Model-based and data-driven learning and control of complex network systems

Ph.D. candidate

Ali Moshiri

Cycle

XXXVIII

Tutors

Prof. Gianfranco Parlangeli
Prof. Giuseppe Notarstefano

1. Description of the research program

The recent technology advances involving interconnected intelligent devices have posed new challenges in the design paradigms for complex systems. The interconnection topology and the local protocols fundamentally affect the dynamical processes of these complex networks and generate relevant collective features (such as aggregation/collaboration, consensus or clustering). Moreover, subsets of nodes may condition the global evolution or may be used to retrieve information on other nodes. Exploring the capabilities of the complex network and identifying main features of the network structure is a research challenge to address that can have a significant impact in several domains as traffic control, social networks, or swarm robotics. The interconnection among network clusters is often affected by adjustable local interaction, so that the value of local parameters may have a strong impact on the overall system performance. The design and tuning of these local interactions and parameters, e.g., by minimizing suitable global performance metrics (e.g., energy consumption) is a challenge to be addressed. Moreover, a timely research direction involves the combination of model-based system-theoretical tools with data-driven approaches (e.g., from Artificial Intelligence) that have shown to be extremely successful in several domains and that allow the designer to take advantage from the availability of massive data.

Considering the above framework, the proposed PhD program will deal with: (i) the investigation of network features with their impact on global behaviors and fundamental limitations of the complex system, (ii) novel approaches for the design of local interactions by taking into account performance indexes and global constraints, and (iii) the exploration of combined system theoretical approaches and data-driven tools to learn and control the network system. The developed methodological studies will be applied to concrete applications scenarios from cooperative robotics.

2. Schedule of the research activities

First academic year

	Description	Period	Activity abroad
Literature review on complex networks	Investigation on the state of the art on the topic of dynamics of complex networks and their relevant collective features	Months 1-9	NO
Literature review on data-driven approaches for learning and control	Literature review and recent advances on data-driven approaches for learning and control of a dynamical system.	Months 1-9	NO
Literature review on combined system theoretical approaches and data-driven tools.	Literature review of combined system theoretical approaches and data-driven tools. Investigation on the possible application scenarios.	Months 6-12	NO
Research work	Statement of a challenging research problem based on the literature review.	Months 9-12	NO

Second academic year

	Description	Period	Activity abroad
Research work	Analysis of the problem statement and investigation of possible solutions based on the literature review.	Month 1-9	NO

	Description	Period	Activity abroad
Simulation/experimental setup	A special focus on the possible application scenarios, choice of a simulation/experimental framework for testing the possible solutions.	3-12	NO
Research work	Individual research activity and preparation of manuscripts.	3-12	NO

Third academic year

	Description	Period	Activity abroad
Research work	Definition of control architectures and algorithms for learning and control of complex networks based on collaborative/distributed data-driven approaches.	1-9	YES (Purdue University West Lafayette, IN)
Research work	Individual research activity and preparation of manuscripts.	6-12	NO
Preparation for final dissertation	Writing of the PhD dissertation.	10-12	NO

3. Training and research activities plan

First academic year

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Analysis and control of cyber-physical systems(DAUSY course)	2023	Yes	3
	A system theoretical approach to the analysis of centralised and distributed algorithms for constrained and unconstrained optimisation (UNIBO course)	TBD	Yes	1
	Introduction to modeling, analysis and control of complex systems (DAUSY course)	January-February or June 2023	Yes	1
	Distributed optimization for cooperative robotics and decision making: theory, numerical methods and toolboxes (International Graduate School on Control - EECI)	June 2023	Yes	3
B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars	Learning influences in large scale dynamical social networks - a systems and control approach	March-July 2023		1.5
	Complex Systems Modeling	TBD		1.5
	Opinion dynamics	February/July/September 2023		1.5
	Linear matrix inequalities in systems and control	April/May/June 2023		3

		Description	Period	Final Exam	ECTS
		Network dynamics and control	January-February or June 2023		3
		Introduction to dynamic control allocation	November 2022-March 2023		3
E.	Participation to international congresses or workshops				
F.	Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES				21.5
G.	Individual research activity				35
H.	Supervision of students				
I.	Integrative teaching activities				
J.	Preparation of manuscripts for conferences or journals				3.5
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES				38.5
	TOTAL OF ECTS				**60**

Second academic year (completed/planned)

		Description	Period	Final Exam	ECTS
A.	Ph.D. courses	PhD courses selected among the available ones		Yes	5
		Winter or Summer Schools		Yes/No	2
B.	Master's degree courses				
C.	Soft skill courses				
D.	Participation to seminars	Seminars selected among the available ones			6
E.	Participation to international congresses or workshops	Partecipation to an international conference			3
F.	Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES				16
G.	Individual research activity				25
H.	Supervision of students				

		Description	Period	Final Exam	ECTS
I.	Integrative teaching activities				
J.	Preparation of manuscripts for conferences or journals				19
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES			44
		TOTAL OF ECTS			**60**

Third academic year

		Description	Period	Final Exam	ECTS
A.	Ph.D. courses				
B.	Master's degree courses				
C.	Soft skill courses				
D.	Participation to seminars	Seminars selected among the available ones			6
E.	Participation to international congresses or workshops	Partecipation to an international conference			4
F.	Presentation of research products at international congresses or workshops	Presentation of one product at an international conference			2
		TOTAL OF ECTS FOR TRAINING ACTIVITIES			12
G.	Individual research activity	Research activity and final dissertation			30
H.	Supervision of students				
I.	Integrative teaching activities				
J.	Preparation of manuscripts for conferences or journals	Writing and reviewing of academic articles for journal and / or conference publications			18
		TOTAL OF ECTS FOR RESEARCH ACTIVITIES			48
		TOTAL OF ECTS			**60**

Ph.D. student name

_Ali Moshiri____

Tutor 1 name and title

___Gianfranco Parlangeli, Associate Professor_____

Tutor 2 name and title

__Giuseppe Notarstefano, Full Professor_____