

The Application of Fractal Theory Based on Urbanization Evaluation ----Urumqi City as example

Tashpolat Tiyip ZhangWei
XinJiang University, China
Geography Department
Tash@xju.edu.cn

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PURPOSE:

Urbanization is a very complicated transforming process. There are many difficult point in urbanization evaluation. It's undoubtedly more objective and accurate to evaluate urbanization level by quantitative methods. but, there are some difficult point : what Indexes should be chosen and how to quantify these indexes, so it can embody the intention of the urbanization.

By discussing the intention of the urbanization, the conclusion can be obtained that the spatial urbanization level as part of the urbanization level contains more information, and fractal theory can be used for evaluating its level. By using remote sensing digital image as data source, and based on the GIS, the fractal theory is used to study the Urumqi city urbanization process in 8 years in this paper.

1.The Importation of fractal theory

1.1 Urbanization and urbanization evaluation

As the research of urbanization comes widely and deeply, peoples have the common sense to nature and character of urbanization:

- (1)Urbanization is a continual ,dynamic, deep process;
- (2)Urbanization is the result of economic and social development, is a widely space phenomenon ;
- (3)Urbanization is a difficult multidimensional problem concerning economic, social, regional space, population aspects and has abundant and comprehensive nature.

Objectively speaking, as for a multidimensional problem like this, complicated index method should be used to set up a overall and representative index system, to measure the degree, rate and distribution of urbanization form different levels and aspects. Theoretically, this method is objective, rational and complete, but exists many difficulties about theory and technology, such as the building of evaluation index system, the relation of different indexes and quantification of indexes.

Evaluation index should reflect the connotation of urbanization completely and deeply. Such indexes reflect spatial urbanization level, economic urbanization level, population urbanization level, lifestyle urbanization level should be selected. And economic urbanization level, spatial urbanization level, population urbanization level, lifestyle urbanization level are linked and improved each other. Generally speaking, economic urbanization is the base, spatial and population urbanization is the expression of economic urbanization, and as a result they improve the social development, the improvement of living standard, lifestyle is more enlightened and modern. Mathematical language is changed to illustrate, the four have connection with each other, but they do not exist linear single function relation. The relationship decides that it can measure the urbanization level on horizontal index of any aspect, and there is always deviation to adopt any single index to evaluate urbanization level. It is the reason why in a sense urban population rate can evaluate urbanization level but has some deviation.

Essay [4] choices 14 sub-index reflected economic urbanization level, spatial urbanization level, population urbanization level, lifestyle urbanization level to build evaluation system, what we are concerns here is the relation between indexes and No.1 main part, so the compositor result is arranged

The Sorted Table of Sub-Index with No.1 Main Part coefficient

Index	L11	E1	L12	S9	S10	L13	E2
coefficient	0.9726	0.9612	0.9564	0.9201	0.9176	0.9135	0.8810
Index	P5	L14	P6	E3	S8	P7	E4
coefficient	0.8451	0.8277	0.9129	0.7782	0.6262	0.3410	0.0773

E*: economic urbanization level; S*: spatial urbanization level;
P*: population urbanization level; L*: lifestyle urbanization level

The bigger the relative modulus is, the closer the index and urbanization development level is. The above arranged result illustrates the following rule: lifestyle urbanization level sub-index generally is arranged the first, spatial urbanization level sub-index second, generally used population urbanization level sub-index the last.(No 6.10,13)

This means lifestyle urbanization level index include much urbanization information, and the urbanization information spatial urbanization level index included is much more bigger generally used population urbanization index.

The reason is that lifestyle urbanization index is the result of other indexes and has great connection with them, accumulate the “contribution” of other indexes to urbanization, therefore it must have connection with No.1 main part, And spatial urbanization level index and population urbanization level index are the same in status as exterior manifest of urbanization. But in China, because of some objective reason like statistics and policy, population rate index commonly can not reflect the true level of urbanization, spatial urbanization level is the direct reflection of population urbanization level. For example, as non-agricultural population increase, it will change urban land and public facilities in city. Spatial urbanization level index relatively reflect general level of urbanization and make it the first. So another idea is introduced: making use of spatial urbanization index to evaluate regional urbanization level.

But it is difficult to quantify the urbanization level index. The reason is that the connotation of spatial urbanization level is wide, includes formation of urban landscape, extent of urban spatial scope, the formation of urban group and urban zone, the increase of city quantity in the region, the grow of urban density.

In nature, the augment of spatial urbanization level displays on two aspects: In one hand, scale improves in order to accommodate more non-agricultural population; On the other hand, the improvement of urban facilities provide material guarantee for economic urbanization level, lifestyle urbanization level, the facilities include not only the increase of production section like factory, but also improvement of road net and increase of recreational place.

It is easily concluded that the comprehensive result of the two aspects shows in space as complication of urban space structure. In addition, the evaluation of urbanization as a continuous progress, aims at the violent degree on development and variation but not the attainable status.

Therefore, the quantification of urbanization level index should conform to the following demands: (1) embody the complex degree of urban spatial structure;(2) reflect the violent degree of urban space development and variation;(3) easily obtain and calculate.

The paper imports fractal theory in accordance with such demand and conclusion. The fractal theory mainly study the disordered system that have similarities. The fractal dimension is used in describing irregular degree of one fractal system quantitatively, that is the complex degree. Fractal dimension itself represents the rate and changeable trend of fractal system in a special application.

Therefore, as for this research fractal system represented spatial urbanization level is

set up, suitable fractal calculated method is chosen to calculate its fractal .To describe quantitatively spatial urbanization level and its violent degree of development and variation. Quantity index which objectively reflected spatial urbanization level is provided for urbanization level evaluation or another more suitable single index is provided.

1.2 The applicable character of fractal theory

Although the introduction of fractal theory has made progress in studying irregular entirety in many subjects, the theory is still in the beginning so that it still not find a fractal suitable for irregular entirety geometry. At present the application and research of fractal theory presupposes the existence of some fundamental fractal theory to find fractal formula suitable for research object combined with fractal character.

Experts like Kenneth Falconer, Takayashi, Bunshi, Ishitake generalized and advanced the common characters of fractal system(assembly): (1) similarities—it has a same figure with the original after a small part of it is enlarged corresponding times. (2) delicate structure—has arbitrarily small scale detail .(3) it is extremely irregular so that its whole and part can not be described by traditional geometry language. (4) common parameter can not be surveyed its size. (5) on most interesting conditions, this kind of can be introduced by a extremely easy way .

1.3 Fractal formula on researching urbanization

The object and the data source (Remote Sensing Digital Image) of the research decide that the choiced fractal method should accord with following demands: (1) Owing to the actual data don't exist clear non-scale range,

The method is not sensitive to non-scale range.(2) this calculated method possesses the character that don't change with scale, it's fractal value remain stable to image and data that have different level and scale.(3) The discrete character of remote sensing digital Image decides that it is not proper to adopt the fractal calculated method, the method is similar to the method which is stated from similarity to calculate coastline. (4) fractal value should have significance that has quickly developed trend.

This paper starts from the above demands, chooses a fractal calculated method based on measure relation.

B.B. Mandelbrot based on studying animal brain fractal structure and put forward the measure relation that animal brain structure satisfy the face square and volume:

$$S^{\frac{1}{D}} \propto V^{\frac{1}{3}} \quad (1)$$

S: Square V: Volume D: Fractal Value

And pointed out the sense of fractal obtained by this calculated method: the degree of D value has close connection with regional activity status. The greater the D value is, the more violent the activity is in the region; When D value is 1.5, it shows that this region is in Brown random activity status and possibly develops toward a direction or another.

Dong Lianke concluded calculated formula suitable for n-dimension Euclid-Space:

$$S^{\frac{1}{D_{n-1}}} = K \cdot r^{\frac{n-1-D_{n-1}}{D_{n-1}}} \cdot V^{\frac{1}{n}} \quad (2)$$

S: Square V: Volume D: Fractal Value K: Constant
R: Measure Scale n: Dimension Value

So according to n=2, parameter can be get .If A(r) represent i P(r) is same parameter, it concludes:

$$P^{\frac{1}{D}} = K \cdot r^{\frac{1-D}{D}} \cdot A^{\frac{1}{2}} \quad (3)$$

If the analyzed object is a fractal system, D is constant in the no-scale region. According to a measure yardstick, natural logarithm is get from two sides and arranged:

$$\ln A = \frac{2}{D} \ln P + C \quad (4)$$

Essay [3] proves the characters of this fractal calculated method through analyzing theoretically and calculating or proving for many experimental data: (1)stability of level—stability of image fractal calculation . (2)no-scale range wide, insensibility of no-scale range

1.4 Building of spatial urbanization fractal system

As for image manner, spatial urbanization manifests the exterior display of urbanization progress in regional space, is mainly the change of urban land and its influence on other kind land. So the utilized type map of urban land comprise of all information of spatial urbanization.

The research method in this paper decide a problem which need care is: Of the several land utilized types, which one most represents the change condition of land and its influence on other land types. Actually, the “shape” of urban land is conformed by change of it and developed action of other utilized type land and reflect the developed condition of spatial urbanization.

This paper choice satellite remote sensing digital image as data source. Therefor, land utilized type maps are get by image, and then urban land distributed map is chosen as fractal system of spatial urbanization.

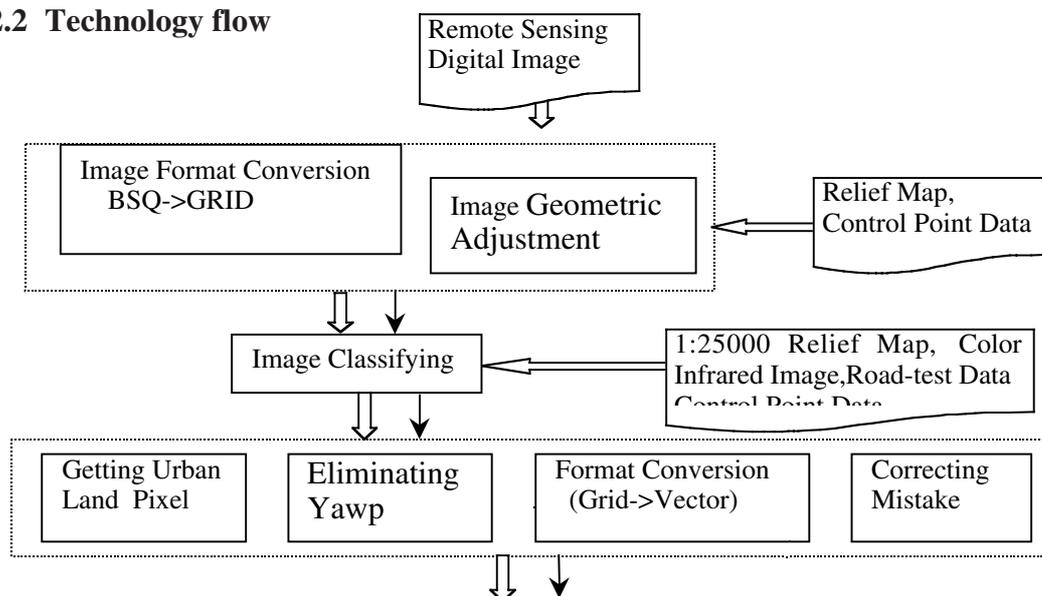
2. Image fractal experiment in researching urbanization

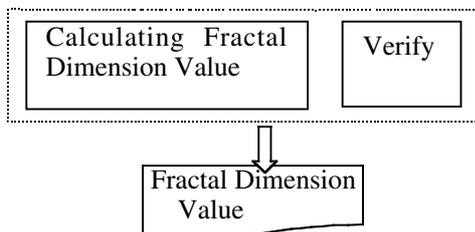
2.1 Present condition in researching region and remote sensing data

The remote sensing image in this paper is Landsat TM image 2,3,4 band. The region is south from Beimen Gate, north from Miquan county Sanquan village, west from the railway station, east from Ges’ village, Urumqi is the centre, the square is 30.72*30.72 kilometers.

In view of the research object and limitation of image data, the regional image is taken from the north of Beimen Gate as researching region, the transit extension is North Latitude $43^{\circ}48'16''$ - $43^{\circ}54'47''$, East Longitude $87^{\circ}27'06''$ - $87^{\circ}45'02''$. The images of three periods on Apr.17.1988, Apr.12.1992, Apr.21.1995 are used.

2.2 Technology flow





Graphic 1

This paper is adopts TM image as data source, the last needed result is fractal value of spatial urbanization fractal system in the researching area. Through deep consideration and experiment, the flow graph like graph 1 is choiced.

This paper uses ARC/INFO to complete the image geometric adjustment and classifying.

The land utilized type in the researching area is parted five kinds-- urban land, agricultural land, greenland, water area and other. In the process of partition, in order to improve the precision of partition, the kinds are classified serveral sub-class combined with spectrum character, for instance the greenland is sub-classified as mountain greenland, fruit orchard etc. The classified method uses as the most common method—maximum likelihood classifier.

Then get the urban land pixel from classified image, eliminate yawp, unite speckle, correct mistakes, convert to vector graphic, at last form the urban land vector map, and adopt it as the spatial urbanization fractal system.

2.3 The result of research

In the support of the above theory, means and technology, fractal value and result of presupposition are calculated showed as table 2.

Table 2

Year	Linear coefficient Index	Intercept	Slope	Sample Amount	F Value	F _{0.05}	Fractal Dimension Value
1988	98.1	-0.316	1.510	1279	20.614	3.84	1.32
1992	96.7	0.116	1.429	1383	21.981		1.40
1995	99.3	0.483	1.384	1505	41.709		1.45

3.Conclusion

The following conclusions are obtained by combining calculated result and other data:

- (1) The progress of urbanization of Urumqi is continuous from1988-1995 and it is a fact that people are realized. From the result of research, the fact that the fractal value of spatial urbanization fractal system in Urumqi increased 1.32 add to 1.45 from 1988 to 1995 is consistent with the actual situation. It reflects that the progress of spatial urbanization in Urumqi is continous and urbanization spatial structure is more and more complicated. It means that the fractal value can better manifest the level of spatial urbanization.
- (2) Physically sensing researching area of fractal value in 1995 was near 1.50, it means that the developed trend of researching area is in the condition of random. To which direction urbanization is developed, man-made factor is critical. It is estimated that urbanization progress of Urumqi will not stop or decay. In fact, the critical point has significance of classifying urbanization trend. The process of fractal value increasing from 1 to 1.5 is the process that fractal system develops from simpleness to complexity, it develops from occupying 1 dimension space to occupying 2dimension space. This is a process from regulation to abnormity. And the process from 1.5 to 2,is the fractal system develops from complexity to simpleness in 2 dimension space, from occupying not full and crash 2 dimension space to occupying 2 dimension space. These two process corresponding to two

phases of urbanization: mightily constructing city utilities And pay attention to inner adjustment and city planning. So, the main trend of the study area urbanization will transform from constructing to inner adjustment.

In the other hand, the index has advantages compared with other indexes: Firstly , it is very proper for analyzing and evaluating urbanization condition by TM image as data source. It manifest by its base of theory and technology flow. In addition, it should be pointed out that this method has for classified precision. Secondly, it is more objective and effective for the index of urban land rate. Area increase of urban land shows at change of fractal value, some results of plan and adjustment also show at change of fractal value. Fractal value itself reflects violent degree of development and variation on urbanization , so it has function which aims at trend.

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