

EFFICIENT NOISE REDUCTION OF LASER SCANNING DATA FOR ARCHAEOLOGICAL SURVEY

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ABSTRACT:

Recently, a ground based laser scanning sensor is receiving more attention as an useful tool for real-time acquisition of 3D data, and its applications are proposed in various fields. For example, a topographic survey for archaeological sites is performed efficiently using a laser scanning sensor. A traverse survey is one of the typical methods for topographic map in archaeological sites. Usually, a traverse survey is performed using a total station, and only 2D planimetric map is obtained by traverse surveys. Therefore, 3D survey system is expected to generate DEM using ground based laser scanning sensor, and efficient visualization of topographic data.

In this paper, the authors investigate efficient noise reduction method, and an efficient DEM generation for archaeological sites using a ground based laser scanning sensor.

1. INTRODUCTION

Regarding topographic surveys, total stations are generally used as a popular survey instruments. High accuracy is not expected in comparison with total stations. However, ground based laser scanners have the advantage in acquiring 3D data in real time. Furthermore 3D traverse surveys is expected to use laser scanners instead of only 2D planimetric map which is obtained from popular traverse surveys.

With this motive, visual traverse system using ground based laser scanning sensors would be useful. There are some to be resolved before the system becomes operational. The most bottleneck problem is the noises caused by trees, grasses, electric poles and so on. Many filtering systems for noise reduction were proposed in air born laser scanning fields (H.Masaharu, 2000, K.Kraus, 2001). These noise reduction methods are not so effective for ground base surveys since ground base surveys are often perform in limited area where is covered with low trees and grasses. This paper reports automatic noise reduction method and interpolated method for the lack of 3D data, and shows the acquired DEM

2. 3D SURVEY SYSTEM

Figure 1 shows the flow of 3D survey system. This system consists of several processes. These processes are measurement, noise reduction, unification of coordinates and visualization. Detail procedures for each process are described in afterward.

3. REMEASUREMENT

3D Laser Scanning Sensor (LD90-3100VHS-FLP,accuracy: $\pm 25\text{mm}$) is used in this paper. Distance, vertical angles and

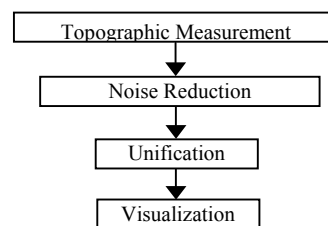


Figure1.Flow of 3D Survey System



Figure 2. Archaeological Site Imagery

horizontal angle to the objects, and the intensity of the objects are obtained by the laser scanning sensor. The intensity is shown by the strength of the laser light reflection, and is changed by the material of subject, distances to a subject and so on. Furthermore, 3D coordinates are calculated automatically from the distances and posture angles.

Figure 2 shows the archaeological site imagery.

3.1 Noise Reduction

In the case of ground based laser scanning, noise caused by trees are estimated, and noise will be removed by automatically. Hence, automatic noise reduction method was investigated. Detail procedures for noise reduction are as follows, Figure 3 shows intensity image. Figure 4 shows the flow of automatic noise reduction method.



Figure 4. Intensity image

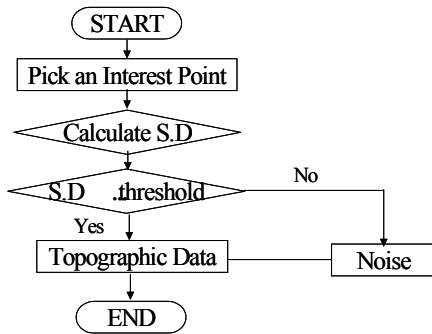


Figure 3 Flow of automatic noise reduction

3.1.1 Standard Deviation (S.D)

Automatic Noise reduction is performed by degree of scatter. Generally, the degree of scatter is called Standard Deviation. The search range is m and n , the height of each point is Z , the number of total point is N . Consequently, S.D σ is calculated by the following equation.

$$\sigma_{ij} = \sqrt{\frac{\sum_{s=1}^m \sum_{l=1}^n (Z_{sl} - M)^2}{(N_z - 1)}} \quad (1)$$

where,

$$M = \frac{\sum_{s=1}^m \sum_{l=1}^n Z_{ls}}{N_z}$$

In order to perform S.D, the following procedures are performed, and Figure 5 shows the coordinates before conversion and those after conversion.

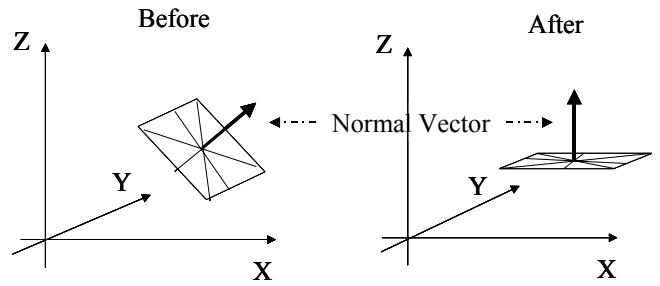


Figure 5. Rotation of Coordinates Imagery

- Rotation of Coordinates
- + Select an interest point using intensity image.
- + A rectangle mask is prepared.
- + 8 triangles are prepared by dividing the mask into 8
- + Calculate the normal that totaled 8 triangular normal vectors
- + Transform the coordinates in the mask for the vector unifying to the Z-axis.

3.1.2 Interpolation

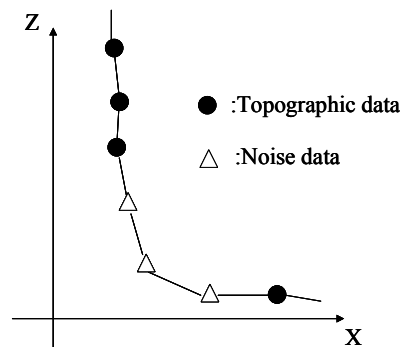


Figure 6. Position of big slopes

Repeating the above procedures, noise caused by trees are considerably removed. However, points of big slopes are removed as noise. Figure 6 shows topographic data and noise data in big slopes. In order to resolve the second issue, the following procedures were created.

- + If an interest point detect as topographic data, compare Z value of all points in the mask with S.D value.
- + If each points of Z value has smaller the interest point of S.D value, the point is recorded as topographic data.

3.2 International Roughness Index (IRI)

Noise reduction is performed by S.D operation with threshold value relative to component called IRI. IRI (Sayers, 1996) was established by World Bank in 1986 and developed as an index

for level of flat ground. Accordingly, The threshold value σ is calculated by following equation.

$$IRI = 0.74\sigma_{3m} + 1.77 \quad (2)$$

where,

IRI: constant value set by IRI(usually 8~20)

This equation is necessary needed to sufficiently sampling the exact calculation. For this purpose, mask size by the use of S.D operation is prepared as 300 mm interval.

Consequently, σ (S.D) was judged by IRI that was a noise at the time of the following conditions. If σ (S.D) was bigger than 0.025m, the point of σ (S.D) is removed as noise.

3.3 Result of Noise Reduction

Figure 7 shows the image which noises are reduced for the Figure 4. It can be observed that effective noise reduction was performed by the above mentioned methods. Similarly the necessity of interpolation is recognized. Figure 8 shows interpolated image. From this figure, it can be said that the interpolation was performed successfully.

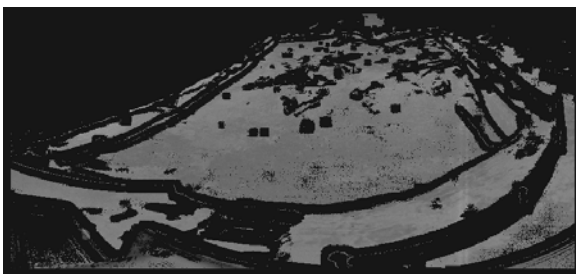


Figure 7. Result of noise reduction

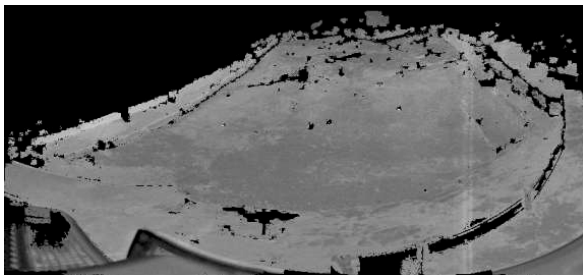


Figure 8. Interpolated image

3.4 Unification of Coordinate System

Generally, lack of data caused by blind spot are estimated from a traverse station. Then, measurements from multiple stations for the same scene become necessary. When laser scanning sensor measure the mirror seal, it could be found

easily in intensity image because the intensity of the seal have high brightness. So, mirror seals were set around the sites as markers, and coordinates system for multiple traverse points are unified automatically as the following procedures.

- + Set mirror seals at around sites.
- + Extraction of mirror seal (3D coordinate) in each intensity image.
- + Generation of TIN models using 3D data of the mirror at every stations.
- + Comparison with TIN models between the stations.
- + Matching conjugate mirrors using area, corner angles and side length for triangulations.
- + Unification of coordinates system using conjugates mirrors.

Table 1 shows the equations that are used to unify the coordinates system. This expression is generally used for three-dimensional transformation.

Table 1 Conversion Expressions

Coordinate	Expressions
X	$x' = ((x-x_b) * \cos \theta - (y-y_b) * \sin \theta) + x_m$
Y	$y' = ((x-x_b) * \sin \theta + (y-y_b) * \cos \theta) + y_m$
Z	$z' = (z-z_b) + z_m$

Where,

- (x,y,z) = Coordinate before conversion,
- (x',y',z') = Coordinate after conversion
- (x_b,y_b) = Origin Coordinate at before conversion
- (x_m,y_m,z_m) = Origin Coordinate at after conversion
- θ = Rotation angle

4. 3D TRAVERSE

3D traverse survey using ground based laser scanning sensor is proposed in this paper, and 3D traverse survey are performed using the above procedures are used in premeasurement.

Table2 shows the major contents for the traverse area. Figure 9 (a) shows the results of 3D traverse, Figure 9(b) shows counter image that is performed by weighting average interpolation using the results of 3D traverse

Table 2 Major components of the experiment

Target	Archaeological Site at Seto-city,Aichi,Japan
Measurement Area	400m*400m
Traverse Point	3 points
Length for leg of traverse	430m

4.1 Accuracy

Accuracy for traverse by laser scanning sensor was 1/7,000. High accuracy was not estimated in comparison with total stations. The accuracy of laser scanning sensor is ±25mm. Nevertheless, it can be seen that good accuracy was acquired. Furthermore, take into account that 1/5000 ~ 1/10000 is demanded in general survey, it can be concluded that traverse survey using laser scanning sensor has enough accuracy.

5. CONCLUSION

3D traverse using ground based laser scanning sensor is proposed in this paper, and noise reduction and interpolation methods and unification of coordinates system were investigated.3D traverse is recognized as having enough accuracy can be obtained. It is concluded that ground based laser scanner will become useful tool in the topographic survey for archaeological. The remarkable points as additional results.

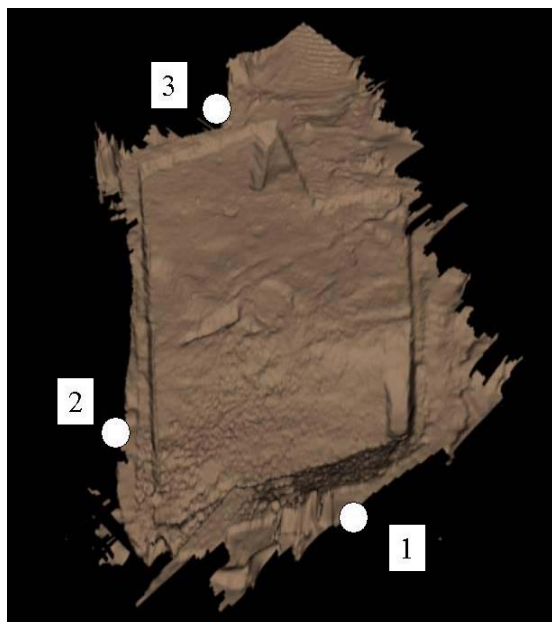
However, there are still issues which needed to be resolved before this method this system becomes operational. These problems include detection of break lines and application for city modelling.

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(a)DEM from Multiple Point (0.1m mesh)



(b)Counter Image (0.5m pich)

Figure 9.Measuraent Result of 3D Traverse

are its ability to perform as 3D traverse survey