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Reconstruction of social group networks from friendship networks using a tag-based model

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HIGHLIGHTS

- A tag-based model is proposed to explain the mechanism on the growth of social groups.
- In the model, social groups expand on a friendship network based on users' tags of interest.
- Users' activity in joining group is related to their degree of friendship network.
- Various distributions of the simulated group network are in agreement with empirical findings.
- Our model throws light on the reconstruction of institute-based relationships.

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ABSTRACT

Social group is a type of mesoscopic structure that connects human individuals in microscopic level and the global structure of society. In this paper, we propose a tag-based model considering that social groups expand along the edge that connects two neighbors with a similar tag of interest. The model runs on a real-world friendship network, and its simulation results show that various properties of simulated group network can well fit the empirical analysis on real-world social groups, indicating that the model catches the major mechanism driving the evolution of social groups and successfully reconstructs the social group network from a friendship network and throws light on digging of relationships between social functional organizations.

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1. Introduction

Gathering groups is widespread in societies covering different cultures and different historical periods [1]. Human individuals form associations, organizations and institutions, and there are usually relatively stable members, clear social tags and boundaries in each of these social institutes. In this paper, this type of social institutes is termed as "*social groups*". Generally, different from the widely-discussed implicit structure termed as "community" [2,3], social group is a type of explicit mesoscopic structure of society because of their clear tags and boundaries. Since these tags usually come from the real-world social functional institutes/organizations, social groups will have strong coincidence with these social institutes/organizations. For example, a user usually would like to join a group whose major members are his/her colleagues or teammates. This correlation actually provides a possible way to investigate the relationships and effective organizations between real-world functional institutes from the group information of online societies. And also, online groups usually are widely used to be a place for information releasing and public discussing, and they therefore play an important role in the spreading of online information and the formation of public opinions.

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Previous researches mainly focus on the implicit communities in social networks [2,3]. In this issue, topology properties of networks have aroused concerns [4–7], and serials of methods to identify and define communities in networks, as well as some confinement [8], have been proposed [9–14]. Community extraction arouses the greatest interest in the domain of social network analysis as well. In Ref. [15], the studies of community structures are allowed to promote further to in a general setting encompassing networks that evolve over time, have multiple types of links (multiplexity), and have multiple scales. Furthermore, finding communities among the system users opens the new possibilities and can be utilized in such disciplines as sociology, biology, and computer science [2] and others [12]. And also, some works explored the evolution of communities from social networks [16–20].

Nevertheless, the research on social groups is still rare. It is partially because of the lack of real-world datasets relating to social groups. Recently, You et al. [21] empirically analyzed the real-world online social groups using Tencent QQ dataset and reported many anomalous properties, including sudden growth of group size, wide-spread scaling anomalies on group size, degree and weight of connection network between groups, and special age effects and gender differences. Similar findings recently were also reported by the analysis for the group information on Tencent Wechat [22]. These findings indicate that there will be rich anomalous patterns hidden in real-world social groups, and raise the questions that what mechanism drives the emergence of these patterns and what impacts of social groups on social dynamics. Furthermore, these empirical findings will uncover some features of the organization of real-world social functional institutes/organizations because of the strong coincidence of social groups. In this sense, the mechanism studies on the evolution of social groups will be helpful for the understanding for the structure of real-world social institutes/organizations.

In this paper, we propose a model based on tag-driven expanding on social networks to mimic the expansion of social groups and reconstruct their connections from friendship networks. Numerical simulations of the model generate rich properties that can generally cover the empirical observations, indicating that the model successfully explains the origin of these anomalous properties of real-world social groups.

2. The model

Since the relevant empirical studies are mainly aimed at the online social groups, the rules of our model also are in the light of the online cases. Generally, a social group has a clear tag, and users who are interested in the tag or belong to the institution attaching to the one tag will join the group. For example, a tag naming "Complex networks" will attract many researchers studying complex networks. After a group is created by a user, its information will spread in his/her circles, and the group will spring from the creator to his/her friends and then extend to their further neighbors if the tag of the group can well fit their interests. This expansion is similar to the spreading of meme in society [23,24]. Actually, in a sense, social groups also can be considered to be a type of meme.

Actually, besides the groups that can well fit the real-world social organizations or institutes and mainly contain strong social contacts, for example, the members in a club or a research team often build groups in social societies, from the daily life experience by the using of online social group, there is another type of group that usually has a tag of common interests (e.g. music, pop stars, etc.) and contains many weak ties. Similar two types of groups have been observed in other group-like online societies, like Tencent Wechat [22]. Empirical studies are difficult to distinguish the two types of groups and we do not know the real-world proportions of the two types directly. Nevertheless, Ref. [21] reported that real-world groups globally have the property of sudden growth, indicating that users usually would like to join a group that they have already intended to join or been interested in before the creation of the group, and thus the strong-tie-driven groups are the vast majority. We therefore construct our model from the tag-driven contacts between users and their neighboring groups.

Moreover, even though our datasets neither support the comparative study in individual level and nor provide direct evidence, it is natural in turn to suppose that users with more social contacts have more possibilities to join groups.

From the perceptions above, our model is therefore based on real-world social networks with the tag-driven growing process and various activities for group joining. For the coincidence with the empirical results of social groups of Tencent QQ, the friendship network of Tencent QQ users is used to be as a background network. The detailed description and sampling method of the dataset of both social groups and friendship networks can be found in the Appendix. With the friendship network, we run the model with the following rules:

(i) Each user (node) in the friendship network is granted an N dimensional binary tag vector $\mathbf{H} = (h_1, h_2, \ldots, h_N)^T$, $h_i = 0$ or 1, $i = 1, 2, \ldots, N$. Here, each h_i represents a tag in the node's interests, and $h_i = 1$ if the user has the corresponding tag and $h_i = 0$ if the user has not the corresponding tag, and N represents the total types of tags. Since each user is assumed to own at least one tag of interest, one randomly chosen component of its tag vector $\mathbf{H}$ is set as nonzero for each node at first. As for each of the rest components of $\mathbf{H}$, it is randomly to be nonzero with a probability ω (see Fig. 1).

(ii) The total number of groups that will be created in the model is $M_G = 3{,}432{,}642$, which is the total number of groups averaged by 10 independently-sampled group sets (see Appendix). The creating method is as follows: each node (user) in the friendship network firstly creates a group, and here we have M_U groups ($M_U = 1{,}052{,}199$ is the total number of nodes in the friendship network). For each of the remaining $M_G - M_U$ groups, with probability ρ, we randomly pick an edge from the friendship network and randomly choose a node on the edge to be the creator of the group; or with probability $1 - \rho$, we randomly pick a node to be the creator.

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