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The integration of water and soil based on three-in-one 3DD-P algorithm

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Abstract: In view of the fact that geomorphic synthesis using conventional three-dimensional Douglas-Peucker algorithm leads threshold setting randomness, Complicated calculation and spatial relationship conflicts in the integrated geomorphic structure line, this paper proposes an improved 3D D-P algorithm of the indirect generalization of terrain which maintains spatial relationship consistency. Firstly, the discrete points on the water systems and the contour lines are sorted on the basis of the 3D Douglas algorithm. Then each sequence assigns a corresponding weight according to their respective characteristics, re-adjusts the position of the point, and integrates the sequence using the "three in one" idea to obtain a more comprehensive queue. Finally, the data is simplified and reconstructed according to the compression ratio to Multi-scale dynamic synthesis of terrain. The experimental results show that the method has higher accuracy in simplification, which can maintain the main topographic features of the drawing area and ensure the topological consistency between the structural lines.

1. Introduction

With the richness of geographical data and the increasing demand of multi-scale geomorphology analysis, the automatic generalization of terrain in the digital environment has been a research hotspot in the field of geographic information and cartography. The main method can be divided into four categories: The first type is the simplification of a single contour line[1-3]. The contour line is regarded as a linear element consisting of a group of discrete points. Then according to the reserved condition of the target scale, the unimportant points were delected so that the integrated contours not only can be deleted the redundant data to the greatest extent, but also can be better expressed the topographical features under the target scale. However, the method of generalization of contour lines was basically negated as early as the 1970s because of its unreasonable reflection of the terrain unreasonable. The second category is the generalization of group contour lines[4-7]. The structural generalization of contour lines by extracting topographic feature lines is still not solving the problem of topology alienation of group contour lines.In most cases, this method exaggerates the positive geomorphology resulting in the micro deformation of the original geo-morphological. As increase the degree of generalization, the phenomenon of jumping is more obvious. The third one is the fractal method and wavelet method, which the application of the two mathematical methods in cartographic synthesis did not attract attention at home and abroad until the 1970s and 1980s[8-9]. The fractal method is different from traditional method of "points are 0-dimensional; lines are 1-dimensional; planes are 2-dimensional; bodies are 3-dimensional". It propose that the point is 0-dimensional; the line is 1-dimensional; the curve is larger more than 1 dimension and less than or equal to 2 dimensions; the plane is 2-dimensional; the surface is larger than 2 dimensions and less than or equal to 3 dimensions (depending on the complexity of the surface); the complex stereo is 3-dimensions. Since the 1980s, the wavelet analysis has been increasingly used for the conversion of time domain and frequency domain of signals and data compression of binary or multiary. Contour lines can be observed and displayed with different resolutions using mathematical language explain, so it is also called a "mathematical microscope." Both of the above mathematical methods are complicated, and they are essentially the generalization of a single contour. The fourth method is the indirect synthesis of contour lines[10-11]. First, the DEM data corresponding to the contour lines are integrated, and then the integrated DEM data is used to reconstruct the contour lines, proposed by Fei and He.

Common problem in the mainstream methods of automated generalization of contour lines: 1.If the single contour lines are directly carried out, space conflicts may occur between the contour lines; if the group contours are integrated, the jump phenomenon will become more obvious as the scale span increases gradually;2.The results of generalization of terrain do not guarantee the inherent coordination between the water systems and the contour lines.

Considering the three-dimensional features of the contour lines and its topological structure, this paper attempts to select and simplify the geo-morphological structural lines from the perspective of generalization of 3D discrete points, and proposes an improved 3D D-P algorithm. First, the computer program directly specifys the first base-faces and the origin points, and treats all points on the contour lines and the water system as the topographical surface description of points. Make full use of the existing 3D geographic information in the original data synthesizes 3D discrete points using the 3D D-P algorithm. While obtaining the correct combined results, it can maintain the inherent harmonious relationship between the natural landscape and the water systems.

2. Three-in-one 3DD-P algorithm

In 1973, the algorithm proposed by Douglas-Peucker recursively simplifies a complex curve (polyline) base on compare the maximum distance between the point and the baseline with a predetermined threshold, the generalized contour lines should reflect the main characteristics of the orignal topography. The three-dimensional Douglas-Peucker algorithm is an extension and innovation based on Douglas-Peucker algorithm. It regards the feature points on contour lines of DEM as a set of spatial points of random and discrete distribution, takes the origin (O) and first base-face of original data set by calculates or specifies as the "view point" and "view plane" that select the feature point, and extracts the most significant spatial feature points for the current "view plane". The three-in-one 3DD-P algorithm improves the computational efficiency by directly selecting three mutually orthogonal rectangular planes as the first base-face and three non-coincident points as the origin point, the generalization of recombined sequences overcome the phenomenon that select feature point appear in inconsist sensitivity.

2.1. Analysis of the problem of three-in-one 3DD-P algorithm

Using three-in-one 3D D-P algorithm automatically simplifies the geomorphology need to consider questions: First, when dealing with topographic maps with high data densities, how to reduce the complexity of the algorithm to improve the generalized efficiency. Second, the generalization of discrete points using conventional 3D D-P algorithm need to determine the compression ratio by artificially set threshold, so it is difficult to obtain a fixed compression ratio. How to establish the mathematical relationship between the threshold and the uniformity of the data sampling density, automatically adjust the generalized parameters, and reduce the randomness of the algorithm both are the key of generalization. Finally, if the generalized object of geomorphology only have contour lines, the reconstructed result and the water system are very difficult to maintain an inherent harmonious relationship, and the operator needs to manually modify relying on the experience of the drawing.

2.2. Improved three-in-one 3DD-P algorithm

According to these problems, this paper makes some improvements based on the three-in-one 3D D-P algorithm. In order to reduce the complexity of algorithm, the first base is determined directly by the "specified method" instead of the automatically determined "maximum vector product method". The experimental results show that the running speed of the program is significantly improved, and the selection result of feature points is also very close to the traditional 3DD-P method. This process is difference that operators not need to manually set thresholds, thus all the original points will be preserved so that the results of the process are more reasonable. Using the "three in one" idea that three orthogonal rectangular planes are used as the first base-face and three mutually non-coincident points are used as the origin points get three point sequences. According to the size of the first base-face and the weight of the water systems, the weights are assigned to different point sequences, and then their sequences are adjusted, this method makes the sensitivity consistency of feature points selection.

In this paper, the generalized object of the contour lines and the water systems as a whole is different from the conventional geomorphological synthesis method, and then point sequences re-adjustment after weight calculation. Finally, This comprehensive sequence is arranged according to the importance of the points in the terrain. Based on this comprehensive sequence, we remove the corresponding proportion of points from the tail of the queue by the compression ratio, which produces the different synthesis results of scatter point according to the percentage of point retention (from left to right, the importance is getting weaker).

3. The generalized of geomorphology

3.1. Point sorting based on 3DD-P algorithm

3.1.1. The Selection of the first base-face When the computer store the original points in the geodatabase, our processing becomes difficult due to the random distribution of discrete points in the space. Therefore, the computer program choose a minimum cuboid which include discrete points, and specify the eight corner points of the cuboid as the origin points and the six cuboid surfaces that passing through the origin points as the base-face. The previous experiments prove that algorithm in program only need to take three mutually orthogonal cuboid surfaces as the first base-face, and then take the three independent points that correspond to three base-face as the origin points. As shown in Figure 3.1.1, the base-surface OAB corresponds to the origin O, the base-surface CDA corresponds to the origin C, the base-surface EFA corresponds to the origin E. By directly specifying the origin point and the base-face, the algorithm runs at a significantly faster rate. The experimental results show that the overall effect is satisfactory.

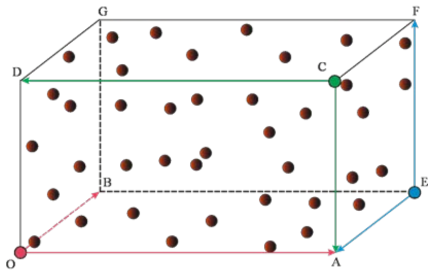

Figure 3.1.1 The selection of the origin and first base-face

3.1.2. Initial queuing The initial queuing adopts idea that select point from top to down, first selects the point with the largest 3D feature, then selects the point with the second largest feature and so on until the end of adding the point with the smallest feature. When selecting point,the computer program first calculate and select the split point according to the distance from the three-dimensional discrete point to the first base-face, and then added to the set of splitting point that wait to be selected. Finally, point with the largest 3D feature is selected from the set of splitting point. As shown in Figure 3.1.2, select a regular quad as the first base-face and three different points on the base-face. Point O as P_1, A as P_2, and B as P_n and put it into the geodatabase. The computer program find the closest point to the three-dimensional distance of A in the remaining original data of point and put it behind A as P_3, and then find the closest point to P_3 in the remaining set of point and insert it into the queue of point as P_4. ..., until the last point P_{n-1} is placed before P_n.

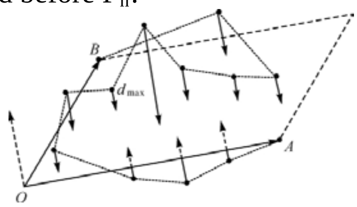

Figure 3.1.2. The first base-face and the distance of point-to-plane

3.1.3. "Three in one" (the integration of three point-queues) The essence of "three in one" is to first perform three-dimensional Douglas-Peucker synthesis for the original discrete points using the three origins and three base-faces. Then we synthesis three sorted point sets to get a more accurate and comprehensive sequence. Experiments show that this method is more effective in solving the problem of uneven sensitivity in selecting the original set of point.

After performing 3 times 3D-DP algorithm on discrete points respectively, three queues are generated to acquire a sequence that contain all the original data: the process that combine the three processed sequences is called "logical plus", that is this point that be selected one or more times or temporary in the selected three queues is preserve. This method avoids phenomenon that some feature points are not selected because they are too close to the origin point.

3.2. The integration of contour lines and water system

3.2.1. Integration Taking the comprehensive structure of the water system as a constraint for the synthesis of three-dimensional discrete points, it can guarantee the comprehensive result as the constraint of synthesis of scatter and the inherent harmonious relationship between the integrated water system and the landform. The integrated process has two main steps:

(1)Three-dimensional water system to achieve three-dimensional: Establishing 3D line store the elevation values of the water system. After find the intersection of the water system and the contour line, we assign the elevation value of the contour line to the point of the water system, the elevation values of the remain of points on the water systems are calculated by interpolation to achieve the purpose of two-dimensional water system to three-dimensional;

(2) The integration of water system and contour line: The importance of discrete points is different in the contour lines and water systems, but the water system is also part of the geomorphic structure line. Therefore, we must assign a certain weight to the contour line and the water system before using the "three-in-one" 3DD-P algorithm for synthesis. The scatter point assigns the respective weight to ensure that important feature points of water systems and contour lines are retained.

3.2.2. The calculation of weight Because the difference of the area of three base-face describes the overall spatial distribution pattern of the scatter points in three dimensions, the position of the three queues can be weighted and reordered by the weight of the area of three base-face.

$$P_s = \frac{\sum_{i=1}^{3} P_{s_i} \times S_i}{\sum_{i=1}^{3} S_i} \tag{1}$$

In formula (1), P_s represents the value of the position after the scatter points are merged, the smaller value show that the scatter point have higher position and larger feature; i indicates the position after each queuing, which is 1, 2, 3⋯ n; S_i indicates the area of base-face after each queuing.

This paper selects the river object by calculating the comprehensive weight value of each river object. In the artificial synthesis from large scale to small scale, more features are retained as the scale increases; when selecting the retained objects, the rivers with high number of rivers, more tributaries and longer rivers are preferentially reserved. The size of the scale, the length of the river, and the number of tributaries are important factors influencing the weight of the river.

$$Weight=a/Scaler+b*LongRate+c/Grade+d*Depth+e*Density+f*FeatW+g*Dista \quad (2)$$

In formula (2), Weight represents the weight value; 1/Scaler represents the scale size obtained by human-computer interaction; LongRate is the ratio of the length of the river to the total length of the river system; Grade records the depth of the tributary; Depth indicates the river Depth; Density is a simple representation of river complexity; FeatW is the attribute weight of the river determined by the expert system; Dista is the distance between adjacent rivers of the same level; the constants of a,b,c,d,e,f,g are determined by the expert through the human-computer interaction interface of the system.

3.3. Reconstructed landform structure lines

According to the principle of “maximum information”, the multi-scale automatic synthesis of landforms is a process of reducing the amount of information under certain boundary conditions, the topographical points and topographic features with the least amount of information and the smallest representation of the surface structure should be gradually removed from the synthesis. Therefore, from the beginning, the selected points will enter the left end of the importance queue one by one according to the absolute value of the volume change. After the experiment, we know that there is an inverse relationship between the composite index and the selected points, that is the more points are selected, the smaller the composite index is, and vice versa.

When the appropriate number of points, the adjustment step size, and the tolerance between the ideal point and the current point are determined, based on the importance queue of point, we generate different levels of synthesis of scatter point according to the percentage of point retention.(From the left end, the selected points are always relatively important), and then the integrated scatter points are reconstructed into the resulting contours (with the participation of topographical structures) to achieve multi-scale synthesis.

In the experiment, when the landform is built directly using the integrated point, there will be the problem of cross-line triangles in some places. The integrated points are made up of contour lines and water systems according to different attributes, and these feature lines under the constraints of linear elements construct the delaunay triangulation network so that the reconstructed contour lines have better effects.

4. Experiment and analysis

The hardware and software environment of experimental computer is: Intel i5 CPU, main frequency of 3.2GHz/s, memory of 8G, operating system of Windows 7.The experimental data is the scale 1:10,000 of hilly area of terrain data in Anhui province, the contour line spacing is 10m, the rivers are 25, the intersection points are 24, the total length of two-dimensional of river is 36074.4m, and the total length of three-dimensional of is 37236.9m. The screenshots only studied some areas of topographic map because the large amount of data are not clear.

After the "three-in-one" 3DD-P algorithm, the points that sorted by importance are integrated. By eliminating redundant points and retaining important feature points to achieve different levels of comprehensive results(figure 1-3). It takes only 49 seconds and is highly efficient.

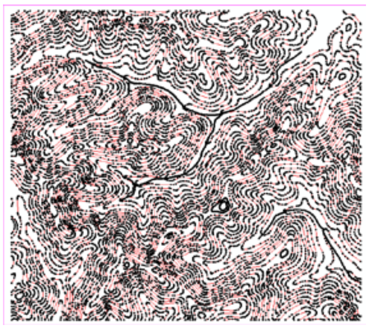

Fig. 1 The retention rate of 100% (13263)

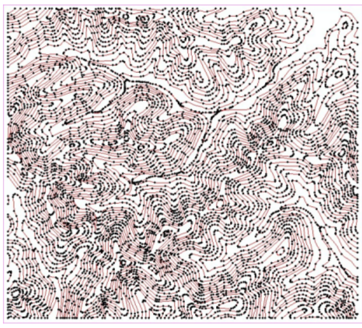

Fig. 2 The retention rate of 50% (6632)

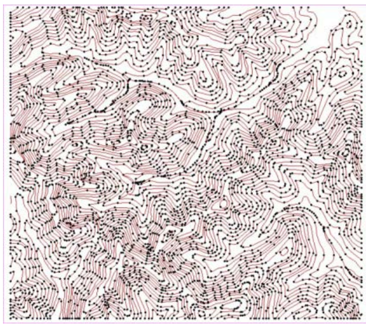

Fig. 3 The retention rate of 25% (3316)

After synthesis, discrete points with different retention ratio generates the shading map. The integrated effect is as follows:

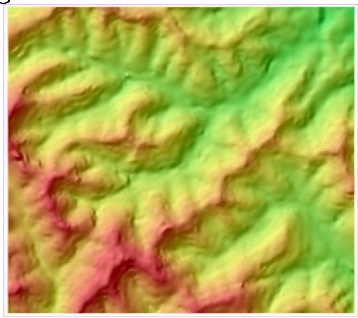

Fig. 4 Shaded map of the retention rate 100%

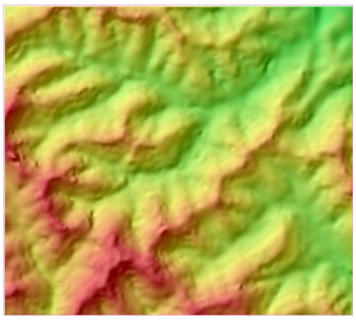

Fig. 5 Shaded map of the retention rate 50%

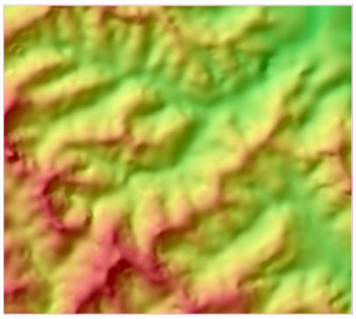

Fig. 6 Shaded map of the retention rate 25%

According to the above shading map that generated by the retention rate 100%, 50%, and 25% of points(figure 4-6), the retention ratio is from large to small, although the landform of performance is gradually weakened, but the degree of attenuation is relatively small, and the original morphology of the landform is basically retained. In particular, when 25% of the data is retained, a considerable amount of storage space is saved, and the original terrain is still preserved while reducing such a large amount of data. This shows that the reserved data represents the important features of the landfrom, and it also express that the improved algorithm is efficient, accurate and scientific.

The Integrated discrete points are respectively reconstructed into the geomorphic structure lines according to their respective geographical attributes. The comprehensive effect is as follows:

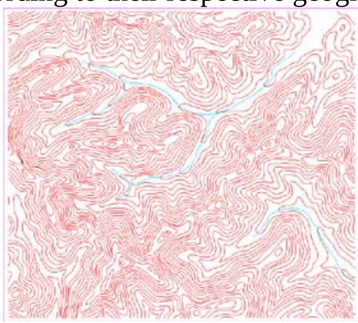

Fig. 7 The retention rate 100% of nesting relationship

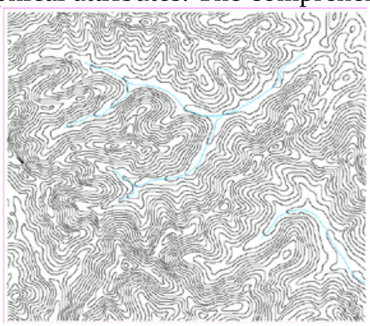

Fig. 8 The retention rate 50% of nesting relationship

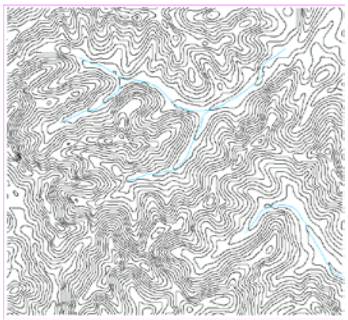

Fig. 9 The retention rate 25% of nesting relationship

The above figure 7-9 is comparison of the contours before and after the integration, the red line represents the original contour line, and the black line represents the integrated contour line. The overall effect is considerable.

The global analysis of the above figure shows that the region with large curvature retains more feature points makes the reconstructed landform is basically the same as the original landform; The reconstructed contour lines in these areas slightly different from the original contours, in that most of unimportant points have been deleted in relatively flat areas. However, this difference is allowed when the retention ratio of the original data is less than or equal to 25%. The integrated results not only saves the considerable storage space, but also basically retains the original skeleton of the landscape. This further demonstrates that the improved algorithm is efficient, accurate and more scientific.

5. Conclusion Acknowledgments

The experiments in this paper mainly improved three-dimensional Douglas algorithm for indirect comprehensive of contour lines and water systems. Taking the water systems as the object of interjection has important in retaining geomorphological skeleton. In the process of interjection, even if the large degree of the generalization of geomorphology, by assigning weights to different feature lines, we can still retain the data with the largest information and delete redundant data. The improved 3D D-P algorithm not only improves the sensitivity of selected points, but also makes the point sequence more comprehensive.

Acknowledgments

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