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A novel opinion dynamics model based on expanded observation ranges and individuals' social influences in social networks

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HIGHLIGHTS

- A model to study the dynamics of the opinion evolution process is proposed.
- The observation range of an individual is expanded, and an affected individual receives social impact from supporter and opponent participants.
- A tradeoff of relaxation time can be found between high interaction intensity and low stability.
- Social influence is introduced to highlight the heterogeneity of individuals.
- The distribution of individuals' social influences when convergence is reached is the power-law.

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ABSTRACT

In this paper, we propose an opinion dynamics model in order to investigate opinion evolution and interactions and the behavior of individuals. By introducing social influence and its feedback mechanism, the proposed model can highlight the heterogeneity of individuals and reproduce realistic online opinion interactions. It can also expand the observation range of affected individuals. Combining psychological studies on the social impact of majorities and minorities, affected individuals update their opinions by balancing social impact from both supporters and opponents. It can be seen that complete consensus is not always obtained. When the initial density of either side is greater than 0.8, the enormous imbalance leads to complete consensus. Otherwise, opinion clusters consisting of a set of tightly connected individuals who hold similar opinions appear. Moreover, a tradeoff is discovered between high interaction intensity and low stability with regard to observation ranges. The intensity of each interaction is negatively correlated with observation range, while the stability of each individual's opinion positively affects the correlation. Furthermore, the proposed model presents the power-law properties in the distribution of individuals' social influences, which is in agreement with people's daily cognition. Additionally, it is proven that the initial distribution of individuals' social influences has little effect on the evolution.

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1. Introduction

In recent years, social network services have become the most significant medium for information sharing and dissemination. Many researchers, including statistical physicists and sociophysicists, have made significant contributions to this field. By using theoretical models and experimental methods, sociological phenomena, such as information diffusion and opinion evolution, have been elaborated and analyzed [1–3], and the idea and concept of interdisciplinary research, such as the combination of complex networks, statistical physics, and evolutionary games, have been adopted and applied [4–7].

Opinion dynamics [1,8,9] is one of the most effective methods to model the spread and evolution of opinions in a multi-agent society by using the Monte Carlo simulation method. Each individual is considered to be an agent holding continuous or discrete opinions in favor of one decision or choice, and each individual interacts with others and tries to persuade or impact others dynamically through his/her opinion.

Several opinion dynamics models have been proposed and can be classified into three main groups: (1) discrete opinions models; (2) continuous opinions models; and (3) continuous opinions and discrete actions models (CODA model). The Sznajd model [10,11] and voter model [12,13] are the most significant representations of discrete opinion models, in which individuals hold binary opinions using Ising spins [14], which are used to model ferromagnetism with ferromagnetic spins in solid-state physics. The generalization, improvement, and applications are further studied in Refs. [13,15–18]. Moreover, the innovative diffusion model combining benefit-driven evolutionary games and discrete behaviors has been proposed to investigate the dynamics of human innovative behaviors [19]. In the second group, the Deffuant model [20] and Hegselmann–Krause model [21] use continuous opinions to evaluate the performances of agents. Continuous opinions are able to quantify the desire of a specified choice for each individual. In the final group, however, each agent shows his/her discrete behavior and carries a continuous opinion updated by observing others' discrete actions [22–24]. The CODA model is a more realistic model and has been attracting increasing attention [25–29]. By differentiating between opinions and actions, the update rule of CODA allows the agents to rationally analyze the observations and their own situations, instead of simply following a flip and follow pattern with no memories. The effect of selective attention, which is described by individual relevance and time-openness, is studied to improve the interactions and updating of individuals' opinions [25]. Selective attention provides a possible explanation for the appearance of large clusters consisting of a set of tightly connected individuals who hold similar opinions. A joint evolution of opinions and trust among individuals is introduced in Ref. [27]. A bounded confidence mechanism and distant observation are introduced by opinion diffusion models in Refs. [21,29–31]. To implement Bayesian posterior estimation, however, the confidence associated with the behaviors of neighbors who represent the degree of being affected is presumed to be constant. This is somehow oversimplified. It appears that individuals in a social network are heterogeneous [32].

As a model of online opinion dynamics, update rules and evolution should take the reproduction and reflection of realistic social phenomenon into primary consideration. The distinction among update rules has the potential to bring out different perspectives and emphases. Many studies are focused on opinion interactions between neighbors, where individuals change their opinions by comparing the differences among each other. However, the process of persuasion and interaction between two adjacent neighbors is overemphasized in many models [11,17,19,28]. In contrast, individuals are more likely to take a wider perspective of their surroundings. Despite the possibly vital role of a certain opinion leader, individuals are inclined to join a discussion of several people and to accept the impact of not only conversion from differences but also enhancement from similarities.

In this paper, an opinion dynamics model considering the social influence, feedback, and accumulation of each individual is proposed by combining psychological studies on the social impact of majorities and minorities [33]. Unlike the classic models mentioned above where an individual is affected by one specified adjacent neighbor, each individual in the proposed model observes the behavior of a number of individuals before he/she updates his/her opinion and makes a decision. Moreover, the persuasion from the opposing sides are accepted and can affect the final decision, and the influence of each persuader and its closeness to the affected individual are taken into consideration in distinguishing the impact of different persuaders. In this paper, we study opinion evolution by using the proposed model. From the perspective of opinion evolution, a complete consensus is not always obtained according to the density of individuals' initial behaviors. When the initial density of either side is greater than 0.8, the enormous imbalance leads to complete consensus. In other circumstances, opinion clusters consisting of a set of tightly connected individuals who hold similar opinions appear. The impact of the observation range and individuals' social influence are analyzed. It can be seen that the observation range of individuals is significantly related to the interaction intensity and opinion stability. Both interaction intensity and opinion stability can speed up the evolution process. Extensive simulations and analysis show that the interaction intensity decreases as the observation range of individuals increases, while the opinion stability increases. Moreover, the stability tends to stabilize when the observation range is large enough. Therefore, a tradeoff between high interaction intensity and low stability is exposed. In addition to the observation range, the social influence of individuals plays a major role in the dynamics of diffusion. When opinion evolution reaches convergence, the distribution of individuals' social influence follows the power-law; however, the initial distribution of individuals' social influence has little effect on opinion evolution.

2. Proposed model

To investigate opinion evolution and the diffusion of individuals clearly and distinctly, the proposed model is simplified on some reasonable bases. When facing a certain isolated question, each individual chooses between binary strategies:

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