Propagation Analysis of Internet Opinion Based on Improved SEIR Model

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Abstract

The exposed group play an important role in public opinion propagation since they can either spread or block the information. In this paper, focusing on the propagation uncertainty and spreading effect of the exposed users on the Internet, the SEIR (Susceptible-Exposed-Infected-Recovered) model is reformulated by introducing new parameters. The improved SEIR model is used to depict the opinion propagation. With the help of MATLAB, we conduct extensive simulations to investigate the effect of various parameters of the model on the propagation of Internet opinion. The simulation results show that the infected probability of the exposed and the susceptible users affect both the outbreak time of opinion and the number of infected users, while the exposed probability of the susceptible users affects only the outbreak time of opinion, and the recovered probability of the exposed and infected users makes a difference on the largest number of infected users only. These conclusions can be helpful for the opinion managers to take measures after an opinion event happens.

Keywords: *Internet opinion, opinion propagation, SEIR model*

1 INTRODUCTION

With the rapid development of the Internet and mobile media, information spreads faster on the internet. On the one hand, people can access a lot of fresh information every day; on the other hand, the Internet provides a new way for the propagation of public opinion, which has brought a new challenge to opinion control. Traditional public opinion usually spread by oral and ear, in newspapers and periodicals, on TV news, etc. Then its spreading area was small, the spreading speed was slow, and people acquired the opinion by single or limited means. However, the online public opinion embeds in the Internet space, directly reflects the social hot spot public sentiment. When a social public emergency or negative news event happens to a corporate, the internet users can directly express their personal views through social media, including negative attitudes and strong opinion preferences. As the Internet breaks the boundaries of time and space, some views may quickly gather into the public opinions and become hot spots in a quite short period. This results in strong negative public opinion, which leads to unexpected bad effects on society or enterprises.

Take Pinduoduo, one of China's leading e-commerce companies, as an example, which owns the largest number of users in the country. The company's image and experience evaluation in the minds of users have been very good, until the news “sudden death of an employee on his way home from work in the middle of the night" happened on January 3, 2021. This breaking news attracts wide attention on the Internet. The company did not give any response to the event officially until 20 hours later. Then the following replies were strongly condemned and accused by the Internet users, which triggered a subsequent public opinion shock, and further led to a stock fall of the company. Therefore, it is very important for enterprises to fully understand the law of public opinion communication or propagation, make effective public opinion analysis in time, and establish a good public opinion risk management and guidance mechanism.

There has been a lot of research about the analysis of public opinion, mainly focusing on the propagation and guidance of public opinion guidance. Adam et al. (2010) [1] point out that in some emergencies, such as fires and earthquakes, people's behavior is dominated by their

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emotions, which are infected by others. Liu et al. (2014) [7] improve the traditional epidemic model to study emotion contagion in financial markets, and investigate the effect of emotion on the price of the stock. Golmohammadi et al. (2017) [4] attempt to predict the abnormal operations in the stock market by analyzing the emotion spread in social networks. Ding et al. (2015) [2] propose to fuse the emotion spread on the social network in the forecasting model, and design the dual sentimental Hawkes process to predict the video popularity. As the goal of public opinion analysis is opinion guidance, many scholars pay more attention to public opinion guidance research. In the evolution of public opinion, Dong et al. (2017) [3] propose a consensus-building process based on user leadership and the structure of social networks. They suggest that the consensus on the social network can be achieved by modifying the structure of social networks. Similarly, from the perspective of group decision-making, Li et al. (2017) [6] develop a dynamic consensus-building model which aims to minimize the loss of information and the structural adjustment of social networks. Further, Zhang et al. (2018) [9] take into account the various concerns and satisfactions of different individuals, and propose a consensus-building mechanism for social network group decision-making. Prasetya et al. (2020) [8] consider the echo chamber effect and investigate opinion dynamics affected by news propagation, they also model the connection strength between individuals with the Independent Cascade (IC) model. Li et al. (2022) [5] propose the attributed influence maximization based on the crowd emotion, aiming to apply the user's emotion and group features to study the influence of multi-dimensional characteristics on information propagation.

Based on the SEIR model, we consider the different effects and propagation uncertainty of the exposed group, and introduce three more parameters to improve the SEIR model. Then we make extensive simulations to reveal the propagation rule of opinion. Lastly, according to the above analysis, the corresponding guiding strategy of opinion is put forward to release or solve the crisis of Internet opinion.

2 MODEL FORMULATION

The propagation of negative opinion on the Internet depends on the communication between netizens that those with strong personal subjective opinions affect those with neutral opinion. The spread process of Internet opinion is quite similar to the spread of infectious diseases, in which the healthy persons are infected by patients. Therefore, the epidemic model is widely used in the analysis of opinion propagation.

2.1 Components of the epidemic model

In this paper we select a typical epidemic model, i.e., the SEIR model to characterize the propagation of opinion. The SEIR model involves the following four components.

S (Susceptible). The Susceptible refers to the ordinary people that lack immune ability and are easy to be infected by those infectious persons. With some communications, the ordinary people who do not know well about the negative opinion will have a certain probability to be infected by the infectious and become infectious ones.

E (Exposed). The Exposed are those people who have come into contact with an infected person but they are not immediately infectious to others. This also means that there is an incubation period. In the propagation process of opinion, the Exposed have a certain probability of becoming infected, and also have a chance of being the Recovered.

I (Infected). The Infected represent those people who have been infected and show their preferences, i.e., disease or negative opinion. With the communications, the Infected can affect the Susceptible and change them to be the Exposed or the Infected. However, with the spread of opinion, an Infected have the probability to turn into the Recovered.

R (Recovered). The Recovered are people who have recovered from an infection and are immune to the same infection. In the spreading process of network opinion, some infectious will not continue to spread their opinions after the clarification or explanation. That means these infectious quit the dissemination and become the Recovered.

2.2 Improvement of SEIR

Based on the theory of epidemic diseases, this paper further considers the characteristics of opinion propagation, and sets three more parameters to control the propagation probability in the spreading of Internet opinion. We propose that a Susceptible can become an Exposed or Infected if he or she communicates with the infected ones. Therefore, we develop a new SEIR model to depict opinion propagation. As the communication of opinions on the Internet is widely diffused, the improved model is more in line with the actual situation of public opinion propagation. The framework of the improved SEIR model is illustrated in Figure 1.

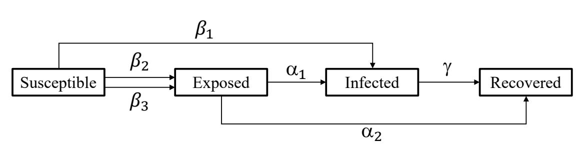

Figure 1: The illustration of the improved SEIR model

Assuming that the total number of internet users is N, all of the Internet users are divided into four groups: S (Susceptible), E (Exposed), I (Infected), R (Recovered). The number of users in each group is S, E, I and R, respectively, and N=S+E+I+R. An infected user contacts with r_1 persons per unit time, and the infected probability of susceptible is β_1. Besides, the Susceptible will have the probability β_2 to become an Exposed after communication with the Infected. This is reasonable because when the infected ones express their opinion to the susceptible users, the latter either accept the opinion immediately to be new Infected, or think over the opinion for a while and become the new Exposed, or refuse the opinion to maintain the susceptible state. The Exposed also communicate with the Susceptible. It is assumed that an exposed user contacts with r_2 person per unit time, and make the Susceptible to be new Exposed with probability β_3 . The description of the parameters involved in the model is shown in Table 1.

Table 1: The parameters in the model

Para-meter	The definition of a parameter
r_1	The number of users that an Infected communicates with
r_2	The number of users that an Exposed communicates with
β_1	The infected probability of a Susceptible after communication with an Infected
β_2	The exposed probability of a Susceptible after communication with an Infected
β_3	The exposed probability of a Susceptible after communication with an Exposed
α_1	The infected probability of an Exposed
α_2	The recovered probability of an Exposed
γ	The recovered probability of an Infected

2.3 Formulation of improved SEIR

Based on the above demonstration of the model, the following differential equations can be established to describe the mechanism of the improved SEIR model:

$$\frac{dS}{dt} = -r_1\beta_1 I\frac{S}{N} - r_1\beta_2 I\frac{S}{N} - r_2\beta_3 E\frac{S}{N} \quad (1)$$

$$\frac{dE}{dt} = r_1\beta_2 I\frac{S}{N} + r_2\beta_3 E\frac{S}{N} - \alpha_1 E - \alpha_2 E \quad (2)$$

$$\frac{dI}{dt} = r_1\beta_1 I\frac{S}{N} + \alpha_1 E - \gamma I \quad (3)$$

$$\frac{dR}{dt} = \alpha_2 E + \gamma I \quad (4)$$

$$S(t) + E(t) + I(t) + R(t) = N \quad (5)$$

$\frac{dS}{dt}$ is the changed number of susceptible users in unit time, which includes three components. The first term in Eq. (1) denotes the number of susceptible users change to be the Infected after communication with infected users. The second term in Eq.(2) denotes the number of susceptible users change to be the Exposed after communication with infected users. The third term in Eq.(2) denotes the number of susceptible users change to be the Exposed after communication with exposed users. $\frac{dE}{dt}$ is the changed number of exposed users in unit time, which contains the increased users changed from Susceptible, i.e., $r_1\beta_2 I\frac{S}{N}$ and $r_2\beta_3 E\frac{S}{N}$, the decreased users changing to be Infected, i.e., $\alpha_1 E$, and Recovered, i.e., $\alpha_2 E$. $\frac{dI}{dt}$ is the changed number of infected users in unit time, which contains the increased users changed from Susceptible and and Exposed, as well as the decreased users changing to be Recovered. $\frac{dR}{dt}$ is the changed number of recovered users in unit time, which contains the users changed from the Exposed and Infected. Eq.(5) signifies that although the number of users in different groups is changing, the total number of Internet users keep unchanged.

3 SIMULATION AND ANALYSIS

In this section, extensive simulations are conducted to reveal the opinion propagation rule on the Internet. We first describe the basic parameter settings, and then analyze the influence of each parameter on the propagation process by varying the values of parameters.

3.1 Parameter Setting

In the simulation, suppose the total number of users on the Internet is N=10000, and N is fixed. At the beginning of the opinion propagation, the number of the infected users is I=1, the number of the exposed users is E=0, and the number of the recovered users is R=0. Moreover, there are 8 parameters involved in the improved SEIR model. The initial values of these parameters are set as follows: $r_1 = 20$, $r_2 = 20$, $\beta_1 = 0.01$, $\beta_2 = 0.03$, $\beta_3 = 0.01$, $\alpha_1 = 0.07$, $\alpha_2 = 0.02$, and $\gamma = 0.1$. In the following simulations, the values of these parameters keep unchanged except for special settings.

3.2 Simulation

3.2.1 The influence of α1

The parameter α_1 denotes the infected probability of exposed users. To evaluate the influence of this parameter on the propagation, we vary the parameter with different values and make the simulation. Fig.2 displays the simulation results of the SEIR model with $\alpha_1 = 0.07$ and $\alpha_1 = 0.1$.

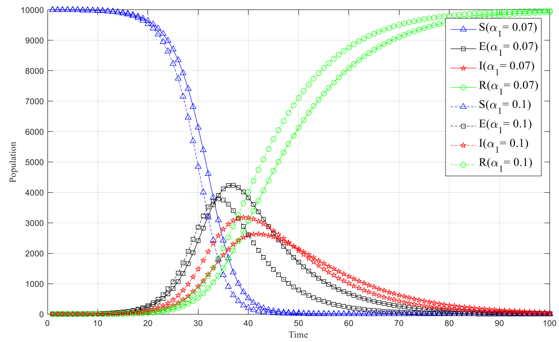

Figure 2: The simulation of opinion propagation with $\alpha_1 = 0.07$ and $\alpha_1 = 0.1$

According to the Fig. 2, when the value of α_1 increases, the largest number of exposed users decreases, but the largest number of infected users rises and the opinion outbreak time speeds up. As a result, when the infected probability of exposed users increases, it will make a challenge for opinion guidance as the outbreak happens earlier.

3.2.2 *The influence of* $\alpha\mathbf{2}$

The exposed users may transfer to the Recovered directly, instead of experiencing the state of Infected. The parameter α_2 denotes the recovered probability of an Exposed. To assess the influence of this parameter on the propagation, we set the value of α_2 to be 0.02 and 0.05, respectively, and make the simulation. Fig.3 shows the corresponding simulation results of the SEIR model.

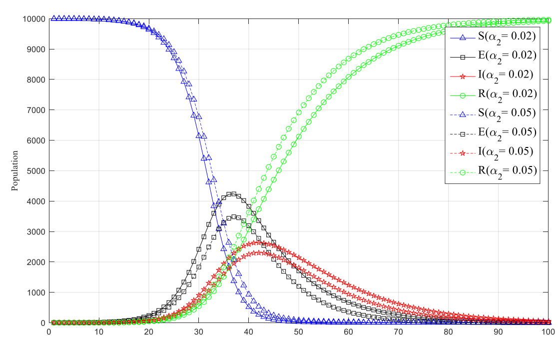

Figure 3: The simulation of opinion propagation with $\alpha_2 = 0.02$ and $\alpha_2 = 0.05$

It can be seen from Fig. 3 that when the value of α_2 increases, the largest number of both exposed and infected users decreases. However, different from the situation where α_1 varies, the change of α_1 does not delay or speed up the outbreak time of the Internet opinion. When the value of α_2 increases, it does not make the obvious influence on the Susceptible and Recovered.

3.2.3 *The influence of* β_1

When a Susceptible contacts with an Infected, the susceptible user will be affected and become either the Exposed or Infected. The parameter β_1 denotes the infected probability of a Susceptible after communication with an infected person. To analyze the influence of this parameter on the opinion propagation, we set the value of β_1 to be 0.01 and 0.04, respectively, and simulate the spreading process of Internet opinion. Fig.4 presents the simulation results with different parameter values.

As observed in Fig. 4, the value change of parameter β_1 significantly affect the opinion propagation. First, with the increase of parameter value, the number of infected users at the outbreak time obviously rises. Second, the opinion outbreak time with $\beta_1 = 0.04$ is much earlier than that with $\beta_1 = 0.01$. As the result, the number of susceptible users decreases sharply between time=10 and time=20. This type of opinion propagation will bring a large challenge for opinion management.

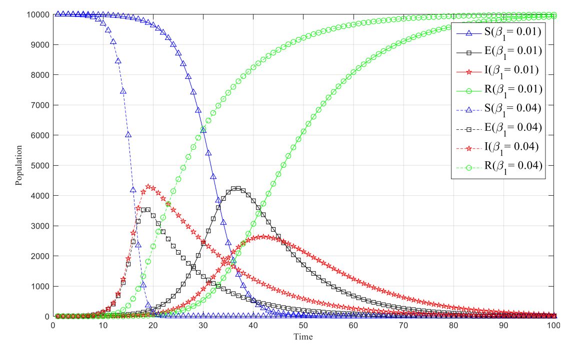

Figure 4: The simulation of opinion propagation with $\beta_1 = 0.01$ and $\beta_1 = 0.04$

3.2.4 *The influence of* $\boldsymbol{\beta 2}$

Different from β_1, the parameter β_2 denotes the exposed probability of a Susceptible after communication with an infected person. Similarly, to inspect the impact of β_2 on the opinion propagation, simulations are conducted by varying the value of β_2, i.e., $\beta_2 = 0.03$ and $\beta_2 = 0.06$. The simulation result is illustrated in Fig. 5.

It can be seen from Fig. 5 that the increasing value of β_2 boosts the largest number of the Exposed and speeds up the explosion time of exposed users and infected users, but does not make a significant effect on the largest number of infected users.

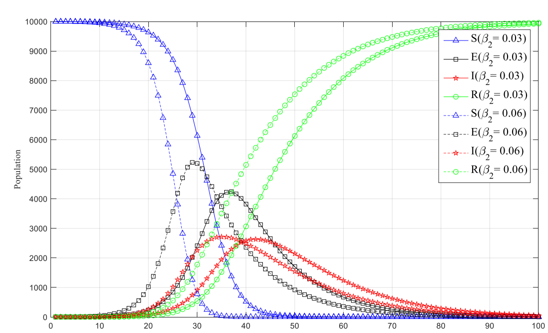

Figure 5: The simulation of opinion propagation with $\beta_2 = 0.03$ and $\beta_2 = 0.06$

3.2.5 *The influence of* $\boldsymbol{\beta 3}$

The parameter β_3 is the other parameter affected the Exposed, which denotes the exposed probability of a Susceptible after communication with an exposed user. To investigate the influence of β_3 on the opinion propagation, we make a simulation by setting this parameter to be 0.01 and 0.03. The simulation of the opinion-spreading process is exhibited in Fig. 6.

Compare Fig. 6 with Fig. 5, when the value of β_3 increases, the simulation result is quite similar to the situation in which the value of β_2 varies. This is reasonable because both the parameters directly affect the number of exposed users in the spreading of Internet opinion.

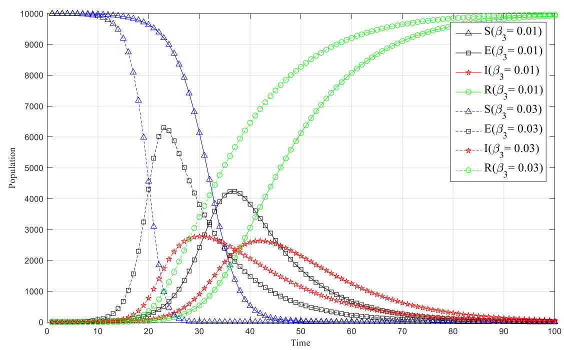

Figure 6: The simulation of opinion propagation with $\beta_3 = 0.01$ and $\beta_3 = 0.03$

3.2.6 *The influence of* γ

The ultimate result of the opinion propagation is that all of the users transfer from the Susceptible to the Recovered, which indicates that the opinion propagation is under control or the propagation ends. The parameter γ represents the recovered probability of the infected users. As the infected users play an important role in the spreading of opinion, the recovered probability of Infected will also affect the overall opinion propagation. We set $\gamma = 0.1$ and $\gamma = 0.2$, and simulate the model. The result is displayed in Fig.7.

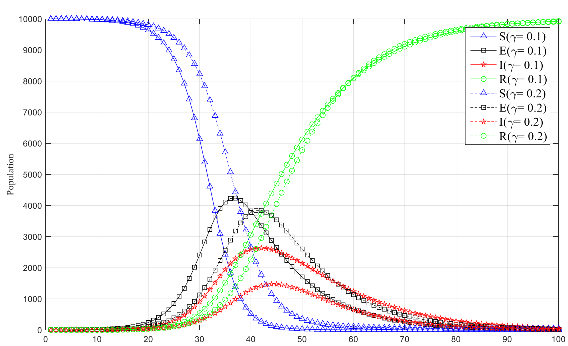

Figure 7: The simulation of opinion propagation with $\gamma = 0.1$ and $\gamma = 0.2$

It is shown in Fig.7 that the value change of γ makes a difference in the number of infected users at the outbreak time, however, it does not affect the outbreak time of opinion, i.e., it neither speeds up nor delays the outbreak.

3.3 *Analysis of simulation results*

In the former subsection, we conduct 6 groups of simulations to examine the influence of each parameter. For the Internet opinion propagation, there are two important issues concerned by the opinion manager, one is the outbreak time of opinion, and the other is the largest number of infected users.

Firstly, according to the above simulations, it can be found that the parameter β_1 and α_1 affect the outbreak time and the number of infected users at the same time. Therefore, it is suggested that the opinion managers take the measures to decrease the infected probability of an Exposed and the infected probability of a Susceptible after communication with an Infected as soon as possible.

Secondly, the parameter β_2 and β_2 apparently affect the outbreak time of opinion only. Trying to delay the outbreak time will allow the opinion manager more time and chance to figure out the reasons for an event, and further find out the solutions. As these two parameters are related to the exposed probability of the susceptible users, it is suggested that an enterprise should maintain its good image and protect the trust of the customers, so that it prevents or delays users from becoming the exposed users.

Thirdly, the parameter α_2 and γ make a difference in the largest number of infected users. These two parameters control the recovered probability and a manager aims at boosting the values of these two parameters. A feasible way is to reveal more positive information to the users, and make them transfer to be the Recovered efficiently.

4 CONCLUSIONS

In this paper, an improved SEIR model is proposed to simulate the opinion propagation by considering the characteristic of Internet opinion. We formulate the new model and conduct extensive simulations to investigate the influence of various parameters on the spreading of opinion.

The opinion propagation on the Internet is quite complicated. For simplicity, in the formulation of the model, we make coupled assumptions and ignore some factors such as the interaction between users in different groups, the participant effect of multi-medias, etc. In the future work, we will consider these factors to construct an updated model which can better characterize the spreading of Internet opinion.

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