

A Simplification Method for Terrain Modeling

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Abstract. To solve the problem of three-dimensional terrain simplification in large-scale based on digital elevation model data, a terrain simplified method based on the theory of spatial autocorrelation was proposed. According to principle of regional similarities in geomorphology, a cluster analysis was performed on the terrain data to get the thresholds distinguish terrain features. On the basis, the gradient-based weighted method was adopted to fit elevation values of the center point and generated a new terrain mesh. The results of experiments show that the method to some extent reduces the size of the data, while maintaining good terrain features and curvature characteristic.

Keywords: spatial-autocorrelation; terrain simplification; Digital Elevation Model; gradient.

1 Introduction

Digital elevation model (DEM) as a basis of DGM, the data structure of which is beneficial to implement the terrain analysis, is a digital description of terrain and locates the elements of terrains by the two-dimensional geospatial. However, the overlarge cell of the DEM grid will has a negatively influencing for the expression of terrain characteristics and has data redundancy [1]. In the construction of the massive three-dimensional terrain, because of higher resolution of the elevation data grid and the wider geographical scope, these factors will result in a tremendous amount of data which will be used for modeling three-dimensional terrain. It will require a better terrain-modeling technique and power computing ability for amount of computing, in this case. So, the simplification for the terrain is the basis of constructing a three-dimensional GIS, especially the data of which is based on DEM [2].

There are numerous studies dealing with simplification for large terrain modeling. Literature[3] proposed new algorithms for simplifying terrain surfaces designed specifically for a new measure of quality based on preserving inter-point distances; Literature[4] proposed a new 3D terrain mesh simplification method, which is based on analysis of clustering and Octree to organize the streamlining processes, achieving the model transition from simple to complex. Literature [5] propose and discuss a new Lepp-surface method able to produce a small triangular approximation of huge sets of terrain grid data by using a two-goal strategy that assures both small approximation error and well-shaped 3D triangles. Literature [6] introduces a real-time LOD method which divides the terrain in a set of nested regular grids centered about the viewer.

2 Clustering analysis and spatial-autocorrelation

Digital Elevation Model can be described as follows: {X, Y and H}, X: longitude, Y: latitude. X and Y determine the location of points at the two-dimensional terrain surface, and H is the elevation value. Spatial autocorrelation theory [7] explicates the relationships of adjacent-space elements between properties and position, such as similarities in an area. The autocorrelation characteristics of local-adjacent positions affect the degree of redundancy of elevation data, the closer the relationship, and the more redundant. If the area has fewer details, the redundancy will be more than an area having more details. Clustering analysis can detect the similarity among things. So, the type of land, such as mountains and plains, can be easily classified on the basis of the spatial-property elevation.

Here, we use the K-means clustering analysis method to classify the elevation value. K-means is based on the idea that a center point can represent a cluster. The points in a cluster are high similarity, and the low degree of similarity between clusters.

The cluster analyzing results: δ_1 representing plain areas, δ_2 as mountain areas. The region δ_1 has less detail and is high redundancy; the δ_2 area, alpine landscape may have dramatically changed in a small region and the redundancy is low. According to the classification thresholds: δ_1 and δ_2 , we can judge the current terrain features, and then determine the direction of windows to compute the elevation values of the center point by the gradient-based distance-weighted algorithm.

3 Simplification Method for Terrain Modeling

On the basis of K-means clustering analysis for the landforms, we can get the mean value of each cluster which was the threshold to judge terrain features and determined the number of search direction that is involved in computing the discrete points. Getting 4 or 12 discrete points around the new grid calculated the inclination as the weights; the tilt angle is large and the weight on the large, otherwise small. For a flat area (i.e. the clustering center value is δ_1), because of the less detail of the terrain and the better spatial autocorrelation, we can use fewer points (4 directions) to calculate the elevation value of the center point; for sharp undulating topography (i.e. the clustering center value is δ_2), the greater the inclination angle of the area, the bigger of the weights, we use dense points (12 directions) for computing the elevation value to avoid being affected by the local elevation error.

Figure 1 shows the both cases for selecting sampling points in a regular grid. p_1, p_2, p_3, p_4 , four adjacent points on the grid, h_1-h_4 is the corresponding elevation values, m_1 is the center point of the grid, and the following $m_2, m_3 \dots$ is also. The goal is to determine the elevation value of m_i ($i=1, 2, 3 \dots n$).

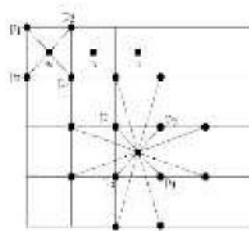


Fig.1. grid of a terrain

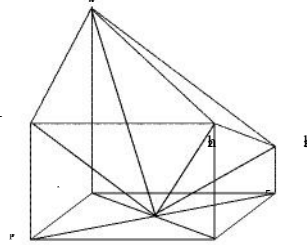


Fig. 2. computing the center elevation

The relationship between m_i and its adjacent points p_i can be described by the inclination. The tilt is defined as $\angle h_j m_i p_j$ ($j=1, \dots, k, k=4$ or 12), the tangent value, calculating formula:
 $\tan \theta_i = |h_i p_i| / |m_i p_i|$. The weight of p_i is:

$$w_i = \frac{d}{d_i} \quad (1)$$

As shown in Figure 2, the number of discrete points is decided by the operation of $|p_i - \bar{p}_1| \leq |p_i - \bar{p}_2|$, p_i : four nearest points p_1, p_2, p_3, p_4 . If the numbers of points meeting the conditions are more than half, the local autocorrelation of terrain is better and we adopt four points to calculate. On the contrary, the terrain is more intense; we extend the four edges outward, and the distance from the points in the extended edge to the center point is closer than others in grid. So, the extended eight points and the adjacent four points have a strong spatial-relationship.

4 Experiment and Result

Select the SRTM DEM data, which is constituted by a set of uniform regular grid (<http://www.gscloud.cn>), cell size: $0.00083333^\circ \times 0.00083333^\circ$. The geographic scope of longitude is between $110^\circ \sim 115^\circ$, and latitude is between $30^\circ \sim 35^\circ$. The column of SRTM data 59, and the row number is 06, the middle-west of Henan province. This region has obvious geographical characteristics, such as plain areas and less mountainous.

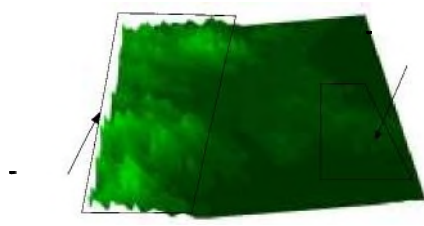


Fig. 3. the effect of modeling

Figure 3 is the effect of terrain loaded by OSG system. Topographic features keeps consistent with the original image; the reconstructed grid can accurately express the characteristics of the surface, and don't have the cracks, dislocation and other issues. From the figure, we can distinguish the mountains and plains very well.

5 Conclusions

To solve the problem of low displaying performance in 3D visualization modules, we simplify the modeling data based on this algorithm. Not only reduce the amount of data modeling, but also improve the efficiency. In the subsequent studies, we will refine the local areas again to optimize the modeling data, so as to improve the performance of the output of terrain model.

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