Group Opinion Evolution Model and Analysis Based on Heterogeneous Individuals

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Abstract—**The occurrence of emergencies and hot events often becomes the focus of attention in a short period of time, which brings massive Internet public opinions. How to correctly understand the mechanism of public opinion evolution is of great significance for ensuring objective public opinion orientation. In this paper, we build an opinion evolution model of heterogeneous individuals, combined with the interaction process of user opinions in the real network. Through simulation experiments, we discuss the impact of various parameters and different cases. The results show that compared with the same trust threshold, it is more difficult for the whole group to reach consensus when the trust threshold is different; the acceptance of opinion can have a significant effect on the number of opinion clusters and the convergence time; heterogeneity in individuals will promote better aggregation of group opinions. This model can explain more conscious opinion evolution in real life and has a significance that effectively guides public opinion.**

Keywords-opinion evolution; public opinion; individual opinion; bounded trust

I. INTRODUCTION

With the development of Internet technology and the advent of the new media era, the attributes of media have changed. Social media platforms based on Weibo and WeChat have been the main positions for information diffusion on the Internet. The doubling of the number of netizens has enabled more and more users to truly have the right to speak, subverting the principle of traditional media's dominance. In this open network environment, social hot topics and emergencies will become the focus of people's attention in a short period of time, and it is often easy to arouse public opinion on the Internet. Therefore, the formation and evolution of research opinions can help to analyze the evolution of public opinion and understand various processes. The essence of similar opinions is of great significance to explain the evolutionary rules of micro-individuals to form the behavior of public opinion in macro-groups.

As an important direction of social dynamics research, opinion dynamics on complex networks mainly studies the interaction between different opinions among individuals in social groups, the evolution of public opinion, and the process of consensus reaching opinions. The study of opinion dynamics has attracted widespread attention from scholars in many fields including statistical physics, applied mathematics, psychology [1], economics [2], sociology [3], and so on. Various theoretical methods, such as statistical physics methods and non-linear science, are used to explore a series of macro phenomena caused by the changing rules of opinions of micro individuals in complex networks. Opinion dynamics [4] is an important research direction for the study of social group dynamics. In recent years, researchers in various fields have proposed many classic opinion dynamic models, which can be divided according to the discreteness or continuity of opinion values to the discrete opinion model and the continuous opinion model [5]. The discrete opinion models use discrete values to represent the individual's opinion value, which are often used to describe situations in which individuals hold approval or disapproval of an event, and can also be used to describe situations where there are more than two limited opinions. The classic models are the Ising model [6], the Sznajd model [7], the voter model [8], the majority principle model [9], social influence model [10], etc. However, in actual society, individuals' opinions on events are not only a few points of opinion, and there may be a lot of changes. Therefore, continuous opinion models use continuous values to represent opinion values. The representative models are based on the bounded trust: Deffuant model [11] and the Hegselmann-Krause model [12].

In this paper, we start from the opinion of complex networks and construct a heterogeneous individual opinion evolution model based on a bounded trust model. The structure is organized as follows: Section 2 introduces the principles of the classic model in the bounded trust model. Section 3 establishes a heterogeneous individual opinion evolution model and Section 4 performs simulation and analysis. Finally, Section 5 summarizes the paper and points out further work.

II. RELATED WORK

The bounded trust model is a continuous opinion model that generally uses social networks to represent the relationship between individuals. When any two individuals have similar opinions, they will exchange opinions and discuss them. Otherwise, the two will only maintain their original opinions. In the Hegselmann-Krause model, the entire group is regarded as a social network and individual users are nodes in the network. Suppose there are n individuals in the social network. At each moment ($t = 0,1,2, \ldots$), the individual holds an opinion value $x_i(t) \in [0,1]$ for an event, and the initial opinion $x_i(0)$ obeys uniform random distribution. The opinion values of individual i and individual j at time t are respectively expressed as $x_i(t)$ and $x_j(t)$. Given the trust threshold ε of opinion interaction, ε is a constant between the range [0,1]. If the difference of opinion values between individuals is within the trust threshold, it will affect each other which satisfy $|x_i(t)-x_j(t)| \leq \varepsilon$ and individuals outside this threshold will not affect each other, that is, the opinion update rule is:

$$x_i(t+1) = \begin{cases} \left|I(i, x(t))\right|^{-1} \sum_{j \in I(i,x(t))} x_j(t), & I(i, x(t)) \neq 0 \\ x_i(t) & , I(i, x(t)) = 0 \end{cases} \quad (1)$$

$$I(i, x(t)) = \{1 \leq j \leq n \mid |x_i(t) - x_j(t)| \leq \varepsilon\} \quad (2)$$

Where, $I(i, x(t))$ is the set of all other opinions within the trust threshold of individual i, $\left|I(i, x(t))\right|^{-1}$ is the weight of opinion influence. The opinion of the individual i at t + 1 time depends on the arithmetic mean of the neighbor's opinion. The size of the trust threshold ε determines the number of opinion clusters that are finally formed after the aggregation of opinions. The value of ε indicates the tolerance level of individuals for other opinions. The larger the ε value, the higher the individual's tolerance for other opinions. The more likely it is, the easier it is for public opinion to converge, and the easier it is to reach consensus among groups.

III. Model

Based on the classic bounded trust model and the actual opinion interaction principle in the real network, the following improvements are proposed for the factors such as homogeneity in the model.

1) Heterogeneity of Trust Threshold

In the traditional model, the individuals in the social network are homogeneous, and the trust threshold of all individuals is set to the same value. However, considering the actual social individuals are subject to complex psychological factors and external influences, it is more realistic and accurate to assume that each individual has different trust thresholds [13].

2) Acceptance of Opinion

In reality, each individual's acceptance of others' opinions varies from person to person. Different education level, living environment, and growth experience may cause differences in acceptance. However, in the traditional bounded trust model, it is often set to a fixed value, which fails to reflect the individual difference in the process of opinion interaction [14]. Therefore, we add the acceptance of opinion μ. In general, the larger value of μ, the less acceptance to others' opinions, which means the less willing to change their original opinions; the smaller value of μ, the more acceptance of other opinion, which means the more willing to accept others opinions and change their original opinion.

3) Principles of Update

Due to the introduction of the time dimension, the update principle must be considered in the view update, usually including synchronous update and asynchronous update. Synchronous update considers that individual updates the current state according to the state of the previous moment, that is, other individuals cannot observe the new state of the individual when updating their state. Observing the dynamic changes of things on a long-term scale, it is not difficult to find that all individuals change their state at the same time, which means that the state changes of things are updated synchronously [15].

Based on the above discussion, a heterogeneous individual opinion evolution model based on the HK model is constructed, as shown in equation (3).

$$x_i(t+1) = \begin{cases} \mu_i x_i(t) + (1-\mu_i)\frac{1}{|I(i,x(t))|}\sum_{j \in I(i,x(t))} x_j(t), & I(i, x(t)) \neq 0 \\ x_i(t) & , I(i, x(t)) = 0 \end{cases} \quad (3)$$

$$I(i, x(t)) = \{1 \leq j \leq n \mid |x_i(t) - x_j(t)| \leq \varepsilon_i\} \quad (4)$$

where, $I(i, x(t))$ is the set of all other opinions within the individual i within the trust threshold ε_i and $\left|I(i, x(t))\right|^{-1}$ is the opinion influence weight. The opinion value of the individual i at time t + 1 is affected by the trust threshold of the individual i and the acceptance of other opinions in all the opinion sets within the trust threshold of the individual i.

IV. Simulation

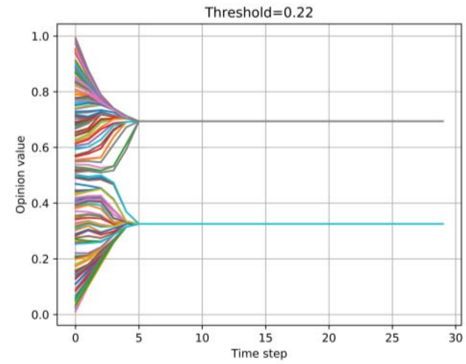
In complex networks, multi-agent modeling is a common simulation modeling method, which is suitable for studying complex systems composed of intelligent micro individuals. Based on the multi-agent modeling method, this paper performs a series of simulation experiments on the impact of heterogeneous user-related parameter changes on the evolution of opinions.

Suppose there are n agents in a social network, and the opinion x_i (t) of the individual i at time t is a continuous value uniformly distributed between 0 and 1. The opinion value close to 0 indicates that the individual holds an extremely opposing opinion; otherwise an opinion value close to 1 indicates that the individual holds an extremely supportive opinion. The individual trust threshold ε takes any value between 0 and 1. The acceptance of others' opinion μ takes any value between 0 and 1, and the value of μ is closer to 0, indicating that the individual is more willing to obey other opinions; otherwise, the value of μ is closer to 1, indicating that the individual is more reluctant to change its original opinion, which is more stubborn. Each individual is randomly assigned a different initial opinion x_i (0).

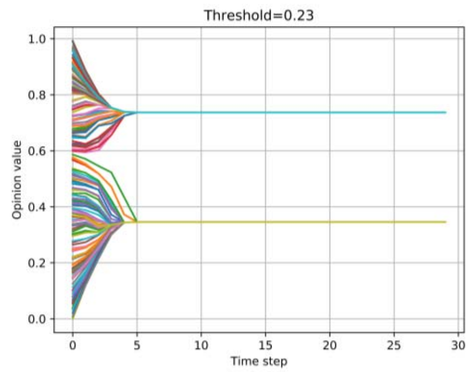
A. Perspective of Opinion Distribution at Steady State

Assume that there are 200 individuals in the network, the simulation results obtained by using the Hegselmann-Krause model are shown in Fig. 1. When the individual trust threshold is less than 0.24, the final group opinion of the entire network holds polarization; when the individual trust threshold is greater than or equal to 0.24, the final opinion interaction status of the entire network holds consensus.

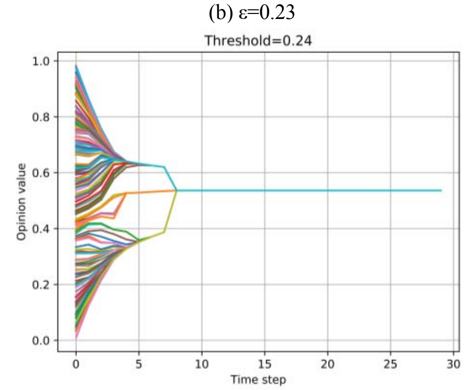
Assume that the individual trust threshold is 0.24, the size of the social network is set to n = 50, n = 200, and n = 1000. The simulation results obtained by using the Hegselmann-Krause model are shown in Fig. 2. The network size is different and the results when the group opinion finally reaches a steady-state are also different. Therefore, when the group opinion reaches a steady-state, the result is that polarization, consensus, or complete division is determined by the size of the social network and the individual trust threshold.



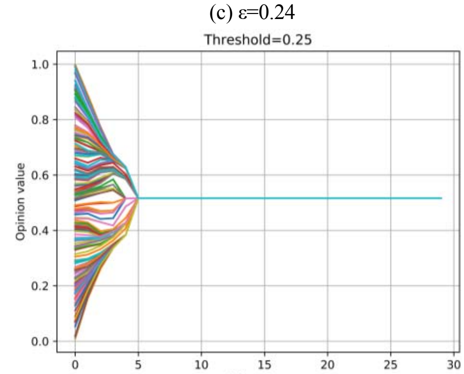
(a) ε=0.22



(b) ε=0.23

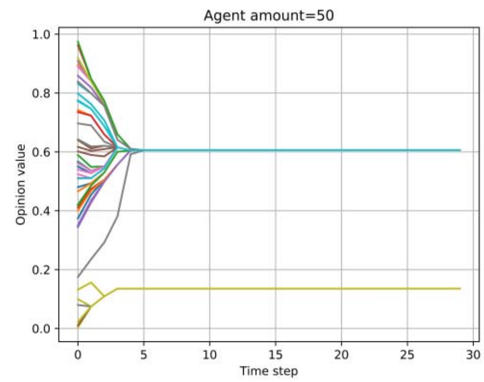


(c) ε=0.24

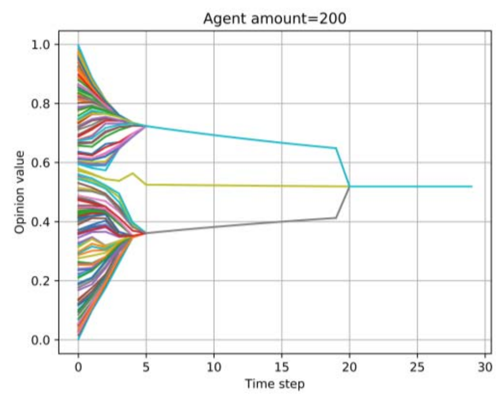


(d) ε=0.25

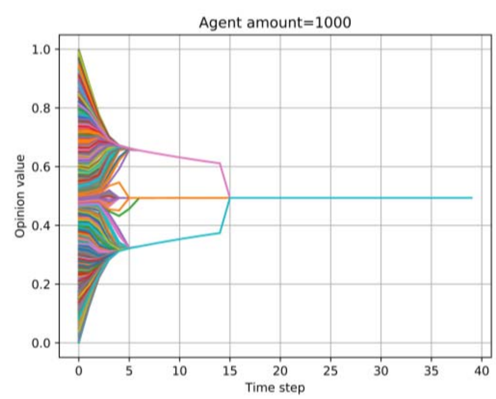
Figure 1. The opinion evolution results change with different trust thresholds, when agent number = 200: (a) threshold=0.22;(b) threshold=0.23;(c) threshold=0.24; (d) threshold=0.25.



(a) n=50



(b) n=200



(c) n=1000

Figure 2. The opinion evolution results change with different network scales, when trust threshold=0.24:(a) agent number=50;(b) agent number=200;(c) agent number=1000.

B. Impact of Non-uniform Trust Threshold

Assume that there are 200 agents in the social network. In the case of a random threshold of trust value, each individual follows the opinion update rule of formula (1). As shown in Fig. 3, when the group opinion reaches a steady-state, eleven opinion clusters are finally formed, and the average trust threshold value ε is 0.52.

Comparing the simulation results in Figure 1, when the trust threshold is much larger than 0.24, the final steady-state presents a phenomenon of multiple opinion clusters. This shows that the entire group is more difficult to reach a consensus in social networks when the trust threshold is different compared with the case where the trust threshold is the same.

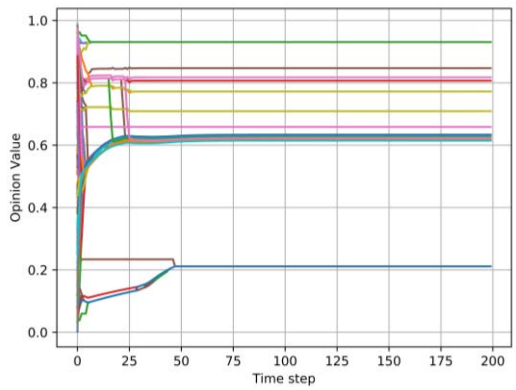


Figure 3. When agent number = 200, opinion evolution results based on the non-uniform trust threshold.

C. Impact of Opinion Acceptance

On the basis of individual non-uniform trust threshold, the parameter of opinion acceptance is added and each individual follows the opinion update rule of formula (3). Assuming that the acceptance of each individual's opinion is consistent, Figure 4 shows that the opinion acceptance is proportional to the convergence time required for the final group opinion to reach a steady-state. The greater the acceptance of opinion, the more difficult it is for the group opinion to reach consensus.

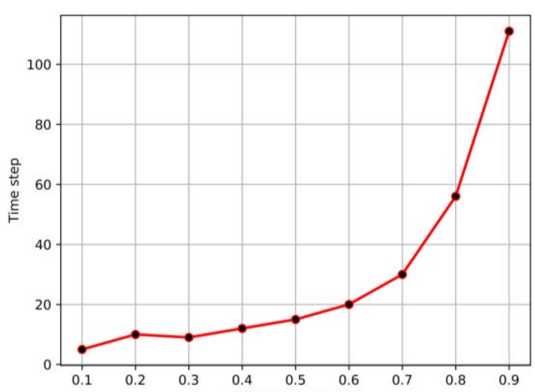


Figure 4. Relationship between opinion acceptance and time for group opinion to reach steady state.

In the actual network, everyone has different acceptance of other people's opinions, so it is necessary to make reasonable assumptions about the distribution of μ. Since the opinion of obtaining individual distribution is very limited, setting μ to obey the normal distribution is better than setting the random distribution to reflect the high homogeneity and low heterogeneity among network individuals. Therefore, the normal distribution is chosen to simulate individual distribution [16]. Under this assumption, there are relatively many individuals with a moderate acceptance of opinion, and relatively few individuals who are completely stubborn or not subjective. These characteristics are basically consistent with the actual distribution in real groups [17], which can describe the interaction of opinions between individual.

Assuming that μ obeys the normal distribution, the simulation results of the opinion evolution model based on heterogeneous individuals are shown in Figure 5. When the group opinion reaches a steady-state, nine opinion clusters are finally formed. The result shows that the evolution results considering heterogeneous individuals are more consistent with the interaction process of group opinions in reality.

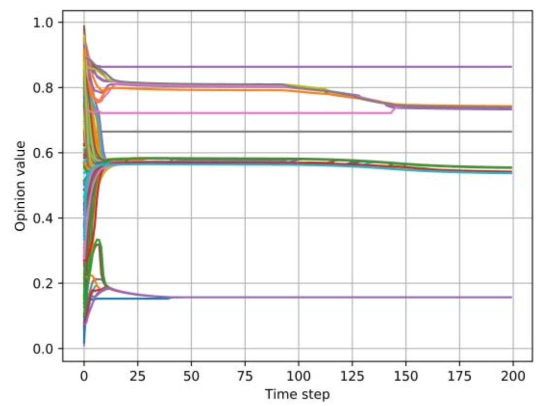


Figure 5. When agent number = 200, opinion evolution results based on the heterogeneous individual opinion evolution model.

V. CONCLUSION

Based on the actual process of individual opinion interaction in social networks, the paper improves the classic model from the trust threshold, the opinion acceptance and the principle of opinion update and proposes a heterogeneous individual opinion evolution model. This model is more in line with the process of interactive group opinion evolution in reality and it is helpful to explore the formation of Internet public opinion further. Through simulation and comparative analysis, this paper studies some factors that affect the steady-state results of group opinion evolution. The experimental results show that: the trust threshold and the size of network jointly determine the steady-state distribution of the group opinion. Compared with the same trust threshold, it is more difficult for the whole group to reach consensus in the network when the trust threshold is different. Heterogeneity in individual will promote better aggregation of group opinions. What's more, the acceptance of opinion has a significant impact on the number of opinion clusters and the convergence time during the evolution. The opinion acceptance is directly proportional to the convergence time required for the final group opinion to reach a steady-state.

The conclusion confirms some real situations in society. Due to the diversity in cultural background, religious belief, education level, etc., it's more difficult for the entire group to reach a consensus. Besides, the wider an event spreads, the more individuals involved in the discussion, which will bring more various voices about the event. Hence, reaching consensus of group opinions will cost more time than we expect.

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