3D Modeling Study Using 3D Laser Scanning Data
Based on Xuzhou Turtle Mountain Han Tomb

Jin Peng Feng [a,] ,Kan Wu1 [a] and Xin Zhao [a]

[a] School of Environmental Science and Spatial Informatics, China University of Mining and Technology, Xuzhou, Jiangsu, 221008，China (arthurashe@126.com,wukan6899@263.net,zhaoxin0726@126.com)

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ABSTRACT:

Using three-dimensional laser scanner system to measure the Turtle Mountain Han tomb and obtained the point cloud. To the noise points and large holes on the surface, this paper first present an approach that based on the basic principle of least-squares to eliminate the noise points. Then on the basis that there is certain continuity between the holes and their surrounding surface, an approach to repair those holes is presented. The method is applied to a certain part of the tomb.

1. INTRODUCTION

Turtle Mountain Han tomb (national cultural heritage site) is located in Xuzhou City, Jiangsu, China. The tomb is a joint burial of two parallel interlinked for couples, including the sixth generation of Western Han dynasty King of Chu-Xiang Wang note (that is, 128 years BC – 116 years BC) and north his wife. Turtle Mountain Han tomb is excavated from the west of the turtle hill. There are two parallel channels into the tomb, each channel is 56 meters long, 1.78 meters high, and 1.06 meters wide , the maximum deviation is only 5 mm from the axis, precision up to 1 / 10000. There are 19 meters away from the north to the south channel, with an angle of 20 seconds, precision is 1 / 16000. In Turtle Mountain Han tomb there were 15 tombs, the tombs total area reaches more than 700 square meters. It is not yet known at that time how to make such a high precision incessantly caressed, as well as digging channels with the highest precision in the world.

Essentially, using three-dimensional laser scanning data modeling is to use the post- procession 3D point cloud data to build three-dimensional model of the object. Three-dimensional modeling of the Turtle Mountain Han tomb is of great significance in the following area:

(1) Three-dimensional modeling is known as the most advanced archaeological research method. This study could bring more support by providing information to the archaeologists for a full range of the research on the Turtle Tomb.

(2)Three-dimensional model is not only an important source of basic information to carry out the design of routine maintenance, but also a guidance to the reconstruction. By the advantage of the professional software, various drawings, such as plans, elevations, contour can be more accurate obtained.

(3)By displaying the 3D model of the Turtle Mountain Han tomb on the computer, visitors can experience the most modern way of heritage gallery, and visitors could measure the tomb by himself, experience the fun of multi-angle observations.

2. CONTENTS OF THE STUDY

Each tomb corridor of Turtle Mountain Han Tomb equipped a number of lighting equipment, indicating device, which will lead to the points leakage and producing a large number of noise points in the procession of obtaining the 3D data, as shown in Figure 2. Remove such noise points by hand is very time-consuming and difficult work. For the final simulation results is more close to the true nature, the noise points must be eliminated. In addition, as these man-made facilities will result in the leakage on corresponding parts of the measured point cloud data, an appropriate algorithm for the point cloud hole repaired need to be presented.

3. NOISE ELIMINATION

There is little change on the gradient of the wall of the Turtle Mountain Han tomb, so it can be regarded as a continuous flat surface, for there is not too much disparity in a lesser extent of the scanning point. The lighting equipment will make the gradient of the scanning data on the wall show sudden changes, therefore, relative to the gradient of the whole inner wall plane. The noise plane formed by the noise points could be eliminated and, a noise point which is not target object could be eliminated relative to the gradient of that part of inner wall.

The approach that based on the basic principle of least-squares to eliminate the noise points means firstly fit the whole surface which could generally response the surface characteristics of the whole measured surface area. At the same time fit the local plane taking the advantage of the divided regular grid point cloud data, and then determine whether this surface contains the noise points which have great impact on fitting the local plane. If these noise points present, remove the points within the grid; if not, determine whether the grid points belongs to the plane one by one by certain rules.

Select the dihedral angle as the test indicator to contrast the reference plane with the plane fitting by the points within the grid. In theory, the dihedral angle between the two planes should be 0^0 or 180^0. Because of this method will delete all the points within the grid if the dihedral angle if out of the threshold, the selection of the threshold should be prudent. If the selected threshold is too small, it will cause that most of the points will be removed. Therefore, only the points in the plane which are distinctly deviation from the reference plane will be removed.

Select the distance of the point to the fitting plane as an indicator, which is used to verify whether the points within the grid is the noise points. In this case, the selection of the distance threshold should be fully taken the accuracy of fitting into account. There is variety of factors affect the accuracy of the plane fitting, the most important is the original data (the accuracy, distribution and density of the points), which is very complicated influenced the fitting accuracy.

The point error in the fitting plane is a comprehensive error in the transmission of the modeling. By practice that it is driven by several factors: the plane characteristics of the surveyed area, the precision of original point, surface plane fitting method.

As the selected indicator is the distance of the point to the plane, therefore, pitch is adopted as to assess the accuracy of the plane fitting. That is, first calculate the distance of each scan point to the fitted plane as d, and that d is an overall error during the measurement which is influenced by variety of factors. Then calculate the square error, so the plane fitting accuracy could be obtained.

$$\delta_{拟合}^2 = \sum_{i=1}^{n} d_i^2 \Big/ n \qquad (1)$$

where $\delta_{拟合}$ = the plane fitting accuracy

d_i = the distance of each point to the fitted plane

n = total number of the points

4. HOLE REPAIR

There is little change in slope of the Turtle Tomb inside wall, for the above situation, this paper presents a practical method of repairing holes, it’s divided into three steps to achieve the algorithm:

(1)Calculate the search step using the approach of Dynamic radius. To the center of each grid intersection, search the points according to the changing step. Expand the search radius when the points are too few; narrow the search radius when the points are too much, and ultimately get the appropriate points (5-20 points selected as the appropriate number in this paper).

According to the average density of the point clouds to determine the initial search step R, the formula is

$$\pi R^2 = 7 \times (A/N) \qquad (2)$$

where N = total number of the points
A = total areas

(2) The coordinator of the intersection of regular grid Y/Z (closely related to the step).First, establish uniform grid with certain step in the plane paralleled to the scanning direction, then export the Y/Z coordinates of the intersection.

(3) Interpolate the elevation of grid intersection. The appropriate interpolation model is selected to interpolate the elevation values of the grid X and output the coordinates of point cloud.

5. APPLICATIONS

To verify the feasibility of these above algorithm, in this paper, part of the tomb scanning data which is shown in Fig.1 is used for the test.

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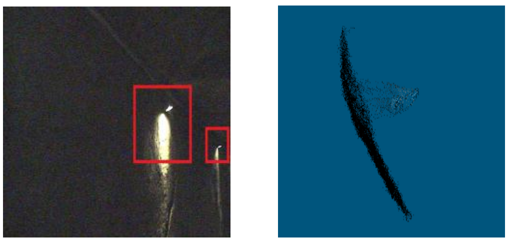
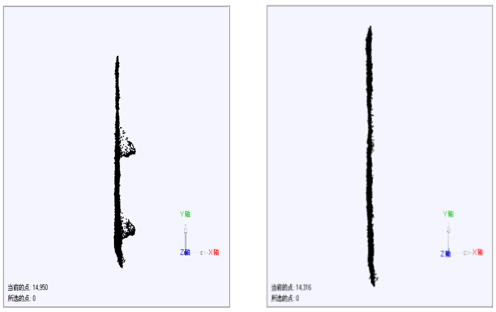


(a) (b)

Figure1. (a) lighting equipment (b) point cloud of the lighting equipment

By using the approach that based on the basic principle of least-squares to eliminate the noise point , the obvious noise point away from the wall of the has been completely removed, but the noise points near the tomb wall lamp is a few retained. The reason for the above phenomenon is due to the selected fitting plane is flat, but the tomb wall was excavated by human, it's undulating, as shown in Fig.2

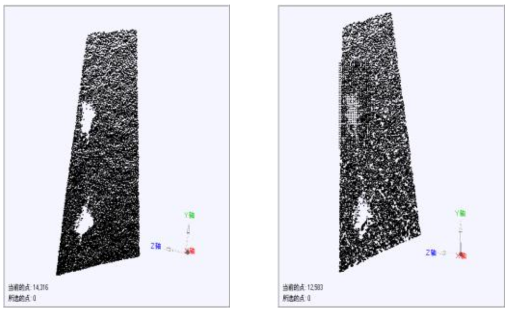


(a) (b)

Figure2. (a) Side view before noise elimination (b) Side view after noise elimination

There are conspicuous noise points (points of landscape on the wall) before noise elimination. By using the approach that based on the basic principle of least-squares to eliminate the noise points , the obvious noise points away from the wall of the has been completely removed, although the noise points near the tomb wall lamp is a few retained. The reason for the above phenomenon is due to the selected fitting plane is flat, but the tomb wall was excavated by human, it's undulating.

Through the interpolation of new points repaired the hole, the verification of the algorithm is tested. To illustrate the effect of this method, Figure 3 (a) (b) show the consequence before and after the repair.



(a) (b)

Figure3. (a) Front view before hole filling (b) Front view before partly hole filling

Hole has been largely filled using the repair method, although the density of the points cloud is less than the normal, and extra points appeared outside. This phenomenon result in the selection of the grid density and the boundary points. Greater density means more points.

6. CONCLUSION

In this paper an approach that based on the basic principle of least-squares for the noise points elimination. Then on the basis that there is certain continuity between the holes and their surrounding surface, an approach to repair those holes is presented. The experiment show the method is feasible. The basic idea of this method is also applicable to other 3D measurement.

REFERENCES

G，J，Yang, Q，H，Liu and W，B，Wu, Research on 3D laser scan surface reconstruction algorithms. 2009, pp. 47-56.

Gruen A, Wang X. CC - Modeler: a topology generator for 3D city model. ISPRS J. *Remote Sensing* 1998:53(4)：pp.286-95.

Lee S J, Kim D H, Park J O. Multiple magnification images based micropositioning for 3D micro assembly. Seventh International Conference on Automation. Singapore, Dec. 2002.

Levoy, M. The digital Michelangelo project: creating a 3D archive of his sculptures using laser scanning. In proceedings of the 2nd International Conference on 3D digital imaging and modeling. IEEE/IEE Electronic Library, 1999, pp.2-13.

L.G.Ma, 2006 The research of terrestrial laser scanning technology pp. 321-332.

Tovari D and Pfeifer N. Segmentation. Based robust interpolation – a new approach to laser data filtering. *Laser Scanning*, 2005. IAPRS, 2005, pp.79 – 84.