

# Modeling and Analysis on the Popularity Accumulation Process of Corporate Emergencies on Social Media

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**Abstract**—The rapid development of social networks has greatly inspected the ability of enterprises to cope with emergencies. The existing researches are difficult to be applied to the analysis of the popularity accumulation law about corporate emergencies, and the corresponding countermeasures cannot be developed more effectively. In this paper, combining with the development course of actual events, the diffusion process of emergencies is described through the concept of system cybernetics and "black box" theory. Based on the conclusion of inference, we carry out the error analysis and image fitting of the first-order system function, the second-order system function and the classical SIR epidemic model. Then we analyze the fitting degree with the actual events and compare the mutual applicability. According to the results, some suggestions are given to the enterprises for dealing with emergencies and formulating the public relations strategies, and we will lay the foundation for further researches.

**Keywords:** enterprise public opinion, popularity accumulation, error analysis, system response function

## I. INTRODUCTION

The rapid development of social networks has changed people's communication methods to some extent. At the same time, a variety of information can be spread through more channels to accelerate the diffusion of information, therefore such phenomenon brings more and more rigorous evaluation for enterprises' ability to cope with emergencies. When enterprise's relevant emergencies occur suddenly on social networks, the popularity will be accumulated rapidly. According to the mechanism of its popularity accumulation, how to build an appropriate diffusion model is of great significance to the management and control of the corporate emergencies' information spread.

Existing researches on information diffusion models have yielded some results, which can portray information dissemination to a certain extent. The diffusion models can be

broadly classified into three categories, namely, threshold model, independent cascade model, and epidemic model. The threshold model[1-3] and the independent cascade model[4-6] are the models for studying the information dissemination law from the perspective of micro-network structure; the other is the epidemic model for conducting spread trend analysis under the macroscopic perspective, divided into SIR model, SI model, SIS model[7-9], SHIR model[10] and so on, and there are many studies on modeling the disseminating trends[11-14]. In social networks, the development stage can be divided for the sequential diffusion of emergencies can form the popularity accumulation of the event. With the development of network technology, vast researches on the timing of information diffusion in emergencies[15] burst out. Whether the dissemination process is characterized from the perspective of the model[1; 2; 6; 16; 17], or from the application point of view, we have achieved solid academic development in the practical problems such as key user identification[18], rumor recognition control[19], diffusion forecasting[20].

It can be seen that the research results of the diffusion model are already abundant, but these results are difficult to apply to the regular analysis of the popularity accumulation process on corporate emergencies. First of all, for the difficulties to obtain valuable information on existing network platforms, most of the research are carried out by portraying the spread of specific types of information on a single platform, while, it cannot completely describe the overall events with ignorance the impact of online media. The network structure of this part is difficult to master. So, we can get the conclusion that the relevant micro-studies based on this are not applicable for the depiction of the popularity accumulation process about the enterprise's emergency. Secondly, although the epidemic model[21] can characterize the information diffusion trend at macroscopic level and predict the total amount of dissemination, it is powerless to analyze the distribution law and the corresponding influencing factors including human

behavior[22] on the timeline. In addition, although some special models can describe and predict the information diffusion trend[11; 12], it is also impossible to conduct corresponding researches on the timeline combined with corporate public relations strategy. Despite of the application of spread models in rumor recognition[17; 19; 23; 24], structural virality[25], key user identification[18] and emergency popularity prediction control[26] having been well developed, how to combine the popularity accumulation law in emergencies with the public relations strategy of enterprises about emergencies so as to improve the effectiveness of corporate relevant countermeasures is still an urgent problem to be solved.

Therefore, on the basis of the system cybernetics method introduction, this research will analyze the popularity accumulation process model of corporate emergencies on social media based on the multi-platform popularity data. The system identification method is used to solve the complexity of the influencing factors of the enterprise emergency popularity accumulation process. It is advisable to analyze and model from the overall perspectives. The popularity accumulation process is very complicated and it is determined by various factors, such as government intervention and corporate behavior. This complex process can be seen as a complex system. Instead of exploring the details of the specific parts of it, we will analyze it as a whole and judge the overall process through the results, namely the "black box" theory. Firstly, the popularity accumulation process in the issue about four actual events is studied, and the popularity accumulation function is derived according to the cybernetics thought combined with the Laplace transform; Secondly, the Laplace transform method is used to analyze the transfer function form with adding the step addition; Thirdly, we structure the second order response function model of the popularity accumulation process, verify the validity of the model validation and conduct empirical researches by detailed analysis based on transfer function with introducing the impact of information editing and reading process on social media. Then the related factors affecting the popularity accumulation law time, the targeted public relations strategy, and new direction for subsequent studies of information diffusion can be explored.

## II. METHODOLOGY AND THEORETICAL ANALYSIS

### A. Qualitative Analysis of the Development Process About Corporate Emergencies on Social Media

According to the development law of general emergencies on social media, the analysis of the incident popularity can be known from the qualitative point of view. The cumulative probability of popularity will increase with time, and finally stabilize with the cumulative velocity described in time series. According to the subdivision process, when the corporate public opinion events occur on social media, they will experience an incubation period during the early time, and the amount of transmission is rarely negligible.

After a certain period of development, the amount of public opinion transmission has produced an explosive growth, and the cumulative speed has surged into a rapid growth period. Then as the growth rate dropped and gradually became zero,

the spread of the event came to an end. This process is similar to the time domain response process of the physical system, but certain fluctuations may occur at different time points due to the intervention of some introductory communicators in the actual process.

TABLE I. COMPOSITION OF POPULARITY DATA

Name	State
Weibo	Weibo account release microblog information related to the enterprise; include 1. Weibo with relevant keywords (consulting with the company to define keywords); 2. Comment containing the keyword Weibo; 3. Forwarding containing keyword Weibo; 4. Like the keyword microblogging.
WeChat public platform	On the WeChat public platform, the related article data is collected in real time according to the keyword of the enterprise.
Online media articles	It includes nearly 20,000 media outlets including central media (such as CCTV News, People's Daily, etc.), new media platforms (such as The Paper, etc.) and technology media (such as tiger sniffing).

Here, we choose the popularity data of four events to analyze, including:

- a) Attack on a female student in Heyi hotel, total popularity 38066;
- b) CCTV exposes "Eleme" dirty workshop, total popularity 11830;
- c) Wei Zexi event, total popularity 66245;
- d) Opening of MWC2016 mobile world congress, total popularity 17319;

All the empirical analysis and researches are based on these four representative events of this paper. The popularity data of the events consist of the Table I. The cumulative probability of popularity changes with time as shown in Fig.1.

It can be seen from the Fig.1 that the development process is in line with the above qualitative analysis after the sudden outbreak of the actual events. And this process is similar to the time domain response of the physical system.

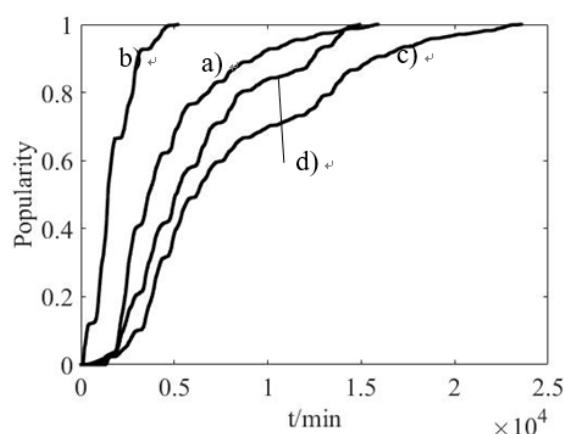


Fig. 1. Popularity cumulative probability distribution curve a) attack on a female student in Heyi hotel; b) CCTV exposes "Eleme" dirty workshop; c) Wei Zexi event; d) opening of MWC2016 mobile world congress.

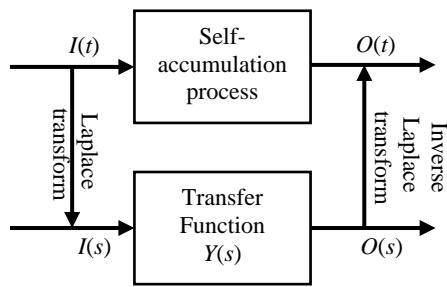


Fig. 2. Popularity accumulation process transfer function form.

Although there are certain fluctuations, these fluctuations are caused by the involvement of key communicators. And we will not discuss this issue in depth here. Therefore, we can use the physical system time domain response method by defining the input events and transfer function to model popularity accumulation process of entire events.

#### B. First-Order Popularity Accumulation Process Distribution Model of Corporate Emergencies

The time-series accumulation form of information diffusion is affected by complex social systems. Combined with the previous actual cases, information dissemination will be interfered by certain external factors besides its own content. As shown in the actual case, the speed of popularity accumulation will develop with the event. The explosive growth come first and then the speed gradually falls back. When there is a key spread node, the speed of information diffusion will produce a step-like increase. But it will eventually fall back to nearly zero, so that the popularity accumulation tends to stagnate. In this paper, we only model the popularity accumulation process, and the specific analysis of the fluctuations caused by external factors will be carried out in the subsequent researches.

We use the transfer function method in system cybernetics and the Laplace transform to solve the problem with the “black box” theory. The overall process for popularity accumulation is shown in Fig. 2 above.

Where  $Y(s)$  is the transfer function of the popularity accumulation process caused by the event itself;  $I(t)$  is the input, which is the quantitative representation of the external environmental impact;  $O(t)$  is the output, which is the cumulative probability of the emergency popularity at time  $t$ . That is the current cumulative popularity quantity or popularity cumulative amount indicating the actual popularity accumulation process  $0 \leq O(t) \leq 1$ ;  $I(s)$  and  $O(s)$  are the Laplace transforms of input  $I(t)$  and output  $O(t)$  respectively.

Firstly, we derive the cumulative function of the event popularity, and consider the input as a dimensionless step function, namely:

$$I(t) = \begin{cases} 0, & t < 0 \\ 1, & t \geq 0 \end{cases}, \quad t \text{ is time.} \quad (1)$$

It means that for the popularity accumulation process, the external environment has continuously the same effect on it. Thereby we can get as in (2):

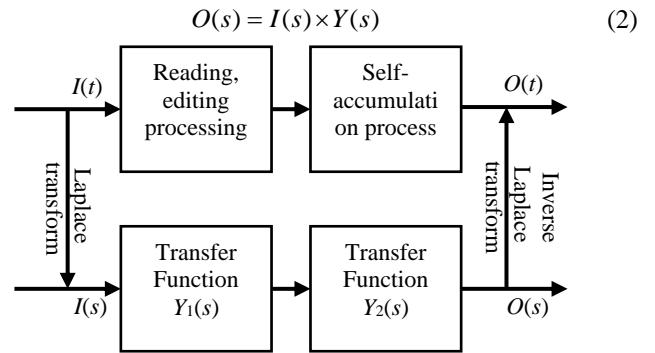


Fig. 3. Popularity accumulation process transfer function form.

And

$$I(s) = \frac{1}{s} \quad (3)$$

Based on this thought and the relevant empirical analysis of the previous article, we would not consider the external environment. We regard the popularity accumulation process caused by the enterprise itself in the emergency as a continuous system changing with time. At this time, the actual process of the system is shown in Fig. 2. In the process of popularity accumulation, the cumulative rate of popularity can be regarded as the derivative of the popularity accumulation amount respect to time. According to the system cybernetic principle, we can get the transfer function of the first-order physical system output response of the popularity accumulation process, as in (4):

$$Y'(s) = \frac{1}{Ts + 1} \quad (4)$$

Where  $T$  is the time constant, and the actual popularity accumulation process has a certain delay. This process is the delay in the diffusion process brought by the social network platform itself. And the delay theorem based on the Laplace transform operation, as in (5):

$$L[f(t - \tau)] = e^{-\tau s} F(s) \quad (5)$$

Then we get the transfer function of the process:

$$Y(s) = \frac{e^{-\tau s}}{Ts + 1} \quad (6)$$

Expression (6) is a transfer function that does not consider the cumulative process of the social media enterprise's own emergencies. That is the first-order pure delay popularity cumulative transfer function model. According to the expression (2)  $O(s) = I(s) \times Y(s)$ , that is (7):

$$O(s) = I(s) \times Y(s) = \frac{e^{-\tau s}}{(Ts + 1)s} \quad (7)$$

By performing the Inverse Laplace transformation of  $O(s)$ , a continuous model of the cumulative distribution probability about corporate emergencies on social media can be obtained as in (8):

$$O(t) = 1 - e^{\frac{-(t-\tau)}{T}} \quad (8)$$

Obviously, the expression (8) can also be regarded as the unit step response of the first-order system.

#### C. Second-Order Popularity Accumulation Process Distribution Model of Corporate Emergencies

In the actual social network information dissemination process, the processes of reading, editing, and forwarding after the communicator obtains the information are involved. Therefore, we need to introduce a transfer function indicating the response process when constructing the related model, as shown in Fig. 3.

Combining this idea with the previous derivation, we can conclude that the transfer function of the process of reading and editing is

$$Y_1(s) = \frac{1}{T_1 s + 1} \quad (9)$$

The transfer function of the emergencies popularity accumulation process is

$$Y_2(s) = \frac{e^{-\tau s}}{T_2 s + 1} \quad (10)$$

Where  $T_1$  and  $T_2$  are the time constants in the corresponding transfer function, then the transfer function of the overall process is the product of the two, as in (11).

$$Y(s) = \frac{e^{-\tau s}}{(T_1 s + 1)(T_2 s + 1)} \quad (11)$$

When the input quantity is a dimensionless step function (1), the Laplace transform of the output response function  $O(t)$  is

$$O(s) = \frac{e^{-\tau s}}{(T_1 s + 1)(T_2 s + 1)s} \quad (12)$$

The continuous model of the cumulative distribution probability about corporate emergencies on social media under this condition can be obtained as

$$O(t) = 1 - \frac{T_1 e^{\frac{-(t-\tau)}{T_1}}}{T_1 - T_2} + \frac{T_2 e^{\frac{-(t-\tau)}{T_2}}}{T_1 - T_2} \quad (13)$$

And expression (13) can be regarded as the unit step response of the second-order system.

#### D. Parameter Estimation and Error Analysis of the Model

For the expressions (8) and (13), if the curve fitting judgment is to be consistent with the actual time data, we need value of the parameter  $\tau$  and the parameter  $T$ . Let the number of samples be  $k$ , and  $O(t_k)$  be a known statistical value.  $O'(t_k)$  is the value calculated by the expression (8) or (13). Then the estimation problem of the parameter  $\tau$  and the parameter  $T$  is the problem of solving the optimization parameter by using the least square method, and that is the parameter optimization method. The aim is to minimize the following objective function, as in (14):

$$J = \sum_{k=1}^m (O(t_k) - O'(t_k))^2 \quad (14)$$

By using this method, we can simulate the cumulative popularity distribution probability statistics of four actual events data and get the corresponding fitting results.

### III. RESULTS

In this part, we obtain the fitting images and error analysis of the popularity accumulation process of the first-order response function, the second-order response function and the SIR model. A comparative analysis of the three can find the differences among them and get the model which are the most consistent with the actual events.

Fig. 4 shows the fitting image and error analysis of the popularity accumulation process of the first-order response output functions of four events. The upper half shows the fitting image of the popularity accumulation process  $O(t)$ , and the lower half shows the error analysis, with time in minutes. It can be seen that the output of the first-order response increases rapidly at the beginning of the event, reaches the final stage quickly and does not change any more; The error is also very large in the initial stage beyond the scale of error analysis. The error is reduced gradually in the actual event accumulation process. This indicates that the first-order response output function is helpful to describe the overall process of popularity accumulation, but the final result is too far from the actual result, so the model is not sufficient to describe the popularity accumulation process of emergencies.

The overall trend of the four events is similar, but the trend is a little different, but it does not affect the fitting effect of the second-order response output function shown in Fig. 5. Compared with the first-order response output function, it is closer to the actual popularity accumulation process. It can be seen from the figure that the fitting results are good, except that different events will have certain fluctuations in different stages and that leads to large errors and large error fluctuations. With the continuous development of events, the errors and fluctuations gradually decrease. Although there are certain fluctuations in the popularity accumulation process, the overall fitting result is good, and where the continuity is stronger, the fitting effect is better. Therefore, the validity and feasibility of the second-order response output function can be seen from the fitting result, and its description of the popularity accumulation process is more accurate.

In contrast, the results shown in Fig. 6 are in the middle of the first two models. Compared with the second-order model, the SIR model has a low degree of conformity with the actual process, but it can describe the overall trend of popularity accumulation process more accurately. And the SIR model can divide the development stages of events according to a certain accumulation rate. However, SIR model is not just one single kind of model. It can be transformed according to the actual environment. Therefore, according to more specific conditions, a more suitable SIR model can be constructed to describe the process of information transmission and popularity accumulation.

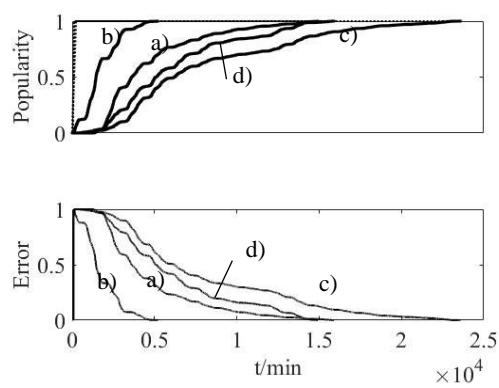


Fig. 4. First-order response output function popularity cumulative distribution fitting curve and error analysis a) attack on a female student in Heyi hotel; b) CCTV exposes "Eleme" dirty workshop; c) Wei Zexi event; d) opening of MWC2016 mobile world congress.

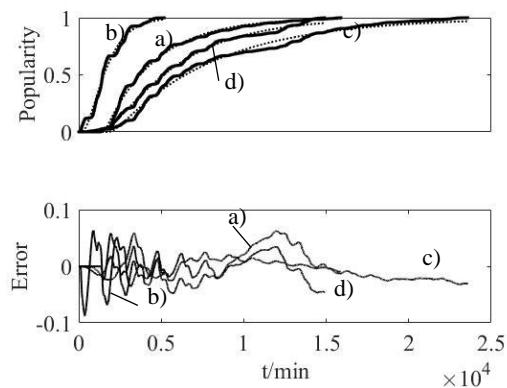


Fig. 5. Second-order response output function popularity cumulative distribution fitting curve and error analysis a) attack on a female student in Heyi hotel; b) CCTV exposes "Eleme" dirty workshop; c) Wei Zexi event; d) opening of MWC2016 mobile world congress.

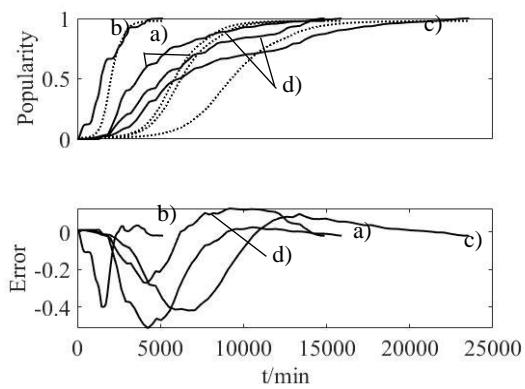


Fig. 6. Popularity cumulative distribution fitting curve and error analysis of SIR model a) attack on a female student in Heyi hotel; b) CCTV exposes "Eleme" dirty workshop; c) Wei Zexi event; d) opening of MWC2016 mobile world congress.

#### IV. CONCLUSIONS

Social media has gradually become an irreplaceable tool in the process of social information interaction and

communication. When the enterprise has an emergency, it is undoubtedly of great significance for it to master, analyze and even control the process of event popularity accumulation on social media. At the same time, the popularity accumulation process model with good guiding significance need to be fully and properly used in the formulation of corporate public relations strategies, which will greatly improve the ability of enterprises to cope with emergencies.

In order to achieve this aim, on the basis of empirical analysis and trend discussion of four events' popularity data, we conducted theoretical derivation of the actual process of popularity accumulation, and tried to describe the overall communication process with the thought of system cybernetics. The fitting images of the first-order and second-order system response output function, SIR model and four practical accumulation processes are obtained.

Based on the analysis of the actual process, it can be seen that there are certain fluctuations at several key time nodes, which significantly increases the rate of popularity accumulation. In this study, several key nodes are the intervention of some influential key disseminators, which is one of the reasons for the large fluctuation of errors in the early stage of the communication in error analysis. The final result is that the second order response output function actually has the best fitting degree. The event development process will experience the initial incubation period and the rapid increase period of the popularity accumulation speed. And it finally will enter the popularity decline period when the popularity accumulation speed gradually returns to zero. The specific stage division will be different according to the actual situation. Compared with the three diffusion models, it can be seen that the process description of the second-order response output function is more realistic, but for the SIR model, it can add more influencing factors to the actual events or environment to build the diffusion model, so as to make it more consistent with the actual spread process.

For enterprises, emergencies are not easy to be found in the incubation period. What enterprises need to do is to make good detection mechanism in advance, and rapidly discover and take control measures in the process of prompt growth. Enterprises can also control the key communication nodes to make an adverse event enter the decline period in advance to reduce the overall transmission amount, or make a beneficial event delay the decline period to increase the overall transmission amount, so as to effectively control the impact of an emergency on corporate image.

The key nodes in this study refer to the intervention of influential communicators, but there will actually be other influencing factors. The researches on this will be carried out in the future. Only using a single diffusion model to describe and analyze the process of the information diffusion is clearly limited. We will explore more models like SIR model in line with the actual social network information diffusion process, and describe the whole tendency combining with the existing research results completely in future studies. We aim to make the given suggestions more effective and realistic to the enterprise application.

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