Building the Web Information Dissemination Model for Product Quality and Safety Based on Complex Network

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Abstract. Based on the model of infectious disease dissemination model, the Unaware Node was introduced and the node of infection was subdivided into the original node and the dissemination node of product quality and safety information. According to the actual communication process of news in the network, the information dissemination model was constructed and its influence on dissemination in complex network was studied; finally MATLAB was used to carry out the simulation experiment for the model, and the influence of different parameters about the model was analyzed.

1. Introduction

The product quality and safety information was as the research object, based on the analysis of propagating characteristics of product quality and safety information in the network, utilizing complex networks and infectious diseases model, to construct the product quality and safety information dissemination model and the simulation experiment was done for the influence of different parameters on the model. The results demonstrated that the model had a good predictive effect on the dissemination of product quality and safety information.

Researchers have applied the mean field for dissemination in a mathematical model to study information dissemination phenomenon of a crisis through a complex network. Leskovec (2007) studied some characteristics of Microsoft's MSN including user distribution, user's activity and user's time characteristic etc., and analyzed two different social networks active network and friends network in detail. Nardi (2004) presented two methods which are based on content analysis and user engagement respectively, and analyzed the theme of the blog and user engagement according to the content of the blog and user’s reviews; Christopher (2006) studied aggregation problem of blog community which is based on label; Chen et al. (2008) used the social network analysis method of blog, studied the blog recommendation problem; Flora et al. (2010) studied the detection problem about blogs’s novelty and redundancy; Java et al. (2007) analyzed Twitter users and geographic distribution characteristics of Weibo; Xie et al. (2012) conducted simulation studies on two competing dissemination topics based on the complex network. Based on the complex network theory, Jalili (2013) used the complex network to analyze the social power and public opinion formation and further conducted a simulation experiment with small-world and scale-free networks. Li et al. (2017) summarized the influence of social network user's behaviour on online information dissemination.
Although numerous researches have been conducted in the transmission of network information, the results are still far from satisfying. First, the depth and the mode of Web information dissemination need to be further analyzed. Additionally, the information dissemination rule in terms of the main channels, structure, path, and evolutionary cycles should be investigated as well. Second, existing researches focus more on traditional news websites. Research on information dissemination model for product quality and safety incidents are still rare. Finally, there are many empirical researches of the complex networks. However, the theory and the practice of the complex networks are not sufficiently related to each other. Particularly, some evolutionary mechanisms of the network model cannot reflect the true characteristics of a real network. This paper focuses on the dissemination model for product quality and safety information based on the complex network.

2. Construction of Product Quality and Safety Information Dissemination Model
The dissemination process of product quality and safety events on the Internet is described as follows:

1. When the news media B browses the product quality and safety event information released by media A, he become a insider from a non-insider, and the insider can choose to spread, also can choose not to spread;
2. When media B chooses to spread this news, its state changes from an unintentional state to a propagating news state, spreading the news to other media;
3. When the media B chooses not to spread, that is informed but not to spread the information;
4. Media B can also choose to change, to spread it after being modified on the basis of the original information and become a new Original Node.

The differences from the SIR model, the Node in the dissemination process of product quality and safety information were divided into four individual states: Unaware Node U, Original Node O, Disseminatable Node S and Keep Node K, as shown in Figure 1.

![State transition diagram](image)

**Figure 1. State transition diagram**

Based on the above state transition relationship, the following definitions were obtained:

- U (t), S (t), K (t), O (t) represent the proportion of Unaware node, Original Node, Disseminatable Node, Keep Node in total number of Node, that is U (t) + S (t) + K (t) + O (t) = 1.
- The total number of Node remains unchanged, that is, in the process of information dissemination, regardless of the node exit and the new node joining, the total number of Node maintains a certain number.
- Assume that the total number of Node is N.
- The trend of Unaware Node U change

Analysis of the situation of Unaware Node in the time from t to t + Δt :

During this period, the number of Unaware Node was increased by \( N^*[U(t + \Delta t) - U(t)] \), and the number of Original Node and Disseminatable Node which became Unaware Node was
\[ N^\ast(S(t) + O(t))((\alpha + \beta + \gamma)U(t) - \Delta t) \text{ in the time of } \Delta t, \text{ then the equation meeting the conditions can be obtained:} \]
\[ N^\ast[U(t + \Delta t) - U(t)] = -N^\ast(S(t) + O(t))((\alpha + \beta + \gamma)U(t) - \Delta t) \tag{1} \]

Both sides were divided by \( \Delta t \), and then the above equation can be simplified as:
\[ \frac{dU(t)}{dt} = -(\alpha + \beta + \gamma)U(t)(S(t) + O(t)) \tag{2} \]

(2) The trend of Original Node I change

In the time of \( \Delta t \), the number of Original Node was increased by \( N^\ast[U(t + \Delta t) - O(t)] \); the number of Unaware Node which became Original Node was \( N^\ast(S(t) + O(t))\beta U(t)\Delta t \), then the differential equation can be obtained as follows:
\[ \frac{dO(t)}{dt} = \beta U(t)(S(t) + O(t)) \tag{3} \]

(3) The trend of Disseminatable Node S change

During this period, the number of Disseminatable Node was increased by \( N^\ast[S(t + \Delta t) - S(t)] \), the number of Unaware Node which became Disseminatable Node was \( N^\ast(S(t) + O(t))\alpha U(t)\Delta t \); the number of Keep Node which became Disseminatable Node was \( N^\ast S(t)\delta K(t)\Delta t \), then the differential equation can be obtained as follows:
\[ \frac{dS(t)}{dt} = \alpha U(t)(S(t) + O(t)) + \delta K(t)S(t) \tag{4} \]

(4) Variation trend of Keep Node K

Within \( \Delta t \) time, the increased quantities of Keep Node is \( N^\ast[K(t + \Delta t) - K(t)] \), quantities of the Unaware Node that changed into Keep Node is \( N^\ast(S(t) + O(t))\gamma U(t)\Delta t \), quantities of Keep Node changed to propagate node is \( N^\ast S(t)\gamma K(t)\Delta t \), so differential equation may be obtained as:
\[ \frac{dK(t)}{dt} = \gamma U(t)(S(t) + O(t)) - \delta K(t)S(t) \tag{5} \]

Simultaneous above differential equation we may obtain differential equation set as shown formula (6).

Complex network is different from common network, its node and conjunctive probability of node itself could not be able to meet uniformly distribution, in view of among Original Node, Disseminatable Node and Unaware Node uniformly distribution cannot be always met. Because considering of topological property of internet, above differential equation shall be translated to the following formula (7).

In consideration of node conjunctive probability issue of complex network, \( P(t) \) was introduced to show conjunctive probability of Original Node, Disseminatable Node and Unaware Node at t moment, above differential equation can be translated to:

\[
\begin{align*}
\frac{dU(t)}{dt} &= -(\alpha + \beta + \gamma)U(t)(S(t) + O(t)) \\
\frac{dO(t)}{dt} &= \beta U(t)(S(t) + O(t)) \\
\frac{dS(t)}{dt} &= \alpha U(t)(S(t) + O(t)) + \delta K(t)S(t) \\
\frac{dK(t)}{dt} &= \gamma U(t)(S(t) + O(t)) - \delta K(t)S(t)
\end{align*}
\tag{6}
\]
\[
\begin{align*}
\frac{dU_i(t)}{dt} &= -(\alpha + \beta + \gamma)U_i(t)(S_i(t) + O_i(t)) \\
\frac{dO_i(t)}{dt} &= \beta U_i(t)(S_i(t) + O_i(t)) \\
\frac{dS_i(t)}{dt} &= \alpha U_i(t)(S_i(t) + O_i(t)) + \delta K_i(t)S_i(t) \\
\frac{dK_i(t)}{dt} &= \gamma U_i(t)(S_i(t) + O_i(t)) - \delta K_i(t)S_i(t)
\end{align*}
\] (7)

\[
\begin{align*}
\frac{dU_i(t)}{dt} &= -K(\alpha + \beta + \gamma)U_i(t)(S_i(t) + O_i(t))P_i(t) \\
\frac{dO_i(t)}{dt} &= K \beta U_i(t)(S_i(t) + O_i(t))P_i(t) \\
\frac{dS_i(t)}{dt} &= K \alpha U_i(t)(S_i(t) + O_i(t))P_i(t) + \delta K_i(t)S_i(t) \\
\frac{dK_i(t)}{dt} &= K \gamma U_i(t)(S_i(t) + O_i(t))P_i(t) - \delta K_i(t)S_i(t)
\end{align*}
\] (8)

Above equation not only portrays time change relations of density among Original Node, Disseminatable Node, and Unaware Node and informed but not willing to propagate, but also reflected network topology structure's influence on dissemination process.

3. Simulation Experiment

3.1. Network Topology Structure's Influence on Dissemination

By using of MATLAB, firstly conduct experiment of primary node degree and degree distribution’s influence on dissemination based on existed model.

(1) Take \( K = 20, 350 \). \( \alpha = 0.4, \beta = 0.1, \gamma = 0.1, \delta = 0.1 \), time steps \( T = 80 \), iteration averaging 80 times to get simulation result of model.

![Figure 2. K value’s influence on model](image)
3.2. Model Parameter’s Influence ON Dissemination

(1) Dereferencing of $\alpha$, $\beta$, $\gamma$’s influence on dissemination

Take $K=4$, $\delta=0.1$ remain constant, $\alpha=0.2$, 0.6, $\beta=0.1$, $\gamma=0.1$, $T=80$.

Take $K=4$, $\delta=0.1$ remains constant, $\alpha=0.4$, $\beta=0.1$, 0.5, $\gamma=0.1$; $T=80$. 
Figure 5. $\beta$ ’s influence on model

Compared with Figure 4 and Figure 5 we can see, dereferencing of $\alpha$ and $\beta$ mainly affect ratio of nodes in steady state, the bigger the $\alpha$ value, the higher the ratio of Disseminatable Node, corresponding ratio of Original Node is lower, but when $\beta$ value is bigger, ratio of Original Node is higher, relevant ratio of Disseminatable Node is lower. Dereferencing of $\alpha$ and $\beta$ also has subtle influence on transmission speed, the bigger its dereferencing, relevant transmission speed shall be faster, yet its increasing extent is not obvious.

Take $K=4$, $\delta=0.1$ remains constant, $\alpha=0.4$, $\beta=0.1$, $\gamma=0.1, 0.5$; $T=80$. The result is shown in Figure 6.

Figure 6. $\gamma$ ’s influence on model
We can see from Figure 6 comparison that dereferencing of $\gamma$ mainly affect value of informed but no dissemination node reached the maximum moment, the bigger the dereferencing, the bigger the maximum ratio of informed but no dissemination node, on the contrary, the smaller the dereferencing, the smaller the maximum the ratio of informed but no dissemination node.

(2) Dereferencing of $\delta$ ’s influence on dissemination

Take $K=4$, $\alpha=0.4$, $\beta=0.1$, $\gamma=0.1$, $\delta=0.1, 0.5$, $T=80$. The result is shown in Figure 7.

We can see from Figure 7 that dereferencing of $\delta$ ’s influence on dissemination basically is negligible, basically no influence on development trend and ratio it occupies total node numbers in dimensionality state of Original Node and Dissemination News Node, it has only slight influence on Keep Node’s change trend and ratio.

4. Conclusion
Product quality safety information spreads fast and has lots of impact, utilizing product quality safety information transmission model established based on complex network has certain accuracy on forecasting product quality safety event's transmission trend on Internet. But there is some difficulties exist in accurately forecasting original node numbers and transmission node numbers of different transmission time interval, because selection of model parameter is established on a large number of product quality safety event's statistical regularity, difference of different types of product quality safety event's model parameter is bigger; Besides, parameter of this text selected data cardinality scale is ordinary and not sorted out as to event type, this is also a factor affect trend prediction accuracy.

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6. References
[1] Christopher H. Brooks, Nancy Montanez. Improved annotation of the Blogosphere via autotagging and hierarchical clustering. Proceedings of the 15th international conference on World Wide Web (WWW2006). Edinburgh, Scotland, 2006: 624 - 632.
[2] Flora S. Tsai, KapLuk Chan. Redundancy and novelty mining in the business blogosphere. Learning Organization, 2010, 17 (6): 490- 499.
[3] Jalili M. Social power and opinion formation in complex networks. Physica A: Statistical Mechanics and its Applications, 2013, 392(4):959-966.

[4] Java, X. Song, T. Finin, and B. Tseng. Why We Twitter: Understanding microblog usage and communities. In Proceedings of the 9th Web KDD and 1st SNA-KDD 2007 Workshop on Web Mining and Social Network Analysis, New York, NY, USA, 2007: 56–65.

[5] Leskovec J and Horvitz E. Worldwide buzz: Planetary-scale views on an instant-messaging network. Technical report, Microsoft Research, June 2007.

[6] Li J, Wu L, Qi J, Yan Q. Research on Information Dissemination in Online Social Network Based on Human Dynamics. Journal of Electronics & Information Technology, 2017, 39(4):785-794.

[7] Nardi.B.A. Why we blog. Communications of the ACM, 2004, 47 (12): 41- 46.

[8] Xie M. S., JiaZ.. Simulating the Spreading of Two Competing Public Opinion Information on Complex Network. Applied Mathematics, 2012, 3:1074-1078.