

Entropy Model of Fractal Supply Chain Network with Multi-agent

Linfeng Bai¹, Yingjun Wang¹, Peixin Qu¹, Lin Chen²

1. School of Information Engineering, Henan Institute of Science and Technology, Xinxiang, 453003, China

2. College of Computer and Communication, Hunan Institute of Engineering, Xiangtan, 411104, China

1. 451800@163.com 2. chenlin_240886393@qq.com

Abstract: The self-avoiding random walk model characterizing fractal dimension of biological macro molecular fractal network is introduced. Entropy through fractal dimension is obtained. Moreover, the system structure entropy model is improved according to the relation between generalized fractal dimension and generalized entropy. Furthermore, entropy model of order degree of fractal supply chain network system is established based on organizational structure entropy and information entropy. Finally, entropy mechanism of fractal supply chain network system mutation is deduced from entropy model of order degree of fractal supply chain network.

Keywords: entropy model; supply chain network; self-avoiding random walk

1 Introduction

The most core elements of SCN are information, human resource and organization structure. Recently, information flow, logistics and funds flow in supply chain network(SCN) are regarded as major factors influencing SCN operation. Because the organizational structure is the vector of existence and development for the information flow and human resource. Staff are both the “nodes” in structure and the vector of information flow. So the influence of staff and other factors outside SCN can be transformed into the effects of organizational structure and information.

Moreover, structure and information are unseparated. That is no independent information from the system, nor independent structure from information.

So the entropies of structure and information are main sources of entropy of SCN in this paper.

To illustrate entropy of order degree of fractal supply chain network(FSCN), we integrate SCN business process(BP) to be FSCN with fractal theory.

Then expand and improve the system structure Entropy model[1], and obtain entropy through fractal dimension by the relation between generalized fractal di-

mension and generalized entropy, furthermore, establish entropy model of order degree of FSCN system. Moreover, entropy mechanism of FSCN system mutation is deduced from the model, and find the way to chaos.

2 Self-avoiding random walk

Biological macro molecular (mainly including protein and nucleic acid) has very sophisticated fractal structure, and it is shown as figure 1. Fractal network structure of biological macromolecules has a very fine and intelligent information, material and energy transmission mechanism.

The well-known American expert polymer P. J.Flory has studied biological macromolecules strand conformation (the mercy way of macromolecular chains in the space) and gets the SAW model[2]:

$$D_f = \frac{d+2}{3} \quad (d \text{ is Euclidean dimension}) \quad (1)$$

Although Flory has made a number of approximate calculation in the deducing process, but the result is correct. Later, P. J. Fisher used statistical mechanics method and proved its correctness and improved it, so it is also called Fisher—Flory formula[2].

3 Entropy and Fractal

Principle of entropy increase revealed all irreversible processes in system to the spontaneous direction is entropy increasing. And, in statistical physics, entropy is metric to the movement of the disorder degree (Boltzmann) and confusion (Gibbs). Just shown by Eq.(1),

$$S = K \ln W \quad (1)$$

The Projects Supported by Scientific Research Fund of Hunan Provincial Education Department(08A009 and 08B015) for supporting this research.; this research is supported by the construct program of the key discipline in Hunan province; project supported by Provincial Natural Science Foundation of Hunan (01JJY2157) support the research; research fund of Hunan Institute of Engineering(0850) supporting the research.

K is Boltzmann coefficient, W is system micro-state number.

N. Wiener and C. E. Shannon built up information theory, and Shannon called the signal uncertainty of information sources in the communication process as information entropy, and the elimination of a number of uncertainties as information.

Generalized Entropy has the characteristics of nonambiguity, additivity, extremum.

Benoit B. Mandelbrot (1975) determined "fractal": A fractal is a shape made of part similar to the whole in some way. And fractal dimension is the dimension number of fractal, and it metrics the ability of system filled space (compact) or crannies (osteoporosis), and characterizes the system disorder.

Generally, fractal dimension is calculated by:

$$D_f = -\ln N(\varepsilon) / \ln \varepsilon \quad (2)$$

ε is measuring-scale, $N(\varepsilon)$ is number of parts under ε .

According to the similarity of fractal theory with lean principle, and based on core competence to integrate SCN business process (BP).

The FSCN system consists of modules: Input, Operation and Output, and is just similar to three large functions of SCN: supply, manufacture and sale. And Input concludes Interface and Transformation sub-modules. Then the task will be transferred to Operation including Decision, Organization and Implementation sub-module. After this, it is monitored in Monitoring and Output sub-module in Output finally. Meanwhile, each sub-module is coupled by several lower-level nested sub-module, until the simplest BP (task group) as the basic fractal unit of FSCN, so that a number of nested layers couple a huge FSCN. And FSCN has been continuously evolution and development with the formation of fractal growth mechanism.

With fractal theory, structure fractal dimension of FSCN is shown as follows:

$$\varepsilon = 1/3 \quad (\text{Input, Operation and Output module}).$$

$N(\varepsilon) = 7$ (Interface, Transformation, Decision, Organization, Implementation, Monitoring and Output sub-module)

$$D_g = -\ln 7 / \ln(1/3) = 1.77 \quad (3)$$

4 Multi-agent

In fact, so far, there is not a fixed definition for the technology of agent. Agent is a software entity connecting with the other related agents and can implement spontaneous in specific environment. The main traits of the agent are as follows: Firstly, it is autonomous, namely, it can complete most of the task without manual intervention. Secondly, the agents can interact each other. Thirdly, the agent can sense the changes from the environment, and make real-time response. Fourthly, the

process of the agent is continuous. Fifth, the agent is self-adaptive, it can adapt the environment by study mechanism. Moreover, it can bring its own contexts and migrate to other environment to implement.

With the continuous development of computer hardware technology and network technology, especially the rapid development of internet technology, the coverage of the software and application areas is expanding, and it makes the complexity of the system grow rapidly, in particular, the distributed traits of the software system become even more obvious. So, the increasing complexity, dynamic and distribution put forward higher requirements of the capacity of software system.

With Multi-Agent technology, it can improve the ability of the whole software system by task decomposition and coordination. Of course, with the cooperation of various agents, it can overcome the defaults only by single agent. So, in this paper, we adopt the multi-agent ideal to optimize the agile supply network model.

5 Trait of fractal supply chain network system

The entropy model of fractal supply chain network has the following traits:

1) Self-organization: The part or whole of fractal supply chain network system needn't specific instructions from outside world on and they can be self-organization, self-creativity, and self-evolution, can be independently from the disorderly to orderly [6].

2) Immediate response: because the fractal structure of information flow layer, logistics layer and funds layer are completely compatible. Namely, every point of information flow layer is respective corresponding to the only point of logistics layer and funds layer, and they are with the fully consistent fractal structure. The dimensions of the three layers are the same, and there is no exchanging delay between the three layers.

3) Self-similarity: every fractal supply chain unit is similar to the whole supply chain, and the similarity includes the purpose of the part and the whole is consistent and the allocation of information flow, logistics and is similar.

4) Flexibility emphasizing: It is flexible and can deal with environment changing or the change caused by the uncertainty of the environment, and can adapt the environment. Furthermore, it can quickly adjust its structural

levels in accordance with the different tasks and changes in environment exchanging, and is with a high degree reconstructed capacity.

5) Whole optimal: The individual fractal supply chain unit could deviate its optimal objective when it completes some specific function, but, through the interaction among the other units, perhaps, the whole supply chain is optimal.

6) Self-adaptability: fractal supply chain network system has become a stable and orderly structure through long-term fractal evolution, due to self-similar, the new members of the system can quickly run and adapt to the system, not causing the system shocks.

7) Lean principles: Fractal realized the connection between supply chain units be "seamless", and let customer demand for the first principle. Product highest quality production-non-defective products; eliminate any Non-value-added link and expand the value-added links; maximize the product value with the minimum cost.

8) Knowledge links: create a learning organization[3], and form a knowledge union of supply chain network, constantly examine their environment, constantly adjust their operational objectives, people-oriented and encourage learning and innovation, and to continually improve the overall competitiveness of the supply chain.

9) Evolutionary principles: with the common role of the nine principles above to the supply chain so that fractal network system and the environment are common evolutionary, and maintain long-term stable and dominant position, moreover, the system gradually from a lower level to senior level.

10) Information strategy: in the ideal state, the information flow is in irreplaceable strategic position. Every fractal supply chain has the full information, and the information is resharing. Moreover, they have the independent information processing system, and can transform or filter destabilizing factors. For example, after the fractal supply chain unit of the suppliers got the customer demand information of the whole supply chain, it will process the information by itself, and transform the information to inventory adjustment.

6 Conclusion

According to the principle, constructing the model with information flow layer, human resource structure layer and organization structure layer of fractal supply chain in the ideal state, and adopting SAW model to compute the fractal dimension is significant to analysis of running features of fractal supply chain network system. It has guiding significance to improve the operational efficiency of the supply chain. But, there are great gap be-

tween actual supply chain network system running and fractal supply chain network system under ideal state. Especially, the dependence of information flow layer to the time scale is difficult to achieve "fully fit" with the organization structure layer, and human resource structure has large uncertainties, and it is difficult to quantify. So, there are a large number of works still need deeper research.

6. Acknowledgment

Authors gratefully acknowledge the Projects Supported by Scientific Research Fund of Hunan Provincial Education Department(08A009 and 08B015) for supporting this research.

This research is supported by the construct program of the key discipline in Hunan province; project supported by Provincial Natural Science Foundation of Hunan (01JJY2157) support the research; research fund of Hunan Institute of Engineering(0850) supporting the research.

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