International Journal of Computer Theory and Engineering, Vol. 3, No. 2, April 2011
ISSN: 1793-8201

Study of the TIN Gross Error Detection based on Terrain Inclination

Sheng Qinghong

***Abstract*—Surface model construction is the basis of three-dimensional model representation and contour drawing. This paper constructs Delaunay triangulation (TIN) with three-dimensional points first, then discusses the unreasonable contour configuration produced by the triangulation data, analyzes the source of errors, and points out that gross errors and random errors are made in the process of image matching and orientation. This paper puts forward a method of TIN gross error detection by using determined points and neighborhood inclinations, which is proved to be a simple and effective method of gross error detection and can eliminate serious distortions of contours in points of gross errors.**

***Index Terms*—digital elevation model; triangulation; contour; gross error detection**

I. Introduction

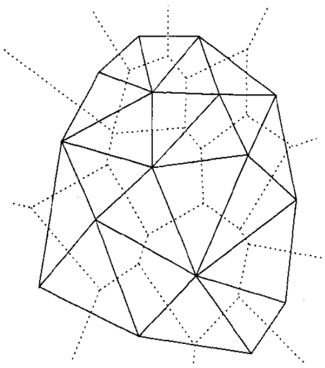
Terrain is the natural feature of geographical environment. The accuracy of digital elevation model representation is of vital importance. At present, there are mainly three methods of gross error detection for digital elevation model data, namely, global method, region method, and point position method [1]. Any algorithm based on global method uses all the data points to fit high-order polynomial function, and then calculate the deviation of each data point from the corresponding surface. If the deviation of a certain point is higher than the threshold, a gross error may exist in this point. Threshold can be predetermined or calculated through the deviation of digital elevation from the global surface. A fatal disadvantage of global method is that it treats every region equally, but surface reliefs of different regions are rarely the same. Therefore, global method which deals with surfaces in the same way may result in a lot of gross errors in uneven surface that has actually no gross errors, but can not detect gross errors effectively in comparatively smooth surface. The algorithm used in region method is rather similar to that in global method. It also uses polynomial function to fit regional surface first, and then detects the deviation of each data point from the corresponding surface [2]. The only difference between these two methods exists in the size of the surface area. Whether region method is to be used partly depends on the size of the characteristic region area. The main disadvantage of global method and region method, both of which use polynomial function to fit the terrain surface, is that those points with gross errors are also used to construct DEM surface. In this case, if a point has serious gross error, under the influence of which those nearby points without gross errors will have serious deviations to the constructed surface and may be regarded to have gross errors consequently. Point position method calculate the difference of statistical values of elevation value of determined points and the elevation value of neighboring points, such as average value, medium value, etc. If the difference value is larger than the threshold, the point has gross errors [3].This approach also neglects the spatial correlation among gross error data. In other words, if a certain point has gross errors, a large number of points in its neighborhood will be affected in the process of interpolating the central point so that the calculated value of statistics will be different from the actual value, and thus will bring difficulties to the judgment of gross errors.

II. Construction of TIN

Based on irregular discrete feature points data, digital terrain models of various kinds of irregular grids such as triangulation, quadrilateral meshes or other polygon grids can be built. However, triangulation is the simplest of them. Surface feature points can be estimated well in irregular triangulation model. D-TIN is the best among all possible triangulations, so it is usually adopted in TIN generation. Delaunay triangulation has been widely used to solve all kinds of problems. Delaunay triangulation has been applied increasingly in all kinds of projects including the nearest neighbor, finite element enmeshment, geometry compression, geometry information analysis, visualization of three dimensional city model and so on. Delaunay triangulation has been used widely in photogrammetry. For example, it has been used in construction of DEM, contour generation, image encryption and matching under triangulation restriction, analysis which unifies problems of region and edge segmentation under restrictive triangulation data organization, etc. Delaunay triangulation is defined to be on two dimensional point set. It is a set of a series of connected but not overlapped triangles, whose circumcircles do not contain any points in this region. Delaunay triangulation is the associated graphic of Voeonoi graphic. The two graphics are powerful tools which has been accepted and adopted widely in analysis and researches on regional discrete data [4,5]. Delaunay triangulation is generated through connecting growth centers of three V polygons with a common vertex (Picture 1 shows the relation between Delaunay triangulation and Voronoi graphic.). The common vertex is the circle center of the circumcircle of the Delaunay. Delaunay triangulation grid has a good structure, a simple data structure, a small data redundancy, a high memory efficiency, and fits

Manuscript received July 30, 2010.

irregular surface feature well. It can also show linear characteristic, superimpose regional boundaries of any shapes. Delaunay triangulation grid can not only be updated easily, but also adapt to data of various distribution density. Based on TIN tracking, contour makes use of original observed data directly, which not only avoids accuracy produced by DEM interpolation, but also shows surface feature more vividly. Therefore, in order to draw reasonable contours, we must get rid of errors of TIN data and enhance the precision of TIN.



Picture 1 Delaunay Triangle

III. Error Analysis of TIN

The key factor that affects the precision of digital elevation model is the characteristics of terrain surface which decides the difficulty of the expression of the terrain surface. Among all the characteristics of the terrain surface, declination is the most important descriptive factor. This thesis proves that declination affects the quality of DEM through experiment, and points out that the precision of DEM will decrease along with the increasing of the terrain declination and the maximum error appears when the declination reaches the maximum. It has been proved by experiment that the relationship between the precision of DEM and the terrain declination changes in a linear manner [6]. Digital elevation model data set can be perceived to be composed by three parts: region signal, local signal, and random error. Obviously, regional signal is the most important in digital elevation model for it describes the basic configuration of the terrain surface. In this thesis the TIN data are get through automatic image matching and filtering in the way of photogrammetry and computer vision[7,8]. The reliability of regional signal is comparatively higher. Regional signal varies with the scale of digital elevation model. Large-scale is very pivotal for showing the details of terrain. In this thesis, the three dimensional data are achieved through feature points matching. Those dense points can show the details of the terrain. Oppositely, random error will more or less distort the reality of the original data no matter what situation it is. Automatic matching produces dense TIN data, but the process of image matching and orientation produces random errors in calculation. This kind of random noise exerts a great influence on the quality of the contour, so we should adopt filtering technology in the smooth processing of TIN data in order to enhance the quality of TIN data. Compared with the random error, the gross error produced by the mismatching of image in image correlation distorts the space variation reflected by digital elevation model more seriously. So this kind of gross error should be detected and rejected.

The quality of digital elevation model data produced irrational problems of contour such as vertical or horizontal concentrated type, and irregular type, shown as figure 1. The quality problem of vertical or horizontal concentrated data refers to the dense horizontal or vertical arrangement of contours along X or Y co-ordinate in a map. This kind of arrangement is very rare in natural terrain, so it can be classified as one of the quality problems of contour data. Another type of quality problems which can not be classified as the type of problems we mentioned above is irregular type. The contours are arranged irregularly in irregular type. Problems of jagged (vertical or horizontal concentrated type) contour are mainly come from the quality problem of DEM data. If the difference of adjacent elevations is small, digital elevation will fluctuate regularly in space. This data quality will make contours unsmooth. Similarly, in irrational contour configuration with unconformable boundaries, digital elevation varies along X or Y coordinates discontinuously. If the difference of adjacent elevations is too obvious, contours will assemble irregularly. This irregular configuration of contours is shown as figure 2.

Types of Irregular Contours	Genetic Type	Configuration	Method of Improving
Jagged	Data Quality Limit	Horizontal Corrugation	Smoothing Method
Unsmooth	Contour Generation Algorithm	Irregular Configuration	Improving Algorithm

Figure 1 Irregular Configuration of Contours

Contour Configuration	Quality Characteristic of DEM Data
Horizontal Corrugation	Regular Vertical and Horizontal Arrangement of Adjacent Elevations
Unconformable Boundary	Discontinuous Variation of Adjacent Elevations along X or Y Coordinate
Irregular Configuration	Obvious Difference of Adjacent Elevations

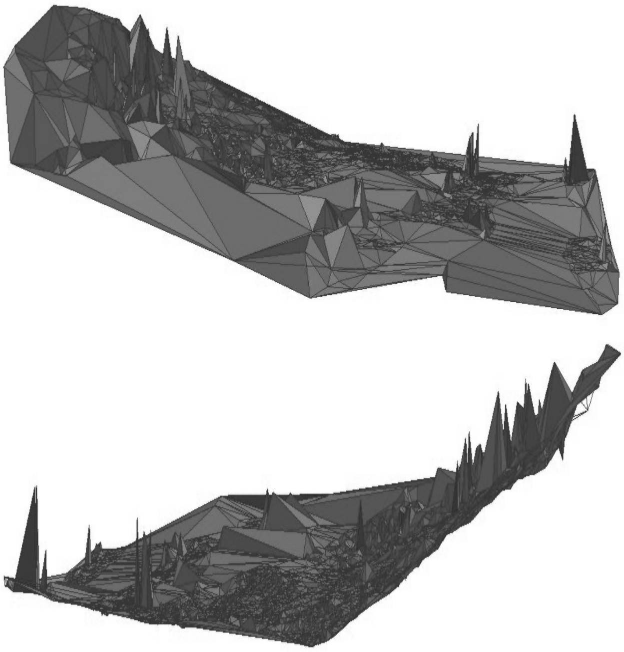
Figure 2 Data Quality Ingredients of Uneven Contours

IV. TIN Gross Error Detection

After the 3d visualization of the TIN model, the gross error points become very explicit. These lines in figure 2 are sides of triangle. The declinations of gross error points under different visual angles are obviously larger than that of those actual topographical points in its neighborhood. Based on gross error detection of declination, the author believes that the declinations of gross error points are obviously larger than that of other points in its neighborhood [9]. The procedures are as follows: At first, define a window of certain size as window R, and determined point P is the center of window R. Then calculate declination S, which is the declination of point P and all the points inside window R (Formula 1). If the maximum difference value is smaller than the given threshold, point P has no gross error. Otherwise, it is gross error.

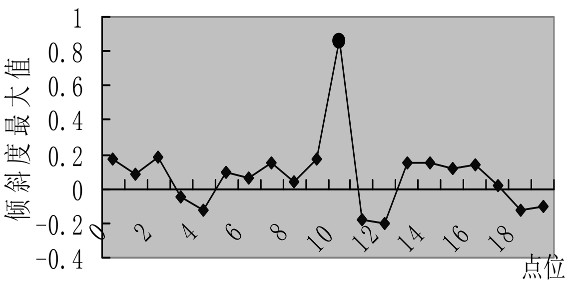
$$S_i = \frac{Z_i - Z_{i-1}}{\sqrt{(X_i - X_{i-1})^2 + (Y_i - Y_{i-1})^2}} \tag{1}$$

where X_i, Y_i, Z_i are coordinates of filter(i), X_{i-1}, Y_{i-1}, Z_{i-1} are coordinates of filter(i-1). In this filtering method, the threshold of declinations should have assured key parameters.

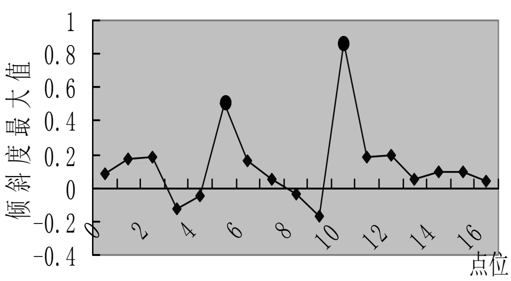


Picture 2 Visualization of TIN Model under Different Visual Angle

Choose a set of TIN data to do two tests as follows. There are 15 to 20 data points inside the neighborhood of determined point P (point position 5). Point P has no gross error, and point 10 is only one gross error inside the neighborhood; point P has a gross error, and point 5 and point 10 are two gross errors inside the neighborhood. Calculate the declinations of point P and the other points inside its neighborhood separately. In order to make it convenient to analyze the results, make the value of point position as x-axis, the declinations of point P and every data point y-axis. The black dot marks the position of gross errors, showing in picture 3 and 4.



Picture 3 Declination Distribution of a Gross Error

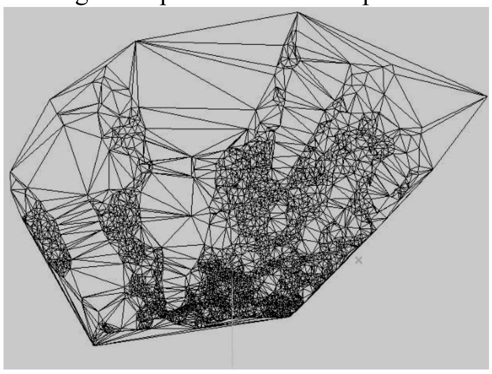


Picture 4 Declination Distribution of Two Gross Errors

In picture 3, when there is a gross error (point 10) inside the neighborhood of point P, the maximum declination of point P among 20 points is 0.1 (actually the declination of the gross error point and point P is negative). In picture 4, when the number of the gross error increased to 2, the maximum declination of point 5 (point P) and point 10 is much larger than 1(actually it is 30 degree).

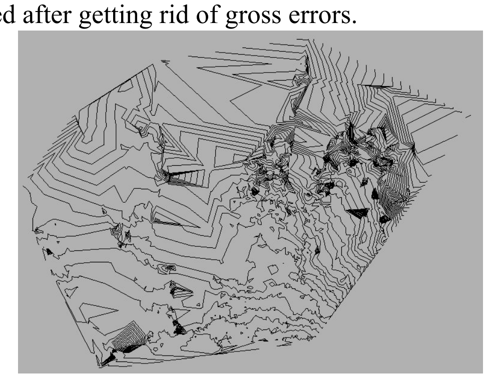
V. Analysis and Result of the Test

The Grid Generation Programme developed by Schwchuk, J.R. of Carnege Mellon University can performance efficiently in the speed of grid generation, floating point operation and so on. As the programme has disadvantages in some aspects such as data construction, function, etc., Jiang Wanshou of Wuhan University expanded its property and function and made it into a fast, reliable utility programme[10]. The Triangulation Generation Programme used in this thesis is the software package after expansion. The triangulation generated through data points is shown as picture 5.

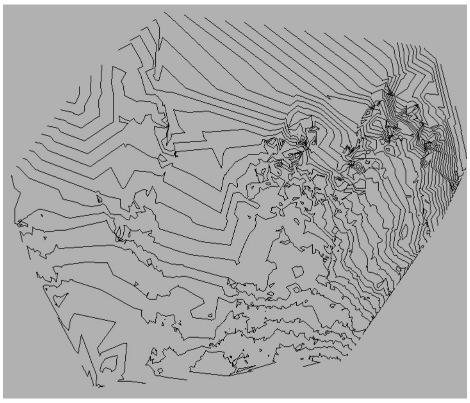


Picture 5 Woodland Triangulation

There are 3866 three dimensional data points in the test area. The threshold of the declination need assured key parameters (choose the maximum terrain declination in the test area as the threshold). The number of data points in the test area varies between 15 and 20. Through this treatment, points of irrational contours will be found. Contours (unsmoothed) generated by data points with gross errors are shown as picture 6. Apparently, gross error points exist in dense contours. After getting rid of gross errors there are 3708 points. Picture 7 shows contours (unsmoothed) generated after getting rid of gross errors.



Picture 6 Contours Generated by Original Data with Gross Errors



Picture 7 Contours Generated by Data without Gross Errors

VI. Conclusion

As three dimensional data generated by image matching have gross errors and large quantities of random noise, gross error test has important significance for the representation of three dimensional models. The gross errors are picked out easily and effectively through determined points and neighboring declinations in this thesis. Serious distortions in gross error points of contours are eliminated, too. As test data used in this thesis are simple, the method of gross error detection which uses declination information directly can meet the needs. However, the problem of unsmooth contours has not been resolved thoroughly. If sample points are lost because of hiding or other reasons, the way to overcome the uncertainty of surface topology connection still needs further researches.

Acknowledgment

Foundation items: the Talent Recruitment Foundation of Nanjing University of Aeronautic & Astronautics (S0881-HT)

References

[1] Li Zhilin, Zhu Qing. Digital elevation model [M]. Wuhan: Wuhan University Press. 2001.
[2] YANG Xiaoyun，GU LI YA，CEN Minyi. A Method Based Fitting of Moving Quadric Surface with Variable Windows for Detecting Gross Errors in Irregular DEM [J]. ACTA GEODAETICA ET CARTOGRAPHICA SINICA .2005.34(002): 148-153.
[3] LU Xi-kui YI Sirong HAN Chunhua. The Method of Detecting and Eliminating Grid DEM Gross Errors Based on the Slope RMSE and 3D Visualization [J]. BULLETIN OF SURVEYING AND MAPPING. 2007.09. 23-25
[4] McLain, D. H. Two Dimensional Interpolation from Random Data [J]. The Computer Journal .1976.19(2): 178-181.
[5] Green, P. J. and R. Sibson. Computing Dirichlet Tessellations in the Plane [J]. The Computer Journal .1978.21(2): 168-173.
[6] Toutin, T. Impact of terrain slope and aspect on radargrammetric DEM accuracy [J]. ISPRS Journal of Photogrammetry and Remote Sensing. 2002. 57(3): 228-240.
[7] Sheng Qinghong,Zhang Jianqing,Xiaohui. A New Approach for Segmentation of Forest Image Based on the Color and Texture [J]. Geomatics and Information Science of Wuhan University.2008.33(3):306-310
[8] Sheng Q H, Xiao H. Research on Filtering of DEM Data Based on the Fisher Functions [A]. Chengdu: IEEE, 2010. 147-150.
[9] Yu jie, Zhang Guoning, Qin Kun. Filtering Method of LIDAR Data [J]. Geospatial information.2006. 4(04):8-10
[10] Wanshou Jiang. Multiple Aerial Image Matching and Automatic Building Detection [D]. Wuhan: Wuhan University.2004

Sheng Qinghong received her PhD (photogrammetry and remote sensing) degree from Wuhan University. She is currently an Lecturer in the College of Astronautics at Nanjing University of Aeronautics & Astronautics. Her current research interest includes digital photogrammetry and computer vision, etc.