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Controllable uncertain opinion diffusion under confidence bound and unpredicted diffusion probability

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HIGHLIGHTS

- The diffusion probability is modified according to the distance between the opinions of interacted nodes.
- An optimization problem and suitable algorithm to show how to control the uncertain diffusion process.
- The performances of traditional influence maximization algorithms are often worse than that of random selection in this optimization problem.
- Reason of that the traditional influence maximization algorithms are not applicable to this problem.

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ABSTRACT

The issues of modeling and analyzing diffusion in social networks have been extensively studied in the last few decades. Recently, many studies focus on uncertain diffusion process. The uncertainty of diffusion process means that the diffusion probability is unpredicted because of some complex factors. For instance, the variety of individuals' opinions is an important factor that can cause uncertainty of diffusion probability. In detail, the difference between opinions can influence the diffusion probability, and then the evolution of opinions will cause the uncertainty of diffusion probability. It is known that controlling the diffusion process is important in the context of viral marketing and political propaganda. However, previous methods are hardly feasible to control the uncertain diffusion process of individual opinion. In this paper, we present suitable strategy to control this diffusion process based on the approximate estimation of the uncertain factors. We formulate a model in which the diffusion probability is influenced by the distance between opinions, and briefly discuss the properties of the diffusion model. Then, we present an optimization problem at the background of voting to show how to control this uncertain diffusion process. In detail, it is assumed that each individual can choose one of the two candidates or abstention based on his/her opinion. Then, we present strategy to set suitable initiators and their opinions so that the advantage of one candidate will be maximized at the end of diffusion. The results show that traditional influence maximization algorithms are not applicable to this problem, and our algorithm can achieve expected performance.

1. Introduction

Previous studies have modeled and analyzed various diffusion processes in social networks [1–6]. Generally, each node in social network is assumed to associate with the binary states-active or inactive. The state of a node may be switched

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based on some rules in the diffusion process. Among the models with different rules, the independent cascade model [3,7] is one of the models that are used the most widely in diffusion analyses. In the independent cascade model, the state of a node is switched based on a probability, and each activation process is independent of others. In various cases, the diffusion probability may be constant [7] or variable [8,9].

Recently, more and more studies have focused on the uncertain diffusion process. The uncertainty of diffusion process means that the diffusion probability is unpredicted because of some complex factors. Previous study has shown that the variety of individuals' opinions is an important factor that can cause uncertainty of diffusion probability [5]. In detail, when someone receives information from others who hold similar opinions with him/her, he/she will be more likely to perform the dissemination behavior [10–12]. Besides, it has been known that opinions can evolve as individuals are reported to assimilate the viewpoints of interacted people [10,13]. Therefore, the diffusion probability becomes uncertain because of the opinion evolution.

Individuals express their opinions in online social networks frequently, such as the tastes in music or movie [10,13], the comments about innovations of product [14,15], and attitudes to the advertisements of candidate [16]. Therefore, these may be various diffusion processes of these opinions in social networks. It means that controlling these uncertain opinion diffusion processes is very important in the context of viral marketing [17] and political propaganda [16]. However, previous studies of opinion [13,18–20] just focus on how opinions evolve to the consensus or the polarization states. These studies usually discuss the influence of network structure, nodal degree or the evolution rules of opinion. As these factors are almost uncontrollable, it is costly or hardly feasible to control the diffusion process based on the conclusions obtained in these studies.

In this paper, in order to control the uncertain opinion diffusion, we discuss this diffusion process and develop feasible strategy to control this diffusion process based on the approximate estimation of the uncertain factors.

1.1. Motivation and contributions

In this paper, we raise the issue of controlling the uncertain opinion diffusion process. In order to show how to control the diffusion process, we present a diffusion model in which the diffusion probability is modified according to the distance between the opinions of interacted nodes. Moreover, each node which is exposed to the information can adjust its opinion depending on the assimilation of others' opinions.

In detail, our contributions can be divided into two aspects:

- First, based on theoretical analyses and simulations, we briefly discuss the properties of the diffusion model in which the diffusion probability is influenced by the distance between opinions. Some conclusions are obtained and helpful in developing strategy to control the diffusion process.
- Second, we present an optimization problem to show how to control the uncertain diffusion process. In detail, we model a voting mechanism in which each node can choose one of the two candidates or abstention based on its opinion. Then, we present suitable strategy to maximize the advantage of one candidate by setting suitable initiators and their opinions in the diffusion process.

This paper is organized as follows. In Section 2, we briefly introduce the related work. Section 3 presents our diffusion model, including the definition of individual opinion, the modification of diffusion probability, and the evolution rule of opinions. In Section 4, we show the properties of the diffusion model, such as how wide the initiator's opinion can spread under different initial distributions of opinions. Then, an optimization problem is provided in Section 5. Finally, we conclude this paper in Section 6.

2. Related works

2.1. Uncertain diffusion process

Many studies have focused on the diffusion process in which the diffusion probability is uncertain. For instance, structural uncertainty [3,21–23], input of multiple entities [8,9,24,25] and the variety of individuals' opinions [5] are three factors that can cause the uncertainty of diffusion probability in previous studies. Adiga et al. [3] raise the issue of diffusion process interfered by structural uncertainty. The structural uncertainty is generally modeled by rewiring edges in the networks [3,21]. Additionally, Adiga et al. [3] mathematically investigate the sensitivity of diffusion process to the structural uncertainty. They also predicted the scales of information spreading affected by the different extents of perturbation. On the other hand, the spreading of multiple entities in social networks is another interference factor to diffusion probability. For instance, two competing diseases are introduced, and being infected by one disease gives a node partial or complete immunity to another [24]. By analyzing the empirical data of multiple contagions in Twitter, Myers and Leskovec reported the great effects of interaction between cooperating and competing information on spreading probabilities [25]. In addition, the variety of individuals' opinions is also an important factor that can cause uncertainty of diffusion probability [5]. The distance between the opinions of interacted nodes can influence the diffusion probability, and the evolution of opinions