Accuracy Evaluation of Laser Scanner Data Depending on Location of GCPs for Monitoring Landslide

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ABSTRACT: Laser scanner is expected as a useful measurement device for monitoring landslide. Laser scanner can acquire three dimensional data in a short time, in wide area. The data of the time series are needed to measure the movement phenomenon such as landslides. Therefore, the geometric transformation that makes the same coordinate system for change detection becomes very important. Accuracy of geometric transform is depending on the types of control point and location of control points. The prism, the reflector sheet, and the multi surface measurement were used as control points in this study. The multi surface measurement showed accurate in in-door experiment. However, accuracy of the multi surface measurement is no good in the out side experiment. The reflector sheet and multi surface measurement showed including systematic error. When the systematic error is eliminated, stable accuracy will be expected. Method to cancel the systematic error must be developed.

1 BACKGROUND

1.1 Observation of landslide

A landslide is a phenomenon of mass movement on the ground, which moves 0.01mm to 10mm/day in the wide area. Current monitoring systems are used expansion gauge, inclinometer or GPS. Those monitoring systems for landslide displacement can measure at some points or along lines. It is difficult to measure whole landslide because of very wide area. Laser scanner is expected as a useful measurement device for monitoring landslide. Laser scanner can acquire three dimensional data in a short time, in wide area. For the extraction of landslide displacement by using laser scanner, millimeter accuracy is required.

1.2 Used Laser scanner

In this study, LMS-Z210 produced by Riegl was used as laser scanner. Maximum measurement range by the laser scanner is 350m. Accuracy is about 2.5 centimeter in standard deviation. Table 1-1 shows Performances of measurement distance.

Table 1-1 Performances of measurement

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

1.3Control Point for Geometric Transform

Time series data must be prepared for monitoring landslide. The each data should be geometrically transformed in order to become same coordinate system for comparing each other. Therefore control point must be set up in the test field. Figure 1-1 shows the kinds of the control point for laser scanner. Currently, there are three kinds of control point for laser scanner such as prism, reflector sheet and multi surface measurement.

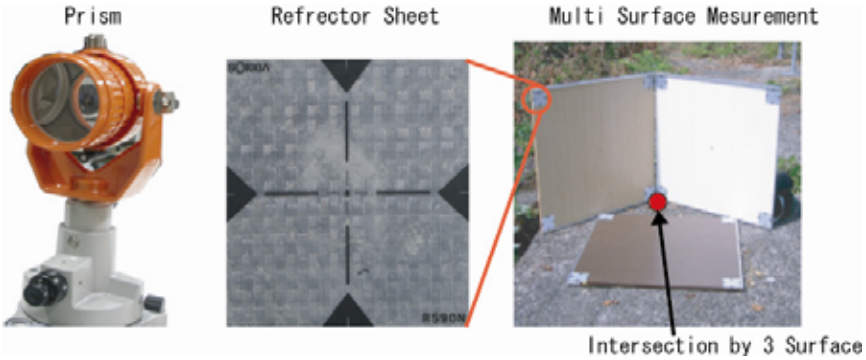

Figure 1-1 kind of the control point

1.3.1 Prism

The prism is often used as a control point. The prism can be strongly reflected laser light that can be set up very far point from laser scanner such as 300m. However, coordinates of the control points in laser scanner data cannot be accurately extracted. The coordinates of the same control point have 10 cm error in maximum when the data were acquired several times in same condition. It was very big error comparing with laser range accuracy (2.5cm).

1.3.2 Reflector Sheet

It is difficult to use a lot of prisms because it was expensive. Therefore, a lot of reflectors sheets are expected to use because of cheap. However, reflection strength is lower than the prism, so the reflector must be set up in 100m distance. from laser scanner.

1.3.3 Multi Surface Measurement

Authors suggested multi surface measurement to keep accurate control point last year.

The accurate measurement of control points can be improved by measuring some flat surfaces. When three flat surfaces are measured, coordinates of the intersection in equation of three planes can be calculated. This intersection can be used as a control point of the laser scanner data. Geometric transformation by using multi surface measurement was high accuracy. However, there are limited spaces to set up the surface in the landslide field to keep enough accuracy. When the flat surface set up in the long distance, very wide board must be prepared.

2 OBJECTIVES

This study is focusing on accuracy of geometric transform. Accuracy of geometric transform is depending on the types of control points and the location. Three types of control points are compared in this study. And special distribution of control point and the accuracy will be discussed.

3 METHODOLOGY

3.1 Ground Control Point

The ground coordinates of control point are measure by the total station. (xi, yi, zi) is represented as ground coordinate. i means number of control point.

3.2 Laser Coordinate of Control Point

Corresponded laser coordinates of the prism and the reflector sheets are extracted from reflection strength of the laser. Coordinates of the intersection are calculated by solving equations of three planes which were derived from many laser points data. (ui, vi, wi) is represented as laser coordinate.

3.3 Geometric Transform

Three dimensional affine transformation was applied for geometric transformation as follows;

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix} = \begin{pmatrix} p_0 & p_1 & p_2 \\ p_3 & p_4 & p_5 \\ p_6 & p_7 & p_8 \end{pmatrix} \begin{pmatrix} u_i \\ v_i \\ w_i \end{pmatrix} + \begin{pmatrix} X_0 \\ Y_0 \\ Z_0 \end{pmatrix}$$

x,y,z: Ground coordinate
u,v,w: Laser scanner coordinate
X_0, Y_0, Z_0:Coordinate of laser scanner point
$p_0 \ldots p_8$:Transform coefficients
i:number of control point

Coefficients of transform are calculated by least square method using control point data which are (x_i, y_i, z_i) and (u_i, v_i, w_i). Transform coefficients $(p_0 \ldots p_8)$ and coordinate of laser scanner point must be derived to establish geometric transform by using control point. At least 4 control points are needed.

3.4 Evaluation

The validation point (x_p, y_p, z_p) was established. The coordinates of the validation point was measured by the total station. The coordinate was assumed as true. The error of transformation can be evaluated by the root mean square error(RMSE) which means distance between transformed coordinate and validation coordinate. RMSE can be

calculated following equation.

$$Error = \sqrt{\frac{\sum (X_p - X_j)^2 + (Y_p - Y_j)^2 + (Z_p - Z_j)^2}{n}} \quad j: \text{number of measurement}$$

4 IN DOOR EXPERIMENT

Firstly, in-door experiment was carried out in a gymnasium. Figure 4-1 shows location in test area. The prism was set up at the four corners in the gymnasium. Four reflector sheets were put on one board. Totally 48 reflector sheet were used. The boards for multi surface measurement were set up in four corners. Validation point was established in the center. Laser scanner measurements were repeated 8 times in same condition.

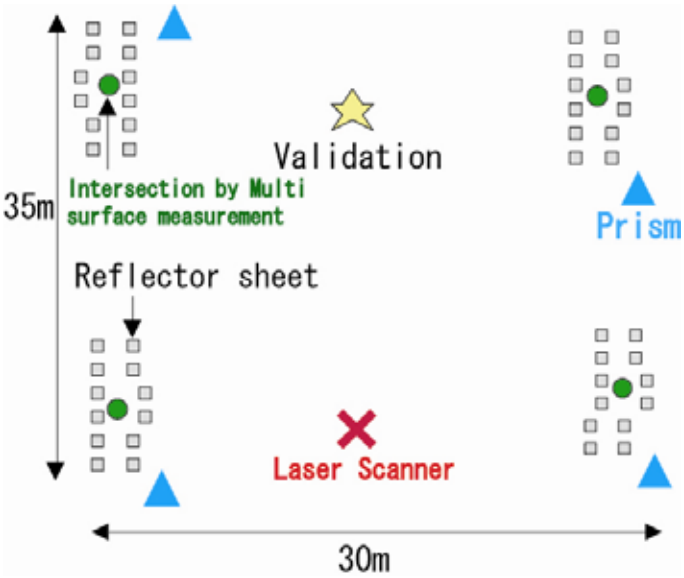

Figure 4-1 Location in test area

Table 4-1 shows R.M.S.Error of geometric transformations by using prism, reflector sheets and by using the intersection of three planes, Figure 4-2 shows coordinates of the verification point in each measurement after geometric transformation.

Table 4-1 R.M.S.Error of geometric transformation(m)

	Prism	Reflect sheet	Multi Surface Mearsurement
measurement1	3.882E-02	5.809E-02	5.033E-02
measurement2	4.223E-02	5.188E-02	4.553E-02
measurement3	6.807E-02	5.182E-02	4.527E-02
measurement4	1.276E-01	5.363E-02	4.526E-02
measurement5	7.794E-02	5.656E-02	4.842E-02
measurement6	8.626E-02	5.664E-02	4.609E-02
measurement7	8.224E-02	5.853E-02	4.607E-02
measurement8	1.122E-01	6.033E-02	5.015E-02
average	7.942E-02	5.594E-02	4.714E-02
S.D	3.073E-02	3.168E-03	2.162E-03

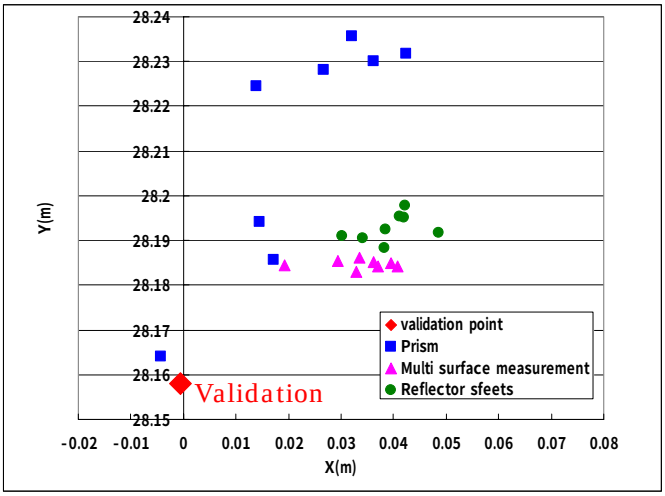

Figure 4-2 coordinates of validation point by each geometric transform

Geometric transformation by multi surface measurement was higher accuracy than geometric transformation by a prism. However, a systematic error is included in the each control point. The systematic error might be come from spatial distribution of control point.

5 OUTDOOR EXPERIMENT

Out door experiment was carried out in landslide area. Figure 5-1 shows the location of control points. The 6 prisms were widely set up on the landslide site. 36 Reflector sheets were put the boards. 3 sets ofthe boards for multi surface measurement were set up around the laser scanner to keep the accuracy within 20m distance. Laser scanner measurements were repeated 10 times in same condition.

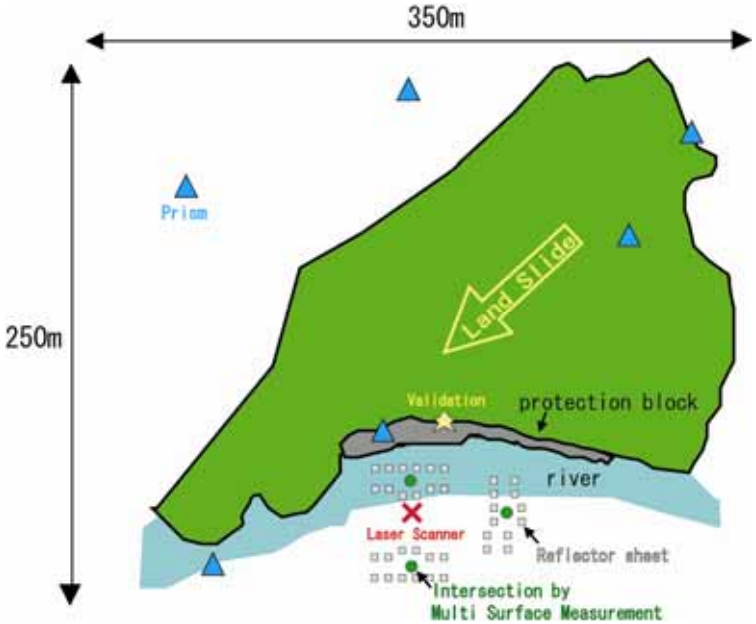

Figure 5-1 Location in Land slide

Table 5-1 shows R.M.S.Error of geometric transformations by each control point. Figure 5-2 shows coordinates of the verification point by each geometric transformation.

Table 5-1 R.M.S.Error of geometric transformation(m)

	prism	reflect sheet	Muti Surface Measurement
measurement1	1.975E-02	7.302E-02	2.859E-01
measurement2	6.591E-02	8.167E-02	2.779E-01
measurement3	3.942E-01	7.718E-02	2.622E-01
measurement4	1.045E-01	7.794E-02	2.773E-01
measurement5	3.515E-02	9.392E-02	2.365E-01
measurement6	1.209E-01	1.050E-01	3.077E-01
measurement7	8.329E-02	1.059E-01	2.598E-01
measurement8	2.507E-02	8.473E-02	2.486E-01
measurement9	9.738E-02	8.521E-02	1.724E-01
measurement10	5.829E-02	8.505E-02	2.488E-01
average	1.149E-01	8.937E-02	2.517E-01
S.D	1.088E-01	1.127E-02	3.652E-02

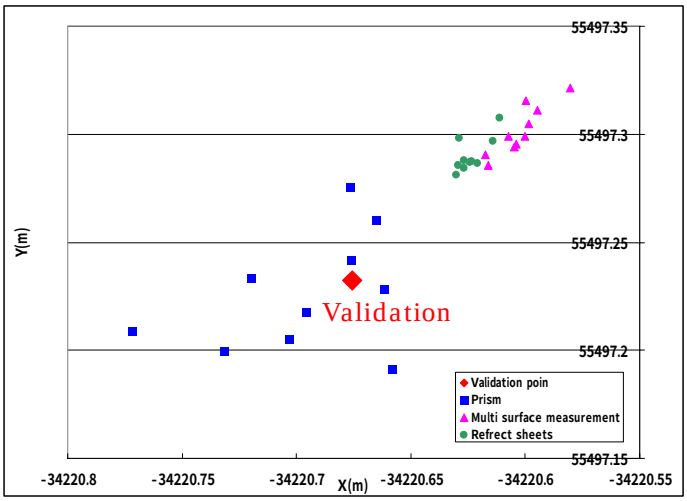

Figure 5-2 coordinates of verification point by each geometric transform

Geometric transformation by prism was higher accuracy than other control point. The error of the geometric transformation of the multi surface measurement was large. A systematic error is included in the reflector sheet and multi surface measurement. However, standard deviation of reflector sheets and multi surface measurement showed very small.

6 CONCLUSIONS

The accuracy of geometric transform is influenced by spatial distribution of control points. Prism can be set up in very wide range, then the average became close to validation point in the landslide area. However, standard deviation was very big. Therefore, stable accuracy cannot be expected. On the other hand, standard deviation of reflector sheets and multi surface measurement showed very small. When the systematic error is eliminated, stable accuracy will be expected.

7 REFERENCES

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