The Dissemination Simulation of Paroxysmal Public Crisis Information Based on Polya Distribution

Zhihong Li, Yuehui Chen, Guanggang Zhou, Xue Bai
School of Business Administration, South China University of Technology
Guangzhou, 510640, China
bmzhhli@scut.edu.cn; yuehui_chen@126.com; baibaizhoudong@163.com;bai-xve@foxmail.com

Abstract—**From the view of information accumulation, the dissemination of web-based information is essentially the process of increasing the amount of information on the Internet. The dissemination of positive and negative information will always follow the Matthew Effect. In this paper, we simulated the dissemination process of a crisis information using the basic model of Matthew— polya, and explained the uncertainty of dissemination and emergence of Matthew effect with probability distribution model. According to the dissemination phenomena and probability distribution features of positive and negative information, the crisis information dissemination process can be divided into three stages: Sensitive period, developing period and stable period. Through the promotion and improvement of the original model, we illustrated the influence in the final outcome that the speed of information dissemination and the probability of the information being acquired can make. The Government can implement the crisis management by controlling the speed of information dissemination and the probability of the information being acquired.**

Index Terms—**Paroxysmal public crisis; crisis information dissemination; Matthew effect; polya distribution**

I. FOREWORD

From the Indian Ocean tsunami to H1N1 in Taiwan, from the 911 terrorist attacks to Tibet riots, seemingly peaceful society bears a variety of crisis. The crisis itself has caused incalculable loss to society, Snowballing dissemination of crisis information bringing greater pressure to the governance. Positive messages can come together to fight against crisis, But the dissemination of negative information may result in rumors, panic, or even various secondary crisis. In particular today, due to the rapid development of Internet, the spread of crisis can break the time and region limits, and all kinds of information can increase geometrically. So the dissemination of crisis information has brought new challenges to crisis management and became the focus of crisis management.

Research on the dissemination, especially web-based dissemination of crisis information has attracted the concern of more and more Chinese and foreign scholars. However, most existing studies only focus on qualitative study of theory and countermeasures. As the rapid development of Internet, the crisis spread research based on web environment has formed a certain scale. Quantitative research on spread mechanism requires a certain mathematical model: SIS model is one of the most widely used dissemination model, and Multi-Agent simulation model has been applied in the dissemination. SIS model establish non-linear differential equations to explain the general trend of spread through top-down approach, while Multi-Agent simulation model simulates the complex systems and observe the phenomenon emerged through the bottom-up modeling approach. They are human-subject, taxonomic studies audiences' behavior. However, in crisis information dissemination process, it is the information that plays the leading role. In Internet, there is only information spreading in it, and no face to face communication. Therefore, the amount and the characteristics of information decided the trend of crisis information dissemination. From the view of information accumulation, the spread of crisis information in the Internet is the process of crisis information accumulation in the Internet.

Matthew effect offer occurs when the accumulation of different types of information is imbalanced. Owing to people's group psychology, once a point of view being dominant, its credibility will getting higher and higher, and the possibility of being re-transmission also increases. Single-cylinder model which has polya distribution explains the reason of Matthew effect using probability theory. In process of Paroxysmal public crisis information dissemination, the reason of the prevalence of rumor in Internet is that the false information is spread further and the possibility to be spread is growing. The manager should prevent Matthew occurring in crisis spread, and guide the crisis information spreads healthily.

II. NEW FEATURES OF CRISIS INFORMATION DISSEMINATION BASED IN INTERNET

As the Internet's development, the spread of crisis information in Internet has shown a lot of new features.

a) The complexity of information. Both the information content and the form of information release in Internet are complex and various. For a crisis, there are positive and objective news, there are also malicious, negative news; and there are also varying degrees of information distortion in dissemination processes. The crisis Information may be expressed in word, and also can be in pictures, videos, etc.

doi:10.4304/jsw.6.8.1492-1497

b) The non-linear of spread. There is chaos in the information dissemination that the result is unpredictable from the initial state.

c) Interaction of Internet has changed the role people play in the dissemination process, that netizens are not only audiences, but also disseminators in crisis information dissemination

d) Great attention to the crisis information. As the Paroxysmal public crisis is related to the vital interests of people, Crises information in Internet often attracts attentions of most. Therefore, the initial acquirers of information are very sensitive to the crisis, and have a strong desire to spread.

III. MODEL CONSTRUCTION AND ANALYSIS

Polya distribution, also known as single-cylinder model, is one of the classic models of information accumulation. The model is based on the following hypothesis: there is a cylinder with a number of red balls and black balls in it. Taking a ball from the jar according to certain rule, red ball means success and black means fail. Supposing there are A red balls and B black balls, we take one ball arbitrarily from the jar, if a red ball, then put it back with other C red balls to the jar, and if black, put it back with other C black balls. Repeat the experiment. In this paper, we simulate the dissemination process with this experiment.

A. Models Hypothesis

According to characteristics of the crisis information dissemination in Internet, we make following hypothesis.

a) We don't consider the diversity of content and forms of crisis information. We suppose crisis information can be divided into two categories: one is positive information, represented by red balls; and the other is negative information, represented by black balls.

b) Suppose that the probability that one kind of information is selected and spread again is same in the free dissemination process,

c) Consider the effective dissemination only. There is no information distort, positive information won't converted into negative information and so is the negative information in the process of dissemination.

d) The same kind of information spread at the same rate.

B. Model with Free Dissemination

1. Polya distribution

Repeat the experiment N times then the number of red balls in the jar is:

$$a_n = a_{n-1} + p_n c \text{,} \quad (1)$$

The number of black ball is:

$$b_n = b_{n-1} + q_n c \text{,} \quad (2)$$

Where p_n represents the probability of the red ball being taken which means positive information is acquired, and q_n represents the probability of the black ball. Every time a ball is selected, add C balls with same color that means accumulation of crisis information. In the dissemination process, we care about not only the number growth of red balls and black balls, but also the proportion changes of the two kind's balls. In completely random state, given the some initial set of values of simulation, three continuous operations gave different results.

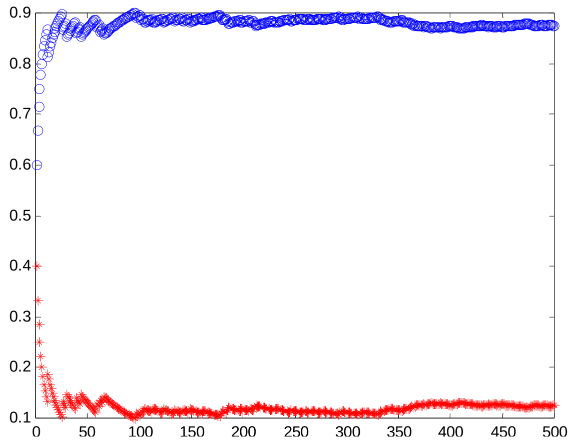

Figure 1(a)

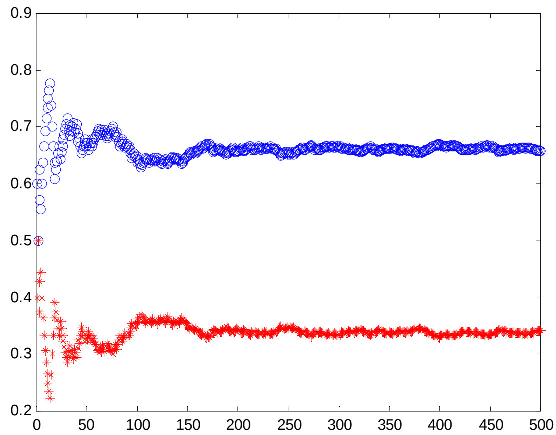

Figure 1(b)

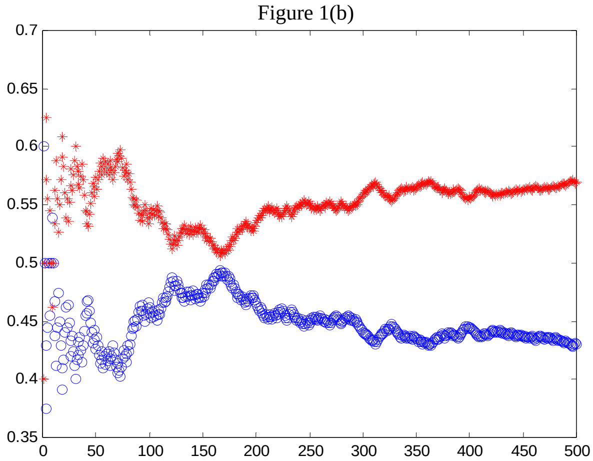

Figure 1(c)

From the result we can see that in random cases the results of dissemination is uncertain. In Fig 1(a) the result shows negative information is dominant. In Fig 1(b) we can see that negative information took advantage and positive information still has a certain share in balance state. But the Fig 1(c) shows that positive information took advantage finally, even if the negative information dominates at the beginning. The results well explain the uncertainty of crisis information dissemination.

From the result of Fig 1(a-c), we find that only one simulation in random situation is far from enough to draw conclusions. Is the uncertainty of crisis information dissemination completely irregular? Of course it's not. In the random process, supposed that the times of the experiment tend to infinitely, the proportion of red balls and black balls in the jar would tend to a stable value. This stable value is subject to some probability distribution. By studying the limit of probability we can analyze the results of dissemination.

Took a as the number of red ball and An as the proportion of red balls after N times test. Then $\{A_n, n \geq 1\}$ is Non-homogeneous Markov chains process with State-space I=$\{a, a+c, \cdots\}$. Its one step transition probability is:

$$p_{ij}(n) = P\{A_{n+1} = j \mid Y_n = i\} = \begin{cases} \dfrac{i}{a+b+nc}, \text{if } j = i+c \\ 1 - \dfrac{i}{a+b+nc}, \text{ if } j = i \end{cases}$$

$X_n = \dfrac{Y_n}{\mathrm{a+b+nc}},$ so $\{X_n, n \geq 1\}$ was Non-homogeneous Markov chains too.

According to the literature [14], that is:

$$\lim_{n\to\infty} P\{X_n \leq x\} = \begin{cases} 0 & x \leq 0 \\ \dfrac{\Gamma(a_1+b_1)}{\Gamma(a_1)\Gamma(b\ \ )}\int_0^x z^{a_1-1}(1-z)^{r_1-1}dz & 0 < x < 1 \\ 1 & x \geq 1 \end{cases}$$

$$a_1 = \frac{\ }{c},\ b_1 = \frac{\ }{c}$$

X_n was $\beta(a_1, b_1)$ and marked with $X_\infty \sim \beta(a_1, b_1)$, $A_\infty \propto \beta(a_1, b_1)$, If $a = b = c$, then A_∞ Obeys uniform distribution. It means that in random case A_∞ may take any value in $(0,1)$, which results in the uncertainty.

The closer the initial value of a and b are, the more obvious the uncertainty is. In the early times of crisis spread, the emergence of both kinds of information is uncertain. That means the value of a and b were uncertain. The uncertainty of the initial state and dissemination caused the difficulties of controlling the crisis.

Mathematical Analysis of Matthew

The crisis information dissemination process is divided into three phases in above analysis. In the stable period, small adjustments of propagation velocity caused substantial impact on the results of the dissemination. In this period Matthew emerges in the crisis information dissemination, the re-transmission probability of the one who have taken advantage is increasing. Take ε as the number of red balls after n times test, then

$$p(\varepsilon = k) = C_n^k \frac{a(a+c)\cdots[a+(k-1)\cdot c]b(b+c)\cdots[b+(n-k-1)\cdot c]}{(a+b)(a+b+c)\cdots[a+b+(n-1)c]}$$

When n>0 $p(\varepsilon = k)$ subjected to negative binomial distribution.

This distribution shows that every time red balls or black balls are taken, it will increase the probability of the same color ball being taken. A successful outcome increases further the chances of success.

Through simulation we can find, after a certain number of experiment, the probability of red balls or black balls only has small magnitude of changes with the propagation velocity c unchanged. We call this phase of the crisis information dissemination stable period. In initial stage of the dissemination, no matter take a red ball or a black ball has a greater impact on the final proportion. We call this phase sensitive period. Between sensitive period and stabilization period, there is a development stage during which positive and negative information goes through a process of accumulation. Therefore, the dissemination of crisis information can be divided into three phases: sensitive period, development period, and stable period.

If red ball could take advantage in stable period, the successful probability of red ball increases. The final results of dissemination will be biased towards red balls. But if black balls take advantage in stable period, it will be very difficult to convert this situation. Therefore, the control in sensitive period is more effective than in stability period.

C. The Dissemination Model with Control

1. The promotion of polya distribution model

Polya distribution assumes that red balls and black balls had the same propagation velocity. However, in actual transmission process, positive information and negative information had different velocities. We promote the polya distribution model as follows: there is a jar with a number of red balls and black balls in it. Taking a ball from the jar according to certain rule, red ball means success and black means fail. Suppose there are a red balls and b black balls, and take one ball arbitrarily. If it is a red ball, then put it back to the jar with other C red balls. If black ball, then put it back to the jar with other D black balls. Repeat this experiment.

After n times experiments the number of red balls and black balls could be showed as $a_n = a_{n-1} + p_n c$, $b_n = b_{n-1} + q_n d$。

We have known crisis information dissemination is uncertain, and the results of an experiment could not explain the problem. Here we define $p_\infty = p_{1000}$, and repeat the experiment 500 times, Observe the distribution of p_{1000} in $(0,1)$. At the first time we set a=20，b=30，c=20，and d=10, and we get the result as fig 2 shows. We set a=20，b=30，c=10，d=10 at the second time, and we get the result as fig 3 shows:

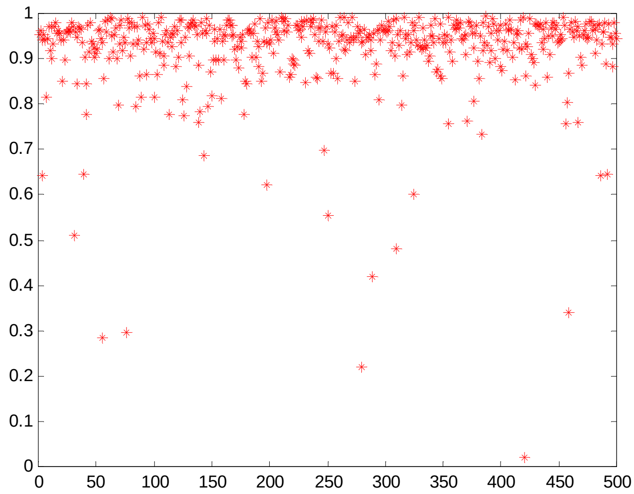

Figure 2 $a = 20$; $b = 30$; $c = 20$; $d = 10$

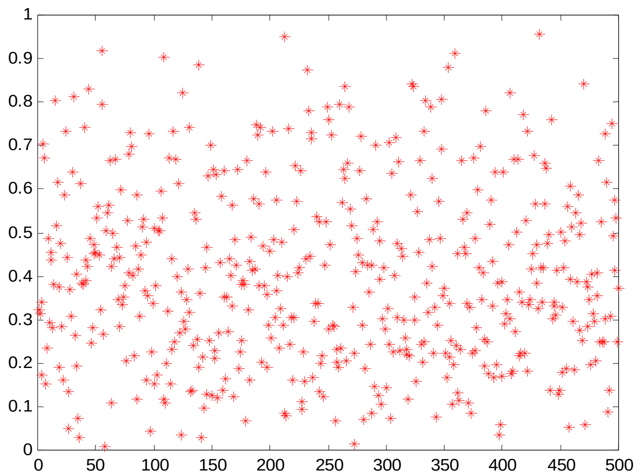

Figure 3 $a = 20$; $b = 30$; $c = d = 10$

We can found from the result that if a b c and d had little difference, the impact to balanced outcome by Velocity was clearer than by Initial values. From fig 2 we can conclude that Velocity played an important role to the result. So we can control the disseminate speed of negative information to control disseminate results.

2. Improvement of Polya Distribution Model

We known that Velocity played an important role to the result, and the Velocity was related to its news value. Government could control the information delivery channels and Internet media can control the layout of crisis information to change the proportion of getting positive and negative information. Adding Controlling factor α and β to improve the mode, then after n time's experiment the number of red ball in the jar was $a_n = a_{n-1} + (p_n)^\alpha c$ and the number of black ball in the jar was $b_n = b_{n-1} + (q_n)^\beta d$, p_n represented the probability to get red ball and q_n represented the probability to get black ball, $(p_n)^\alpha + (q_n)^\beta \le 1$. α and β were crisis Controlling factors. To increase the probability of taking red ball need $\alpha \le 1$, the other way round $\beta \ge 1$.

Government could control the information delivery channels and Internet media can control the layout of crisis information to change the proportion of getting positive and negative information. Fig 4 showed the result when $\alpha = 0.5$, and with the obvious improvement in results than in the fig 3. By increasing the control factors to increase probability to take the red ball can be a good management to control the dissemination trends of crisis information. The management of crisis information dissemination can be started with controlling the probability of taking positive and negative messages.

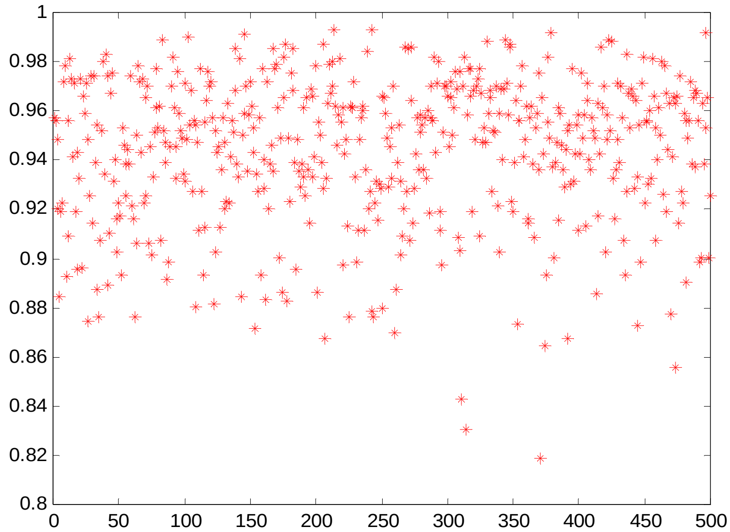

Figure 4 $a = 20$; $b = 30$; $c = d = 10$; $\alpha = 0.5$; $\beta = 0.5$

IV. MODEL INSPIRATIONS

By simulation we find that there is uncertainty in crisis information dissemination. But the dissemination process can be roughly divided into three stages. Effective crisis management in sensitive period can avoid the Matthew effect of negative information. The governor of crisis can implement controls on the speed and the probability of information being acquired. This model has the following guiding significance for the actual control of the crisis information dissemination.

1). Enhance the government' crisis consciousness, eliminate the imbalance of amount of positive and negative information in initial period. In initial period of crisis disseminations, if there is only negative news in Internet and the government delays again and again telling the truth, the possibility of rumors circulated will be increasing. Thus, once negative information appears in Internet, the Government should respond timely.

2). Early control can prevent the Matthew Effecter of negative information. Matthew effect of positive information is beneficial. However, if it is about the negative information, it will increase difficulty of crisis control, so government should adopt a series of measures to prevent this and prevent the society's premature recognition of negative information which has potential impact on social stability? To control the crisis dissemination in different stages will have different effects. Crisis management would be more effective in sensitive period, with less input of manpower and material. Therefore, the Government should pay main attention to the sensitive period of dissemination, and intervene timely and control crisis actively

3). Develop the reason of netizens and control the speed of crisis information dissemination. The disseminate speed of positive and negative information have direct impact on the disseminate results. The degree of netizens' reason plays a decisive role in the speed of information dissemination. Government should strengthen crisis education on netizens, and develop netizens' reason to distinguish between positive and negative information correctly in order to control the speed of positive information dissemination effectively.

4). control actively to improve the probability of positive information being acquired. The effects of controlling factor on the result can't be ignored. Controlling factors can be variety of Internet technology and the intervene in the Internet media. The Government should choose a site with high credibility to release crisis information, and supervise a number of large sites who would release negative crisis information.

V. CONCLUSIONS

This paper built a web-based crisis information dissemination model from the view of Information accumulation, explained the mechanism of dissemination of crisis information and provided the basis for decision-making of crisis management. However, the assumption of our model has limited many variables involved to build a simpler model. The dissemination model with higher forecasts accuracy that considers more factors requires further study.

ACKNOWLEDGMENT

This work was supported in part by a grant from the humanities and social science research projects of Guangdong Education Department (its number is 306N5040060) and the Guangdong Philosophy and Social Sciences Planning Projects (its number is B16N4070500).

REFERENCE

[1] Guo Huiming. Crisis communication vs Risk Management [J]. PR Magazine. 2009,(2):92
[2] Garnett, J.A. Communicating throughout Katrina: Competing and Complementary Conceptual Lens on crisis communication[J]. Public Administration Review. 2007, 67, 171

[3] Normal L. Nielson, Anne E. Kleffner, Ryan B. Lee. The evolution of the role of risk communication in effective risk management[J]. Risk Management and Insurance Review, 2005, 8(2): 279-289
[4] Li Zhihong, He Jile, Wu Pengfei. 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
[5] Yuan Zhangqiong. The main subjects research on crisis communication care about[J]. Southeast Communication. 2007, 11: 67-69
[6] Perry,D.C, Taylor, M&Doerfel, M.L. Internet-based communication in crisis management[J]. Management Communication Quarterly, 2003, 17(2):206
[7] Ren Yuanyuan. The Reestablishment and A pplication of the Modes of Crisis Communication in the Internet Era[D]. Shangdong University Master’s Thesis. 2008, 4
[8] Fjeld, K&Molesworth. M. PR practitioners’ experiences of, and attitudes towards, the Internet’s contribution to external crisis communication. Corporate Communication; An International Journal, 2006, 11(4): 391-405
[9] Tang Sihui, Yang Jianmei. Study of two diffusion model of mutual information spreading Internets[J]. studiees in science of science. 2008, 26(3): 476-480
[10] LIU Chang-yu, etc. Public Opinion Propagation Model Based on Small World Internets[J]. Acta Simulata Systematica Sinica. 18(12), 2006.12: 3608-3610
[11] YU Yong-yang etc. A Study on Public Opinion Evolutionary Model Based on Agent[J]. computer simulation. 2008, 25(9): 9-14.
[12] Liu Jinling. The Genesises of Obstacle about Information Resources Sharing Based on the Information Asymmetry[J]. Modern Information. 2008, 9: 45-47
[13] Ma Feicheng. Etc. Information managenment [M]. Wuhan University Press. 2004. pp75
[14] Yang Jilong, Ye Erhua. Generalization of a Limit Distribution of Polya Urn Model[J]. Journal of Nanjing University of Aeronautics & Astronautics. 20(4), 1988.12: 123-127

Zhihong Li was born in Fuzhou, China in 1969. He obtained the Bachelor of Industry Management Engineering from Department of Management Engineering, South China University of Technology, Guangzhou, China in 1992. At the same university, he obtained the Master of Management Science and Engineering in 1998 and the Ph.D. of Management Science and Engineering in 2006. His major field of study includes management information systems, electronic commerce, knowledge system engineering, etc.

He was a Lecturer of IM&IS, School of Business Administration, South China Technology of China, Guangzhou, China from 1998-2006. Science 2006, he has been an Associate Professor of management science and engineering at the same school. He published more than 60 papers in the journals and conference proceeding and some books. His latest edited book is entitled “The Theory and Practice of Knowledge Management” (Beijing, China: Tsinghua University Press, 2007). His current research interest is Knowledge Management.

Yuehui Chen, male, born in 1975, come from Zhangzhou in Fujian province, He obtained the Bachelor of chemistry from Hunan University in 1997.Now he is working in the Quality and Technology Supervision of Zhongshan city. Meanwhile he is also a master student of South China University of Technology. His research interests include crisis management, knowledge management.

Guanggang Zhou, male, born in 1987, come from Jining in Shandong, master of South China University of Technology, research interests include crisis management, knowledge management.

Xue Bai was born in Anyang, China in 1986. He obtained the Bachelor of IM&IS from Department of Computer Science and Information Engineering, Guangxi Teachers Education University, Nanning, China in 2009. Now he is a master student of South China University of Technology. His research interests are Mobile Commerce and Knowledge Management.