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Feature Extraction Method of Urban Road Network Structure Based on Fractal Algorithm

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The structure of an urban road network affects the smoothness of traffic flow. There are several problems with the existing feature extraction methods applied to the urban road network structure, such as the time it takes to extract features and the great number of feature extraction errors. In this paper, a method for extracting urban road network features is designed based on a fractal algorithm. The proposed method involves: analyzing the urban road network structure and road network density, and determining the hierarchical relationship of urban road network structure. The polarized light intensity is reduced by means of the Stokes vector to obtain an image of the urban road network structure. The different gray values of this image are transformed by the three-component method using the average gray value to obtain the image. The average filtering method is used to complete image preprocessing. The core algorithm of the fractal algorithm is analyzed, the dimension of the urban network structure is divided with the Koch curve, the terrain slope and surface fluctuation of the urban road network structure are determined, and the feature extraction is achieved by means of the fractal algorithm. The experimental results show that the proposed method can effectively improve the accuracy of the feature extraction and reduce the number of extraction errors. Furthermore, the proposed extraction process is relatively simple, cost-effective, and feasible.

Keywords: Fractal algorithm: urban road network; structural features; extraction method; three-component method; Koch curve

1. INTRODUCTION

Urban streets are an important external space in a city. Since they first emerged, urban streets have evolved to meet the needs of people when moving from one location to another– first by walking, then by horse-drawn carriage, and finally by car during industrial era. Urban streets have undergone great changes. Roads have become wider and longer. Wide asphalt roads carry an increasing amount of urban traffic [1]. Cars can access remote places that are difficult to reach on foot. It seems to have become a matter of course that cars can travel as far as houses can be built and cities can be paved. In order to ensure that travel by car is quick and comfortable, road traffic planning experts have suggested various professional methods, such as hierarchical construction of urban roads [2]. The interspersed viaducts, expressways and other special lanes constructed for cars have come rapidly one after the other, giving vehicles more dedicated space, but gradually eroding a lot of pedestrian space. The rights-of-way of pedestrians and non-motor vehicles have been occupied by cars or even denied to pedestrians again and again. The once beautiful transportation dream facilitated by cars has also become the nightmare of some congested cities today. The street is like the living room of a city. It is the most important public place in the city. The interaction between people, the urban traffic and the flow of energy are carried out on the street all the time. Beautiful streets make the city beautiful, smooth roads make the city run smoothly, and a reasonable road network structure improves the transmission and flow of products, information and energy of the city [3].

The urban road network is composed of various interconnected roads in the city [4]. The network and skeleton formed

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by the interconnection of roads with different functions and levels is intended to make the road division clear and smooth traffic. There are various types of road structures such as grid, ring radiation, etc. The structure of an urban road network affects the development of the whole city [5]. Therefore, research on the structural characteristics of urban road networks has become crucial to the design of an urban road network structure. The rationality and smoothness of urban road network structure planning are closely related to its characteristics [6]. Therefore, many researchers have focused on developing algorithms that can effectively extract the structural features of an urban road network, and achieved some notable results.

Wang et al. [7] proposed an intelligent road extraction method based on structural features present in remote sensing images. Using the unique structural characteristics of a road network, these researchers propose a road extraction method based on structural feature representation from two perspectives: road network structural similarity loss function and structural feature operator. Firstly, focusing on a small number of road targets in remote sensing images, a codec network structure with shallow depth and high resolution was designed. Secondly, the structural similarity loss of road network was introduced, and a road structural feature descriptor was proposed to optimize the results of feature extraction. This method can effectively analyze road features through remote sensing images, but the extraction process is complex and needs to be concise. Zhang et al. [8] proposed a method for mining the key nodes of an urban road network based on the amount of spatial traffic and extracting the structural features of a network. This method was an attempt to address the problem that the traditional methods used for the identification and management of key nodes in an urban road network do not consider the influence of multiple factors such as structure and flow, the presence of too many weight parameters and strong subjectivity. Zhang et al. [8] introduced two new concepts of node spatial flow degree and network structure flow entropy, constructed a directed weighted road network model, and proposed an identification method for urban key nodes based on the level of spatial flow. Taking the road network within the Fourth Ring Road in Beijing as an example, the distribution of traffic number and traffic speed of the road network are analysed, and the effectiveness of different methods is compared. However, this feature-extraction method is subject to errors, which ultimately leads to poor planning decisions. Lin et al. [9] proposed a compressed sensing image reconstruction method integrating spatial location and structure information, which is used to extract the structural features of an urban road network. Firstly, the initial estimated value of the image block is obtained by linear mapping of the observed value. Then, the spatial position information and structure information are extracted from the image, enhanced and fused based on the block grouping reconstruction branch and the full image reconstruction branch. Then the final reconstructed image is obtained by fusing the output of the two branches by means of the weighting strategy. In the block grouping reconstruction branch, reconstruction resources are allocated according to the data characteristics of image blocks. In the full image reconstruction branch, the information of adjacent image block pixels is exchanged through bilateral filtering and the structural feature interaction module. With this method, the focus is on the image, and its application to the feature extraction of road network structure is not comprehensive.

In order to address and solve the problems inherent in the aforementioned methods, in this paper, an urban road network structure feature extraction method is designed based on fractal algorithm. After the initial acquisition and preprocessing of the road network structure image, the structural features of urban road network are extracted with the help of the fractal algorithm and theory. This is done with the steps described below.

Step 1: Analyze the urban road network structure and road network density, and determine the hierarchical relationship of urban road network structure;

Step 2: Reduce the polarized light intensity with the help of Stokes vector to obtain the urban road network structure image, and convert the different gray values of the urban road network structure image through the average gray value using the three-component method to obtain the urban road network structure image. The mean filtering method is used to remove the noise in the image of urban road network structure, and the image acquisition and preprocessing of urban road network structure are completed.

Step 3: Analyze the core algorithm of fractal algorithm, divide the dimension of urban network structure with a Koch curve, determine the terrain slope and surface fluctuation of urban road network structure, and complete the feature extraction of urban road network structure using the fractal algorithm.

Step 4: Experimental analysis.

Step 5: Conclusion and future work.

2. IMAGE ACQUISITION AND PREPROCESSING OF URBAN ROAD NETWORK STRUCTURE

2.1 Urban Road Network Structure

In order to extract the characteristics of urban road network structure, it is necessary to clarify the meaning of 'urban road network structure'. Therefore, before extracting the image of urban road network structure, this paper examines the relationship between urban road network structure and its level.

In the urban road network structure, the road system can achieve good overall performance only if it consists of a reasonable and stable combination of elements including overall form, grade configuration, arrangement mode, connection mode, etc. [10]. Road network structure is a comprehensive concept. Different road network structures can be derived from different angles of road network composition. Some scholars divide the road network structure into three types: functional structure, hierarchical structure and layout

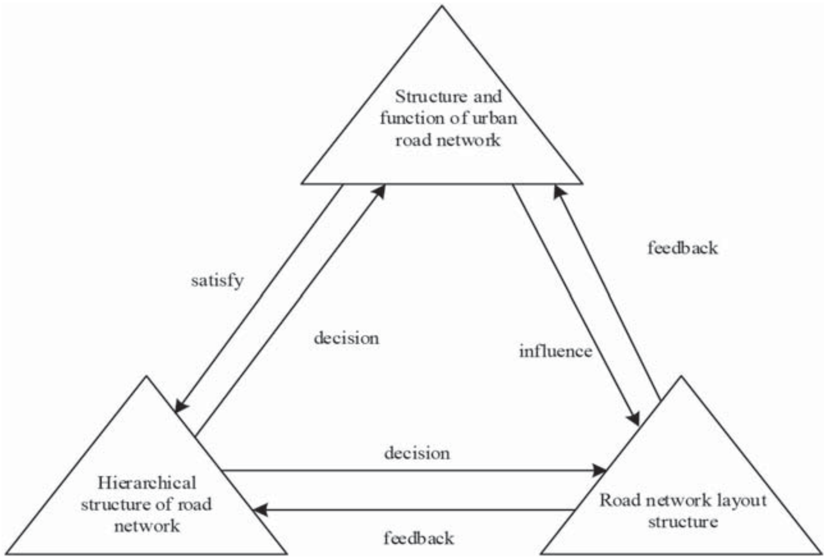

Figure 1 Schematic diagram of the relationship between urban road network structure, hierarchical structure and layout structure.

Table 1 Regulations on urban road network density.

	City size and population (ten thousand people)		Expressway	Arterial road	Secondary trunk road	Branching
Density of road network (km/km^2)	large city	> 200	0.4–0.5	0.8–1.2	1.2–1.4	3–4
		<= 200	0.3–0.4	0.8–1.2	1.2–1.4	3–4
	Middle city		-	1.0–1.2	1.4–1.4	3–4
	small city	> 5	-	-	3–4	3–5
		1–5	-	-	4–5	4–6
		< 1	-	-	5–6	6–8

structure. They discuss the essential characteristics of urban road network structure in terms of these three structural characteristics. The meaning of road network structure is not limited to any one of the three aforementioned structures. The spatial layout of roads with different functions and grades in the city combine to form the road network structure. The road network structure is an organic combination of these three structures, and there are some inevitable connections and complex relationships among them [11], as shown in Figure 1.

In the urban road network structure, the road's functional structure affects the road layout, and the function needs the layout corresponding to it. In turn, the road layout structure reflects the functional structure. In addition, the road function structure also determines the hierarchical structure, that is, the kind of function that requires a corresponding road level to match it. The hierarchical structure also determines the layout structure of the road, and the layout structure is constantly fed back during use. At this time, an unsuitable road hierarchical structure should undergo timely adjustment [12]. The three structures are interrelated and adapt to each other. When the three are balanced, the urban road network can operate well.

The road design standard code used in the planning of many cities in China is the code for planning and design of urban road traffic (gb50220-95). The provisions regarding road network density specified in the code are shown in Table 1.

The code stipulates that when the building floor area ratio in the central area reaches 8, $\overline{the}$ branch network density should be 12–16 km/km^2; the branch network density in general commercial concentrated areas should be 10–12 km/km^2. The secondary trunk road and branch road network should be divided into 1:2–1:4 rectangular grids: the intersection spacing should be increased along the main traffic direction.

2.2 Image Acquisition and Preprocessing of Urban Road Network Structure

In order to extract the features of an urban road network structure, it is necessary to collect an image of the structure, and use this as the basis for feature extraction. Because the urban road network structure image is different from the general image, it is usually acquired by infrared technology in order to reduce the influence of external factors on the urban road network structure. In this paper, the image of urban road network structure is obtained by reducing the intensity of polarized light using Stokes vector [13].

In the extraction, the angle of the urban road network structure image is a_1, the linear polarization component b_1, b_2 obtained from the decomposed incident radiation of different coordinate systems, the radiating circular polarization component b_3, the rotating infrared polarization sheet, and the starting polarization angle β and Stokes parameters are:

$$P = a_0 + b_1 \tan(2\beta) + b_2 \cos(2\beta) \tag{1}$$

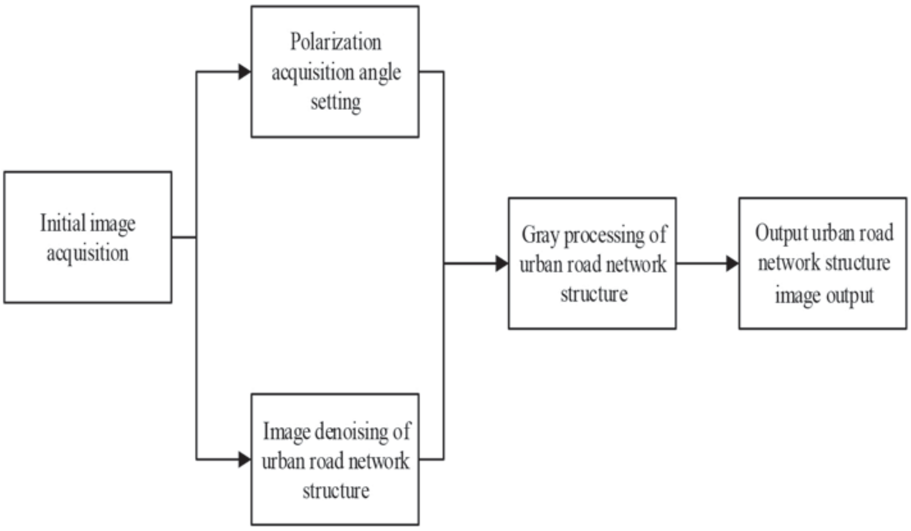

Figure 2 Image acquisition and preprocessing process of urban road network structure.

where P represents the collected structural image of urban road network, and a_0, b_1, b_2 represents the three components of Stokes.

Assuming there is the same distance between the different angles of the urban road network structure images, $\beta_i = 2\pi i/n, i = 1, 2, 3, \cdots, n$. Then, the urban road network structure image is obtained by Formula (2):

$$P' = \beta_i \frac{\sqrt{b_1^2 + b_2^2}}{a_0} \tag{2}$$

By means of the polarization device 360, the urban network structure image is collected at every 30 minutes, maintaining the real-time update of the urban network structure image, and taking it as the initial image of the study.

The original image of the urban road network structure does not meet the standards specified in the image processing technology in terms of format, pixel, brightness and definition. Therefore, without preprocessing, the feature sextracted from the urban road network structure will be less accurate [14]. Therefore, in this paper, the image is preprocessed.

Firstly, the image lines need to be converted into gray images. For the gray-scale processing of the image, firstly, the three component pixel values in image are extracted as the gray-scale values of three gray-scale images using the component method [15], that is:

$$gray = \begin{cases} G1\ (i, j) = r(i, j) \\ G2\ (i, j) = g(i, j) \\ G3\ (i, j) = c(i, j) \end{cases} \tag{3}$$

In formula, $G1/G2$ and $G3$ are different gray values representing the three components of urban network structure images. For r, g, c, the three primary colors of the image, $r(i, j)/g(i, j)$, and $c(i, j)$ respectively, are the pixel values of the image at the point.

After obtaining the maximum value of the three component pixel values of the image, the average value of the sum of the three component pixel values in the image line is calculated, the average gray value of the image is obtained, and the gray processing of the image is completed,namely:

$$gray(i, j) = \frac{r(i, j) + g(i, j) + c(i, j)}{3} \tag{4}$$

Through the three-component method, the different gray values of the image are transformed through the average gray value to obtain the urban road network structure image, which enables better noise reduction of urban road network structure feature extraction.

Because there is still more noise in the grayed urban road network structure image, which affects the effective extraction of image features, in this paper, denoising of the image is conducted, as described below.

The mean filtering method is used to process the noise in the image. A pixel is randomly selected from the urban road network structure image as the center point, and then a square field around the center point is determined [16], the pixel values of all points in the square field are counted, the average value is calculated, and the filter window is used to move up, down, left and right on the image, so that the value of the center position of the window is replaced by the calculated average value. This process denoises the urban road network structure image, that is:

$$q = \frac{\sum_{(i,j)\in p} g(i, j)}{N} \tag{5}$$

where q represents the gray value of any pixel point; $g(i, j)$ represents the original image where the center point pixel is (i, j); p represents the set of all neighborhood pixels in the filter window of the center point; N represents the total number of pixels in p.

The image acquisition and preprocessing of the urban road network structure is shown in Figure 2.

In the image acquisition and preprocessing of urban road network structure, the polarized light intensity is reduced with the help of the Stokes vector to obtain the image of an urban road network structure. The different gray values of urban road network structure image are transformed by the three-component method through the average gray value to obtain the image of urban road network structure; The mean filtering method is used to remove the noise in the image of urban road network structure, and the image acquisition and preprocessing of urban road network structure are completed.

3. FEATURE EXTRACTION OF URBAN ROAD NETWORK STRUCTURE BASED ON FRACTAL ALGORITHM

3.1 Fractal Algorithm

Many phenomena in nature show very complex characteristics, such as unpredictable clouds, overlapping peaks, leafy trees, running rivers, wind driven lightning and the shape of coastline. These complex features cannot be characterized by regular graphics such as points, lines, surfaces and bodies in European space. In order to solve this dilemma, American mathematician Mandelbort proposed the concept of "fractal" [17]. A fractal can also be regarded as a set of several characteristics. After constant revision by many scholars, five typical characteristics of a fractal are given:

(1) A fractal has fine structure, that is, there are arbitrarily small-scale details.

(2) A fractal is very irregular, and its whole and part cannot be described by traditional geometric language.

(3) A fractal usually has some form of self-similarity, which may be approximate or statistical.

(4) The fractal dimension of a fractal defined in some way is generally greater than its topological dimension.

(5) In most cases, a fractal can be defined in a very simple way and may be generated by iteration.

In Euclidean geometry, dimension is an important characteristic of geometric objects. It is used to determine the number of independent coordinates or independent directions required for a point in geometric objects. For example, a coordinate is needed to determine the point on a straight line, indicating that the dimension of the straight line is 1; two coordinates are needed to determine the point on a plane, indicating that the dimension of the plane is 2; three coordinates are needed to determine the point in a solid, indicating that the dimension of the solid is 3. This dimension in Euclidean geometry is called topological dimension, and they are all integers. However, the integer dimension is not enough to describe various complex phenomena in nature such as clouds, lightning and so on. Therefore, in fractal theory, the concept of dimension is further extended from the integer domain to the real domain. The dimension of a fractal is generally fractional, but there are also cases where the dimension of a specific fractal is an integer [18].

Of the five typical characteristics of a fractal, its self-similarity is easy to describe, and the fractal dimension is an important physical quantity used to measure the self-similarity of a fractal. Four typical fractal dimensions are self-similarity dimension, box dimension, information dimension and capacity dimension. The self-similarity dimension is the most intuitive, reflecting the self-similarity of the split form. It is usually expressed by the symbol V, and is defined as: given a fractal graph, the scaling factor u (the multiple of the graph) and the number of subblocks required to generate a new graph are:

$$e = u^V \tag{6}$$

where e represents the number of subblocks required to form a new drawing.

The box cover method can effectively calculate the fractal dimension of some ungauged fractal, overcoming the shortcomings of the self-similarity dimension, and the method is widely used in fields such as image detection. Box dimension is defined as: the box size is *3*, $\eta_\theta(u)$ is the minimum number of boxes required to cover the set, that is:

$$V_b(u) = \lim_{\vartheta \to 0} \frac{\log \eta_\vartheta(u)}{\log 1/\vartheta} \tag{7}$$

When calculating the box dimension, only the number of boxes is considered, not the difference in the number of nodes covered by each box [19]. Therefore, the concept of information dimension is proposed and defined as follows:

$$V_i = \lim_{\vartheta \to 0} \frac{\sum_{i=1}^{n} k_i(\vartheta) \ln p_i(\vartheta)}{\ln \vartheta} \tag{8}$$

The capacity dimension is derived from Kolmogorov and is usually expressed in V_c. The basic idea has yet to cover the partition form. Specific definition: assume that a circle or sphere of radius R to cover the partition, if the minimum number of circles or balls required to cover the partition $M(R)$, the V_c value is:

$$V_c = \lim_{R \to 0} \frac{\ln M(R)}{\ln(1/R)} \tag{9}$$

3.2 Feature Extraction of Urban Road Network Structure

To sum up, the application of fractal theory to the feature extraction of urban road network structure is effective, and the fractal dimension can be used as an effective tool to describe the spatial structure of urban traffic network. The fractal dimension value of urban road network reflects the centralization of cities and the perfection of a road system in an urban structure. The traffic network is the backbone of urban spatial structure. The fractal dimension of urban traffic network shows the fractal characteristics of urban road network structure. Therefore, using fractal theory to explore the complexity of traffic network distribution has important practical significance. When the road system reaches a better fractal shape, it can form an efficient spatial network and improve the urban road traffic system [20].

In order to better obtain the feature extraction of urban road network structure with the help of the fractal algorithm, the image data obtained above needs to be regarded as the main data for feature extraction. These data are converted into a square and the length of each side is extended to four times the original, as shown in Figure 3.

The D-dimensional geometric objects in the urban network structure image are set as an independent direction and

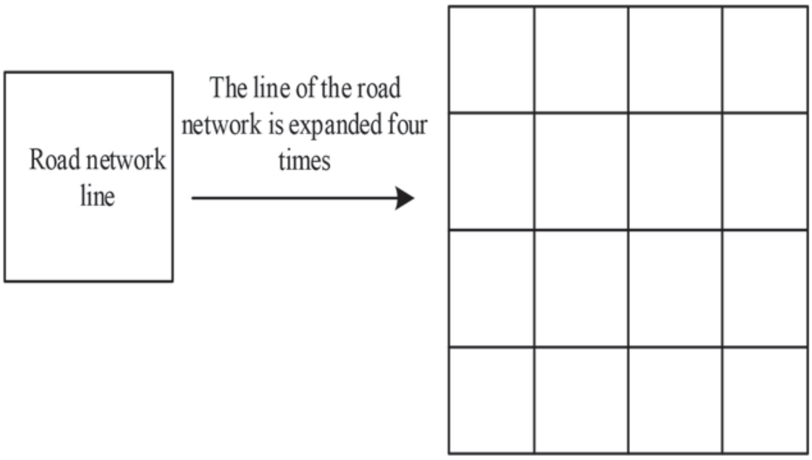

Figure 3 Schematic diagram of the expansion of the image data of the urban road network structure.

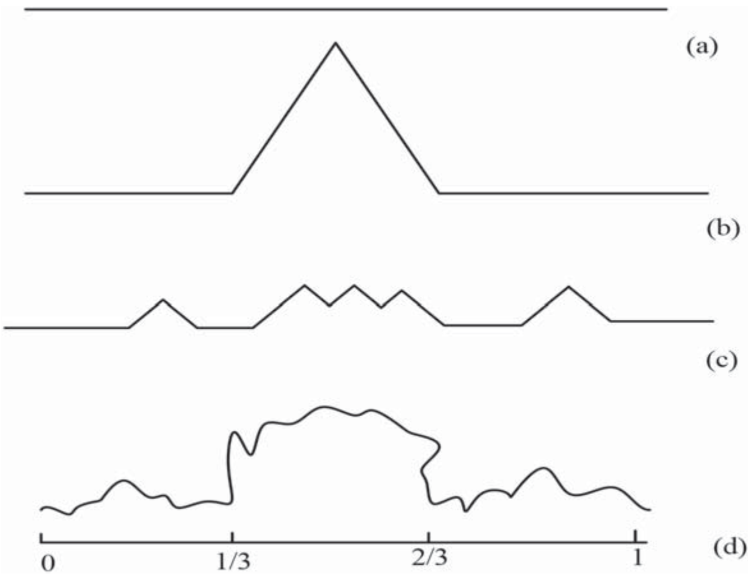

Figure 4 Schematic representation of the Koch curve.

increased to the original L times. The result is n initial urban network structure image data. The relationship between these three data images is $l^d = N$. For ordinary objects of European geometry, this relationship is:

$$d = \frac{\ln N}{\ln l} \tag{10}$$

The topological dimension d as defined by Formula (10) is all integers in Euclidean geometry. If d is not restricted as an integer, its generalization can be defined as the dimension in the fractal geometry, called the fractal dimension, and recorded as:

$$V = \frac{\ln N}{\ln l} \tag{11}$$

Then to analyze the problem from a practical perspective, a ruler of length R is used to measure the curve in the structural image of an urban road network, in N times after the complete curve measurement, the length of the curve can be approximate as:

$$C = N \times R \tag{12}$$

Because the curve of the measured urban road network structure image is irregular, the measurement results of C choose different lengths. R changes with C, and the time R is smaller, the measured L is closer to the true length. When $R \to 0$:

$$C = \lim_{R \to 0} N \times R \tag{13}$$

Based on the determined urban road network structure image curve, the fractal dimension value of the specific urban road network structure image is calculated by means of the Koch curve in the fractal algorithm. The Koch curve is shown in Figure 4.

In Figure 4, the unit segment is a 1. Divide a into three equal parts, and replace the middle part with two broken lines with side length of 113 into B 2. Divide each segment in B into three segments, and replace one segment in the middle of each segment with two broken lines with side length of 1/9 to obtain C 3. Repeat continuously, and Koch curve D is generated after countless iterations. In terms of the construction method, the Koch curve can be divided into four parts where each part is 1/3 of the original, so $n = 4$, $r = 3$, then the fractal dimension of Koch curve is ≈ 1.26.

When the fractal dimension is larger, there are more network edges with edges passing through the grid, the

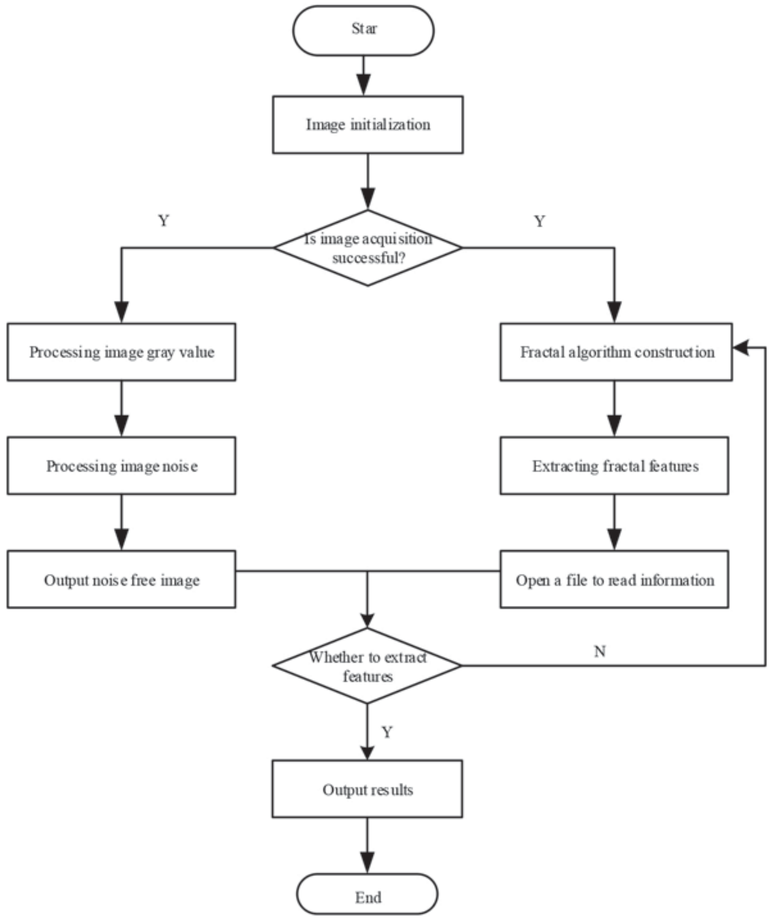

Figure 5 Schematic diagram of fractal algorithm for extracting structural features of urban road network.

similarity between the new network and the original network is higher, and the coverage of the urban road network structure is better. A value of 2 indicates complete self-similarity (each grid has the edge of the network passing through). Coverage reflects the quantitative degree of road network uniformity. Under the same road network density, the more uniform the route distribution is, the higher is the road network coverage index value, and the better is the accessibility. According to this theory, the main characteristics of urban road network structure are extracted.

In an urban road network structure, the slope of the road is a key feature affecting its structure. The formula for extracting the slope feature of the urban road network structure is:

$$H = \tan^{-1}\sqrt{t^2 + z^2} \tag{14}$$

Specifically, t represents the slope of the urban road network structure, and z represents the degree of variation of the midline units in different directions.

According to the determined slope of urban road network structure, the absolute slope of urban road network structure is extracted to obtain:

$$|H| = \frac{1}{4(N-1)}\sum_{b=1}^{n}\left(\frac{|z_c - z_b|}{w(n-1)/2}\right) \tag{15}$$

where $|H|$ represents the absolute slope, N represents the moving window size, z_c represents the moving window center cell elevation value, z_b represents the value of the moving window edge cell elevation, and w represents the raster size.

The surface relief in an urban road network structure is also its key characteristic. The formula of surface relief in urban road network structure is calculated by the projection area method in the fractal algorithm, and the following is obtained:

$$S_l = \int_v (1 + f_x^2 + f_y^2)^{1/2} dx dy \tag{16}$$

where S_l represents the surface fluctuation of urban road network structure, f represents the area value of urban road network structure, dx represents the integral area, and dy represents the partial derivative of the function.

According to the determined main key features of urban road network structure, the final result of feature extraction is obtained with the help of the fractal algorithm:

$$\varphi = \frac{\sqrt{\left(\sum_{i=1}^{n} x_i\right)^2 + \left(\sum_{i=1}^{n} y_i\right)^2 + \left(\sum_{i=1}^{n} z_i\right)^2}}{n} \tag{17}$$

where φ represents the final result of urban network structure feature extraction, and $x/y/z$ represents the different directions of urban network structure.

The dimension of urban network structure is divided using the Koch curve, the terrain slope and surface fluctuation of urban road network structure are determined, and the feature extraction of the urban road network structure is completed using the fractal algorithm, as shown in Figure 5.

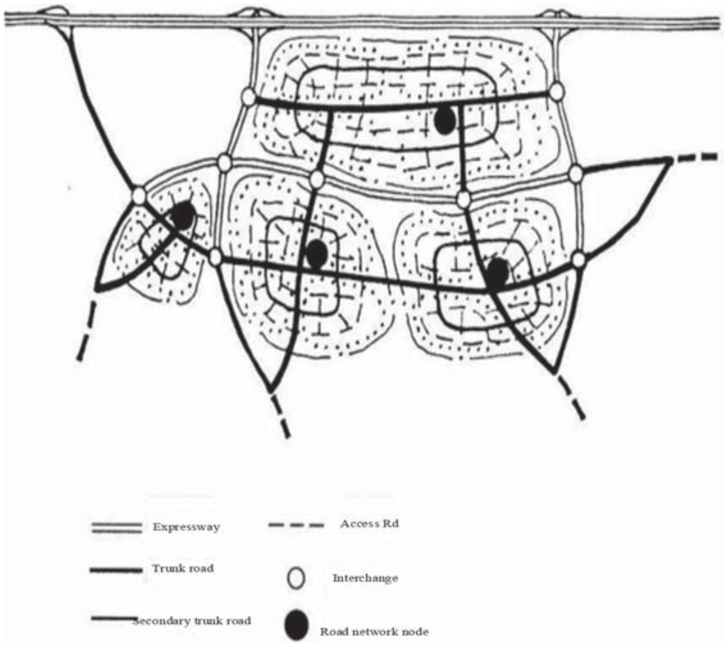

Figure 6 Schematic diagram of the urban road network structure in the study area.

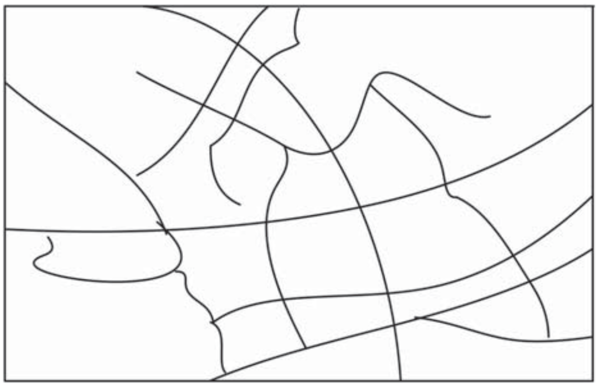

Figure 7 Freestyle structure diagram of the studied regional urban road network structure.

4. EXPERIMENTAL ANALYSIS

In order to verify the scientific effectiveness of the proposed method, experimental analysis was conducted. In order to determine the feasibility of this method, the experiment was carried out by comparing the results obtained by the proposed method with those of two traditional methods. This experiment involved: selecting experimental objects, designing experimental environment, collecting urban road network structure images and, finally, completing the extraction of urban road network structure features. Following this process, the extraction results obtained by each of the three methods were analyzed to determine the feasibility of the proposed method.

4.1 Experimental Scheme Design

In the experiment, taking a certain area of a city as the research subject, the structural characteristics of urban trunk roads, secondary trunk roads and branch roads in this area were extracted. The study area is a typical strip city, which is limited by the natural terrain, and urban characteristics, activities and functions. In order to further improve the central city status of the city and strengthen the urban functions, the urban functional structure needs to move from the valley basin in order to improve the urban layout and spatial structure from a larger perspective. The schematic diagram of urban road network structure in the study area is shown in Figure 6.

By intercepting the minimum block scale, medium block scale and maximum block scale of the study area, it can be seen that the block scale interval of the core area of the area is between 183m–668m, most block scales are about 500m–550m, and the block scale is large. The structure of the urban road network in this region is shown in Figure 7.

In the experiment, the GIS software counted the number of grids with different scales of grid coverage based on the software. The corresponding grid scale and the statistical non-empty grid number were drawn and plotted on the two-log coordinate map, and the statistical results were fitted according to the relevant formula of the fractal dimension. The obtained number of grids with roads passing under different scale grid coverage is shown in Table 2.

Table 2 Grid size and number of non-empty grids in traffic network of the study area.

Grid size (M)	20	40	80	160	320	640	1280
Non-empty grid size (M)	5678	5341	1301	2310	3541	24	15

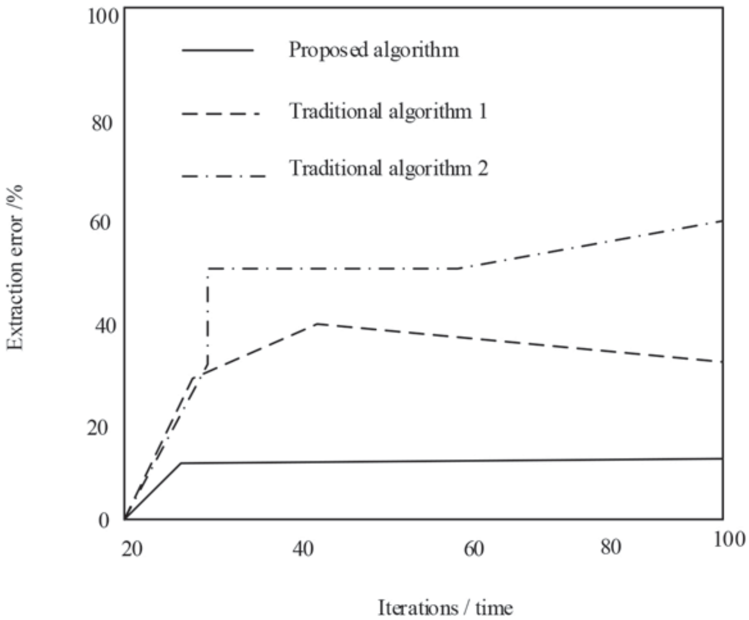

Figure 8 Error analysis of urban road network structure features extracted by different methods.

Following the above experimental environment and scheme design, the urban road network structure features of the study area were extracted. In the experiment, the error of urban road network structure feature extraction, the time cost of extraction and the accuracy of fractal calculation of road network structure features were taken as the experimental indicators. The experimental data were iterated several times, and the results were averaged.

4.2 Experimental Analysis

In the experiment, firstly, the proposed method, traditional method 1 (Reference [7]) and traditional method 2 (Reference [8]) were applied to extract the structural features of urban road network in the selected study area. The feature-extraction error rates of the three methods are shown in Figure 8 for comparison.

The results depicted in Figure 8showthe feature extraction errors obtained by the three methods used to extract the structural features of urban road network: the proposed method, traditional method 1 (Reference [7] method) and traditional method 2 (Reference [8] method) when applied to the urban road network selected for the experiment. The extraction errors of the two traditional methods are as high as 60% and 45%, while the extraction error of the proposed method is always less than 20%.

In the experiment, the performances of the proposed method, traditional method 1 (Reference [7] method) and traditional method 2 (Reference [8] method) are analyzed to extract the structural features of urban road network in the study area selected in the experimental scheme. The time cost of extracting the structural features of an urban road network by means of the three methods is shown in Figure 9.

The results presented in Figure 9 show that the proposed method, traditional method 1 (Reference [7] method) and traditional method 2 (Reference [8] method) extract the structural features of urban road network in the study area selected in the experimental scheme. There are some differences in the time cost of extracting the structural features of urban road network compared with the three methods. Among them, the time cost of the proposed method for urban road network structure feature extraction always remains low, and is always less than 1.5s, while the time cost of the other two methods is higher than that of the proposed method. The verification of this index also changes with the change of extraction area. Therefore, the current experimental results are effective only for the time cost of the current sample area.

The experiment determined the accuracy of the proposed method, traditional method 1 (Reference [7] method) and traditional method 2 (Reference [8] method) in the fractal calculation of the structural characteristics of the road network in the sample area. The results are shown in Table 3.

From Table 3, it can be seen that the accuracy of the proposed method, traditional method 1 (Reference [7] method) and traditional method 2 (Reference [8] method) in the fractal calculation of the structural characteristics of the road network in the sample area remains relatively stable, and the accuracy of the fractal calculation of the structural characteristics of the road network in the sample area is within a reasonable range. However, when comparing the overall values of the proposed method, traditional method 1 (method [7]) and traditional method 2 (method [8]), it can be seen that the accuracy of fractal calculation of road network structure

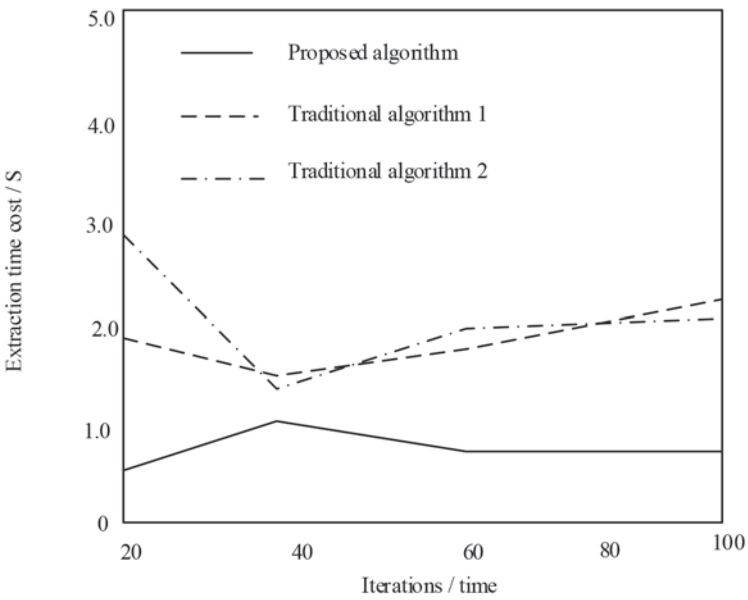

Figure 9 Time cost analysis of extracting structural characteristics of urban road network by different methods.

Table 3 Accuracy of fractal calculation of road network structure characteristics in sample areas with different methods (%).

Number of iterations/times	The proposed method	Traditional method 1	Traditional method 2
20	95	90	89
40	96	90	88
60	96	91	90
80	95	90	88
100	96	92	90

characteristics in the sample area by using the proposed method is always maintained at about 95%, which is higher than the other two methods.

5. CONCLUSION

In order to solve the problems of a great number of feature extraction errors and large time cost incurred by current extraction methods, this paper proposes a method for extracting the features of an urban road network structure, based on the fractal algorithm. The urban road network structure and road network density is analyzed, and the hierarchical relationship of urban road network structure is determined. The polarized light intensity is reduced by means of the Stokes vector to obtain the urban road network structure image. The different gray values of the urban road network structure image are transformed by the three-component method using the average gray value to obtain the urban road network structure image. The mean filtering method is used to remove the noise in the image of the urban road network structure, and the image acquisition and preprocessing of the urban road network structure are completed. In this paper, we analyze the core algorithm of fractal algorithm, divide the dimension of urban network structure with Koch curve, determine the terrain slope and surface fluctuation of urban road network structure, and complete the feature extraction of urban road network structure with fractal algorithm. The experimental results show that the proposed method can effectively improve the accuracy of urban road network structure feature extraction, reduce the extraction error, and the extraction process is relatively simple, reducing the time required for the extraction.

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