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Estimating the diffusion models of crisis information in micro blog

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ABSTRACT

The study tries to construct the diffusion models of crisis information in micro blog. We propose three information release patterns in micro blog according to the duration of crisis information released, namely concentrated release, continuous release, and pulse release. Based on Logistic function, three respective diffusion models are constructed. We choose three crisis events to test the diffusion models using the variables of the number of micro blogs with the crisis information (NMCI) and the increment of NMCI. The estimate results show that the diffusion of crisis information in micro blogs can be described by Logistic function, and the growth curve of NMCI is S-shaped.

1. Introduction

Since the advent of Twitter, the user number of micro blog grows rapidly. In China, there were 250 million micro blog users until the end of December 2011 (CNNIC, 2012). Before the micro blog appeared, almost all of the news stories were generated from the official media agendas. At that time, for some serious crises, people might not receive relevant information in time because it can be blocked by some administration bureaus. The openness and convenience of micro blog makes every user to be a news reporter, which can speed up the diffusion of information on the Internet. Using micro blog, the public can track the process of crisis evaluation, and express their opinions and emotions. The spread of micro blog has an essential influence on China's social management reform. For example, the earliest information of Wenzhou Train Accident in 2011, which caused 40 passengers dead and 172 injured, appeared in micro blog, and then the information spread quickly to most of the micro blog users. The Ministry of Railways of China who was in charge of handling the accident had to change its response measures.

However, the micro blog also has the positive effect on the effective crisis communication. To utilize benefits of the micro blog in crisis communication, it is necessary to explore the crisis information diffusion law in micro blog. In the field of informetrics, Goffman and Price did pioneering research in measuring information growth. Goffman applied an epidemic model to study the diffusion of ideas and the growth of scientific specialties (Goffman, 1966, 1968, 1971; Goffman & Newill, 1967). Price studied the number growth patterns of scientists, scientific journals and papers, finding an exponential growth rate of 5% for the scientific literatures over the past two centuries, corresponding to a doubling time of 15 years (Price, 1963, 1975). Since then, literature growth study has become very common in the fields of bibliometrics and informetrics (Yitzhaki & Shahar, 2000).

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Studying the growth patterns in the U.S. National Library of Medicine's serials collection and in Index Medicus journals between 1966 and 1985, Humphreys and McCutcheon (1994) concluded that, in general, the data appears to support Price's analysis. Furthermore, Goffman (1971) described the growth as an initial period of exponential growth, followed by saturation and slowdown to a steady rate of increase. A similar conclusion was reached by other researchers. Funkhouser (1973) discussed the relation between quantity of news report and mass perception by 10 years data set in three weekly newspapers. The Simmon–Yule framework is often expressed in such a way to model the growth of the population of authors publishing in a field. However, Allison (1980) and others (Allison, Long, & Krauze, 1982; Rao, 1980) have expressed it explicitly as a model for the increasing rate of publication for individual authors. This model implies that the distribution shape of production across a population arises from the distribution of production within each individual's career. The "Law of Exponential Growth" has been further proposed by Rao and Meera (1991), Egghe and Rao (1992) and many others. Most articles proposed that literature grows exponentially and it is described mathematically by the exponential function $Y(t) = a * \exp(bt)$ where $Y(t)$ represents the size at time t, a is the initial size, and b is the continuous growth rate which is related to the annual growth rate r, as: $r = \exp(b) - 1$. Egghe and Rao (1992) claimed that the power model (with exponent > 1) is the best growth model for sciences and technology fields, while the Gompertz S-shaped distribution fits the fields of social sciences and the humanities.

But the crisis information diffusion is different from the literature growth model. When crisis happened, crisis information would disseminate quickly (Barton, 1969). Social impacts, which include psychosocial, socio demographic, socioeconomic, and sociopolitical impacts, can develop over a long period of time and can be difficult to assess when crisis occurred (Lindell & Prater, 2003). After the period, the crisis will disappear gradually from people's memory and discussion. Previous research (Duggan & Banwell, 2004; Pelletier & Msukwa, 1990; Pijnenburg & Duin, 1990; Wei, Zhao, Yang, Du, & Marinova, 2010) mainly focused on crisis response strategy, crisis communication media selection, crisis communication conceptual model, simulation of crisis information diffusion. Few scholars studied quantitative model of crisis information diffusion. Erickson, Nosanchuk, Mostacci, and Dalrymple (1978) traced rumors after an explosion of a downtown office building. Greer and Moreland (2003) focused online crisis communication of United Airlines and American Airlines following the September 11 terrorist attacks. They drew quantity curves of daily messages published on the two companies' websites. Matsumura, Yukio, and Mitsuru (2002) proposed an Information Diffusion Model (IDM) in text-based communication, and present their discoveries on experiments.

As a new field, information communication and dissemination in micro blog began to interest the academic, most research studied the function of communication (Chen, 2011; Ebner, Lienhardt, Rohs, & Meyer, 2010; Forkosh-Baruch & Hershkovitz, 2012; Scanfeld & Scanfeld, 2010; Starbird, Palen, Hughes, & Vieweg, 2010; Yang & Counts, 2010), and also some studied network structure of micro blog website such as Twitter (Shen, Li, Ye, & He, 2010; Takhteyev, Gruzd, & Wellman, 2012). This paper discusses the diffusion model of crisis information based on micro blog communication, which have rarely been mentioned before.

2. Diffusion pattern of crisis information

Usually, when micro blog users browse the valuable crisis information, some of them will quote and transmit it. Some of their online followers will do the same activity when they read the transmitted information, which shapes an information transfer chain. If the number of micro blogs is boundless, and no factor restricts the diffusion of the crisis information, then the number of the micro blogs containing the crisis information will increase rapidly. We use the variable of the number of micro blogs with the crisis information (hereafter "NMCI") to measure the crisis information diffusion status at one moment. We assume the grow model obeys the exponential rule which can be formalized by the equations as follows:

$$\frac{dN}{dt} = rN \quad \text{or} \quad N = N_0 e^{rt} \tag{1}$$

N represents NMCI, t represents time, r represents increment rate of NMCI and N_0 represents the initialization number of the micro blogs with the crisis information.

In fact, it is impossible for NMCI to grow up exponentially all along considering of the bound of the Internet and micro blogs. The growth of NMCI will inevitably be affected by information newsworthiness and competition of new information, which will restrict and reduce the growth rate. Thus, as time goes by, and with the restriction of various complex factors, the growth curve always emerges as an S-shaped profile. It may be described by Logistic function (Bass, Krishnan, & Jain, 1994; Murray, 1989) which was firstly developed by Verhulst (1838). We use this model to describe the growth of NMCI under the bounded situation. The model can be described as follows:

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right) \tag{2}$$

Solves the Logistic function with the separation quantity method and get:

$$N = \frac{K}{1 + ce^{-rt}}, \quad c = \frac{K - N_0}{N_0} \tag{3}$$

In Eqs. (2) and (3), N, t, r and N_0 are the same in Eq. (1). K represents the maximum value NMCI can reach, namely NMCI capacity. Assumptions of this model are:

(1) NMCI has a maximum value, called NMCI capacity, commonly referred to K. When NMCI reaches K, N will no longer grow.
(2) When NMCI increases by one unit, the increment rate of NMCI, namely r will reduce by $1/K$ immediately. If the micro blog space contains N micro blogs with the crisis information, the growth space is N/K, and the surplus space that supplies to grow is $1 - N/K$.
(3) There's no time delay between the increase of NMCI and the decrease of its increment rate.
(4) None of the micro blogs is deleted during a crisis.

3. The three crisis information release patterns and relevant diffusion models

3.1. The definitions of the three crisis information release patterns

Crisis events are different in information release patterns, especially in the release duration. The crisis information release duration refers to the days in which the crisis news stories generate. According to the difference of crisis information release duration, the crisis information release patterns can be classified into three types, namely concentrated release, continuous release, and pulse release. Correspondingly, there are three crisis information diffusion models.

3.1.1. Concentrated release

This pattern refers to all the crisis information is released in one day. Since this kind of crisis event is familiar and unserious, people pay little attention and discuss little in micro blogs. Therefore, little information will be released after the concentrated release. Generally, natural disasters, mine disasters, traffic accidents, and usual enterprise crisis events in China, and natural disasters happened in foreign countries fit the concentrated release model. Furthermore, information release of rumor fits this pattern because people prefer disseminating rumor to discussing it.

3.1.2. Continuous release

In this pattern, crisis information is released continuously during some days after the crisis event. Generally, serious natural disasters, serious traffic accidents, and other serious enterprise crisis events fit this pattern. This kind of crisis event severely affects people's living, or influences social orders and social stability. After the event, the government always issues the crisis information continuously, and individuals always pay close attention to the process and discuss it in micro blog hotly.

3.1.3. Pulse release

In some crises, some crisis news stories fluctuate significantly because some new newsworthy information emerges during the days of crises. After the first news story of Fuyang Inferior Formula Scandal in China, the amazing and newsworthy material which attracted public's attention were disclosed continually in the following days (Wei et al., 2009). The newsworthy material included the breach of local government officers' duties, the large cumulative number of victims, and the origin of the inferior formula. The news stories on this event fluctuated in the following response days. We name this kind of information release model as pulse release pattern which has been proved in some case studies (Shih, Wijaya, & Brossard, 2008; Vasterman, Yzermans, & Dirkzwager, 2005; Wei, Zhao, & Liang, 2009). According to the evolution process of the event situation, the pulse release pattern can be divided into several stages. In each stage, the micro blog users focus on different newsworthy materials. Therefore, the quantity and duration of news stories on the crisis are different. Generally, crisis event with serious losses and various scandals fit this pattern, especially some serious enterprise crisis events and social security incidents.

As Fig. 1 shows, in the concentrated release pattern, crisis information is released fully at time 0 when the event happens. In the continuous release pattern, crisis information is released continuously between time 0 and time n_2. In the pulse release

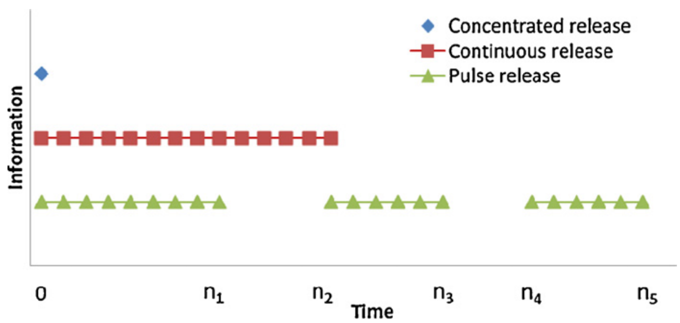

Fig. 1. Three release patterns of crisis information.

pattern, crisis information is released on and off, for example, information is released between time 0 and time n_1, between time n_2 and time n_3, between time n_4 and time n_5.

3.2. Diffusion model of concentrated release

Crisis information is released once in concentrated release pattern. We use the Logistic model mentioned above to estimate the growth of NMCI as follows.

$$N(t) = \frac{K}{1+ce^{-rt}} \quad (4)$$

The increment of NMCI is $M(t)$.

$$M(t) = \begin{cases} \dfrac{K}{1+ce^{-rt}} & (t=0) \\ \dfrac{K}{1+ce^{-rt}} - \dfrac{K}{1+ce^{-r(t-1)}} & (t>0) \end{cases} \quad (5)$$

$N(t)$ and $M(t)$ describe the diffusion of crisis information released concentratedly.

3.3. Diffusion model of continuous release

After a crisis happens, information relevant to the event is various in different aspects, and it can't be released completely at one time. When a crisis bursts out, the most valuable information will be "what's the matter going on? How much is the loss?" then it follows "How is the government responding?" and so on. Therefore, a combination of different information will be transmitted.

Supposing a crisis event occurs, the crisis information is released from time 0 to time n, then diffusion function in each time is:

$$N_i(t) = \frac{K_i}{1+c_i e^{-r_i t}} \quad (6)$$

NMCI at time t is:

$$N(t) = \sum_{i=0}^{p(t)} N_i(t) = \sum_{i=0}^{p(t)} \frac{a_i K_i}{1+c_i e^{-r_i(t-i)}}$$
$$p(t) = \begin{cases} t \ (t \le n) \\ n \ (t > n) \end{cases} \quad (7)$$

a_i represents the number of crisis information pieces release at time i.

For a crisis event, the information that generates in the same period of time is often processed into one single piece. As a result of the continuous attention, diffusion pattern of information released in each time are similar. Therefore, the parameters in Eq. (7) can be simplified.

$$\forall i \le n, a_i = 1, c_i = c, r_i = r, K_i = K$$

Then Eq. (7) can be simplified as Eq. (8).

$$N(t) = \sum_{i=0}^{p(t)} \frac{K}{1+ce^{-r(t-i)}}, \quad p(t) = \begin{cases} t \ (t \le n) \\ n \ (t > n) \end{cases} \quad (8)$$

To compute increment of NMCI, we divide the release duration into several stages and calculate $M(t)$ piecewise.when $t = 0$

$$N(t) = \frac{K}{1+ce^{-rt}} \quad (9)$$

$$M(t) = N(t) = \frac{K}{1+ce^{-rt}} \quad (10)$$

when $0 < t \le n$

$$N(t) = \sum_{i=0}^{t} N_i(t) = \frac{K}{1+ce^{-rt}} + \frac{K}{1+ce^{-r(t-1)}} + \cdots + \frac{K}{1+ce^{-r(t-i)}} + \cdots + \frac{K}{1+ce^{-r(t-t)}} \quad (11)$$

$$M(t) = N(t) - N(t-1) = \frac{K}{1+ce^{-rt}} \quad (12)$$

when $t > n$

$$N(t)=\sum_{i=0}^{n}N_i(t)=\frac{K}{1+ce^{-rt}}+\frac{K}{1+ce^{-r(t-1)}}+\cdots+\frac{K}{1+ce^{-r(t-i)}}+\cdots+\frac{K}{1+ce^{-r(t-n)}} \tag{13}$$

$$M(t)=N(t)-N(t-1)=\frac{K}{1+ce^{-rt}}-\frac{K}{1+ce^{-r(t-n-1)}} \tag{14}$$

Therefore, the diffusion model of continuous release is:

$$N(t)=\begin{cases}\sum_{i=0}^{t}\frac{K}{1+ce^{-r(t-i)}} & (t\le n)\\ \sum_{i=0}^{n}\frac{K}{1+ce^{-r(t-i)}} & (t>n)\end{cases} \tag{15}$$

$$M(t)=\begin{cases}\frac{K}{1+ce^{-rt}} & (t\le n)\\ \frac{K}{1+ce^{-rt}}-\frac{K}{1+ce^{-r(t-n-1)}} & (t>n)\end{cases} \tag{16}$$

3.4. Diffusion model of pulse release

Sometime, the crisis information is released on and off. As in Fig. 1, information is released piecewise in pulse release model, so it can be thought as a combination of several continuous release models. In some cases, $n_1=0$ or $n_2=n_3$ or $n_4=n_5$, then the pulse release model can be thought as a combination of several concentrated and continuous release models.

We take the pulse release pattern described in Fig. 1 as an example. NMCI is $N(t)$ as follows.

$$N(t)=\sum_{i\in S(t)}N_i(t)=\sum_{i\in S(t)}\frac{a_iK_i}{1+c_ie^{-r_i(t-i)}}$$
$$S(t)=\begin{cases}[0,t] & (t\le n_1)\\ [0,n_1] & (n_1<t<n_2)\\ [0,n_1]\cup[n_2,t] & (n_2\le t\le n_3)\\ [0,n_1]\cup[n_2,n_3] & (n_3<t<n_4)\\ [0,n_1]\cup[n_2,n_3]\cup[n_4,t] & (n_4\le t\le n_5)\\ [0,n_1]\cup[n_2,n_3]\cup[n_4,n_5] & (n_5<t)\end{cases} \tag{17}$$

As the same reason with diffusion model of continuous release, we suppose:

$$a_i=1,\forall i\in[0,n_1]\cup[n_2,n_3]\cup[n_4,n_5]$$

In this kind of crisis event, individuals' focus is always changing as time going on. Parameters of functions in each stage may be different. So, we suppose:

$$\forall i\in[0,n_2-1],\; c_i=c,\; r_i=r,\; K_i=K$$
$$\forall i\in[n_2,n_4-1],\; c_i=c',\; r_i=r',\; K_i=K'$$
$$\forall i\in[n_4,n_{end}],\; c_i=c'',\; r_i=r'',\; K_i=K''$$

n_{end} represents the end time of crisis information spread. For increment of NMCI, $M(t)$, it can be derived by the formula (18). The result of $M(t)$ is not concise or significant, thus we do not show it here.

$$M(t)=N(t)-N(t-1) \tag{18}$$

4. Empirical analyze

4.1. Concentrated release: the rumor of egg attacking car

Since 20 February 2012, a rumor began to propagate in micro blog website of China. It said if a driver was attacked by eggs when he or she was driving at night, he or she should not use the wiper or the automatic sprinkler of the car. The reason was that the combination of eggs and water is too milky to see the front road. When the driver parked on the roadside to

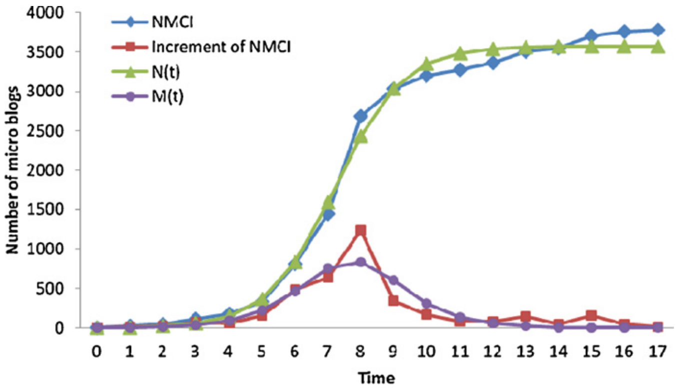

Fig. 2. Actual curve and fit curve of the rumor of egg attacking car.

clean the window, some robbers would jump out and rob the car. The rumor caused public panic since there were a large number of automobiles in China, around 106 million by the end of 2011, and numbers of them are running on the road at night. People posted the rumor in many social websites. Moreover, most of the Chinese influential news websites including XINHUANET.com, SINA.com, and SOHU.com concerned the rumor. We choose the micro blog website of SINA.com, which called Weibo, as the data source. Using the search engine of Weibo (retrieved 20 April 2012), we got NMCI and the increment of NMCI each day. The beginning time of the diffusion is 20 February 2012 (time 0), and the ending time is 8 March 2012 (time 17).

According to the diffusion model of concentrated release, we use NMCI from time 0–17 to estimate c, K, r. With the curve fit tool in MATLAB, c, K and r are estimated as $c = 1132$, $k = 3574$, and $r = 0.9735$, respectively. The determination coefficient is $R^2 = 0.9933$.

$$N(t) = \frac{3574}{1 + 1132e^{-0.9735t}} \tag{19}$$

$$M(t) = \begin{cases} \dfrac{3574}{1 + 1132e^{-0.9735t}} & (t = 0) \\ \dfrac{3574}{1 + 1132e^{-0.9735t}} - \dfrac{3574}{1 + 1132e^{-0.9735(t-1)}} & (t > 0) \end{cases} \tag{20}$$

Fit result of $N(t)$ and $M(t)$ is computed, as shown in Fig. 2. To test and verify the effectiveness of this model, we calculated the determination coefficient of the increment of NMCI in the model, use the equation as follows, $R^2 = 0.8035$.

$$R^2 = 1 - \frac{\sum_{i=1}^{m} (y_i - \hat{y}_i)^2}{\sum_{i=1}^{m} (y_i - \bar{y}_i)^2} \tag{21}$$

4.2. Continuous release: bullet train wreck in Wenzhou

On 23 July 2011, a bullet train rear-ended another, and four carriages fell from viaduct, making 40 deaths in Wenzhou, East China. Micro blog users in China quickly disseminated the information about the accident, discussed the cause and the government responsibility in this event. The news stories on this crisis are released continuous in the first days.

On 23 July, the bullet train wreck happened.
On 24 July, an on-site meeting was started, and Dejiang Zhang, Chinese vice Premier, took the chair. In the meeting, the rescue and recovery headquarter and work groups of the accident were set up.
On 25 July, residents in Wenzhou congregated in a square to mourn the deaths in the accident.
On 26 July, the bullet trains destroyed were carried away, and the first reparation agreement of death in the accident was made.
On 27 July, the blockade of the accident scene was removed, and the families of the deaths congregated in the Wenzhou South Station to express their appeal.
On 28 July, Jiabao Wen, Chinese Premier came to the scene of the accident, mourned the deaths, and visited the injured and the families of the deaths.
On 29 July, Feng Yang, whose five families died in the accident, asked the government to issue the true number of the death.

From 23 July to 29 July, crisis information relevant to the accident was released every day, and each of the news stories is independent. After 29 July, there was little new information released. Therefore, we can use the diffusion model of continuous release to estimate the growth of NMCI of this case. In this case, the beginning time of the diffusion is 23 July 2011 (time 0),

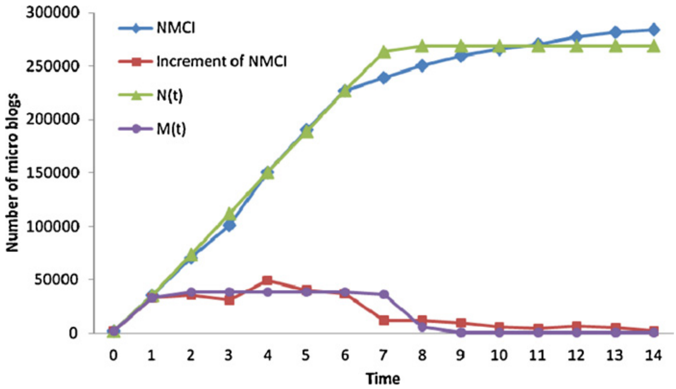

Fig. 3. Actual data and fit result of bullet train wreck in Wenzhou.

and the ending time is 6 August 2011 (time 14), the release duration $n = 6$. NMCI and the increment of NMCI were searched on 15 March 2012.

To get the value of c, K, r, we use model (16) to analyze the increment of NMCI from time 0 to time 6. The result is $R^2 = 0.8607$, $c = 18.64$, $k = 38\,430$, $r = 4.758$. We calculated the determination coefficient of NMCI and the increment of NMCI from time 0 to time 14. The result are $R^2 = 0.9877$ (NMCI), $R^2 = 0.7218$ (the increment of NMCI). Comparison of actual data and fit result data is shown in Fig. 3.

$$N(t) = \begin{cases} \sum_{i=0}^{t} \dfrac{38\ 430}{1 + 18.64e^{-4.758(t-i)}} & (t \le 6) \\ \sum_{i=0}^{6} \dfrac{38\ 430}{1 + 18.64e^{-4.758(t-i)}} & (t > 6) \end{cases} \tag{22}$$

$$M(t) = \begin{cases} \dfrac{38\ 430}{1 + 18.64e^{-4.758t}} & (t \le 6) \\ \dfrac{38\,430}{1 + 18.64e^{-4.758t}} - \dfrac{38430}{1 + 18.64e^{-4.758(t-7)}} & (t > 6) \end{cases} \tag{23}$$

4.3. Pulse release: Chinese Fujian Greetown Company extracting bear bile

Fujian Greetown Medicine Industry Co. Ltd. of China is a traditional Chinese medicine manufacturing company where bears are raised for extracting the bile twice a day. Many animal right activists and groups, such as Animals Asia Foundation, thought it was cruelty to bears and expressed a vehement protest. On 1 February 2012, Greetown Company applied for IPO (initial public offerings), most people and some NGO organizations were opposed to the application because they thought the IPO would encourage animal cruelty. Then an unprecedented wide discussion happened in micro blog, lasting more than one month. In the event, crisis information was released on and off.

On 1 February, Greetown Company applied for IPO. Animals Asia Foundation appealed for prohibiting mistreatment, they wanted to save the bears.
On 6 February, China Association Of Traditional Chinese Medicine supported the Greetown Company, claiming the arrestment of IPO was a plot of Animals Asia Foundation.
On 13 February, Animals Asia Foundation demanded an apology of China Association Of Traditional Chinese Medicine.
On 14 February, more than 70 personages signed and supported a petition to China's Securities Regulatory Commission to oppose the IPO.
On 15 February, China Security Journal showed off a set of photos describing how to extract bile from bear captured in the factory of Greetown Company.
On 16 February, China Association Of Traditional Chinese Medicine called a press conference in Beijing to supported the Greetown Company, the president of the association said the using of new technology made the bear feel no painful when the bile was extracted.
On 19 February, Greetown Company decided to open their factory to welcome people's visiting after two days. Micro blog users doubted the exoteric area is limited and they could not understand why only journalists had admission to visit.
On 20 February, the Greetown Company claimed the open of factory was unlimited in area.
On 21 February, Animals Asia Foundation called a press conference in Beijing, it still insisted on abolishing feeding bear for bile.

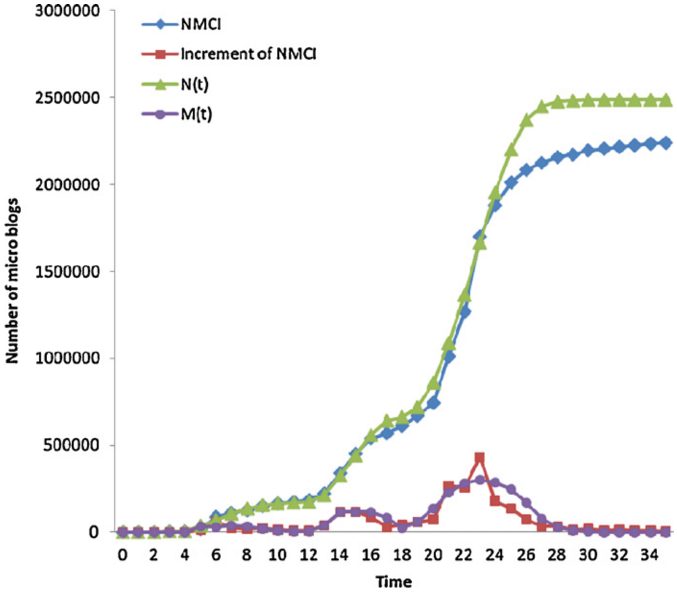

Fig. 4. Actual data and fit result of Chinese Fujian Greetown Company extracting bear bile.

On 22 February, the factory of Greetown Company was open to some journalists invited.
On 23 February, the Greetown Company registered micro blog in Weibo (micro blog website of SINA), many Weibo users posted messages to it.
On 24 February, the factory of Greetown Company was open to NPC members, opinion leaders, scholars, animal protection groups.

In this case, the beginning time of the diffusion is 1 February 2012 (time 0), and the ending time is 7 March 2012 (time 35), crisis information is release at time 0, 5, 12–15, 18–23, it is a combination of two concentrated release models and two continuous models. To fit the case, we modify the pulse release model as equation (24). Total quantity and increment of relevant micro blogs is searched on 5 April 2012.

$$
\begin{aligned}
&N(t)=\sum_{i\in S(t)}N_i(t)=\sum_{i\in S(t)}\frac{K_i}{1+c_ie^{-r_i(t-i)}}\\
&S(t)=\begin{cases}[0] & (0\le t<5)\\ [0]\cup[5] & (5\le t<12)\\ [0]\cup[5]\cup[12,t] & (12\le t\le 15)\\ [0]\cup[5]\cup[12,15] & (15<t<18)\\ [0]\cup[5]\cup[12,15]\cup[18,t] & (18\le t\le 23)\\ [0]\cup[5]\cup[12,15]\cup[18,23] & (23<t)\end{cases}\\
&\forall i\in[0,4],\ c_i=c,\ r_i=r,\ K_i=K\\
&\forall i\in[5,11],\ c_i=c',\ r_i=r',\ K_i=K'\\
&\forall i\in[12,18],\ c_i=c'',\ r_i=r'',\ K_i=K''\\
&\forall i\in[18,35],\ c_i=c''',\ r_i=r''',\ K_i=K'''
\end{aligned}
\tag{24}
$$

As a combination of concentrated and continuous models, the pulse model in this case fits piecewise. At first, we get the diffusion function of information released at time 0 based on micro blogs quantity of time 0–4, then the effect of the information is subtracted from the quantity of time 5–35. Similarly, the other three models fit one by one using quantity of time 5–11, 12–15, 18–23. The R^2 are 0.9831, 0.9562, 0.9857, and 0.7977.

The model is described as follows:

$$N(t)=\begin{cases}\dfrac{4754}{1+52.98e^{-1.523t}} & (0\le t<5)\\ \dfrac{4754}{1+52.98e^{-1.523t}}+\dfrac{168700}{1+3.992e^{-0.887(t-5)}} & (5\le t<12)\\ \dfrac{4754}{1+52.98e^{-1.523t}}+\dfrac{168700}{1+3.992e^{-0.887(t-5)}}+\sum_{i=12}^{t}\dfrac{117700}{1+147.1e^{-4.237(t-12)}} & (12\le t\le 15)\\ \dfrac{4754}{1+52.98e^{-1.523t}}+\dfrac{168700}{1+3.992e^{-0.887(t-5)}}+\sum_{i=12}^{15}\dfrac{117700}{1+147.1e^{-4.237(t-12)}} & (15<t<18)\\ \dfrac{4754}{1+52.98e^{-1.523t}}+\dfrac{168700}{1+3.992e^{-0.887(t-5)}}+\sum_{i=12}^{15}\dfrac{117700}{1+147.1e^{-4.237(t-12)}}+\sum_{i=18}^{t}\dfrac{307400}{1+15.55e^{-1.27(t-18)}} & (18\le t\le 23)\\ \dfrac{4754}{1+52.98e^{-1.523t}}+\dfrac{168700}{1+3.992e^{-0.887(t-5)}}+\sum_{i=12}^{15}\dfrac{117700}{1+147.1e^{-4.237(t-12)}}+\sum_{i=18}^{23}\dfrac{307400}{1+15.55e^{-1.27(t-18)}} & (23<t)\end{cases} \quad (25)$$

$M(t)$ is not concise or significant, therefore it is not showed here. We calculated the determination coefficient of the model using the actual data and fit result of time 0–35, the results are $R^2 = 0.9695$ (NMCI), $R^2 = 0.7733$ (the increment of NMCI). That means the models fits this case very well.

5. Discussion

The three diffusion models we propose in this study fit the crisis information diffusion process accurately. Each determination coefficient R^2 is large enough to support the model, and R^2 decreases when the release pattern becomes complex, i.e. the diffusion model of concentrated release performs better than the other two. The R^2 value of NMCI is larger than the R^2 of the increment of NMCI in each model, because NMCI, as a sum variable, is affected by fewer factors than the increment. Some factors ignored in the model assumption may affect the model, for example, some users browse micro blog every few days, they know and communicate the crisis when the discussion has subsided; in the later period of the crisis, some information having limited influence areas is ignored by our model. These factors result to the long-tail of the increment of NMCI and the slow increasing of NMCI while N(t) reaching a ceiling in the later period, showing in Figs. 2–4.

The good performance of determination coefficients means the diffusion of crisis information can be described by Logistic model, the growth curve of NMCI is S-shaped. But the curves vary with different release patterns. The curve of concentrated release seems normal S-shaped; the continuous release curve lacks of a gentle increasing stage because of the severity of the crisis; the curve of pulse release is a combination of several S-shaped curves.

In the Logistic model, if N_0, NMCI at time 0, increases, then parameter c will drop. The spread of crisis information will speed up, and the time that reach to micro blog capacity K will reduce, supposing r and K are constant. Therefore, increasing the initial individuals knowing the crisis information might reduce the dissemination cost and the time cost.

For some crisis events, information is released continuously. If the duration of information releasing is shortened, the length of dissemination time and the scope of dissemination are also shortened. For example, in the case of bullet train wreck in Wenzhou of China, if the duration reduces from day 0–6 to day 0–5, the dissemination ends one day ahead, and the scope of dissemination is narrowed down to 85.7% of its original scope.

In case of the crisis events of pulse released, every stage has various focuses of news stories which cause round and round of discussion. The number of stages in pulse affects the diffusion. In the case of Fujian Greetown Company in China extracting bear bile, crisis information is release at time 0, 5, 12–15, 18–23, if the releasing of crisis information is compressed in the first three time pieces, the scope of crisis diffusion is narrowed down to 25.9% of its original scope, the dissemination ends 13 day ahead.

6. Conclusion

The purpose of this article is to construct the diffusion models of crisis information in micro blog. In Section 3, we propose three information release patterns in micro blog according to the duration of crisis information released. Using the Logistic function (Bass et al., 1994; Murray, 1989; Verhulst, 1838), we derive the diffusion models for different release patterns, as shown in Eqs. (4), (5) and (15)–(18). We choose three cases occurred in China which have far-reaching influences. The R^2 values of NMCI are 0.9937, 0.9877, and 0.9695, respectively. The R^2 values of the increment of NMCI are 0.8035, 0.7218, and 0.7733, respectively. The diffusion models based on Logistic function and S-shaped diffusion curve (Bass et al., 1994; Egghe & Rao, 1992) is proved quite well in the three cases.

In the diffusion model, NMCI posted at the first day of the crisis (N_0) and the increment of NMCI (r) affect the diffusion process directly. The augmentation of N_0 and r will accelerate the speed and scope of the diffusion. For continuous and pulse release pattern, duration of release affects the diffusion, the longer of the duration, the longer of the diffusion time, the wider of the diffusion scope. As we know, public risk perception is high relative with the media agenda setting (Funkhouser, 1973), micro blog as a new popular media will affect public perception. From the view of public memory, impression and risk perception of micro blog users will last and be deep if they receive information continuously (Wei, Wang, & Zhao, 2012). Therefore, for some crises which caused public panic, such as SARS in 2003 and nuclear leak of Fukushima nuclear power plant in 2011, the government and the relevant crisis stricken organizations should take measure to weak public risk perception and crisis influence. For example, they should release information via micro blog accounts of government, enterprises, and celebrities as much as possible at the first time. There is always a hot debate in micro blog, so they should release relevant information as soon as possible to reduce time and influence of the debate. They should release what people want to know which can help to avoid the spread of guess and rumor about the crisis, and also can avoid the appearance of new news topics or scandal. By contrast, for some positive information in crisis, the government may want to strength risk perception and impression of public, they should take some measures to increase the release time.

The Internet communication circumstance is complicated and it offers challenges for informetric analysis (Egghe, 2000). The diffusion models based on Logistic function suitably explains the crisis information diffusion in Micro blog. Further research also can be done using Goffman's epidemic model (Goffman, 1966) to describe the diffusion model of NMCI, and test the differences of the two kinds of diffusion models by simulating on the complex network.

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