

CHANGE DETECTION OF SURFACE ELEVATION BY ALOS/PRISM FOR DISASTER MONITORING

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ABSTRACT:

In October 2006, remotely sensed data of PRISM (Panchromatic Remote-Sensing Instrument for Stereo Mapping) sensor that mounted on Japanese satellite ALOS (Advanced Land Observation Satellite) was began to provide for general users. ALOS has some missions such as mapping, regional observation, disaster situation observation and survey of natural resources. In the mission of disaster situation observation, it is important to do change detection of the affected area with high accuracy. ALOS has three sensors namely PRISM, AVNIR-II, PALSAR. The PRISM sensor is three lines scanner with 2.5 meters sampling distance. Triplet imagery can be acquired to, the same location at the same time from the same orbit. Therefore, acquired data of PRISM sensor is expecting to generate 3D data. The 3D data can be used for natural disaster monitoring and many others. Authors report the change detection of surface elevation by ALOS/PRISM. The DSM (Digital Surface Model) generation technique that used stereo PRISM images was constructed. The proposed method needs some GCPs (Ground Control Point) and corresponding points by stereo matching. GCPs are measured by VRS-GPS (Virtual Reference Station Global Positioning System) measurement. And the basic geometric model is established using GCPs. Corresponding points of stereo matching are computed by template matching and least squares matching. Surface elevation is calculated by least squares method using basic geometric model and corresponding points of stereo images. The accuracy of generated DSM showed about 2~10 meters. The amount of the changes can be detected by computing the generated DSM before and after the changes. Target area was selected around Kochi Prefecture. For change detection of surface elevation, accuracy of DSM must be improved. Recently, method of stereo matching is revised. In future, change detection of surface elevation will be carried out.

1. BACKGROUND

In October 2006, remotely sensed data of PRISM sensor that mounted on Japanese land observation satellite ALOS was began to provide for general users. PRISM sensor has three lines scanner (forward, nadir, backward looks) with the ground resolution of 2.5 meters and it can be observed at the same time from the same orbit. Therefore, acquired data of PRISM sensor is expecting to generate accurate 3D data by processing triplet images. 3D data can be used for natural disaster monitoring, etc. Generally, 3D data can be generated using several geometric models. PRISM's RPC (Rational Polynomial Coefficient) is usually use, which is produced from RESTEC (Remote Sensing Technology Center of Japan). On the other hand, basic geometric model with GCP data can also make 3D data. Then each geometric model should be evaluated for accurate change

detection. After that change detection with the most accurate transformation will be carried out.

2. OBJECTIVE

For high resolution satellite imagery, some geometric models can be applied ¹⁾. Nakagawa 2008 ²⁾ proposed that method of 3D measurement using basic geometric model for ALOS/PRISM. This method could archive 3D measurement without RPC model. The accuracy of this method showed about 15m in hilly area and about 3m in plain area. On the other hand, KOJIMA 2009 proposed that method of 3D measurement using RPC model by Monte Carlo method. This method showed about 10m in hilly area and 2.8m in plain area. The result using RPC model is better than basic geometric model. But, these

results were not verified in same situation. Therefore, the comparison of accuracy by basic geometric model and RPC in same condition should be carried out. Finally, multi temporal 3D data will be used to detect the change for disaster monitoring.

3. USED DATA

3.1 PRISM imagery

Nadir and backward images of PRISM is used. They were observed in December 2006. Test area is selected around "TOSAYAMADA-CHO" in SHIKOKU Island, JAPAN (Figure3-1). The area covered the mountainous area and the plain area. There are many GCPs in the area. The selected PRISM imagery is nadir and backward of level 1B1 processed data. Figure3-2 showed used PRISM image, distribution of GCPs and test area. Red points showed used GCPs. Yellow area showed test area in this study. And table.3-1 showed information of used ALOS PRISM image.

Sensor	PRISM
Process	level 1B1
Ground resolution	2.5m
Test area	TOSAYAMADA-CHO
Using images	Nadir & Backward
Date	2006 December
Test area width	8440*7430 m
Left top latitude	33.782
Left top longitude	133.534
Right bottom latitude	33.351
Right bottom longitude	133.820
Number of GCP	23 points

Table 3-1 Meta data of ALOS PRISM

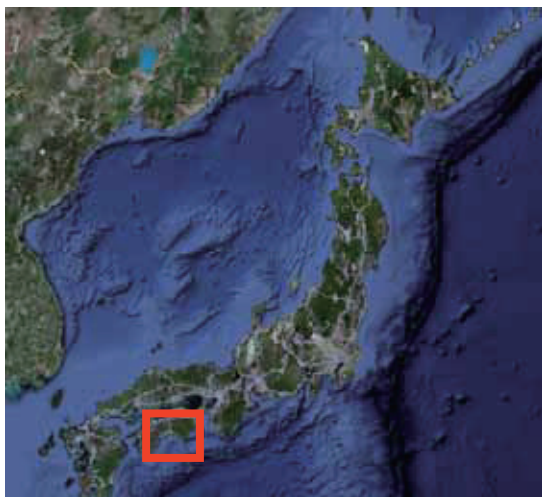


Figure3-1 test area

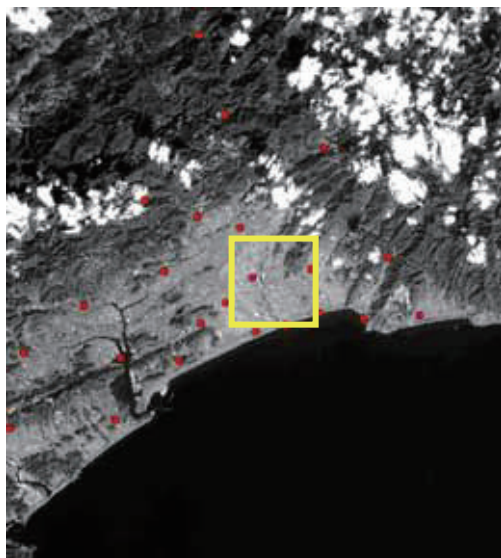


Figure3-2 used GCPs and test area

3.2 Ground Control Points

23 GCPs were observed using GPS-VRS (GPS with Virtual Reference System) observation. GPS-VRS observation can measure with centimeter level accuracy. These GCPs data are opened to the public from TAKAGI laboratory in Kochi University of Technology (Figure3-3). There are over 500 GCPs in SHIKOKU Island. They included information of latitude longitude, rectangular plane coordinate, geography altitude, photographs of the situation around the subset of observed area and the satellite imagery of ALOS (Figure3-4).

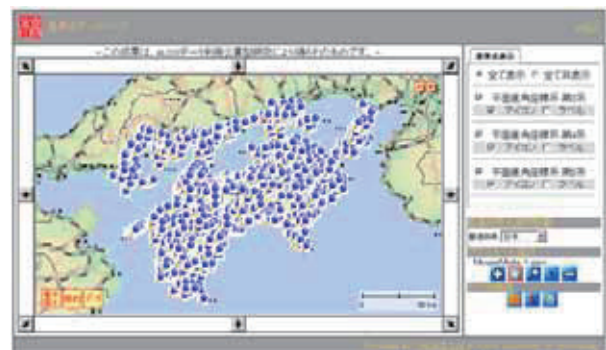


Figure3-3 GCP database
(URL:<http://www.infra.kochi-tech.ac.jp/takalab/Information/research/GCPDB/GCPDB.html>)



Figure3-4 information of GCPs

3.3 Air Borne LiDAR Data

Air borne LiDAR data was used to verify 3D data of PRISM within the same range of test area. Figure3-4 showed shaded image of air borne LiDAR data. This data was observed by high accurate and high density. Therefore, this data is trusted in verification data of 3D measurement.

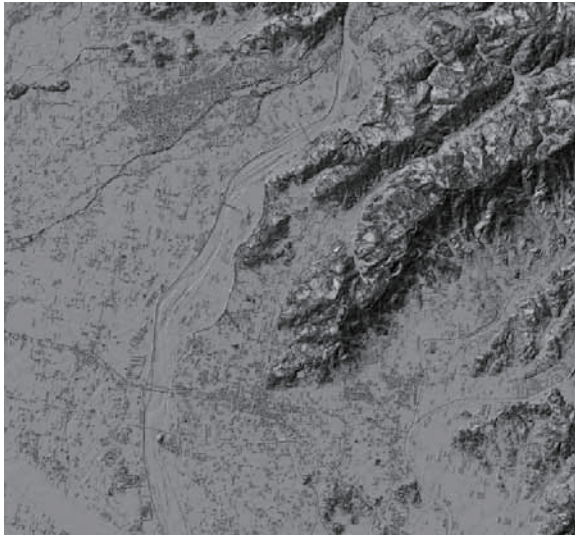


Figure3-4 Air borne LiDAR Data

4. ESTABLISHMENT OF GEOMETRIC MODEL

4.1 Basic Geometric Model

In this study, 3D projection Model (equation.1), Gupta & Hartley Model (equation.2) and separated 3D projection model (equation.3) were selected as basic geometric model. Eq2 and Eq3 are based on line sensor geometry. Transform coefficients are calculated using GCPs by least squares estimation. Table.4-1 showed residual error around GCPs. The accuracy showed within 1pixel around GCPs in the all models. Especially Gupta & Hartley Model is slightly good.

$$\begin{cases} u = \frac{a_1X + a_2Y + a_3Z + a_4}{b_1X + b_2Y + b_3Z + 1} \\ v = \frac{a_5X + a_6Y + a_7Z + a_8}{b_4X + b_5Y + b_6Z + 1} \end{cases} \quad (1)$$

$$\begin{cases} u = \frac{a_1X + a_2Y + a_3Z + a_4}{b_1X + b_2Y + b_3Z + 1} \\ v = a_5X + a_6Y + a_7Z + a_8 \end{cases} \quad (2)$$

$$\begin{cases} u = \frac{a_1X + a_2Y + a_3Z + a_4}{b_1X + b_2Y + b_3Z + 1} \\ v = \frac{a_5X + a_6Y + a_7Z + a_8}{b_4X + b_5Y + b_6Z + 1} \end{cases} \quad (3)$$

where

- $X, Y, Z = \text{Ground_coordinate}$
- $u, v = \text{Image_coordinate}$
- $a_1 \sim a_8 = \text{Transform_coefficients}$
- $b_1 \sim b_6 = \text{Transform_coefficients}$

4.2 RPC Model

RPC model (equation.4) is the systematic model of PRISM sensor. RPC model is offered by RESTEC, JAPAN (Remote Sensing Technology Center of Japan). There are 80 coefficients in RPC model. And there are 10 standardization coefficients. The RPC model was contained location and orientation error. Therefore, those errors must be corrected using GCPs as bias correction. Table4-1 showed residual error of RPC model. Accuracy showed less than 1 pixel around GCPs in bias corrected model.

$$\begin{cases} Cn = \frac{f_1(P, L, H)}{f_2(P, L, H)} \\ Rn = \frac{g_1(P, L, H)}{g_2(P, L, H)} \end{cases} \quad (4)$$

where

- $C_i, R_n = \text{Image_Coordinate}$
- $P, L, H = \text{Ground_Coordinate}$

Table 4-1 accuracy of geometric model

		u	v
3D projection	nadir	0.774	0.943
	back	0.823	1.104
Gupta & Hartley	nadir	0.625	0.844
	back	0.78	1.108
Separated 3D projection	nadir	0.625	0.707
	back	0.625	1.016
Raw RPC	nadir	2.838	2.030
	back	1.751	2.651
RPC after bias shift	nadir	0.707	0.731
	back	0.939	0.979

5. IMAGE MATCHING

The corresponding points in stereo imagery are searched by image processing which call image matching. Image matching is the automated extraction method of the corresponding points

from stereo imagery. In this study, two method of image matching are combined for searching accurate corresponding points.

5.1 Image Correlation

First, corresponding points are searched by image correlation method. The correlation coefficient is calculated by NCC (Normalized Cross-Correlation) (equation.5).

$$r(u_0, v_0) = \frac{\sum_{j=0}^m \sum_{i=0}^n (\bar{T} - T(i, j))(\bar{L} - L(u_0 + i, v_0 + j))}{\sqrt{\sum_{j=0}^m \sum_{i=0}^n (\bar{T} - T(i, j))^2} \sqrt{\sum_{j=0}^m \sum_{i=0}^n (\bar{L} - L(u_0 + i, v_0 + j))^2}} \quad (5)$$

where

$$r(u_0, v_0) = \text{correlation_coefficient}$$

$$\bar{T}, \bar{L} = \text{pixel_value_of_search_area}$$

The highest coefficient point means corresponding point.

5.2 Least Square Matching

After calculated the corresponding points by image correlation, the most accurate corresponding points can be computed by Least Square Matching. Least squares matching is a method of image matching using density conversion and geometric correction. Linear transformation is used for density conversion (equation.6). Affine transformation is used for geometric correction (equation.7). This matching is the high accurate method. However, initial coordinate must be given. Then, result of image correlation method is used for initial coordinate.

$$T(i, j) = aL(u, v) + b \quad (6)$$

where

$$a = \text{gain}$$

$$b = \text{offset}$$

$$T(i, j), L(u, v) = \text{image_coordinate}$$

$$\begin{cases} u = c_1(i - ic) + c_2(i - ic)(j - jc) + c_3(j - jc) + uc \\ v = c_4(i - ic) + c_5(i - ic)(j - jc) + c_6(j - jc) + vc \end{cases} \quad (7)$$

where

$$ic, jc = \text{center_of_template_image}$$

$$uc, vc = \text{center_of_scanning_image}$$

$$c_1 \sim c_6 = \text{Transform_coefficients}$$

6. 3D MEASUREMENT

After the establishment of Basic Geometric Models, 3D measurement should be carried out. When image coordinates (u, v) of the corresponding points in stereo imagery are input to geometric model, unknown values are ground coordinates (X, Y, Z). The required number of equation is two in each image. Then the total number of equation become four in the case of stereo imagery. Therefore, three unknown values (X, Y, Z) can

be solved.

6.1 Least Squares Estimation

Basic geometric models can be expressed a linear transformation. Then, least square estimation can be computed simply.

6.2 Monte Carlo Estimation

RPC model is a nonlinear expression. Therefore, the least square estimation is difficult to apply. Then, Monte Carlo Estimation was carried out. Monte Carlo estimation is a calculation method for nonlinear expression using random values. In this study, the uncertainty of solution is decreased by setting the initial value. The initial value was used the result of 3D measurement using basic geometric model.

7. DSM GENERATION USING STEREO MATCHING

Digital-Surface-Model (DSM) using geometric models was generated for test area. The corresponding points are used about 185,000 points. The calculated 3D coordinates are random point data, so random point data are interpolated to grid data using TIN (Triangulated Irregular Network). Grid data are set to 10 meters interval. Figure7-1 showed shaded images of PRISM 3D data generated by RPC models. When the result of 3D measurement was compared with Air borne LiDAR data (Figure3-4), there are big differences. And there are many noises data in the result of 3D measurement data. Figure7-2 is the ortho image of test area. The big error occurred in cloudy area. More over many noises were remained by miss matching. Therefore, noise elimination method should be developed. The factor of big error located in geometric model and image matching. Error of geometric model influenced by error of GPS-VRS observation and error of corresponding point selection by visual interpretation. Accuracy of GPS-VRS observation is about 2.5 centimeters. And, accuracy of visual interpretation is about 0.5 pixels. Therefore, error of geometric model might be influenced slightly. The miss matching will be influenced very much comparing with geometric model.

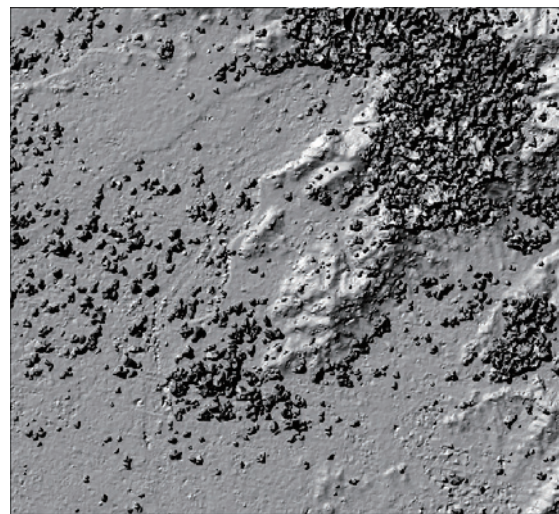


Figure7-1 result of basic geometric model

8. EVALUATION OF VISUAL INTERPRETATION

Figure8-1, Figure8-2, Figure8-3 and Figure8-4 showed distribution of residual error between 3D data of PRISM and Air borne LiDAR data. The error calculated difference of elevation on each grid. Table8-1 showed RMS of residual error of 3D projection, Gupta & Hartley, separated 3D projection and RPC model. There was no big difference in distribution of residual error of basic geometric model. But, the result of RPC model showed big errors in test area. RMS of residual error of 3D projection and separated 3D projection model were 5.0m. On the other hand, Gupta & Hartley model was 4.6m. And RPC model showed about 10.2m error. That was twice of basic geometric models. In RPC model, the error will be included in RPC model itself. Bias correction will be not enough for the correction. More over, Monte Carlo estimation might be influenced. Other calculation method should be tried to calculate.

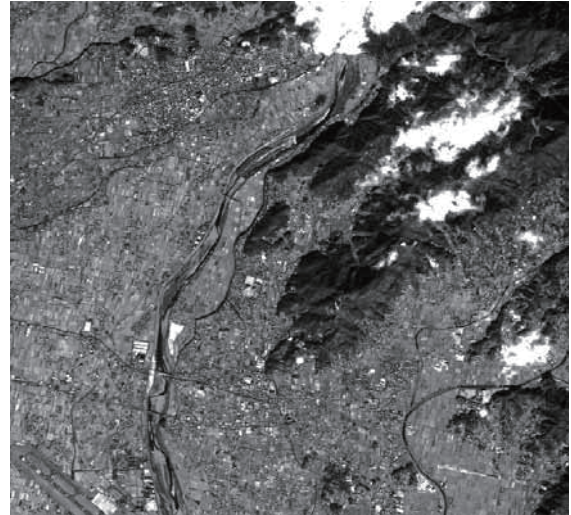


Figure7-2 Ortho image of test area

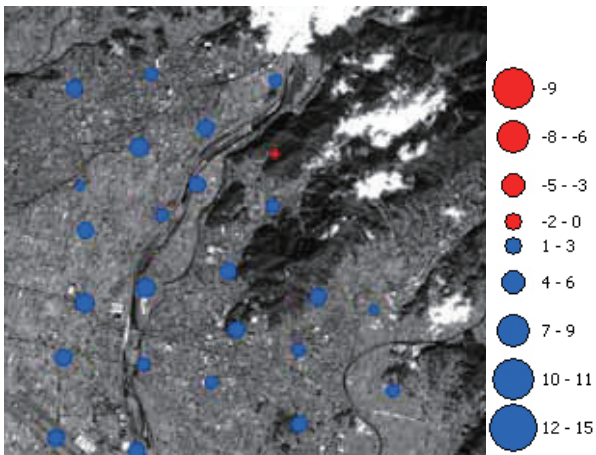


Figure8-1 distribution of error
RPC model

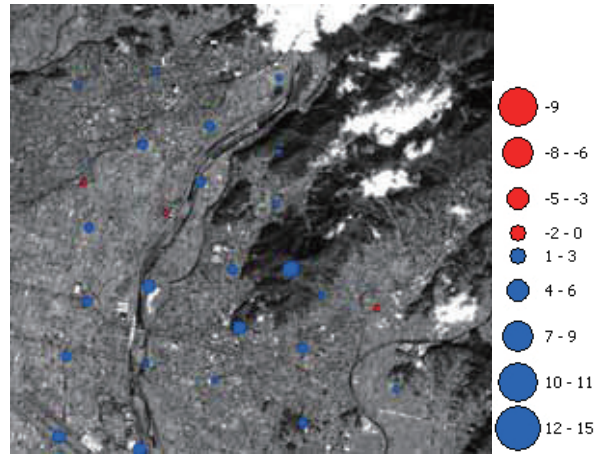


Figure8-3 distribution of error
Gupta & Hartley model

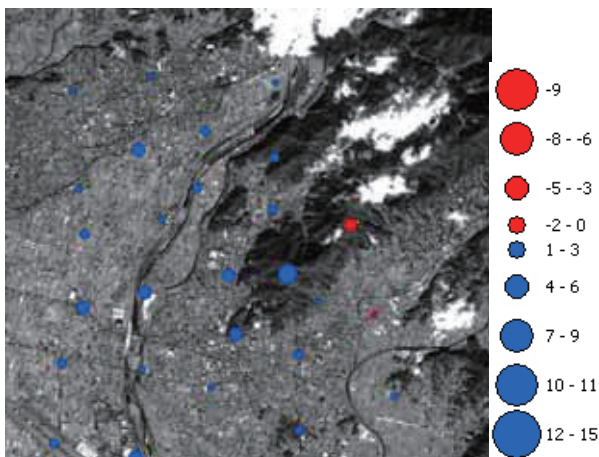


Figure8-2 distribution of error
3D projection model

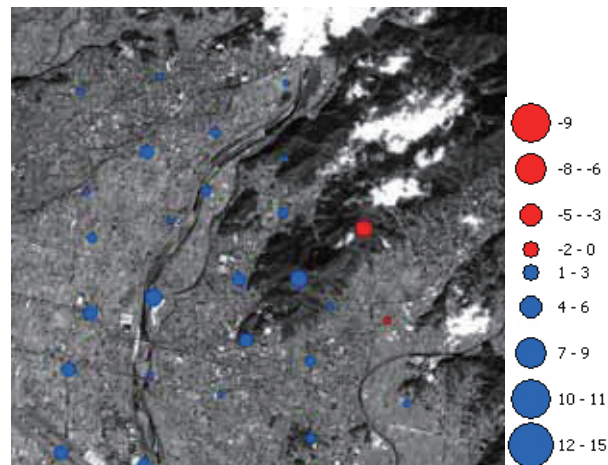


Figure8-4 distribution of error
Separated 3D projection model

Table8-1 RMSE of 3D measurement

Geometric model	RMSE (m)
RPC	10.165
3D projection	5.012
Gupta & Hartley	4.577
Separated 3D projection	5.147

9. CONCLUSION

Results showed that the accuracy of 3D data by PRISM images were almost 5m. Especially, Gupta & Hartley model's RMS showed less than 5m. Therefore, Gupta & Hartley model is suitable model for 3D measurement from PRISM images. Finally, 3D measurement using basic geometric model can be applied for change detection. Method of DSM generation using PRISM imagery was succeeded to develop. At least, 10m change will be detected by developed method.

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REFERENCES

- Ayaman habib, Sung Woong Shin, Kyungok Kim, Changjae Kim, Ki-In Bang, Eui-Myoung Kim, and Dong-Cheon Lee, Comprehensive Analysis of Sensor Modeling Alternatives for High Resolution Imaging Satellites, Journal of American Society for Photogrammetry and Remote Sensing, vol 73, No11, pp.1241-1252, 2007
- Takahiro NAKAGAWA, ACRS2008, Accuracy evaluation of 3D data generation from PRISM images using least squares matching method, pp.31, 2008
- Shunji MURAI, Direct Linear Transformation, Analytical photogrammetry, published from Japan Society of Photogrammetry and Remote Sensing, pp.149-152, 1983
- Mitsuhiro KOJIMA, SSMS2008, Establishment of Ground Control Point Database for Satellite Remote Sensing, SMS09-179, 2008