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Modeling the dynamics of information dissemination under disaster

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ABSTRACT

Information dissemination has drawn increasing attention of scholars and the government for its importance to disaster response. Understanding the dynamics of information dissemination can help the government disseminate information effectively. Considering people tend to share information with the intimate under disaster, social distance which measures the intimacy between individuals is introduced in this paper. An information dissemination model with preference selection based on social distance is also proposed. Through extensive simulations, we discover the information dissemination process will be suppressed if people prefer disseminating information to individuals with short social distance. In order to facilitate the information dissemination, award to spreaders is found useful for its significant acceleration in dissemination speed. In addition, we examine the efficiency of strategies the government adopts to disseminate information. Comparing to inform-way (q fraction of nodes informed in descending order of H-index), the government is recommended to disseminate information by broadcast-way (all nodes accepting information with a probability λ_b). Our work contributes to understanding the dynamics of information dissemination, and provides the government with suggestions to disseminate information effectively under disaster.

1. Introduction

Information dissemination has drawn increasing attention of scholars and the government for its importance to disaster response. On one hand, when disaster happens, the spread of false rumors can resist the access of people to real information and lead to panic in society [1], which is very harmful to disaster response. For example, when the earthquake in Japan caused nuclear leakage in 2011, thousands of people rushed to buy salt because they thought salt would reduce the nuclear radiation [2]. On the other hand, the dissemination of accurate information can promote the disaster response. Scholars have discovered that the epidemic can be controlled by the information dissemination on social networks [3,4]. Information spreading on Twitter is also found useful for fighting fire [5,6]. At the same time, under disaster, the mutual aid among people and the government rescue also demand the fast spread of accurate disaster information [7]. With the rapid development of communication technologies, information spreads much faster [8], which makes information dissemination increasingly valuable for disaster response in the modern society.

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A subset of previous research about information dissemination focused on the spread dynamics on complex networks. A number of models [9–12], such as SIHR model [10] and 8-state ICSAR model [12], have been proposed. In these models, people are divided into several parts and the transition probability between these parts are defined. Recent years, the factors that affect the information dissemination process, including the feature of information [13–16], the network structure [17–20] and psychological behaviors [21–24], have attracted much academic attention. Zheng et al. [13] found that information quality was a stronger factor comparing to the popularity of the spreader. Chen et al. [14] reported the more important the information was, the faster it would diffuse. The attractiveness of information [15] and information update mechanism [16] were also found influential during the information spreading process. Moreno et al. [17] figured that the homogeneity of network degree had a great influence on spread dynamics. Pan et al. [18] indicated a network with high clustering could resist spreading, while one with low clustering showed the contrary. Yang et al. [19] focused on the effect of dynamical network structure on information dissemination process. Zhang et al. [20] introduced an information spread model on coupled networks. In addition, some psychological behaviors, such as forget-remember mechanism [21–23] and social reinforcement [24], have also been introduced by researchers. Lu et al. [24] discovered that social reinforcement will bring a remarkable improvement in the final spread scale. Previous studies also revealed that some other factors would affect the information spreading process significantly, such as individual judgment heterogeneity [25], individual privacy concerns [26], individual's reputation [27].

Another subset concerns about the practical applications of information dissemination. Some researchers have investigated how to maximize the information spreading scale under emergency [28–30]. Dong et al. [28] proposed a greedy algorithm for selecting the optimal information sources to start dissemination. Morone et al. [29] localized these influential spreaders through optimal percolation on networks. Litou et al. [30] aimed to find efficient techniques to disseminate information with the time and cost constraints. Scholars have also focused on information dissemination models under disaster [31–33]. Zhang et al. [31] developed a comprehensive information dissemination model to analyze the effect of governmental assistance on information dissemination under disaster. Shan et al. [32] constructed an emergency information dissemination model based on the information entropy method which is useful for predicting the occurrence of incidents and improving the emergency response. The effective measures to prevent rumors spreading have also been proposed. The government is recommended to respond to disaster rumors immediately, ensuring the disaster information accurate and transparent [33]. Information dissemination case study has also been a topic [34–37]. Pourebrahim et al. [34] and Scott et al. [35] analyzed the information dissemination on social media during the Hurricane Sandy and Louisiana Floods respectively, and found that the information on social media was valuable for identifying disaster damages and planning relief efforts. Kryvasheyeu et al. [36] demonstrated the online social information can be used for rapid assessment of damage caused by a large-scale disaster. Zhong et al. [37] proposed a typhoon disaster information dissemination model, which is useful for providing the government disaster response guidance.

However, there are some limitations in previous studies, such as the lack of investigation of human behaviors under disaster. When disaster happens, people care about their close relatives and tend to share disaster information with the intimate immediately, which is quite different with the normal condition. In order to overcome the problem above, social distance is introduced to describe the intimacy between individuals. An information dissemination model with preference selection base on social distance is also proposed in this paper. In addition, the effects of award and penalty to spreaders on information dissemination are investigated. In view of practice, we also examine the efficiency of two strategies that the government adopts to disseminate information. The results can help the government choose the effective way to disseminate information under disaster. The paper is organized as follows. In Section 2, the information dissemination model is stated in detail. In Section 3, extensive simulations are performed and the results are described. We draw conclusions in Section 4.

2. Model

Complex networks, where nodes and edges represent individuals and relationships between them respectively, are powerful tools to describe social relationships in real world. In this paper, we model the information dissemination dynamics under disaster by spreading dynamics on complex networks. In our model, nodes can be one of the five states: *unaware (U)*, *informed (I)*, *panic (P)*, *disseminative (D)* and *exhausted (E)*. Nodes in unaware state means that they have not received the information, contrary to the nodes in informed state. Nodes in disseminative state will transmit the disaster information to their neighbors, while the panic nodes try to escape and exhausted nodes are unwilling to disseminate information. Initially, a node is chosen randomly as the disaster information source (i.e., set it as disseminative state), while all the other nodes are in unaware state. At each time step, node i in disseminative state decides whether to disseminate information with a probability p_D (to be defined later). Specifically, if p_D is smaller than a critical value p_c, node i will transfer to exhausted state and never disseminate information in the remaining process. When deciding to disseminate information, node i will choose node j among its neighbors with a probability p_{ij} (to be defined later) to transmit information. If node j is currently in unaware state, node j will accept the information with a probability p_a. Considering the social reinforcement [24], that is, the more times an individual is exposed to information, the more likely he/she is to accept it, p_a is defined specifically in Eq. (1):

$$p_a = 1 - (1 - \lambda)e^{-b(m-1)} \tag{1}$$