Noised Diffusion Dynamics with Individual Biased Opinion

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Abstract. In online social network, the personal information dissemination behavior is reported to be affected by the clash of social individuals' biased opinions. In this paper, we present a model to discuss the influence of individual biased opinion on diffusion dynamics. Based on multi-agent simulations, we obtain some conclusions which are helpful for recommender systems and in controlling diffusion. In addition, our study offers potential avenues for the study of diffusion dynamics with personal biases.

1 INTRODUCTION

The issue of modeling and analyzing diffusion dynamics in social networks has been extensively studied in the last few decades [1-3]. Recently, many studies have focused on the noised diffusion dynamics in which the state transitions and interactions between agents are interfered by many uncertain elements [4]. Generally, structural uncertainty [4] and input of multiple entities [5] are the two main aspects of noise involved in most previous studies. However, it is ubiquitous that people disseminate information combining with their opinions in online social networks, such as the comments about tastes in music or movie [6]. These individual biased opinions can also affect the diffusion dynamics. For example, the similarity between individuals' opinions helps to induce the behaviors of dissemination, which is evident from some studies in statistical physics [6]. What's more, individual may adjust his/her opinion through the biased assimilation of the viewpoints of interacted acquaintances in the diffusion process [6, 7]. As the differences between individuals' opinions widely exist, those varied opinions can be considered as noise when someone receives the information. Thus, it is essential to investigate the diffusion dynamics with individual biased opinion. However, few studies have analyzed the issue.

In this paper, we develop a model of noised diffusion dynamics by extending the independent cascade model with the modifications of diffusion probability and opinion. We perform multi-agent simulations to analyze the timely process and final state of the diffusion dynamic.

2 THE MODEL

2.1 Noised diffusion model

Our model is based on the independent cascade (IC) model which has been widely used in past studies [4]. Let $G = (N, E)$ be a social network and every node in G is considered as an agent. Let $X_i(t)$ denote the state of agent i at discrete time t. Then, we have

$$X_i(t) = \begin{cases} 0, \text{not infected} \\ 1, \text{infected} \end{cases}. \quad (1)$$

Here, $X_i(t) = 0$ means that agent i has not received the information or does not perform dissemination behavior after receiving. Correspondingly, $X_i(t) = 1$ denotes that agent i diffuses the information. Every infected agent tries to infect its neighbors only once with probability p_0 at the next time step after being infected.

Each infected agent diffuses not only the information, but also its opinion on the information. Let $S_0(i) \in [0, 1]$ denote agent i's "initial opinion" on the information, and then, let $S(i) \in [0, 1]$ represent the "modified opinion" which is expressed by agent i to its neighbors. Here, 0 and 1 denote opposite extreme opinions. $S(i)$ is based on $S_0(i)$ and the opinions expressed by the agents who infect agent i.

Then, we define the influence of biased opinions on diffusion probability. Agent i infects agent j with probability $p_{i,j}$ which is given by

$$p_{i,j} = p_0 e^{-|S(i)-S_0(j)|+\theta}. \quad (2)$$

Here, θ is a factor which is used to adjust the diffusion probability [8]. This equation means that information is more easily transmitted between the agents of the same camp.

Next, the modified opinion $S(i)$ is given. Let A_i denote the set of agents which can influence $S(i)$, and A_i is Φ initially. Agent j would be added to A_i if it infects agent i with $p_{j,i}$ successfully. Then, we have

$$S(i) = \alpha S_0(i) + (1-\alpha)[\tfrac{1}{|A_i|}\textstyle\sum_{node\ j \in A_i} S(j)]. \quad (3)$$

Here, $\alpha \in [0, 1]$ is a weight that represents the bias with which agent assimilates its neighbors' opinions [7]. This equation means that agent does not assimilate others' opinions at all if $\alpha = 1$. On the contrary, agent follows its neighbors completely when $\alpha = 0$.

2.2 A simple case analysis

A simple case of noised diffusion dynamics with individual biased opinion is shown in Figure 1. The agent a_1's modified opinion ($S(1) = 1$) is quite different with a_2's initial opinion ($S_0(2) = 0$), so the infection is failed. At next time step, a_3 infects a_2 successfully because of similar opinions. After being infected, a_2 tries to infect a_4. The agent a_2 modifies its initial opinion ($S_0(2) =$

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0 and $S(2) = 0.1$) according to a_3's modified opinion ($S(3) = 0.2$). Here, $\alpha = 0.5$.

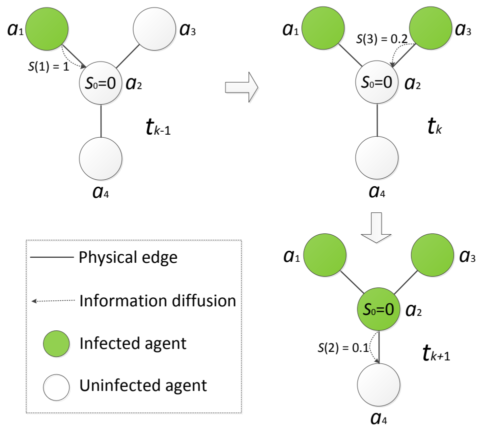

Figure 1. A simple case of diffusion process.

3 SIMULATIONS AND CONCLUSIONS

The simulations are based on a random network [9] with 10000 agents. Besides, the average degree $\bar{d} = 10$. The basic probability p_0 is set as 0.1 and the adjustment factor θ of probability is 1. Each trial is performed with 1000 replications. Meanwhile, only one agent is randomly chosen to be the initial infected agent every round. Because the noise is generated by initial opinions S_0 and the assimilation of noise is adjusted by bias weight α, the influences of S_0 with different distributions and α are analyzed principally.

It is assumed that all the agents have same α which is varied from 0 to 1. Besides, S_0 obeys four distributions [10] [11] which denote four typical states of social opinions. Here, $x \in [0, 1]$:

(i) Uniform distribution: $f_{S_0}(x) = 1$.

(ii) Normal distribution: $f_{S_0}(x) = \frac{10}{\sqrt{2\pi}} e^{-50(x-\frac{1}{2})^2}$.

(iii) Anti-normal distribution: $f_{S_0}(x) = \begin{cases} \frac{10}{\sqrt{2\pi}} e^{-50x^2} & , x < 0.5 \\ \frac{10}{\sqrt{2\pi}} e^{-50(x-1)^2} & , x \geq 0.5 \end{cases}$.

(iv) Truncated normal distribution: $f_{S_0}(x) = \frac{10}{\sqrt{2\pi}} e^{-12.5x^2}$.

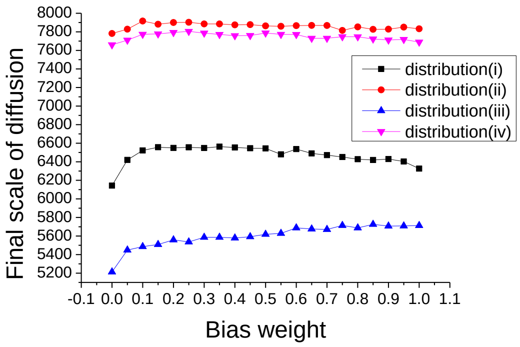

Figure 2. The final scale of diffusion with varied bias weight α. Here, S_0 obeys four distributions.

As shown in Figure 2, the scale of diffusion would be large if most individuals hold similar opinions (S_0 obeys distribution (ii)). Moreover, fewer individuals would perform dissemination behaviors in the case that most individuals completely follow the herd without insisting initial biased opinions ($\alpha = 0$). This situation can also represent that nobody but the initial communicator is allowed to express personal opinion. What's more, part assimilation of others' opinions can facilitate diffusion when most individuals initially hold convergent opinions ($\alpha = 0.2$ and S_0 obeys distribution (i) (ii) or (iv)). Oppositely, the modification of initial opinion according to acquaintances decreases the scale of diffusion if the initial opinions is polarized in social networks (S_0 obeys distribution (iii)).

These conclusions can help develop strategies to control the information spreading in online social networks. For instance, banning users from making comments may inhibit the spread of information. Generally, encouraging individuals to partly assimilate others' opinions can facilitate diffusion processes when many people hold similar opinions initially. For the internet-based recommender system, more buying behaviors may be induced if selected biased comments are post according to clients' biased preferences on product attributes.

In addition, some real-field studies report the co-evolution of network structure and individual biased opinion. Therefore, the present study offers potential avenues for the study of noised diffusion dynamics with structural uncertainty and biased opinion. It is hoped that our work will contribute to the issue of diffusion dynamics in social networks.

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