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Cross-network dissemination model of public opinion in coupled networks

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ABSTRACT

In a coupled network system, information can be sourced and disseminated in many ways. In this study, we investigate the diffusion effect of information in a coupled social network environment, using two new node states to augment information dissemination. Using an improved SIR model, this paper posits that a coupled network comprises two categories of nodes, independent spreaders and cross-network spreaders, which participate in the process of information spreading. The independent spreaders act as a source for information, leading to a higher spreading probability and a wider spreading scope. The cross-network spreaders transfer the spreading onto another network. Our simulation result using synthetic data suggests that the environment of the coupled social network affects the diffusion of information and information diffusion has a prolonged relaxation time due to these nodes. Further, we analyze the data collected from Weibo and WeChat of an actual news event to visualize the information spread process in the cross-network dissemination case of public opinion, and show that our improved SIR model provides a good fit to explain the data.

1. Introduction

About half of the world's population join online social networks to share interests, acquire information, and discuss common hot button topics [20]. With the rapid development of the Internet and social networks, the number of online users today is increasing, and online social networks are changing the online user's preferred mode of receiving information. Indeed, public opinion has become an important norm in social information dissemination. As the main dissemination mode of public opinion, the online network is affecting all walks of life. Internet users can now obtain their news feed and daily information online. They can also monitor government departments and their activities because of the immediacy and rapid dissemination through online social networking. However, due to the complexity of the Internet and social networks, it is not always ideal and productive for information dissemination. For starters, before forwarding the information, the online users cannot accurately determine the authenticity nor accuracy of the information. This can potentially give lead to the unwanted and extensive dissemination of rumors and fake news, affecting the course of public opinion.

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Already, the world is linked by a complex mesh of networks through which information, news, and goods flow. These networks are interdependent, and present structural and dynamical features different from those observed in standalone, isolated networks. A coupled system exists not only between the physical and communication networks, but also between other online networks. People not only use e-mail, instant messaging tools such as QQ and WeChat to exchange information, but also use Web 2.0 social network services, such as Twitter, Facebook, Instagram, and Weibo to share their viewpoints and communicate with others. Clearly, an online user may be active in many of these networks. Similarly, the online user can acquire information by criss-crossing the physical and social networks. Information no longer disseminates in a closed single network, rather it does so through a coupled network platform. With the continuous upgrading of the network platform function and the increasing reach of the online user, the information dissemination process of the online network presents some complex characteristics. At the same time, as the carrier of information, the nodes in a network determine the path of information dissemination across the network. In a coupled network environment, users receive information from multiple social networks, resulting in information being disseminated to multiple networks; this can sometimes lead to information attenuation and distortion, if left unmanaged.

To overcome these challenges, this paper proposes a public opinion dissemination model of a coupled network based on the traditional infectious disease model, and analyzes the influence of the horizontal and longitudinal dissemination of online information under a coupled network environment. Scholars have applied similar epidemic-like models in a social context such as the studies on excess weight [23] and tax evasion dynamics [2]. Our contribution is thus two-fold. First, we elicit a better understanding of information dissemination by identifying the key nodes and pathways in the dissemination process. Second, through this, we establish a policy mechanism to limit the spread of fake news.

The rest of this paper is structured as follows. Section 2 presents an overview of the extant work. Section 3 describes the dissemination process for public opinion in a coupled network. Section 4 communicates the information dissemination model in a coupled network environment. The model is analyzed in Section 5. In Section 6, a simulation analysis of this model is performed. A case study is also provided to validate the proposed method. Section 7 concludes with future research directions.

2. Current research status

Ever since Sudbury [22]'s infectious disease SIR (Susceptible, Infected, and Recovered) model has been applied to explain the dissemination of rumors, other scholars have used the model to describe the dissemination of public opinion. For instance, Parshani et al. [14] study a system comprising an interdependent global port network and a global airport network to show that well-connected ports tend to couple with well-connected airports. Shu et al. [18] numerically study how weak ties influence the predictability of epidemic dynamics based on the contact process. González-Parra et al. [6] combine the non-standard finite-difference schemes and Richardson's extrapolation method to obtain numerical solutions of two biological systems. van den Driessche and Watmough [25] offer a tight definition of the basic reproduction number and propose a general compartmental disease transmission model using ordinary differential equations. These studies assume that the network is isolated and information is spread in a closed environment. However, the reality is that the network is not a single network; networks criss-cross and overlap, and public opinion can spread through multiple platforms.

Recently, some scholars have studied the multi-layer network to explain the across-network dissemination of public opinion. For example, Xie et al. [28] investigate the regularity of the spread of information and public opinion towards two competing products in a complex network. Through mathematical modeling and simulating its evolution process, Xie et al. find statistical regularity for the support rates of two different products in steady state. Gao et al. [5] propose a nonlinear coupled information-epidemic model (I-E model) and present a comprehensive analysis in a more generalized scenario. Zhao et al. [31] modified a flowchart of the rumor spreading process with the SIR model, to make the rumor spreading process more realistic and apparent. Liu and Li [10] text mine on Internet public opinion hotspot detection. Lian et al. [9] propose a model to describe the topology of the Internet public opinion. Ma and Liu [11] propose a super-edge rank algorithm for opinion leader identification based on super network theory, which combines network topology analysis and text mining. Nuno [13] studied opinion formation in a voter-like model defined on a square lattice. The agents are in three different states, representing a public debate with three choices.

Qian et al. [16] discuss the phenomenon in complex networks by adopting the concept of independent spreaders. They developed the classic "ignorant-spreaders-stiflers" or SIR model of rumor diffusion process for complex networks. In Xu et al.'s [29] work, an agent-based model was formed to analyze the impact of suppressing guides on information spreading. They found that the spreading threshold depends on the attractiveness of the information and the topology of the social network with no suppressing guides. Alvarez-Galvez [1] showed that the success of minority opinions depends on network structure and composition, and thus on externalities such as mass media action that can mediate the strength of these internal determinants. Zhang et al. [30] extracted the online communities by analyzing the replies of each post in a bulletin board. An opinion leader community mining method is proposed based on the level structure. Zhao et al. [32] investigated the interaction mechanism of a group of autonomous agents in an e-commerce community (or social network), and the influence power of opinion leaders during the formation of group opinion. Zhang [26] introduced a model of continuous network public opinion (NPO) dynamics with opinion leaders by modifying the Weisbuch–Deffuant model and analyzed the diffusion of NPO under the influence of opinion leaders based on the SIR model and complex networks. Dong et al. [4] proposed a strategy which adds a minimum number of interactions in the social network to form a consensus based