

An Exploratory Study on the Measure of Organizational Interactive Network's Heterogeneity

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Abstract. Based on the organizational context, the organization personnel and the interactive relations generated from business process are abstracted to the organizational interactive network. On this basis, the concept of network structure entropy is proposed to quantitatively depict the heterogeneity of organizational interactive network. Taking a certain organization as an example, the change of heterogeneity of the organization with time is analyzed. The study in this paper is an exploratory study on the application of network science to organizational management.

Introduction

Many things in the real world can be depicted as networks. With the development of network science, complex systems in numerous fields have been quantitatively described and analyzed [1-4]. Some scholars attempted to introduce the complex network theory into organization research [5-8]. The description of organization from the perspective of network is in essence abstracting "organization" to "organizational interactive network". The node represents the component of organization (e.g., personnel, roles, departments, etc.), the edge represents the interactive relation between the components (e.g., task allocation, cooperation, information transmission, etc.). Like most real-world systems, organizational interactive networks are usually uneven, that is, heterogeneity. The heterogeneity of network affects information transmission [9], viral transmission [10] and invulnerability [11] of the network. While in an organization, some people are busy, some people are idle, and the manpower resources owned by and the workload born by the employees may be uneven, resulting in that some businesses are often stuck in individual process, affecting the work efficiency of the organization. Therefore, the heterogeneity of organizational interactive network is an attractive property to measure.

As a measure of system disorder, entropy is widely used in many fields such as physics, information theory, cybernetics and life science with its unique connotation and concise expression [12]. Entropy can also reflect the heterogeneity of a system. The more homogeneous the energy distribution, the more stable the state of the system and the greater the entropy value. The form for the definition of network structure entropy is the research focus of scholars, such as entropy of degree distribution [13], entropy of redundancy distribution [12], "Wu" network structure entropy [14,15], "Cai" network structure entropy [16], network structure entropy based on maximum flow [17], etc. These network structure entropies in different definition forms reflect the complexity and disorder of network state from different angles. Entropy can be applied to an organizational network to describe the organization's macro heterogeneity. In this paper, based on the characteristics of organization network, the interaction difference of node is defined, a new method for measuring the organizational network structure entropy is proposed.

Organizational Interactive Network

The busy degree of personnel in an organization is related to the organizational nature, the organization's work arrangement, and the personnel's service ability and work efficiency. In some organizations, a person's main business needs to be completed by interacting with other people, for example, production personnel in the production workshop complete the working procedures

according to the assembly line, and the government administrative office staff handle the government affairs based on the administrative flow. The interactive relation can be a kind of order relation, or a kind of cooperative relation. The above interactive relation accompanied by the implementation of work business is the key to the work progress. The existence of interactive relations means the existence of work flow or work cooperation, which on the one hand can bring together the divisions of labor for cooperation, and on the other hand increases the cost. In such organizations, the personnel are regarded as nodes, the interactive relations between personnel generated from business process are regarded as edges, the organizational interactive network can be built, and the heterogeneity of the organization can be analyzed based on the network model. Nodes can be attached with node attributes according to the organizational context, such as post and department, and edges can be attached with edge attributes according to the business situation, such as business name and execution time. As an explore research, this paper takes un-directed and un-weighted organizational interactive network into consideration. If two personnel have interaction due to work, the corresponding nodes would be linked by an edge.

Heterogeneity Metrics

According to the organizational context and the business operating state, the organizational interactive network is built. In the constructed organizational network, the difference in business interaction between nodes is not only related to the number of nodes involved in the interactive relations, but also related to the scale difference between the groups to which different business interactive situations belong. After mapped to the network, the difference in business interaction between nodes is manifested in the difference between node degree values and that in the scale between corresponding node groups. The difference between nodes is transited to that of the whole network by entropy.

The interaction difference of Node i is defined as

$$I_i = \frac{k_i}{k_{\max}} [1 - p(k_i)] \quad (1)$$

where k_i is the degree of Node i , k_{\max} is the largest degree in the organizational interactive network, $p(k_i)$ is the proportion of nodes with degree of k_i in the network.

The relative interaction difference of Node i is defined as

$$I'_i = \frac{I_i}{\sum_{j=1}^N I_j} = \frac{\frac{k_i}{k_{\max}} [1 - p(k_i)]}{\sum_{j=1}^N \frac{k_j}{k_{\max}} [1 - p(k_j)]} \quad (2)$$

where N is the number of nodes.

The network structure entropy based on the interaction difference is defined as

$$E = - \sum_{i=1}^N I'_i \ln I'_i \quad (3)$$

In order to compare the structure entropies under different network sizes, the relative network structure entropy is defined as

$$S = \frac{E}{E_{\max}} \quad (4)$$

where E_{\max} is the maximum value of the network structure entropy based on the difference in business interaction when the network size is kept the same. The larger the relative organization network structure entropy S is, the more disorder the organization network is, and the more homogeneous the network is. For the maximum value of the organizational interactive network

structure entropy, the objective function is set to be $E = -\sum_{i=1}^N I'_i \ln I'_i$, and the limiting condition is $\sum_{i=1}^N I'_i = 1$. The Lagrange multiplier method is used to obtain the extreme value, and it is gotten that the maximum value is $E_{\max} = \ln N$ when $I'_1 = I'_2 = \dots = I'_N = 1/N$.

Case Study

We take an actual organization with functions of education and management as a example, whosedaily work is carried out by semesters. To constructing a organizational network, the data of its personnel and interactive relations generated from business processwas collected in the period of March 2013 to August 2016, spaning 7 semesters. In this paper,the personnel in the organization are abstracted as nodes, and two personnel are linked by an edge if they had business transmission and execution relations. Therefore, we can plot undirected and unweighted organizational interactive networks for semester 1-7. The basic information of the data is shown in Table 1.

Table 1. Basic information of case organizational interactive network.

Semester	Time of Log	Log Record Count	Node Number	Edge Number	Network Density
Semester 1	2013.3.1-2013.8.31	3380	224	1136	0.053
Semester 2	2013.9.1-2014.2.28	3976	246	1519	0.050
Semester 3	2014.3.1-2014.8.31	5174	331	1885	0.035
Semester 4	2014.9.1-2015.2.28	5999	349	2093	0.034
Semester 5	2015.3.1-2015.8.31	6126	355	2072	0.033
Semester 6	2015.9.1-2016.2.29	5678	388	2052	0.027
Semester 7	2016.3.1-2016.8.31	5599	369	2023	0.030

In the meanwhile, a stochastic network as the same scale (with same number of nodes and edges) as actual organizational interactive network of each semester was constructed for comparison. Then, the structure entropy in both of stochastic networks and actual organizational interactive networks are calculated. The results are showed in Figure 1, in which the structure entropy of stochastic network is the mean value obtained by 20 experiments.

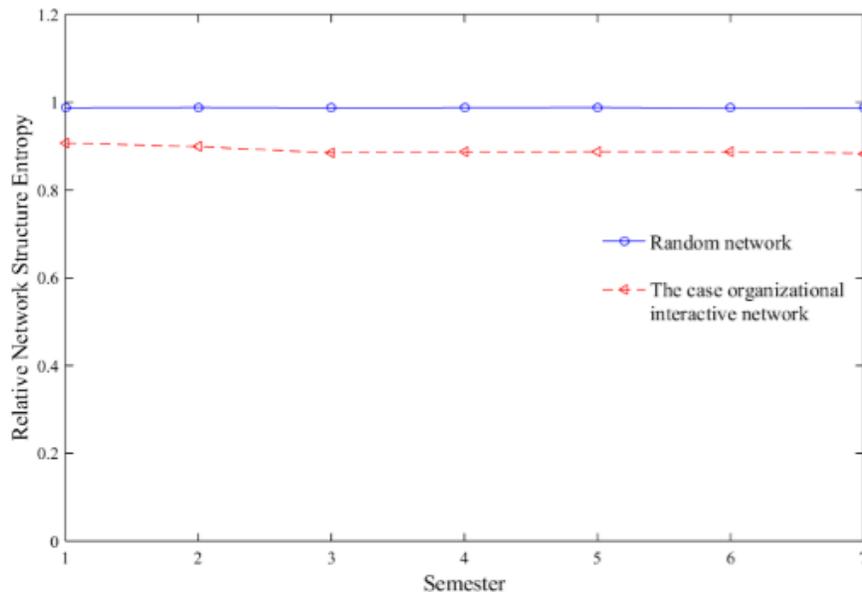


Figure 1. Relative network structure entropy of case organizational interactive network.

According to the calculation results, the relative network structure entropy fluctuates in a small range of [0.88, 0.91] in 7 semesters, indicating that the heterogeneity of the organization network is basically stable. The structure entropy of the actual organizational network is smaller than that of stochastic networks of the same size. We found that this actual official organization is in a mature state, with less personnel changes and seasonal daily affairs, which may be the cause of the stability of the network heterogeneity.

Summary

This paper explores the application of complex network theory and method in organization and management. The unweighted and undirected organizational network was constructed combining the background as well as business situation. To measure the heterogeneity of organization network, the network structure entropy was proposed, whose usability is verified by an example of actual organizational network. Furthermore, the heterogeneity of directed networks or weighted networks is remained to be discussed.

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