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Research on Delay Characteristics of Information in Scale-free Networks Based on Multi-Agent Simulation

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Abstract

It is always assumed that the information spreads in the regular networks or completely random networks and utilizes third-order delay to express information delay process in the studies of system dynamic. The information delay is also a process of information diffusion in networks, in recent years the studies of complex networks have revealed that information diffusion network structure is not a regular networks or a completely random network. This research combines the theory of complex networks with multi-agent modelling technology basis on the computer experimental methods, establishes a multi-agent simulation model of information diffusion in scale-free network environment, simulates the process of information diffusion and analyses delay characteristics of information diffusion in scale-free network environment. The results show that not all of the diffusion processes in scale-free network can simulated by third-order delay structure, when the value of M is relatively great we should consider using fourth- order delay structure to simulate the diffusion behaviours; In addition, the greater the value of the scale-free networks parameter *M* is, the shorter the corresponding average delay time of the delay function is.

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Keywords: Multi-agent simulation; System dynamics; Delay function; Information Diffusion

1. Introduction

System dynamics believes that the complex behaviour of the system is the common-effect of feedbacks and delays. For a feedback system, delay is the key for the feedback system to produce the dynamic behaviour, which has a significant impact on the characteristics of nature and behaviour of feedback system structure [1]. The delay in the system dynamics model is divided into fixed delay and exponential delay, fixed delay can be used as exponential delay with infinite order. Fixed delay is generally better to understand and relatively easy to determine, however, the order of delay links and the average delay time of the exponential delay often requires combining the use of statistical methods with the experience of the researchers to determine.

Due to the delay plays a critical role in the model, setting the order of delay links and the average delay time of the exponential delay correctly or not becomes the key issue to ensure the correctness of the model. Feedback phenomena abound in real complex feedback systems, which comprise two categories, the logistics delay and the information delay. Logistics delay is the time for the materials spent in the transfer process from one location to

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another, as the delay between ordering and delivery; Information delay includes the information propagation delay, the information processing delay and the delay among reactions[2]. In the course of studying the specific issues, logistics delay often has better controllability and the data is readily available; Nowadays, information technology and means of communication are well – developed, which leads to the process of delay can hardly be controlled by human, the determination of information delay often by virtue of statistical hypothesis analysis on the basis of experience. In statistical hypotheses the network structure is often assumed to be the regular network or completely random network.

In fact, the system dynamics model is based on differential equations, the exponential delay process is also expressed by one or a plurality of differential equations, the network structure is difficult to combine with the differential equation. Thus in order to express the impact of the network structure in a system dynamics model, the most direct way is to adjust the order of delay links and the average delay time of the delay process.

In recent years, studies on complex networks indicate that a common information network is not a regular network or completely random network with simple structure, but a complex network with uneven structure, network topology structure has a major impact on the process of information delay. The research will choose information diffusion in scale-free network (From the perspective of system dynamics this process is an information delay) as research subject to analyse the impact of network topology structure on characteristics of information delay process.

Since the difficulty of collecting actual data, the research is on the basis of computer experimental methods, which combines the theory of complex networks with multi-agent modelling technology, establishes a multi-agent simulation model of information diffusion in scale-free network environment, simulates the process of information diffusion and analyses delay characteristics of information diffusion in scale-free network environment.

2. Literature Review

Fig. 1 is the smoothing function curves with initial input of step function STEP (100, 0.1), delay time for 30.

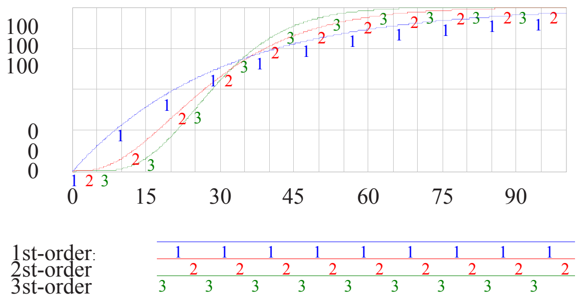

Fig. 1 Smoothing function curves

In addition to the 1st-order smoothing function, the other higher order smoothing function curves are S-shaped curves, this characteristic is very similar to the feature of 1st-order S-shaped growth system[3], "diffusion" related phenomena, such as the diffusion of new products, the transmission of infectious diseases, the spread of rumours, and other characteristics have very similar characteristics. For example, the new products diffusion process is the growth of new products in the market, can be also seen as the delay process between products appearance and customer awareness. If the object of the system dynamics does not require in-depth study of the diffusion process, we can use the exponential function represents the new products diffusion process.

The majority of system dynamics models, for example, in the fields as logistics supply chain [4], production management [5-7], ecosystem construction concern the delay process [8]. Many of the studies, the parameters and order of delay process involved were always subjective or only brushed lightly. The main theoretical researchers study on the parameters and order of delay process of the country are Maokang Su et al.

The researches of Maokang Su [9] show that the impulse response of k-order exponential delay is

$$O(t) = L_1(0)[(\frac{k}{D})^k \frac{t^{k-1}}{(k-1)!} e^{-kt/D}] \tag{1}$$

Where k is a positive integer represents the order of delay, D represents the average delay time, $L_1(0)$ represents pulse intensity.

If we set

$$f(t) = (\frac{k}{D})^k \frac{t^{k-1}}{(k-1)!} e^{-kt/D}, \quad t \geq 0 \tag{2}$$

Obviously, $f(t)$ is actually represents the unit impulse response of the delay process. It is similar to the form of the probability density function of ERLANG distribution, in fact, $f(t)$ is the probability density function of ERLANG distribution with parameters k and D. Eq. (2) indicates that the time for the unit substance to pass through delay process can be seen as a continuous random variable, it is subject to ERLANG distribution with parameters k and D.

The step function is the function integral of the pulse, can be proved theoretically, if the initial condition to zero, the step response of the delay process with the height of H equals to the integral of the impulse response with the intensity of H. From the Eq. (1), the expression of the step response with the delay process height H can be deduced as follows.

$$O(t) = H \int_0^t (\frac{k}{D})^k \frac{\tau^{k-1}}{(k-1)!} e^{-k\tau/D} d\tau \tag{3}$$

Where H represents step height, k is an integer represents the delay order, DEL represents the average delay time.

On the other hand, the studies on delay process reflects in delay function expression and parameters assessment, Tao Chen [10], Maokang Su [11] and Weiyuan Tu [12] carried out researches in this area.

For the delay function expression and parameters assessment, Maokang Su proposed estimation method based on ERLANG distribution, econometric methods based on multiple regression and ordinary least squares method and other methods, which have some implications on our research[13].

Until recent years, scientists have discovered a large number of real networks are neither regular network nor random network, but has the different statistical characteristics from the former two networks and scientists call these networks complex networks. Complex network has many different statistical characteristics from regular networks and random networks, of which the most important is the small-world effect [14] and scale-free property [15-16].

So far, the network topology models for studies mainly are regular networks, random networks, small-world networks and scale-free networks.

There are already some applications using multi-agent simulation in the field of information diffusion. Xiaoguang Gong and Zhicheng Li established a new Product Diffusion simulation model based on multi-agent and implemented the model [17], which was well able to simulate the diffusion process of new product. Maienhofer and Finholt established a multi-agent simulation model to explore the optimal goal of innovation diffusion [18].

Berger[19] proposed a multi-agent simulation model to evaluate the impact of a combination of strategies on innovation diffusion and the use of resources, the results show that the multi-agent space modeling is a better way to understand the process of innovation diffusion and the use of managing resources. Neri [20] utilized multi-agent technology to analyze market behavior under certain information diffusion conditions and obtained relatively good simulation results. Xiaofei Meng et al utilized multi-agent model to simulate under network environment the knowledge diffusion process and analyzed the impact of different variables on knowledge diffusion [21].

Hongzhong Deng et al adopted an approach based on multi-agent to establish a multi-agent simulation model for the spread of the disease and study the disease infection processes and rules with different parameters [22]. Xiaoguang Gong and Renbin Xiao designed and implemented a multi-agent simulation model of epidemic news spread to explore the impact of personal number of social ties, trust degree on epidemic news, the epidemic diffusion capacity and dissemination network structure on epidemic news spread [23]. Tongyang Yu et al utilized the multi-agent modeling techniques to construct a multi-agent model of gaming products diffusion on the basis of neighborhood relationship network to study the impact of advertising effect and word-of-mouth effect on gaming products diffusion [24].

3. Design of Multi-agent simulation model based on scale-free networks

3.1. Analysis of Multi-agent simulation model

Through the analysis of the problem description to abstract the actual system, and divide the diffusion model of the information into two types of agent: audiences agent and circumstance agent. Audiences agents have exactly the same properties, for example, they are subject to the effect of advertising and word-of-mouth and have the same state set etc.; Circumstance agent is a special agent providing space for the interaction activities of audiences agent. The architecture design of multi-agent model is shown in Fig. 2.

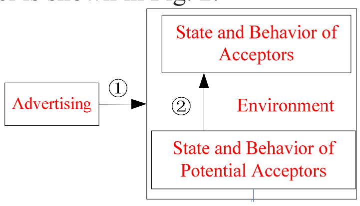

Fig. 2 The architecture framework Fig. of the model

In Fig. 2, Arrow ① indicates the advertising effect, that is, the software products advertisers run ads to audiences agents to make the audiences familiar with the information of new products and to promote the transformation of potential information acceptors into information acceptors. Arrow ② indicates the word-of-mouth effect, that is, the effect of word-of-mouth of the existing information acceptors on the potential information acceptors makes the potential information acceptors to the information acceptors similarly.

3.2. Diffusion process simulation flow analysis

According to the description and assumptions of the issue, combined with the characteristics of multi-agent modeling technology, analyze the simulation process of diffusion of information, as shown in Fig. 3.

The simulation process of diffusion of information is as follows: Before the start of the simulation experiment, firstly, build circumstance agent and construct a scale-free network at which the diffusion of information is located（①）; Then create audiences agent, simulate part of audiences agent are transformed into information acceptors agents because of the effect of advertising when the simulation experiment starts（②）; According to whether they are already familiar with the information of the new products, audiences agents can be divided into two parts: the information acceptors and the potential information acceptors（③）; After the start of the diffusion process, information acceptors agents will send recommended messages to the connected agents at a certain frequency（④，this process can be seen as the simulation of the word-of-mouth effect）; For potential information acceptors agents, if the recommended messages from other agents is received they will accept the messages with a certain probability (its value is fixed), so then they transform themselves from the potential information acceptors into the information acceptors, otherwise, keep their own state unchanged（⑤⑥⑦）; During the diffusion process, if the time of the simulation experiment has run out, stop sending the recommended messages and collect relevant diffusion information to be analyzed, the simulation experiment has finished.（⑧）.

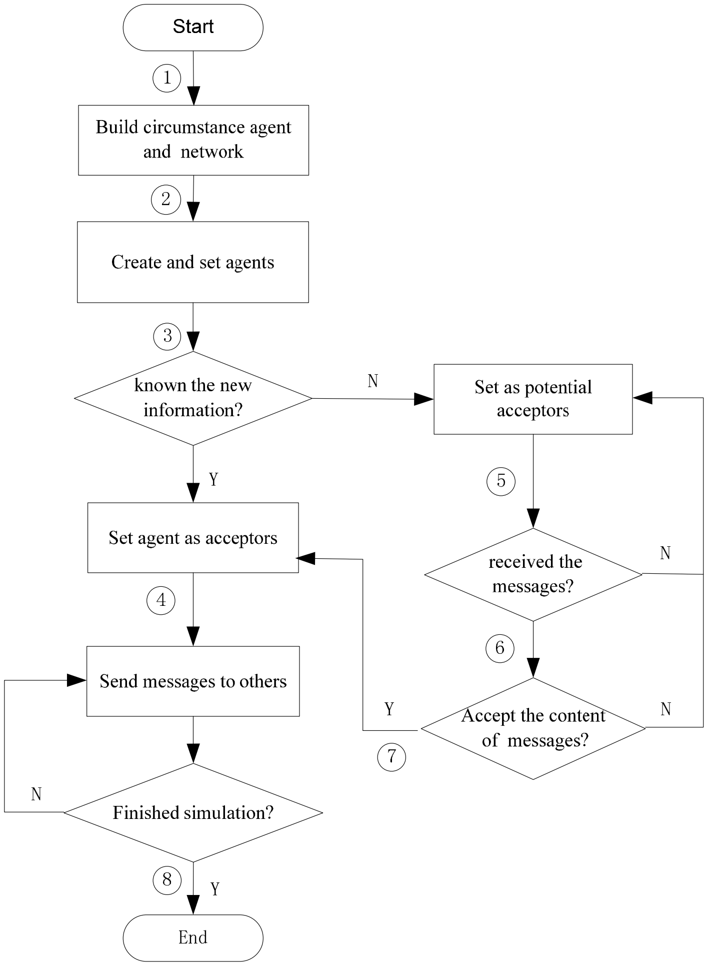

Fig. 3 the simulation flowchart of diffusion of information

3.3. Multi-agent model design

In this paper, a powerful hybrid modelling tool AnyLogic ® is adopted to create the multi-agent simulation model of diffusion of information based on scale-free network (hereinafter referred to as "scale-free agent model"). Based on multi-agent modelling analysis, the model designs two agent classes: circumstance agent class and audiences agent class. Among them the instance of audiences agent has two states: the information acceptors and the potential information acceptors. The organizational structure between circumstance agent class and audiences agent class as shown in Fig. 4.

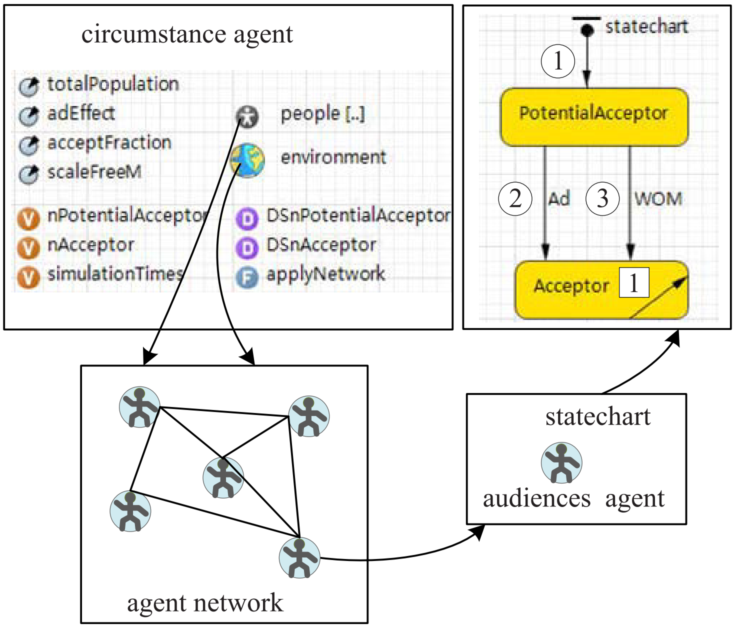

Fig. 4 the organization chart of two types of agent

1） circumstance agent

The circumstance agent class is a special class which only generates one instance when "scale-free agent model" is operated. The role of the instance in the simulation process include: control the operation of the simulation model, provide space for activities of audiences agents, define and set the environment object, define various global variables and parameters etc. . The specific attributes of circumstance agent class described in Table 1.

Table 1. Node importance ranking of the top 5 places

attribute	Data type	initial	description
totalPopulation	int	10.000	Number of audiences agents
adEffect	double	0.011	Advertising effect size
acceptFraction	double	0.015	Word-of-mouth effect size
scaleFreeM	int	10	Scale-free network parameters
nPotentialAcceptor	int	0	Number of potential information acceptors
nAcceptor	int	0	Number of information acceptors
DSnPotentialAcceptor	Set	{0}	Number set of potential information acceptors
DSnAcceptor	Set	{0}	Number set of information acceptors
simulationTimes	int	0	Simulation run times
applyNetwork	void	-	Generate scale-free network function
people	Person	-	Object set of audiences agent class
environment	Environment	-	Environment object

（1） advertising effect and word-of-mouth effect

adEffect is the size of the advertising effect, namely, the possibility of potential information acceptors who receive the ads accept the advertising content(Familiar with the information of new software products). In this model, the number of ads and the possibility of potential information acceptors are familiar with the information of new products due to the impact of advertising are the same in each period.

The advertising effect plays a major role only in the early stages of the product launch. As time goes by, the main driving force of the diffusion of the product information is transferred to the word-of-mouth effect of product information acceptors. The word-of-mouth effect depends on the interaction among the agents, when information acceptors send recommended messages of the new product to potential information acceptors, the possibility of the potential information acceptors accept the messages (Familiar with the information of new software products) is *acceptFraction*, which means there is a 1.5% chance to make the potential information acceptors transformed into information acceptors. Obviously, in a scale-free network the agents with greater degree values are more important, because they send the messages more frequently, thus they can persuade more potential information acceptors to be transformed into information acceptors.

（2）Environment agent

The communication among the agents can only occur in a certain environment, the environment object environment is used to define the common attributes of a group of agents. The environment defines the layout type, scope of activities, and network type of the space where the agents are located.

（3）Object set of audiences agent class

Audiences agent is the basic elements of the "scale-free agent model", each agent are given a set of rules which the interaction among the agents must observe. These interactive behaviors will produce the overall behavior of the entire system. This model abstracts the audiences agent with Person class, which is called audiences agent class. Since audiences is homogeneous, each audiences agent has the same attributes and behaviors, therefore, each agent is an instance of the Person class included in the object set of audiences agent class namely people.

（4）Scale-free network

This article assumes that information diffuse in scale-free networks, the classic scale-free network model is the BA model proposed by Barabasi and Albert [25], this model emphasizes two important characteristics of the actual network: Unlimited growth characteristics (growth) and preferential attachment characteristics (preferential attachment), the BA scale-free network model construct the algorithm as follows.

First, consider adding a new node to a network having m_0 nodes, which is connected to the m ($m \leq m_0$) nodes of the original network according to the preferential attachment mechanism. Repeat the above steps until the total number of nodes of the network achieve the desired.

The probability of a new node is connected to an already existing node i is Π_i , the degree of node i is k_i and the degree of node j is k_j, Π_i , k_i and k_j satisfy the following relations,

$$\Pi_i = \frac{k_i}{\sum_j k_j} \tag{4}$$

The role of the *applyNetwork* function is to generate the BA scale-free network where the agents are located according to the above algorithm, it has a parameter namely *scaleFreeM* indicates the number of the nodes of the original network (that is m), in this model $m = m_0$.

Audiences agents are the major participants in diffusion of information, given the certain rules and behaviors they can simulate the behavior of the diffusion of new software products in the actual network. Audiences agent interactions depend on the environment they are located, so the audiences agents must be encapsulated in the circumstance agent.

In the process of information diffusion, audiences agent has two states: *PotentialAcceptor* (potential information acceptors) and Acceptor (information acceptors), as shown in the upper right part of Fig. 4. *statechart* is the entry point of the state-chart, ①②③represent the paths of the state transitions, is the activities of the agents, which means the oral communication behavior among the agents.

At the beginning of the simulation experiment all the audiences agents are potential information acceptors, the path of state transition is ①.When the simulation experiment is being conducted, since the impact of advertising there will be a certain percentage of potential information acceptors are transformed into information acceptors, the path of state transition is ②. As the simulation progresses, the information acceptors send messages and spread the information of products to the connected agents in accordance with certain rules, as activity shown. If the agent receiving the information is potential information acceptor, it will accept the contents of the message according to a certain probability to make itself transformed into information acceptors, this is the so-called word-of-mouth effect, as ③shown.

3.4. Simulation results analysis

In the simulation experiment, the scope of activities of the multi-agent is a 500*300 rectangular space; represents an agent, there are 10000 agents in total; the simulation time is 100 (days). The interrelated agents connected with a straight line, the agents and the connection among themselves constitute a scale-free network. In the course of the simulation experiment the state changes of the agents shown in Fig. 5.

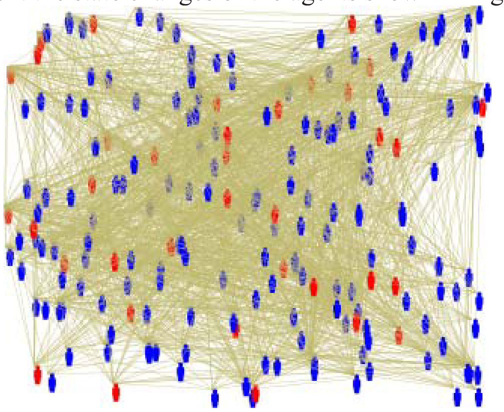

Fig. 5 the state changes of the agents in the course of "scale-free agent model" operated

When the agent is excessive, the network structure shown in Fig. 5 will become blurred, in order to clearly show the changes of the network structure and agent state when the experiment is running, Fig. 5 only selects 200 agents, and marked agents in different state with different colors (Blue indicates the agents in the state of potential information acceptors, red indicates the agents in the state of potential information acceptors).

After several times of simulation experiments, the variation of the number of information acceptors with different parameters of scale-free network can be shown in Fig. 6.

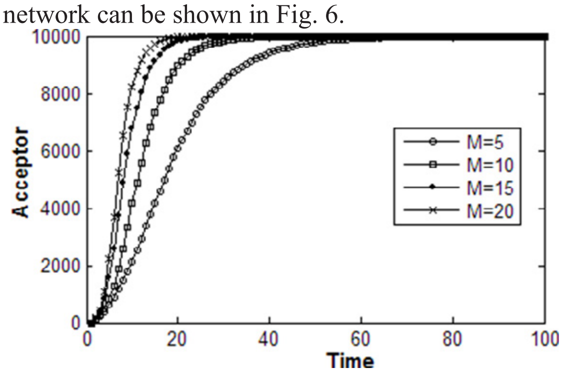

Fig.6 the impact of parameters of scale-free network on diffusion process

In Fig. 6 *M* represents the parameter of scale-free network *scaleFreeM*. The result shows that the quantity curve of the information acceptors is a relatively regular S-shaped curve, during a period after the simulation experiment start the number of the information acceptors first increases slowly, after that accelerates to a certain height, and then the rising speed gradually slows down and tends to smooth, eventually all the agents will become information acceptors.

Because the degree of the node in the scale-free network has a strong heterogeneity, the small numbers of nodes occupy the most of the network's edges. We call such nodes "big node". Big node occupies a high position in the network because it has a great impact on the nature of the network. Fig. 7 covers statistics on the relation between the value of M namely the parameter of scale-free network and the number of the big nodes.

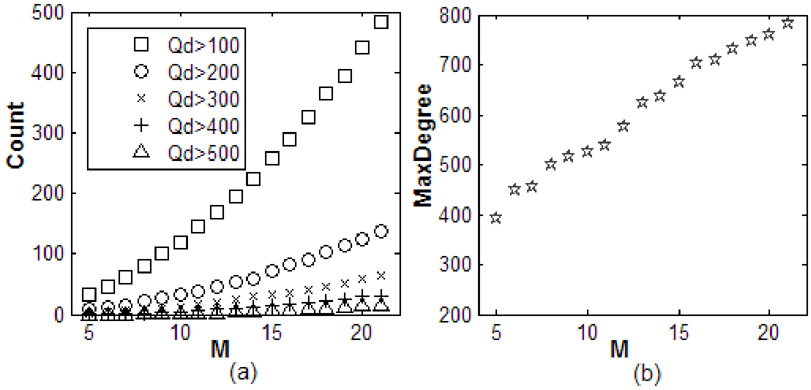

Fig. 7 The relation between value M and big nodes

Fig. 7 (a) indicates the relations between the degree of the agents under different levels and the value of *M* in the network. $Qd > 100$ indicates the number of the agents whose degree value greater than 100 , and so on; Fig. 7 (b) indicates the relations between the greatest value of degree of the agents and the value of *M* in the network. Fig. 7 shows that under different levels the number of big nodes increases with the increase of *M*, and the greatest value of degree of the big nodes increases with the increase of *M* as well.

Fig. 6 shows the larger the value of *M*, the less time it takes for the curve to reach the steady-state. This is because the larger the value of *M*, the greater the number of big nodes in the network. During a period after the simulation experiment start， agents in the status of big nodes are not yet information acceptors, so the curve rises at a slow speed. But once the big node agents become information acceptors, they send messages to the other agents at a frequency which was significantly greater than the general agents, therefore, the number of the agents of information acceptors increases sharply, which is called "amplification effect". Finally although the number of the big node agents in a state of information acceptors gradually increases, since the number of the agents in a state of potential information acceptors gradually decreases, the rising speed of the curve gradually slows down and tends to smooth.

4. Research on the delay characteristics of the diffusion of information

4.1. Fitting algorithm design of delay function

In order to analyze the delay characteristics of the diffusion of information in the scale-free network, this paper designs a fitting algorithm for delay function

$$Smooth(k,D,t) = H\int_0^t \left(\frac{k}{D}\right)^k \frac{\tau^{k-1}}{(k-1)!} e^{-k\tau/D} d\tau \tag{5}$$

Where *k* is an integer represents the number of the order of the delay, *DEL* represents the average delay time, *t* represents time, *H* represents the height of the steps. For a certain pair (*k, D*), the value of the Smooth function can be found at any given time.

1）The basic idea of the algorithm

Higher-order (order 3 and above) information delay curve is also a regular S-shaped curve; many of its properties are very similar to the diffusion curve of the information in the scale-free network. From a perspective of transmission dynamics, think of the diffusion process of the information in the scale-free network as a delay of product information propagation in the network nodes. It is believed that there is bound to be a pair of (*k, D*) in one parameter of the scale-free network, which makes the diffusion curve of the information as consistent as possible with the information delay curve.

The simulation experiments covers statistics on the variation of the number of information acceptors with different values of *M* while the time parameter *t* changes. Compare the number of information acceptors at time *t* (donated as Y_t) to the value of the function $Smooth(k, D, t)$ (donated as Y_t^s) and fit the curve based on the principle of least square method. If the pair of real number (k^*, D^*) can minimize the sum of squared errors between Y_t and Y_t^s , the curve of the function

$$S^2 = \sum_t (Y_t - Y_t^s)^2 \tag{6}$$

$Smooth(k^*, D^*, t)$ can be considered the same as the diffusion curve of the information, $Smooth(k^*, D^*, t)$ is the fitting delay function of the diffusion of the information.

4.2. The impact of network topology parameters on delay characteristics

According to the automatic fitting algorithm based on delay function, use the Eclipse tools to develop an automatic fitting program of delay function based on the Java language (see Appendix 1). After running the program we can obtain the fitting delay function parameters correspond to different scale-free network topology parameters M as shown in Table 2.

Table 2. Node importance ranking of the top 5 place

M	k^*	D^*	S^2	RS^2
5	3	18.15	1417101.02	2.6691
6	3	15.67	560577.07	1.8512
7	3	14.16	262662.36	1.4662
8	3	12.72	150885.24	1.0548
9	3	11.79	228269.36	0.9205
10	3	11.24	539962.18	0.9086
11	3	10.02	237108.77	0.6508
12	3	9.25	323139.23	0.5857
13	4	8.53	379660.05	1.2362
14	4	8.21	261569.46	1.1203
15	4	7.84	174353.54	0.9964
16	4	7.35	162923.25	0.8826
17	4	7.16	104933.99	0.8232
18	4	6.9	93835.69	0.6655
19	4	6.62	92328.17	0.6554
20	4	6.37	170479.5	0.6145
21	4	5.98	62600.01	0.5358

In Table 2, S^2 is the sum of squared errors calculated according to Eq. (6); RS^2 represents the sum of squared relative errors calculated according to Eq. (7).

$$RS^2 = \sum_t (1 - Y_t^s / Y_t)^2 \tag{7}$$

1） Goodness of fit test of delay function

（1）Intuitive goodness of fit test

Table 2 lists the fitting delay function parameters correspond to the different scale-free network topology parameters *M*, statistics in the Table on the sum of squared errors are great judging from the absolute value, this is because the original diffusion data and the value of delay function are both great; But judging from the sum of squared relative errors, the degree of fit of scale-free network diffusion curve and fitting delay function curve is still quite high. Fig. 8 shows the comparison between scale-free network diffusion curve and fitting delay function curve.

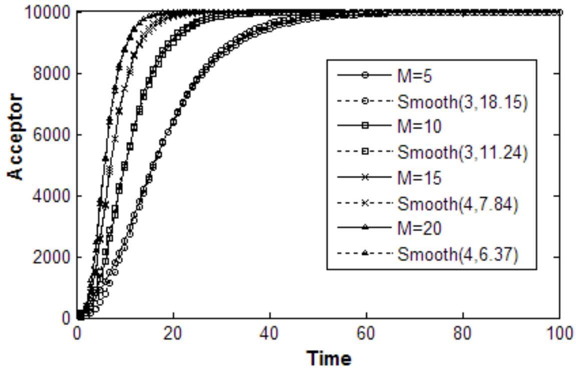

Fig. 8 the scale-free network diffusion curve and the corresponding fitting delay function curve

As can be seen from Fig. 8, the different scale-free network diffusion curve and the corresponding fitting delay function curve are almost overlapping; this also shows that the level of delay function curve fitting is very high.

（2）Goodness of fit test on delay function with the sample coefficient of determination

For the regression model there is always the following total deviation decomposition:

$$\sum (Y_i - \overline{Y}_i)^2 = \sum (\hat{Y}_i - \overline{Y})^2 + \sum (Y_i - \hat{Y}_i)^2$$

Namely, $TSS = RSS + ESS$

In this equation, the sum of squared total deviations $TSS = \sum (Y_i - \bar{Y}_i)^2$ indicates the total degree of variability of the sample observations;

$RSS = \sum (\hat{Y}_i - \bar{Y}_i)^2$ indicates the part of total deviation can be explained by the regression curve;

$ESS = \sum (Y_i - \hat{Y}_i)^2$ indicates the part of total deviation cannot be explained by the regression curve;

The sample coefficient of determination refers to the proportion of the part of total deviation can be explained by the regression curve in total deviation. R^2 indicates the sample coefficient of determination, that is,

$$R^2 = \frac{RSS}{TSS} = 1 - \frac{ESS}{TSS}$$

Obviously, $0 < R^2 < 1$, the more the value of R^2 is close to 1, indicates that the higher the degree of fit of the regression curve and sample observations.

Because R^2 is related to the sample size, it increases with the increase of the sample size, in applications we generally replace R^2 with the corrected coefficient of determination $\overline{R}^2$.

$$\overline{R}^2 = 1 - (1 - R^2)\frac{n-1}{n-k-1}$$

In this equation, *n* indicates the sample size and *k* indicates the number of independent variables.

Conduct goodness of fit test on information diffusion curve and fitting delay function curve and the results as Table 3 shown.

Table 3. the results of goodness of fit test

M	k^*	D^*	R^2	$\overline{R}^2$
5	3	18.15	0.99829	0.99826
6	3	15.67	0.99927	0.99925
7	3	14.16	0.99964	0.99963
8	3	12.72	0.99977	0.99977
9	3	11.79	0.99964	0.99963
10	3	11.24	0.99913	0.99911
11	3	10.02	0.99957	0.99956
12	3	9.25	0.99937	0.99936
13	4	8.53	0.99922	0.99920
14	4	8.21	0.99945	0.99944
15	4	7.84	0.99962	0.99961
16	4	7.35	0.99962	0.99961
17	4	7.16	0.99975	0.99974
18	4	6.9	0.99977	0.99977
19	4	6.62	0.99976	0.99976
20	4	6.37	0.99955	0.99954
21	4	5.98	0.99982	0.99982

In Table 3 the value of the sample coefficient of determination and the corrected coefficient of determination are both greater than 99.8%, basically close to 1, which is indicating that the goodness of fit of the delay function curve is high.

2）Analysis of the network topology parameters and delay characteristics

（1）The impact of M on delay order

As shown in Table2, when the value of M range from5 to12, we can use third-order Smooth delay function to fit the scale-free network diffusion curve; And when the value of M range from13 to 21, we can use fourth-order Smooth delay function to fit the scale-free network diffusion curve. This is the new characteristic of delay function in the scale-free network. Traditionally we generally use third-order delay structure to simulate the diffusion behavior of the system and obtain good results, but this is the conclusion drawn without considering the complex network environment. The traditional diffusion model basically does not consider the impact of network topology structure on the diffusion process, or assume the system locates in regular network and random network even consider the impact of network structure, the conclusion about transmission dynamics drawn under this premise often has one - sidedness characteristic.

In recent years, the researches on complex network theory suggest network topology structure has a major impact on the diffusion behavior of the system. For scale-free networks, if the value of network topology parameter M is relatively great, in that case the number of the big nodes in the network is relatively large, thus greatly influence the network structure. As shown in Fig. 6 it is evident that the greater the value of M, the “steeper” the new products information diffusion curve is. From a perspective of system dynamics, the “steep” degree of diffusion curve can be explained by the order of delay function, the larger the order is, the greater the initial input transient response to. When study the system behaviors by the system dynamics method we should use fourth-order delay structure instead of third-order delay structure to simulate diffusion process to get better results.

（2）The impact of M on the average delay time

Table 2 shows the average delay time of the fitting delay function gradually decreases with the increase of the value of the scale-free network parameter M. In the simulation experiments, big node agents play a pivotal role in the diffusion process of the new products information, their communication frequency is much higher than the general agents, and thus be able to convince more potential information acceptors to be transformed into information acceptors. The greater the value of *M* is, the larger the number of the big nodes is, the less time the diffusion costs to reach steady-state and the shorter the average delay time of the fitting delay function is. When $M > 16$, the average delay time even shorter than 7 unit time, it shows that the speed of diffusion of information in scale-free network is very fast.

5. Conclusions

This chapter mainly discusses the impact of Scale-free network parameter M on delay characteristics of the diffusion of information. First use AnyLogic ® to establish a multi-agent simulation model of diffusion of information and get the statistics of the diffusion data under different network parameters; and then design an automatic fitting algorithm of delay function based on the least squares method; Finally use the Eclipse tools to develop an automatic fitting program of delay function based on the Java language, find the correspondence relationship between different network topology parameters and fitting delay function parameters and conduct goodness of fit test on delay function. The main conclusions are as follows.

(1) The scale-free networks parameter *M* determines the number of big nodes in the network, the greater the value of *M* is, the larger the number of big nodes is in the network and the greater the maximum degree is.

(2) Not all of the diffusion processes in scale-free network can simulated by third-order delay structure, when the value of *M* is relatively great we should consider using fourth- order delay structure to simulate the diffusion behaviors.

(3) The scale-free networks parameter *M* and the average delay time of the fitting delay function have a negative correlation, the greater the value of *M* is, the shorter the corresponding average delay time of the delay function is.

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