

Title of the research project:

Emergent collective dynamics in economic and social networks

Keywords (up to five)

Complex networks, Synchronization, Symmetries and Group theory, Hypergraphs and Simplicial Complexes

Supervisors (at least two from two different areas):

Supervisor 1 (name, contact details, homepage, area of expertise)

Prof. Dr. Stefano Boccaletti, CNR, Institute for Complex Systems, Florence, Italy

Mail: stefano.boccaletti@gmail.com Area of expertise: Statistical and nonlinear physics

Supervisor 2 (name, contact details, homepage, area of expertise)

to be decided

Project description (max 5000 characters)

The main scope of the project is that of investigating the fundamental mechanisms underneath the emergence of collective dynamics in networked units, with applications in econophysics and social science.

In particular, the project aims at studying synchronization in economy by considering economic agents as coupled oscillators, with money and goods assumed to be analogous to kinetic and potential energy, respectively. The plan is to model the emergence of money and wealth as a consequence of debt and credit connections between economic agents on networks. The latter will imply the decomposition of weighted signed graphs into debt and credit networks, with a multilayer network approach.

Furthermore, we plan to investigate opinion dynamics on multi-layer networks as a framework for the emergence of collective intelligence in society, developing machine learning inspired models where synchronization of opinions is analogous to optimizing opinions just as weights in neural networks. We plan to extend Ising like models to multilayer networks, to study opinion dynamics, as well as we plan to study power dynamics in society, where power has 4 components (physical, mental, resource and relation) that are exchanged by agents in a network to shape the hierarchical structure of the society.

Finally, we plan to use group theory, scale invariance, universality and renormalization groups to generalize and better characterize the behavior of different networks for what concerns common symmetries, cluster synchronization, and structured collective dynamics

Relevance to the MERC PhD Program (max 2000 characters)

The project is openly multidisciplinary, as it involves bridging methods and tools from statistical physics, Monte Carlo simulations, random walks processes, stochastic differential equations and Markov chains, probabilistic graphical models and energy minimization algorithms, dynamical systems and information theory with those of applied mathematics and group theory.

The novel methods and tools that will be developed will therefore be of great value and large use in a variety of fields and circumstances, far beyond the practical case to which they will be applied in the present project.

Potential applications and beneficiaries are therefore numerous, and it is easy to forecast that the results obtained will be of essential value in a wealth of circumstances along the following years. The project has clear implications in the areas of “network theory” and “mathematical modelling and simulation of complex systems”, thereby squarely fitting within the MERC program.

Key references

- 1) [Complex networks: Structure and dynamics](#), S Boccaletti, V Latora, Y Moreno, M Chavez, DU Hwang, Physics reports 424 (4-5), 175-308 (2006);
- 2) [The structure and dynamics of multilayer networks](#), S Boccaletti, G Bianconi, R Criado, CI Del Genio, J Gómez-Gardenes, ..., Physics reports 544 (1), 1-122 (2014);
- 3) [Statistical physics of human cooperation](#), M Perc, JJ Jordan, DG Rand, Z Wang, S Boccaletti, A Szolnoki, Physics Reports 687, 1-51 (2017) ;
- 4) [Social physics](#), M Jusup, P Holme, K Kanazawa, M Takayasu, I Romić, Z Wang, S Geček, ..., Physics Reports 948, 1-148 (2022);
- 5) [The structure and dynamics of networks with higher order interactions](#), S Boccaletti, P De Lellis, CI Del Genio, K Alfaro-Bittner, R Criado, S Jalan, ..., Physics Reports 1018, 1-64 (2023).

Joint supervision arrangements

The supervisor is working at the CNR, Institute of Complex Systems, in Florence.

He is a member of the Board of MERC, a member of the Academia Europaea, and a Fellow of the American Physical Society.

A second supervisor will be soon individuated within the group of scientists working at the newly established International Center for Complexity in Hangzhou (China), where the candidate will pass most of his period abroad.

During the period of stay in Italy, weekly meetings will be organized with the supervisor, and at least two visits of the supervisor to Naples will be made to ensure the best as possible supervision of the candidate. Regular online meetings (at least on a monthly basis) will be organized involving the PhD student, the two supervisors during the entire duration of the project.

Location and length of the study period abroad (min 12 months)

The project foresees a total of 12 months where the candidate will collaborate with the group of network scientists at the International Complexity Center of the Beihang University in Hangzhou (China), who is led by the Supervisor.

A co-supervisor of the thesis will be chosen among the main scientists forming that group.

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