3 Dimensional Measurement by Satellite Remote Sensing for Disaster Monitoring

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Summary: 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 lines scanner with 2.5m ground resolution and it can be observed at the same time from same orbit. Then, three dimensional (3D) measurements can be carried out in 2.5m spatial resolution. The 3D measurement using PRISM has a potential to detect 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. Result showed about 1 pixel error in z axis. Then, at least 5m width of slope failure might be expected to detect by PRISM using 3D perspective projection.
Keywords: 3D Measurement, Slope Failure, Disaster Monitoring

1 INTRODUCTION

Mudflow enormous foundation disaster had occurred by slope failure. It is necessary to get a scent of slope failure before it occurred to reduce the mudflow damage. It was difficult to detect slope failure in remote region of the country; for the reason, wide area monitoring technique by satellite images is expected. ALOS satellite mounted PRISM sensor that has three lines scanner(Forward, Nadir, Backward) with 2.5 meters ground resolution and it can be observed at the same time from same orbit. In general known, stereo image can be generated 3D data(DSM: Digital Surface model). Therefore, it is possible to generate DSM by PRISM data and to extract slope displacement using multi temporal DSM data. The goal of this research is generating accurate DSM data and detecting slope failure in using temporal DSM.

Following are research items to achieve the goal.

- Establishment of Ground control point(GCP) database using VRS measurement
- Establishment of geometric model for PRISM
- Generate DSM data for wide area from PRISM
- Accuracy evaluation of PRISM's DSM data
- Establishment of change detection method using multi temporal DSM data
  it would be developed to detect mass movement

- Validate the change detection

3D measurement of PRISM data will have a potential to detect slope failure with the scale of 25m^2 in spatial distribution. In this paper, a system of DSM generation and accuracy of DSM will be evaluated.

2 METHODOLOGY

To make DSM Data, Geometric Transformation Model between image coordinate and ground coordinate must be decided. Usually, RPC model was used for 3D measurement[1][2]. But to get high accuracy, geometric correction by GCP data is needed[3]. On the other hand, 3D perspective projection can be applied for geometric transform model. At least 11 GCPs are required to establish this model. Therefore, it is necessary to establish GCP data set in the test field. GCPs were observed using GPS-VRS observation. Over 30 points GCPs should be prepared in each test field. Next correspondence points between Nadir and Backward image are requested for stereo matching.

At last 3D measurements was achieved by obtained correspondence points substituted for transformation model. The least square method was applied for calculating 3D coordinates in this study. Generated DSM was evaluated using validation points.

3 USING DATAS

3.1 PRISM image data

Test field was selected around“CHOJA” in SHIKOKU Island, JAPAN. Figure3.1 depict geological map in Shikoku. Red area and yellow area showed a dangerous geological region of landslide because of fracture by geological tectonic line.

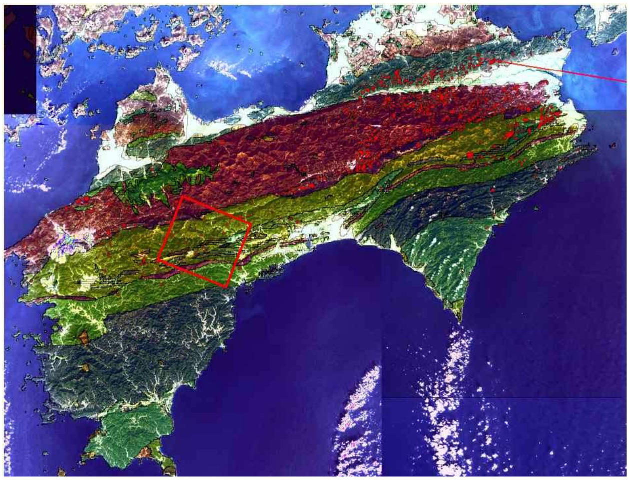


Figure 3.1 Test Area

In this study, Nadir and Backward images were used. Forward image taken a picture from the North and image processing was difficult because of Sunlight reflection. Therefore, Forward image doesn't use in this study. Figure3.2 shows PRISM images of Nadir and Backward. Table 3.1 showed meta data of PRISM image.

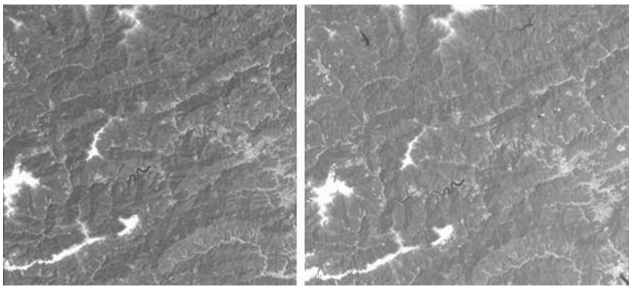


Figure 3.2 PRISM Images(Nadir, Backward)

3.2 DEM Data

When 3D measurement, digital elevation model of 50 mesh data in SHIKOKU Island was used to get initial condition for stereo matching in this study.

Table 3.1 meta data of PRISM images

item	spec
Process level	level 1B2
Area	CHOJA in KOCHI
Width	35km * 35km
Date	April in 2007
Ground resolution	2.5m

3.3 Ground Control Points

Figure 3.3 showed distribution of GCP and validation points. 45 points were observed using GPS-VRS observation. GPS-VRS observation can measure very accurately with a few centimeter. GCPs were observed at intersections of road and the center of bridges.

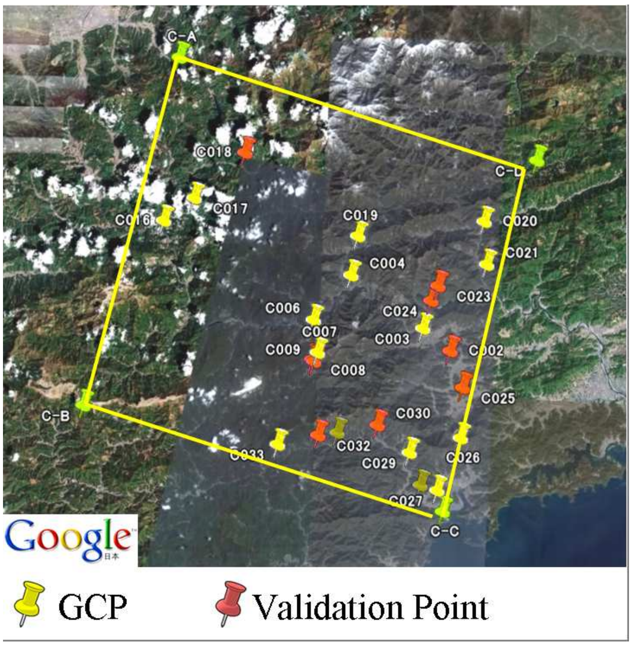


Figure 3.3 Location of GPS VRS Observation

In this study, 24 points were used as GCP and 21 points were used as validation points. Observed GCPs on satellite image were selected by visual interpretation. An accuracy of visual interpretation showed within 1 pixel.

4 ACCURACY VERIFICATION OF TRANSFORM MODEL

In this study 3D perspective projection was selected for geometric transform model. This equation is based on area sensor geometry. Ground coordinate(x,y,z) can be transformed to image of PRISM coordinate(u,v).

$a_1, a_2, \cdots, a_{11}$ are unknown parameters.

$$\begin{cases} u = \dfrac{a_1x + a_2y + a_3z + a_4}{a_9x + a_{10}y + a_{11}z + 1} \\ v = \dfrac{a_5x + a_6y + a_7z + a_8}{a_9x + a_{10}y + a_{11}z + 1} \end{cases} \tag{4.1}$$

Because of PRISM is line sensor, 3D perspective projection does not presented accurate model. However, using 3D perspective projection will make satisfactory result for geometric correction of high resolution satellite images. Unknown coefficients were calculated from 24 GCPs data by least square method.

Error was defined in terms of difference between image coordinates obtained by the calculation and image coordinates visually interpretation from satellite image. Table 4.1 showed residual error around validation points.

Table 4.1 Residual Error of 3D Projection Model around Validation Point (Unit: Meter)

Image	Column	Row
Nadir	2.043	1.886
Backward	1.683	1.912

Accuracy showed within 2.5m around validation point. This numeric number was proper for about 1 pixel in PRISM image.

5 IMAGE MATCHING

Automated extraction of correspondence point from the stereo images by the image matching must be established. Least squares matching is powerful method for image matching. However, initial coordinates must be given. Then, determination method of initial coordinates must be developed. To acquire an initial condition of the least squares matching, PRISM images were converted into ground coordinates by geometric model. This image is called ortho image(Figure 5.1). To generate ortho image, DEM of 50 mesh data in SHIKOKU Island was used. When Nadir and Backward images were converted into the same coordinate system, it can be expected to image matching becomes easy.

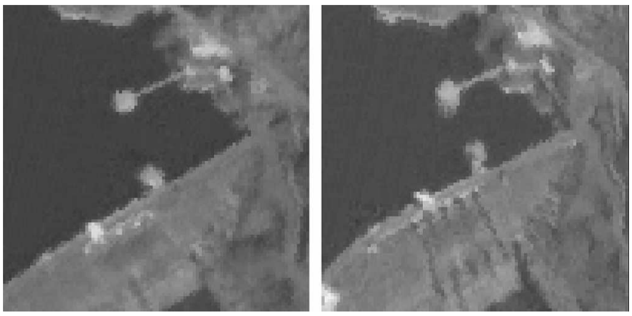
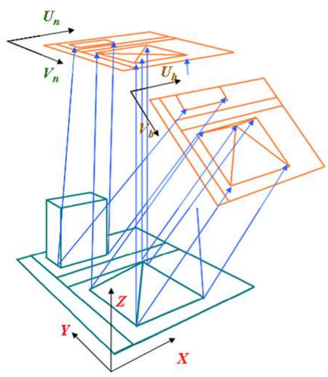


Figure 5.1 Ortho image Nadir and Backward

Same coordinates of two ortho images transform original image coordinate by transform model and this value is used as initial condition of least squares matching. Then correspondence points between original Nadir image and Backward image were extracted. Because of satellite image size, it takes much time to make DSM data in whole area. Therefore in this study, image matching was carried out range of 1500m * 1500m (300pixel * 300pixel).

6 3D MEASUREMENT

When the column(u) and row(v) 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 become four in the case of stereo imagery. Therefore, three unknown values (X, Y, Z) can be solved by least square method.



$$
\begin{cases}
U_n = \dfrac{a_{n1}X + a_{n2}Y + a_{n3}Z + a_{n4}}{b_{n1}X + b_{n2}Y + b_{n3}Z + 1} \\
V_n = \dfrac{a_{n5}X + a_{n6}Y + a_{n7}Z + a_{n8}}{b_{n1}X + b_{n2}Y + b_{n3}Z + 1} \\
U_b = \dfrac{a_{b1}X + a_{b2}Y + a_{b3}Z + a_{b4}}{b_{b1}X + b_{b2}Y + b_{b3}Z + 1} \\
V_b = \dfrac{a_{b5}X + a_{b6}Y + a_{b7}Z + a_{b8}}{b_{b1}X + b_{b2}Y + b_{b3}Z + 1}
\end{cases}
$$

Figure 6.1 Geometric model

7 ACCURACY EVALUATION OF 3D MEAUREMENT

82,000 of correspondence points was obtained among 90,000 points as a result of the image matching, and 3D coordinates were calculated. Calculated 3D coordinate was converted digital surface model(Figure 7.1). 3D data compared with GPS data of validation point for accuracy evaluation. Error was defined in terms of difference between Z values of validation point and calculated one. Table 4.1 showed residual error around validation points in Z value. Maximum error showed 3.5 m and RMSE showed 2.4 m accuracy that was very small range of error. Figure 7.2 and 7.3 showed location of validation points on Nadir image of PRISM.

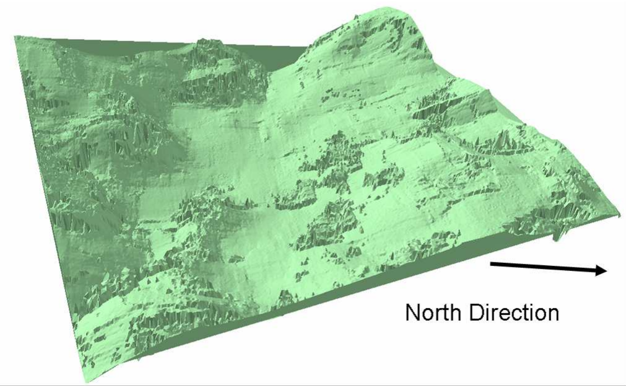


Figure 7.1 Bird's Eye View of Generated Digital Surface Model

Table 7.1 Residual Error of 3D Measurement (Unit: Meter)

Point No.	Z(GPS)	Z(PRISM)	Error
1	297.956	299.493	-1.536
2	291.025	291.398	-0.373
3	290.097	287.595	2.502
4	327.953	324.479	3.474
5	325.426	323.690	1.736
6	312.236	309.774	2.462
7	306.098	307.069	-0.971
8	309.322	312.575	-3.253
9	309.049	311.938	-2.889
10	315.088	311.910	3.178
11	319.438	317.350	2.088
12	324.520	322.466	2.054
13	289.559	291.716	-2.157
14	317.969	315.710	2.259
			RMSE 2.364

When satellite image compared with 3D data, there were some noises in place of low contrast area such as forest or flat area. As for such a area, the possibility of the matching error will be high. Therefore accuracy of validation points thanks in part to advantaged place of high contrast area.

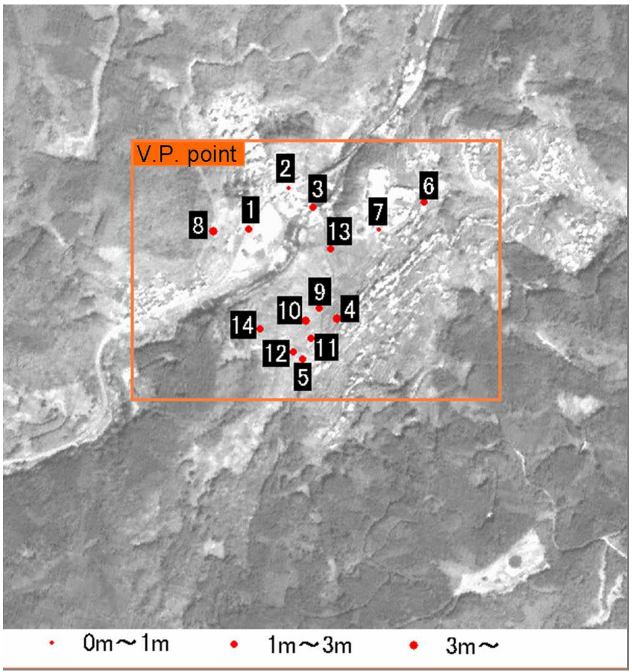


Figure 7.2 Location of Validation Point(VP) on Nadir Image of PRISM

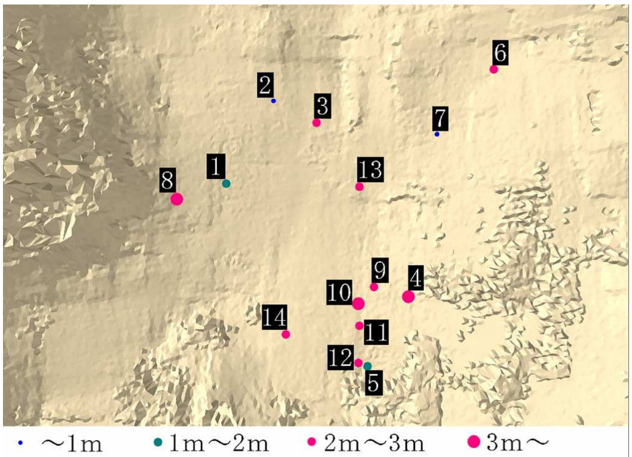


Figure 7.3 Location of VP on shaded relief map by DSM data

8 DISCUSSION AND CONCLUSIONS

In this study the accuracy of 3D measurement can get within 2.5m was predicted. This accuracy is almost PRISM 's ground resolution accuracy. However, the following problems were remaining. Image matching takes too much time. So it is necessary to make transaction speed fast in a future study.

Such forest and flat area where low contrast of the image, especially attribute noise was generated to miss matching. Because of validation point was observed by GPS observation, it was not possible to observe in the forest where the signal of the GPS satellite was not caught easily. If miss matching decrease in low contrast area, Accurate DSM can be expected for disaster monitoring.

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