Research on Digital Elevation Model Construction Method Based on TIN

Quan Peng, Xiaolong Zheng
Xi'an High-Tech Research Institute, Xi'an, Shaanxi, 710025, China
Corresponding author’s e-mail: 951344833@qq.com

Abstract. Digital Elevation Model (DEM) is a very important part of geographic information system and a key part of various terrain surface studies. In this paper, we first introduce the classical DEM construction method based on irregular triangulation (TIN). In view of the shortcomings of the classical DEM construction method, this paper proposes a volume segmentation method based on variance criterion, in which the variance criterion can take full account of the elevation information of the original data and select the triangles with good shape in space to ensure that the constructed DEM is closer to the actual surface. Finally, an example is given to demonstrate the advantage of the variance criterion relative to the empty circumscribed circle criterion. The classical DEM construction method and the method of volume segmentation based on variance criterion are realized by MATLAB programming.

1. Introduction
In 1958, Miller put forward the concept of Digital Elevation Model (DEM). After decades of research, many basic problems of DEM have been solved. With the development of the new military reform and the arrival of the information age, information and digital army is the main direction and trend of our army's development. Digital Elevation Model is the foundation of building digital army.

At present, most DEMs are based on regular grid. The DEM based on regular grid is ineffective in describing the complex terrain fluctuation and has a large amount of information redundancy. The DEM surface model based on TIN is not limited by the spatial distribution of terrain data, and is suitable for all situations[1].

2. DEM Surface Interpolation Based on TIN
DEM surface model based on TIN is to connect scattered data in space into TIN which is not overlapping and overlapping. By processing and optimizing, the triangle network can be used to fit the real terrain surface and approximate the irregular triangle network. It has better applicability than regular grid in the representation of various terrain and landforms, and it is easy to fuse various terrain structural lines. At the same time, in DEM model of flat and simple surface, DEM based on TIN is not easy to generate data redundancy, which is a common way[2].

2.1. Triangulation criterion
Nowadays, there are six main triangulation criteria [4]. Since only the outer circle criterion is used in this paper, as shown in Figure 1, this paper focuses on the introduction of this criterion. The outer circle criterion refers to that within TIN, the outer circle of each triangle cannot include other points in the original data points[3].
2.2. Generation algorithm of Delaunay triangulation

The scattered surface data in space are projected to get the surface data in plane, and then TIN is formed according to the criterion of outer circle. The main steps are as follows\[4\]:

1) Select any point in the scattered surface sampling points on the two-dimensional plane, and then find the shortest distance from this point. After the two points are connected, the baseline is formed.
2) Find the third point according to the criterion of outer circle and form a triangle.
3) The connection from the third point found in step 2 to the starting point of the initial baseline and from the third point to the end point of the initial baseline are used as the new baseline to be processed.
4) Repeat steps 2 and 3. until all newly formed baselines have been processed.

2.3. DEM Surface Interpolation Method

Spatially scattered surface data can be triangulated by Delaunay triangulation to form an irregular triangular network in two-dimensional plane. However, the irregular triangular network is only formed by triangulation after the original data is projected to the horizontal plane, and the elevation value of the original data is not used. Therefore, in order to get a DEM surface close to the real surface, we must use the elevation value of the original data points to fit the surface, which is called interpolated surface. This method is called surface interpolation if the formed surface contains all the data points of the original terrain surface. In addition, it is called surface approximation if the original data points do not pass through the constructed surface strictly, but only near the surface. In this paper, surface fitting is based on the three vertices of each triangle in the triangle network, and ensure that the three vertices of the triangle pass through the surface. Therefore, this paper only studies surface interpolation\[5\]. At present, the main interpolation methods are linear interpolation method, distance weighted interpolation method, smooth interpolation method based on Taylor formula and so on.

3. Volume segmentation method based on variance criterion

At present, the criterion of circumscribed circle is often used as the criterion for the formation of TIN. However, it is found that only the plane coordinates (i.e. x, y) of the original data are taken into account when triangulation is carried out by using the criterion of outer circle, and the elevation values of the original data are not taken into account, that is to say, the judgment is only carried out on the two-dimensional plane. However, the actual terrain surface is three-dimensional. It is one-sided and sometimes wrong to judge the shape of a triangle only by using the criterion of outer circle in two-dimensional plane, because it can not judge the shape of the triangle in space, but only consider the shape of the triangle formed by its projection in two-dimensional plane. In view of the shortcomings of the above-mentioned DEM construction process, this paper proposes a volume segmentation method based on variance criterion.

3.1. Method overview

The classical method only considers the projection of the original data in the plane, but does not consider its geometrical shape in space. As a result, there is a big gap between the DEM model and the actual terrain surface. In other words, the classical method only chooses triangles with good shape on the plane, while the actual surface is in three-dimensional space. After searching the data, it is found that the results of triangles with good shape in two-dimensional plane are usually unsatisfactory in three-dimensional space. In addition, when the plane coordinates (x, y) of some points in the original data are the same and
3.2. Model Construction Algorithms

Point-by-point insertion algorithm \cite{6} is an important way to realize triangulation of scattered terrain data points. The volume partition method based on variance criterion proposed in this paper is based on point-by-point insertion algorithm. The difference is that variance criterion is used to replace the outer circle criterion in LOP optimization. The specific steps are as follows:

1) Create a polygon from raw data and make sure it contains all the raw data.
2) Choose a point Q arbitrarily in the original data and find the triangle S where point Q is located. Connect Q with the three vertices of point Q to form three triangles. Optimize the triangles by using LOP criterion. (When dealing with the triangles by using LOP criterion, judge whether to exchange diagonals according to variance criterion, if the sum of variances of triangles A and B is greater than the sum of variances of triangles C and D, Exchange diagonals; conversely, no exchanging.) The optimization process of LOP criteria is shown in Figure 2.

![Figure 2. LOP optimization diagram.](image)

3) According to step 2), the polygons formed by each point are checked by LOP in turn until all points are processed.

3.3. Verification of volume segmentation results

In the process of DEM construction, the special terrain such as mountains and valleys is the key and difficult point, while the construction of DEM in gentle terrain is relatively simple, which is not discussed in this paper. By searching for data, topographic data of a certain area are obtained. There are 2401 topographic surface sampling points in the form of (x, y, z).

In order to test the feasibility of volume segmentation method based on variance criterion, and to compare the volume segmentation method based on variance criterion with the classical DEM method more vividly, this paper uses variance criterion to optimize LOP on the basis of the point-by-point insertion algorithm introduced in the previous paper, and realizes the algorithm through MATLAB programming. The spatial distribution scatter plot of the data is shown in Figure 4. The results obtained by linear interpolation method in the classical DEM method are shown in Figure 5 and the results of volume segmentation are shown in Figure 6.

![Figure 3. Original graph.](image)
4. Conclusion
In this paper, the construction method of DEM based on TIN is discussed in depth. Based on the analysis of classical DEM construction methods, a volume segmentation method based on variance criterion is proposed. This method directly triangulates the original data instead of projecting it on the plane, making
full use of the elevation value of the original data, and does not need any interpolation, thus simplifying the process of DEM construction. Finally, the advantage of volume segmentation method based on variance criterion is verified by MATLAB programming. Because of the author's limited ability, this study is not very mature. In the future research, we will focus on the accuracy of DEM based on variance criterion. Thank you.

References
[1] Guoan Tang, Xuejun Liu, Guoliang Lv. (2005) Principles and Methods of Digital Elevation Model and Geological Analysis. Science Press, Beijing.
[2] Qiuyan Song. Irregular Triangular Network and Its Visualization Implementation. Changsha: Central South University, 2008.
[3] Duowen Xu. Construction and Application of Irregular Triangular Network (TIN). Ganzhou: Jiangxi University of Technology, 2010.
[4] Jiaming Fan. Research on DEM Surface Model and Accuracy Evaluation Based on TIN. Zhengzhou: PLA Information Engineering University, 2007.
[5] Xinxiu Zhang. Research on Railway Terrain Model and Visualization. Lanzhou: Lanzhou Jiaotong University, 2014.
[6] Xiaodong Guo. Optimal algorithm of point-by-point insertion method for Delaunay triangular network. Zhengzhou: Henan Meteorological Bureau, 2014: 112-114.