Chapter 14
Universal Dynamics on Complex Networks, Really?
A Comparison of Two Real-World Networks that Cross Structural Paths … but Ever so Differently.

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ABSTRACT

The complex network approach developed in statistical physics seems particularly well-suited to analyzing large networks. Progress in the study of complex networks has been made by looking for shared properties and seemingly universal dynamics, thus ignoring the details of networks individual nodes, links, or sub-components. Researchers now need to assess the differences in the processes that take place on complex networks. The author first discusses briefly the theoretical understanding of evolutionary laws governing the emergence of these universal properties (small-world and scale-free networks) and recent evolutions in the field of network analysis. Using data on two empirical networks, a transaction network in the venture capital industry and an interfirm alliance network in a major sector of the bio-pharmaceutical industry, the author then demonstrates that networks can switch from one 'universal' structure to another, but each in its own way. This chapter highlights the need of knowing more about networks, as 'more is different'.

INTRODUCTION

Studying relationships among actors, be it individuals or organizations, is essential to the social sciences. Social network analysis, or SNA, has been defined by Breiger (2004; p. 505) as the "disciplined inquiry into the patterning of relations among social actors, as well as the patterning of relationships among actors at different levels of analysis (such as persons or groups)."

Complexity theory has become instrumental in recent models in social sciences. As part of complexity theory, the 'complex network' approach developed in statistical physics seems to

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be particularly appropriate for the analysis of the macro environments, whether technical, social, or natural, into which entities are embedded (Frenken, 2006; Pyka, 2009).

The past decade has indeed witnessed the birth of a new movement of research in the study of complex networks, with the main focus switching from the analysis of small networks to that of networks whose structure is large, irregular, and evolves dynamically in time (Newman, 2003; Boccaletti et al., 2006; Albert and Barabási, 2002). What is also new in network-based research is the availability and exponential growth of computing power that allows handling and managing unprecedented volumes of empirical data.

The literature on complex networks reveals a rapid growth of articles, starting after 2000, which corresponds to the emergence of this new paradigm (Pyka, 2009). Though the notion on networks in general is a shared subject among different disciplines (graph theory in discrete mathematics, philosophy, sociology, anthropology, and more recently economics and strategy (Ahuja et al., 1993; Bollobas, 1998; Degenne and Forse, 1994; Gay, 2005; Jackson, 2007; Scott, 2000; Wasserman and Faust, 1994; West, 1996), statistical analysis is the proper tool for a useful mathematical characterization when studying large scale networks and their complex topologies. The mathematical language of graph theory is thus used to describe these systems and to investigate the formal properties of the interactions defining them.

Although we will highlight the need to combine key network concepts, perspectives, or modeling, spanning from different research traditions, complex networks are therefore conveniently conceptualized here graph-theoretically, i.e. as objects containing nodes and links.

A network is hence described in very general terms as a graph whose nodes identify the elementary constituents of the system, the interconnections between these entities being represented by the linkages in the network. As stated by Madhavan, Koka, and Prescott (1998, p. 441)

i. A network at a given point in time is a 'snapshot' that shows interactions as they currently exist …. True structural change would be evidenced by significant variation over time in the underlying pattern of relationships that bind a given set of actors

The first issue that has been faced in statistical physics has been to define new concepts and measures to try to infer the structural properties of large empirical networks. The main outcome has been the identification of a series of unifying principles and statistical properties shared by most of the real-world networks examined.

Real-world networks were in effect found to have statistical regularities that had not been anticipated from the classical random graph theory of Erdös and Rényi (1960). In particular they often have the small-world property (relatively short paths between any two nodes and a large clustering coefficient), and scale-free degree profile (power-law scaling for the probability distribution of the number of links at a node). New models were developed to reproduce the structural properties observed in real topologies. Networks with high clustering coefficient and small average path length can be generated with an evolution by the small-world model of Watts and Strogatz (1998), while networks with power-law degree distribution can be generated with an evolution by the scale-free model of Barabàsi and Albert (1999).

These studies have been motivated by the anticipation that understanding and modeling the structure of complex networks would contribute to a better knowledge of their evolutionary mechanisms, and to a better grasp of their dynamical and functional behavior. However there have been too much specious claims regarding statistical regularities such as universality scaling properties and the functions that they produce. Moreover these claims have been made without testing through periodization of the processes if these functions are truly capable of producing the