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AGENT HETEROGENEITY IN SOCIAL NETWORK FORMATION: AN AGENT-BASED APPROACH

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ABSTRACT

In this study, the author intends to use the simulation method — agent-based modeling — to reassess the Barabasi-Albert model (BA model), the classical algorithm used to describe the emergent mechanism of scale-free network. The author argues that BA model as well as its variants rarely take agent heterogeneity into the analysis of network formation. In social networks, however, people's decision to connect is strongly affected by the extent of similarity. The author proposes that in forming social networks, agents are constantly balancing between instrumental and intrinsic preferences. Based on agent-based modeling, the author finds that heterogeneous attachment helps explain the deviations from BA model, and points out a promising avenue for future studies of social networks.

1 INTRODUCTION

Social network analysis (SNA) has an especially long tradition in the social science. In recent years, a dramatically increased visibility of SNA, however, is owed to statistical physicists. Among many, Barabasi-Albert model (BA model) has attracted particular attention because of its mathematical properties and its appearance in a diverse range of social phenomena (Barabasi and Albert 1999). BA model assumes that nodes with more links are more likely to be connected when new nodes entered a system. However, significant deviations from BA model have been reported in many social networks, and numerous variants of BA model still share the key assumption that nodes with more links were more likely to be connected.

The author argues that this line of research is problematic since it assumes all nodes possess the same preference. It overlooks the potential impacts of agent heterogeneity on network formation. When joining a real social network, people are not only driven by instrumental calculation of connecting with the popular, but also motivated by intrinsic affection of joining the like (McPherson, Smith-Lovin, and Cook 2001). In this study, the author proposes an integrative agent-based model of heterogeneous attachment encompassing both instrumental calculation and intrinsic similarity. Particularly, it emphasizes the way in which agent-heterogeneity affects social network formation. This integrative approach can strongly advance our understanding about the formation of various networks.

2 MODEL AND ASSUMPTIONS

1. **Heterogeneity**: Vertices are intrinsically different from each other on certain aspects. All of the relevant characteristics of vertices are captured by a finite set of $c \geqslant 1$ types: $\{1, 2, \dots c\}$. Based on this finite set of relevant characteristics, it is possible to construct C_i, representing the characteristic position of node i.
2. **Dynamic Growth**: The network continuously expands by the addition of new vertices. The network starts with a small number (n_0) of nodes, at each time step t, a new node with m edges that link the new node to m different nodes already present in the system.
3. **Heterogeneous Attachment**: The probability that two vertices are connected is jointly determined by the connectivity of the existing vertices and the intrinsic similarity between vertices. the joint

probability that a new vertex at time step $t+1$ will be connected to vertex i depends on,

$$U = f(k_{it}, C_i, C_{t+1}) = \frac{\lambda k_{it}}{\sum_j k_{jt}} + (1-\lambda) \cdot g(C_i, C_{t+1}), \quad (1)$$

where λ is a weighted product of the instrumental preferential probability and intrinsic preferential probability. Connectivity of node i at time step t thus is k_{it}. The probability of a new node and a random existing node are connected for intrinsic purpose at time $t+1$ can be captured by $g(.)$, in which $g(C_i, C_{t+1})$ decreases as $C_{diff}(C_i, C_j)$ increases for $i \neq j$.

For the purpose of simplicity, let $m = 1$, $n_0 = 2$, $C_i \in \{\text{“Red”}, \text{“Blue”}\}$ and

$$g(C_i, C_{t+1}) = \begin{cases} \frac{1}{\mu N_d + N_s} & \text{for } C_{t+1} = C_i \\ \frac{\mu}{\mu N_d + N_s} & \text{for } C_{t+1} \neq C_i, \end{cases} \quad (2)$$

where N_s is the number of nodes $C_i = C_{t+1}$, N_d is the number of nodes $C_i \neq C_{t+1}$, and we let $\mu = 0.5$. So far, μ in the model is held at the value of 0.5, indicating that similarity of agents is relatively significant, and $\lambda \in (0, 0.25, 0.5, 0.75, 1)$ for different levels of “similarity matters.” The simulation is stopped when there are 1000 nodes in the system, and there are 30 runs per configuration.

3 STATISTICAL ANALYSIS AND CONCLUSIONS

Following statistical analysis techniques provided by (Clauset, Shalizi, and Newman 2009), the author is able to make the following conclusions:

1. The simulation results suggest that social networks driven by intrinsic preferential attachment ($\lambda = 0$) is significantly different from those driven by instrumental preferential attachment ($\lambda = 1$).
2. When $\lambda = 0$, there are more agents with medium-level connectivity, and there are virtually no super nodes. In contrast, when $\lambda = 1$ there are fewer agents with medium-level connectivity and there many super nodes.
3. How agents balance between intrinsic goods and instrumental goods strongly structures the formation of social network

4 FUTURE WORKS

Future research will focus on simulation more scenarios and validating models with available large social network graphs. Moreover, author will explore the impact of “adaptivity” on social network by revealing the ways in which agents respond to their changing “popularity” and “proclivity.”

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