Integrating Swarm Sensors for Distributed Monitoring and Agent Based Modeling for Environmental Systems Control

An individual perspective on climate awareness

Ph.D. candidate

Vittoria Socci

Cycle

XXXIX

Tutors

Professor Chiara Mocenni

1. Description of the research program

The research project described herein aims to address one of the most pressing problems facing humanity today: climate change. The focus is on the role single individuals play in this context, as their daily behavior can significantly influence the overall environmental impact. In this sense, I will focus on developing models that can guide individuals' behavior towards sustainable decisions with the aim of reducing the environmental impact of human activity, thus contributing to reverse the trend of rising temperatures and increasing the extreme weather events due to climate change.

Agent-based models (ABMs) are particularly suitable for this purpose, representing complex systems where agents are autonomous entities interacting with each other and the environment. So, I will enlarge my knowledge about them and all the related disciplines which can be used to analyze social phenomena such as complex systems, game theory, graph theory and control theory.

Game theory (GT) and evolutionary game theory (EGT) can be used to describe the human decision-making process in ABMs and to analyze how behaviors of individuals vary over time. However, the human decision-making process can be characterized using many other techniques. In this sense, I will focus on investigating not only GT and EGT but also machine learning (ML) techniques, Markov decision-making processes (MDPs) and neural networks (NN) which can be used to describe how individuals make decisions.

Graph theory makes it possible to represent social interactions between individuals, which are crucial in influencing their choices. Therefore, I will also focus on investigating networks dynamic.

In addition, a more in-depth study of control theory will provide insight into how to influence the collective behavior of the system described by the ABM towards a sustainable scenario.

The focus of the research will be on art cities in Italy (e.g., Siena). Since in cities of art citizens are not the only agents whose daily behavior have an impact on the environment, the agents of the model will be citizens and tourists. In this context, the aim is to develop targeted strategies for both citizens and tourists to guide them towards sustainable decisions.

I will distribute surveys among both citizens and tourists to geo-reference them and to identify different types of agents according to their propensities towards sustainable practices.

In addition, local external environmental data will be included in the model. Such exogenous data will be collected by swarm sensors, physical devices that will be included in the model as autonomous non-human agents with the only aim of providing such data to the model's human agents. The data collected by the swarm sensors will be previously pre-processed to make them more accessible to the agents of the model to whom they are provided. In this sense, I will enlarge my knowledge on all the machine learning techniques that can be used to reprocess the data. Feeding data to the model agents will increase their climate awareness, consequently promoting more sustainable behaviors among them.
Moreover, I will study how climate awareness varies among individuals in the population of agents taken into consideration and analyze how it influences human decision-making, with the final aim of increasing it.

Finally, I will study how to validate the model. A possible approach for the validation is using data: not only social and physical data are used to tune the model, but further and updated data will be collected at different times to validate it. However, my intention is to broaden my knowledge in this field and explore other validation methods as well.

2. Schedule of the research activities

The research program proposed herein begins with a thorough study of the state of the art of the relevant literature on climate change and all the disciplines useful in counteracting its effects: agent-based modelling, decision-making, networks dynamic, machine learning and control theory.

Subsequently, I will develop agent-based models which consider all the techniques analyzed from the literature to foster sustainable behaviors in the population with the ultimate goal of counteracting the effects of climate change.

First academic year (planned)

	Description	Period	Activity abroad
Study the relevant literature	-Analysis of the state of the art of the relevant literature on climate change, climate awareness, agent-based modelling, decision-making, machine learning, networks dynamic and control theory.	1-12 months	NO
Application to Climate Change	-Application of all disciplines and techniques studied to counter the effects of climate change. -Research in the field of sustainable tourism.	1-12 months	NO

Second academic year (planned)

	Description	Period	Activity abroad
Data analysis and development of new models	-Analyses of local external data collected from both human (surveys) and technological (physical devices) swarm sensors using machine learning techniques studied in the first year of the research and which will be used to tune the model. -Development of new agent-based models interacting on art cities in Italy that include both citizens and tourists.	1-12 months	YES (to be acknowledged)
Validation of the models	-The model will be validated by collecting new and updated social and physical data from swarm sensors at different time instants. -However, any other validation techniques will be analyzed from the relevant literature.	1-12 months	YES (to be acknowledged)

Third academic year (planned)

	Description	Period	Activity abroad
Analysis of the results	-Analysis of the results obtained with the aim of developing strategies to foster sustainable behaviors among the population to reduce the anthropogenic impact on the environment and reverse the trend of rising temperatures and the increase in extreme weather events caused by climate change.	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

		Period	Final Exam	ECTS
A. Ph.D. courses	Intelligent Control Systems	Jenuary-February 2024	Yes	2
	Game Theory for Controlling Autonomous Systems	June-July 2024	Yes	2
	From Least Squares to Subspace Identification	February-March 2024	Yes	2
	Participation to a PhD course provided by a partner university according to availability.	1-12 months	Yes	2
	Participation to a PhD course provided by a partner university according to availability	1-12 months	No	5
B. Master's degree courses				
C. Soft skill courses	Participation to one soft skill course according to availability.	1-12 months	Yes	2
D. Participation to seminars	Participation to at least four seminars according to availability.	1-12 months	No	7.5
E. Participation to international congresses or workshops	Participation to at least one international congresses or workshops according to availability.	1-12 months	No	2
F. Presentation of research products at international congresses or workshops	Presentation of the results obtained to at least one international congresses or workshops.	1-12 months	No	2
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			26.5
G. Individual research activity	Research activity in the topics of agent-based modeling, machine learning, decision-making, networks dynamic and control theory.	1-12 months	No	15.5
H. Supervision of students	Supervision of Students under the guidance of the tutor.	1-12 months	No	4
I. Integrative teaching activities	Integrative didactive activities to be carried out under the supervision of the tutor.	1-12 months	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 months	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	Participation to at least four PhD courses according to availability.	1-12 months	Yes	8
	Participation to at least one PhD course according to availability.	1-12 months	No	2
B. Master's degree courses				
C. Soft skill courses	Participation to one soft skill course according to availability	1-12 months	No	2
D. Participation to seminars	Participation to at least two seminars according to availability.	1-12 months	No	3

	Description	Period	Final Exam	ECTS
E. Participation to international congresses or workshops	Participation to at least one international congresses or workshops according to availability.	1-12 months	No	2
F. Presentation of research products at international congresses or workshops	Presentation of the results obtained to at least one international congresses or workshops.	1-12 months	No	2
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			19
G. Individual research activity	Research activity in the topics of agent-based modeling, machine learning, decision-making, networks dynamic and control theory.	1-12 months	No	18
H. Supervision of students	Supervision of Students under the guidance of the tutor.	1-12 months	No	3
I. Integrative teaching activities	Integrative didactive activities to be carried out under the supervision of the tutor.	1-12 months	No	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 months	No	10
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			41
	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 two international congresses or workshops according to availability.	1-12 months	No	4
F. Presentation of research products at international congresses or workshops	Presentation of the results obtained to at least two international congresses or workshops.	1-12 months	No	4
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			8
G. Individual research activity	Research activity in the topics of agent-based modeling, machine learning, decision-making, networks dynamic and control theory.	1-12 months	No	20
H. Supervision of students	Supervision of Students under the guidance of the tutor.	1-12 months	No	8
I. Integrative teaching activities	Integrative didactive activities to be carried out under the supervision of the tutor.	1-12 months	No	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 months	No	14
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			52
	TOTAL OF ECTS			**60**

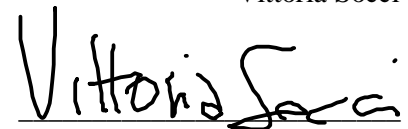# 4. List of the publications written by the candidate in the triennium

Master Thesis of M.Sc. Program in Applied Mathematics

Socci V., An Agent-Based Model to foster sustainable behaviours in citizens: the case of Siena, University of Siena (20 october 2023).

International Conference Proceedings

[c1]   Vitanza E., Socci V., Dimitri G.M., Mocenni C., Artificial Intelligence and Agent-Based Models to Raise Awareness and Reverse Climate Tipping Points, Conference on Complex Systems CCS2023, Salvador da Bahia, Brazil Oct. 16-20, (2023). (poster presentation)

Vittoria Socci

Prof. Chiara Mocenni

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