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A Method for Generating Mountain of Predetermined Shape Based on GIS Data

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***Abstract*—Based on GIS data, a new algorithm for generating mountain terrain of predetermined shape is presented in this paper. During geographical analysis, topographic macro-attributes are convenient to grasp the general geography characteristic in huge GIS data, and four topographic macro-attributes are designed as target parameters of predetermined mountain. With the geography relativity, sample regions are selected around the mountain generating region in syncretizing region. Synthesis fuzzy similitude value of each sample, used to calculate sample weights, can be obtained by enduing different attribute weights to execute fuzzy similitude priority algorithm. Elevation matrix of generated mountain is figured out by adding weighted mean of the entire sample relief matrices with elevation matrix of generating region. According to geography uncertainty, there are errors between macro-attributes of generated mountain and target parameters. Generated mountain can be regarded as predetermined mountain by adjusting attribute weights to control each attribute error within the 10 percent range. Thereby different mountains can be gained as predetermined mountain to syncretize with surrounding physiognomy.**

Keywords- GIS; fuzzy similitude priority; predetermined shape

I. INTRODUCTION

The study of terrain generation has greatly improvement in computer graphics. Zhou Yuanhua [1]has succeed in applying fractal technology to simulate natural mountain growth, but it can not control the shape change; Tang Xiaoqin [2]proposed that overlapping the Gauss function surface with fractal surface to realize the mountain shape control, but change ability of Gauss function surface is limited to simulate the various natural terrain; K. Raiyan Kamal [3]has introduced Ployline Walk Algorithm to generate mountain by designing math features, which are pure complex mathematic quantities and do not accord with geography principle.

Methods above have following common shortcomings: ① They don't take predetermined mountain and surrounding terrain environment into account together. ② Mountain terrain data, derived from pure math count in computer graphics, can not be compatible with factual terrain data. ③ They don't define specific parameters to express the predetermined mountain shape and lack of mining topographic attributes.

Combined geography principle with fuzzy mathematics theory, a new algorithm is presented in this paper based on GIS data, which can generate mountain of predetermined shape in the factual physiognomy background, and put data mining technology and knowledge discovery in the same framework [4]. Thereby it has important application significance.

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II. TARGET PARAMETERS OF PREDETERMINED SHAPE MOUNTAIN

In geographical analysis, topographic macro-attributes are the statistic results of topographic micro-attributes. So taking macro-attributes as target parameters is helpful for grasping general feature of predetermined shape mountain to make it syncretize well with surrounding physiognomy. Four macro-attributes are designed as target parameters based on regular grid Digital Elevation Model (DEM), which is in common use as GIS data. Definitions of these attributes are given as follows and the later two attributes are proposed in this paper:

a) Average slope [5]*:* It is the arithmetic mean of the entire grids slope in the analysis region.

b) Relief amplitude [5]*:* It is difference between the maximum and the minimum of elevation in analysis region.

c) Saturation amplitude: Even though different mountains have the same relief amplitude, steep or gradual slope directly affects the mountain shape. The saturation is a digital expression for the phenomenon: column shape has been considered as the ideal saturation amplitude in this paper, which is defined as 1, but valleys in terrain make the saturation amplitude impossibly to reach 1. The saturation is：

$$sat = \frac{h_1 \ldots + h_{i-1} + h_i + h_{i+1} + \ldots h_n}{n h_{\max}} \tag{1}$$

Where h_i is relief amplitude of the i th unit grid; n is the number of total grids contained in analysis region.

d) Sample distance: According to geography relativity [6], the closer distance between different positions in geography, the more interrelated influence between them. So δ is designed to reflect the distance between predetermined generating region and sample regions.

$$\delta = d_i(p, s_i) \tag{2}$$

Where p is the geometry center position of predetermined generation region; s_i is the geometry center position of the i th sample region; d_i is the Euclidean geometry distance.

III. GENERATION PRINCIPLE OF PREDETERMINED SHAPE MOUNTAIN

The purpose of generating predetermined mountain is to make it syncretize well with the surrounding physiognomy;

otherwise it does not have application significance. Thus the principle can be expressed by the following basic points:

a) Confirm target parameters: Based on geography relativity, target parameters should be within the range of the syncretizing region macro-attributes to reflect the surrounding physiognomy. So sample regions are selected around generating region in syncretizing region, and the mean of sample region attributes are designed as target parameters.

b) Obtain generated mountain: Based on the fuzzy mathematics theory, synthesis fuzzy similitude value of each sample is obtained by enduing different attribute weights to execute the fuzzy similitude priority algorithm. With the similitude value, each sample region is endued weight and generated mountain is derived from weighted mean of sample.

c) Obtain predetermined mountain: Based on the geography uncertainty, there are errors between generated mountain attributes and target parameters. Generated mountain can be regarded as predetermined mountain via adjusting attribute weights to make each attribute error of generated mountain within 10 percent range.

IV. Generation Process of Predetermined Shape Mountain

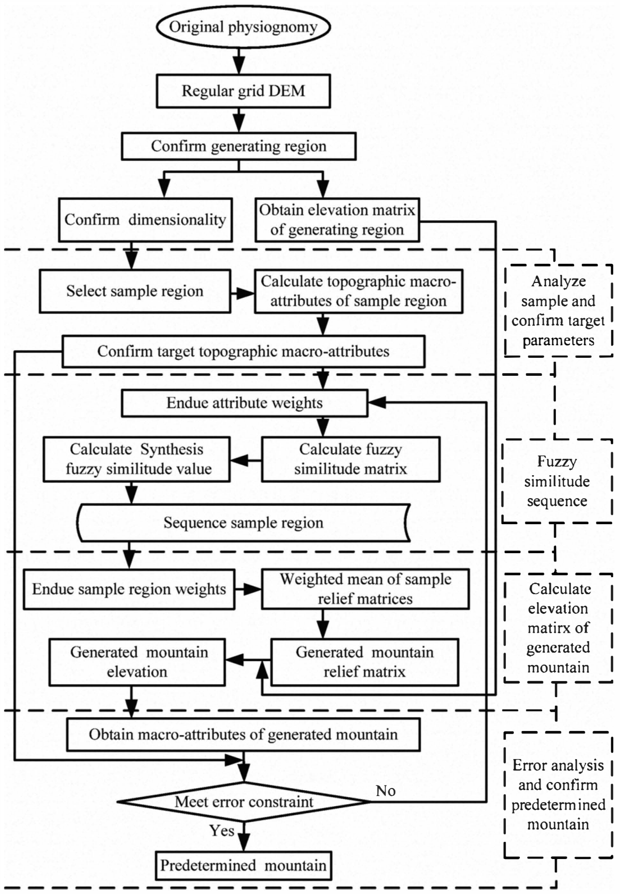


Figure 1. Generation flow chart of predetermined mountain

As shown in Fig. 1, generating region of predetermined shape mountain should be confirmed in the syncretizing region firstly. It includes dimensionality and elevation matrix of generating region. Generation process of predetermined shape mountain contains four steps based on regular grid DEM.

A. *Analyze sample regions and confirm target parameters*

Sample regions are selected around the generating region in syncretizing region, and confirm target parameters within the range of sample region attributes.

1) Select sample regions. With the same dimensionality as generating region, sample regions are chosen in syncretizing region according to the following basic constraints:

a) Dimensionality equality constraints: Around the predetermined generating region, the dimensionality of all the sample regions should be equal with the generating region.

b) Mountain mainly constraints: The main terrain in sample region should be mountain, because it has the obvious mountain attributes to be extracted.

c) Close slope constraints: According to geography relativity, sample regions should be selected in near place where slope is close to generating region as possible.

2) Extract sample attributes to confirm target parameters. Average values of sample region attributes are confirmed as target parameters in the paper. With slope and distance function in the spatial analysis toolbox in ArcGIS, it's easy to extract average slope and sample distance. Transferring elevation matrix of each region into the MATLAB, and executing the following commands can obtain other two attributes:

1: relief matrix=data-min (min (data));
2: relief amplitude =max (max (data))-min (min (data));
3: [i, j]=size (data); large=i*j;
4: saturation amplitude=sum (sum (relief matrix))/ (large*max (max (relief matrix))).

B. *Fuzzy similitude sequence*

Synthesis fuzzy similitude value of each sample and sequencing sample regions are gained by executing fuzzy similitude priority algorithm [7]. It includes two steps:

1) Establish fuzzy similitude matrix. Euclidean geometry distance in each attribute between samples and predetermined mountain is taken to express the attribute difference, which is used to form similitude priority ratio to establish fuzzy similitude matrix. Thus each attribute has a corresponding fuzzy similitude matrix. The attribute difference is:

$$D_{ij} = \sqrt{\frac{1}{n}\sum(x'_{ij} - x'_{ik})^2} \tag{3}$$

$$x'_{ik} = \frac{x_{ik} - x_{k\min}}{x_{k\max} - x_{k\min}} \tag{4}$$

$$x'_{ij} = \frac{x_{ij} - x_{j\min}}{x_{j\max} - x_{j\min}} \tag{5}$$

Where x_{ij} is j th kind attribute of the i th sample in (5), $x_{j\max}$ and $x_{j\min}$ are maximum value and minimum value of the j th kind attribute respectively. The similitude priority ratio is:

$$\begin{cases} \gamma_{ij} = D_{jk} / (D_{ik} + D_{jk}) \\ \gamma_{ji} = 1 - \gamma_{ij} \end{cases} \tag{6}$$

Suppose that comparing predetermined mountain x_k with sample x_i and sample x_j, $\gamma_{ij} \in (0.5, 1.0)$ reflects that x_i is prior to x_j; $\gamma_{ij} \in (0, 0.5)$ expresses that x_j is prior to x_i. Under extreme condition, $\gamma_{ij} = 1$ means that x_i is prior to x_j in evidence, however, $\gamma_{ij} = 0$ shows that x_j is prior to x_i in evidence and $\gamma_{ij} = 0.5$ reflects equal priority.

2) Sequence sample based on fuzzy similitude value. Similitude values of each attribute are gained by using collection of λ value to intercept fuzzy similitude matrix. The sum of all the values in one sample is considered as synthesis fuzzy similitude value of the sample, which is used to sequence samples. But actually each attribute has different influence on synthesis similitude value of the sample, it is necessary to endue each attribute with different weights to calculate results, which meet actual circumstance much more.

C. Elevation matrix of generated mountain calculation

Less synthesis value, more similar between sample and predetermined mountain. Elevation matrix of predetermined mountain is gained by adding elevation matrix of generating region with weighted mean of the entire sample relief matrices, which is obtained by enduing sample region weights.

Suppose that v is the collection of synthesis fuzzy similitude value: $v=\{v_1,v_2,\ldots,v_n\}$. The weight of the j th sample is defined as w_j, and elevation matrix of predetermined mountain is expressed as follows:

$$w_j = \frac{1/v_j^2}{\sum_{i=1}^{n} 1/v_i^2} \tag{7}$$

$$E_p = E_o + \sum_{j=1}^{n} H_j w_j \tag{8}$$

Where E_p is elevation matrix of predetermined mountain; E_o is elevation matrix of generating region; H_j is relief matrix of the j th sample region.

D. Analyze errors to confirm generated mountain

According to geography uncertainty, it's normal in geographical analysis that errors exist between the generated mountains and predetermined mountain [8]. Moreover, errors are changing with the data resolution. Thus the error of each attribute between generated mountain and predetermined mountain should be within the certain range, which can be used as a constraint to choose the available generated mountain as predetermined mountain. So predetermined mountain can be gained by continuing adjusting attribute weights until the errors are fulfill with the constraint as follows:

$$\frac{|x_{k0} - x_{ki}|}{x_{k0}} \le \eta \tag{9}$$

Where x_{ko} is target value of the k th attribute; x_{ki} is the k th attribute of the i th generated mountain; η is error constraint.

V. GENERATION EXPERIMENTS OF PREDETERMINED SHAPE MOUNTAIN

1) Generation of Predetermined Shape Mountain. The DEM of 90 meters resolution, range from 90.29-90.41 degree in east longitude and 36.83-36.93 degree in north latitude, is gained from the International Scientific Data Service Platform (ISDSP) as syncretizing region. 6 sample regions are selected around generating region, which contains 320 data points and the area is 2.018 km^2 shown in Fig. 2. With extracting sample attributes and calculating target parameters in table 1, synthesis similitude value of each sample derived from executing fuzzy similitude priority algorithm on the Data Process System (DPS) is used to endue sample weights in table 3. Elevation matrices of generated mountain are obtained in three experiments shown in Fig. 3 based on the attribute weights in the table 2.

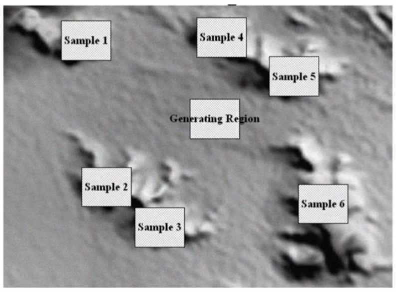


Figure 2. Select sample in syncretizing region

TABLE I. SAMPLE ATTRIBUTES AND TARGET PARAMETERS

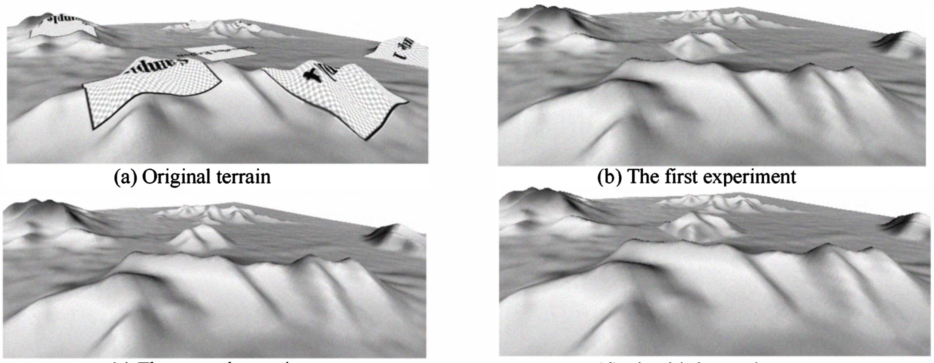
Sample	Topographic Macro-attributes			
	Average slope	*Terrain relief*	*Terrain saturation*	*Sample distance*
1	9.533	170.781	0.3777	4.36
2	8.057	152.189	0.4101	3.71
3	6.940	116.776	0.4227	4.11
4	9.889	161.649	0.4419	2.92
5	7.266	126.031	0.5477	3.07
6	9.682	199.619	0.5477	4.62
Target Parameters	8.561	154.508	0.4580	0

TABLE II. ATTRIBUTE WEIGHTS OF EACH EXPERIMENT

Experiment Number	Weights of attributes			
	Average slope	*Terrain relief*	*Terrain saturation*	*Sample distance*
1	0.25	0.25	0.25	0.25
2	0.20	0.20	0.40	0.20
3	0.60	0.20	0.10	0.10

TABLE III. CONFIRM SAMLPE WEIGHTS BASED ON SYNTHESIS FUZZY SIMILITUDE VALUE

Sample	Experiment 1			Experiment 2			Experiment 3		
	Synthesis Fuzzy Similitude Value	*Priority Sequence*	*Weights of Sample*	*Synthesis Fuzzy Similitude Value*	*Priority Sequence*	*Weights of Sample*	*Synthesis Fuzzy Similitude Value*	*Priority Sequence*	*Weights of Sample*
1	4.0080	2	0.1010	4.4088	4	0.0832	2.9058	2	0.1489
2	2.1120	4	0.3639	2.3232	2	0.2996	1.4784	1	0.5752
3	4.5390	5	0.0788	4.0584	5	0.0982	5.5536	5	0.0408
4	2.4570	1	0.2689	2.1840	3	0.3391	3.9312	4	0.0814
5	3.5945	3	0.1256	3.6972	1	0.1183	3.9026	6	0.0826
6	5.1250	6	0.0618	5.1250	6	0.0616	4.2025	3	0.0712



(a) Original terrain (b) The first experiment

(c) The second experiment (d) The third experiment

Figure 3. Experiments of generating mountian

2) Results Analysis. Due to the data of 90 meters resolution, η is defined as 0.1 in experiments [9]. From the table 1, attributes of sample 2 are closest to fulfill the error constraint, which can be reflected in the first experiment that sample 2 is prior to others in the equal weights condition. So it should enforce the contribution of sample 2 for generating mountain. As increasing terrain saturation weight in second experiment, terrain saturation error is within the constraint range, but sample 4 is prior to others. With adjusting attribute weights in the third experiment, the main contribution for generating mountain is sample 2, and the entire errors are within the constraint range, thus the generated mountain can be regarded as predetermined mountain.

TABLE IV. ATTRIBUTES COMPARISON BETWEEN GENERATED MOUNTAIN AND PREDETERMINED MOUNTIAN

Mountain	Topographic Macro-attributes			
	Average slope	*Terrain relief*	*Terrain saturation*	*Sample distance*
Target	8.561	157.6060	0.4580	0
Experiment 1	6.531	129.7575	0.5165	0
Experiment 2	7.328	138.7812	0.4310	0
Experiment 3	7.853	143.4016	0.4622	0

VI. CONCLUSIONS

Based on GIS data, predetermined mountain can be obtained to syncretize well with surrounding physiognomy by executing the algorithm proposed in the paper. The method is helpful for exploiting GIS software and improving the topographic attributes mining. Moreover, generating predetermined mountain as camouflage shape can improve the camouflage ability in the battlefield. Thereby the method has important application significance in modern life and military.

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