Research Article

A Network Public Opinion Trend Estimation Model Using a Scale-Free Network Algorithm

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Online public opinion is gradually becoming an important medium that influences society's mainstream direction in today's period of rapid development of new media and network oversight. The propagation of public opinion on the Internet has become a serious issue affecting economic and social development, as well as national security. As a result, this research investigates the evolution of public opinion and the evolutionary stability strategy of groups. Furthermore, a scale-free network is introduced to develop a network public opinion propagation model based on the scale-free network to tackle the problem that the existing public opinion propagation model cannot fully reflect the law of public opinion propagation in real life. The model incorporates components such as external environmental influences, individual personality characteristics, and interpersonal intimacy, in addition to the law of public opinion dissemination in real society. This study uses MATLAB to carry out simulation and comparison analysis in order to test the model's performance. Simulation findings reveal that this model's stability is around 95.6 percent, and its highest accuracy is 94.3 percent, which is greater than that of the Krause–Hegselmann and Deffuant models. The obtained forms of public opinion are richer, and the results of public opinion evolution are more in line with the process of public opinion evolution in real society, thanks to this model's ability to visually reflect the changes in individual opinions held over time in the process of public opinion evolution. It has practical implications for future studies.

1. Introduction

The characteristics of the information era are becoming more and more visible, thanks to the rapid expansion of the Internet and the appearance of a vast number of new media. Mobile phones and the Internet have ushered in a new era of communication [1]. The media environment has changed dramatically as communication technology and network technology have converged. The network structure complexity of the modern social system has substantially enhanced when compared with the social network in conventional sociological research [2]. Researchers' empirical studies of diverse complex networks demonstrate that practically all genuine networks have a small-world effect, and the degree of nodes follows a power-law distribution [3]. Internet public opinion communication is a process that starts with micro individual behavior and ends with macro public opinion emergence, in which all subjects in the network interact with one another according to specified principles and eventually build a stable overall system structure. In today's context, public opinion communication has taken on many new characteristics, such as strong real-time interaction, rapid communication, a big amount of data, a broad spectrum of communication, and a high number of participants. Furthermore, the shift in communication medium has a significant impact on the public opinion formation mechanism, exacerbating the difficulties of managing relevant departments. The emergence and growth of online public opinion is largely down to the communication behavior of each individual in the public. As a result, an increasing number of scholars are focusing on the incidence and transmission mechanisms of online public opinion communication. Public opinion study has steadily expanded beyond communication to include artificial intelligence [4–6], complex systems, numerical computation, physics, cybernetics, and other interdisciplinary topics.

With the gradual deepening of the research on real complex networks, people have found through more and more data that a large number of networks in the environment of human life have scale-free network characteristics. However, the scale-free network model has opened a new chapter in the theoretical understanding of complex networks [7]. In real life, the spread of public opinion is not only influenced by the interaction between groups but also interfered by the external environment such as media and opinion leaders in social networks [8]. Therefore, the introduction of complex networks as the interpersonal network of public opinion evolution can make the dynamic model of public opinion evolution more reasonable and accurate. Studying the process of public opinion communication in the social network and the key factors influencing communication plays an important role in predicting public opinion and guiding public opinion in time [9]. However, at present, more studies only pay attention to the participation degree and development scale of public opinion communication, while ignoring the changing trend in the process of behavior evolution. And most models cannot truly reflect the evolution process of public opinion in the real world. The establishment of its interaction rules often does not consider the interpersonal network and at the same time lacks a positive and effective way to guide the development of public opinion. Therefore, this paper makes an in-depth study of network public opinion communication and proposes and constructs a network public opinion communication model based on a scale-free network. The innovations of this paper are as follows: (1) in this paper, a scale-free network is innovatively introduced to build a network public opinion communication model based on the scale-free network, aiming at the problem that the existing public opinion communication model cannot truly reflect the real life public opinion communication law. It also probes into the deep-seated reasons behind the features of online public opinion; and (2) in this paper, a scale-free network is used as an interpersonal network, and individual personality characteristics, intimacy between individuals, and external environmental factors of complex networks are introduced as model parameters. In the process of network modeling, the network parameters and performance of the scale-free network evolution model constructed in this paper are compared with other models. The results show that this model has certain advantages in performance.

2. Related Work

In recent years, professionals and researchers from both home and abroad have focused on two features of the social network system as one of the primary study topics: the public opinion transmission model and the network model. In network research, scale-free networks are becoming increasingly relevant. The researchers used the network model to the analysis and prediction of real networks and conducted multilevel and multiangle research, starting with a discussion of the basic theory of scale-free networks and progressing through its improvement and enlargement.

Zhang et al. studied the dynamics of public opinion propagation on scale-free networks under the dual influence of external field and inertia. The experimental results show that when the public opinion evolution state is stable, the network structure changes from the power-law distribution at the initial moment to the Poisson distribution, indicating that the evolution of public opinion gradually tends to be consistent with the development of time [10]. Wei-Dong et al. conducted research on scale-free networks and proposed a two-layer scale-free network rumor propagation model [11]. Anne used complex network theory to study the dynamics of public opinion evolution. It constructed a dynamic model of public opinion evolution based on a small-world network and obtained important conclusions about the critical value of public opinion evolution [12]. Schober et al. built a network public opinion model algorithm based on a small-world network and adopted a quantitative analysis method and found that two indicators, power spectrum entropy and dynamic characteristics, can quantitatively study the emergent behavior of network public opinion [13]. Liu et al. introduced a scale-free network with variable clustering coefficients to study public opinion propagation [14]. Ai et al. constructed a public opinion evolution dynamics model based on a scale-free network and further used computer model simulation to obtain the evolution results of the model [15]. Ma et al. studied the dynamics of public opinion propagation on scale-free networks under the dual influence of external field and inertia. The study found that when there is no inertia, the total number of public opinions in the network will decrease with the evolution of time. After adding inertial actions, the total number of public opinions shows rich changes [16]. Liu and He studied the propagation law of opposing public opinions on scale-free networks [17]. Based on the model, Kanaan and Suveren studied the phase transition phenomenon in the evolution of public opinion on small-world networks and scale-free networks. Through experiments, the quantitative relationship between the network clustering coefficient and the formation of public opinion is obtained. That is, the larger the network clustering coefficient is, the easier it is for opinion evolution to form a consistent public opinion [18]. Based on the scale-free network and disease transmission model, Zhang et al. fully considered the influence of the number of media, reporting intensity and credibility on the spread of public opinion, and proposed a public opinion topic spread model of media intervention. After research, it is concluded that under this circumstance, the speed of dissemination of online public opinion topics is accelerated, the dissemination range is expanded, and the propagation relaxation time is shortened [19]. Liang and others found that public opinion can spread more widely under scale-free networks when investigating the influence of scale-free networks and small-world networks on public opinion spread [20].

Based on the in-depth study of the previous literature and referring to the fitness model, this paper puts forward the concept that there is a correlation degree between nodes and systems in the network and gives a new network public opinion propagation model based on a scale-free network

according to the correlation degree. The evolution process of the network with system correlation degree is described. The complex network theory and mathematical methods are used to analyze the process of the model. MATLAB simulation analysis is carried out to explore the influence of network media intensification, network media divergence, and network media penetration on the process of network public opinion dissemination. The simulation results show that the model in this paper can visually reflect the changes of opinions held by individuals with time in the process of public opinion evolution, the obtained forms of public opinion are richer, and the results of public opinion evolution are more in line with the process of public opinion evolution in real society. The results show that the research of this model has certain practical significance and practical value.

3. Methodology

3.1. Communication Mechanism of Network Public Opinion. The general public spreads ideas and consciousness by word of mouth [21], and traditional social public opinion occurs in people's daily conversations. Due to geographic, linguistic, and other constraints, public opinion is now sluggish to disseminate, has a small influence range, and has a short duration. People's communication is becoming increasingly close as the Internet develops, and the clash between ideas and values is becoming more pronounced. The Internet has been formally recognized as the new "fourth media" [22], following the conventional mass media such as newspapers, radio, and television. The broad and narrow senses of public opinion on the Internet can be distinguished. Internet public opinion, in a broad sense, is public opinion created through the use of the Internet as a medium. The influence of online public opinion is limited to the Internet in a narrow sense, where netizens' free speech and comments on major forums and news websites progressively begin to have a variety of consistent opinions. The public's cognition, attitudes, emotions, and behavior patterns about social events are triggered by diverse social events and produced by the public in a social network made up of numerous social groupings, according to this study. Because of the speed with which online public opinion can be expressed, the variety of information available, the interaction of methods, and the network's openness and virtuality, online public opinion has certain distinct characteristics; specifically: (1) direct rapidity, (2) randomness, (3) diversification, (4) controllability, (5) concealment, (6) deviation, and (7) sudden.

Public opinion is crucial in guiding the overall value of society, predicting the human society's development trend, communicating and regulating social connections, motivating and supervising social members and organizations, and promoting the development of diverse social endeavors. The concept of complex social networks has sparked interest in information distribution studies. In comparison with prior media, public opinion communication in modern society has a high level of real-time interaction, a quick rate of information transmission, a huge amount of information capacity, a vast communication space, and a large number of

participants. Researchers will find it challenging to capture the public opinion propagation legislation and understand the government's management and control of public opinion propagation because of these qualities. Communication is used to depict the formation, emergence, and evolution of public opinion. Internet public opinion, like all other forms of development, has its own "life cycle," which spans the stages of birth to death or "the entire process from cradle to tomb." The process of public opinion communication is a type of information generated as a result of social changes that spreads from information sources through specific communication channels, reaches a specific range of information receivers, forms widely held opinions, and influences social events until the problem is resolved. Therefore, according to the different characteristics of public opinion evolution in each period, public opinion can be divided into four stages: incubation period, growth period, maturity period, and recession period. The formation and evolution mechanism of public opinion is shown in Figure 1.

Online public opinion is still in its infancy after the early incubation period. When a hot topic achieves a particular level of popularity, more people become aware of public opinion events, indicating that online public opinion has progressed to the growth stage. The public's views tend to be consistent as Internet public opinion spreads. The truth of public opinion progressively emerges, the event process is well defined, and the truth of events as reflected by online public opinion becomes more apparent. It is mature at this time. Finally, network public opinion matured to the point where the public opinion was clear, the truth was evident, and the public opinion entered a period of decline. Monitoring, early warning, and response are three connections in the supervision and resolution of public opinion. These three links are intertwined and sequential. Monitoring is the most energy-intensive of these tasks because it is done on a daily basis. When a change in public opinion that could have a detrimental influence is identified, the early warning stage begins. When the actual crisis occurred, the reaction process began. The significance of crisis response, on the other hand, cannot be overstated.

The influence of event development state on public opinion communication is a common subject of simulation research on network public opinion communication mechanisms at the moment. The impact of individual psychological traits of network users and social network characteristics on the transmission of online public opinion has received little attention. The abstraction of a complicated system is a complex network. The overall behavior or features of a complex system cannot be explained by the behavior or characteristics of its components [23]. An open complex network is a network with self-organization, self-similarity, attractor, small world, scale-free portion, or all that is generated by incorporating external environmental stimuli into the network with self-organization, self-similarity, attractor, small world, scale-free part, or all. Complex network theory is a useful approach, tool, and platform for promoting social network research, and communication research adds social and practical value to the subject of complex networks.
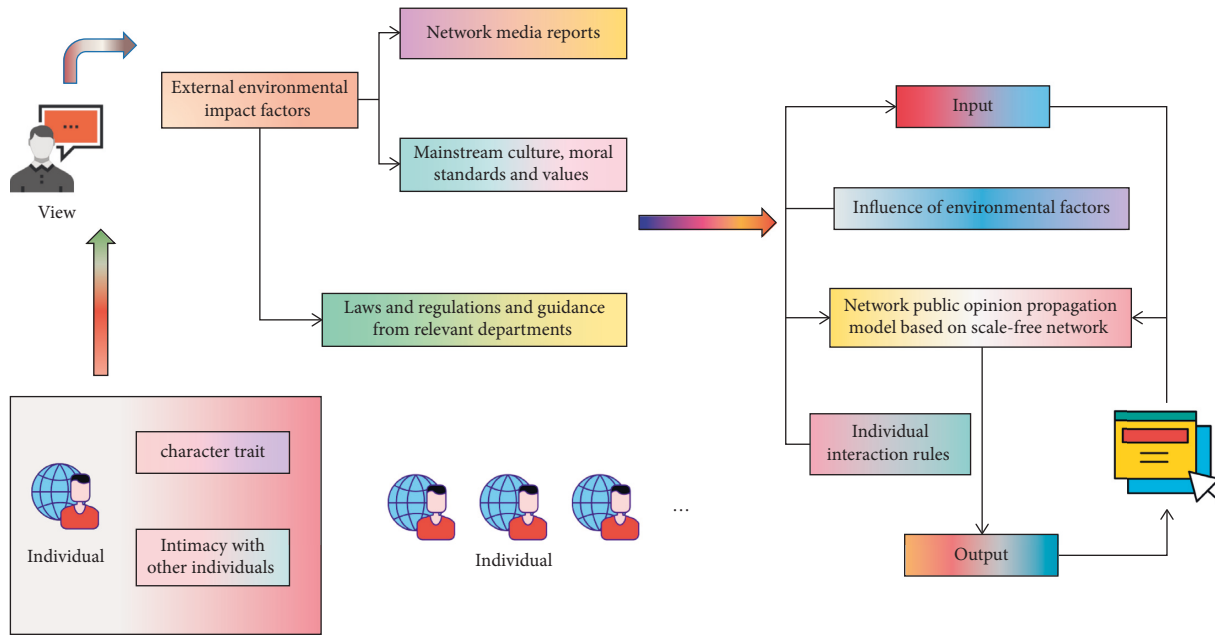
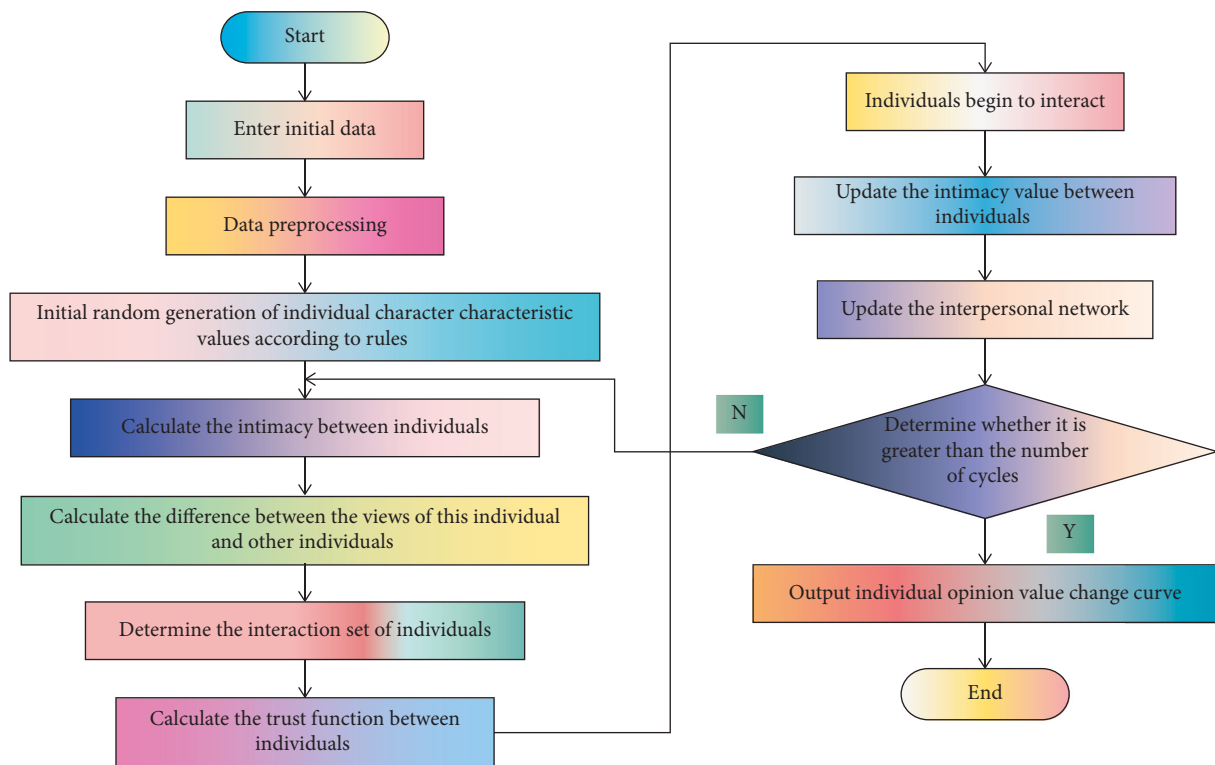FIGURE 1: The formation and evolution mechanism of public opinion.

FIGURE 2: The flow chart of the simulation program of the public opinion propagation model based on scale-free network.

3.2. Modeling of Public Opinion Propagation Based on the Scale-Free Network Model. The importance of social networks on public opinion development cannot be overlooked as a breeding environment. Orderliness, chaos, spontaneity, self-organization, and predictability characterize both the public opinion development system and the social network system, which are typical complex systems. The goal of

complex network theory is to research the nature of complex systems from the perspective of their connections, as well as to study the structure, model, and other laws of complex systems in depth. A significant number of real networks are discovered to virtually all have a small-world effect, and the degree of nodes in the network follows a power-law distribution. Transportation networks, communication

networks, and social networks are all network models in real life, and the public opinion communication group we stated before is a social network. Because the external network environment will have a significant impact on people's opinion decision-making, the complex network external environment variables are introduced to reflect the impact of the external environment on public opinion evolution. At the same time, as a member of the social network, individuals will choose to interact with other persons who are close to them rather than with the general public. Figure 2 shows a flow chart of a simulation program for a scale-free network-based public opinion propagation model.

It is quite likely that two people who are friends with one other and their friends will become friends with each other on a social network. This characteristic is known as the network's clustering characteristic. The aggregation degree of the network is described by the network's clustering coefficient. Individuals can exchange views with each other within a reasonable range in this model and then obtain the average view value of their neighbors by introducing complex network external environment factors, intimacy between individuals, and setting a two-degree trust threshold, so that individuals can exchange views with each other within a reasonable range and obtain the average view value of their neighbors. This chapter does not discuss network changes in the process of public opinion spreading because neither routine events nor hot information takes long to propagate. The term "social relationship" refers to the bond that exists between people who communicate with each other on a regular basis and in a variety of ways, including strong and weak relationships. The link between strength and weakness is introduced to the threshold model in this chapter. The degree distribution of a scale-free network is

$$P(k) = \frac{2m(m+1)}{k(k+1)(k+2)} \propto 2m^2 k^{-3}, \tag{1}$$

$$C_{BA} = \frac{m^2(m+1)^2}{4(m-1)} \left[\ln\left(\frac{m+1}{m} - \frac{1}{m+1}\right) \right] \frac{[\ln(t)]^2}{t}. \tag{2}$$

The average path length of a scale-free network is

$$L \propto \frac{\log N}{\log\log}. \tag{3}$$

The evolution mechanism for the construction of complex networks can be addressed from the perspectives of node life and connection cost, preferred connection mode (linear or nonlinear), accelerated growth, and hierarchical organization structure. In this model, a scale-free network is used as the initial interpersonal network, which compensates for the classic model's absence of a realistic interpersonal network environment. The external environment variables of a complex network are provided as model parameters to describe the influence of the external environment on the evolution of public opinion, and the interpersonal network will alter in response. The environment between people in a social network is complex and changeable due to the large number of participants, and at the same time, each user's cognition and judgment level of various social networks is limited, so he must constantly learn and adjust his own strategies in the process of many games. As a result, "limited rationality" is a legitimate assumption to make while studying the game of public opinion communication through social media. The degree of association between newly recruited members and the original network may differ during evolution, and the resulting network properties may differ as well. This study introduces the concept of correlation degree to capture this aspect.

Assuming that the network initially has m_0 nodes and e_0 edges, add e_1 new edges with probability p_0. One end of the newly added edge randomly selects nodes to be connected, and the other end adopts the method of preferential connection. The preferential connection probability of the node is

$$\prod(k_i) = \frac{k_i + \alpha}{\sum_j (k_j + \alpha)}, \tag{4}$$

where k_i represents the degree of node i; H represents the mutual trust degree between individuals; and h_{ij} represents the trust degree of the individual i to j, which is determined according to the relative size of the node degree:

$$h_{ij} = \frac{1}{2} \frac{k_j - k_i}{\max(k_i, k_j)} + \frac{1}{2}. \tag{5}$$

Set the distance limit threshold of opinion exchange to d', and then the average proportion of individual neighbors who can communicate with them is

$$p_d = \frac{4 - (2 - d')^2}{4}$$

$$= \frac{4d' - d'^2}{4}. \tag{6}$$

In the process of system evolution, $0 \le p$ and $p_2 \langle 1$ should be guaranteed. At the same time, there are $p_0 + p_1 + p_2 = 1$, $p_2 \ge 0$, and $e_3 \langle e_2$ to ensure the growth of the network. Let the system evolution time be t. When $t \longrightarrow \infty$,

$$p(k) = \frac{1}{B} \left[\frac{A}{B} + \alpha + e_2 \right]^{\frac{1}{B}} \left[\frac{A}{B} + \alpha + k \right]^{-\gamma}. \tag{7}$$

At this point, the scale is

$$\gamma = \frac{1}{B} + 1. \tag{8}$$

Among them,

$$A = \frac{p_0 e_1 - 2 p_2 e_3}{p_1},$$

$$B = \frac{p_0 e_1 + p_1 e_2}{2 p_0 e_1 + 2 p_1 e_2 - 2 p_2 e_3 + \alpha p_1}. \tag{9}$$

Analysis of B shows that $B = 1/2$ when interest decay and initial attraction are not considered and $\gamma = 3$ at this time. Therefore, the value of p_2 and e_3 will directly affect the size of the power exponent.

Social network is a network composed of the relationship between individuals. From the point of view of graph theory, it is a weighted directed graph with "individuals" as nodes and "relationships among individuals" as edges. For undirected networks, there is no distinction between in-degree and out-degree. In the face of different network objects, the meaning of degree expression is also different. However, no matter how the network is distinguished, the degree of nodes in the network has the characteristics that the greater the degree, the greater the individual influence and the greater the role it plays in the whole system. Therefore, the degree of a node in the network also represents the position of this node in the network system. This model stipulates that individuals in each time step need to fully consider the opinions of all surrounding individuals and establish the evolution process of individual opinions by combining the methods of average and weight values of opinions.

4. Result Analysis and Discussion

According to the network public opinion propagation model based on scale-free network established above, the validity and rationality of this model are verified by simulation with MATLAB. Firstly, the values of each parameter in the model are determined, and the trust limit is set to 3; the initial network cooperation rate is 0.5; set the evolution time limit to 60. Import data from the real network environment to analyze the practicability of this model. Using the network data capture technology, the real data in the real network environment is obtained, which are manually processed and then imported into the model to observe the evolution result of the model. The individual character parameters introduced in this model are shown in Table 1.

The degree of network public opinion media obeys scale-free distribution, and its evolution process must obey the growth characteristics and priority connection characteristics of the scale-free network. These two characteristics can be explained from the nature of the public opinion media itself, that is, every moment, new users express new views on existing views, and when expressing new views, they tend to be hot events, which is easier to get attention. Through the simulation of the model on the MATLAB platform, it is observed that individual opinions in the scale-free network will form different public opinion forms under different parameters. At the early stage of evolution, the individual views of Internet converged into two mainstreams and the number of individuals who chose cooperative strategies declined. After that, the mainstream of the two viewpoints quickly converged to form a viewpoint stream, at which time the proportion of corresponding cooperation strategies also increased first and then decreased. The simulation experiment shows that the stability of this system is shown in Figure 3. Accuracy is shown in Figure 4.

TABLE 1: Individual personality trait parameters.

Character color	Value	Trait	Distribution proportion (%)
Blue character	1	Obedient	12
Green character	0.6	Easy-going	69
Yellow character	0.1	Bigot	9
Red character	0.02	Stubborn	10

As can be seen from Figure 3, compared with the other two models, the stability of this system is higher. Figure 4 shows that the accuracy of this system is higher than that of the other two models. This result further verifies the superior performance of this system. When online public opinion arises, some unknown people obtain public opinion information and question its validity, resulting in hesitators; there are still some people who have not received public opinion information or are not interested in becoming immune persons. Those who hesitate, influenced by the network media, hold opposing opinions on online public opinion and become advocates and opponents of public opinion information distribution or lose interest in public opinion and cease propagating and become immune people. To identify the role of community identity in it, it is divided into two categories: strong community identification and low community identity. Figure 5 depicts the impact of network composition on the level public opinion communication in communities with high and low community identification. Figure 6 depicts the impact of network composition on the speed of public opinion communication in communities with high and low community identification.

In this paper, the penetration distribution of nodes in the network has power-law characteristics, and most of the nodes have small penetration, that is, grassroots nodes in the network. However, a few nodes have large penetration, that is, 100 users in the network, and the network structure constructed by the model accords with the reality. Table 2 shows partial node degree distribution and network average degree.

With the increase of community identity, most of the growth rate of public opinion communication level in the network composed of high networks remains in a stable state in a certain range, that is, the increase of relationship strength brings an obvious growth of communication level. However, for the defensive focus, with the increase of community identity, the growth rate of network public opinion communication level composed of high network mostly stays near the horizontal axis, that is, the increase of relationship strength does not bring about an obvious increase of public opinion communication level. The selection set of relationship strength and community identity is shown in Table 3.

This model more comprehensively considers the influencing factors of online public opinion in the process of communication. The network media intensification, network media divergence, network media penetration rate, and government intervention coefficient all have an effect on the path of online public opinion communication, which better simulates the changing state of online public opinion
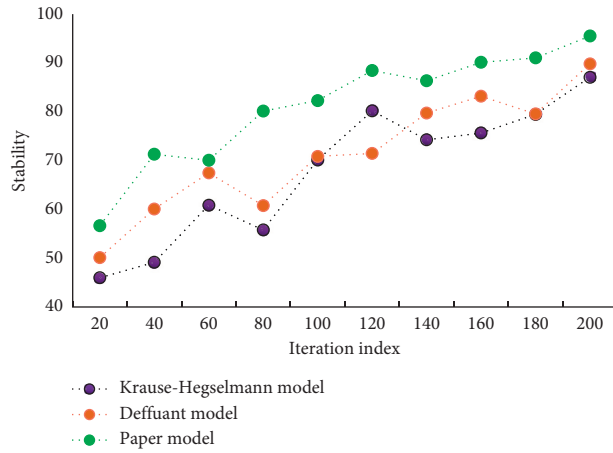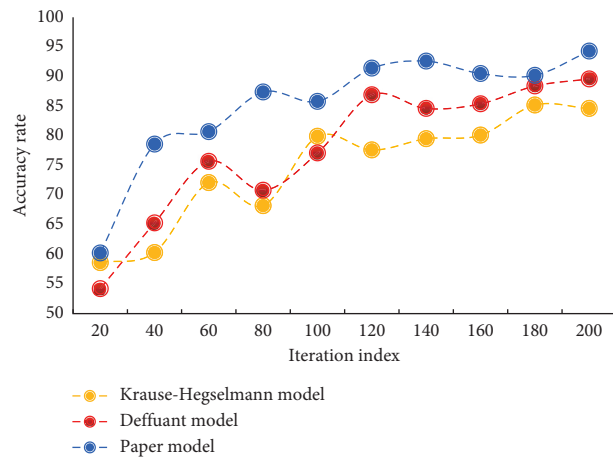
FIGURE 3: System stability comparison.

FIGURE 4: Comparison of the accuracy of the system.
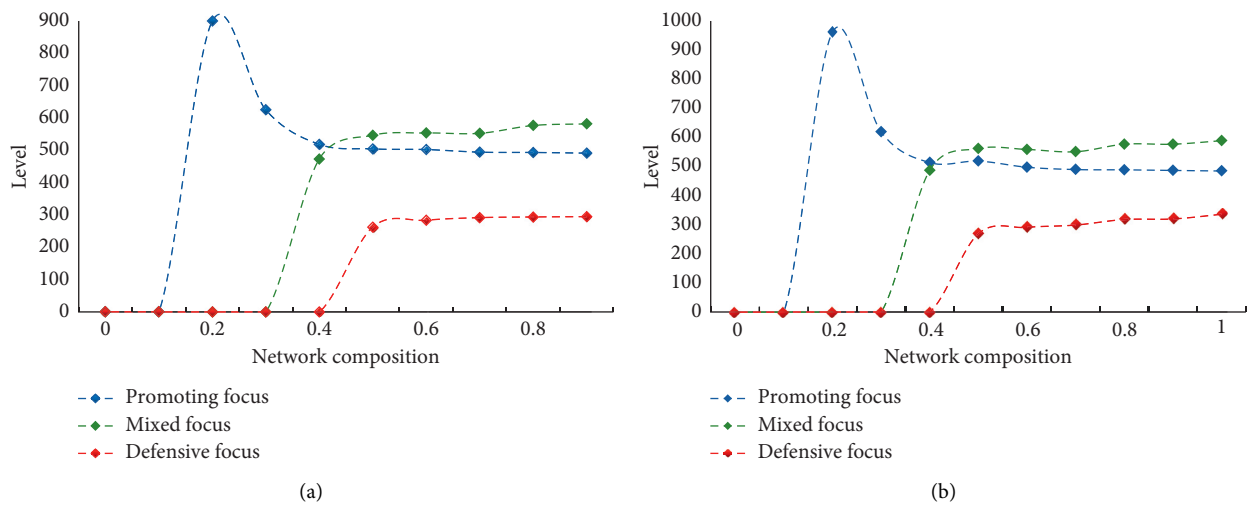

(a)

(b)

FIGURE 5: The influence of network composition on the level of public opinion dissemination with high and low community identification.

development. For the focus of promoting regulation, the speed of public opinion transmission is higher than that of mixed and defensive, promoting the adjustment focus.

Under the condition of proper network structure, the speed of public opinion can reach its maximum. The weak relationship environment is more conducive to the promotion

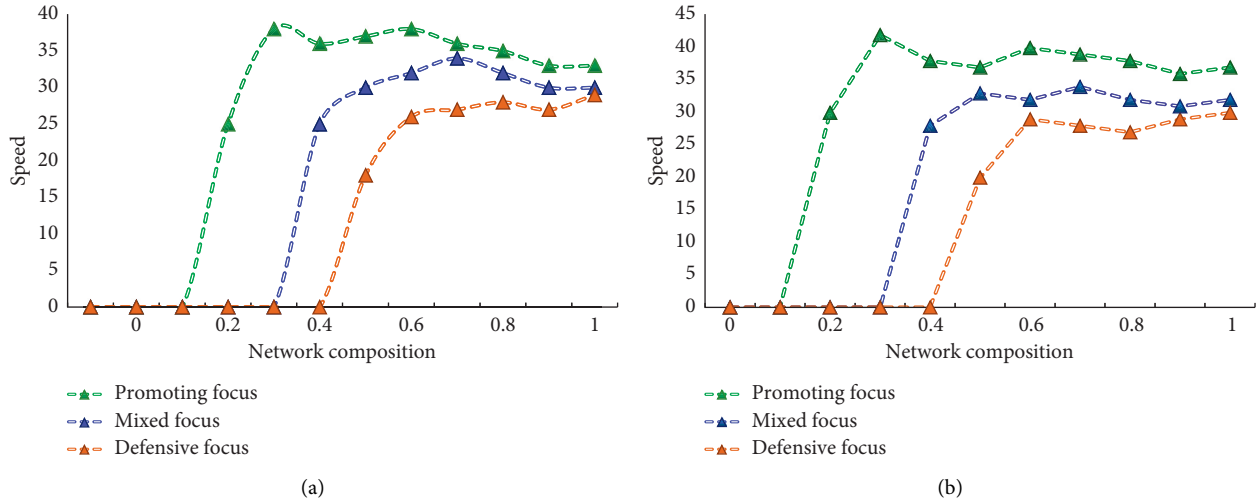(a)   (b)

FIGURE 6: The influence of network composition on the speed of public opinion dissemination in high and low community identification.

TABLE 2: Degree distribution of some nodes and the average degree of the network.

Node	1	2	3	4	5	. . .	Average degree
Out-degree	1	2	0	2	2		1.945
In-degree	10	12	9	14	9		1.945

TABLE 3: Relationship strength and community identity selection set.

Relationship	High community identity	Low community identity
Strong relationship	Level of communication (940) Propagation speed (40)	Level of communication (940) Propagation speed (45)
Weak relation	Level of communication (960) Propagation speed (43)	Level of communication (980) Propagation speed (48)

of the propagation speed of network public opinion with the focus of promoting regulation, and the network composition parameters needed to reach the maximum value at this time are lower. Under the same network scale, different network densities may also affect the spread of public opinion. Add 3, 4, and 5 edges to each time step considered in the simulation test. The densities are respectively recorded as mlink = 3, mlink = 4, and mlink = 5. The experimental results are shown in Figure 7.

It can be demonstrated that in a scale-free network, different network densities result in very varied proportions of people participating in public opinion propagation. The more the people who participate in public opinion communication in the network, the wider the range of communication, and the greater the influence, the larger the scale-free network density. In this model, the threshold of opinion difference is a necessary condition for individuals to become neighbors, which is mapped to actual life. If an individual's number of neighbors grows, it indicates that he or she is actively involved in the group organization, and contact between individuals will also grow. On the other hand, because the contact surface of individuals grows larger, and there are many people in the group who have the tendency to drift with the tide, it is simpler to reach a consensus. This chapter found through experiments. Compared with the defensive network and hybrid network, the
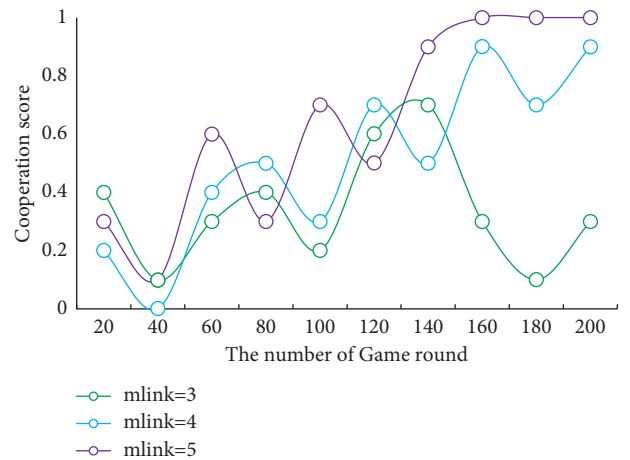

FIGURE 7: Effect diagram of network density.

level and speed of public opinion communication in promoting regulatory focus network is the highest. Low community identity and weak relationship environment are more conducive to the promotion of the level and speed of online public opinion communication. The simulation results show that the statistical characteristics of the model are consistent with the actual data. The stability of this model can reach about 95.6%,

and the highest accuracy is 94.3%, which is greater than that of the Krause–Hegselmann model and Deffuant model. This research has certain practical significance for the research of online public opinion communication.

5. Conclusions

It is very crucial to carefully and effectively handle online public opinion communication in today's world with developed information and communication. This research investigates the scale-free aspects of online public opinion media and provides a particularity analysis. It also examines the complexities of network public opinion media and the factors that influence their formation, as well as some of their basic characteristics. This paper introduces factors such as external environmental influence factors, individual personality characteristics, and individual intimacy between individuals and constructs a network public opinion communication model based on scale-free networks, based on analysis of existing public opinion communication models combined with interdisciplinary research of complex systems and other disciplines. It explores the network public opinion communication mechanism from the three levels of "individual-community-network," simulating the influence of adjustment focus, community identity, relationship strength, and other factors on the level and speed of public opinion communication in a scale-free network. Online public opinion has a lot of scale-free properties and a power-law distribution, according to statistical data and experimental investigation. The subject's herd mentality of public opinion and the decline in interest in issues all contribute to the complexity, and the close interaction between online public opinion and real society is another essential factor. Simultaneously, network properties and performance based on the scale-free network evolution model and other models are compared and studied during the network modeling process. For simulation and comparison analysis, MATLAB is utilized. The model's stability is around 95.6 percent, and its best accuracy is 94.3 percent, which is greater than that of the Krause–Hegselmann and Deffuant models. The findings indicate that this model offers some performance advantages. Although some research achievements have been made in this paper, there are still some shortcomings in this paper due to the limitation of knowledge level and time. How to excavate the in-depth characteristics of network public opinion media, further improve the network public opinion evolution model, and construct a complete and reliable network public opinion media topology generator will be the focus of future work.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors do not have any possible conflicts of interest.

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