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Global stability of a two-mediums rumor spreading model with media coverage

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HIGHLIGHTS

- Our model involves different mediums of rumor spreading and the different ways for spreaders.
- We calculate the equilibria of the model and construct the reproduction number $\Re_0$.
- The transition rate between two mediums has a direct effect on spreaders on each medium.
- Different media coverage has a significant influence on the dynamics behaviors of rumor spreading.

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ABSTRACT

Rumor spreading is a typical form of social communication and plays a significant role in social life, and media coverage has a great influence on the spread of rumor. In this paper, we present a new model with two media coverage to investigate the impact of the different mediums on rumor spreading. Then, we calculate the equilibria of the model and construct the reproduction number $\Re_0$. And we prove the global asymptotic stability of equilibria by using Lyapunov functions. Finally, we can conclude that the transition rate of the ignorants between two mediums has a direct effect on the scale of spreaders, and different media coverage has significant effects on the dynamics behaviors of rumor spreading.

1. Introduction

Rumor is one form of human communication, its spreading exerts significant influence on human affairs. It causes unnecessary and induces economic loss to affected countries [1–4]. Better understanding of spreading dynamics will contribute to make more effective strategies to control or make use of these dynamics processes. Therefore, spreading dynamics draw a lot of attention to many areas [5–7].

A classic rumor model was DK model proposed by Daley and Kendall in 1965 [8]. In their model, the population was divided into three groups: people who knew and spread the rumor, people who did not know the rumor and people who knew but did not transit the rumor. Maki and Thomson modified the DK model into the MK model, which assumed that a spreader changed to a stifler (who knew but did not transmit the rumor) [9]. A number of scholars researched rumor spreading considering the topology properties of social networks [10–14]. Besides, Zanette studied the spreading model on small-world networks and found the existence of the critical threshold for rumor spreading [15,16]. Moreno and Nekovee et al. examined the mean-field equations to describe rumor propagation in small-world networks [17]. Besides, scholars found that networks structure influenced spreading dynamics, the most of which was that heterogeneous structures lead to the absence of any diseases outbreak threshold [18,19].

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Afterward, Zhao et al. refined the classical rumor spreading model with consideration of the forgetting mechanism and the remembering mechanism in homogeneous networks [20,21]. Zhao et al. modified a rumor spreading model by considering the prevalence of new media [22]. Huo et al. established a rumor propagation model with considering latent period and varying population [23]. They depended on Pontryagin's maximum principle, acquired the optimal solution when the emergency response incurred nonlinear costs. Indeed, some scholars discussed media coverage was a key factor in the transmission process of infectious disease. Wang proposed a SIS network model to investigate the influence of media coverage on disease transmission [24]. Moreover, media coverage had a great impact on individual behavior towards the rumor. Some scholars developed a theoretical framework to analyze the participatory social reporting phenomenon to affect the rumor spreading [25].

Media, being the prime source of information, can influence the ignorant behavior. Media makes people acquainted with rumors, which will exert great effects on the judgment of individuals. People's response to the threat of rumor was dependent on their perception of risk, which was influenced by public and information disseminated widely with the media. Previous model only considered that access way of rumor information was same. A limit of these models lied in the neglect of different mediums of knowing information for individual in networks. Based on the above situation, we make some changes in this paper. We consider individual preference, the attitude on the rumor spreading and the different mediums to obtain information. Due to the diversity of individuals and the different preferences to obtain information for individuals, for example, some people only are willing to believe traditional magazine, television, newspaper information, and some people only believe microblogs media information. And our model involves two ways of rumor spreading described below. One of which is oral transmission from person to person, other is through social networks.

In this paper, a dynamic model of rumor spreading is proposed with different mediums of rumor spreading and the different ways for spreaders. The organization of this paper is organized as follows. In Section 2, we depict our rumor model of spreading dynamics on network considering different mediums of rumor spreading process and the ways for spreaders. In Section 3, we study the model system including existence of the equilateral and their stability analysis. In Section 4, numerical simulation of the model is presented to exhibit the rule of the spreading. Finally, we conclude the paper in Section 5.

2. The model formulation

The spread of rumors is a complex and comprehensive process. In our model, the dynamic model of rumor spreading is proposed which involves different mediums of rumor spreading and the different ways for spreaders. In this paper, individual only believe medium information that they prefer. For example, some people only believe traditional magazine information, and some people only believe microblogs media information. Based on compartment model, we divided individuals into five categories: the ignorants of preferring medium1 (one group of people who prefer medium1 but never hear the rumors), oral spreaders on medium1 (people who spread rumors through oral transmission from person to person), the ignorants of preferring medium2 (one group of people who prefer medium2 but never hear the rumors), oral spreaders on medium2 (people who spread rumors through oral transmission from person to person), stiflers (one who know it but never spread it). In addition, we consider the rumor spreading model under the different ways of spreaders, media broadcast has an important influence on the ignorants. The model involves amount of medium1 broadcast (people who spread rumors through medium1) and amount of medium2 broadcast (people who spread rumors through medium2). At time t, we use $X_j(j = 1, 2)$ to stand for the ignorants of preferring medium $j(j = 1, 2)$ and $Y_j(j = 1, 2)$ stands for oral spreaders on medium $j(j = 1, 2)$, $Q_j(j = 1, 2)$ stands for the amount of media j coverage, Z stands for stiflers.

Following, we assume that there is a constant rate $p_j(j = 1, 2)$ of ignorant individuals in the two mediums. An ignorant individual becomes a spreader following two possible routes of transmission: either by direct contact with individuals who spread rumor through oral, or indirectly through social medium where rumors are discussed. In this paper, we assume that the media coverage only has effect on the ignorants. And the ignorants only believe medium information that they prefer. Due to personal preference type of the ignorants, when an ignorant individual of preferring medium j interacts with oral spreaders on medium j, the ignorants of preferring medium j only become oral spreaders on medium j with probability $\lambda_j(j = 1, 2)$. Media broadcast only has an influence on the ignorants of preferring different mediums, the ignorants of preferring medium j affected by medium j broadcast with probability $\beta_j(j = 1, 2)$. Owing to differences in the preferences, knowledge background, experience of the ignorants, the ignorants of two mediums will be reciprocal transformation. Here, we account for the probability α_1 by assuming that ignorants of preferring medium1 may transit into ignorants of preferring medium2. Similarity, the ignorants of preferring medium2 also transit into the ignorants of preferring medium1 with probability α_2. In addition, because of great interest and inspiration for the rumors, oral spreaders on medium j will share rumor to their friends on social media j with probability $\omega_j(j = 1, 2)$. As oral spreaders on different mediums, both of them have known the rumor, and they do not affect the ignorants of other mediums and spreaders. When oral spreaders on medium j contacts stiflers, the former rumor spreader may become a stifler with probability $\delta_j(j = 1, 2)$ which we define as the stifling rate. Besides, due to the recession of the rumor interest for medium and the decrease of heat for rumors, medium1 or medium2 stop to broadcast with probability $\gamma_j(j = 1, 2)$. Moreover, we assume the leaving rate of individuals on medium j is $\mu_j(j = 1, 2)$.

The rumor spreading process is shown in Fig. 1.