An Online Social Platform Public Opinion Communication Model Based on BP Neural Network

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Abstract. With the development of Internet technology, the number of Internet users in China has exceeded 1 billion. Network public opinion has gradually replaced traditional media as an information communication channel. On one hand, the efficient and convenient online platform plays an important role in promoting positive values. But on the other hand, false and even harmful information can also be spread widely through the Internet. Therefore, how to correctly identify the key factors in the communication of public opinion on social platforms and use them to promote or curb them in the process of public opinion communication has become an important issue in the current era of big data. This paper sets the research object as the hot search topic data on the Zhihu platform, and uses the DEA model to initially calculate the relative public opinion transmission efficiency. Then, use the BP neural network and the theory of the strong and weak tie to provide theoretical support for identifying key nodes and key paths of public opinion communication, enhance the work efficiency and effect of the platform supervisors or public opinion operators, and achieve the purpose of promoting positive public opinion communication and curbing negative public opinion communication.

Keywords: Public opinion communication · Social network analysis · Opinion leader · BP neural network

1 Introduction

With the continuous progress of information technology, the infrastructure construction of the Internet and mobile Internet in China has been constantly improved. The production, discussion and dissemination on online platforms has gradually replaced traditional media. Online social platforms have gradually become the main occasions for people to obtain the latest information. At the same time, the necessity of public opinion supervision has also increased year by year. False and harmful information has posed a huge challenge to the online community environment [1].

Public opinion communication is one of the research hotspots in the academic field. For example, public opinion guidance [2] in the field of media science, user portraits

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[3] and recommendation algorithms [4] in the field of computer science, and group behaviour [5] in the field of sociology are closely related to public opinion communication. Reasonable guidance and promotion of public opinion communication can play a positive role in precise marketing, exploring potential needs, promising social supervision, and monitoring the online community environment. On June 10, 2022, the beating incident at Tangshan in Hebei Province was rapidly spread on social platforms such as Weibo, Zhihu, WeChat, etc. Under the attention of netizens across the country, the local police carried out a special action of "Thunderstorm" to receive clues from the masses. However, curbing false and harmful information is also a very urgent research topic at present. "Alibaba female employee event" is a typical event that caused multiple corporate public relations crises due to the "apparent agency" behavior of the parties [6]. The parties involved have hidden and misleading words, which caused huge repercussions under the collision of many social hot issues such as drinking culture, workplace issues, gender difference, ethics and law, and finally led to the volatility of the company's stock price, the public relations crisis of the company, the waste of police resources and other serious consequences.

How to maximize the advantages and avoid the disadvantages has certain social value and practical significance in the current age. This paper takes Zhihu platform as an example, based on the theory of strong tie and weak tie in social network analysis, constructing a neural network model about the public opinion communication, which can identify the propagation path of the target topic on Zhihu platform and suggest the appropriate measures.

2 Literature

2.1 Content

Many scholars believe that the content quality of news determines the topic communication efficiency. These scholars tend to study the impact of the characteristics or attraction of the content. They are committed to improving the efficiency of public opinion communication in terms of word expression and argument setting. Wang and Zou [7] studied the negative public opinion of brands such as D&G and Burberry in the Chinese market, and found that the surface symbols of brands may lead to misreading of consumers in cross-cultural and cross-context situations, and then cause consumer resistance. Andrea [8] found that media comments, while reflecting public opinion, will also shape public opinion and influence more ordinary people to become advocates of this view. Anandita [9] has found that exposure to an online community environment with "angry consensus" on climate change will strengthen people's expectations of collective behavior related to climate protection.

Through the study of these literature on the content of public opinion, we can find that the discussion heat of public opinion mainly comes from the following three aspects: attraction, relevance, and emotional satisfaction. Relevance is the core of the content of public opinion, that is, the more relevant a news or topic is to the interests of the reader, the more likely the reader will spend time and energy to participate in the discussion. The attraction reflects the degree to which the content of the news can arouse the curiosity

of ordinary readers. Emotional satisfaction reflect the quality of news and the vitality of a topic in a long time. It may also exist in the subsequent user discussion.

2.2 Opinion Leader

Many scholars believe that opinion leaders play an important role in the communication of public opinion. An influential opinion leader can gather a certain scale of user groups with the same views. Zhou and Wu [10] divided the evolution of public opinion into two stages: the normal update of opinions by groups and the adjustment of opinions by different decision-maker roles. With the help of graph theory and DeGroot model, they established an authority-rebel ER network model to describe the evolution of public opinion. Rossman and Fisher [11] have verified that if only information is delivered through social networks and the quality of advertising itself is low, then after breaking through the core network layer, the possibility of information transmission will collapse catastrophically. After the Fukushima nuclear power plant accident in 2011, Yukie [12] built a temporary forwarding network through the relevant comment information in 1.3 million accounts and 24 million tweets on Twitter. The research proved that new tweets from the directly affected people can effectively spread information based on scientific evidence.

Through the analysis of the literature on opinion leaders, we can find that the discussion heat of public opinion mainly comes from three aspects: the personal charm of opinion leaders, the "distance" between the audience and opinion leaders, and the confrontation between opinion leaders. The personal charm of opinion leaders can be measured in various ways in different literature, such as the degree of authority, which can reflect fans' willingness to actively disseminate ideas. Distance refers to the length of the shortest path between two social network nodes. Generally, the longer the social network distance, the lower the impact of the personal charm of opinion leaders on the audience. The confrontation between multiple opinion leaders is represented by the collision of multiple opinion leaders with different views and their fan networks. In modeling, it can be understood as the establishment of a large number of temporary strong connections between networks, which ultimately leads to the increase of discussion.

2.3 Social Network Structure

Some scholars believe that the social network structure will have an impact on the process of public opinion dissemination. With the development of social network analysis methods, scholars have proposed strong tie social network, weak tie social network and scale-free social network.

2.3.1 Strong Tie Social Network

Strong tie social network means a network in which all nodes in the network have strong connections with each other. Social networks with strong relationships generally have the characteristics of high trust, behavioral convergence and knowledge convergence. In reality, they often appear in the form of family and colleagues. The efficiency of information flow among members of the strong tie social network is very high, which is also the

reason why the network often makes the same decisions and has the same knowledge. However, the strong tie social network has little contact with the outside world, so it does not have many opportunities to access different information. Therefore, it is difficult to generate new knowledge. Uzzi studied the social links and work performance of employees in 23 clothing companies in the United States [13], and found that the highly embedded organizational structure ensures high work performance, performance bonus and work enthusiasm of employees. The average employment period of these employees is also higher than that of employees in other networks. However, Uzzi also found that no matter what their professional background before entering the company, these employees will eventually become very similar groups.

2.3.2 Weak Tie Social Network

In the weak tie social network, each node has strong connection with only a few other nodes. The overall link mode of the network is loose, dynamic and difficult to estimate. Network members often join the network based on identity, and in reality, they often appear in the form of alumni associations, fan groups, etc. The individual differences among members of weak social networks are relatively obvious, and they often do not perform well in situations requiring group decision-making, but they can expect to have good results in knowledge and information sharing. Burt calls the connectors between multiple organizations in the social network as structural holes [14]. The node in the position of the structural hole can have a perspective that other nodes do not have, and also have more opportunities to understand the thinking mode and action rules of multiple organizations. Fleming studied the social network formed by American public patent holders [15] from 1975 to 2002, and found that people who established connections between multiple research groups were more likely to create new knowledge, thus achieving success in research and development.

2.3.3 Scale-Free Social Network

Scale-free social network refers to that a few nodes in the network are connected to almost the entire network, while most nodes have only a few connections. It can be considered that when a core node appears in the weak relationship social network and is connected with most other nodes, it will show the characteristics of a scale-free network. The expansion of scale-free network has obvious Matthew effect, that is, the nodes that originally reside in the center of the network enjoy the highest discussion heat and authority in the network making the nodes that subsequently access the network actively pay attention to the information and dynamics of the center node, thus realizing a positive feedback cycle of larger network scale and higher authority.

3 Methods

3.1 Data Resources

The data in this article comes from the Zhihu platform, which entered the top five topics of the Zhihu hot search list from 20/01/2021 to 20/02/2021. For each topic, this article continued collecting its cumulative views, cumulative likes, cumulative comments, real-time discussion heat and other topic data until its hot search ranking is at 50. The data in this paper was collected manually, and finally 319 effective topic data were collected, with a total of 1210 observation intervals. Before constructing the public opinion communication model, this paper filled in the missing values, handled the abnormal values and finished the normalization of the collected raw data.

3.2 Data Envelopment Analysis

Before establishing the public opinion propagation model, this paper first uses the Data envelopment analysis (DEA) method to analyze the relative communication efficiency of the topic in each time interval in the original data. This paper adopts the classic DEA-BCC model [16] proposed by Charnes. This paper takes the public opinion performance of a topic in a time interval as a DMU, uses real-time discussion heat as the output index of the model, and takes new likes, new comments, new views and interval time as the input index. After the DEA calculation, the relative communication efficiency will be taken as the actual value and compared with the predicted value of the subsequent neural network model, so as to evaluate the reliability of the neural network model.

The calculation of DEA model is completed with the help of DEAP 2.0 software.

3.3 Neural Network Model Constructing

According to the DEA analysis results, this paper proposes that public opinion communication on social platforms can be divided into three propagation modes according to the participating motivation of users, namely, communication for the purpose of seeking knowledge, communication for the purpose of sharing, and communication for the purpose of discussing.

Figure 1 explains how the neural network is established.

3.3.1 The Structure of the Neural Network Model

Original discussion heat is the very beginning of the neural network. This paper believes that for each time interval, the initial topic heat can reflect the attraction of the topic to all users of the Zhihu platform at the current time point. Therefore, the initial topic heat can be equivalent to the initial network scale and then determine the efficiency. After a series of neuron calculations, all the undetermined coefficients will be obtained based on the principle of reducing the loss function.

The value of opinion leaders is another input. This paper holds that weak relationship networks and opinion leaders are mutually exclusive, that is, networks with opinion

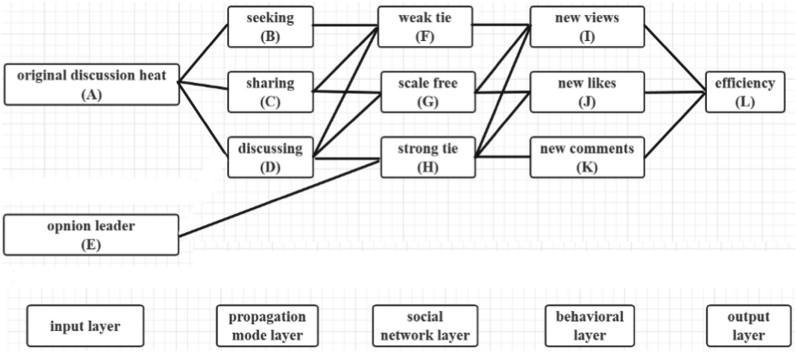

Fig. 1. The diagrammatic sketch of neural network model

leaders cannot be weak relationship networks. In scale-free networks, the value of opinion leaders is to gather a group of users with the same opinions, but it has no obvious effect on the discussion heat of topic. Only in the strong tie social network, the value of opinion leader could be converted into the communication of the topic.

The propagation mode layer indicates the reason why users participate in the communication process of this topic. As previously analyzed, this paper classifies the user groups related to a topic into three types of communication modes: seeking knowledge, sharing and discussing, which are all input from the "original heat" neurons, and their user size is calculated through their respective weights and offsets.

This paper holds that the three communication modes of seeking knowledge, sharing and discussing will enhance the discussion heat of public opinion in the weak relationship network. For the scale-free network, only sharing and discussing mode can increase its value because seeking knowledge will end with getting the satisfied answer. And for strong tie network, only discussing mode could affect it.

The behavior layer represents the actual actions of social network users. The weak network user group will only have views behavior. The scale-free network group will cause views and likes around its core nodes. The user group of strong tie network will lead to all the three behaviors.

The output layer is the finish of the model. The predicted value of the output layer is calculated by three neurons: views, likes and comments. The observed value is the relative efficiency calculated by the DEA model. The iterative principle of this model is to constantly update the parameters to make the error between the predicted value and the observed value smaller and smaller.

3.3.2 Neuron Computing

For example, for the neuron F, it receives the outcomes from neuron B, C and D, and the bias from itself. So, we can express the formula about calculating the value of F as formula (1).

$$F = B * \omega_{BF} + C * \omega_{CF} + D * \omega_{DF} + b_F \tag{1}$$

3.3.3 Activation Function

The sigmoid function is one of the more commonly used activation functions, which can convert any input value into an output value between (0,1), thus ensuring the nonlinearity of the model. In this model, f (x) is used to represent the sigmoid function. In the later analysis, this paper uses the "out" value as the standard value after activation, and the "origin" value as the normal value before activation.

3.3.4 Loss Function

In this paper, the mean square error function MSE (mean square error) is used as the loss function of the model. It can be calculated by formula (2). The mean square error can intuitively show the deviation between the predicted value and the actual value of all samples in the model.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(observed_i - predicted_i)^2 \tag{2}$$

3.3.5 Gradient Calculation

The gradient represents the contribution of the current weight adjustment to the reduction of the overall model error. Due to space limitation, $\frac{\partial MSE}{\partial \omega_{AD}}$ is an example to introduce the gradient calculation process as formula (3). All the other links' gradient calculation can work in the similar way. According to the chain rule:

$$\begin{aligned}\frac{\partial MSE}{\partial \omega_{AD}} = \frac{\partial MSE}{\partial L} * \frac{\partial L}{\partial \omega_{AD}} = \frac{\partial MSE}{\partial L} * \left(\omega_{IL} * \frac{\partial out, I}{\partial \omega_{AD}} + \omega_{JL} * \frac{\partial out, J}{\partial \omega_{AD}} + \omega_{KL} * \frac{\partial out, K}{\partial \omega_{AD}}\right)\\ = \left(-\frac{2}{n}\sum_{i=1}^{n} true_i + 2L\right)*\\ (\omega_{IL} * I_{out}(1 - I_{out}) * \omega_{FI} * F_{out}(1 - F_{out}) * \omega_{DF} * D_{out}(1 - D_{out}) * A + \omega_{GI}\\ *G_{out}(1 - G_{out}) * \omega_{DG} * D_{out}(1 - D_{out}) * A + \omega_{HI}\\ *H_{out}(1 - H_{out}) * \omega_{DH} * D_{out}(1 - D_{out}) * A\\ +\omega_{JL} * J_{out}(1 - J_{out}) * \omega_{GJ} * G_{out}(1 - G_{out}) * \omega_{DG} * D_{out}(1 - D_{out}) * A + \omega_{HJ}\\ *H_{out}(1 - H_{out}) * \omega_{DH} * D_{out}(1 - D_{out}) * A\\ +\omega_{KL}*K_{out}(1 - K_{out})*\omega_{HK}*H_{out}(1 - H_{out})*\omega_{DH}*D_{out}(1 - D_{out})*A)\end{aligned} \tag{3}$$

3.3.6 Parameter Update

After calculating the gradient of each weight, it can be used to update the weight parameters to achieve model learning. The parameter update formula is as follows:

$$\omega_i^{updated} = \omega_i - \eta * \frac{\partial MSE}{\partial \omega_i} \tag{4}$$

The parameter update process generally requires a large number of iterations to make the model continue to learn until satisfactory results are obtained. η, the learning rate, which affects the fitting speed of the model. This paper sets the learning rate as 0.01.

Table 1. The final outcome of the parameters

link	value	link	value	link	value	link	value
ω_{AB}	0.8291	ω_{CG}	0.7747	ω_{FI}	0.7815	ω_{HK}	0.0810
ω_{AC}	0.0748	ω_{DF}	0.0083	ω_{GI}	0.0809	ω_{IL}	0.0051
ω_{AD}	0.0111	ω_{DG}	0.1055	ω_{GJ}	0.3621	ω_{JL}	0.0040
ω_{BF}	0.8506	ω_{DH}	0.6238	ω_{HI}	0.4964	ω_{KL}	0.0056
ω_{CF}	0.8506	ω_{EH}	0.6968	ω_{HJ}	0.3538	MSE	0.0234

4 Result

By comparing the predicted value of the model with the actual observation value, finally the average prediction error of the model in this paper is 8.39%, and the mean square error after training is 0.023. In general, the model in this paper has achieved good fitting effect. However, for the extreme abnormal values in the sample, the error tends to be larger. One is the topic with the characteristics of phenomenon level events, and the other is the old topic of "rejuvenated". The former refers to topics that go beyond the scope of normal entertainment needs, social needs, emotional satisfaction and other conventional topics, such as "Hua Chenyu responded to having a daughter with Zhang Bichen". These topics often rise to the height of social reflection, policy remarks and national identity, and have more discussion value than other topics. The latter refers to topics that have been fully discussed, but because of some opportunities, these topics rejuvenated, such as "What kind of boy is doomed to be single?" and "How to evaluate the actress Mary?", have been on the Zhihu Hot List again because of Valentine's Day and the Spring Festival film. For the mathematical model, it is difficult to identify such rejuvenated topics, so it still predicts a relatively optimistic efficiency. But in fact, such topics are like a gold mine which has been fully explored, and it is difficult to provide continuous attraction to user groups. Usually, the discussion heat of such topics comes and goes fast.

Table 1 summarizes the training outcome of the weight of each link in the neural network.

5 Conclusion

Through the result of the training outcome, we can identify the function path of three propagation modes and propose the suggestions about promoting or curbing the public opinion communication.

The typical path of communication for the purpose of seeking knowledge is A-B-F-I-L, that is, Zhihu users do not establish a connection with other users or opinion leaders, but click to enter the topic of their interest. During this process, they basically provide viewing behavior for the topic's discussion heat. This communication mode is driven by users' own interests, and generally does not involve practical interests. The relationship between users is characterized by a weak relationship network. In this communication mode, advertising will be a strategy with high expected income, such as paid consultation,

which will get more exposure opportunities under the support of high views volume. If we need to curb the fake news or false knowledge in this mode, it would be a better choice to control the propagation path, such as actively deleting inappropriate responses or platform managers blocking the release of negative responses. Because few users will track the follow-up development of the topic in this mode, they will turn their attention to other topics after browsing.

The typical path of communication for the purpose of sharing is A-C-G - (I + J) - L. There will be some core nodes look like opinion leaders in such topics, but these opinion leaders are selected spontaneously from such topics. Therefore, the user group of this communication mode often presents the characteristics of a scale-free network. On the sub-network of this topic, the advantages of authority and interest relevance will be amplified. Therefore, users with professional knowledge highly related to topics can quickly accumulate fans by answering these topics. In this mode of communication, the "opinion leaders" will unify the views within the sub-network. Therefore, it is difficult to curb the spread of such topics unless there is a more authoritative node (usually Zhihu administrator). To eliminate the negative effect of rumors, the best way is to control the source, because the normal nodes in the scale-free network will not influence the robustness of the whole network. Legislation and punishment on rumormongers would be the most effective way.

For the purpose of discussion, the typical action path is E-H - (I + J + K) - L. The main promoters of such topics are well-known opinion leaders. One of the characteristics of this mode of communication is the fight for the voice of public opinion. In this process, opinion leaders often have motives, such as flow attraction and flow realization, for establishing the advantage in public opinion. In this mode, strong connections have been established among user groups. As a result, users have a higher probability of repeatedly viewing and commenting on topics. Generally, this communication mode is based on the widespread social contradictions, so the existence of high interest relevance and large user base is an inevitable feature of this communication mode. Topics such as gender relations, urban comparison and regional cultural differences naturally have the attribute of public opinion competition. For the statements that do not use offensive words but tend to be negative, cold treatment is the best way. Platform operators and government regulators should promote what is the positive and try to make it the theme of the online community environment.

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