Articulation points in multiplex networks

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Many of the natural and artificial systems are represented efficiently by a notion of graphs, or networks. Thus, studying network science is very important for understanding the underlying principles of behavior of complex systems. Particularly, it is important to study the articulation points distribution in graphs. An articulation point in a network is a node whose removal disconnects the network. Being able to find articulation points and understanding the patterns of their behavior can help both prevent crucial systems from destruction (for example, designing more resilient infrastructure networks) or find weaknesses in such systems [1].

There has been some research on articulation points behavior in monoplex networks. However, some phenomena are more naturally described by multiplex networks. A multiplex network is a collection of monoplex networks, or layers, where all the nodes exist simultaneously in all the layers but the links within each layer can differ [2]. An example of such system is a network of Facebook as one layer and a network of Twitter as the other. Nodes represent people participating in these networks, and links represent connections between them in each of the networks.

Many effects found in multiplex networks are not observed in monoplex networks. This also concerns articulation points distribution. For example, removal of one such point from a usual network simply disconnects it leaving two independent clusters. However, removal of an articulation point from a multiplex network can produce an iterative cascade of failures in several interdependent networks. Example of this was observed in 2003 in Italy when the shutdown of power stations directly led to the failure of nodes in the Internet communication network, which in turn caused further breakdown of power stations resulting in electrical blackout [3].

This area is relatively young and there is a necessity and a possibility for research of articulation points’ behavior in multiplex networks.

The work currently consists of reproducing results from other papers in order to better understand the terminology, approaches and best practices in the field. The workflow can be described as obtaining analytical expressions for articulation points distribution and other parameters in different scenarios and verifying them experimentally via numerical simulations. Conducting analytical calculations and writing Python code for simulations are the main techniques.

Plan

1. Literature search and review

Mar 2022-Sept 2022

2. Reproducing the results for articulation point properties in monoplex networks

Oct 2022-Nov 2022

3. Study of articulation points in multiplex networks

Dec 2022 – Jan 2022

4. Application of the model to the data from real networks

Feb 2022-Mar 2022

5. Writing up the thesis and the manuscript draft

Apr 2022 – May 2022

Literature

1. Tian, L. et al. Articulation points in complex networks. Nat. Commun. 8, 14223 doi: 10.1038/ncomms14223 (2017)
2. Saeed Osat. Percolation on complex networks and its applications
3. Buldyrev, S., Parshani, R., Paul, G. et al. Catastrophic cascade of failures in interdependent networks. Nature 464, 1025–1028 (2010). <https://doi.org/10.1038/nature08932>
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6. Wandelt, S., Sun, X., Feng, D. et al. A comparative analysis of approaches to network-dismantling. Sci Rep 8, 13513 (2018). <https://doi.org/10.1038/s41598-018-31902-8>