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Role of propagation thresholds in sentiment-based model of opinion evolution with information diffusion

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HIGHLIGHTS

- Propose a model to study opinion dynamics with information diffusion.
- Two sentiment-based propagation thresholds are introduced.
- Large infected threshold restrains information diffusion and weakens the extremism.
- Large refractory threshold facilitates decision exchange and promotes the extremism.

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ABSTRACT

The degree of sentiment is the key factor for internet users in determining their propagating behaviors, i.e. whether participating in a discussion and whether withdrawing from a discussion. For this end, we introduce two sentiment-based propagation thresholds (i.e. infected threshold and refractory threshold) and propose an interacting model based on the Bayesian updating rules. Our model describe the phenomena that few internet users change their decisions and that someone has drop out of discussion about the topic when some others are just aware of it. Numerical simulations show that, large infected threshold restrains information diffusion but favors the lessening of extremism, while large refractory threshold facilitates decision interaction but promotes the extremism. Making netizens calm down and propagate information sanely can restrain the prevailing of extremism about rumors.

1. Introduction

During the last years, there has been a great interest in the study of how human behavior forms large-scale phenomena in a society, such as culture dynamics [1,2], language formation [3,4], crowd behavior [5,6], information or rumor propagation [7,8], and opinion evolution [9–12]. The primary problem is, understanding the laws that the macroscopic global evolution and convergence are nontrivially affected by the interaction of a large number of microscopic simple elements [13]. Among these interesting problems, information propagation and opinion evolution are always treated as two independent processes.

Opinion dynamics is an attempt at describing how agents choose interacting peers to exchange opinions and how they persuade each other. The models generally suppose that all agents know about the topic or event at the beginning, and have

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initial attitudes toward it. There are many paradigmatic models to reflect opinion formation. From the way opinion variables are defined, the main investigations can be divided into two groups: discrete opinion models [14–17] and continuous opinion models [18–20]. The former, e.g. Sznajd model [14,15] and Voter model [16], are used to describe situations when people must make a choices between two answers on a certain topic, e.g. yes/no, left/right, and adopt/reject. While the latter, e.g. Deffuant model [18] and Hegselmann–Krause model [19], can explain cases in which individual's opinion can vary smoothly from one extreme to the other, e.g. political orientation of an individual, inclination to a choice.

Comparing with the hypothesis of opinion dynamics, i.e. all agents knowing about the topic in advance, information propagation focuses on the spreading process across all the agents. Generally, research on information diffusion is inspired by epidemic dynamics, i.e. investigating how disease infected across populations. The most classical models are susceptible–infected (SI) model [21], susceptible–infected–susceptible (SIS) model [22], susceptible–infected–refractory (SIR) model [23], and susceptible–exposed–infected–refractory (SEIR) model [24]. SI model defines that susceptible agents can be infected with a given probability by infected neighbors to be new infectors. It means that, all the agents would be infectors in the end of evolution. SIS model make infectors have a probability to recover to susceptible ones. SIR model introduced refractory state, with which agents have immunity and cannot be infected again. SEIR model take exposed state into model, in which, susceptible agents has been infected but cannot infect other susceptible ones during a latent period. These classical epidemic dynamics models are extensively used on research of rumor diffusion and innovation propagation. The feasibility of applying individual-based epidemic models to topic diffusion was demonstrated in Ref. [25], due to the better fit between modified SI and SEI model and empirical data. For characterizing information propagation on online microblogs, contacted state was introduced to indicate the state in which people know the rumor but have not transmitted it [26]. Ref. [27] considered the joint strength between agents, which represents the degree of closeness of relationship, and made the traditional constant infection factor be a function of joint strength. Ref. [28] surveyed the research output on innovation diffusion, and divide agents into two kinds, innovators and imitators.

Information diffusion defines simple differential-equation-based compartmental model to mimic information propagation process, while they are limited in their capability to capture heterogeneities at the microscopic level and in the interaction between individual agents. Opinion dynamics can mimic microscopic interaction and opinion evolution, but ignore the process of contacting the topic initially. However, topic evolution is nonlinear combination of micro-process that every person experiences, from knowing about a topic to having a definite personal attitude on it, in online social network. Generally, a topic is known about by only a few people, and these people have different opinions on it because of respective standpoint. The sentiment of some of these people becomes so extreme over time that they issue their opinions on topic on the internet. Thus the diffusion process of topic begins. At the same time, there are interactions between two persons who have known this topic. They often exchange opinions with each other, and try to persuade the other one. Thus, process of opinion evolution continues, and topic evolution becomes a combination process of information diffusion and opinion exchange. These two processes are interacted on each other, i.e. the speed of information diffusion determines the speed of opinion convergence, and the extremeness of opinion determines whether to publish attitude about this topic. Ref. [10] proposed a three-state opinion model accompanied by information diffusion, in which latent agents become infected with a probability and infected agents become refractory ones with another probability. The probability model is oversimplified, neglecting the effects of agents sentiment on information diffusion and opinion interaction.

The goal of the present paper is to suggest a sentiment-based model with information diffusion and opinion interaction to study this problem, and understand its implications. Luckily, considering the asymmetry between internal opinion (sentiment) and external decision, the Continuous Opinions and Discrete Actions (CODA) model was proposed [29]. It presents a more accurate description of emergence of extremism, and proposes intriguing mathematical updating rules on the basis of Bayesian decision theory, according which agents vary both their internal opinions and external decisions based on the observation of their peers decisions. Its model variations have been proved equivalent to the continuous models [30] as well as a general case to the discrete models [31]. In view of that, we propose an opinion dynamics model based on CODA model, in which topic evolution is a combination process of information diffusion and opinion exchange, and investigate the effects of sentiment on information diffusion and opinion interaction.

This paper is organized as follows. In the next section, we present a new sentiment-based model with information diffusion and opinion interaction. Section 3 is devoted to study the consequences of extreme degree of sentiment on the behavior of the model in a square lattice. Finally, we sum up and draw our conclusions in Section 4.

2. Model

As in most opinion models, agents are postulated to have their opinions initially, and update their opinions following a series of rules by exchanging information about their opinions. However, a popular topic is always aroused by a small percentage of people. The usual process is as follows: Initially, some witnesses or parties declare themselves on the internet due to slightly extreme attitudes. Then, the information with opinions about this topic is propagated, and this topic is known about by most people. In general, people do not have extreme attitude on most types of topics at first. Instead, they often have a fuzzy view with a little polarity, and the extremism is the consequences of local reinforcement of people with same decisions. When the attitude or sentiment is polarized to a certain extent, people will deliver their decisions trying to persuade others. Thus, the information of topic is further spread and become popular. As time goes on, the extremism of people is continuously enhanced and is so polarized that, people think it meaningless to continue discussing about this topic