PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Anna Di Meglio

XXXII Cycle

Training and Research Activities Report – First Year

"Modelling and control of coevolving dynamical networks with multiple time-scales"

Tutor: Franco Garofalo

1. GENERAL INFORMATION

Graduated in Management Engineering – Università di Napoli, Federico II
XXXII Cycle – ITEE – Università di Napoli, Federico II
M.I.U.R. grant
Tutor: Franco Garofalo

2. STUDY AND TRAINING ACTIVITIES

i Courses attended:
- "Modeling, simulation and control of collective behavior"; Prof. Maurizio Porfiri -ad hoc-;
- "Analisi e controllo di reti e sistemi complessi"; Prof. Pietro De Lellis -MSc;
- "Piecewise smooth dynamical systems"; Prof. John Hogan -ad hoc-;
- "Dinamica e controllo non lineare"; Prof. Mario Di Bernardo – MSc -.

ii Other courses:
- "Fondamenti di analisi funzionale"; Prof. Renato Fiorenza -ad hoc-;
- "Controlli Automatici" (Bachelor degree);
- "Stochastic Processes"; Prof. Enrica Pirozzi -MSc.

iii Seminars:
- "Plasma stability and dynamics events in tokamaks with resistive wall" Prof. Vladimir Dmitrievich Pustovitov organized by Prof. Guglielmo Rubinacci.
- "Fuzzy logic, genetic algorithms and their applications to next generation networks", Prof. Leonard Barolli organized by Prof. Flora Amato at Università degli studi di Napoli Federico II.
- "Complex dynamics in Memristor networks", Prof. Fernando Corinto, organized by Prof. Mario Di Bernardo at Università di Napoli Federico II.
- "Power system stability and synchronization" Prof. Navdeep M. Singh organized by Prof. Franco Garofalo at Università degli studi di Napoli Federico II.
- "Automatica 4.0", Prof. S. Bittanti, Prof. L. Nicolais,", organized by Prof. Paolo Bolzern at Politecnico di Milano.
- "Prospettive e nuove sfide tecnologiche e scientifiche nel settore dell'Automatica", Matteo Bianchi, Lorenzo Fagiano, Giuseppe Notarstefano, Chiara Ravazzi, organized by Prof. Maria Prandini at Politecnico di Milano.
- "Remote sinchronization in complex networks", Prof. Mattia Frasca, organized by Prof. Fabio Dercole at Politecnico di Milano.
- "Identification of nonlinear systems: from theory to applications", Prof. M. Gabriella Xibilia, organized by Prof. Fabio Dercole at Politecnico di Milano.
- "Forward action for MIMO systems passification", Prof. Arturo Buscaino, organized by Prof. Fabio Della Rossa at Politecnico di Milano.
- "An overview of nonlinear dynamics", Prof. Sergio Rinaldi at Politecnico di Milano.
- "Optimal control of networks: energy scaling and open challenges", Prof. Francesco Sorrentino, organized by Prof. Franco Garofalo at Università degli studi di Napoli Federico II.
- "Optimal control of glucose level for diabetes type I/II" Doc. Afroza Shirin organized by Prof. Francesco Sorrentino at University of New Mexico (Albuquerque).

- "HAMVET. A procedure for numerical optimal control" Doc. Isaac Samuel Klickstein organized by Prof. Francesco Sorrentino at University of New Mexico (Albuquerque).
- "Cluster synchronization in multi-layer networks" Doc. Abu Bakar Siddique, organized by Prof. Francesco Sorrentino at University of New Mexico (Albuquerque).

3. RESEARCH ACTIVITY

"Modelling and control of coevolving dynamical networks with multiple time-scales"

My research is focused on collective behaviors that can arise in complex dynamical networks [1].
A complex network is a set of dynamical systems coupled through a graph with non-trivial topological features. These types of systems are ubiquitous and the list of the applications is very long. For example, we see them in: biological (protein-protein interaction, gene regulatory, metabolic and neuronal networks) [2-4]; ecological (food webs; between and within species interaction networks; epidemic propagation) [5-6]; technological (internet network; power grid system; transportation and distribution networks; sensor network) [7] and social systems (financial markets; social networks; scientific collaboration networks; influence spreading; leadership; political comping; opinion dynamics) [8-10].
All the above examples are widely investigated by various communities of researchers. Two common simplifying hypotheses are made to study these networks:

1) the interconnections among the entities are fixed at time zero and remain unchanged (no edges-nodes coevolution);
2) the time-scales of the nodes' and edges' systems are infinitely separated and so one of them can be neglected.

The aim of these assumptions is that of making the mathematical model of the network tractable or simpler. Nevertheless, in some situations, none of the dynamics of the network can be neglected and we are forced to simultaneously consider the two dynamics with their own time-scales [11-13]. The so-called "Singular Perturbation Theory" [14] is the mathematical tool we will try to exploit to study a coevolving network in which the set of edges represents the slow system and the set of nodes the fast one. By the application of this mathematical technique, the two parts of the network can be studied separately and then merged to investigate its overall behavior.
In the first year of my PhD I began the study of the literature on coevolving networks and the settings in which the singular perturbation approach may be well-defined.

[1] Boccaletti S., Latora V., Moreno Y., Chavez M., Hwang D.-U. "Complex networks: structure and dynamics" Physics Reports 424, 4-5 (175-308) 2006.
[2] Fell D. A., Wagner, A. The small world of metabolism. *Nature biotechnology*, *18*(11), 1121, 2000.
[3] Girvan M., Newman, M. E. "Community structure in social and biological networks." *Proc. Natl. Acad. Sci. USA*, *99*(0112110), 8271-8276, 2001.
[4] Bullmore E., Sporns O. "Complex brain networks: graph theoretical analysis of structural and functional systems." *Nature Reviews Neuroscience*, *10*(3), 186, 2009.
[5] Sole R. V., Montoya M. "Complexity and fragility in ecological networks." *Proceedings of the Royal Society of London B: Biological Sciences*, *268*(1480), 2039-2045, 2001.
[6] Dunne J. A., Williams R. J., Martinez, N. D. "Network structure and biodiversity loss in food webs: robustness increases with connectance". *Ecology letters*, *5*(4), 558-567, 2002.
[7] Motter A. E., Myers S. A., Anghel M., Nishikawa, T. "Spontaneous synchrony in power-grid networks." *Nature Physics*, *9*(3), 191, 2013.
[8] Vitali S., Glattfelder J. B., Battiston S. "The network of global corporate control." *PlosOne*, *6*(10), e25995, 2011.
[9] Castellano C., Fortunato S., Loreto V. Statistical physics of social dynamics. *Reviews of modern physics*, *81*(2), 591, 2009.
[10] Leduc L. "Opinion change and voting behaviour in referendums." *European Journal of Political Research*, *41*(6), 711-732, 2002.

[11] Gross T., Sayama H. “Adaptive networks”. Springer, 2009.
[12] C. Kuehn. “Multiple time scale dynamics” Springer, 2015.
[13] Pacheco J. M., Traulsen A., Nowak M. A. “Coevolution of strategy and structure in complex networks with dynamical linking.” *Physical review letters*, *97*(25), 258103, 2006.
[14] Kokotovic P., Khalil H. K., O'reilly, J. *Singular perturbation methods in control: analysis and design* (Vol. 25). Siam. 1999.

4. PRODUCTS

i. Journal Papers:

- DeLellis P., DiMeglio A., Garofalo F., Lo Iudice F. (2017). **“The evolving cobweb of relations among partially rational investors.”** *PloS one*, *12*(2), e0171891.
- DeLellis P., DiMeglio A., Garofalo F., Lo Iudice F. (2017). - De Lellis P., Di Meglio A., Lo Iudice F. (2017). **“Overconfident agents and evolving financial networks.”** *Nonlinear Dynamics*, 1-8.
- DeLellis P., DiMeglio A., Garofalo F., Lo Iudice F. (2017). **“Steering opinion dynamics via containment control”.** *Computational social networks*, *4*(1), 12.

ii. Conference Papers:

- DeLellis P., DiMeglio A., Garofalo F., Lo Iudice, F. (2017, May). **“Evolution of networks of financial agents driven by herding phenomena.”** In *American Control Conference (ACC), 2017* (pp. 1598-1603). IEEE.

iii. Conference Abstracts:

- De Lellis P., Di Meglio A., Lo Iudice F. (2016). **“Evolving topologies in artificial financial networks.”** Proceedings of the IEEE, COMPENG 2016.
- DeLellis P., DiMeglio A., Garofalo F., Lo Iudice, F. **“Containment control of networks with time-varying weights: an application to opinion dynamics in financial markets”.** 5th International Workshop COMPLEX NETWORKS AND THEIR APPLICATIONS.

iv. In preparation:

- “Containment control of large signed networks.”
- “Optimal weight adaptation for a faster consensus protocol”.

5. CONFERENCE PRESENTATIONS AND SEMINARS

- IEEE Compeng 2016 (Catania 3-5 July 2016, Università degli studi di Catania. Presentation of “Evolving topologies in artificial financial networks”, http://www.compeng16.dieei.unict.it/);
- 5th International Workshop COMPLEX NETWORKS AND THEIR APPLICATIONS. (Milano, 30 November - 02 December 2016. Presentation of “Containment control of networks with time-varying weights: an application to opinion dynamics in financial markets”, http://complexnetworks.org/index2016.html);
- American Control Conference 2017 (Seattle (WA, USA), 24-26 May. Presentation of “Evolution of networks of financial agents driven by herding phenomena.”, http://acc2017.a2c2.org/); iii) Sidra 2017. (Presentation of “Containment control of multi-agent system with proximity interactions”. Milano,11-13 September http://www.sidra2017.deib.polimi.it/);

- 2 hours seminar in “BEST Autumn Course 2017 — Analysis and Control of Complex Systems”. The topic was the simulation of modelling and synchronization of complex networks using MATLAB/Simulink.

6. ACTIVITY ABROAD

- Albuquerque, NM (USA) to University of New Mexico, Department of Mechanical Engineering under the supervision of Professor Francesco Sorrentino (fsorrent@unm.edu).

7. TUTORSHIP

- Exercise lessons of Identificazione e controllo ottimo (Master degree course of Automation Engineering);
- Exercise lessons of Identificazione dei modelli e controllo ottimo (Master degree course of Managnent Engineering);
- Exercise lessons of Analisi e controllo di reti e sistemi complessi (Master degree course of Automation Engineering) and tutoring of students for master thesis;
- Weekly 2 hours tutorship for the courses of Identificazione e controllo ottimo and of Identificazione dei modelli e controllo ottimo;
- Co-supervision of thesis master students for the course of Identificazione dei modelli e controllo ottimo.
  TOT. HOURS: 40.