Landslide Monitoring by LiDAR and Digital Camera with Band Path Filters

Kenta Sugiyama[1],Shinpei Akiyama and Masataka TAKAGI[2]
Geomatics Laboratory
Kochi University of Technology
Tosayamada, Kochi, Japan
[1]E-mail: 185102v@gs.kochi-tech.ac.jp
[2]E-mail: takagi.masataka@kochi-tech.ac.jp

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ABSTRACT: LiDAR (Light Detection And Ranging) can observe land surface and any objects on the earth. The topographic analysis using LiDAR is tried in various research organizations. Geomatics Laboratory in Kochi University of Technology is developing method of landslide monitoring using LiDAR. Landslide area is covered by vegetation which disturb observation of ground. Objectives of this study are vegetated area will be eliminated from LiDAR data using customized digital camera and change detection method using least square matching will be established. The test area was selected Choja landslide in Shikoku Japan. Choja landslide is moving 2～3cm a year. In the test area, LiDAR measurement was carried out in February 27th 2012 and March 28th 2013.LiDAR data were converted to ground coordinates in 3mm accuracy using GCPs. In this study, digital camera was used for image acquisition of Normalized Differential Vegetation Index (NDVI). Then IR customized digital camera "Canon EOS kiss X5 SEO" and band path filters were used. Non-vegetated points in LiDAR data were extracted according to NDVI which is less than 0.2.

In this study, least square matching was applied for the change detection of landslide. The point cloud data of LiDAR data were projected to X-Z plane for generating image. A pixel value which means brightness was assigned a distance from the X-Z plane. The least square matching can derive accurate matching point in the imagery. The change detection showed over 2cm displacement along Y axis. The results were accepted comparing with other landslide monitoring results. This suggested methodology should be applied to wide area monitoring as future work.

1. INTRODUCTION

LiDAR (Light Detection And Ranging) can observe land surface and any objects on the earth. Moreover LiDAR can observe wide area in a high density. Therefore, LiDAR has a potential to monitor landslide. A change detection method for multi temporal LiDAR will be effective. However, Landslide area is covered by many vegetations. Therefore, vegetated area should be eliminated from LiDAR data. Normalized Differential Vegetation Index (NDVI) by infra-red imager can be used to eliminate the vegetations. Objectives of this study are vegetated area that will be eliminated from LiDAR data using customized digital camera and change detection method using least square matching will be established.

2. TEST AREA

The test area was selected Choja landslide in Shikoku Japan. Shikoku has a lot of landslide along the big techtonic line. Choja landslide is moving 2～3cm a year, the width is about 200m, the length is about 900m, the average slope incline is 15degrees.

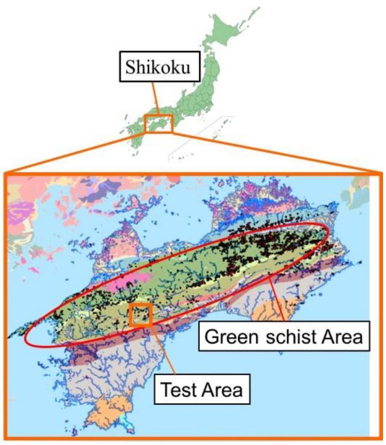

Figure 2.1 Test area

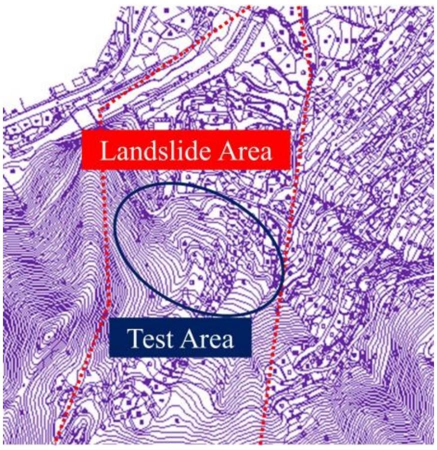

Figure 2.2 Test area

3.LiDAR DATA ACQUISITION

3.1.Used LiDAR

In this study, GLS-1500 produced by TOPCON was used. GLS-1500 uses laser of the short wave infrared band to measure distance. The Wave length of the laser is 1535nm. Figure 3.1 showed appearance of GLS-1500. Table 3.1 showed specification of GLS-1500.

3.2. Acquired LiDAR Data

In the test area, LiDAR measurement was carried out in February 27th 2012 and March 28th 2013. Figure 3.2 showed acquired LiDAR data in 2013. To extract Landslide displacement, local coordinates(x_i,y_i,z_i) of LiDAR data must be converted to ground coodinates(X_i,Y_i,Z_i). In this study, thee dimensional affine transformation eq(3.1) was applied for the conversion.

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$$\begin{pmatrix} X_i \\ Y_i \\ Z_i \end{pmatrix} = \begin{pmatrix} p_0 & p_1 & p_2 \\ p_3 & p_4 & p_5 \\ p_6 & p_7 & p_8 \end{pmatrix} \begin{pmatrix} x_i \\ y_i \\ z_i \end{pmatrix} + \begin{pmatrix} X_0 \\ Y_0 \\ Z_0 \end{pmatrix} \qquad \text{eq(3.1)}$$

Conversion coefficients(p_0～p_8) and LiDAR position(X_0,Y_0,Z_0) were derived using 8 GCPs by least square method. A refrector sheet was used as GCP. The coordinates of GCPs were measured by total station. As a result of affine transformation, RMSE showed less than 3mm. Table3.2 showed RMSE around control point at 2012 and 2013.

Figure 3.1 showed appearance of GLS-1500

Figure 3.2 Acquired LiDAR data in 2013

Table 3.1 Accumulation of area on changed pixel

Products of Laser Scanner	GLS-1500
Effective measurement range	500m
Measurement angle	70 ×360
Ranging accuracy	±4mm(in 150m)
Measurement density	Max 1mm(in 20m)
Max points	100,000,000 points
Measurement principle	Time of Flight
Wavelength of the laser	1535nm

Table 3.2 RMSE around control point

	X(m)	Y(m)	Z(m)
2012	0.020	0.001	0.001
2013	0.002	0.002	0.003

4. CUSTOMIZED DIGITAL CAMERA IMAGE ACQUISITION

4.1. Used digital camera and filters

In this study, Digital Camera was used for image acquisition of Normalized Differential Vegetation Index (NDVI). Usually, “infra-red (IR) light block filter” is adapted in normal digital camera. For NDVI image generation, IR block filter must be removed. Then IR customized digital camera “Canon EOS kiss X5 SEO”, and band path filters were used (Figure 4.1). This camera is usually used for astronomical photography.

Three filters were used to take a visible red band and an near infra-red band imagery (Figure 4.2). For the visible red band, “Kenko SR64 and IDAS UIBARⅢfilter” were used. Combination of these filters can transmit 640nm ～ 700nm wave length (Figure 4.3). For the near infra-red band, “IDAS I-filter” was used. This filter can transmit 700 m ～ 900nm wave length(Figure 4.4).

Figure 4.1 IR customized digital camera

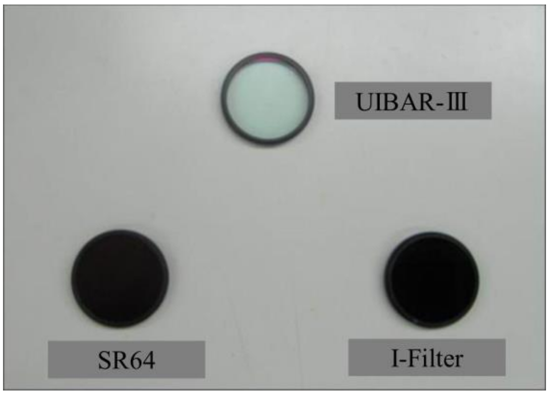


Figure 4.2 Used filters

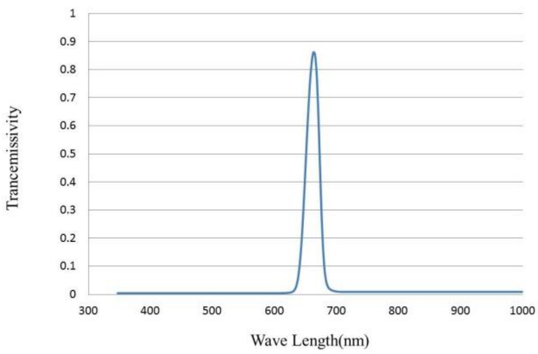


Figure 4.3 Transmissivity of Visible red filter (UIBARⅢ+SR64)

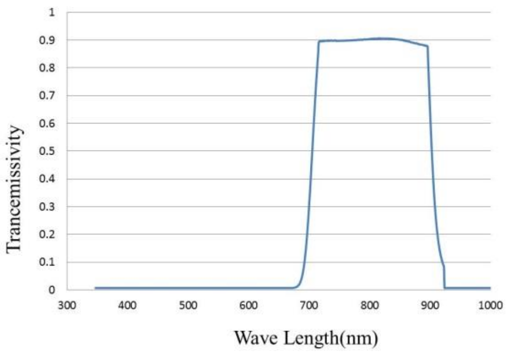


Figure 4.4 Transmissivity of Infrared Filter(I-Filter)

4.2. Orientation of Digiral Camera Image

Visible red band data and near infra-red band data must be added to LiDAR data from customized digital camera images. The ground coordinates (X,Y,Z) must be converted to image coordinates (u,v) by three dimensional projective transformation eq(4.1).

$$u = \frac{a_{11}X + a_{12}Y + a_{13}Z + a_{14}}{a_{21}X + a_{22}Y + a_{23}Z + 1}$$
$$v = \frac{a_{31}X + a_{32}Y + a_{33}Z + a_{34}}{a_{41}X + a_{42}Y + a_{43}Z + 1} \quad \text{eq(4.1)}$$

Conversion coefficients(a_{11}～a_{14}, a_{21}～a_{23}, a_{31}～a_{34}, a_{41}～a_{43}) were derived by 9 ground control points. RMSE around control point showed less than 2 pixels (Table 4.1).

Table 4.1 RMSE around ground control point

ID	u (pixel)	v (pixel)
1	-0.21	-0.56
2	0.17	0.53
3	-0.05	0.55
4	-0.70	-1.01
5	-1.71	1.09
6	2.23	-1.66
7	-1.13	1.18
8	-0.18	0.55
9	0.86	-0.71
RMSE (pixel)	0.80	0.96

5. DATA EXTRACTION OF TARGET AREA

NDVI was calculated by visible red band (VR) and near infra-red band (IR). Eq(5.1) showed the expression.

$$NDVI=\frac{IR+VR}{IR-VR} \quad \text{eq(5.1)}$$

Figure 5.1 showed NDVI images. NDVI ranges from -1 to 1. Vegetation area has a high NDVI value. In the test area, vegetated area showed over 0.2 of NDVI. Figure 5.2 showed extracted points of LiDAR as non-vegetated points were extracted according to NDVI which is less than 0.2 (Figure 5.2). Extracted points were almost located in stones. The stones compose a terraced field of agriculture land, where is called a stone wall. The stone wall was selected for the change detection of landslide.

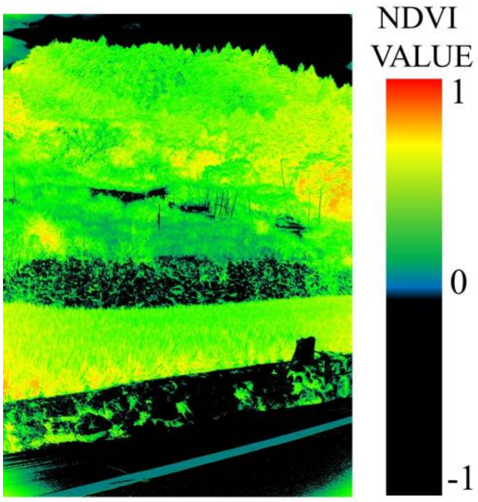


Figure 5.1 NDVI image

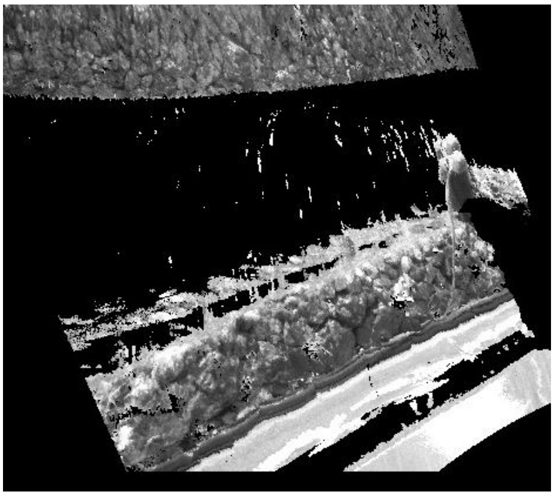


Figure 5.2 Extracted LiDAR data of Non-Vegetated Area

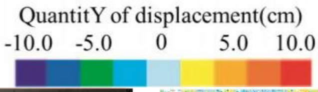
6.DECTION OF LANDSLIDE DISPLACEMENT

In this study, least square matching was applied for the change detection of landslide. The least square matching was usually used for stereo matching for 3D measurement using stereo imagery.

The point cloud data of LiDAR were projected to X-Z plane for generating image. A grid size of the projected imagery was 1cm. Because, a size of each stone for change detection was almost 30cm. Then 1cm grid will be enough spatial resolution. There were over 3 LiDAR points in the 1x1cm grid. A pixel value which means brightness was assigned a distance from the X-Z plane. Therefore, the point cloud model data were converted to a imagery. Therefore, least square matching can be applied.

The least square matching can derive accurate matching point in the imagery. Then change in X-Z plane can be detected. Moreover, the least square matching can also derive result of brightness conversion factors which means gain and offset. In the case of this imagery, gain will be fixed 1.0, because shape of stone wall was not changed, and offset will be shifting value a long y axis. Therefore, three dimensional displacements will be detected by the least square matching.

Template size in least square matching was 11x11 pixels, which was decided by empirical approach. Therefore, the template was almost 1/3 of the each stone. Figure 6.1 showed area of change detection and the locations of validation templates. Figure 6.2 ～ 6.4 showed the result of change detection along each axis. Along Y axis, the displacement showed over 2cm. Table 6.1 showed displacements of validation points. The averages were -0.8cm along X axis, +2.5cm along Yaxis and -0.6cm along Z axis. The displacements were almost same with results of other measurements which were total station, GPS, inclinometer and so on.



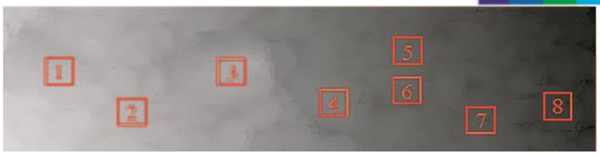


Figure 6.1 Aea of change detection and the locations of validation templates

Figure 6.2 X axis direction

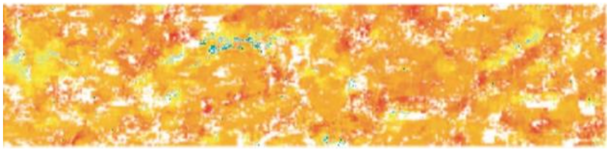


Figure 6.3 Y axis direction

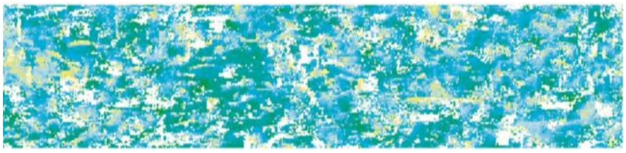


Figure 6.4 Z axis direction

Table 6.1placements of validation points

ID	X axis direction(m)	Y axis direction(m)	Z axis direction(m)
1	-0.022	0.052	-0.011
2	0.017	0.045	-0.022
3	-0.027	0.049	-0.013
4	-0.008	0.076	-0.011
5	0.018	0.052	-0.017
6	0.005	0.035	0.004
7	0.016	0.051	-0.005
8	-0.015	0.045	-0.016

7. CONCLUSIONS

In this study, vegetated points were eliminated from LiDAR data by NDVI imagery using a customized digital camera with band path filters. This method could support landslide monitoring.
A displacements of landslide were computed by least square matching using projectied imagery from point cloud data. The results were accepted comparing with other landslide monitoring results. This suggested methodology should be applied to wide area monitoring as future work.

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