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A rumor spreading model with variable forgetting rate

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HIGHLIGHTS

- We propose a rumor spreading model with forgetting rate varying over time.
- We derive mean-field equations of the model in small-world networks.
- Numerical solution results on LiveJournal show that forgetting rate affects rumor spreading.
- Influence of rumor spreading differs when forgetting rate is variable and constant.

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ABSTRACT

A rumor spreading model with the consideration of forgetting rate changing over time is examined in small-world networks. The mean-field equations are derived to describe the dynamics of rumor spreading in small-world networks. Further, numerical solutions are conducted on LiveJournal, an online social blogging platform, to better understand the performance of the model. Results show that the forgetting rate has a significant impact on the final size of rumor spreading: the larger the initial forgetting rate or the faster the forgetting speed, the smaller the final size of the rumor spreading. Numerical solutions also show that the final size of rumor spreading is much larger under a variable forgetting rate compared to that under a constant forgetting rate.

1. Introduction

Rumor as one way of communication can have great impact on the society as well as individual human life. Taking the digital ride in the information age, rumors have been exerting a rapidly increasing influence. Like the two sides of a coin, while a lot of times we can take full advantage of the fast information transmission to deliver urgent information such as emergency warning to the public for the preparation of disasters [1], there are often times when destructive rumors can cause social panic and even huge economic loss [2]. As such, the study of rumor spreading has important theoretical as well as practical implications.

A classic rumor model is the DK model proposed by Daley and Kendal in 1965 [3]. In their model, the population of interest is divided into three groups: people who know and spread the rumor, people who do not know the rumor and people who know but do not transmit the rumor. Then Maki and Thomson [4] modified the DK model into the MT model, which assumes that a spreader changes to a stifler (who knows but does not transmit the rumor) once s/he contacts another spreader. Based on these early models, many researchers carried on the study of rumor spreading [5–7] and related it to the topological properties of social networks [8–10]. Besides, Zanette [11,12] studied the rumor spreading model on small-world networks

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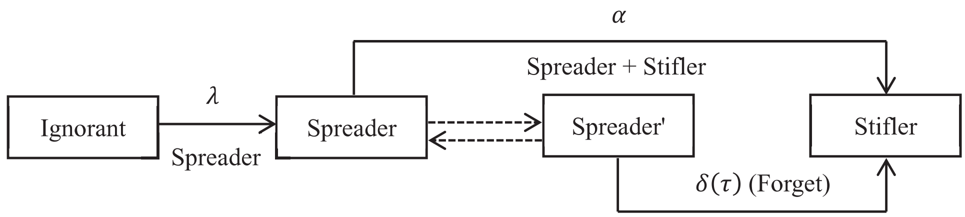

Fig. 1. Structure of the rumor spreading process.

and found the existence of the critical threshold for rumor spreading. Moreno et al. [13] examined the dynamics of rumor spreading on scale-free networks. Isham et al. [14] analyzed the final distribution size of rumors on general networks.

In both the DK and MT models, stifling is assumed to be the only way for the rumor to die out. In reality, however, spreaders may forget to spread the rumor or choose not to spread it anymore because of losing interest. This can also lead to the cessation of rumor. Nekovee et al. [15] modified the spreader–ignorant–stifler (SIR) rumor spreading model to take into account the forgetting mechanism and used the mean-field equations to examine the threshold and dynamics of rumor spreading in different networks. Zhao et al. [16] provided a detailed description of rumor spreading processes considering the forgetting mechanism in a SIR model. They applied the model to an online social blogging platform called LiveJournal. Zhao et al. [17] then went on to refine the SIR model by considering forgetting and remembering mechanisms, creating the so-called SIHR model. They also studied the dynamics of rumor spreading in homogeneous networks. Based on the model of Nekovee et al. [15], Roshani and Naimi [18] proposed a generalized rumor spreading model and investigated rumor spreading on scale-free networks.

In most of the previous studies [15–18], the forgetting rate is considered as a constant. However, in reality, the longer one holds a rumor, the easier s/he tends to forget it. Hence, the forgetting mechanism shows a strong time-dependency. Wei et al. [19] and Gu et al. [20] introduced forget and remember mechanisms in a two-state (holding message or being out of message) model called the SI model and suggested two functional forms (linear and exponential) for the forget and remember function. They analyzed the effects of message spreading on a BA scale-free network using numerical simulation and showed that the forget–remember mechanism could result in a termination of dissemination. However, in their model only two types of individuals (spreader, ignorant) were considered.

In this paper, we study rumor spreading modeling with variable forgetting rate as a function depending on time, which is more in line with reality. The rest of this paper is organized as follows. The rumor spreading model with forgetting rate varying over time in small-world networks is first described in Section 2, with the mean-field equations also derived in the same section. Then numerical solutions on the dynamics of the established model are carried out on an online social blogging platform called LiveJournal in Section 3. Finally, conclusions are drawn in Section 4.

2. A rumor spreading model with variable forgetting rate

We investigate the rumor spreading model in small-world networks, which is a category of homogeneous network [21]. In homogeneous networks there are no degree correlations and the degree fluctuations are very small [15]. The degree distribution of small-world networks approximately obeys a Poisson distribution, which peaks at the average value and then decays exponentially. The small-world network is first proposed by Watts and Strogatz, which interpolates between low-dimension lattice and random graph and shows both the clustering and small-world properties [22]. Let's consider a small-world network of N individuals mixing three different states, namely ignorant, spreader and stifler. We assume that the rumor spreading process moves forward through direct contacts between spreaders and other individuals. We refer to this small-world network as an undirected social interaction network $G = (V, E)$, where V and E are a set of vertices and edges respectively.

As shown in Fig. 1, Ignorants are those who have never heard of the rumor and can be easily infected by the rumor. Spreaders refer to individuals who have got the rumor and pass it on to others. Stiflers comprise individuals who have heard of the rumor but will not spread it to others any more. The rules of rumor spreading are defined as the following. Once a spreader contacts an ignorant, the ignorant turns into a spreader with probability λ. When a spreader contacts another spreader or a stifler, the initial one becomes a stifler with probability α. On the other hand, the spreader can also spontaneously forget the rumor and switch his state to a stifler with forgetting rate $\delta(\tau)$, which is a function depending on the history time τ since the individual became a spreader.

Spreader' in the spreading process represents a temporary state that a spreader maintains if s/he does not meet other spreaders (or stiflers) or does not transform into a stifler by contacting them. We assume that the process from one spreader to one spreader' is instantaneous, taking zero or negligible time. As discussed earlier, a spreader' may forget the rumor or lose interest in it, and then transforms to a stifler, otherwise s/he will turn back into a spreader. We denote the proportions of spreaders, ignorants and stiflers within the network at time t by $S(t)$, $I(t)$ and $R(t)$, respectively. Also, we denote the proportions of spreaders, ignorants and stiflers with degree k at time t by $S_k(t)$, $I_k(t)$ and $R_k(t)$, respectively. We can derive that $S(t) = \sum_k S_k(t)P(k)$, where $P(k)$ is the degree distribution, and so do $I(t)$ and $R(t)$. There are two obvious constraints that $S(t) + I(t) + R(t) = 1$ and $S_k(t) + I_k(t) + R_k(t) = 1$.