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Energy model for rumor propagation on social networks

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HIGHLIGHTS

- We propose a novel model for rumor propagation based on physical theory.
- The proposed model shows rumor propagation experiences three evolutionary stages.
- We investigate why some weakening rumors can experience resurgence.
- The proposed model shows different people have different effects on rumor propagation.
- We study the impacts of some influencing factors on the dynamics of rumor propagation.

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ABSTRACT

With the development of social networks, the impact of rumor propagation on human lives is more and more significant. Due to the change of propagation mode, traditional rumor propagation models designed for word-of-mouth process may not be suitable for describing the rumor spreading on social networks. To overcome this shortcoming, we carefully analyze the mechanisms of rumor propagation and the topological properties of large-scale social networks, then propose a novel model based on the physical theory. In this model, heat energy calculation formula and Metropolis rule are introduced to formalize this problem and the amount of heat energy is used to measure a rumor's impact on a network. Finally, we conduct track experiments to show the evolution of rumor propagation, make comparison experiments to contrast the proposed model with the traditional models, and perform simulation experiments to study the dynamics of rumor spreading. The experiments show that (1) the rumor propagation simulated by our model goes through three stages: rapid growth, fluctuant persistence and slow decline; (2) individuals could spread a rumor repeatedly, which leads to the rumor's resurgence; (3) rumor propagation is greatly influenced by a rumor's attraction, the initial rumormonger and the sending probability.

1. Introduction

A rumor, as a form of social communication, widely exists in human lives. As it always involves influential events such as political and economic issues or public figures, a rumor can easily shape public opinion, cause panic, harm others and has significant impacts on society. For example, last year, there was a rumor that the earth would experience three days of darkness during the end of the world spreading in some districts of China. Some people believed it and stocked up on candles, which led to a temporary supply shortage of candles. Traditionally, a rumor spreads by word of mouth. However,

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as information technology develops, computer-mediated communication is becoming a major method of information dissemination. There are some new characteristics of rumor propagation emerging on social networks such as fast velocity, wide extent and being liable to repetition, that bring new challenges to this problem.

Rumor propagation has attracted close attention from many researchers and there are several classical models on it found in the literature. Since rumor spreading could be regarded as a social contagion process [1], early scholars borrowed epidemic models to describe this phenomenon [2–4]. However, epidemic models are not specially designed for rumor propagation and the mean-field rate equations are too simple to depict its complex evolution accurately. Subsequently, Zhao et al. improved epidemic models and applied them to rumor spreading on social networks [5,6]. Nonetheless, they still did not overcome the natural flaws of epidemic models. Galam proposed a novel model called Galam's Model to simulate rumor propagation [7], and then Ellero et al. introduced a new scheme to improve Galam's Model [8]. Nevertheless, these models are confined to word-of-mouth information exchanging and are not suitable for describing rumor spreading on large-scale social networks. Zhang et al. investigated the interplay between rumor propagation and emergency development [9–11]. However, their work focused on studying the strategy to minimize negative impacts of rumor propagation instead of modeling the evolution.

Reviewing the existing work, we find that the mechanisms of rumor propagation in most of the current models are designed by macromethod but are lacking in the following important details. Firstly, a rumor's attraction to people always presents a downtrend and such a characteristic should be described in the model. Secondly, different individuals have different capabilities to transmit a rumor to others. In large-scale networks, high-degree nodes usually have more authority to influence other nodes [12]. Thirdly, the probability that an individual transmits a rumor to others is not constant. When people first hear a rumor, they actively share it with others. However, as people lose interest in the rumor gradually, the transmit probability correspondingly decreases. Based on these observations, we analyze this problem from five aspects, including the characteristics of a rumor, the impact of a rumor on an individual, the accumulation of an individual's energy, the impact of a rumor on a network and the rules of rumor transmission. Along this line, we introduce the physical theory to analogize and formalize rumor propagation. Specifically, we find a rumor's influence involves three factors, i.e. the rumor's attraction, the infected individual's authority and the infected individual's discriminability of the rumor. Then we adopt the heat energy calculation to formalize their relationship. We also use a simulated annealing schedule to describe the characteristics of a rumor and apply the property of Metropolis rule to formulate the rumor transmit probability. Finally we integrate these physical theories to propose a novel model called the Energy Model for simulating rumor propagation. In addition, we systemically conduct experiments on both synthetic and real-world data sets to evaluate the performance of the proposed model for simulating rumor spreading and investigate the dynamics of rumor propagation.

The rest of the paper is organized as follows. In Section 2, we state the problem and introduce some preliminary knowledge related to our work. In Section 3, we expound our model including the design methodology and algorithmic details. In Section 4, we perform experiments on both synthetic data sets and real data sets to visualize the evolution of rumor propagation and study its dynamic characteristics. Finally we conclude this paper in Section 5.

2. Problem statement and preliminary knowledge

To better understand the proposed model and comprehend how we apply the physical theory to analogize and formalize rumor propagation, we introduce the problem statement and preliminary knowledge here.

2.1. Problem statement

The problem statement of rumor propagation could usually be defined as follows [13]. Consider a population formed by N individuals where some of them may have closed relationships and each individual can be in one of three different possible states: an ignoramus who has not yet heard the rumor, a spreader who is trying to spread the rumor to his neighbors, a stifler who no longer believes or spreads the rumor. Initially, only one individual is a rumormonger and the remainder are ignoramuses. And in the subsequent time steps, the rumor spreads in the network by some certain mechanisms. Our work is to build a model to simulate this phenomenon and discuss its dynamic characteristics.

2.2. Preliminary knowledge

2.2.1. Heat energy calculation

Substances absorb or release thermal energy when the temperature of surrounding changes. In physics, the amount of heat energy transfer is determined by three factors, i.e., mass, heat capacity and temperature change. Their relationship is defined by heat calculation formula as follows.

$$\Delta E = cm\Delta T, \tag{1}$$

where ΔE is the amount of heat energy transfer, m is mass, c is heat capacity and ΔT is temperature change.

In this paper, we use the analogy that rumors bringing effects to individuals is similar to substances absorbing or releasing thermal energy. Their correlation and how we incorporate heat energy calculation into the proposed model will be detailed in Section 3.