RESEARCH ON THE INFORMATION GLOBULAR RADIATION MODEL IN CYBERSPACE

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Abstract: According to advantage of information diffusion in cyberspace, the process of information diffusion can be simulated a compound process of time-variation and space spreading. On basis of Network Dimension-force theory, this paper builds the information globular radiation model in cyberspace. Starting with the ideal cyberspace and reality cyberspace, the model simulates the process of information diffusion with time as the diffuse radius and the amount of information as the diffuse volume. Using physics properties and rigorous mathematical reasoning, the paper proved existence and rationality of the model, which provided new directions for network information diffusion.

1 INTRODUCTION

With the rapid development of network, the world enters into the information age charactered by high efficiency. Owing to network, the superiorities of information diffusion is mainly about small time difference but large quantity. From the point of view of information science, information diffusion in cyberspace is a process of information diffusing from one node to the whole space .In other words, it is a compound process of time-variation and space spreading (Zhao, 2006). From the perspective of the cyberspace, complicated network is abstracted into nodes and paths (Deng, 2008). The nodes represent the location of the information, and the paths represent the area of flow of information. The paper advances a completely new model of information diffusion in cyberspace on the basis of the above-mentioned two views, namely globular radiation model of information in cyberspace.

2 THE THEORETICAL RESEARCH ON THE GLOBULAR RADIATION MODEL OF INFORMATION IN CYBERSPACE

2.1 The Definition of Cyberspace

The three elements of cyberspace are information, information nodes and paths between nodes. Therefore cyberspace is defined as three-dimensional vector $\Omega_1 = \{M, P, L\}$. $M = \{m_1, m_2, \cdots, m_n\}$ represents a set of flowing information in cyberspace, where m_i flowing in connecting paths and existing on the network nodes is a set of information. Considering information with properties of sets, therefore $\forall m_i \in M$. Otherwise m_i is called fake information of M (Chen, 2004). $P = \{p_1, p_2, \cdots, p_n\}$ represents a set of nodes in cyberspace. In the theory of Network Dimension-force, information source nodes are divided into two types: shining point and vanishing point. A shining point represents the node being able to send out information, while a vanishing point represents the opposite. Information sink nodes can be classified as reachable points and unreachable points. A reachable point is the node being able to receive information, while an unreachable point is the

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opposite. $L = \{l_{11}, \cdots, l_{ij}, \cdots, l_{nn}\}$ represents the set of paths of network space. l_{ij} represents the path between p_i and p_j .When p_i and p_j are both shining points or reachable points, l_{ij} is called access .When at least one of p_i and p_j is vanishing point or unreachable point, l_{ij} is considered as a broken path or inexistent.

2.2 The Mode of Information Diffusion in Ideal Cyberspace

In cyberspace, the information diffusion is a process of information transmitted from one point to another (Deng, 2008). In ideal cyberspace, the information dissemination is not affected by any restraints of objective and subjective conditions .In such a circumstance all the information source nodes are shining points, and all the information sink nodes are reachable points .All the paths l_{ij} are connected. Therefore, in ideal cyberspace the information on the information source node is transmitted to the numerous information sink nodes in diffuse way during $\Delta t(\Delta t \to 0)$. As Fig. 1 showed, the numerous nodes formed a spherical surface with Δt as the radius. The surface is formed by the information transmitted to all the information sink nodes after Δt . During the next Δt , all the information sink nodes become information source nodes, then the information on the nodes is transmitted to the numerous new information sink nodes in diffuse way. Obviously, a new spherical surface is formed by each node. Because $\Delta t \to 0$, a new spherical surface is formed out of the previous one with the same sphere's center, but the radius of the new spherical surface is 2 Δt . So when the number of Δt approaches infinite, numerous spherical surfaces, with $n\Delta t(n = 1, 2, ... + \infty)$ as their individual radius and the same center, are formed. Thus, a sphere with $t = n\Delta t \to +\infty$ as the radius is formed after $n\Delta t$ .The formation of the sphere with t is the process of the information diffusion in the ideal cyberspace. This diffusion way is there-dimensional from point to plane. The information transmission mode is constructed as globular radiation model of information in ideal cyberspace (Cai, 2010). The model can fully reflect that information diffusion is a complex process of time variation and space spreading. This section must be in one column.

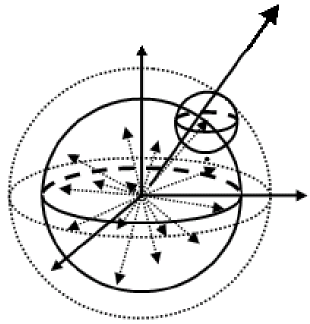

Figure 1: The picture of the process of the information diffusion.

2.3 The Mode of Information Diffusion in Reality Cyberspace

Unlike in the ideal cyberspace, however, information can not spread to every information node in the reality cyberspace .Due to various reasons, a few information nodes related to the information of information source are not able to receive information .Such information node is called vanishing point of information. According to different kinds of information, the number of the vanishing points of information is different. A vanishing point can lead to a number of unreachable points. Figure 2 is a schematic illustration of vanishing point of information.

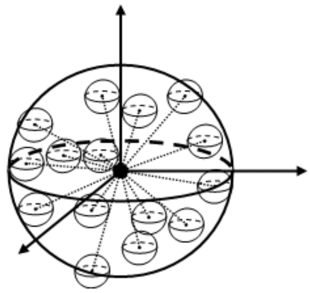

Figure 2: The picture of vanishing points of information diffusion.

2.4 The Globular Radiation Model of Information in Cyberspace

Described as the globular radiation model of information in ideal cyberspace, it is the amount of information of diffusing that formed infinitely many spherical surfaces with $n\Delta t(n = 1, 2, \cdots, +\infty)$ as their radius and the same center. The amount of information of diffusing formed a sphere with $t = n\Delta t$ as the radius. Let $s(t) = 4\pi(\tau t)^2$, where $s(t)$ is the surface area of the sphere at time t and

τ is time-intensity parameter. Because $s(t)$ is an integrable function on interval $[0,+\infty)$, $q(t) = V(t) = \int_0^t 4\pi r(\tau t)^2 dt = \frac{4\pi}{3}(\tau t)^3$ $(t \to +\infty)$. $q(t)$, the total number of information at time t in an ideal state, accord with the variation rule of the volume of the sphere with τt as the radius.

In the reality cyberspace, under the influence of various subjective and objective conditions, information nodes that can not transmit information with time are existent. In other words, $P = \{p_1, p_2, \cdots, p_n\}$,the set of nodes, has vanishing point or unreachable point p_i. As figure 2 shows, more new vanishing points and unreachable points are caused by these vanishing points and unreachable points. Information transmission would produce the losses of the amount of information with an obvious randomness in the reality cyberspace, namely $q(t)_R \le q(t)_I = \frac{4\pi}{3}(\tau t)^3$, where $q(t)_I$ represents the total information of the ideal cyberspace and $q(t)_R$ represents the total information of the reality cyberspace.

3 THE PROOF OF GLOBULAR RADIATION MODEL OF INFORMATION IN CYBERSPACE

When describing the cyberspace, there is an important measure, network measure distribution function $\rho(k)$, the definition of which is the probability of the node randomly selected with k connecting paths. In the globular radiation model of information in cyberspace, the shorter the connecting time Δt among points, the more the paths k from point to point. Therefore there are a certain inverse relationship between time t and connecting path k, namely $k \propto \frac{1}{\Delta t}$.According to the study in recent years, the network measure distribution function shows power exponent law, namely $\rho(k) \propto \Delta k^{-\gamma}$, so $\rho(k) \propto \Delta t^{\gamma}$, where γ is power exponent (Wang, 2004). The basic constitution of the globular radiation model of information in cyberspace is as follows. Starting with $t = 0$, there are at least $\eta(0)(\eta(0) \ge 1)$ information originating nodes. $\eta(t)$ represents the number of nodes in cyberspace at time t. After that the following four processes would happen during every Δt time step.

1) Some information source nodes are vanishing points in cyberspace, and information source nodes becoming vanishing points are stochastic. Let the number of the nodes without information sent out is c.

2) Stochastic selection of diffusion, information sink nodes receive information transmitted by information source in the reality cyberspace on the basis of competitive selection .The number of information sink nodes is several ,therefore information source nodes and information sink nodes would produce e connecting paths l_{ij} between nodes .The preferential probability that information source node p_0 reaches information sink node p_i,

$$\prod_i = \frac{k_i}{\sum_j k_j} \tag{1}$$

3) r connecting paths of information nodes in cyberspace as l_{ij} :a connecting path is the path from shining points to reachable points, the preferential probability of the information source node determined by (1).

4) n broken paths of information nodes in cyberspace as l_{ij} : when information sink nodes are unreachable points, information sent to space can not be received ,which would cause broken paths. Meanwhile information source node p_0 are selected in anti-preferential probability (Jia, 2009)

$$\prod_i' = \frac{1 - \prod_i}{\eta(t) - 1} \tag{2}$$

Consequently, $\eta(t) = (1-c)t + e$. $\vartheta(t)$ represents the total measure of the nodes in cyberspace at time t ,namely $\vartheta(t) = \sum_j k_j$ .Therefore $k(t) = \frac{\eta(t)}{\vartheta(t)}$ at time t ,where $k(t)$ represents the average measure of information nodes at time t .

According to Dynamical Mean-Field Theory, (Xu, 2010)measure distribution of node p_i in cyberspace can be obtained. If k_i is successive, k_i satisfies

$$\frac{\partial k_i}{\partial t} = e\prod_i - r\frac{k_i}{\eta(t)} + r(\prod_i \times 1 + \sum_{i \ne j} \prod_i \prod_j)$$

$$-n(\prod_i \times 1 + \sum_{i \neq j} \prod_i{}' \prod_j{}') \quad (3)$$

And average measure distribution of information nodes in t time is

$$k(t) = \eta(t) \big/ \vartheta(t) = \frac{2[e - ck(t) + r - n]}{1 - c} \quad (4)$$

Then $k(t) = \frac{2(e+r-n)}{1+c}$ when $t \to +\infty$ .Insert function $\eta(t) = (1-c)t$ and average measure distribution of information nodes into（4）,where

$$\eta(t) = \frac{2(e+r-n)(1-c)}{1+c} t \quad (5)$$

Applying (3) with $\eta(t)$ 、 $\vartheta(t)$, we obtain approximating linear differential equation

$$\frac{\partial k_i}{\partial t} = \frac{e + 2r - ce + 2cn}{2(e+r-n)(1-c)} \frac{k_i}{t} - \frac{2n}{1-c} \frac{1}{t} \quad (6)$$

Let $x = \frac{e + 2r - ce + 2cn}{2(e+r-n)(1-c)}$, $y = -\frac{2n}{1-c}$, initial condition is $k_i(t) = e$， whence

$$k_i(t_i) = (e - \frac{y}{x})(\frac{t}{t_i})^x - \frac{y}{x} \quad (7)$$

The solution of the inequality $k_i(t_i) < k$ is

$$t_i > t \left(\frac{e + \frac{y}{x}}{k + \frac{y}{x}} \right)^{\frac{1}{x}} \quad (8)$$

Therefore

$$\rho(k_i \le k) = \rho(t_i \ge t \left(\frac{e + \frac{y}{x}}{k + \frac{y}{x}} \right)^{\frac{1}{x}}) = 1 - \rho(t_i < t \left(\frac{e + \frac{y}{x}}{k + \frac{y}{x}} \right)^{\frac{1}{x}}) \quad (9)$$

If t_i satisfying homogeneous distribution (Samuel, 2009), measure distribution function of information nodes is

$$\rho(k) = \frac{\partial \rho(k_i < k)}{\partial k} = \frac{1}{x} \frac{t}{\eta(0) + t} \frac{(e + \frac{y}{x})^{\frac{1}{x}}}{(k + \frac{y}{x})^{\frac{1+x}{x}}} \quad (10)$$

So when time is $t = n\Delta t (n = 1, 2, ..., +\infty)$, then

$$\rho(k) = \frac{1}{x} (e + \frac{y}{x})^{\frac{1}{x}} (k + \frac{y}{x})^{-\gamma} \quad (11)$$

While

$$\gamma = \frac{1}{x} + 1 = \frac{2(e+r-n)(1-c)}{(e+r)(1-c) + 2cn} + 1 \quad (12)$$

We have on the basis of (11) that information nodes measure distribution function $\rho(k)$ have parameter exponent and power exponent, and power exponent γ is to correspond with $\gamma = \frac{1}{x} + 1$. Since $k \propto \frac{1}{\Delta t}$ and $t = n\Delta t (n = 1, 2, ..., +\infty)$, therefore $\rho(k) \propto \Delta t^\gamma$,thus, $q(t) \propto t^\gamma$. In the information globular radiation model in network, time t be a continuous increasing variable, clearly the parameters show that $e > 0, 0 \le c < 1, r \ge 0, n \ge 0, e + r \ge n$. Inserting this parameters into (12), the power exponent γ is to correspond with $1 < \gamma \le 3$. Firstly, while $\gamma > 1$, it indicates the information is being transmitted and received from the source nodes. While $0 < \gamma \le 1$, there is no source node or the source point transmit nothing in the cyberspace. While $1 < \gamma < 3$, there are vanishing and unreachable points in the cyberspace. Only when $\gamma = 3$, the cyberspace is ideal, where all the source nodes are shining points and all the sink nodes are reachable points. Therefore the quantity of information function can be illustrated as $q(t) = \frac{4\pi}{3} (\tau t)^3 \quad (0 < t < +\infty)$. This equation meets suppose of information diffusion spherical radiated model in ideal cyberspace.

4 CONCLUSIONS

Network Dimension-force discovered that network provided the superiority in time and space to information diffusion. This paper based on this superiority build the information globular radiation model in network space, to show the process of information diffusion is the complex process of network information with time variation and space spreading. And the model of existence and rationality has proved though the physics nature of network, for this reason, the information globular radiation model in network space is able to describe information diffusion in cyberspace. Thereby this model is suitable in research on information diffusion in cyberspace and analysis of the problems of network information.

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