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 – Third 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

	Credits year 2							
	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary
Modules	0	0	0	0	0	0	0	**0**
Seminars	1,5	1,7	0	2,6	0	0	0	**4,3**
Research	58,5	8,3	10	7,4	10	10	10	**55,7**
	60	10	10	10	10	10	10	**60**

3. Study and training activities

- Attended courses: None
- Attended seminars:
  - Giornata di Studio su Reti Sociali e Comportamenti Emergenti — Franco Garofalo, Francesco Vasca, Claudio Altafini, Andrea Salvini, Sandro Zampieri, Francesco Lo Iudice, Pietro De Lellis, Paolo Frasca, Anna Maria Zaccaria, Antonello Giannitrapani, Paolo Bolzern, Patrizio Colaneri, Carmela Bernardo
  - Optimization and Classification — Manlio Gaudioso
  - Optimization in Deep Learning — Laura Palagi
  - Modeling, Analysis, and Control of Complex Networks and Cyber-Physical Systems — Thomas Parisini, Marios Polycarpou, Sandro Zampieri, Jacquelien Scherpen, Mattia Frasca, Pietro De Lellis, Francesco Sorrentino, Henrik Sandberg, Bruno Sinopoli, Ioannis Paschalidis, Giovanni Russo, Giacomo Como, Luca Schenato, and others.
- External courses: None

4. Research activity

Title of the whole research activity: Analysis and control of discontinuous dynamical systems and networks.

- **Title:** Study on the conditions for consensus/synchronization of complex networks of discontinuous dynamical systems.
  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:** Study on the conditions for consensus/synchronization of complex networks of heterogeneous dynamical systems.
  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: Pietro De Lellis, and Mario di Bernardo — 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:** Power flow minimization in electrical microgrids.
  Description: Modern electrical power networks pose a series of new research challenges. Indeed, more and more renewable energy generators are being incorporated into the grids; these new components typically have negligible electrical inertia, which makes the network much less robust to fluctuations in power demand and other disturbances. In particular, if some links in the network become overloaded as a result of a change in the power demand, those links will be disconnected by the grid operator. This can cause malfunctioning or even black-outs. To help prevent such scenarios, we devised an algorithm to intelligently control the percentage of use of the generators in order avoid congested links while still powering up all the loads.
  Collaboration: Saber Jafarpour, Francesco Bullo and Mario di Bernardo — S. Jafarpour and F. Bullo are with the University of California Santa Barbara (U.S.A.), M. di Bernardo is with both the University of Naples Federico II and the University of Bristol (UK).

5. Products

- Journal papers:
  - [ongoing review process] M. Coraggio, P. De Lellis, and M. di Bernardo — Achieving Convergence and Synchronization in Networks of Piecewise-Smooth Systems via Distributed Discontinuous Coupling — submitted to Automatica.
- Conference papers: None
- Keynotes:
  - M. Coraggio — “A Multilayer Discontinuous Approach to Achieve Convergence in Networks of Piecewise-Smooth Systems” — SIAM Conference on Applications of Dynamical Systems 2019.
  - M. Coraggio — “Synchronization of Piecewise-Smooth Systems” — 14th SICC Workshop “Modelling, Analysis and Control of Complex Networks and Cyber-physical systems” 2019.
  - M. Coraggio — “Distributed Switched Control of Networks of Piecewise-Smooth Systems” — SIDRA Conference “Automatica.it” 2019.

6. Conferences and seminars

- Presenter at: SIAM Conference on Applications of Dynamical Systems 2019, delivery of the talk “A Multilayer Discontinuous Approach to Achieve Convergence in Networks of Piecewise-Smooth Systems”.
- Presenter at: 14th SICC Workshop “Modelling, Analysis and Control of Complex Networks and Cyber-physical systems”, delivery of the talk “Synchronization of Piecewise-Smooth Systems”, presenter.
- Attendee at: Threshold networks workshop 2019.

- Presenter at: SIDRA Conference “Automatica.it” 2019, delivery of the talk “Distributed Switched Control of Networks of Piecewise-Smooth Systems”.

7. Activity abroad

- Short-term scholar visiting at University of California Santa Barbara — Santa Barbara, U.S.A. — from 01/04/2019 to 24/06/2019, except for 18/05/2019 to 24/04/2019.
- SIAM Conference on Applications of Dynamical Systems 2019 — Snowbird, U.S.A. — from 18/05/2019 to 24/04/2019.
- 14th SICC Workshop “Modelling, Analysis and Control of Complex Networks and Cyber-physical systems” 2019 — Ischia, Italy — from 29/06/2019 to 30/06/2019.
- Threshold networks workshop 2019 — Nottingham, U.K. — from 21/07/2019 to 24/07/2019.
- SIDRA Conference “Automatica.it” 2019 — Ancona, Italy — from 10/09/2019 to 14/09/2019.

8. Tutorship and teaching assistance

- Teaching assistance:
  - 12 hours in the course Dinamica e Controllo Non Lineare, in Ingegneria dell’Automazione (magistrale).
  - 6 hours in the course Sistemi di Controllo per la Bioingegneria, in Ingegneria Biomedica (magistrale).
- Tutorship:
  - 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).