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DIFFUSION OF FALSE INFORMATION DURING PUBLIC CRISES: ANALYSIS BASED ON THE CELLULAR AUTOMATON METHOD

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Abstract. The progress of false information diffusion in the public crisis is harmful to the society. When the public crisis occurs, the public respond in different ways and the public also want to tell others what they think right. But what they think is right is not recognized by the government. Thus the false information forms and it begins to diffuse. As the false information spreads, the harm to society magnifies gradually. Particularly in network society, false information diffusion can easily cause secondary hazards and accelerate public crises to a devastating degree. Thus intervening and controlling the false information diffusion is an important aspect of the public crisis management. From the perspective of the social network theory, this study analyzes the progress of false information diffusion in terms of different public crisis management strategies and presents the result of false information diffusion through simulation on cellular automaton of different public crisis management strategies. In simulations on cellular automaton, interventions are also carried to control false information diffusion and alternatives are proposed to help reduce public crises. This study also extends the theory of false information management, which is significant for the government to improve the ability to evaluate the false information and carry out interventions effectively to control the false information when it begins to diffuse.

Keywords: Cellular automaton, public crisis, false information, intervention mechanism, network interactions

Mathematics Subject Classification 2010: 37Fxx, 93Cxx

1 INTRODUCTION

1.1 Background

When public crises occur, they typically develop rapidly and in unexpected directions, leading to high uncertainty about future trends, and increasing public concern and interest. Indeed, in recent years, the rapid development of the Internet and growing number of Internet users through both traditional and mobile platforms has meant that more and more people are willing to participate in virtual discussions to express their views, exacerbating the upsurge of public opinion in addition to traditional channels.

When vast amounts of information are collected, discordant voices are inevitable, and this creates false information. The outbreak and evolution of recent public crises has notably been accompanied by the diffusion and dissemination of false information, which greatly increases the difficulty of managing such events. Examples of the diffusion of false information during public crises include the frenzy of buying radix during the SARS outbreak in 2003, the Wen'an incident in 2008, the panic to buy salt following the nuclear leak in Japan in 2011, and the DiaoYu Island incident in 2012. The diffusion of false information during the evolution of a public crisis not only increases public uncertainty, it also creates obstacles for the crisis recovery and may even endanger social and political stability. Therefore, the effective management of false information (FIM hereafter) during public crises has become an important element of research on public crisis management.

1.2 Related Research

Because the diffusion of false information such as spreading rumors in interpersonal networks is similar to the proliferation of a virus, most rumor spreading models are drawn from epidemic models. Rapoport and Rebhun [1] were the first to use an epidemic model to discuss information diffusion problems, while Goffman and Newill [2] also compared the spread of disease and rumors and used the stability of the infectious disease spread model to explain the final state of rumors. In the 1960s, Daley and Kendall [3] proposed a mathematical model for rumor spreading in which individuals are categorized based on their health status, infection status, and removed or immune status. Their model analyzes the rumor problem by using random processes and assumes that the probability of role conversion between the statuses above satisfies a certain mathematical distribution. Although this model does not fully comply with the actual diffusion of false information, it is a reasonable approximation under certain conditions.

In recent years, along with the in-depth study of dynamics, rumor spreading based on dynamics has drawn more scholarly attention. For instance, Dickinson et al. [4] was another author to compare the spread of infectious diseases with that of rumors in order to analyze and summarize the correlations in their communication processes. Similarly, Thompson [5], by using the Daley-Kendall model, took account of the impact of the differences between susceptible persons and disseminators during the spread of rumors. Based on statistical data derived from MSN chatrooms, the author found that population activity is the most sensitive parameter that affects rumor spreading and that the number of communicators in the 18-34 age group is far more than those over 55 years old. In addition, this finding shows that increasing activity can control the size of rumors, but encouraging people to spread rumors faces many ethical issues. Indeed, according to simulation experiments based on the collected data, a second wave of rumors tends to spread, which will gradually become weaker and disappear.

Kawachi [6], by considering the different parties involved, established finite and infinite dimensional dynamical models and determined the threshold at which rumors spread. In the same vein, Lebensztayn et al. [7] discussed the final state of rumor spreading, but assumed differences in individual behavior (i.e., randomly deciding to spread rumors or not).

With a specific focus on the diffusion of false information in public crises, Zhang and Zhang [8] established an interactive model of rumor spreading and crisis management, finding that spreading rumors may have a negative effect on public crises and providing appropriate recommendations for FIM in such incidents. Huo et al. [9], who studied the spread of rumors after the occurrence of unexpected events and the effectiveness of the government response, used simulation data to draw a phase diagram of the system. Finally, Zhong et al. [10] divided information into real and false to discuss FIM from an ecological perspective, discovering that the diffusion of false information during public crises has different diffusion rates. Thereafter, Maki and Thomson [11], and Murray [12] have been carrying out studies using a mathematical model of rumors that focus on the theoretical analysis. Kawachi et al. [13] consider the impact of different contacts on the ultimate spread in another paper and used the mathematical modeling methods to explore the results of the final spread.

Zanette [14] studied the spread of rumors, based on the small-world networks he established a rumor spread model and drew some conclusions, including the critical value of the rumor spread. Moreno et al. [15] also established a rumor propagation model based on scale-free networks and compared conclusions obtained by random analysis method and by computer simulation. Chinese scholar Wang Xiaofan paid more attention to clustering coefficient of the network, and she found that increasing clustering coefficient of the network can effectively inhibit the spread of rumors. Since then, on the basis of two basic network models – small-world networks and scale-free networks, some other scholars have proposed many modified models of networks, such as Newman and Park proposed NP model, Boguna et al. proposed social distance model, Jin, Girvan and Newman et al. proposed JGN model, Jackson and Rogers proposed JR model, as well as Vazquez proposed CNN model. Seeger [16] used chaos theory to explain the deep complex problems of information dissemination in crisis and put forward some universal problems about the complexity of information dissemination in crisis, which is extremely important for us to understand the process of information spread in crisis essentially. Monge and Noshir [17] from the perspective of complex adaptive systems theory proposed a “multi-theory and multi-level framework" model. They used mathematical modeling and computer simulation to study coevolution among variable parameters of crisis diffusion network and they also discussed the structural mechanisms of chaos emergence.

Meanwhile, on the basis of Zanette's [14] and Moreno's [15] work, many scholars extended study about the false information diffusion in public crisis. Pan et al. [18] from Shanghai Jiaotong University applied Moreno's [15] rumors spread model on the variable clustering coefficient scale-free networks, and studied rumors spread though scale-free networks. Their scale-free networks obey a power law degree distribution and have variable clustering coefficient. By changing the parameters of a special network clustering coefficient to observe changes of rumors spread, they came to the conclusion that spread rumors and clustering coefficient of network have a negative correlation. Chu and Tong [19] from the theoretical perspective of crisis diffusion, reviewing the latest theory of crisis diffusion, explored the chaotic prediction, co-evolution, complex adaptive systems and other complex features of crisis diffusion.

However, although rumor spreading models are based on mathematical principles that have a high degree of abstraction, rigorous logic and application breadth, describing the process of diffusion of false information is somewhat non-intuitive. In other words, although rumor spreading can be represented by a mathematical model, dynamics differential equations of infectious diseases is a mathematical model based on macroeconomic statistics where no microscopic mechanisms are used. So, such models cannot explain the process completely.

The cellular automaton is a discrete mathematical model, its physical image is clear, it is fully parallel without truncation errors, etc., such that in recent years it has become a powerful tool for exploring nonlinear complex systems. Xuan and Zhang [20] detailed the rumors diffusion model based on the cellular automata. Their model can reproduce the process of rumors spread through local interaction among individuals. The individuals to spread false information in public crisis are discrete and independent, false information diffusion in public crisis is scenario-dependent, so this article is based on the forecast method and uses cellular automata to build management simulation model of false information diffusion in public crisis. According to the thought on policy test, the designed test solution is converted to the corresponding code. The code is generated into the management simulation model. Different codes represent different management schemes. Thus the simulation model reflects phenomenologically the process of false information diffusion in public crisis.

2 RESEARCH HYPOTHESE

FIM during public crises is a process of repeatedly comparing goals and correcting deviations effectively. Further, the process of FIM during public crises consists of a series of interconnected, continuous management activities as well as discrete management activities that are time independent. Meanwhile, the interventions about false information in public crisis also are simple, complete, coordinate, open, adaptive, direct and indirect. Specifically, simplicity means that the relevant government department manages the false information unilaterally, whereas completeness means that various management policies, systems, and commands are used in the process of false information management without their own errors or major defects. In other words, the fewer the number of such defects or errors generated during implementation, the higher the degree of completeness of management's countermeasures; coordination means that the various strategies used to manage false information during public crises support and cooperate with each other without contradiction and conflict in management activities. In addition, open and adaptive management means that the initiatives of potential recipients can be mobilized. In other words, the ability to identify potential recipients can be controlled and improved.

To examine the diffusion of false information in different intervention scenarios during public crises, this study puts forward the following hypothese:

Hypothesis 1. In the process of FIM, coordinated management is more effective than a simple management strategy.

Hypothesis 2. Open, adaptive management during public crises can effectively prevent or even eliminate the diffusion of false information, but cannot control the diffusion direction of false information.

During public crises the frequency of correcting deviations represents management skills. In other words, in the process of FIM during public crises, the more (less) the corrective deviation, the stronger (weaker) are the skills to manage information. According to ascending order of performing frequency, the execution is divided into defensive, discrete and continuous. Hence:

Hypothesis 3. The greater the enforcement the better the false information in public crisis can be controlled.

Any management behavior can effectively correct the deviation to a certain extent and achieve management objectives. FIM assumes that an individual that has accepted false information provides false information, whereas an individual that has not accepted false information maintains the original state.

Hypothesis 4. The lower the acceptance probability of false information in public crisis the more easily the false information diffusion can be controlled.

3 MODEL DESIGN

3.1 Research Method

Cellular Automaton (CA) is used to simulate and predict the behavior of complex systems. CA was dating back to the study of Ulam and Von Neumann (the father of modern computers) in the 1940s. They found a simple iterative calculation algorithm could replace complex models to explain many phenomena in the nature.

CA uses some very simple local rules to effectively simulate the spatial pattern formation process of complex systems. In 1980s, Wolfram made a lot of contribution to the development of CA [21]. Now CA is used to simulate natural and artificial complex systems in physics, chemistry, biology, geography, and other fields [22, 23]. CA's "bottom-up" research philosophy fully reflects that in complex systems local individual behavior affects the overall order and direction so it is very suitable for CA to simulate and predict the formation of public opinion. At the same time, more and more scholars use CA to simulate and predict the geographic phenomenon. In 1980s, Couceleis used CA to simulate geographic phenomenon and got some important conclusions [24, 25, 26]. Some scholars also used CA to simulate urban sprawl [27], land use dynamic evolution [28], volcano spread [29], etc.

Wolfrarm [30] divided CA into four categories according to the dynamic behavior of cellular automaton:

1. Smooth type: from any initial state, after running a certain period of time, cellular space keeps a stabilized configuration, that is each cellular refers to a fixed state and it does not change with time.
2. Cycle type: after running a certain time, a series of simple cellular space tends to be a fixed structure or periodic structure.
3. Chaos type: from any initial state, after running a certain period of time, every cellular shows the chaotic non-periodic behavior.
4. Complex: local structure becomes complex, or partial chaos attends, some cellular will continue to spread.

Chaos theory is fundamentally linked to the management of false information in public crises [31]. As a complicated social phenomenon, the generation and diffusion of false information during public crises is essentially a kind of complex nonlinear evolutionary process, which has chaotic characteristics typical of complex systems, such as the evolution of diffusion randomness, the information variation of the butterfly effect, and the propagation path of fractal characteristics [32]. Chaos theory is an emerging science about nonlinear systems, and it is different from traditional scientific thoughts that explain social phenomena. It reveals both the unity and the opposition between inevitability and contingency and between disorder and order, while also providing two of the most basic complex research paradigms for FIM in public crises. These two paradigms, namely the simple-complex paradigm (simple system explaining complex behavior) and the complex-simple paradigm (complex system driven by simple rules), provide a new methodology to support the theory of FIM in public crises.

The chaos forecasting method based on chaos theory is a type of method for predicting nonlinear system evolution [33]. Chaos prediction mainly adopts bottom-up modeling ideas that assume that the evolution of complex systems is the result of many primitive interactive roles that aim to simulate macroscopic disorderly phenomena by using micro-level orderly rules. The basic idea is that under the assumed conditions, a micro-level dynamic mechanism (e.g., rule or policy) aggregates the results of individual behavior, thus predicting complex scenarios (patterns) at the macro level. As a general modeling method, predicting chaotic situations focuses more on the application of chaos theory. Because it mainly explains and analyzes the formation and evolution of complex phenomena, it is widely used to simulate, evaluate, and imitate complex socioeconomic phenomena and formulate public management policy [34]. Further, compared with traditional mathematical models and simulation methods, the chaos forecasting method can easily describe interactions among elements. Although some complex phenomena may be difficult to analyze and express, it can thus accurately simulate them and their evolution. Therefore, it can vividly and truly reflect the detailed structure and pattern of a large number of individual interactions in order to predict the future prospects of the evolution of false information in public crises. In summary, the chaos forecasting method is an effective research tool for simulating FIM during public crises.

False information management in public crisis depends on situations. There exists a complex, dynamic relationship among Public crisis management strategies, executive skill and FIM performance. So it is very suitable to use Chaos forecasting method to simulate and imitate. In this paper, a management simulation model of false information diffusion in public crisis will be constructed, which is based on chaos forecasting method. According to the thought of policy test, the designed test schemes are converted into the corresponding code, this code is generated into the management simulation model, and we use this method to simulate evolution of the false information diffusion in public crisis phenomenologically.

3.2 Model Building

A management simulation model of the diffusion of false information during public crises is as follows:

1. Primitive and space (L_d): Space refers to the entire space in which false information during public crises spreads. In this space, each primitive is a potential recipient in the real world that is likely to accept false information during public crises. Each primitive has its own state and behavior, and it exchanges information with the external environment and other cellulars to update the status of the entire system.
2. Neighbors (N): This study uses the Moore type of neighbors. Specifically, the primitive makes eight adjacent primitives (three above, three below, one on each side) as its neighbors, as is shown in Figure 1. The neighboring state of each primitive depends on its own and on the surrounding neighbors' current states. As the first step in this paper we regard all neighbors' acceptance probability in the same way and that will be considered such as neighbors' acceptance probability depending on places, space, their characteristics and so on.
3. State (S): There are two kinds of primitive states, 0 and 1. The primitive state of 0 means that potential recipients refuse the false information, whereas 1 means that they accept the false information.

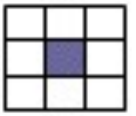

Figure 1. MOORE-type neighbors

4. Decision rules (f): A decision rule generalizes and abstracts potential recipients' behaviors and decisions when diffusing false information during public crises. The local decision rules are defined as follows:
   (a) has the false information been accepted by a neighbor;
   (b) if yes, then the individual decides whether to accept the false information according to a certain probability.

This study adopts a two-dimensional interface as a system space for the diffusion of false information during public crises. Hence, we assume that the false information diffuses from the center to the surrounding area. If a primitive accepts the false information being spread, the primitive's state is marked on the screen. The program flow is shown in Figure 2.

3.3 Research Plan

In this study, the influence of FIM strategies and management skills during public crises on the diffusion of false information is discussed. A public crisis management system is based on institutional systems, policy, and security. For example, the institutional system includes the relevant organizational settings, interdepartmental operations, functions, and coordination, while policy represents the policymaking decisions by various government departments. In addition, management strategies can be divided into

1. simple, complete management,
2. coordinated, direct management, and
3. open, adaptive management.

In the space of the diffusion of false information during public crises, these strategies correspond to

1. a whole line, when execute simple, complete management strategy, the number of affected individuals is that all individuals on a line in false information diffusion system space;
2. one ring (including a central point), when execute coordinated, direct management strategy, the number of affected individuals is that all individuals on one ring (including a central point) in false information diffusion system space, and

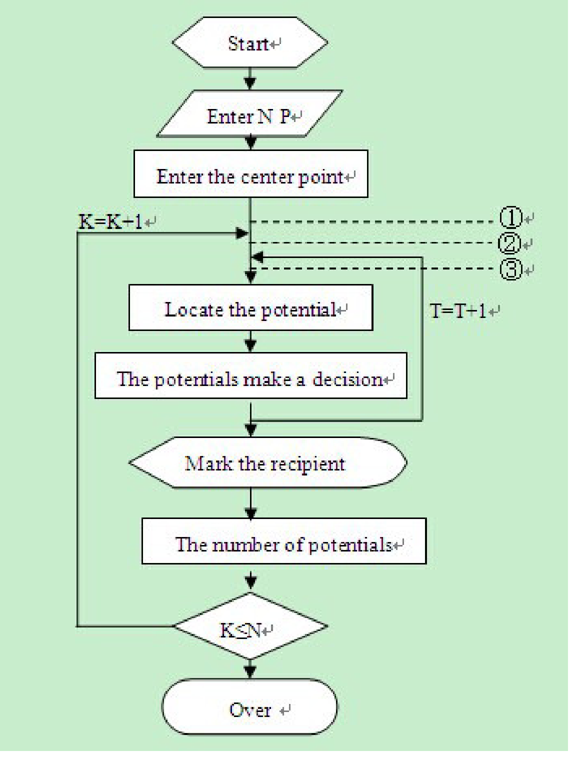

Figure 2. The process of fake information

3. several randomly distributed points, when execute open, adaptive management strategy, the number of affected individuals is several randomly distributed points in false information diffusion system space respectively.

In the simulation, we write the corresponding code of these three management strategies to make the potential recipient not accept the false information.

Player	1. Simple and Complete	2. Coordinate and Direct	3. Open and Adaptive
Defensive management	AI	BI	CI
Discrete management	AII	BII	CII
Sustainable management	AIII	BIII	CIII

Table 1. Simulation scheme of fake information management in public crisis

From the aspect of the simulation of management skills, ①②③ three insertion points are set to represent defensive management, discrete management, and sustainability management, respectively. From the perspective of the control function of management, and according to the different positions into which the code is inserted, these three cases may be constructed as feed forward control, feedback control, and field control, respectively. As for the difference between emergency management and crisis management, insertion point ① means simple precautions beforehand, insertion point ② represents a certain lag in the emergency management mode, and insertion point ③ represents the new public crisis management mode affected by non-linear thought (i.e., "try to do").

First, we assume that the probability for potential recipients to accept false information in public crisis is P and the total simulation time is N. When the total simulation time is beyond N, the simulation process is over. We use ①②③ three different interventions to impact the potential recipients of false information and ①②③ three interventions are set to represent defensive management, discrete management, and sustainability management, respectively. After impacted by interventions, the potential recipients of false information make decision whether accept the false information or not. And we calculate the number of the recipients of false information and mark them in the simulation process. If simulation time is less the total simulation time assumed at the beginning of the experiment, we continue to execute the interventions and calculate the number of the recipients. When the total simulation time is beyond N, the experiment is over.

The simulation process shows the different execution frequency of the code in each of these three locations. The code inserted into ① (simple precautions beforehand) only works at the beginning of the simulation, that inserted into ② (a certain lag in the emergency management mode) is executed N times throughout the process (import N in the program initialization), and that inserted into ③ (try to do) is executed $T \times N$ times throughout the process. In the simulation, the code of the corresponding management strategy is inserted into ①②③, respectively, which is used to simulate phenomenologically the evolution and management performance of the nine management strategies shown in Table 1.

There are 9 kinds of management simulation schemes, which are AI, AII, AIII, BI, BII, BIII, CI, CII and CIII in Table 1. Actually, the false information diffuses freely when the schemes AI, BI and CI are executed. So this article will not study these 3 schemes AI, BI and CI and only consider the other 6 schemes AII, AIII, BII, BIII, CII and CIII.

4 RESULTS AND ANALYSIS

In order to make general observations, the acceptance probability P of false information was set to 0.3. The simulation clock was set to 25 K and the simulation interface to 100×100 (i.e., the number of potential recipients is 10 000), while potential recipients of false information were defined as $(0,0)$–$(100,100)$ (the positive integer points out the coordinates in the two-dimensional space). Moreover, to simplify the simulation process, we ensured that:

1. The horizontal axis was X and vertical axis was Y, the X axis represents the simulation time and the Y axis represents the number of the false information receivers;
2. The source of false information during public crises was located at the point $(50, 50)$, namely the diffusion distance T was 50;
3. The evolution scheme in a circular area was centered on $(50, 50)$ with a radius as inspected. If the primitive in a circular area accepted the false information during public crises, the corresponding coordinates were marked and the number of recipients recorded.

The nine kinds of management simulations shown in Table 1 were conducted several times, changing the spread direction, speed, quantity, and spatial distribution of the receiver of the false information under these various scenarios. Then, the simulation results and management performance were observed and measured. Through these simulation tests, the most typical evolution distribution and quantity variation were recorded. The results of the simulations are summarized next.

In scheme A, the FIM function area was represented by the 25^{th} line. The simulation results show that scheme AII can delay the diffusion of false information, as illustrated in Figure 3. Although the spread speed from the center to the function area lags significantly behind that in the other directions, it is difficult to block the spread of false information effectively in terms of quantity, as shown in Figure 4. In this scenario, when $K = 10$, the diffusion of false information during public crises is affected by FIM. Because the number of receivers decreases, false information "bypasses" the region and continues to spread outward. Then, the number of receivers soars to more than 800, close to the number of false information receivers in the free diffusion scheme.

Having observed the diffusion of false information and quantity variation in scheme AIII, we know that scheme AIII effectively prevents false information from spreading outside the function area. As shown in Figure 5, all the parts on the left-hand side of the 25^{th} line are blank, while diffusion in the other direction is unaffected, meaning that the diffusion of false information during public crises is shared by function area. Moreover, in scheme AIII the number change curve of the false information receiver at $K = 10$ and $K = 15$ has clear fluctuations, but the overall curve retains a rapid growth trend. Indeed, the ultimate recipient number is below 700, fewer than the number of false information receivers in scheme AII.

Comparing the evolution of the distribution of false information during public crises and quantity change in both schemes allows us to conclude that scheme AIII is more effective at preventing false information from spreading outside the function area compared with scheme AII. Further, this scheme is more effective at reducing the number of false information recipients during public crises than scheme AIII, which suggests that administrative skills are important for the diffusion of false information during such events.

In scheme B, the layer 4 neighbors outside the center are used for the action area, namely the circle (marked with red in Figures 7 and 9) is made up of line 46,

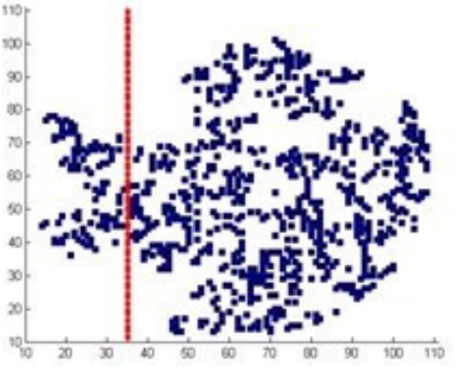

Figure 3. The evolution of distribution in AII scheme

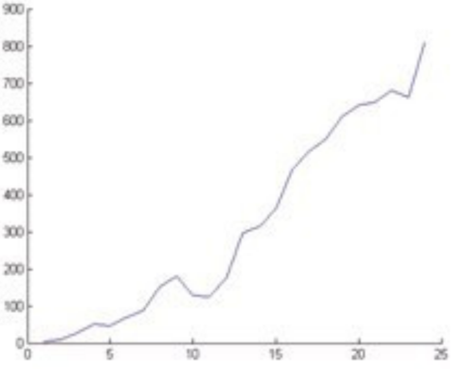

Figure 4. Changes of the number of recipients in AII scheme

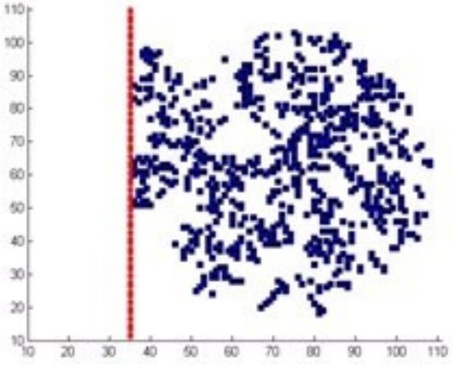

Figure 5. The evolution of distribution in AIII scheme

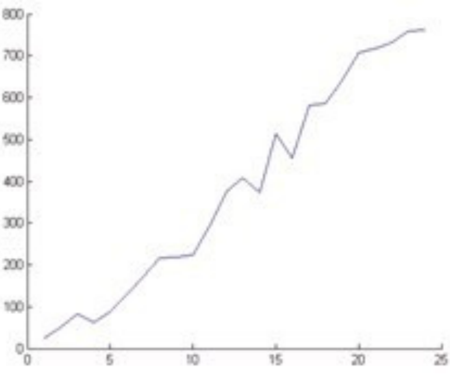

Figure 6. Changes of the number of recipients in AIII scheme

row 54, and columns 46 and 54. The simulation results show that scheme BII has a clear influence on the diffusion of false information during public crises, which mainly manifests in the following two aspects. First, compared with the free diffusion scheme, the diffusion speed of false information in each direction from the center to the surrounding no longer converges (high in some directions and low in others; Figure 7). Second, in terms of quantity changes, the change curve of the receiver number is coarser, with jagged peaks appearing many times, as shown in Figure 8. Further, at the beginning of the spread, the growth rate of false information recipients is far lower than that in the other scenarios (except for scheme BIII), while the final number of false information recipients is only 450, far below that in the free diffusion scenario, showing that scheme BII has more impact on the diffusion of false information during public crises.

In scheme BIII, false information is strictly controlled within the function areas (i.e., it cannot penetrate the area; Figure 9) and the number of false information recipients changes irregularly and randomly, as shown in Figure 10. This finding suggests that this scheme can effectively control and limit the spread direction of false information during public crises. Comparing the effects of schemes BIII and BII thus allows us to conclude that both influence false information at the beginning of the diffusion process. In other words, in the early stages, the gap in the number change is unclear, but the ultimate evolution results are different because of the differences in management skills. Hence, the former continue to spread out to reach 450, while the latter are strictly limited in function area and the largest number of recipients is only 15. This finding shows that FIM during public crises must receive constant attention and that FIM skills must not be lax in order to effectively prevent and eliminate the diffusion of false information.

In scheme C, the random distribution rate (pp) is set to 0.01, 0.05, and 0.1 in order to examine the sensitivity of the diffusion of false information during public crises to the random distribution. The simulation results show that in scheme CII, as shown in Figures 11, 13, 15, with an increasing random distribution rate, the false

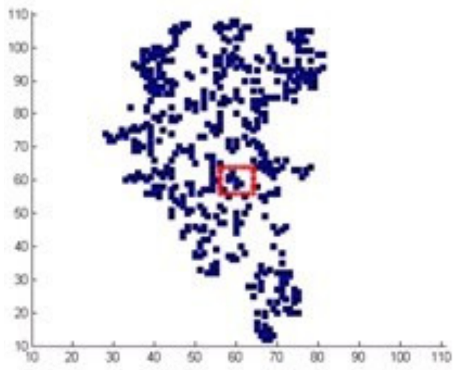

Figure 7. The evolution of distribution in BII scheme

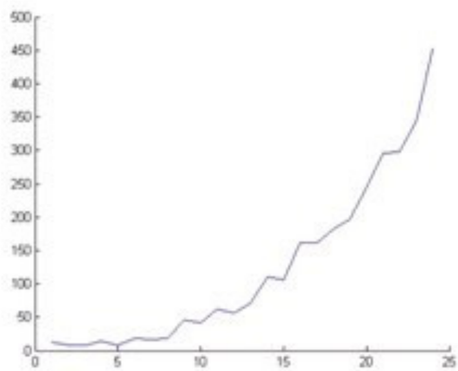

Figure 8. Changes of the number of recipients in BII scheme

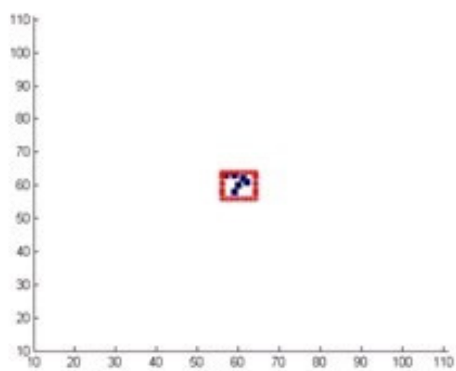

Figure 9. The evolution of distribution in BIII scheme

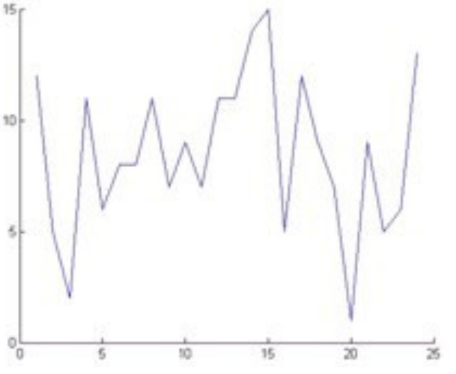

Figure 10. Changes of the number of recipients in BIII scheme

information spread becomes more irregular and the diffusion speed gradually slows down. Thus, the growth rate and number of false information recipients during public crises gradually diminishes, too. As presented in Figures 12, 14, 16, the quantity change curve shows that when K = 15 in all three schemes, the number of recipients is more than 300, fewer than 300, and close to 200, respectively. By contrast, when K = 24 in these three schemes, the number of recipients decreases greatly to more than 600, just fewer than 600, and just over 500, respectively.

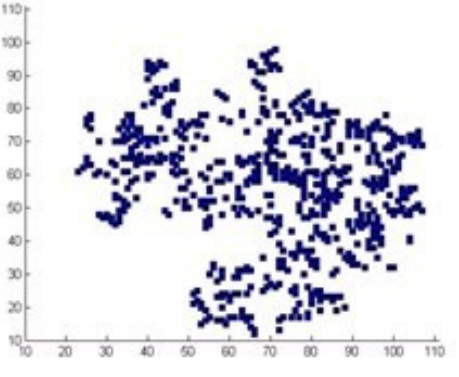

Figure 11. Evolution distribution of spread when pp = 0.01 in CII

The test results of scheme CIII suggest that an increase in the random distribution rate makes it more and more difficult to spread false information during public crises. Compared with scheme CII when pp = 0.01, the diffusion of false information during public crises in scheme CIII when pp = 0.01 is very slow. In addition, its number change curve fluctuates and the receiver number is only about 250 at the end, far less than in scheme CII (pp = 0.01). When pp = 0.05, the spread of false information is impacted strongly: only the individual points become false

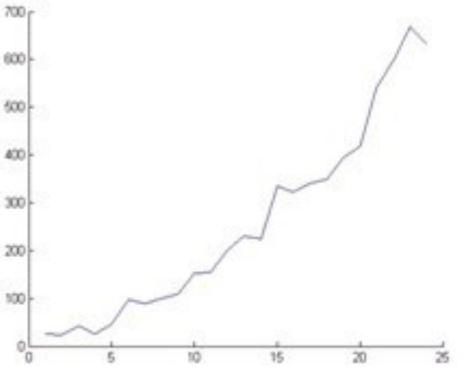

Figure 12. Changes of the number of recipients in CII scheme when pp = 0.01

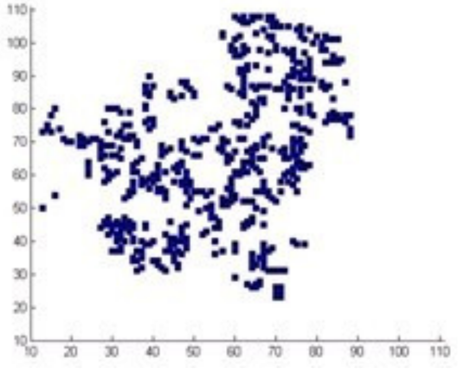

Figure 13. Evolution distribution of spread when pp = 0.05 in CII

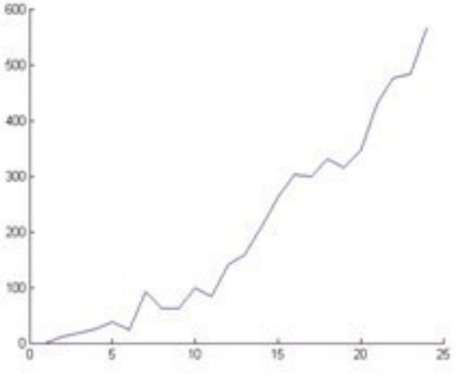

Figure 14. Changes of the number of recipients in CII scheme when pp = 0.05

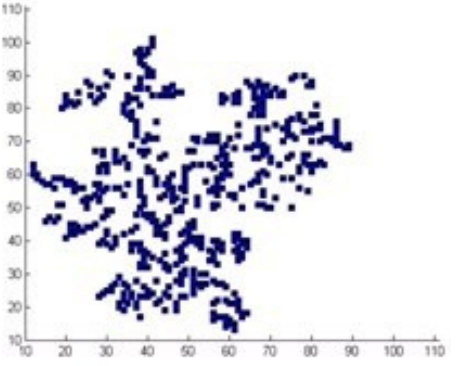

Figure 15. Evolution distribution of spread when pp = 0.1 in CII

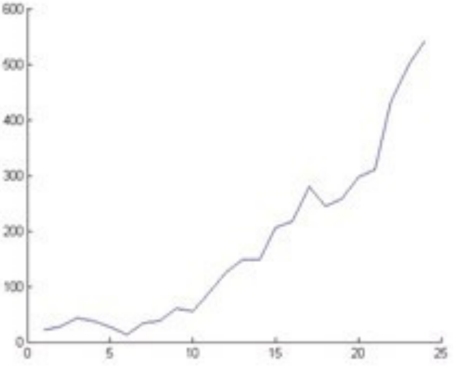

Figure 16. Changes of the number of recipients in CII scheme when pp = 0.1

information recipients (as shown in Figure 18), the changes in number tend to be smooth, and the largest number of receivers is only 12 (as shown in Figure 21). When pp = 0.1, false information is rarely able to spread (the center is just selected as the initial random distribution point). This finding indicates that this scheme can prevent the generation of false information to a certain extent. Even if false information somehow manages to spread (as shown in Figure 19), the number of false information receivers in this scheme is extremely low, where the largest number of false information receivers is only three (as shown in Figure 22).

These simulation results show that the adaptive and sustainable management of false information during public crises can control its spread in a timely and effective manner. In addition, the higher the openness and adaptability, the lower is the diffusion speed of false information during public crises. When openness and adaptability occur to a certain extent, such as mobilizing 0.01 of the public to participate in the prevention and control of false information during public crises (pp = 0.01),

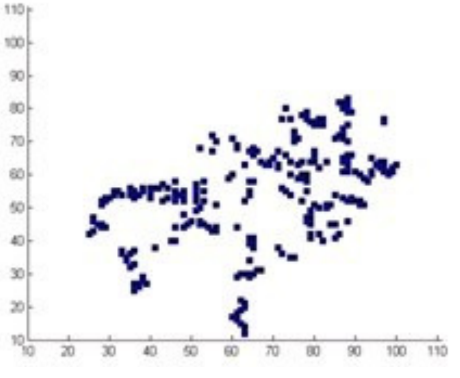

Figure 17. Evolution distribution of spread when pp = 0.01 in CIII

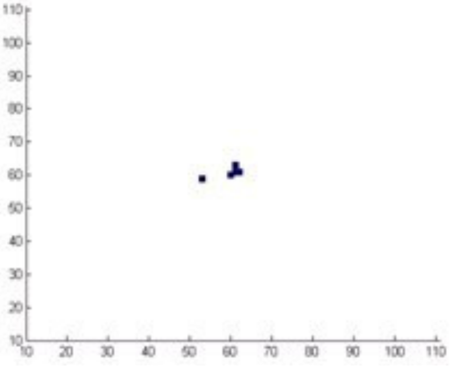

Figure 18. Evolution distribution of spread when pp = 0.05 in CIII

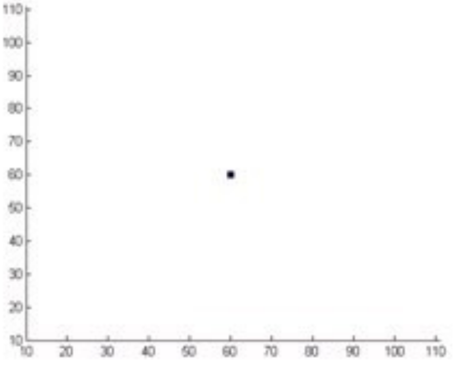

Figure 19. Evolution distribution of spread when pp = 0.1 in CIII

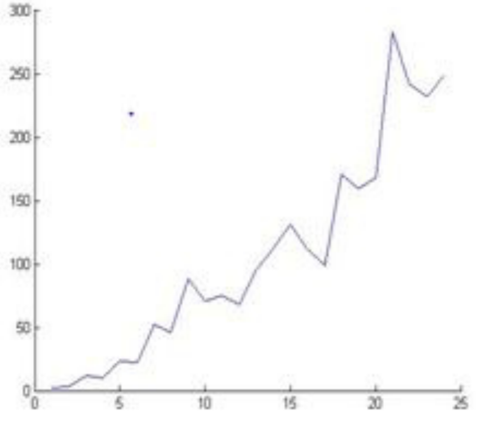

Figure 20. Changes in the number of recipients in scheme CIII when pp = 0.01

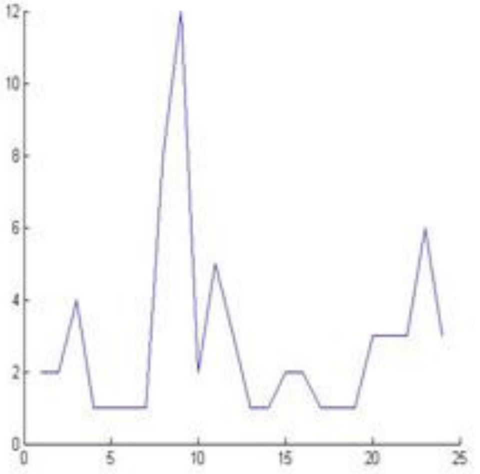

Figure 21. Changes in the number of recipients in scheme CIII when pp = 0.05

the proliferation and spread of false information can be inhibited significantly. This result has important managerial value for FIM during public crises, suggesting that nongovernmental organizations and their members should actively join FIM during such events. When openness and adaptability improve even further (pp = 0.05), a repressive influence on the diffusion of false information appears.

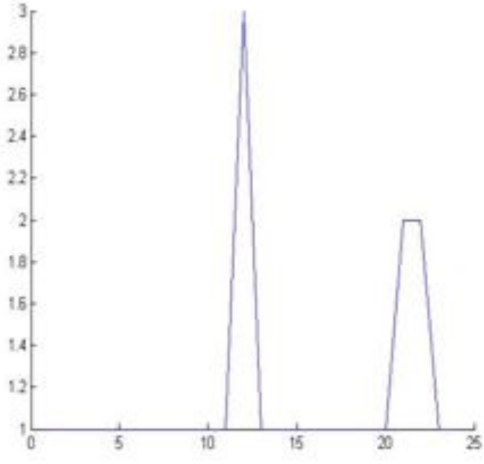

Figure 22. Changes in the number of recipients in scheme CIII when pp = 0.1

5 CONCLUSIONS

From the perspective of cellular automata method, this study analyzed the diffusion of false information in terms of public crisis management, drawing the following four main conclusions.

First, coordinated management strategy is more effective than simple management strategy, which confirms the hypothesis 1 as shown in Figures 4 and 6. Because in the coordinated management mode, the direction and quantity of the diffusion of false information can be effectively controlled, whereas simple management can only prevent the diffusion of false information in a certain direction. The diffusion speed of false information during public crises is very high, which is harmful for political and even social stability. False information diffusion sources are diverse and uncertain, the distribution of potential is irregular. A department only knows a little information about the false information so it is beyond its power to control the false information diffusion process from all aspects. The coordinated management among many departments can control the false information diffusion process better from many aspects because every department knows a lot different information and possess a variety of human and material resources. Therefore, FIM during public crises should pay more attention to coordinating the various countermeasures in addition to their performance and capabilities. Coordination is not only among staff but also among resources of various departments. The crisis education and training should be often carried out to enhance the awareness of cooperation among various departments. To make sure resources are shared among different departments, related departments should establish a unified command center to allocate resources reasonably.

Second, the open, adaptive management during public crises can effectively prevent or even eliminate the diffusion of false information, but cannot control the diffusion direction of false information, which confirms the hypothesis 2 as shown in Figures 12, 14, 16. Because with the increasing of random distribution probability, the false information diffusion rate becomes quicker and quicker and the number of infections becomes larger and larger. But, the diffusion direction remains unchanged. The false information diffusion resources and the potential recipients are dependent individuals in real life, those dependent individuals are easier to be impacted by other individuals who are same with the dependent individuals in some aspects. So the public and the influential in group are the key for the government to control the false information in public crisis. But distribution of the public and the influential in group is irregular, it is difficult to control the false information diffusion direction. This finding implies that management organizations should consider countermeasures to mobilize the public and improve individual and group initiatives in order to increase active participation in preventing and controlling false information.

Third, among the various kinds of schemes examined here, sustainable management was found to be superior to discrete management which confirms the hypothesis 3 as shown in Figures 5, 6, 9, 10 and 17, 18, 19, 20, 21, 22. Because sustainable management can affect both the direction and the speed of the diffusion of false information during public crises as well as the number of false information receivers to a significant degree, while the effects of discrete management are relatively weak in all these aspects. Discrete management strategy can only control the false information for a short time in some degree, which is harmful to the society in a long run. Sustainable management strategy can control the whole process of the false information diffusion for a long time from the beginning to the end. Thus the government has a chance to know more about the false information diffusion mechanism and gain experience from the feedback. This finding suggests that in the process of FIM during public crises, FIM skills and the execution of various management strategies must be strengthened and the consistency and continuity of management measures and countermeasures in each stage should receive enough attention. It will take some time to organize stuff and resources to control crisis. Relevant departments establish special emergency response teams in advance. Emergency response teams can take actions to control the situation immediately when crisis occurs which can reduce losses caused by lag.

Finally, the most fundamental and effective management method is reducing the probability of accepting false information during public crises, which confirms the hypothesis 4 as shown in Figure 17, 18, 19 and 20, 21. Because the false information diffusion range and direction is smaller and controlled better, the number of false information recipients is lower. The public is the subject to accept and diffuse the false information, when they refused to accept the false information, grapevine and other unknown information, the source of infection and the transmission of infection are well controlled and even the susceptible population. So reducing the acceptance probability of false information is the key to solve the problem. If this probability cannot be reduced, using a timely adaptive management strategy can effectively control information diffusion despite incurring high workload and management costs. In addition, targeted measures to isolate information can control the number of false information receivers and diffusion scope during public crises, although this is often difficult in practice. Therefore, combining several programs could be considered. When crisis occurs, the official media should release timely and accurate information on the status of the crisis continuously to strengthen the authority. When faced with gossip and news released by official media, the public are more willing to be convinced by official news.

FIM during public crises is complex, involving sociology, management, psychology, communication, information science, political science, informatics, linguistics, anthropology, and public relations among many other fields. In future researchers will study the diffusion of false information in public crises from other aspects, such as type, sources, lifecycle and so on. In more complex evolution schemes, how to combine management strategy with management skills more effectively to control the diffusion of false information during public crises should also be studied more in-depth.

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