Laser Scanner Measurement for Monitoring Landslide Displacement

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Abstract: Recently, the ground based laser scanner is considered as useful measurement equipment that can acquire a three-dimensional data in a short time over a wide area with a high resolution. However, it is difficult to acquire a highly accurate position information using ground based laser scanner, and to measure the change in shape of the displaced land surface owing to the following reasons. 1) The range measurement data of ground based portable laser scanner have random error. 2) It is difficult to set up the equipment at exactly the same point for each observation. To solve the problems, this study proposes a surface observation method. The surface observation method performs average data scanning same surface. To carry out the accuracy verification, repeated scanning data of 100 times in total were used in observation room. Then, the appropriate number of measurement point can be decided for deriving accurate plane equation. The result showed the error decrease almost 1/5 using over 250 measurement points. After that, the proposed method should be applied to monitor landslide.

Keywords: Landslide, Laser Scanner, High accurate surface position, Iteration measurement

1. INTRODUCTION

1.1 Measurement of Landslide

A landslide is a phenomenon of mass slowly movement, which moves 0.01mm~10mm/day in the wide area. Current monitoring systems are used expansion gauge, inclinometer, or GPS. The monitoring systems for landslide displacement can measure at some points or along lines. It is difficult to measure whole landslide area.

Currently, laser scanner and digital photogrammetry are expected to monitor landslide. Especially, laser scanner can acquire three-dimensional data in a short time, in wide area. The laser scanner is a kind of electro-optical distance meter without prism. It can measure distance by elapsed time that the laser pulse reach targets and come back. At same time, the horizontal angle and vertical angle also measured. Finally, distance to targets, angles, reflection intensity of targets and color information are detected. Therefore, ground based portable laser scanner will suite to detect displacement of landslide. For the extraction of landslide displacement by using laser scanner, millimeter accuracy is required.

1.2 Problems in accurate measurement

1.2.1 Accurate Measurement

Figure1-1, 1-2, 1-3 showed Digital Surface Model(DSM) of smooth flat board which was measured by laser scanner in several measurement distance. The DSM was represented by Triangulated Irregular Network, which was given shading for easy understanding. In each DSM, measured points seemed including random error. Therefore, noise reduction system should be developed for accurate measurement.

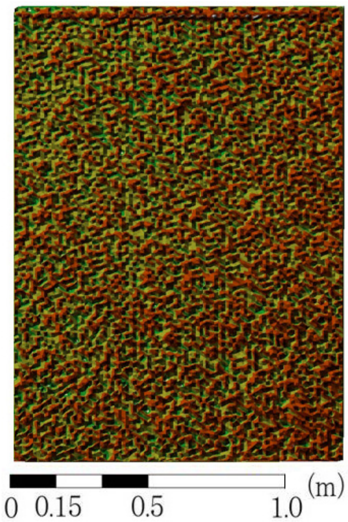

Figure 1-1: Sample of Laser Scanner data in case 10m distance

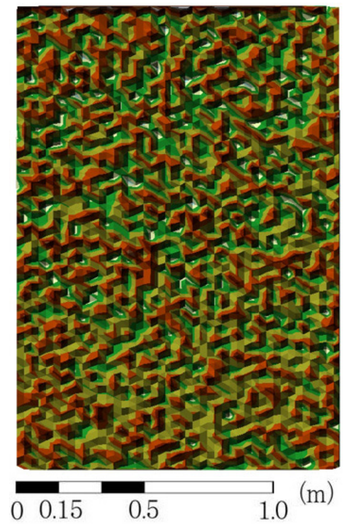

Figure 1-2: Sample of Laser Scanner data in case of 20m distance

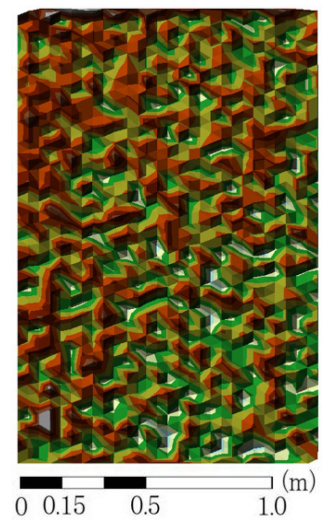

Figure 1-3: Sample of Laser Scanner data in case of 30m distance

1.2.2 Accurate setting

When displacement of a landslide is measured by using portable laser scanner, time series data are needed. Then the laser scanner must be set repeatedly at same point. It is difficult to set accurately at same point in each observation. The position of laser scanner in horizontal plane can be adjusted by centering equipment. However, it is difficult to set in vertical axis. In addition, starting point for scanning is not always same point.

1.2.3 Accurate control points in laser scanner data

A transformation of a coordinate system using control points is necessary for detecting displacement when repeated setting is difficult. Some prisms for control points must be prepared. The control points on the ground can be measured by using Global Positioning Systems or Total Station. On the other hand, the control point in laser scanner data can be extracted automatically according to reflectance intensity of laser data by software of a laser scanner. However, extracted coordinates of control points was slightly different in each observation. The reflectance intensity might be influenced by the sun angle and the direction from the laser scanner to the prism. Therefore, coordinates of control points in laser data have unstable value.

2. OBJECTIVES

This study is focused on measurement accuracy of a ground based laser scanner. Each measurement point using laser scanner has random noise. To reduce the random noise, surface observation will be efficient. When the flat surface is observed, many points will be acquired on the surface. The random error will be reduced by average calculation using many points. Therefore, objective in this study is developing noise reduction system based on flat surface observation. Appropriate number of points for surface observation will be decided. Moreover, the possibility of noise reduction by iteration measurement will be discussed. A landslide is a very slow movement phenomenon. The movement is 0.01mm~10mm/day. Measurement of landslide displacement is difficult because accuracy of laser scanner is 2.5 centimeter in standard deviation. Therefore, accuracy of a laser scanner should be proceeded 1/5 of current accuracy.

3. TEST AREA

3-1. Landslide area for the case study

Figure 3-1: Observation field in landslide area

In Shikoku, Japan, There are four big active faults. Many landslides are occurred along the active fault. Now, landslide prevention areas exist over 1,500 places. In this study, Chouja landslide area was selected for this study. In Chouja, the width of landslide is about 200m, and the length is about 900m and the average slope is about 15 degrees. It is one of the biggest landslide areas in Japan. As Observation site, shore-protection blocks were selected (Figure 3-1) because they are located in the end of landslide area where is large movement. And there are many flat surfaces.

3-2. Experiment for accuracy validation

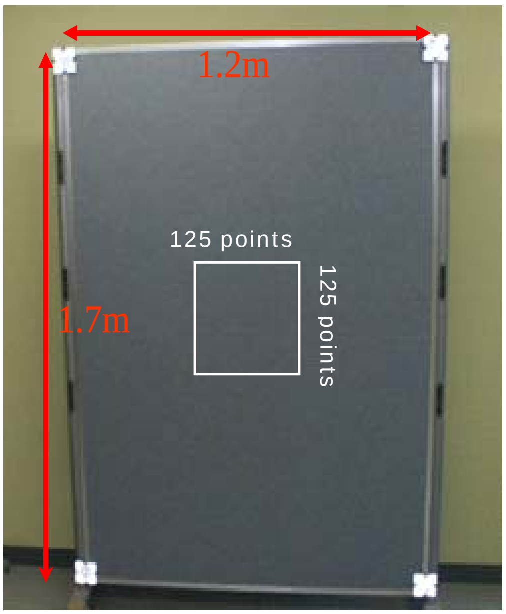

Figure 3-2: Observation board

(Flat surface)

The indoor experiment was performed for measuring error characteristics of laser scanner. Figure3-2 showed observation board for indoor experiment. The width of the observation board was 1.2m. The length of the observation board was 1.7m. The observation board assumed a flat surface. Distance between laser scanner and observation board was about 3m. Laser scanning was repeated 100 times in same condition. The number of points in each observation board was 170,000 points. In this study, 125 points by 125 points were extracted from the center of observation board in the laser data to generate validation data.

4. THE SPECIFICATION OF USED LASER SCANNER

Maximum measurement range is 350m. Accuracy is about 2.5 centimeter in standard deviation. Table 1-1 showed specification of Laser scanner. Table 1-2 showed Performances of measurement distance.

Table 1-1: Specification of laser scanner

	Frame scan (vertical direction)	Line scan (Horizontal direction)
Pixel(max)	1106 pixels	4621 pixels
Angle Range	±40°	0°～ 333°
Scan Speed(/s)	5line ～ 52line	1°～ 15°
Pixel(max)	1106 pixels	4621 pixels
Angle resolution	0.036° (actual 0.072°)	0.018° (actual 0.072°)

Table1-2: Performances of measurement distance

Range	≦350m (reflectance≧80% of objects)
Range	≦150m (reflectance≧10% of objects)
Shortest Distance	2m
Measurement Accuracy	±2.5cm (Standard Deviation)
Laser Wavelength	0.9μm (Infrared)

5. THE ACQUISITION OF VALIDATION DATA

At the beginning, data composite method was proposed to make accurate data. The composite method performs an average calculation of repeated scanning of the same position. If each point in each scanning is pointing the same position, error can be reduced by calculating average. Actually, data composite method is effective method to reduce noise in image processing. However, it was difficult to get same points data. Only 12 scenes in 100 scenes data ware pointing same direction because start position for scanning was not always same position. A surface observation method with many points was preferable to data composite method. When flat surface is observed, many measurement points are acquired on the surface. Then equation of plane can be calculated using many measurement points by least square method. Eq. (1) showed equation of plane.

$$ax + by + cz = 1 \quad \cdots (1)$$

x,y,z : coordinates

a,b,c : coefficients

The derived equation of plane will be accurate position of the surface. Number of measurement point will influence to accuracy of the derived equation.

Validation plane was derived by using measurement points which are 125points×125points×100scenes. Coefficients of the equation were calculated to fit plane to measured points by least square method. Next, distance between validation plane and each measurement points were calculated. Then, histograms of the distance and normal distribution were calculated (Figure5-1). From figure5-1, measured point by laser scanner had contained a random noise. The error showed 3.9 centimeter in standard deviation.

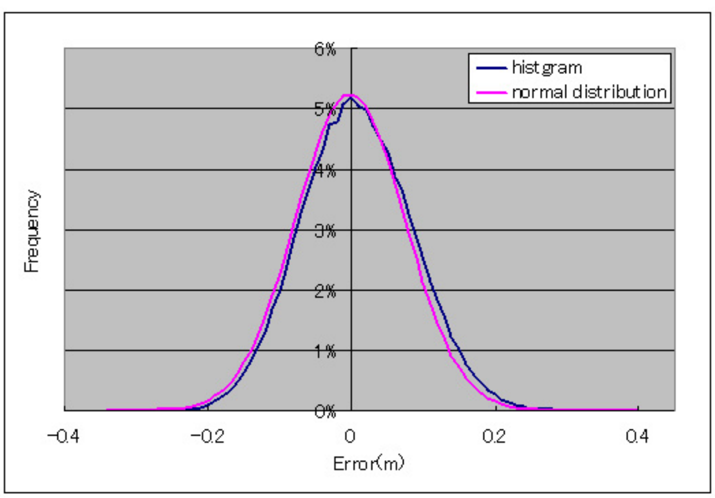

Figure 5-1: Normal distribution and histogram of validation data

6. MEASUREMENT OF ACCURATE SURFACE POSITION

It is necessary to know the least number of points to measure surface accurately. In this chapter, measurement point was used from 4 points to 4096 points. The number of points is corresponded to area. By using each point data, equation of plane was derived. The distance between each derived plane and validation plane was calculated, which direction is center of laser scanner to measurement points. The distance means the error of derived plane. Figure6-1 showed relationship between error (standard deviation) and number of point to derive plane. From figure 6-1, the error was decreased according to the number of point. For example, error showed less than 1 centimeter when over 256 points were used.

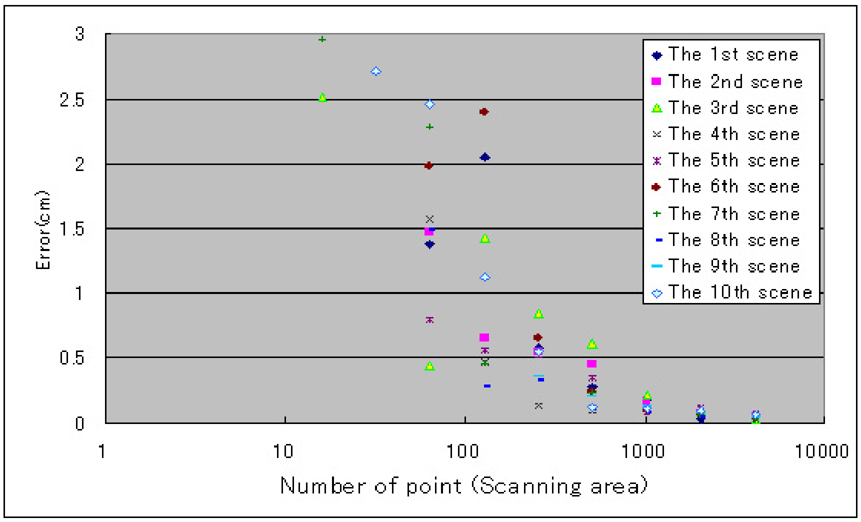

Figure 6-1: Relationship between error and number of point

7. ITERATIVE MEASUREMENT FOR A NARROW SURFACE

256 points were necessary to measure accurately surface. However, there is no flat surface that can be acquired 256 points in the observation field. Actually, 256 points from the surface of a shore-protection block cannot be acquired because the distance between laser scanner and the shore-protection block is too far to obtain 256 points. Therefore, data integration is necessary to keep enough accuracy for smaller surface. The high density data can be made by integrating each scene data. When 100 scenes were prepared, 100 times density data will be acquired. For example, very narrow surface which consisted with 4 points data will become 400 points data by integrating 100 scenes data.

Data integration was tried to proceeds accurate measurement. Integrated data was used for deriving equation of plane. And distance between each derived plane and validation plane was calculated. In this study, the required accuracy is less than 1/5 of current accuracy (0. 8 centimeter). Figure7-1 showed relationship between number of integration and the error in each origin number of point data. From figure 7-1, decreasing error had limitation in each point data. Data integration with few points was not efficient. To keep 1/5 of current accuracy, at least 64 point data were required.

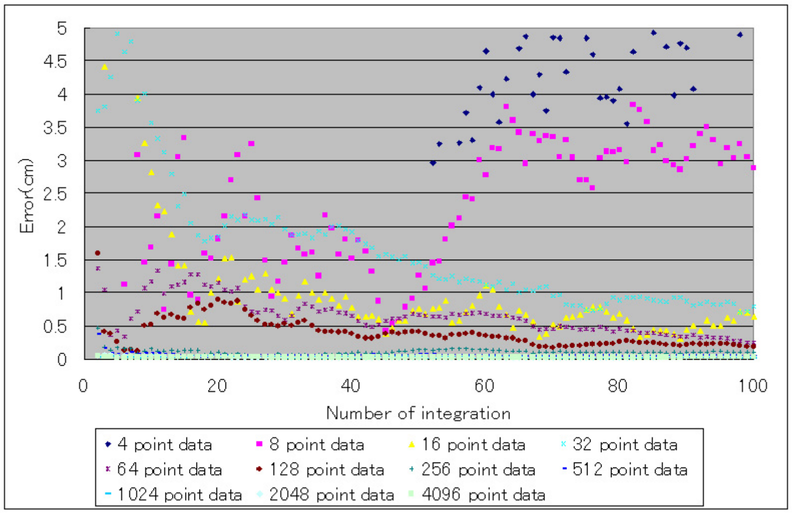

Figure 7-1: Relation of error and iteration of integration

8. CONCLUSIONS

Noise reduction system based on flat surface extraction by iteration measurement was developed. At least 256 point data for surface measurement could be satisfied with requirement accuracy by 1 scene. When data integration with 40 time measurement was applied, at least 64 point data could be satisfied.

Developed system should be applied to monitor land slide displacement. Figure 8-1 showed shore-protection blocks in observation field. There were many flat surface witch was painted white rectangle in the image. Those flat surfaces will be measured accurately. The distance between shore-protection blocks and laser scanner was about 50 meter. In this condition, about 100 point can be acquired. For accurate measurement, 40 times measurement will be needed. As future work, landslide displacement might be succeed by developed system.

Figure 8-1 Shore-protection block and test surface

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