Complex networks analysis of time-series data: finding patterns in socio-economic systems

Marija Mitrović Dankulov, Roderick Melnik, Bosiljka Tadić
Institute Of Physics Belgrade, Belgrade, Serbia

The development of information-communication technologies enabled access to large-scale data about the structure and dynamics of different socio-economic systems. The data on system elements and interactions between them are not always explicitly available but are hidden in dynamical system outputs represented by time series. The time series contain information about the dynamics of each element and its coupling with the rest of the system. Mapping time series to graphs and topological analysis of these graphs are non-trivial problems. We demonstrate our approach by analyzing the time-series data from two social systems, SARS-CoV-2 epidemics infections and death rates [1] and Meta Data for good mobility data, and USA financial sector companies [2] to uncover how different forms of crisis in these systems change their structure. We combine approaches from complex network theory, computer science, and statistical physics to study the evolutions of these systems and uncover patterns and predominant drivers of the dynamics of each system. We use correlation-network mapping to map the data onto graphs and study the spectral properties of these graphs. Eigenvector localization reveals the mesoscopic organization of these graphs and the change in the structure due to systems evolution through the crisis. K-means clustering combined with multifractal time series analysis reveals a finer mesoscopic structure of these systems.

Our analysis of two phases of SARS-CoV-2 epidemics, the outbreak and immunization phase, show the existence of robust communities of different countries and regions that further break into clusters according to similar profiles of infection fluctuations. The structure of communities and clusters in the outbreak and immunization phase differ drastically, indicating a change in epidemic dynamics due to the start of immunization. Multifractal analysis of time series reveals that persistent fluctuations around the local trend occur in intervals smaller than 14 days. Analysis of the network of relations between USA companies operating in the financial sector further confirms that the system changes during crisis periods. We find that connectivity between communities is strongly influenced by the crisis and economic measures taken by the country. Furthermore, the occurrence of crisis is also seen in the patterns of eigenvector localization. Application of described methodology on mobility data in different countries during the SARS-CoV-2 epidemic shows that a combination of epidemic measures, culture, and the infectious curve influences both mobility patterns.

References

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