Nature Inspired Methods Can Advance Information Network Modeling

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CHALLENGE

The study of information networks has recently gained increased attention. This interest is mainly motivated by the successful application of network theory in the area of information retrieval (e.g. because of the Page Rank algorithm) and communication systems (social network theory). Furthermore, in several areas people recently started to study possible applications of nature inspired methods in order to model behaviour of information networks, e.g. based on the aspect of "natural" growing and ageing in biological, physical and social networks (scale-free network theory).

The notion of scale-free networks [1] was created in the late 1990s when researchers at the University of Notre Dame investigated the distribution of the number of links connected to a node, i.e. the degree distribution of a network, of real networks such as the World-Wide Web [2] or metabolic networks [3]. In the World-Wide Web, web pages are the nodes and hyperlink references represent the links while in metabolic networks substrates are the nodes and a link exists between two nodes when the corresponding substrates interact. With the power law distribution they found a strong deviation from the random network model by Erdős and Rényi (which predicts a Poisson distribution) that had prevailed in network modelling until then [4-6]. This finding led to the development of a novel approach which models the evolution of a network and is able to reproduce the observed degree distribution. The model is based on two principles: growth and preferential attachment. At each time step, a new node enters the network and connects to a specific number of nodes already present in the network. This simple model was later extended to take into account actions such as the removal of links and nodes, link rewiring as well as aging of nodes. This kind of network construction leads to a characteristic degree distribution defining scale-free behaviour. Networks exhibiting this behaviour can be found in the field of technology (the World-Wide Web, the Internet), in social networks (citation networks, actor networks) and in many biological and chemical networks. For a short introduction into the theory of scale-free networks and an overview of recent results see, e.g., [7].

After this first research hype on scale-free networks, meanwhile many researchers reviewed carefully the huge amounts of results published. They point out that many of the first approaches seem to oversimplify the modeling of certain types of networks and that further studies seems to be necessary in order to prove or disprove the provided results. However, on the other hand it also turned out that many artificial and natural networks seem to follow very similar rules and can be described and modeled with very similar techniques. Thus, the underlying idea of transferring modeling approaches from natural networks to human designed artificial networks was able to strongly bring forward research on complex artificial networks.

However, network analysis and modelling in general address a much wider spectrum of problems that underlie domains consisting of objects that are linked together into complex networks. Here, we are looking for answers to questions in common to these networks like aspects of adaptability, error and attack tolerance, complexity, community structures, and propagation patterns. Unfortunately, most of these features are still not sufficiently studied and thus cannot be appropriately modelled. However, several of the aspects that we are interested in are typical features of natural networks, like their ability to adapt to changing environments while maintaining an appropriate pattern of behaviour. Such adaptive capacity can be found, for example, in gene-protein interaction networks within individual cells or complex ecosystems. However, we still do not have a thorough understanding of the underlying processes, even though significant insight into the structure of biological networks has already been gained.

We think that research on natural networks will very likely provide deeper insights into several aspects of complex networks, which could then promote research on more general theoretical models. Thus, our main aim is to study

information networks with respect to underlying nature-inspired aspects for adaptation, optimization, visualization and modeling, especially with respect to their dynamics. We are interested in nature inspired aspects in information networks in general, but we also focus on specific networks such as the internet and computer networks in general (underlying physical network, aspects of adaptivity and self organization, robustness), the World Wide Web (as a link network) and ad hoc, fixed and mixed network architectures in communication networks.

KEYWORDS: Networks, growth, ageing, adaptability, dynamics, graph theory, scale-free networks.

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STATEMENTS FOR OPEN DISCUSSION

- Research in the area of natural networks has and will strongly bring forward research on information networks.
- Many (artificial and natural) networks that are currently called scale-free in fact do not belong to this category.
- Adaptability is a key feature of complex networks.
- Dynamics are an inherent property of networks and require more attention.
- The type of a link in a network is more important than yet considered in most models.