*International Journal of Intelligent Information and Management Science*
*ISSN: 2307-0692, Volume 8, Issue 3, June, 2019*

# Research on Fractal Calculation Method of Network Spatial Structure based on Artificial Intelligence

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**Abstract:** Network spatial structure has the attributes, like multi-period, multi-scale and strong spatiality, which are closely related to the daily life of modern people. Fractal data is an effective parameter for describing network spatial structure. Because the traditional fractal calculation method of network spatial structure is time-consuming, labor-consuming and the results are not accurate, the research on fractal calculation method of network spatial structure based on artificial intelligence is proposed. By introducing artificial intelligence, determining the data of network spatial structure, and constructing the fractal calculation model of network spatial structure, the research on fractal calculation method of network spatial structure based on artificial intelligence is completed. The experimental results show that the fractal calculation method of network spatial structure based on artificial intelligence is more effective than the traditional fractal calculation method of network spatial structure, and can be used in urban planning.

**Keywords:** Artificial intelligence; Network space; Spatial structure; Fractal calculation of spatial structure

## 1. Introduction

The evolution of urban system and the development of traffic network are a process of spatial interaction. The fractal geometry feature of urban system implies the self-similarity of traffic network. With the in-depth study of fractal theory of cities and urban systems, more attention has been paid to the fractal theory of transportation networks. Research on fractal is the main quantitative criterion, but there are few studies on traffic network morphology, structure and spatial differences, time evolution, and fractal characteristics of traffic network, which are still in the preliminary stage of exploration. With the continuous development and innovation of modern science and technology, modern society has turned to the era of network information development [1]. Computer network technology occupies a very important position in modern society. It can provide guarantee for modern people's work and life. Artificial intelligence is a new type of intelligent technology based on computer network technology, which can create more real scenes for users through simulation and setting. Thus, this paper puts forward the research on fractal calculation method of network spatial structure based on artificial intelligence.

## 2. Fractal Calculation Method for Determining Network Spatial Structure based on Artificial Intelligence

### 2.1. Introducing artificial intelligence

When artificial intelligence is applied in computer technology research in practice, it mainly classifies and judges the computer technology through expert system, so as to further ensure that the process and quality can be controlled in the research of computer technology. The field of electronic technology in computer technology is a common technology in the development of modern science and technology. While there are many problems in the research of electronic technology, such as uncontrollable process, insufficient technology and technical loopholes, which will not only affect the future development of electronic technology, but also affect the actual operation of electronic technology. When the expert system in artificial intelligence is applied to the research of electronic technology, it can provide guarantee for the research process, professional technology and perfect technology of electronic technology based on the characteristics and functions of expert system, so as to provide a good basis for the development of artificial intelligence and computer technology [2]. The introduced artificial intelligence is shown in Figure 1.

Expert system of artificial intelligence technology belongs to a relatively intelligent program. When the artificial intelligence expert system is applied to the evaluation system in practice, it can accumulate the experience and knowledge of experts in the process of continuous application, and construct a resource input system by summing up and summarizing the accumulated experience [3]. On the basis of resource input system, several

different expert systems are constructed to improve the actual application effect of computer evaluation system in a real sense, and to further grasp the uncertainties and changing rules of computer network, so as to ensure that the practical application effect of artificial intelligence can provide guarantee for the regular operation of computer evaluation system.

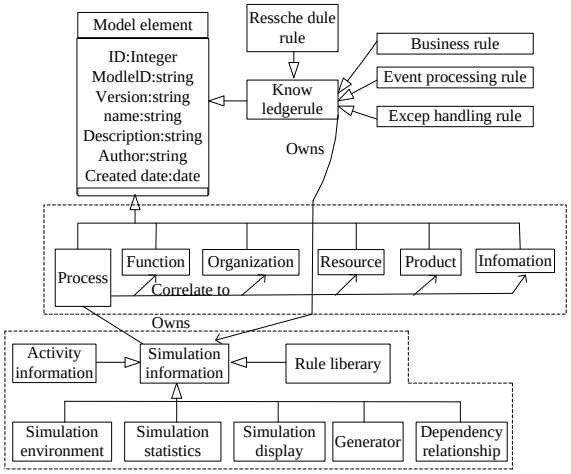


**Figure 1. Artificial intelligence model diagram**

### 2.2. Determining network spatial structure data

The spatial structure of point-axis system and geographical phenomena interact. In reality, the geographical factors are unevenly distributed, especially the differences of topographic factors such as oceans and rivers, which lead to the different gravitational attraction of various points in geographic space to population and so on. Therefore, it is believed that the regional point-axis system is based on the following two assumptions: (1) the region is an unbalanced surface, existing differences in physical and geographical factors; (2) the initial state of population concentration and economic activities in the region is unbalanced distribution. This is different from the assumption of the regional homogeneous surface of the continental avenue [4]. It is believed that only based on the situation of unbalanced geographical factors can the unbalanced development of regional point-axis system be brought about. Meanwhile, the assumptions of non-equilibrium also conform to the development history of human social space.

There are four stages in the formation of spatial structure of point-axis system. According to fractal theory, the evolution of spatial structure of point-axis system is from integer dimension to fractal dimension.

Random Stage: the surface is heterogeneous space. As can be seen from Figure 2a, the points are randomly distributed with no hierarchical differences. This is consistent with the fact that most of the human settlements in the early agricultural society first appeared and developed slowly in the river alluvial plain suitable for cultivation. Figure 1a is meshed. The mesh size $\varepsilon$ is changed, thus, $N(\varepsilon) \propto \varepsilon D$, in which $N(\varepsilon)$ is the number of meshes occupied by points and D is the fractal dimension of points [5]. According to the feature of random fractal and its geographical significance, the point spatial distribution in Figure 2a has fractal feature, and $0 \le D < 1$. At this stage, there is no connection between the points and there is no axis. Incubation stage: the point distribution differentiates. The settlements with good resources and traffic location develop into cities and towns, the traffic axis is formed between the divergent points, and the regional part begins to appear organized state. As is shown in Figure 2b, point A and B in the regional space differentiate, and an axis is formed between point A and B. Under the influence of market principle, the differentiation points are distributed along AB axis. Its fractal dimension can be approximately expressed as $D = 1$, which is an integer dimension spatial form.

Development stage: the main spatial structure framework of point-axis system has been formed. With the rapid evolution of the society and economy, and the spatial structure changes greatly. As is shown in Figure 2c, the dimension of the point-axis system increases gradually from $D = 1$, and its spatial structure begins to appear self-similar irregularities. Mature stage: the point-axis system is highly developed and the spatial structure tends to be stable [6]. As is shown in Figure 2d, the system geographic factors appear to be fragmented and random, but in fact have scale-free self-similar system. This is a fractal dimension structure, a subset of scale-free network, and has self-optimization characteristics. Its fractal dimension D generally satisfies: $1 < D < 2$.

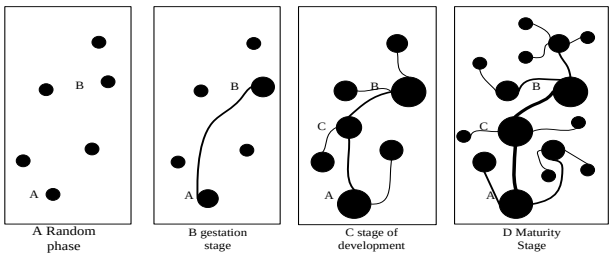


**Figure 2. Spatial structure sketch**

### 2.3. Constructing fractal calculation model of network spatial structure

The basic idea of the point-axis system theory is to consider the point and axis of a region in a unified way and use them in planning and layout, so as to form the best spatial structure of a region. The previous research on fractal mostly studies the points and axes separately [7]. In the process of the formation and development of point-axis system, the formation of spatial structure of point system precedes the formation of spatial connectivity of axis system. Therefore, the spatial structure of

point system in a region determines the spatial connectivity of axis system, while the further optimization of spatial structure of axis system has reaction force.

Point-axis system is the center of network space, the gathering point of social and economic factors at all levels, and the center of driving regional development at all levels. The axis of point-axis system refers to the "infrastructure bundle" connected by transportation, transportation trunk lines, energy and water channels, which is mainly used to connect all points in the system [8]. In the mature spatial structure of point-axis system, the connection between points forms a scale-free network. Most of the network space points achieve optimal connection mainly through a few reasonable transitions with a large number of Hub points. Therefore, the point-axis system of the regional network space is generally distributed along the connection. The transportation system is a network space with some traffic axes distributed and interrelated in the network space points. Based on this, the fractal characteristics of spatial structure of point-axis system in regional network space are discussed with the network space-transportation system as the carrier.

The length and width of the research area are regarded as 1 unit length. The region is meshed with a scale of $\varepsilon$. The number of meshes $N(\varepsilon)$ occupied by the network space is investigated. $N(\varepsilon)$ changes according to the change of the mesh size $\varepsilon$. Previous research has shown that the spatial structure of regional network has self-similarity, as is shown in formula (1):

$$N(\varepsilon) \propto \varepsilon^{a}$$
$$Dh = a = \frac{\ln N(\varepsilon) - A}{\ln(1/\varepsilon)} \quad (1)$$

According to Hausdorff dimension formula, it can be known that A is a constant and $Dh = a$ is a fractal dimension, a generalized capacity dimension. Since capacity dimension can not reflect spatial imbalance, Shannon entropy used to describe spatial equilibrium has been proved to be equivalent to Hausdorff dimension [9]. Therefore, on the scale of $\varepsilon$, the meshes are numbered as J accordingly. Let the number of network spaces in the jth mesh be $Nj(\varepsilon)$, N the total number of network spaces in the region, I the constant, and the approximate expression of the network space falling into the jth mesh is shown in formula 2:

$$I(\varepsilon) = -\sum_{j}^{k} Pj(\varepsilon) \ln Pj(\varepsilon) \quad (2)$$

In the formula, $k = 1/\varepsilon$, which is the number of segments of the region edge length on the scale of $\varepsilon$. According to the definition of information dimension, the transformation of formula (2) is as follows:

$$I(\varepsilon) = I_0 - Di \ln(1/\varepsilon)$$
$$Di = \frac{I_0 - I(\varepsilon)}{\ln(1/\varepsilon)} \quad (3)$$

In formula (3), I0 is constant and Di is information dimension. The results show that the information dimension $Di < [0,2]$, which reflects the uniformity of spatial distribution of regional networks. When $Di = 0$, it means that all the network space is concentrated at one point, and there is only one city in the region. When $Di \to 2$, it means that the regional network space is evenly distributed, which is the case with the standard central model. The larger Di is, the more balanced the spatial distribution of the regional network is. Generally, $Di \in (0,2)$ and $Di < Dh$. In the case that space are distributed equally in network space, $Di = Dh \to 2$.

In the process of the formation and development of point-axis system, the formation of spatial structure of point system precedes the formation of spatial connectivity of axis system. Therefore, the spatial structure of point system in a region determines the spatial connectivity of axis system, and the further optimization of spatial structure of axis system has reaction force. Specifically, the spatial structure of regional urban-traffic system is affected by the location and evolution of residential areas on the one hand, and the road connecting these residential areas on the other. The interaction of the two influences the spatial structure of regional network space-traffic system [10].

The scale-free area of network spatial distribution is determined by visual method, and the least square regression analysis model is embedded in the program, which can automatically display and calculate the information dimension of urban points. Similarly, the attribute tables of network spatial distance (including linear distance and traffic distance) are calculated under different distance scales. The workflow diagram of the fractal calculation model of network spatial structure is shown in Figure 3.

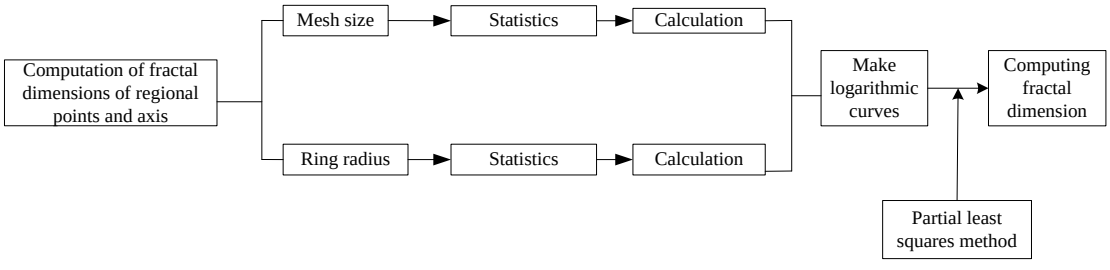

**Figure 3. Workflow diagram of fractal calculation model of network spatial structure**

By introducing artificial intelligence, determining the data of network spatial structure, and constructing the fractal calculation model of network spatial structure, the research on fractal calculation method of network spatial structure based on artificial intelligence is completed.

## 3. Test Verification

In order to verify the validity of the fractal calculation method of network spatial structure based on artificial intelligence proposed in this paper, simulation experiments are carried out. The traditional fractal calculation method of network spatial structure is used as the experimental contrast object, and the fractal accuracy of different fractal calculation methods of network spatial structure is obtained under different experimental variables by comparing with the known city profile.

### 3.1. Experimental content

During the experiment, the general situation of Jinan research area was simulated according to the known parameters. Jinan City is located in the juncture zone between the hills in the middle and south of Shandong Province and the alluvial plain in the northwest of Shandong Province, featuring with obvious topographic characteristics. The topographic pattern has a certain influence on the spatial pattern of cities and towns. The spatial distribution of cities and towns in the study area contains a lot of fractal information. It is a typical area to study the fractal feature of the spatial structure of cities and towns. There are 145 township and sub-district offices in Jinan administrative area. When investigating the spatial connectivity of the regional point-axis system, only 19 cities and towns, sub-district offices, provincial and above development zones where the governments of different districts and counties in Jinan are located are selected. The data points of the distance between two cities and towns are N2=19*19=361.

After querying the relevant traffic mileage tables, the minimum road traffic distance between two points of 19 distribution towns are obtained, which is shown in Table 1. Statistical analysis of 361 distance data points shows that the data distribution of straight line distance and traffic distance is highly discrete, as is shown in Table 2.

**Table 1. Minimum road traffic distance between two points of distribution towns**

| Region | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| A | 0/0 | 6/8 | 67/76 | 44/51 | 70/71 | 4/6 |
| B | | 0/0 | 61/69 | 50/57 | 76/87 | 10/11 |
| C | | | 0/0 | 108/148 | 131/157 | 72/91 |
| D | | | | 0/0 | 72/100 | 40/71 |
| E | | | | | 0/0 | 70/78 |
| F | | | | | | 0/0 |

**Table 2. Data sheet of straight line distance and traffic distance**

| Distance type | Straight line distance | Traffic distance |
|---|---|---|
| Average value/km | 37.07 | 44.3 |
| Maximum value/km | 130.5 | 157 |
| Minimum value/km | 0 | 0 |
| Label difference/km | 26.95 | 33.71 |
| variance/km | 726.36 | 1136.25 |

Based on the spatial distribution map of Jinan town points and the attributes tables of straight line distance and traffic distance corresponding to 19 distribution town points, the corresponding calculation can be carried out by setting different scales and calculating the fractal structure of two kinds of networks.

### 3.2. Experimental results and analysis

On the premise of fractal calculation of network spatial structure based on artificial intelligence, it can be found that:

The spatial structure of Jinan's cities and towns is fractal, the regional cities and towns are in a state of agglomeration as a whole, and the spatial connectivity between the urban agglomeration and distribution points is strong.

The capacity dimension Dh > information dimension Di of Jinan cities and towns, which indicates that the spatial distribution of Jinan cities and towns is unbalanced. The approaching of information dimension Di to 1 further verifies that Jinan cities and towns point system is in the condition of axial agglomeration.

The spatial correlation dimension Dt of Jinan distribution town points based on traffic distance is slightly less than 1, which indicates that the distribution town points have close connection structure and strong connectivity.

Therefore, Jinan's town system should be in the development stage of point-axis system. On the basis of the existing spatial layout of town points, the distribution town points have initially formed an axial structure and reacted on the town point system to promote the balanced

distribution of cities and towns. The system has begun to have self-similarity and self-optimization.

However, the traditional fractal calculation of network spatial structure can not effectively analyze and calculate the town spatial structure of Jinan, which shows that the fractal calculation of network spatial structure based on artificial intelligence has high effectiveness.

## 4. Conclusions

In this paper, the research on fractal calculation method of network spatial structure based on artificial intelligence is proposed. By introducing artificial intelligence, determining the data of network spatial structure, and constructing the fractal calculation model of network spatial structure, the research on fractal calculation method of network spatial structure based on artificial intelligence is completed. The experimental results show that the fractal calculation of network spatial structure based on artificial intelligence is effective and can be used in urban planning. It is hoped that this research can provide technical reference for the impact analysis of logistics enterprises on logistics quality.

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