Possibility of Wide Area Monitoring of Slope Failure Disaster Using PRISM:
Accuracy Verification with Geometric Distortion

Takahiro NAKAGAWA[(1)], **Kyaw Sann Oo**[(2)] **and Masataka TAKAGI**[(3)]

Department of Infrastructure Systems Engineering

Kochi University of Technology

Tosayamada, Kochi, Japan

[(1)]E-mail:115114y@gs.kochi-tech.ac.jp
[(2)]E-mail:108007u@gs.kochi-tech.ac.jp
[(3)]E-mail: takagi.masataka@kochi-tech.ac.jp

Abstract

Shikoku Island in Japan has many slope failure disasters by the torrential rain every year. The slope failures induce other serious disaster such as landslide, mudflow and debris flow. Therefore, hidden slope failure must be found immediately.

PRISM sensor mounted on ALOS has three line scanner of ground resolution 2.5m and it can be observed at the same time from same orbit. Then, 3 dimensional measurements can be carried out in 2.5m spatial resolution. The 3D measurement using PRISM has a potential to detect hidden slope failure.

In the present research work, accuracy verification of 3D measurement using PRISM was carried out and the possibility of wide area monitoring of slope failure disaster was concluded. The result showed less than two pixels accuracy at validation point in the transformation of 3D perspective projection. Accuracy of 3D measurement showed less than 10m. Then, at least 10m width of slope failure might be detect by PRISM using 3D perspective projection.

Keywords: RPC model, DLT, 3Dmeasurement, verification

1. INTRODUCTION

Shikoku Island faces a series of typhoons in every year and it brings heavy rain promoting many disasters as mudflows, landslides, slope-failures and so on. Those disasters cause huge damages. For this reason, it was imperative to predict the disasters before it happen. The solution could be gained by detecting mass movement of land. The objective of this study is to develop a technique to detect mass movement and to conduct verification of the possibility for monitoring wide area slope failure disaster using PRISM images. The method extract slope displacement is divided into the following 4 parts as main branches.

1. Geometric Transformation must be established. Usually, RPC model was used for 3D measurement. RPC model of PRISM is a pay product from RESTEC. Therefore, 3D projective transformation should be evaluated using accurate GCPs. When 3D projective transform has enough accuracy, easy 3D measurement system can be developed.

2. Automated extraction of correspondence point from the stereo images by the image matching must be established. Least square matching is powerful method for image matching. However, initial coordinates must be given. Then, determination method of initial coordinates must be developed.

3. Three-dimensional measurement using obtained correspondence point must be established. PRISM has three line scanners. And triplet images can be acquired. Therefore, calculation method using triplet image must be solved. And this process makes DSM data.

4. Final part is to extract displacement of slope using time series DSM. DSM is initially generated as point cloud model. Then, point to point comparison can not be carried out because location of the point is slightly different. Therefore, area comparison method using point group must be developed.

This study mainly focused on establishment of transformation and three-dimensional measurements.

2. USING DATA

2.1. Test field

Test field is selected around landslide area "Choja" in Shikoku Island. Figure1 depict geological map in Shikoku. Red area and yellow area showed a dangerous region of landslide because of fracture by geological tectonic line.

Figure 1. Geological Map in SHIKOKU

Choja is located on a mountainous area and effected by landslide is many times. TAKAGI Geo-informatics laboratory in Kochi University of Technology is observing that area every year. Figure 2 represents a PRISM image acquired on April 2007. Level 1B1 and 1B2 was used for the purpose of this research. In the image the red spot showed landslide area.

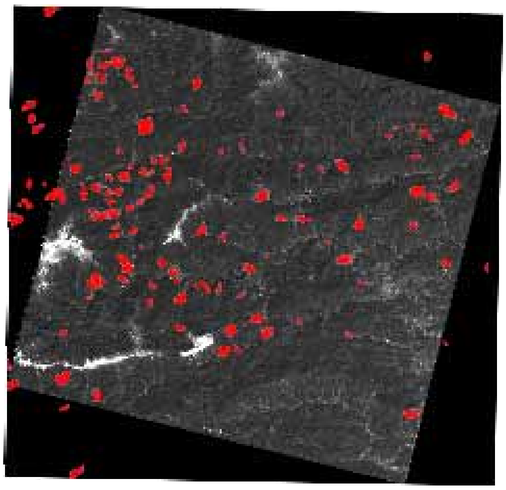

Figure 2. PRISM image in Choja area

2.2. GPS-VRS observation

Figure 3 showed distribution of GCP and validation points. This October, 22 points were observed using GPS-VRS observation. GPS-VRS observation can measure a few centimeter accuracy. GCPs were observed at intersection of road and the center of a bridge. In this study, 14 points were used as GCP and 8 points were used as validation points.

Observed GCP points on satellite image were selected by visual recognition. An accuracy of visual observation showed within 1pixel.

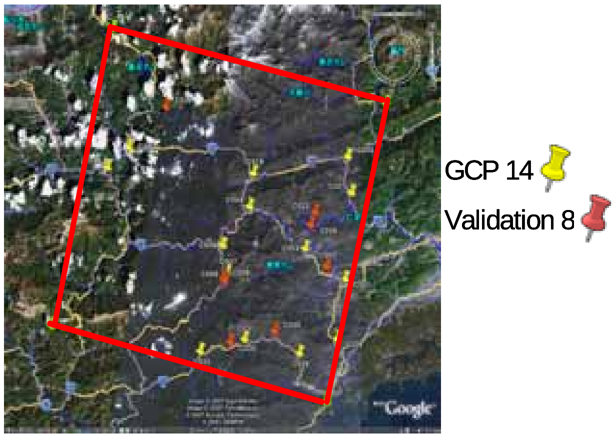

Figure 3. Distribution of GCP and Validation points

3. ACCURACY VERIFICATION OF TRANSFORM MODEL

3.1. RPC model

At first, accuracy of RPC model was evaluated. This RPC model was produced by RESTEC. RPC model can converts ground coordinates (X, Y, Z) to image coordinates (*column*, *row*). Table 2 showed residual error between converted image coordinate of GCP and selected GCP on the image. In case of nadir residual error showed about 1 pixel, but in case of forward and backward big residual error occurred in row line.

Table 2. Residual error around GCP

	Column(pix)	Row(pix)
Forward	1.558	1.303
Nadir	0.540	8.484
Backward	1.646	7.153

Table 3 showed residual error around validation points. Same as a GCP big residual error occurred forward and backward. This error will make value is predictable adverse effect for 3D measurement. For accurate measurement, bias correction of RPC model must be carried out.

Table 3. Residual error around validation points

	Column(pix)	Row(pix)
Forward	2.125	1.529
Nadir	1.276	8.262
Backward	2.007	7.034

3.2. Three dimensional perspective projection

Next 3D-perspective-projection was also taken into account as geometric transformation. Table 4 showed residual error. In the case of 3D perspective projection, in all three scanning images, accuracy showed within 1pixel around GCP.

Table 4. Residual error around GCP

	Column(pix)	Row(pix)
Forward	0.293	0.257
Nadir	0.249	0.210
Backward	0.267	0.261

Table 5 showed residual error around validation points. In whole number increase compared with GCP. But obtainable result was stable, so 3D-perspective-projection has a potential to carry out 3D measurement.

Table 5. Residual error around validation points

	Column(pix)	Row(pix)
Forward	1.248	0.947
Nadir	1.586	1.284
Backward	1.905	0.899

4. METHOD OF 3D MEASUREMENT

In this research, nadir and backward data were used for 3D measurement. Equation 1 showed 3D projective transformation.

$$column = \frac{b_1 X + b_2 Y + b_3 Z + b_4}{b_9 X + b_{10} Y + b_{11} Z + 1} \quad \textbf{(1)}$$
$$row = \frac{b_5 X + b_6 Y + b_7 Z + b_8}{b_9 X + b_{10} Y + b_{11} Z + 1}$$

(X, Y, Z) : *Ground Coordinate*
$(column, row)$: *Image Coordinate*
$b_1 \sim b_{11}$: *Coefficient*

Previously, coefficients (b1, b2,…,b9) of transformation and image coordinate from each image were calculated. When the column and row of the correspondence point in stereo pair image are input, unknown values are ground coordinates (*X, Y, Z*). The number of equations is two in each image. Then the total number of equations becomes four in the case of stereo imagery. Therefore, three unknown values (*X, Y, Z*) can be solved by least square method. Here in after this method called DLT (Direct Linear Transform).

The advantage of DLT is needless of initial value for reason that line shape. Disadvantage point is there are many unknown parameters which are 11. Therefore, at least 6 GCPs are required to establish the transformation.

5. ACCURACY VERIFICATION OF 3D MEASUREMENT

In this study, coefficients of 3D-perspective-projection were calculated from 14 GCPs. The coordinates of correspondence point in stereo pair image at GCP were selected by visual interpretation. And 3D measurement was carried out. Table 6 showed error between observed GCP coordinate and calculated ground coordinate from DLT. RMSE showed almost 1pixel in X and Y axis, but Z axis showed 2 pixels.

Table 6. Error of 3D measurement Using DLT Method

	X(m)	Y(m)	Z(m)
max	4.374	5.302	9.882
min	0.805	0.037	0.128
mean	2.023	1.778	3.353
RMSE	2.436	2.474	4.639

6. DISCUSSION AND CONCLUSIONS

In this study the accuracy of 3D measurement from DLT in case of 14 GCP in 35km * 35km area can get within 2pixel was predicted. This accuracy was not enough for monitoring landslide because of amount of displacement is few cm/year. However, it is useful to specify dangerous area of mudflow that is a secondary disaster of rapid slope failure displacement from heavy rain and earthquake and also useful to observe the occurred slope failure displacement without being seen. It is proposed for future work that automated image matching to select the correspondence point must be developed. It is also suggested that more and more validation points for accurate evaluation is needed.

References

[1] Jong Hyeok JEONG and Masataka TAKAGI, “An adapted Method for Removing Change Detection Errors due to Pointing Direction Shifts of a Satellite Sensor,” *Journal of JSPRS*, Vol. 45, No.2, pp16 - 23, 2006

[2]Jong Hyeok JEONG and Masataka TAKAGI, “Empirical Evaluation of Data Acquisition Methods for Disaster Monitoring, Proceedings of International Symposium on Management Systems for Disaster Prevention,” JAPAN, Session G6, 2006

[3]Takeshi MIYATA・Jong Hyeok JEONG and Masataka TAKAGI, “Extracting Method of Mudflow Disaster by using Arial Photography,” Proceedings of International Symposium on Management Systems for Disaster Prevention, JAPAN, Session B6, 2006

[4]Takesi MIYATA・Jong Hyeok JEONG and Masataka TAKAGI, “Suitable Type of Ground Control Point for High Resolution Satellite Imagery,” Proceedings of the 26th Asian Conference on Remote Sensing, Hanoi