Dynamic Motifs in Socio-Economic Networks

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Abstract

Socio-economic networks are of central importance in economic life. We develop a method of identifying and studying motifs in socio-economic networks by focusing on "dynamic motifs," i.e., evolutionary connection patterns that, because of "node acquaintances" in the net- work, occur much more frequently than random patterns. We examine two evolving bi-partite networks: (i) the world-wide commercial ship chartering market and (ii) the ship build-to-order market. We find similar dynamic motifs in the data from both bipartite networks during this period, even though they describe different economic activities. We also find that influence and persistence are strong factors in the interaction behavior of organizations. Influence occurs when two or more companies share the same customers. Probably due to information sharing, one company's customers tend to become other companies' customer as well. Persistence occurs when companies with close business ties to customers tend to maintain those relationships over a long period of time.

Keyword: Complex network, Social network, Organization behavior

1. Introduction

Many complex physical, biological, and social systems can be modeled and better understood as complex networks. Socio-economic research is a multidisciplinary research area in which relationships between economic activities and their social environment are used to constitute socio-economic networks. Understanding patterns of economic organization interactions is essential if we are to uncover the mechanism and the structure of the socio-economic environment. To understand the economic activity of an organization, one should investigate not only the firm itself but also the structure of its interactions in the socio-economic network. Network motif analysis is a sub-graph mining method proposed by Milo et al. Motifs are small (usually from three to seven nodes in size) connected sub-graphs within a given structure that appear in the network more frequently than they would if the network links were completely random. Because most complex phenomena, including economic behavior, are time-varying, researchers are beginning to consider dynamic networks that evolve over time. Both network topology and its time evolution must be considered if we are to understand the dynamics of a complex network. Our approach to this problem is to develop a method that allows us to analyze statistically the evolution of socio-economic motifs. We define dynamic network motifs as statistically significant sub-graph patterns that evolve in a network. By tracking the occurrence of dynamic motifs in a network that models organizational socio-economic interactions, we can observe the evolution of local configurations. Using this model we can then evaluate how a socio-economic network influences a company's decisions, such as those associated with choosing a design, ending a transaction with a supplier, or initiating a transaction with a supplier.

2.Model

Since business relationships are naturally changeable, and the usual static

analysis of motifs is unable to capture the dynamic characteristics of organizational interactions, we develop and analyze dynamic network motifs to understand the dynamic evolution process of a network. We define network motifs to be statistically significant recurring local structural patterns in networks. We use the following definition to abstract two deterministic elements: (i) The local structure is represented by a sub-graph with n nodes and edges. Variety of node sizes and connection patterns often produces a series of sub-graphs that are not isomorphic. These we regard as network motif "group candidates." (ii) To evaluate the significance of a recurring motif candidate we compare it to its counterpart in a random network. This is the hull model. We carry out a statistic hypothesis test to determine whether the mo- tif candidate occurs more frequently than it would in a completely random network.

In a way similar to static motif analysis, we generate random networks R according to the real network N to compute the statistical significance of an evolutionary motif. Figure 2 shows the specific process of the randomization algorithm.

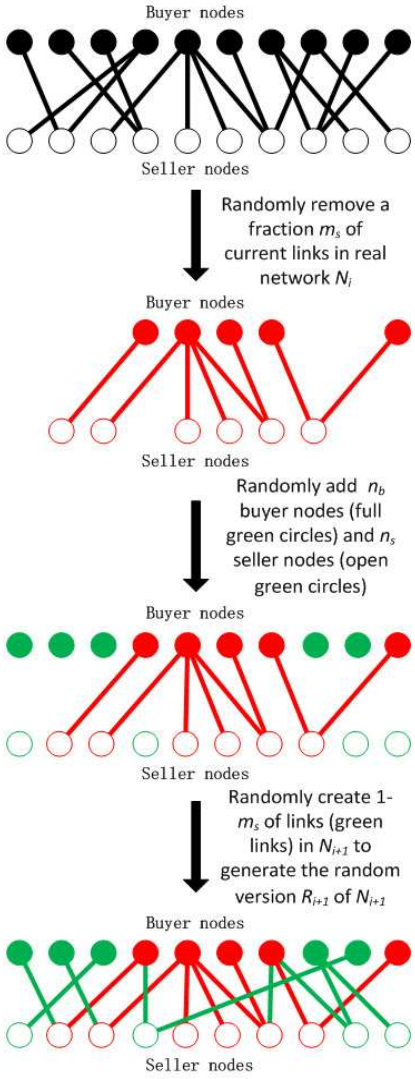

Fig. 2: Randomization algorithm to create random network

3. Conclusion

We have empirically characterized dynamic organization interactions in socio-economic environment. Network motifs that have been widely used in modeling social networks have difficulties in capturing the dynamic characteristics of economic behavior. We proposed a dynamic motif model that incorporates features of social influence of organizations' economic behavior. Detecting dynamic motifs from firms' buyer-seller transaction data, we found two motifs which present organizational interaction patterns in different business networks. This suggests that we can extract important social effects of organizational interaction in socio-economic behavior. These findings provide a valuable insight into the relationship between the economic function and social network structure.

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