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Communication Effect of Passengers on Information Diffusion in Metro Emergency

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Abstract: Information diffusion is significant for emergency management as it can decide the severity of accidents. In this paper, we set up a communication model of passengers for the metro emergency. In the model, four categories of passengers are defined as unknown passengers, supportive passengers, neutral passengers and opposed passengers. Three passengers' characteristics are taken into account, such as spreading desire, the trustworthiness and the passengers' uncertainty about their opinions. From the simulation results, we can see that the passengers' uncertainty about their opinions has a positive correlation with the time of passengers' opinions reaching consensus, while other two factors both have a negative correlation. The result is useful for metro officials to guide and control emergency information.
Key words: metro emergency; communication; information diffusion; multi-agent simulation
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0 Introduction

With the development of city transportation system, metro has become an important transportation way in daily life. However, with the increasing rate of metro emergency, which causes serious loss of properties and lives, the control of metro emergency has become a popular social issue. On September 27, 2011, rear-end collision happened in Shanghai Rail Transit Line 10. At first, the passengers in the carriage pushed the panic button without any information about the emergency. Later with the timely guide of official information, the passengers calmed down and left the carriage in well-controlled order. On 20th April, 2015, a female passenger fainted on the metro station in Shenzhen, and then caused serious stampede. According to the official guider in that emergency, the passengers surrounding the fainted passenger were calm because they knew what happened. However, when the surrounding passengers stepped back to give more space, the other passengers not aware of the accident fell into panic and began to run and scream, which then led to stampede. The other passengers are much affected by the wrong information when they did not have access to official information. On April 3, 2014, there was also a stampede emergency in Guangzhou subway due to the diffusion of wrong information of releasing poisonous gas in the carriage of subway. From quantities of metro emergency, we can find that the severity of metro emergency positively correlates to information diffusion. Fast diffusion of wrong information will bring passengers in panic, even cause stampede. Inversely, the timely and large-scale diffusion of correct information can avoid serious effects.

Therefore, information diffusion in emergency has attracted the attention of many scholars. Wei and Zhao[1] proposed a diffusion model of emergency information based on Shannon and Weaver's diffusion model of information, indicating that the factors affecting the diffusion of emergency information include type of emergency, diffusion channel and interpretation of information. Li *et al*[2] proposed a model of public emergency information diffusion based on the concept of information flow. Ji and Guo[3] analyzed the effect of leader on the propagation of emergency information online. Generally, there are two methods to study the propagation rules of emergency information: modeling and simulation. Modeling is used earlier than simulation. For example, in 1960s, Berlo [4] extended the Epidemic Model to describe the propagation rules of rumor (D-K Model) based on mathematics analysis. Wang *et al*[5] mainly used the physical method to analyze propagation rules of rumor based on Potts model. Besides rumor, truth was also taken into account. For example, Zhong *et al*[6] applied the Lotka-Volterra model to describe the competitive dynamic process between the truth and rumor from the viewpoint of ecology. Wei *et al*[7] applied BASS model to analyze the propagation rules of both truth and rumor in public emergency. Recently, with the development of complex network theory, it is found that the agents in the emergency are in complex relation network[8-10]. Therefore, more studies have begun to analyze the propagation rules based on different relation network. This kind of method is typical for analyzing the microcosmic features from the macroscopic law, which is difficult to give more mathematic proof[11]. Method of simulation appeared later than model. At first, simulation was just an assistant for modelling. But with more and more simulation tools appearing, the multi-agent simulation has become a powerful tool to study the propagation rules of information by setting rules for each agent and observing the macroscopic law[12,13].

Motivated by the previous study, the multi-agent simulation tool Netlogo is applied to study the propagation rules of information in metro emergency. By setting the communicating rules of each passenger, the macroscopic information diffusion rules are analyzed. Zhang *et al* [14] studied the propagation rules of rumor by setting a mutual inductance formula, which is mainly applied in this paper to set the communicating rules among passengers.

1 Model

During the metro emergency, some passengers get the information about the emergency earlier than others. The information can be truth or rumor. In this paper, we will take the stampede emergency that happened in Guangzhou subway on April 3, 2014 as a case for analysis.

According to the spot report, two teens were playing with the pepper spray in the rear carriages of the subway. However, the passengers nearby mistook it as the poisonous gas and rushed towards the front carriage, which terrified panic among more and more unknown passengers. After the subway stopped and the door was opened, all the passengers rushed to the door, which caused a serious stampede. In order to model the communication process of passengers in metro emergency, here we make assumptions as follows:

Assumption 1 For the passengers who get the emergency information first will hold three kinds of opinions, which are supportive opinions, opposed opinions and neutral opinions[14].

Assumption 2 For the passengers who are unware of the emergency, when they hear the emergency information from other passengers, they will come up with an initial opinion at first. Then they will communicate with the other passengers following the set rules in the model with their initial opinions.

Assumption 3 In the metro emergency, passengers can only communicate with their neighbors due to the limited space in the subway.

Assumption 4 The passengers' spreading desire and trustworthiness will not change.

In this experiment, two kinds of agents are taken into consideration, the emergency information and the passengers. The attributes for the two kinds of agents can be seen in Table 1.

Table 1 Agents and attributes

Agents	Attributes
Emergency information	Pertinence
	Faintness
Passengers	*S* (Spreading desire)
	U (Uncertainty)
	TP (Trustworthiness)

Motivated by the assumptions above, here we consider one metro carriage with N passengers. At any discrete time t, the agent i has the opinion $O_i \in R$ for i=1,···, N, which is a variable in the opinion interval [0,1], where $0 \leqslant O_i < 0.5$ represents passenger i who is opposed to the information, and $0.5 < O_i \leqslant 1$ represents passenger i who is supportive to the information and $O_i = 0.5$ represents passenger i holds the neutral opinion. Accordingly, the number of passengers with supportive opinions, opposed opinions, neutral opinions and unware of the emergency are respectively set as N_s, N_o, N_n, N_u. Therefore $N_\text{s}+N_\text{o}+N_\text{n}+N_\text{u}=N$. The passenger's spreading desire is set as $S_i \in R$ for i=1, ···, N, where 0 represents the passenger i who will not spread the emergency information and 1 represents passenger i who will spread the emergency information. The passenger's uncertainty is set as $U_i \in R$ for i=1,···, N, where 0 represents the passenger i who is totally uncertain about his own opinion and 1 represents passenger i who is sure about his own opinion. The trustworthiness of passenger is set as $\text{TP}_i \in R$ for i=1,···, N, where 0 represents the passenger i who is not reliable, and other passengers will not trust him and 1 represent the adverse. The variables O_i, S_i and U_i are all in the interval [0,1]. The attributes of emergency information considered are $\text{faintness} \in R$ and $\text{pertinence} \in R$, which are both variables in the interval [0,1]. Therefore, the communicating rules between the passengers are as follows:

1) Factor of mutual inductance K_{ij}

$$K_1 = \min(O_i(t) \times \text{pertinence} + U_i(t) \times \text{faintness}, \quad O_j(t) \times \text{pertinence} + U_j(t) \times \text{faintness}) \tag{1}$$

$$K_2 = \max(O_i(t) \times \text{pertinence} - U_i(t) \times \text{faintness}, \quad O_j(t) \times \text{pertinence} - U_j(t) \times \text{faintness}) \tag{2}$$

$$K_{ij} = K_1 - K_2 \tag{3}$$

Where K_{ij} represents the degree of impact on other passengers, which is the basis of the function of mutual inductance.

2) Function of mutual inductance force (i, j) and force (j, i)

$$\text{force}(i,j) = \begin{cases} 0, \ K_{ij} < U_i(t) \\ S_i(t) \times \text{TP}(t) \times (K_{ij} \div U_i(t) - 1), K_{ij} \geqslant U_i(t) \end{cases} \tag{4}$$

$$\text{force}(j,i) = \begin{cases} 0, K_{ij} < U_j(t) \\ S_j(t) \times \text{TP}(t) \times (K_{ij} \div U_j(t) - 1), K_{ij} \geqslant U_j(t) \end{cases} \tag{5}$$

Where force (i, j) denotes the effect of passenger i on passenger j and force (j, i) denotes the effect of passenger j on passenger i. From (4) and (5), we can see if passengers have much uncertainy about their opinions, their opinions will be affected by other passengers. The threshold value of uncertainty U is the factor of mutual inductance K_{ij}.

3) Updating law of opinion and uncertainty

$$O_i(t+1) = O_i(t) + \text{force}(j,i) \times \text{TP}(t) \times (O_j(t) - O_i(t)) \tag{6}$$

$$U_i(t+1) = U_i(t) + \text{force}(j,i) \times (U_j(t) - U_i(t)) \tag{7}$$

$$O_j(t+1) = O_j(t) + \text{force}(i,j) \times \text{TP}(t) \times (O_i(t) - O_j(t)) \tag{8}$$

$$U_j(t+1) = U_j(t) + \text{force}(i,j) \times (U_i(t) - U_j(t)) \tag{9}$$

Where $O_i(t+1)$ is the updated opinion of passenger i in next time step and $U_i(t+1)$ is the updated uncertainty of passenger i about his opinion. $O_j(t+1)$ and $U_j(t+1)$ are the same.

2 Simulation and Analysis

The simulation environment is as Fig .1. Tick is one time step for each update. The blue persons represent the passengers holding the supportive opinions. The red persons represent the passengers who hold opposed opinions. The yellow ones represent the passengers whose opinions are neutral and the white ones represent the passengers unaware of the emergency information. With the update of the passengers' opinions, the color of agents in the simulation interface will change accordingly. In the subsequent experiments, each experiment runs 20 times to avoid the effect of random. T represents the process time of experiment from start to the end when the number of passengers with three kinds of opinions remain unchanged. T' is the average number of T of 20 times for each experiment. In the simulation, the effect of passenger's spreading desire, uncertainty and trustworthiness are analyzed separately. Here in this paper, we mainly focus on the effect of passengers' characteristics on the communication in metro emergency. Three main characters are selected as passengers' spreading desire, uncertainty about their opinions and trustworthiness. In the following simulation part, we will mainly analyze the law of information diffusion from the three aspects above.

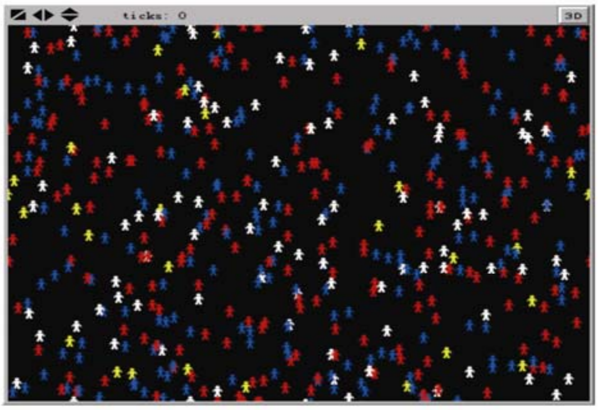

Fig.1 Simulation environment

2.1 Spreading Desire

In this experiment, the total number of passengers is selected as $N = 400$, and the number of passengers with different kinds of opinions are respectively selected as $N_s = 200$, $N_o = 200$, $N_n = 0$, $N_u = 0$. The uncertainty and the trustworthiness of passengers both follow a uniform distribution in the unit-length interval [0, 1]. As we all know, the spreading desire differs in different passengers due to the diversity of passengers' background such as age, education, and purpose to spread rumor. In total, spreading desire refers to a large number of psychological factors. Here we conclude to the characteristic of spreading desire. In order to study the effect of spreading desire, we control the other two factors of uncertainty and trustworthiness unchanged. Control the spreading desire to be same for passengers with different opinions. Here three different values for spreading desire are selected as 0.2, 0.4 and 0.6. In order to get the average dynamic curve for 20 experiments, we select the 20 experiment results which all the passengers have supportive opinions at the end of experiment. The results can be seen in Fig.2, where the curves support 1 and oppose 1 respectively represent the number of passengers with supportive opinions and opposed opinions whose spreading desire is 0.2. The curves support 2 and oppose 2 represent the number of passengers with supportive opinions and opposed opinions whose spreading desire is 0.4 and the curves support 3 and oppose 3 represents the number of passengers with supportive opinions and opposed opinions whose spreading desire is 0.6. This experiment runs 20 times to avoid the effect of random.

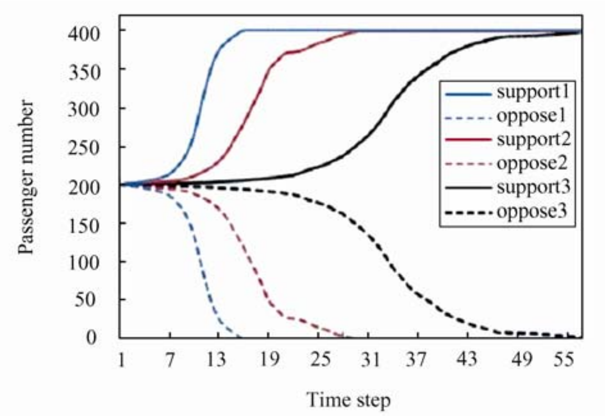

Fig.2 Emergency information diffusion with three value sets of spreading desire

From Fig.2, we can see that with the increase of spreading desire, the diffusion speed of emergency information increases and the experiment reaches the end status earlier. Therefore, in metro emergency, the spreading desire has a negative correlation with the time of passengers' opinions reaching a consensus, which means the higher the spreading desire is, the faster the information diffuses. If the information is rumor and some passengers prepare to make chaos in public making use of the rumor, those passengers will have higher spreading desire and will increase the spreading desire of rumor diffusion. In this case, the metro officers should pay attention to the rumor propagators. The best way is to release the official information actively in the shortest time. In this case the official information will spread faster than the rumor among the passengers to relieve the panic.

2.2 Uncertainty

In this experiment, the initial value set of the number of passengers is $N = 400$, $N_s = 200$, $N_o = 200$, $N_n = 0$ and $N_u = 0$. The spreading desire and the trustworthiness of passengers both follow a uniform distribution in the unit-length interval [0, 1]. It is known that when the information is ambiguous, or passengers are in panic, they will hold an equivocal attitude towards their own opinions, especially when faced with uninformed situation, in which the passengers can not have the right opinions. Therefore, here we set different values for the uncertainty of passengers to study the effect of uncertainty on information diffusion in metro emergency. Control the uncertainty to be same for passengers with different opinions. Here three different values for uncertainty are selected as 0.1, 0.2 and 0.3. In order to get the average dynamic curve for 20 experiments, we select the 20 experiment results which are all the passengers with supportive opinions at the end of experiment. The results can be seen in Fig.3, where the curves support 1 and oppose 1 respectively represent the number of passengers with supportive opinions and opposed opinions whose uncertainty is 0.1. The curves support 2 and oppose 2 represents the number of passengers with supportive opinions and opposed opinions whose uncertainty is 0.2 and the curves support 3 and oppose 3 represents the number of passengers with supportive opinions and opposed opinions whose uncertainty is 0.3. This experiment runs 20 times to avoid the effect of random.

From Fig.3, we can see that T' increases with the increase of uncertainty, which denotes that the passengers are harder to reach a consensus if they are sure about their opinions. This can be explained by (4) and (5) where if the passengers' uncertainty is more than the threshold value K_{ij}, they will not be affected by neighbor passengers. Therefore, uncertainty has a positive correlation with the time of passengers' opinions reaching a consensus, which means that if the passengers are stubborn enough, they will not change their opinions easily by others. It is good for decreasing the diffusion of rumor as the passengers can hold on to their own initial opinions. However, if passengers doubt their opinions, there will be a great risk that rumor spreading fast among the passengers. In that case, passengers will change their opinions more easily to tend to the rumor. It is known that if passengers can get the emergency knowledge in their daily life, they will be clear of the all kinds of emergency or the actions that should be taken in metro emergency. If so, they tend to be more certain about their own opinions, instead of being affected by the false information. Therefore, in order to avoid the effect of rumor diffusion, two aspects need to be taken into account by the subway officials. One is that the subway officials make the true information clear. There are many ways to improve the release of official information, such as putting more broadcasts in the subway carriages, distributing more loudspeakers to the official guiders and so on. The other is to help the passengers acquire more emergency knowledge in daily life. For example, the emergency videos should be played on the screen on the carriage wall, or the emergency manual can be provided to the passengers.

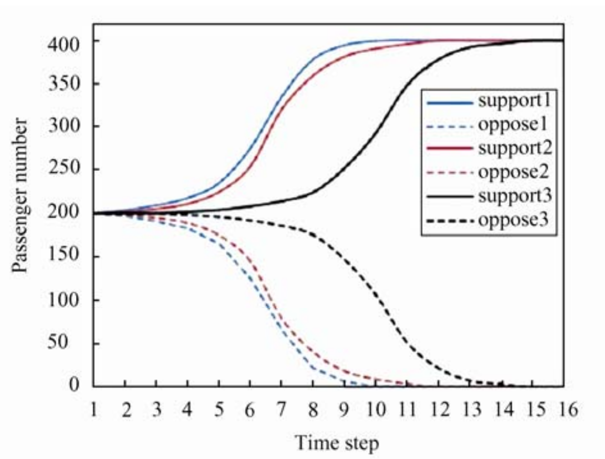

Fig. 3 Emergency information diffusion with three value sets of uncertainty

2.3 Trustworthiness

In this experiment, the initial value set of the number of passengers is $N = 400$, $N_s = 200$, $N_o = 200$, $N_n = 0$ and $N_u = 0$. The spreading desire and the uncertainty of passengers both follow a uniform distribution in the unit-length interval [0,1]. We know that in different period, passenger *i* is trusted by other passengers not because he is more trustworthy but because other passengers tend to believe others. For example, during the period when the terrorist incidents happen frequently, any information related to the terrorist incidents will stimulate passengers' nerve. In that case, they tend to trust the information concerning terrorist incidents even though it is a rumor. Here we set different values for trustworthiness to study the effect of trustworthiness information diffusion in metro emergency. The trustworthiness is controlled to be the same for passengers with different opinions. Here three different values for uncertainty are selected as 0.1, 0.2 and 0.3. In order to get the average dynamic curve for 20 experiments, we select the 20 experiment results that all the passengers have supportive opinions at the end of experiments. The results can be seen in Fig. 4, where the curves support 1 and oppose 1 represent the number of passengers with supportive opinions and opposed opinions whose trustworthiness is 0.1, respectively. The curves support 2 and oppose 2 represent the number of passengers with supportive opinions and opposed opinions

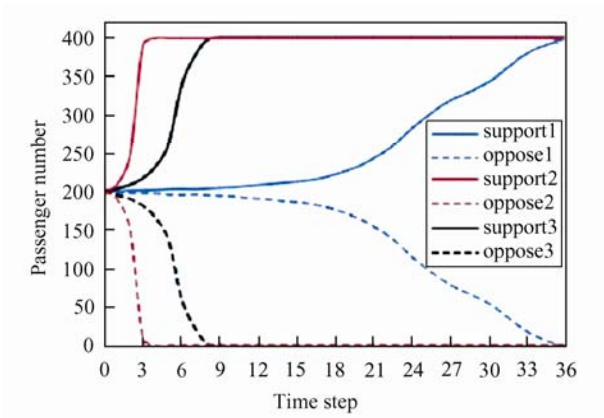

Fig. 4 Emergency information diffusion with three value sets of trustworthiness

whose trustworthiness is 0.2 and the curves support 3 and oppose 3 represents the number of passengers with supportive opinions and opposed opinions whose trustworthiness is 0.3. This experiment runs 20 times to avoid the effect of random.

From Fig. 4, we can see that T' decreases with the increase of trustworthiness, which denotes that the more reliable the passenger is, the more influence the passenger will have on others. Therefore, trustworthiness has a negative correlation with the time of passengers' opinions reaching a consensus, which means if the level of trust of the passengers is higher, the passengers' opinions will be impacted more easily so that the passengers' opinions will change rapidly before reaching to consensus. The result, can explain why in Guangzhou subway on April 3, 2014, the wrong information could spread so fast and cause such a serious stampede as the passengers tended to trust such kind of information. The result can also be applied to the release of official information. For example, if the subway officials are one of the spreading agent in the emergency, the law can be explained that the more the passengers trust the officials, the better the official information spreads to help relieve the panic caused by the emergency. Therefore, the credibility of subway officials is especially important in the subway emergency. The subway officials should pay more attention to credibility. For example, they can play the official emergency video on the screens on the carriage wall to strengthen the importance of official guide in emergency. In addition, the subway officials need to play vital role to maintain a trustworthy image to the public.

3 Conclusion

In this paper, a model based on the communication rules between passengers is created against the background of metro emergency. The factors mainly considered are the characteristics of passengers, like the spreading desire, the uncertainty and the trustworthiness. From the results of simulation, we can find for the factor of spreading desire, it has a negative correlation with the time of passengers' opinions reaching a consensus, which means the higher the spreading desire is, the faster the information diffuses. Then for the factor of passengers' uncertainty about their opinions, it has a positive correlation with the time of passengers' opinions reaching a consensus, which means that if the passengers are stubborn enough, they will not change their opinions easily by others. And last for the factor of trustworthiness, it has a negative correlation with the time of passengers' opinions reaching consensus, which means if the level of trust of the passengers is higher, the passengers' opinions will be impacted more easily so that the passengers' opinions will change rapidly till to a consensus finally. The results above can be used for the guide and control of emergency information for the subway officials. For example, based on the result of spreading desire, the advice for the metro officials is to pay attention to the rumor propagators and to release the official information actively in the shortest time, in which case the official information will spread faster than the rumor among the passengers to relieve the panic. Two pieces of advice based on the effect of passengers' uncertainty are given. One is the subway officials make the true information clear in many ways to improve the quality of official information, such as putting more broadcasts in the subway carriage, distributing more loudspeakers to the official guiders. The other is to help the passengers acquire more emergency knowledge in daily life. For example, the emergency videos should be played on the screen on the carriage wall, or the emergency manual can be provided to the passengers. According to the effect of trustworthiness, following advices are proposed that subway officials pay attention to building the credible image for the public, in which case passengers will choose to trust the officials and will be more affected by the official information. They can play the official emergency video on the screen on the carriage wall to strengthen the importance of official guide in emergency. In addition, the subway officials need to play vital role to maintain a trustworthy image to the public. In the future, the effect of officials and media will be taken into account to create a more complete model of information propagation in metro emergency.

References

[1] Wei J C, Zhao D T. Research on the crisis information communication model and its impact factors[J]. *Information Science*, 2006, **24**(12): 1782-1785 (Ch).

[2] Li Z H, He J L, Wu P F. The time period characteristic of information communication model and it's management strategies of paroxysmal public crisis[J]. *Library and Information Service*, 2007, **51**(10): 88-91.

[3] Ji D, Guo Z. Research on the factors influencing the power of

opinion leaders online in crisis communication [J]. *Journal of Intelligence*, 2015, **28**(3): 142-147 (Ch).

[4] Berlo D K. *The Process of Communication*: *An Introduction to Theory and Practice*[M]. New York: Holt, Rinehart and Winston, 1960: 397-398.

[5] Wang J F, Tan X J. The canonical and micro-canonical transitions of the potts model for rumor[J]. *Journal of Hubei University* (*Natural Science Edition*), 2004, **26**(4): 8(Ch).

[6] Zhong Q, Qi W, Zhang L. Social-pattern crisis information diffusion model under Lotka-Volterra system[J]. *Systems Engineering-Theory & Practice*, 2012, **32**(1): 104-110 (Ch).

[7] Wei J C, Zhou L, Zhao D T. Crisis information diffusion model based on BASS model[J]. *Systems Engineering*, 2011, **29**(9): 16-22 (Ch).

[8] Zanette D H. Dynamics of rumor propagation on small-world networks[J]. *Physical Review E*, *Statistical*, *Nonlinear*, *and Soft Matter Physics*, 2002, **65**(4part1): 041908.

[9] Moreno Y, Nekovee M, Pacheco A F. Dynamics of rumor spreading in complex networks[J]. *Physical Review E*, *Statistical*, *Nonlinear*, *and Soft Matter Physics*, 2004, **69**(6part2): 066-130.

[10] Song N, Lu F B, Bao Q, *et al*. Cyber terrorism spreading and optimal intervention policies based on a scale-free network[J]. *Systems Engineering-Theory & Practice*, 2015, **35**(3): 630-640 (Ch).

[11] Zhan F, Si G Y, Luo P. A survey for rumor propagation models[J]. *Complex Systems and Complexity Science*, 2009, **6**(4): 1-11 (Ch).

[12] Li Z H, Wang H Y, Bai X. Paroxysmal public crisis information transmission simulation and management countermeasures in network environment[J]. *Journal of Public Management*, 2010, **7**(1): 85-93 (Ch).

[13] Du R, Liang H X. Simulating government's guide effect on network opinion of public crisis[J]. *Journal of Intelligence*, 2011, **30**(11): 61-66 (Ch).

[14] Zhang F, Si G Y, Luo P. Rumor propagation model based on communication functions and finite memory[J]. *Journal of System Simulation*, 2011, **23**(11): 2482-2486 (Ch).

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