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Modeling cascading failures with the crisis of trust in social networks

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HIGHLIGHTS

- We model the user trust and the minimum tolerance with a nonlinear equation.
- We construct the process of cascading failures based on the crisis of trust.
- We adopt two attack strategies to evaluate the proposed dynamics.
- We study the changes of topology, connectivity, cascading time and cascade effect.

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ABSTRACT

In social networks, some friends often post or disseminate malicious information, such as advertising messages, informal overseas purchasing messages, illegal messages, or rumors. Too much malicious information may cause a feeling of intense annoyance. When the feeling exceeds a certain threshold, it will lead social network users to distrust these friends, which we call the crisis of trust. The crisis of trust in social networks has already become a universal concern and an urgent unsolved problem. As a result of the crisis of trust, users will cut off their relationships with some of their untrustworthy friends. Once a few of these relationships are made unavailable, it is likely that other friends will decline trust, and a large portion of the social network will be influenced. The phenomenon in which the unavailability of a few relationships will trigger the failure of successive relationships is known as cascading failure dynamics. To our best knowledge, no one has formally proposed cascading failures dynamics with the crisis of trust in social networks. In this paper, we address this potential issue, quantify the trust between two users based on user similarity, and model the minimum tolerance with a nonlinear equation. Furthermore, we construct the processes of cascading failures dynamics by considering the unique features of social networks. Based on real social network datasets (Sina Weibo, Facebook and Twitter), we adopt two attack strategies (the highest trust attack (HT) and the lowest trust attack (LT)) to evaluate the proposed dynamics and to further analyze the changes of the topology, connectivity, cascading time and cascade effect under the above attacks. We numerically find that the sparse and inhomogeneous network structure in our cascading model can better improve the robustness of social networks than the dense and homogeneous structure. However, the network structure that seems like ripples is more vulnerable than the other two network structures. Our findings will be useful in further guiding the construction of social

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networks to effectively avoid the cascading propagation with the crisis of trust. Some research results can help social network service providers to avoid severe cascading failures.

1. Introduction

In recent years, social networks, such as Facebook, Twitter and Sina Weibo [1], have become an indispensable part of our lives. The rising of social network society has reshaped social life and brought about changes in social structures and modes of communication. Facebook had 1.35 billion monthly active users and 864 million daily active users (on average) during October 2014 [2]. Twitter had 284 million monthly active users (in total) as of October 2014 [3]. Akin to a hybrid of Twitter and Facebook, Sina Weibo is a Twitter-like social forum in China and is becoming one of the most popular Chinese websites, with 156.5 million monthly active users and 69.7 million daily active users as of August 2014 [4]. They all offer rich functionality to communicate with friends, publish content, and share interests.

Nevertheless, the rapid development of social networks has brought some potential problems. It is worth mentioning that, although each user base keeps growing, user activity has decreased in some social networks. For instance, according to a widely sourced report by third party data tracking service WeiboReach [5], Sina Weibo's activity in 2013 was down by 30% compared to the beginning of 2011. There are some direct and indirect reasons for this. One of the key reasons is *the crisis of trust*. In social networks, some low-quality friends often post or disseminate malicious information, such as advertising messages, informal overseas purchasing messages, illegal messages, or rumors. Too much malicious information may cause a feeling of intense annoyance, creating distrust for low-quality friends and bringing about the crisis of trust. As the crisis of trust occurs, users will cut off their relationships with low-quality friends. Once a few of these relationships are unavailable, it is likely that other friends will decline trust, and a large portion of the social network will be influenced, which could paralyze the whole network.

To formalize the above phenomenon, we abstract this phenomenon as a process of cascading failure. A cascading failure is a procedure in which the failure of one part of a system can trigger the successive failures of many other parts of the system. Cascading failures are common phenomena [6–11] and occur in many real-world networks, such as power grids [12–14], communication networks [15], economical networks [16] and social networks [17]. In these networks, certain loads are transported from nodes to nodes. If attacks or failures occur at some nodes in the network, then loads are redistributed from these failed nodes. The redistribution of loads may cause more nodes to fail. As this process continues, the phenomenon of cascading failures takes place.

Some pioneering and distinguished researchers have begun to investigate and study the impact of cascading failures in many networks. The important aspects of cascading failures have been discussed and many valuable results have been obtained. Wang et al. [18] proposed a two-stage cascading model in the interdependent networks. They found that the link patterns had important effects on improving the robustness of the interdependent networks. Moreover, Wang [19] demonstrated the efficiencies of the mitigation strategies to enhance the robustness of scale-free networks against cascading failures and gave the order of the effectiveness of the mitigation strategies. These results were very helpful for avoiding various cascading-failure-induced disasters in the real world. Yi et al. [17] identified the cascading failures issue within social networks and showed that social networks with super users were vulnerable to attacks. Dou et al. [20] proposed a non-linear load–capacity model against cascading failures. Tan et al. [21] extended the cascading failure model used in isolated networks to the case of interconnected networks. Li et al. [22] modeled the cascading dynamics in scale-free networks, WS small-world networks and ER random networks. They also further revealed the process under edge-based-attack. Eppstein [23] described a stochastic RC algorithm to identify large collections of multiple contingencies that initiated large cascading failures in a simulated power system. Bernstein [24] studied the effects of geographically correlated outages and the resulting cascades. He also compared their numerical results to the actual events in a recent blackout in the San Diego area, thereby demonstrating that the model's predictions were consistent with real events. Koç Y. et al. [25] investigated the relationship between topology and phase transitions in power grids and considered three spectral graph metrics to assess the impact of topology on transitions. They also verified that these metrics correlate with phase transitions in the grid robustness. Yin [26] modeled load redistribution based on the variable load and fixed capacity in WSNs (wireless sensor networks). They also investigated the relationship between the variable load and cascading failure scale of scale-free topology in WSNs.

Although many experts and scholars have explored the issues of cascading failures in different perspectives and achieved a series of achievements, cascading failures resulting from the crisis of trust in social networks have never been studied. In this paper, we focus on the cascading failures resulting from the crisis of trust, theoretically analyze this process and demonstrate the phenomenon by using a real social network dataset. In short, we conduct our investigation as follows:

(1) Based on social networks, we first compute the trust between two users in terms of user similarity and model the user capacity with a nonlinear equation. Meanwhile, we construct the processes of cascading failures dynamics by adjusting the changes of trust and propose a simulation algorithm for cascading failures based on the crisis of trust.
(2) We adopt two attack strategies, including the highest trust attack (HT) and the lowest trust attack (LT), to evaluate the effectiveness of the proposed dynamics based on real social network datasets (Sina Weibo, Facebook and Twitter).