Morphology and Entropy in Networks

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INTRODUCTION

This article concerns the relation between the *morphology* (concentration and connectivity) and the *entropy* of networked structures. We will introduce the network morphology concept, we will address two approaches to network characterization--traditional network measures and the concept of entropy--and we will link the entropy concept to the network characteristics. It will be shown that entropy will grow steeply if a certain balance between connectivity and concentration is disturbed.

It is known from theory that the morphology of a business network, be within an organization or between organizations, greatly affects the behavior of agents in the network (Ahuja, 2000; Burt, 1992; Coleman, 1988; Gulati, 1999; Powell, Koput, & Smith-Doerr, 1996; Walker, Kogut & Shan 1997). Also it is known that the morphology of networks is an important determinant of the extent of innovation diffusion (Abrahamson & Rosenkopf, 1997; Den Hartigh, 2005). It is therefore important to explore further some basic notions of network morphology.

BACKGROUND

Every network has a *morphology*. Morphology is defined as the form and structure of a network. The morphology of a network can be described by two separate elements: *connectivity* and *concentration*.

The connectivity of a network can be defined as the relationship between the number of nodes and the number of connections between the nodes. The higher the number of connections with respect to the number of nodes, the higher the connectivity.

Concentration defines the number of connections between a certain node and the others. The higher the number of connections from one node to all the others, the higher the concentration. The measurement of concentration has a relationship with the kurtosis of the distribution of connections among the various nodes.

MAIN FOCUS OF THE ARTICLE

Relation between Connectivity and Concentration

We have defined a network as a structure consisting of nodes and links. Concentration and connectivity provide information over the network; they have a certain relationship, as shown in Figure 1. Networks with a high connectivity and a high concentration cannot exist. This would imply that every node is connected to every other node, but still nodes exist that have more connections than others. The same reasoning can be done for medium concentration/high connectivity and medium connectivity/high concentration networks. They also cannot exist. Obviously, the border areas between high, medium, and low are somewhat fuzzy.

Let us relate these abstract network measures to economic networks, such as business organizations. The morphology concept can be applied to social systems by analyzing the links between social entities. Different configurations yield different levels of order/disorder. In this way, order in social systems can be seen as an expression of the existence of meaningful and purposeful relationships between functional elements of such a system. Without such relationships, the whole of the system can have no meaning or purpose. In such cases, the whole is identical to the sum of parts and no synergy or common purpose can exist. The principles of order through fluctuations were first formulated in thermodynamics. The central idea is that self-organiz-

Figure 1. Relation between connectivity and concentration

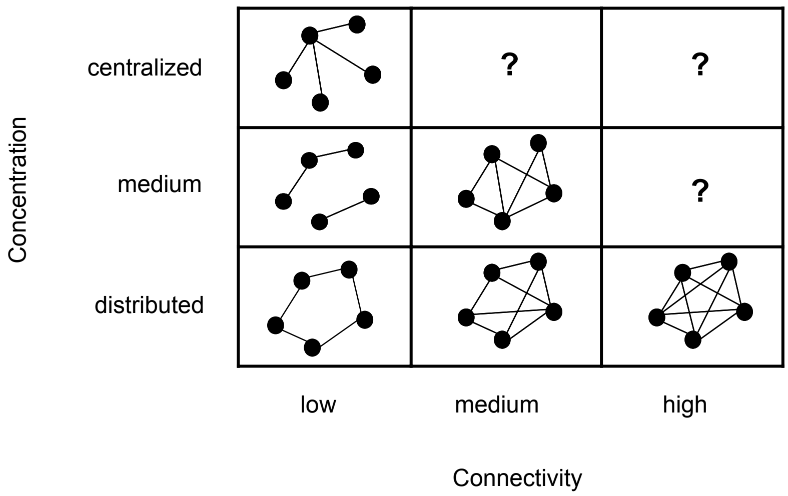
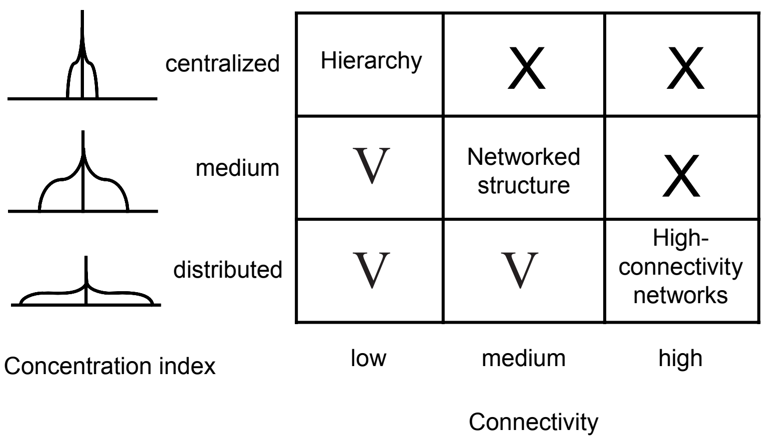


Figure 2. Connectivity and concentration in economic networks



ing systems do not solely thrive on order, they need a certain amount of chaos (Nicolis & Prigogine, 1989). If the system fixes itself in a certain configuration, it will no longer be adaptive. It follows that a certain amount of disorder should be present for the system to remain adaptive (Ashby, 1958). In other words, the system should have a certain level of entropy somewhere between order and chaos. In an optimally adaptive system, order and variety (chaos) are in an optimal balance (Nicolis et al., 1989). Neither can be reduced without reducing the system's adaptability.

It is a popular belief that networked structures exist because of the ability or even necessity for all agents to relate to all other agents. Yet it can be shown that a high connectivity factor of a system (the average number of links any agent in the network has) combined with a low concentration factor (there are no concentration points) leads to a very rich "solution space" and increasing inability to find a suitable solution (Van Asseldonk, 1998). In other words, if the number of degrees of freedom in relation to new solutions is larger than the complexity of the problem itself, the payback will rapidly decay as opposite to the conventional hierarchical situation. This, in turn, is an example of under-complexity, in which the solution space of the organization is too small for the complexity of the outside world. Here, there is a low connectivity factor, combined with a high concentration factor.

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