Theory for controlling Autonomous Systems	Jun-Jul 2024	Yes	2
	Electronic Information and Industrial Bioengineering (ScuDo)	TBD	Yes	2
	Deep neural networks (ScuDo courses)	TBD	Yes	2
B. Master's degree courses	Big Data Analytics	First Semester	Yes	6
C. Soft skill courses				
D. Participation to seminars	Introduction to dynamic control allocation			3
	Introduction to fault diagnosis and fault prognosis			1.5
E. Participation to international congresses or workshops				
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			20.5
G. Individual research activity	Research activity on intelligent systems that improve the diagnosis, monitoring and treatment of CNS diseases (Machine Learning and Deep Learning models)			35
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	TBD			4.5
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			39.5
	TOTAL OF ECTS			**60**

Second academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	TBD		Yes	2
	TBD		Yes	1
B. Master's degree courses	Model Predictive Control		Yes	6
C. Soft skill courses				
	TBD			3

D. Participation to seminars				
E. Participation to international congresses or workshops	TBD			4
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			**16**
G. Individual research activity	Study and implementation of ML models for the design and development of a Digital Twin.			40
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	TBD			4
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			44
	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	TBD			3
F. Presentation of research products at international congresses or workshops	TBD			3
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			**6**
G. Individual research activity	Optimization and validation of the proposed Digital Twin model.			50
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	TBD			4
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			54
	TOTAL OF ECTS			**60**

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