frontiers | Frontiers in Physics

TYPE Editorial
PUBLISHED 19 July 2022
DOI 10.3389/fphy.2022.972037

OPEN ACCESS

EDITED AND REVIEWED BY
Matjaz Perc,
University of Maribor, Slovenia

*CORRESPONDENCE
Gaogao Dong,
gago999@126.com
Dongli Duan,
mineduan@163.com
Yongxiang Xia,
xiayx@hdu.edu.cn

SPECIALTY SECTION
This article was submitted to Social Physics, a section of the journal Frontiers in Physics

RECEIVED 17 June 2022
ACCEPTED 27 June 2022
PUBLISHED 19 July 2022

CITATION
Dong G, Duan D and Xia Y (2022), Editorial: Network resilience and robustness: Theory and applications. *Front. Phys.* 10:972037.
doi: 10.3389/fphy.2022.972037

Editorial: Network resilience and robustness: Theory and applications

Gaogao Dong[1]*, Dongli Duan[2]* and Yongxiang Xia[3]*

[1]School of Mathematical Science, Jiangsu University, Zhenjiang, China, [2]School of Information and Control Engineering, University of Architecture and Technology, Xi'an, China, [3]School of Communication Engineering, Hangzhou Dianzi University, Hangzhou, China

KEYWORDS

network resilience, network robustness, network science, network application, network theory

Editorial on the Research Topic
Editorial: Network resilience and robustness: Theory and applications

Network science opens up a new perspective for studying complex networks in social, technological, biological, climate systems, and so on [1]. The structural robustness and dynamic resilience of systems play a key role in risk reduction and damage mitigation [2, 3]. The dynamic resilience of a system is characterized by its ability to adjust its activities to maintain its essential functions in the face of internal disturbances or changes in the external environment. Network robustness refers to the ability of a network to maintain a certain level of structural integrity and original functionality after an attack, and it is the key to whether a compromised network can continue to function properly [4]. In real-world scenarios, networks do not exist in isolation but are coupled together in different ways, including dependent, multi-support, and inter-connected patterns. And, when a coupled network suffers from structural instability or dynamic perturbations, the system with different coupling patterns shows rich phase transition behaviors [5]. The dynamic resilience of a system is characterized by its ability to adjust its activities to maintain its essential functions in the face of internal disturbances or changes in the external environment.

The main areas covered in the collection are the analysis of structural robustness, dynamic elasticity and stability. In particular, the subject focuses on critical phenomena, phase transitions, network dynamics, percolation behavior in network systems, and network applications [6]. This Research Topic also investigates network-specific percolation models, applications of network structure analysis, and applications of network dynamics [7]. The twenty papers it contains do indeed do that. Hopefully, the research papers among them spawn new work and the reviews are useful for those that considers entering this field.

We describe the papers in the order in which they have been published.

The first paper (Guo et al.) according to percolation approach to network reliability is applied to brain networks to study the resistance of the network to interference and associated failure modes. Different forms of interference are applied to the brain network depending on the metrics characterizing the network structure for percolation. The results show that brain networks are mostly reliable to random or k-core-based percolation, but become vulnerable to degree-based percolation.

The second paper (Lin et al.) is based on the fact that alarm management is essential for high-quality performance of telecommunication systems. Building functional networks by observing pairwise similarities between time series is an effective way to filter and reduce alarm messages.

Paper three (Dongli et al.) reveals the functional importance and resilience patterns of nematode neurons, where the regulatory relationships between neurons and their topology are effectively coupled. By using theoretical approaches such as high-dimensional differential equations and mean fields, they can be used to reveal the influence of biological connectome.

Paper four (Fu et al.) compares four types of synthetic networks by Element Elimination Method (EEM), Resource Allocation method (RAM) and Structural Perturbation Method (SPM). The results show that EEM has higher reconstruction accuracy metrics on the four types of synthetic networks compared to RA and SPM.

Paper five (Huang et al.) studies the resilience enhancement of power systems with a high penetration of renewable energy sources in emergencies. An optimal decision-making approach is proposed to maximize the supply to critical loads and minimize the risk of instability due to the stochastic nature of renewable energy output power.

Paper six (Wu et al.) discusses the effect of intra-layer angular correlation on robustness in terms of embedding interdependent directed networks into hyperbolic spaces. They find that under targeted attacks, robustness decreases with increasing intra-layer angle correlation. Interdependent directed networks without intra-layer angular correlation are always more robust than networks with intra-layer angular correlation.

Paper seven (Du et al.) constructs an inter-provincial virtual water delivery network by combining a multi-regional input-output model and complex network theory, analyzes the overall structural characteristics of the network model, and identifies the structural role of each province. The results show that the "external degree" and "external strength" of the capacity of direct virtual water output have a significant positive impact on water consumption.

Paper eight (Zou et al.) proposes a grid division method considering generator nodes and network weights based on the cluster discovery method in complex network theory. The cascading failure survival capability of different types of networks under different strategies is simulated and analyzed. It is found that the proposed two attack strategies based on subnet division are better than two traditional intentional attack strategies.

Paper nine (Cai et al.) defines two robustness evaluation indicators based on maximum network traffic: traffic capacity robustness to evaluate the network's ability to withstand an attack, and traffic recovery robustness to evaluate the network's ability to rebuild the network after an attack and simulates four networks to analyze their robustness.

Paper ten (Dong et al.) presents coupled network models with different coupling modes developed from real scenarios in recent years to study the robustness of the system. For coupled networks with different coupling modes, the effect of coupling modes on network robustness is described based on network percolation theory.

Paper eleven (Wang et al.) emphasizes that financial crises are rooted in the lack of system resilience and robustness, which can cause severe economic and social losses. The different shapes of the network reveal higher-order correlation patterns in the financial system The proposed approach provides a new perspective for detecting key signals and can be extended to predict other crisis events in natural and social systems.

Paper twelve (Wang et al.) shows that most critical infrastructure networks are frequently subject to vicious attacks, which can lead to network failures. Game theory-based defense strategies are developed to enhance the robustness of networks. In the study, the purpose of protecting infrastructure networks is achieved by allocating limited resources to the targets for monitoring.

Paper thirteen (Song et al.) presents a new network robustness metric for epidemics that combines three characteristics: transmission speed, epidemic threshold, and steady-state infection density. In both homogeneous and heterogeneous networks, the network becomes more robust as the average degree grows.

Paper fourteen (Song et al.) demonstrates that homogeneous networks are more robust than heterogeneous networks at the beginning of the epidemic, while heterogeneous networks become more robust than homogeneous networks as the epidemic progresses. In addition, the irregularity of degree distribution reduces the network robustness of homogeneous networks. In both homogeneous and heterogeneous networks, the network becomes more robust as the average degree grows.

Paper fifteen (Zhan et al.) presents a framework for evaluating the resilience of UAV swarms, which takes into account the load balancing of UAV swarms subjected to disturbances, and demonstrates that topology also has a very important impact on the resilience of UAV swarms.

Paper sixteen (Cui et al.) discovers a framework for classifying normal and abnormal brain activity through a method for constructing multilayer aggregated functional networks, and also provides a general method for constructing more informative functional networks from multiple time series data.

Paper seventeen (Gross and Barth) notes some commonly overlooked complications in computing the size of giant components. Derive simple formulas to capture the impact of common attack scenarios on arbitrary (configuration model) networks.

Paper eighteen (Li et al.) presents an improved reputation evaluation method by combining the structure of a two-sided rater-subject network with rating information and introducing penalty and reward factors. The results show that the method has better performance than the original correlation-based approach in the presence of spam attacks.

Paper nineteen (Liu and Li) derives closed-form form formulas for the resistance distance and Kirchhoff exponent in terms of the resistance distance and Kirchhoff exponent, respectively, using simple connection diagrams and Laplacian spectra in the general case.

Paper twenty (Sun and Yang) creates a connected graph G with vertex set V(G) and finds that the resistance distance between vertices in S (S⊂V(G)) can be given by the elements in the inverse matrix of the auxiliary matrix of the Laplace matrix of G [S] and deduces the reduction principle obtained in by algebraic methods.

Author contributions

All authors have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

Funding

This research was supported by grants from National Natural Science Foundation of China (Grant Nos. 61973143, 71974080, and 71690242), the Young backbone teachers of Jiangsu Province.

Acknowledgments

We thank all authors contributions for this special issue.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. Gao J, Barzel B, Barabási A-L. Universal resilience patterns in complex networks. *Nature* (2016) 530(7590):307–12. doi:10.1038/nature16948

2. Dong G, Fan J, Shekhtman LM, Shai S, Du R, Tian L, et al. Resilience of networks with community structure behaves as if under an external field. *Proc Natl Acad Sci U.S.A* (2018) 115(27):6911–5. doi:10.1073/pnas.1801588115

3. Dong G, Wang F, Shekhtman LM, Danziger MM, Fan J, Du R. Optimal resilience of modular interacting networks. *Proc Natl Acad Sci U S A* (2021) 118(22): e1922831118. doi:10.1073/pnas.1922831118

4. Buldyrev SV, Parshani R, Paul G, Stanley HE, Havlin S. Catastrophic cascade of failures in interdependent networks. *Nature* (2010) 464(7291):1025–8. doi:10.1038/nature08932

5. Fan J, Dong G, Shekhtman LM, Zhou D, Meng J, Chen X, et al. Structural resilience of spatial networks with inter-links behaving as an external field. *New J Phys* (2018) 20(9):093003. doi:10.1088/1367-2630/aadceb

6. Ganin AA, Kitsak M, Marchese D, Keisler JM, Seager T, Linkov I. Resilience and efficiency in transportation networks. *Sci Adv* (2017) 3(12):e1701079. doi:10.1126/sciadv.1701079

7. Barzel B, Barabási A-L. Universality in network dynamics. *Nat Phys* (2013) 9(10):673–81. doi:10.1038/nphys2741