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Topological evolution of virtual social networks by modeling social activities

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HIGHLIGHTS

- Two mathematical abstract concepts of social activities are formalized.
- The social actions of hobbies searching and friend recommendation are characterized.
- A social activities based topology evolution model is developed.
- The model has embraced key network topological properties of real social networks.

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ABSTRACT

With the development of Internet and wireless communication, virtual social networks are becoming increasingly important in the formation of nowadays' social communities. Topological evolution model is foundational and critical for social network related researches. Up to present most of the related research experiments are carried out on artificial networks, however, a study of incorporating the actual social activities into the network topology model is ignored. This paper first formalizes two mathematical abstract concepts of hobbies search and friend recommendation to model the social actions people exhibit. Then a social activities based topology evolution simulation model is developed to satisfy some well-known properties that have been discovered in real-world social networks. Empirical results show that the proposed topology evolution model has embraced several key network topological properties of concern, which can be envisioned as signatures of real social networks.

1. Introduction

As the Internet evolved, virtual social networks, such as Facebook, MySpace and Flickr, have great influence on interpersonal relationships and reframed the social networks [1], especially by mashing up mobile communication devices. The social networks are becoming increasingly human centric [2]. In other words, the human social behaviors and activities must be carefully studied in association with such networks [2–5]. However, it is intractable to conduct rigorous studies of human centric networking and communications over a large-scale virtual social network because of the large scale, complex topology and security problems of network. In addition, it is illegal to carry out special scientific researches and experimental

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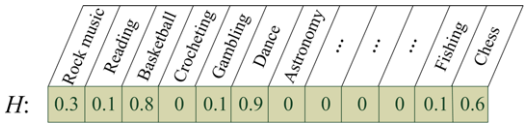

Fig. 1. Each entry $H(k) \in [0, 1]$ of the Hobbies vector denotes a hobby, such as rock music, reading, basketball and fishing.

developments on real social networks, such as social-aware routing protocol design, faults [6] and worm propagation [7–11], and advertising promotion [12]. As such, the structural modeling [13] and conceptual properties [14–16] of virtual social networks are well studied as a special form of the networks. For examples, Faloutsos et al. [17] showed that internet topologies exhibit the power law distribution. Holger Ebel et al. [18] investigated one of the earlier social network, i.e., email network, and discovered a so-called scale-free property. Boguñá et al. [19] studied a class of models of social network formation in terms of the social distance. Their model reproduces some statistical properties of real social networks, such as hierarchy of communities. Moriano and Finke [13] proposed triad formation mechanism to guarantee strong neighborhood clustering and community-level characteristics as the network size grows to infinity. A departure from the previous form of social network is the online groups or online communities which allow users to create, post, comment to and read from their own interest and niche-specific subject [20,21]. Backstrom et al. [20] studied the evolution of such online groups on real LiveJournal and DBLP social networks, and discovered that the tendency of someone to join a community is mostly influenced by the relationships with its friends. Bu et al. [22] proposed a novel evolution network model with the new concept of "last updating time", which exists in many real-life online social networks. Their model can maintain the robustness of scale-free networks and improve the network reliance against intentional attacks. Leskovec and Horvitz [23] constructed a social network model composed of 180 million nodes and 1.3 billion undirected edges based on real conversations of the MSN instant-messaging system. Their major finding is that people are tempted to interact more with each other when they have similar age, language, and location. Likewise, they discovered that a link is significantly more likely to be friendly when its two endpoints have multiple common neighbors, which means that communities are mostly formed by the principle of "the friend of my friend is my friend" [24].

It is worth noting that social groups on networks are now becoming one of footstones for human societies [25] in a way of strengthening their ties or friendship by sharing similar interests and activities etc. However, most of the current topology models lack a rigorous study over the social properties of current virtual social networks. This is because that human and social activity's impact on topological evolution model is difficult to be evaluated and hence is mostly ignored. To address this outstanding problem, an evolution model is suggested from the viewpoint of finding new friends. It characterizes the social actions of hobbies searching and friend recommendation in a social network, which are known as common ways for meeting friends and forming communities. The advantage of the underlying model is the generation of an artificial network that reproduces several key statistical properties inhabited in real social networks. It is fundamental for many social network researches including reliability estimation, worm propagation and advertising promotion.

2. Topology evolution model

Virtual social networks can be formed as the actual social relations existing in the real world through common interests and mutual acquaintances. In the networking model, each social network user can be represented by a sensor node. One pair of network users can be linked together via a network edge if there exists an interaction or association between them. The edge direction is the orientation, in which information is being transmitted, e.g., viewing someone's sharing or @ somebody. Furthermore, the weight attached to the edge reflects the frequency of the information exchanged between two nodes. The larger the weight is, the stronger relationship exists between them.

2.1. Mathematical abstract concepts

Hobbies vector: The hobbies vector H describes the interest intensity distribution of a social network user as shown in Fig. 1. The value of entries indicates the intensity of involvement or interest in the hobby. For examples, zero means that he/she is not interested in the hobby, while one denotes the maximum interest. The proposed hobbies vector can be used to seek new friends congenial to new network user and therefore is beneficial to form the community structures.

Recommendation friend set: Given a network user i is linked to the social network, a friend set RF_i can be formed by the recommendations based on its neighbor set, as Eq. (1). Fig. 2 illustrates an example of the RF_i in which the elements are dynamically updated as i links to more existing nodes. The notion $NS_i = \{j | w_{ij} \neq 0 \text{ or } w_{ji} \neq 0\}$ denotes neighbor set of node i, i.e., the node j is an element of set NS_i iff there exists a link between node i and node j.

$$RF_i = \bigcup_{j \in NS_i} NS_j - NS_i. \tag{1}$$

Moreover the recommendation index δ ($0 < \delta < |N|$) is used to control the number of connected friends during topology evolution process.