PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Marco Coraggio

XXXII Cycle

Training and Research Activities Report – Second Year

Tutor: Mario di Bernardo – co-Tutor: None

1. Information

Marco Coraggio, MSc in Ingegneria dell'Automazione – University of Naples Federico II

XXXII Cycle – ITEE – University of Naples Federico II

University of Naples Federico II ITEE fellowship

Tutored by Prof Mario di Bernardo

2. Credits summary

	Estimated	Credits year 2						Summary
		1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	
Modules	3	0	0	3	0	0	5	**8**
Seminars	2	2,2	1,6	0,6	0,4	0,2	0	**5**
Research	55	7	8	7	9	10	6	**47**
	60	9,2	9,6	10,6	9,4	10,2	11	**60**

3. Study and training activities

- Attended courses:
  - Ad hoc — Delay differential equations (DDEs) and their applications — John Hogan.
  - Ad hoc — Elettromagnetismo e relatività — Amedeo Capozzoli.
  - MS module (attended course but exam not done) — Geometria Differenziale — Francesco D'Andrea.
- Attended seminars:
  - Tecnologie digitali e scienze umane - Internet e Intelligenza artificiale: ordine spontaneo o regolato? — Raffaele Bifulco, Giorgio Ventre
  - Tecnologie digitali e scienze umane - Etica e intelligenze artificiali — Guglielmo Tamburrini, Remo Bodei
  - Tecnologie digitali e scienze umane - Le nuove frontiere della robotica cognitiva e l'interazione — uomo-robot — Alberto Finzi, Barbara Henry
  - Tecnologie digitali e scienze umane - Razionalità limitata nell'uomo e nella macchina — Luigi Sauro, Maurizio Ferraris
  - Tecnologie digitali e scienze umane - Lasciamo parlare i dati: riflessioni sull'apprendimento — automatico e i big data — Anna Corazza, Gino Roncaglia
  - Tecnologie digitali e scienze umane - Internet, Intelligenza artificiale e tutela della privacy — Piero Andrea Bonatti, Giovanni Buttarelli
  - Enabling the Innovators and Entrepreneurs of Tomorrow — Xiao Xi, Wang Jian
  - How does MathWorks accelerate the pace of engineering and science? — Francesco Alderisio
  - Discovering the network topology of complex systems — Daniel A. Burbano-L.
  - The Napoli Federico II IEEE Student Branch — Stefano Marrone
  - Wearable Systems: design and implementation challenges — Mona Ghassemian
  - Domains of attraction and manifolds in a gear model — Petri Piiroinen
- External courses:
  - -

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4. Research activity

Title of the whole research activity: <u>Analysis and control of discontinuous dynamical systems and networks</u>.

- **Title:** <u>Study on the conditions for consensus/synchronization of complex networks of discontinuous dynamical systems</u>.
  Description: Both piecewise smooth (PWS) dynamical systems and complex networks are deeply investigated topics with numerous applications. In practical scenarios, it may happen to find complex networks composed of PWS agents, then a complex network of PWS agents emerges (mechanical ensembles, power grids, cardiac and neuronal cells, etc.). In the framework of complex networks, one of the most studied and significant behaviours is synchronization; however, all existing approaches for studying it in network of PWS agents have some sort of limitation. Our aim was to find general conditions for global synchronization. In particular, we found that adding a discontinuous coupling layer to the usual linear diffusive one it is possible to enforce synchronization. Namely, the coupling strengths of the two layers need to be above some threshold values, which are given as a function of the internal node dynamics, the coupling protocols and the topologies of the coupling layers. A noteworthy fact is the dependence of one of the thresholds on a crucial quantity that we named minimum density, having a purely topological meaning and deep relations with graph theory.
  Collaboration: Mario di Bernardo, Pietro De Lellis and John S. Hogan. — P. De Lellis is with the University of Naples Federico II, J. Hogan is with the University of Bristol (UK), M. di Bernardo is with both Universities.
- **Title:** <u>Study on the conditions for consensus/synchronization of complex networks of heterogeneous dynamical systems</u>.
  Description: When the problem of synchronization in complex networks of multiple dynamical systems is considered, one of the most common assumptions is that all the agents are equal. In practice, this may not be the case, either because the various systems are originally different or because of some other action (e.g. a disturbance, wear) has changed the behaviour of one of more of them. We are investigating the use of a discontinuous coupling action to guarantee synchronization, similarly to what we did for piecewise-smooth systems. Our early findings suggest that it is possible to achieve such synchronization, provided that, either the agents trajectories do not diverge, or their dynamics differ only for bounded terms.
  Collaboration: Daniel A. Burbano-L., Pietro De Lellis, and Mario di Bernardo — Daniel A. Burbano-L. is with the University of Northwestern University, (USA), P. De Lellis is with the University of Naples Federico II, M. di Bernardo is with both the University of Naples Federico II and the University of Bristol (UK).
- **Title:** <u>Control of Painlevé Paradox in a Robotic System.</u>
  Description: When a rigid stick is dragged on a surface, abrupt jumps may occur. This phenomenon, known as Painlevé paradox, is annoying when a piece of chalk makes a high-pitched sound on a blackboard, but is dangerous and/or costly when industrial applications are concerned. This may happen when robotic arms perform cuts or move parts on a moving belt, resulting in damaged or unusable products. We have compared different control scheme in their ability to suppress the occurrence of the phenomenon and have shown that a classic hybrid force/motion control can be effectively used to such aim.
  Collaboration: Davide Marchese, John S. Hogan and Mario di Bernardo. — D. Marchese was a master student at the University of Naples Federico II, J. Hogan is with the University of Bristol (UK), M. di Bernardo is with both Universities.
- **Title:** <u>Adaptive and quasi-sliding control of shimmy in airplane landing gears</u>.
  Description: Shimmy is a dangerous phenomenon that occurs when aircraft's nose landing gears oscillate in a rapid and uncontrollable fashion. In our research we investigated and validated the use of two nonlinear control approaches (zero average control, and model reference adaptive control based on minimal control synthesis) as simple yet effective strategies to suppress undesired oscillations, even in the presence of uncertainties and partial state measurements.
  Collaboration: with Daniel A. Burbano L., Mario di Bernardo, Franco Garofalo and Michele Pugliese. — D. Burbano is with the Northwestern University (USA), M. di Bernardo, F. Garofalo and M. Pugliese are with the University of Naples Federico II.

5. Products

- Journal papers:
  - M. Coraggio, P. De Lellis, J. S. Hogan, and M. di Bernardo — Synchronization of Networks of Piecewise-Smooth Systems — IEEE Control Systems Letters, 2(4), pp. 653-658, 2018 (also a conference paper at CDC 2018).
- Conference papers:
  - D. A. Burbano L., M. Coraggio, M. di Bernardo, F. Garofalo and M. Pugliese — "Adaptive and quasi-sliding control of shimmy in landing gears" – ECC 2018 (European Control Conference);
  - [submitted] D. Marchese, M. Coraggio, S. J. Hogan, M. di Bernardo, — "Control of Painlevé Paradox in a Robotic System", ECC 2019 (European Control Conference).
- Keynotes:
  - M. Coraggio — "Synchronization in Piecewise-Smooth Networks" — ComplexCity@PoliTO 2018, workshop.

6. Conferences and seminars

- ECC 2018, European Control Conference, presentation of the paper "Adaptive and quasi-sliding control of shimmy in landing gears".
- CDC 2018, Conference on Decision and Control, presentation of the paper "Synchronization of Networks of Piecewise-Smooth Systems".
- ComplexCity@PoliTO 2018, delivery of the talk "Synchronization in Piecewise-Smooth Networks".

7. Activity abroad

- ECC 2018, European Control Conference — Limassol, Cyprus — 11-16 June 2018
- ComplexCity@PoliTO 2018, Workshop — Turin, Italy — 28-30 October 2018
- Conference: CDC 2018, Conference on Decision and Control — Miami Beach, USA — 13-20 December 2018.

8. Tutorship and teaching assistance

- Teaching assistance:
  - 7.5 hours in the course Dinamica e Controllo Non Lineare, in Ingegneria dell'Automazione (magistrale).
  - 2 hours in the course Controlli Automatici, in Ingegneria Informatica (triennale).
  - 6 hours in the course Nonlinear Systems, in Mathematical Engineering (magistrale).
  - 3 hours in the course Fondamenti di Sistemi Dinamici, in Ingegneria Elettronica (trieannale).
- Tutorship:
  - Co-supervisor for the thesis of 5 bachelor students in Ingegneria Informatica (Mauro Romito, Pasquale Luca Rullo, Fabiana Scielzo, Emanuele Antonio Varchetta, Mattia Cardone)
  - Co-supervisor for the thesis of 2 master students in Ingegneria dell'Automazione (Fabrizia Auletta, Davide Marchese).
  - Weekly 2 hours tutorship ("ricevimento") for the course of Dinamica e Controllo Non Lineare in Ingegneria dell'Automazione (magistrale), and the course of Controlli Automatici in Ingegneria Informatica (triennale.)

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