NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Awareness in human-human and human-robot interactions

Mathematical and artificial intelligence models of human behaviors for climate change

Ph.D. candidate

Eleonora Vitanza

Cycle

XXXVIII

Tutors

Professor Chiara Mocenni

Professor Domenico Prattichizzo

1. Description of the research program

The research program described herein is rooted in the fields of Climate Change and decision-making. In particular, I will point my focus on studying the current social awareness on Climate Change challenges, and on developing behavioral models which possibly modify the current situation.

Many disciplines are concerned with studying social phenomena. From a mathematical point of view, the most important ones are certainly graph theory and game theory. The latter provides a mathematical framework that formally analyzes situations in which individual choice is interdependent on the decisions made by others.

Also, worth mentioning in this context is Evolutionary Game Theory (EGT). 'Evolution' may, in the context of social science, often be understood as *cultural* evolution, where this refers to changes in beliefs and norms over time. Moreover, EGT as an explicitly dynamic theory, provides an important element missing from the traditional theory.

In this context, I will enlarge my knowledge, studying and deepening the areas of complex systems, networks dynamic and control theory.

Another particularly aspect that this research program is going to address is the leverage of machine learning to analyze data in the simplest and most useful way. The purpose is to make data more accessible to the population, increasing awareness. In addition, game theory, graph theory and optimization models will be used to study human behaviors. The goal is to identify and set critical parameters and values for human decisions and tendency to cooperation. Hence, I will investigate what role awareness plays on critical decisions, either with a survey-based field validation or providing public good games models with voluntary participation.

Modern data analysis techniques based on machine learning, such as clustering, make it possible to synthesize large masses of data and to capture interesting patterns from data. Reinforcement learning (RL) is an area of machine learning concerned with how intelligent agents ought to take actions in an environment to maximize a cumulative reward. RL can be considered the meeting point between game theory, optimization, and machine learning, as it uses data and machine learning to reinforce awareness and guide people decisions. As many studies point out, the line between these methodologies is not so clear-cut .

Further development of the project could involve focuses on different levels of depth, for instance addressing decision-making processes between communities or between nations.

The ultimate goal is to go beyond individual approaches, seeking a link between them to identify management strategies at various levels: individual, corporate, regional, national, and so on. That is, control, optimization, and management strategies are sought to improve the state of the environment, reduce environmental impacts, and help reverse the trend of rising temperatures and extreme events related to climate change.

2. Schedule of the research activities

The research activity plans to carry out as a first step a thorough study of the state of art of the relevant literature related to decision-making, climate change, opinion dynamics, and so on. I will then study and design new models of decision-making processes in this context. The research in the state of art will also focus on the general topic of machine learning. Note that the research in the state of art is planned as an activity which will be carried on during all the period of research by actively monitoring and studying the most important international conferences and journals related to my research program. The new techniques proposed will be tested in control scenarios and will be carefully analyzed. The obtained results will be disseminated through publications in the proceedings of high impact international conferences and journals.

First academic year (planned)

	Description	Period	Activity abroad
Study the relevant literature	-Research in the state of art of AI and control models for network systems, cooperation mechanisms, opinion dynamics and so on.	1-12 months	NO
Application to Climate Change	-Application of those models and tools to climate change. -Study of the state of the art in this interdisciplinary field.	1-12 months	NO

Second academic year (planned)

	Description	Period	Activity abroad
Study and design of models	-Development of decision-making models at various levels: agents, groups and communities. -Focus on the role of awareness.	1-12 months	YES (POSTDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH, CAMBRIDGE CENTER FOR CLIMATE SCIENCE)
Data analysis and validation on the field	-Data analysis on both climate and behavioral data. -Surveys on the field, considering individuals as active participants and not just passive observers.	1-12 months	YES (POSTDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH, CAMBRIDGE CENTER FOR CLIMATE SCIENCE)

Third academic year (planned)

	Description	Period	Activity abroad
Analysis of results	-Identification of management strategies at micro, meso and macro level with the final aim of give a contribution to downgrade the Earth tipping point, triggering virtuous social mechanisms.	1-12 months	NO
Writing of the PhD Thesis	-Writing of the PhD thesis.	1-12 months	NO

3. Training and research activities plan

First academic year (planned)

	Description	Period	Final Exam	ECTS

A. Ph.D. courses	Introduction to modeling, analysis and control of complex systems	January-February or June 2023	Yes	1
	Optimal control for Climate change and air quality	March-April 2023	Yes	1
	Complex networks: Theory, Methods, and Applications (6th edition)	May 2023	No	5
	Linear algebra for control applications	Spring 2023	Yes	2
	Mathematical introduction to control and optimal control problems	TBA	Yes	4 approx.
B. Master's degree courses				
C. Soft skill courses	Research Methodology	TBA	Yes	2
D. Participation to seminars	Complex Systems Modeling	TBA		1.5
	Network dynamics and control	January-February or June 2023		3
	Opinion dynamics	February/July/September 2023		1.5
	Sustainable exploitation of renewable energy souces	TBA		1.5
E. Participation to international congresses or workshops	Human-Machine Collaboration 2022 workshop	1-2 December 2022		2
F. Presentation of research products at international congresses or workshops	Presentation of the results obtained to at least one international congresses or workshops associated to a high impact factor.	1-12		2
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			26.5
G. Individual research activity	Research activity in the topics of machine learning and decision-making.	1-12		15.5
H. Supervision of students	Supervision of Students under the guidance of the tutor.	1-12		4
I. Integrative teaching activities	Integrative didactive activities to be carried out under the supervision of the tutor.	1-12	No	4
J. Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.	1-12	No	10
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			33.5
	TOTAL OF ECTS			**60**

Second academic year (planned)

	Description	**Period**	**Final Exam**	**ECTS**
A. Ph.D. courses	A system theoretical approach to the analysis of centralized and distributed algorithms for constrained and unconstrained optimisation	TBA	Yes	3 approx.
B. Master's degree courses	Reinforcement Learning	TBA	Yes	6
C. Soft skill courses	Participation to one soft skills course according to availability.	1-12	No	2

D. Participation to seminars	Participation to at least two seminars according to availability.	1-12		3
E. Participation to international congresses or workshops	CCS 2023 – Conference on Complex Systems	Autumn 2023		5
F. Presentation of research products at international congresses or workshops	Presentation of the results obtained to at least one international congresses or workshops associated to a high impact factor.	1-12		2
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			21
G. Individual research activity	Research activity in the topics of machine learning and decision-making.	1-12		18
H. Supervision of students	Supervision of Students under the guidance of the tutor.	1-12		1
I. Integrative teaching activities	Integrative didactive activities to be carried out under the supervision of the tutor.	1-12		10
J. Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.	1-12		10
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			39
	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	Participation to at least one workshop according to availability.	1-12		3
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.	1-12		4
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	TOTAL OF ECTS FOR TRAINING ACTIVITIES			
G. Individual research activity	Research activity in the topics of machine learning and decision-making.	1-12		23
H. Supervision of students	Supervision of Students under the guidance of the tutor.	1-12		8
I. Integrative teaching activities	Integrative didactive activities to be carried out under the supervision of the tutor.	1-12		8
J. Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.	1-12		14

	TOTAL OF ECTS FOR RESEARCH ACTIVITIES	53
	TOTAL OF ECTS	**60**

4. List of the publications written by the candidate in the triennium

International Journal Articles

[j1] "A multi-modal machine learning approach to detect Extreme Rainfall Events in Sicily", E. Vitanza, G. M. Dimitri, C. Mocenni **(under preparation).**

Eleonora Vitanza

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Prof. Chiara Mocenni

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Prof. Domenico Prattichizzo

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