



NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Study of hybrid dynamic systems and their applications to sustainable mobility.

Ph.D. candidate

Silvia Di Girolamo

Cycle

XXXVIII

Tutors

Prof. Antonino Sferlazza

Prof. Filippo D'Ippolito

1. Description of the research program

The research program described here focuses on the study and analysis of hybrid dynamic systems and their applications to sustainable mobility topic.

Although the study and analysis of hybrid systems is in general more difficult than that of purely discrete or purely continuous systems, hybrid systems provide a natural framework to describe, suitably, some categories of complex systems that embed both continuous and discrete dynamics, as well as discrete events. In general, hybrid systems have the advantage of including larger classes of systems within their structure and this clearly allows greater flexibility in the modeling of various dynamic phenomena in a wide range of applications including mechanical systems, electrical circuits, etc. -and in all these systems the "discrete" components (switches, valves, computers, etc.) will be modeled as they introduce instantaneous changes in the "continuous" components (capacitor charge, chemical reactions, etc.)-.

For this reason, the first part of the research activity will be devoted to the study of hybrid dynamical systems from the theoretical point of view, by investigating the last works presented in the literature about this topic.

On the other side, sustainable mobility has received great attention during the last years and represents one important topic of the PNRR presented by the Italian government, and it represents, in turn, the founding program of this PhD scholarship. Specifically, sustainable mobility is aimed at reducing or eliminating atmospheric and noise pollution, road congestion, the accident rate, etc. It will therefore focus on ecologies, environment and improving people's quality of life.

That being stated, in large part of the literature it is shown that many complex systems, such as traffic models, vehicle models, and so on, can be cast in the framework of the hybrid dynamical systems. For this reason, the main idea of this project is to exploit the theory, of the last years, about the hybrid systems, in order to develop new control strategies for improving sustainable mobility. In particular, two key aspects will be analyzed: the first one will focus on the control of electrical/hybrid vehicles by improving their efficiency and, in general, their environmental impact, and the second one will focus on the traffic management.

With respect to the control of electrical/hybrid vehicles, the interest is aimed at innovation and development of advanced control systems, by means of the hybrid dynamical system theory, to manage electric power flows among the various devices. In particular, the power train of a vehicle contains different elements: usually there are storage devices (battery, super-capacitor, ...) that source one or more electrical motors by means of suitable power converters. The control of all these elements and the optimization of the energy flows among them is a crucial task to increase as much as possible the efficiency of the vehicle.

With respect to the traffic management, the goal of this work will be to design a framework to control large-scale traffic systems using a multi-level control structure and to determine a tractable control design methodology for use within this framework. A structured and tractable design methodology will be developed for robust control of the vehicle. The main innovation will be on traffic control and management strategies, based on stochastic hybrid system framework, with special attention at the roadside infrastructure.

In conclusion, this research program aims to present advanced research for sustainable mobility through the use of hybrid dynamical systems by exploit the recent theory on this topic, and it is of great interest for the public administration involved in field.

2. Schedule of the research activities

First academic year (planned)

	Description	Period	Activity abroad
Background study	Study of dynamic hybrid systems	11-2022/ 2-2023	NO
Problems Statement	Preliminary problem formulation and introduction to the proposed solutions.	3-2023/11-2023	NO

Second academic year (planned)

	Description	Period	Activity abroad
Proposed solutions	Development of advanced control systems, by means of the hybrid dynamical system theory, to optimize energy flows in electrical vehicles	11-2023/5-2024	YES (LAAS-CNRS)
Proposed solutions	Development of traffic control and related management strategies, based on stochastic hybrid system framework.	6-2024/11-2024	YES (LAAS-CNRS)

Third academic year (planned)

	Description	Period	Activity abroad
Simulations and analysis	Development of a simulation setup, analysis and validation of the results.	11-2024/8-2025	NO
Thesis writing	Thesis writing, editing and submission	8-2025/11-2025	NO

3. Training and research activities plan

First academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Fault detection techniques in condition monitoring: model based and data driven methods	Tbd	Yes	1
	Modeling, filtering and controlling aerospace systems	March-July 20223	No	1.5
	Navigation systems for autonomous systems	Jan-Feb, Oct/Nov 2023	Yes	1.5
	Modeling and simulation of biological and medical systems	January-June 2023	No	1.5
	Introduction to modeling, analysis and control of complex system	January-February or June 2023	No	0.5
	Nonlinear hybrid dynamical systems	Aug-Sep 2023	No	1
	Model predictive control	March-April 2023	No	1
B. Master's degree courses	Estimation, filtering and system identification	Nov 2022-January 2023	Yes	9
C. Soft skill courses	Industry 4.0: optimization, control and security	January 2023	Yes	2

	Applications of MATLAB	June-July 2023	Yes	2
	Numerical methods for ordinary differential equations	Tbd	No	1
	Numerical methods for multidimensional differential problems	Tbd	No	1
	Optimization and control of complex systems	February 2023	Yes	2
D. Participation to seminars	Applied data-driven fault diagnosis	Feb-March 2023		1.5
	Complex systems Modeling	Tbd		1.5
	Introduction to dynamic control allocation	Nov 2022-March 2023		3
	Introduction to fault diagnosis and fault prognosis	March-April 2023		1.5
	Learning influences in large scale dynamical social networks-a systems and control approach	March-July 2023		1.5
	Linear matrix inequalities in system and control	April-May-June 2023		3
	Theory and Applications of contracting dynamical systems	November 2022		3
	Network dynamics and control	Jan-Feb or June 2023		3
E. Participation to international congresses or workshops	M14-Introduction to nonlinear systems & control	9 to 12/ 05/ 2023		3
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			46
G. Individual research activity	Research activity	250 h		10
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Preparation of manuscripts for journals, as research products of individual research activity	100 h		4
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			14
	TOTAL OF ECTS			60

Second academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	SIDRA Summer school courses	July 2024	Yes	5
			Yes/No	
			Yes/No	
B. Master's degree courses	Digital control	Nov 2023-Jan 2024	Yes	6
			Yes/No	
C. Soft skill courses			Yes/No	
D. Participation to seminars				
E. Participation to international				

congresses or workshops				
F. Presentation of research products at international congresses or workshops	Conference on Decision and Control (CDC) 2024	December 2024		2
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			13
G. Individual research activity	Research activity		975h	39
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Articles concerning the research activity carried out for publication in scientific journals.		200 h	8
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			47
TOTAL OF ECTS				60

Third academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses			Yes/No	
			Yes/No	
			Yes/No	
B. Master's degree courses			Yes/No	
			Yes/No	
C. Soft skill courses			Yes/No	
D. Participation to seminars				
E. Participation to international congresses or workshops				
F. Presentation of research products at international congresses or workshops	European Control Conference (ECC) 2025	June 2025		1
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			1
G. Individual research activity	Research activity and writing of the PhD thesis		1175 h	47
H. Supervision of students	Tutor of students during the master thesis development		50 h	2
I. Integrative teaching activities	Assistant professor during teaching activities		50 h	2
J. Preparation of manuscripts for conferences or journals	Articles concerning the research activity carried out for publication in scientific journals		200 h	8
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			60
TOTAL OF ECTS				60

Insert Ph.D. student name

Insert Tutor 1

Prof. Filippo D'Ippolito

Insert Tutor 2

Prof. Antonino Sferlazza
