Advances in Engineering Research, volume 123
2nd International Conference on Materials Science, Machinery and Energy Engineering (MSMEE 2017)

Dynamic Society's Information Networks Based on the Complex Network Theory and the Dynamics of Infectious Disease: Part1. Model Theory

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Abstract: In this paper, the society's information network simulation model is established to analyze how information flow, how public interest and opinion can be changed through the information networks, how information value and other parameters can be used to spread information and influence public opinion, and predict the communication situation in the future.

Keywords: complex network theory dynamics of infectious diseases normal distribution

1. Introduction

The insufficiency of analyzing the possible influence of information flow based on society's information networks has been discussed during last two decades. Society's information networks are considered valuable resources that are specific and inimitable and that helps the ICM to understand the evolution of the methodology, purpose, and functionality of society's networks. So it is important and necessary to analyze the society's information flow networks.

Actually, the Society's Information Networks can be established in different periods to address the problems to some extent, especially for analyzing the relationship between the flows of information to inherent value of information. What is the evolution of Society's Information Networks in different periods, how to evaluate the influence of information networks on public interest and opinion and how to predict the information communication based on the passed data. All these will be discussed and solved in this paper.

2. Symbols and Descriptions

Table 1 Symbols and Descriptions

Symbols	Descriptions
Te	The total existing days after one piece of information is produced
Pr	The probability that a person spread the right information that he got
Pw	The probability that a person spread the wrong information that he got
P1	If a spreading node gets touch with a not-infected node, the not-infected node will be a spreading node with the probability of p1.

3. Fundamental Assumptions

The accuracy of our model relies on certain key simplifying assumptions. These assumptions are listed below:

1. The modes that people can use to get information mainly depend on the information transmission modes and the relationship networks among people.
2. The information which can flow including both the right information and the false information.
3. Sexual distinction can be ignored in the dynamic information flow process.
4. The discrepancy of sexual won't be specially discussed to simplify the model. Actually, in the information flow model, the man and woman both have their own information choosing factors.
5. There are not serious destructions to the main information transmission modes.

4. Model theory based on the complex network

4.1 The theory for information flow networks

In the information flow network[1], every person is seen as a node with many parameters.

Based on the spreading law of information in relationship networks, we define the nodes in information flow networks into three kinds: the spreading nodes, the not-infected nodes and the immune nodes.

The spreading nodes mean that nodes get the information from his friends and he get the ability to spread that information; the not-infected nodes mean that nodes have not get the information from his friends but they have the probability to touch the information that means they can be infected; the immune nodes mean that nodes have get the information from his friends but he do not have the ability to spread the information to others.

Changing among the spreading, not-infected, and immune situations of the nodes not only depends on the situation of his self-situation but also is related to the situations of his friends, thus we define the following spreading laws:

1. If a spreading node gets touch with a not-infected node, the not-infected node will be a spreading node with the probability of p_1.
2. If a spreading node gets touch with an immune node, the spreading node will become an immune node with the probability of p_2.
3. The spreading nodes will not spreading forever, it will become immune nodes with the speed of stopping spread valued v, and it do not need to get touch with other nodes.

4.2 The dynamic process of information flow networks

4.2.1 The information flow network based on the person's relationship network [2]

The information flow network changing over time, at the beginning, the ways that people can get information are mainly the relationship networks that he have. The relationship networks including friends, family, colleagues, strangers and so on.

With the advancement of the new technique, the ways that people can use to get information will change over time. That means the ways that people can get information will change from just rely on personal relationships to rely on the information transmission modes also.

The information flow network when take the information transmission modes into account can be shown as follows:

The Opinion leaders are those who can get information more easily and quickly and they will transfer information to the people around them. That is to say they can affect a number of people in a region, the influence could even be very big.

Based on the analyzation above, we can get the conclusion that the relationships among people become more close together because of the influence of the better information transmission modes.

We can also get the infer that with the advancement of the techniques, the influence of information will change from just affect the local regions to affect a larger region and even all around the world based on the information flow network above.

4.2.2 The information flow model

With the change of time, the situation among different nodes will change as following:

$$Nn \to Ns \to Ni$$

The details of the situation changing are as follows:

(1) $Nn \to Ns$

We can know that $P_i s^j = 1 - P_i i^j$, and in the formula:

$$P_{ii}^j = \left(1 - \Delta t P_1\right)^g \tag{1}$$

Explanation: g=g(t), which means at the t moment, the number of J's friends who have the ability to spread.

We assumed that J node has k sides, and g is a random variable which obeys the following binomial distribution:

$$\prod(g,t)=\binom{k}{g}w(k,t)^{g}\left(1-w(k,t)\right)^{k-g} \tag{2}$$

In formula (2), w(k, t) means that at the t moment the probability that connecting from nodes with k sides of not-infected sides to a spreading node. W(k, t) can be written as follows:

$$w(k,t)=\sum_{k'}p(k'|k)\,p(s_{k'}|i_k)\approx\sum_{k'}p'(k'|k)q'(k',t) \tag{3}$$

Explanation:
p(k’|k) is the related function for degree, which means the conditional probability that a node with the degree of k connects with a node with the degree of k’;
$p(s_{k'}|i_k)$ means the probability that a node with k’ edge is at the spreading situations at the condition that it connects to a not-infected node with the degree of k.
q’(k’,t)means at the t moment, the density of the spreading nodes with the degree of k’.
Thus, we can get the value of $\overline{P_{ii}}$(k,t) as follows:

$$\overline{P_{ii}}(k,t)=\sum_{g}^{k}\binom{k}{g}(1-p_1\Delta t)^{g}w(k,t)^{g}\times\left(1-w(k,t)\right)^{k-g}=(1-p_1\Delta tw(k,t)^{k} \tag{4}$$

When we take the formula (3) to the above formula, we can get that:

$$\overline{P_{ii}}(k,t)=\left(1-p_1\Delta t\sum_{k'}p(k'|k)q'(k',t')\right)^{k} \tag{5}$$

(2) $Ns\rightarrow Ni$
We can know:

$$P_{ss}^{j}=\left(1-\Delta tP_2\right)^{g}\left(1-v\Delta t\right) \tag{6}$$

Thus, we can get the formula to describe the average transmission probability formula from the [t,t+Δt] period as follows:

$$\overline{p}_{ss}(k,t)=(1-\Delta tp_2\sum_{k'}p(k'|k)q'(k',t)^{k} \tag{7}$$

So we can get the transmission probability that a node changing from the spreading stage to immune stage is:

$$\overline{p_{s1}}(k,t)=1-\overline{p_{ss}}(k,t) \tag{8}$$

And we can easily know that:

$$L(k,t)+S(k,t)+R(k,t)=N(k,t) \tag{9}$$

Thus, the changing of the total number of not-infected nodes with the degree of k in the network in the [t, t+Δt] period is as follows:

$$\begin{aligned}I(k,t+\Delta t)&=I(k,t)-I(k,t)(1-\overline{p_{ii}}(k,t))\\&=I(k,t)-I(k,t)\times[1-(1-p_1\Delta t\sum_{k'}p^{s}(k',t)\,p(k'|k)^{k})]\end{aligned} \tag{10}$$

Similarly, we can get the changing of the total number of the spreading and immune nodes with the degree of k in the [t, t+Δt] period as the following formula:

$$\begin{aligned}S(k,t+\Delta t)&=S(k,t)+I(k,t)\left(1-\overline{p}_{ii}(k,t)\right)-S(k,t)(1-\overline{p_{ss}}(k,t)\\&=S(k,t)+I(k,t)\times[1-(1-p_1\Delta t\times\sum_{k'}\rho^{s}(k't)\,p(k'|k))^{k}]-S(k,t)[1-(1-p_2\\&\quad-\sum_{k'}\rho^{r}k',tp(k'|k))^{k}(1-v\Delta t)\end{aligned} \tag{11}$$

$$R(k,t+\Delta t)=R(k,t)+S(k,t)\left(1-\overline{p}_{ss}(k,t)\right) \tag{12}$$

Based on the formula (9) and (10), we can get the following formula:

$$\frac{I(k,t+\Delta t)-I(k,t)}{N(k,t)\Delta t}=-\frac{I(k,t)}{N(k,t)\Delta t}[1-(1-p_1\Delta t\times\sum_{k'}\rho^s(k',t)\,p(k'|k))^k] \quad (13)$$

When Δt→0, we can get the Taylor expansion of the right of the (10) formula as follows:

$$\frac{\partial\rho^i(k,t)}{\partial t}=-kp_1\rho^i(k,t)\sum_{k'}\rho^s(k',t)\,p(k'|k)^k] \quad (14)$$

Similarly, based on the (8) formula, we can get the following formula:

$$\frac{\partial\rho^s(k,t)}{\partial t}=kp_1\rho^i(k,t)\sum_{k'}\rho^s(k',t)\,p(k'|k)-kp_2\rho^s(k,t)\sum_{k'}\rho^r(k',t)\,p(k'|k)-v\rho^s(k,t) \quad (15)$$

Based on the (9) formula, we can get a formula as follows:

$$\frac{\partial\rho^r(k,t)}{\partial t}=kp_2\rho^s(k,t)\sum_{k'}\rho^r(k',t)\,p(k'|k) \quad (15)$$

Based on formula (14), (15) and (16), we can get the dynamical evolution equations of the information flows to describe the changing of the density of spreading nodes, not-infected nodes and the immune nodes with the changing of time. The procedure is affected by the transmission theory and the network topology structure.

4.2.3 The degree correlation model in networks

The degree correlation in networks can be used to describe the difference among different network structures.

Based on the reference [5], the degree correlation in information flow networks is generally less than zero (i.e. the degree correlation in the Renren is -0.0036).

Thus the degree correlation function in the formula (3) can be written as follows:

$$P(k'|k)=\frac{k'P(k')}{\bar{k}} \quad (17)$$

Explanation: P(k') is the degree distribution formula and $\bar{k}$ is the average degree of nodes in the network.

5. Conclusions

Based on the theory mentioned above, the Dynamic Society's Information Network model based on the Complex network Theory and the Dynamics of Infectious Disease was made. In section 2, the model testing will be put forward.

6. References

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