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 – Third Year

Tutor: Prof. Franco Garofalo

1. Information

Anna Di Meglio, MSc in Management Engineering – University of Naples, Federico II
XXXII Cycle - ITEE – University of Naples, Federico II

University of Naples, Federico II – ITEE fellowship

Tutor: Prof. Franco Garofalo

2. Study and Training activities

- Attended course: "Data Mining out of the Black Box: a Mathematical and Algorithmic Approach".
- Seminars:
  - "Analytics for Sharing Economy: Mathematics, Engineering and Business Prospective" - E. Cristolomi, H. Florian, B. Ghaddar, J. Naoum-Sawaya, G. Russo and R. Shorten.
  - "Control and Networking in Cyber-physical Systems" – S. Hirche, J.S. Baras, K. Wehrle and M. H. Mamduhi.
  - "Modeling, Control and Operation of Advanced Energy Storage Systems in Grid Connection" – L. Glielmo and D. Liuzza.

3. Research activity

- **Title:** Optimal control of stochastic temporal networks.
  Description: Recently, it has been suggested that network temporality can be exploited to substantially reduce the energy required to control complex networks. This somewhat counterintuitive finding was explained through an evocative example of the advantage of temporal networks: when navigating a sailboat, we raise the sails when the wind helps us while lowering them when it works against us. Unfortunately, controlling complex networks inherits a further analogy with navigating a sailboat: having to face the inherent uncertainty of future winds. We rarely, if ever, have deterministic knowledge of the evolution of the network we want to control. Here, our challenge is to exploit the potential advantages of temporality when only a probabilistic description of the future is available. We prove that, in this more realistic setting, exploiting temporality is no more a panacea for network control, but rather an asset of a wider toolbox made available by the scientific community. One that can indeed turn out useful, provided that the temporality of the network structure matches the intrinsic time scales of the nodes we want to control.
  Collaboration: Pietro De Lellis*, Francesco Lo Iudice* and Franco Garofalo*.
  *Università di Napoli, Federico II

- **Title:** Controlling networks with symmetries.
  Description: We study if and how it is possible to exploit the peculiarities of linear dynamical networks endowed with symmetries. Such symmetries in the network topology induce a partition of the nodes' set into clusters (subsets of nodes such that their union is

the node set and their intersection is the empty set). An issue related to such networks is the fact that they prevent from their control as the network pair (A, B) is proved to be not controllable. However, an invariant group consensus subspace can be defined, in which all the nodes belonging to the same cluster evolve towards the same trajectory. By exploiting a special change of variable, we obtained a controllability transformation allowing us to separate the network dynamics parallel and transversal to the group consensus manifold. Then, as they are completely uncorrelated, we offer a possibility to control the group consensus that instead encompasses the controllability subspace.
Collaboration: Francesco Lo Iudice*, Fabio Della Rossa*[+] and Francesco[#] Sorrentino.
***** Università di Napoli, Federico II, [+]Politecnico di Milano, [#]University of New Mexico.

- **Title:** Partial containment control over signed graphs
  Description: A traditional assumption made by the control networks theory is that the nodes of the network have a cooperative behavior, that is, they aim to collaborate to achieve the same goal. However, it is not rare that in a network could exist antagonistic relations among the nodes. In this case, the modeling tool of the signed graphs (graphs whose edges can be associated to negative weights, too) turns to be especially useful. Indeed, it has been shown that such graphs are able to induce the emergence of a sort of bi-consensus if we control the network through a consensus protocol. We focus on the case in which it is not possible to contain the entire network due to a constrained number of control signals. Then, we study the problem of selecting the nodes where control inputs must be injected to maximize the number of contained nodes. We do it by leveraging graph condensations, that is, we find a suboptimal solution to this problem by solving an integer linear problem.
  Collaboration: Pietro De Lellis*, Franco Garofalo* and Francesco Lo Iudice*.
  ***** Università di Napoli, Federico II.

- **Title:** Direct reciprocity and model-predictive rationality explain networks reciprocity.
  Description: Network reciprocity is the simplest mechanism supporting the evolution of cooperation when the interactions are localized, rather than all-to-all. Indeed, local interactions favors, local interactions favor cooperation when unconditional cooperators play a prisoner's dilemma against unconditional defectors under an imitation process. However, imitation lacks rationality in heterogeneous communities and did not clearly emerge in experiments. What did emerge is a form of conditional cooperation based on direct reciprocity. Nonetheless, the beneficial effect of local interactions seems to be confirmed, whereas what drives strategy update remains unclear. To resolve the controversy, we exploit a model that show the emergence of network reciprocity when conditional players update their strategies by maximizing a model-based prediction of future incomes.
  Collaboration: Fabio Della Rossa*[+] and Fabio Dercole[+].
  ***** Università di Napoli, Federico II, [+]Politecnico di Milano.

if and how it is possible to exploit the peculiarities of linear dynamical networks endowed with symmetries. Such symmetries in the network topology induce a partition of the nodes' set into clusters (subsets of nodes such that their union is the node set and their intersection is the empty set). An issue related to such networks is the fact that they prevent from their control as the network pair (A, B) is proved to be not controllable. However, an invariant group consensus subspace can be defined, in which all the nodes belonging to the same cluster evolve towards the same trajectory. By exploiting a special change of variable, we obtained a controllability transformation allowing us to separate the network dynamics parallel and transversal to the group consensus manifold. Then, as they are completely uncorrelated, we offer a possibility to control the group consensus that instead encompasses the controllability subspace.

Collaboration: Francesco Lo Iudice*, Fabio Della Rossa*[+] and Francesco[#] Sorrentino.

***** Università di Napoli, Federico II, [+]Politecnico di Milano, [#]University of New Mexico.

4. Products

- Journal Papers:
  i. F. Della Rossa, D. Salzano, A. Di Meglio, F. De Lellis, M. Coraggio, C. Calabrese A. Guarino, R. Cadorna Rivera, P. DeLellis, D. Liuzza, F. Lo Iudice, G. Russo and M. di Bernardo "Intermittent yet coordinated regional strategies can alleviate the COVID-19 epidemic: a network model of the Italian case", in Nature Communications (2020).
  ii. P. DeLellis, A. Di Meglio, F. Garofalo and F. Lo Iudice "The inherent uncertainty of temporal networks: a true challenge for control", under review for publication in Scientific Reports.
  iii. A. Di Meglio, F. Lo Iudice, F. Della Rossa and F. Sorrentino "Controlling networks with symmetries", submitted to IEEE Control Systems Letters.
  iv. A. Di Meglio, P. DeLellis and M. di Bernardo "Decentralized gain adaptation for optimal pinning controllability of complex networks" IEEE Control Systems Letters, 4,1 (2019), pp. 253-258.
  v. F. Dercole, F. Della Rossa and A. Di Meglio "Direct reciprocity and model-predictive strategy update explain the network reciprocity observed in socio-economic networks", Games, 11, 1 (2020), 1-16
- Conference Papers:
  i. P. DeLellis, A. Di Meglio, F. Garofalo and F. Lo Iudice "Partial Containment Control over signed graphs", In 2019,18th European Control Conference (ECC), pp.596-601, IEEE.
  ii. A. Di Meglio, F. Dercole and F. Della Rossa "Direct reciprocity and model predictive rationality: a setup for network reciprocity over social ties", In 2019, 18th European Control Conference (ECC), pp.1531-1536, IEEE.

5. Conferences and Seminars

- Attended at IEEE-CSS Italy Workshop on Modelling and Control of the COVID-19 Outbreak, co-author of the presentation "Network model of the COVID-19 epidemic in Italy to design and investigate possible containment and mitigation strategy"
- Presenter at: 58th Conference of Decision and Control – December 2019, Nice, France. Delivery of the talk "Decentralized gain adaptation for optimal pinning controllability of complex networks".
- Presenter at: SIDRA Conference "Automatica 2019". Delivery of the talk "Partial containment control over signed graphs", September 2019, Ancona, Italy.
- Attended and co-organizer of 14th SICC Workshop "Modelling, Analysis and Control of Complex Networks and Cyber-physical systems", June 2019.
- Presenter at: 18th European Control Conference - June 2019, Napoli, Italy. Delivery of the talks "Partial Containment control over signed graphs" and "Direct reciprocity and model predictive rationality: a setup for network reciprocity over social ties" (invited session).

6. Activity abroad

- Researcher visiting at University of New Mexico, Department of Mechanical Engineering – New Mexico, Albuquerque, USA- from January 2018 to March 2019 under the supervision of Professor Francesco Sorrentino.
- 58th Conference of Decision and Control – 10-14 December 2019, Nice, France.

7. Tutorship

- Teaching assistance:
    - 10 hours in the course of Identificazione e Stima dei Modelli, Ingegneria Gestionale (magistrale).
    - 2 hours in the course of Identificazione e Controllo Ottimo, Ingegneria dell'Automazione (magistrale).
    - 14 hours in the course of System Process and Control, Ingegneria Gestionale (magistrale).
- Tutorship:
    - 2 office hours per week for the course of Identificazione e stima dei modelli (Ingegneria Gestionale, magistrale), Identificazione e controllo ottimo (Ingegneria dell'Automazione, magistrale) and System Process and Control (Ingegneria Gestionale, magistrale).