A time-respecting null model to explore the structure of growing complex networks

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Network representations of real systems have been used to gain insights in phenomena as diverse as the epidemics spreading in social networks and the ranking of web sites. When analyzing a network, statistical null models are essential in assessing if an observed property is a sign of a particular feature of the networks organization, or rather an outcome of randomness and basic constraints such as the network size, for example. While many network null models have been proposed in the past, we still lack a reliable model to assess the significance of structural properties for networks that grow in time as many networks do. We bridge this gap by proposing a null model specifically aimed at growing networks.

One of the simplest and most popular null models, the Configuration Model, has been applied to many distinct problems. This model can be used to generate random networks with a given number of connections of each node. We propose the Dynamic Configuration Model that produces networks where not only the final number of connections of each node, but also its time evolution are fixed. Thus-generated random networks can closely reproduce temporal growth patterns of any given network.

We provide several examples that illustrate how the new model can be used to distinguish between fundamental and accidental observations in networks. In particular, we show that the dynamic configuration model brings important insights for three classes of network properties: (1) degree-degree correlations, (2) correlations between centrality metrics, (3) centrality metrics ability to uncover significant nodes in the network. Furthermore, we use the dynamic configuration model to build a new quality function for community detection, called temporal modularity. We use the data produced by a growing network model to show that temporal-modularity optimization outperforms modularity optimization in identifying the planted ground-truth communities for a wide range of model parameters, and clarify how the relative performance of the two methods depends on the systems aging timescale. In the future, many more properties of growing networks can be re-examined with the Dynamic Configuration Model, leading to a better understanding of how do networks change in time and why.

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