Landform Change Detection using Satellite Remote Sensing

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ABSTRACT: On 11 March 2011, huge earthquake was occurred in Tohoku Japan. There was big diastrophism due to the earthquake. Maximum ground displacement in the horizontal direction was more than 5 m. three-dimensional measurement by the satellite image can be also applied to detect the displacement. The satellite remote sensing technology can observe the situation in wide area. If the landform change can be detected by satellite images, the satellite remote sensing technology will be effective for disaster monitoring. Therefore, the purpose of the present study is landform change detection by using the satellite remote sensing. PRISM sensor is expecting to generate accurate 3D data by processing stereo images.

3D measurement uses a general method. Firstly, geometric model of satellite imagery should be established. Reference points data are required for accurate geometric model. After that, the corresponding points in stereo imagery must be found by the image matching. Ground coordinates (X, Y, Z) can be calculated using geometric model and image coordinates of the corresponding points. The displacement of geographical features can be extracted by comparing multi temporal 3D surface models using satellite imageries.

Test area was selected around ISHINOMAKI City in the Tohoku, JAPAN. The huge earthquake was occurred in Tohoku on March 11 2011. So big damages were given to this area. The used PRISM image was observed in August 15 2007 and April 10 2011. 3D measurement has not been generated yet. But the change in the geographical features after a huge earthquake can be detected with original satellite imagery using neighborhood correlation method. The correlation showed 70% or more were changed in each test area. The results should verified aerial photograph or field survey in near future.

***KEYWORD*S**: ALOS/PRISM, 3D measurement, DSM Change Detection

1. INTRODUCTION

On 11 March 2011, huge earthquake was occurred in Tohoku Japan. There was big diastrophism due to the earthquake. Maximum ground displacement in the horizontal direction was more than 5 m (Figure 1.1). The displacement was observed by Geographical Survey Institute (GSI), Japan. They were measured by ground station of GPS which called electronic reference point. There are 1,240 stations in Japan.

On the other hand, three-dimensional measurement by the satellite image can be also applied to detect the displacement. The satellite remote sensing technology can observe the situation in wide area. If the landform change can be detected by satellite images, the satellite remote sensing technology will be effective for disaster monitoring. Therefore, the purpose of the present study is landform change detection by using the satellite remote sensing.

In October 2006, remotely sensed data of PRISM sensor that mounted on Japanese land observation satellite ALOS was begun to provide for general users. PRISM sensor has three lines scanner (forward, nadir, backward looks) with 2.5 m ground sampling distance 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 stereo images.

Figure1.1 Measurement Results of displacement by GPS in Tohoku, JAPAN (© GSI)

2. METHODOLOGY OF LANDFORM CHANGE DETECTION USING SATELLITE REMOTE SENSING

Figure 2.1 shows general idea of 3D measurement. Firstly, geometric model of satellite imagery should be established. Reference points data are required for accurate geometric model. After that, the corresponding points in stereo imagery must be found by the image matching. Ground coordinates (X, Y, Z) can be calculated using geometric model and image coordinates of the corresponding points. The displacement of geographical features can be extracted by comparing multi temporal 3D surface models using satellite imageries.

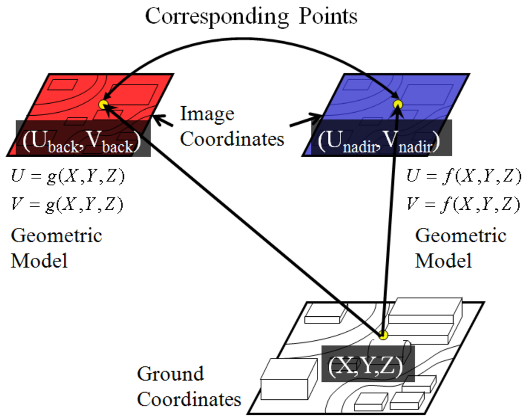


Figure 2.1 General Idea of 3D Measurement using ALOS PRISM

2.1 ALOS PRISM Data

The selected PRISM imageries were nadir and backward of level 1B1 processed data. Forward imagery is not suitable for 3D measurement because of Bidirectional Reflectance Distribution Function in northern-hemisphere. Table 2.1 showed specification of ALOS PRISM imagery. And Figure 2.2 showed sample of PRISM imagery. Shape of slope in each imagery is different by parallax of stereo imagery.

Table 2.1 Specification of ALOS PRISM

Sensor	PRISM
Process	Lebel 1B1
Ground resolution	2.5 m
Test area	ISHINOMAKI-CITY
Using images	Nadir & Backward
Acquisition Date	August 15 2007
	April 10 2011
Test area width	14496 * 16000 m

Nadir Imagery Backward Imagery

Figure 2.2 Sample of PRISM Data

2.2 Establishment of Geometric Model

In this study, Rational Polynomial Coefficient (RPC) model (equation.(1)) was used as geometric model.

$$U = \frac{a_1 + a_2 Y + a_3 X + \cdots + a_{20} X^3}{b_1 + b_2 Y + b_3 X + \cdots + b_{20} X^3}$$

$$V = \frac{c_1 + c_2 Y + c_3 X + \cdots + c_{20} X^3}{d_1 + d_2 Y + d_3 X + \cdots + d_{20} X^3} \quad \cdots (1)$$

U, *V*: Image coordinates

X, *Y*, *Z*: Ground Coordinates

a, *b*, *c*, *d*: transform coefficients

RPC model is the general model for any satellite sensors. RPC model of PRISM is offered by RESTEC, JAPAN (Remote Sensing Technology Center of Japan). There are 80 coefficients in RPC model. The RPC model is including location error and orientation error. Therefore, bias correction must be carried out using Ground Control Points (GCP).

GCP database has been established and opened to the public by author's laboratory in Kochi University of Technology.

(URL:http://www.infra.kochi-tech.ac.jp/takalab/gcp_correction/GCPDB/index.html).

Figure 2.3 shows Web page of GCP database. There are over 500 GCP. In each point, accurate coordinates were observed by GPS-VRS (GPS with Virtual Reference System) observation with 2 ~ 3cm accuracy. Bias correction of RPC model can be carried out using this GCP database.

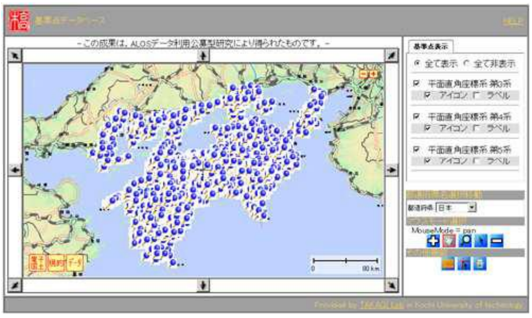


Figure 2.3 GCP Database

The bias correction eliminates generally shift error. The shift correction can be solved using s1 and s2.

$$s1 = \frac{a_1 + a_2 Y + a_3 X + \cdots + a_{20} X^3}{b_1 + b_2 Y + b_3 X + \cdots + b_{20} X^3} - U$$

$$s2 = \frac{c_1 + c_2 Y + c_3 X + \cdots + c_{20} X^3}{d_1 + d_2 Y + d_3 X + \cdots + d_{20} X^3} - V \quad \cdots (2)$$

*s*1, *s*2: shifting amount

U, *V*: Image coordinates

X, *Y*, *Z*: Ground Coordinates

a, *b*, *c*, *d*: transform coefficients

s1 and s2 are unknown numbers. When, the GCP has enough accuracy, shifting amount can be derived by one GCP. However, the error margin is usually included in the GCP. Therefore, the amount of the correction is calculated by the average using several GCP.

2.3 Stereo Matching and 3D Coordinate Calculation

The corresponding points in stereo imagery are searched by image processing which call image matching. The 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. Firstly, feature extraction method is applied to find corresponding points roughly. Secondly, Least Square Matching method is applied to obtain accurate matching results.

2.3.1 Feature Extraction

The feature points on satellite imagery were requested by the edge extraction using sobel filter. Figure 2.4 shows original image. Figure 2.5 shows edge enhanced image by sobel filter. Figure 2.6 shows extracted feature point of edge by binarization using threshold. When spatial resolution is very high, too many edge will extracted. Then coarse to fine approach is needed to solve this problem.

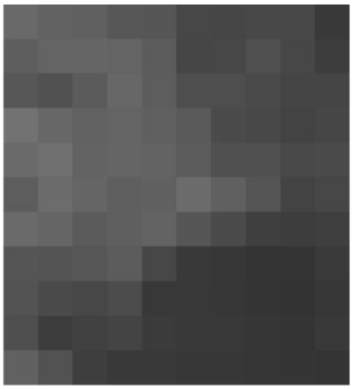


Figure 2.4 Low resolution Image

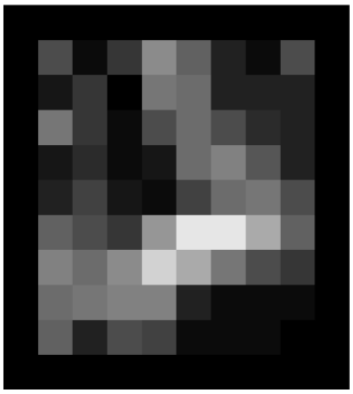


Figure 2.5 Subtracted Image

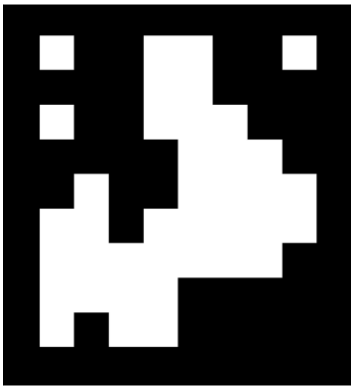


Figure 2.6 Image to which edge is extracted

2.3.2 Least-Squares matching

After calculating the corresponding points by feature extraction, the most accurate corresponding points can be computed by Least-Squares Matching. Least-Squares matching is matching method based on successive approximation using density conversion and geometric transformation. Linear transformation is used for density conversion. Pseudo Affine transformation was used for geometric transformation. This method performs the accurate matching.

2.3.3 3D Coordinate Calculation

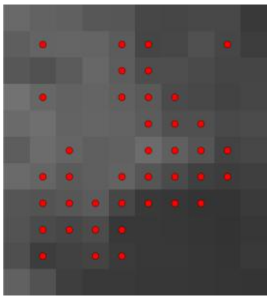
After the deriving of geometric models and extracting corresponding points, 3D measurement should be carried out. When image coordinates (u, v) of the corresponding points in stereo imagery are input to geometric model, unknown values are ground coordinates (X, Y, Z). The number of equation is two in each image. Then the total number of equation became four in the case of stereo imagery. Therefore, (X, Y, Z) can be solved.

RPC model is a nonlinear expression. Therefore, the least squares estimation is difficult to apply. Then, Monte Carlo Estimation was applied. Monte Carlo estimation is a calculation method for nonlinear expression using random values. In this study, the uncertainty of solution was decreased by setting the initial value. The initial value was used the Digital Elevation Model which produced by GSI, Japan.

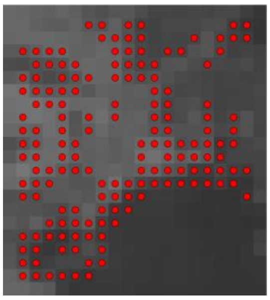
2.4 Coarse to Fine Approach

Coarse to fine approach should be applied. If the spatial resolution make very low, accurate features will be extracted. After that, the spatial resolution should make higher. Figure 2.7 shows extracted feature points in each resolution.

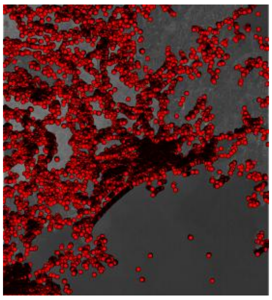
The resolution was varied in 6 steps from 80m to 2.5m. The feature points were extracted from both the nadir and backward imagery of each resolution. However, accuracy of matched coordinates showed varied that the feature extraction method should be revised.



Low resolution



medium resolution



High resolution

Figure 2.7 Coarse to Fine Method

2.5 Method of Landform Change Detection

The neighborhood correlation coefficient method was used to detect the geomorphic change. This method was suggested by Kazuo Oki 1). This technique can apply for displacement extraction by comparing two data sets. The presence of the change is specified by acquiring the u*v pixel area and the corresponded area. Following equation (3) was used for the calculation of the correlation coefficient.

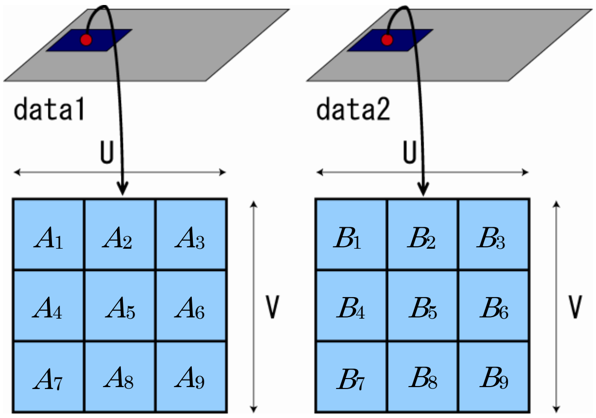


Figure 2.8 Neighborhood correlation coefficient method

$$r = \frac{\sum_{i=0}^{n}(Ai-\mu_a)(Bi-\mu_b)}{\sqrt{\sum_{i=0}^{n}(Ai-\mu_a)^2}\sqrt{\sum_{i=0}^{n}(Bi-\mu_b)^2}} \quad \cdots \quad (3)$$

r: Correlation coefficient

$\mu 1$, $\mu 2$: Average value in neighborhood pixel

When the correlation coefficient shows almost 1.0, that point is not change.

3. CASE STUDY OF LANDFORM CHANGE DETECTION

Test area was selected around ISHINOMAKI City in the Tohoku, JAPAN (Figure 3.1). The huge earthquake was occurred in Tohoku on March 11 2011. So big damages were given to this area. The used PRISM image was observed in August 15 2007 and April 10 2011.

The test area was selected according to geomorphic change. Figure 3.2 shows the location of three test area. Figure 3.3 shows each test area.

3D measurement has not been generated yet. But the change in the geographical features after a huge earthquake can be detected with original satellite imagery using neighborhood correlation method. Figure 3.4 shows displacement of the geographical features by the neighborhood correlation method. A low correlation is shown in red. A high correlation is shown in transparent. Table 3.1 and 3.2 shows accumulation of area on changed pixel and the ratio.

The ratio of a negative high correlation showed small. And, the ratio of a positive correlation under 0.5 showed large. Therefore, the earthquake damage showed so big. In each test area, 70% or more were changed by earthquake.

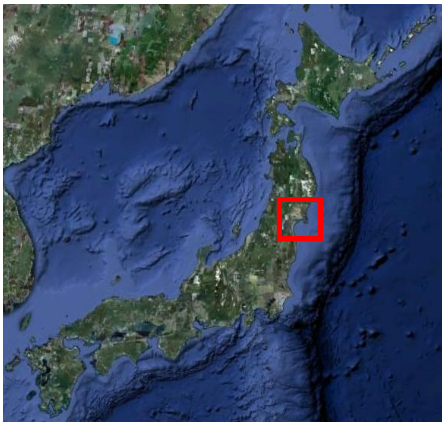


Figure 3.1 Place in test area

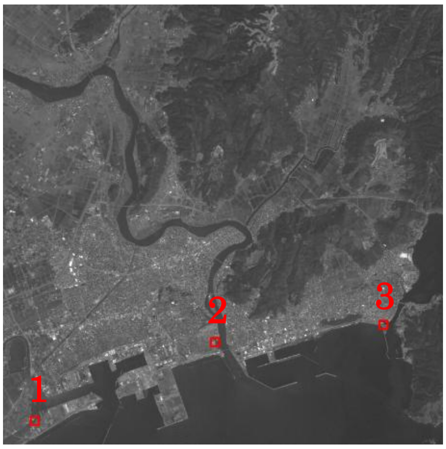


Figure 3.2 Ishinomaki Area

Test area 1

August 15 2007 Imagery April 11 2011 Imagery

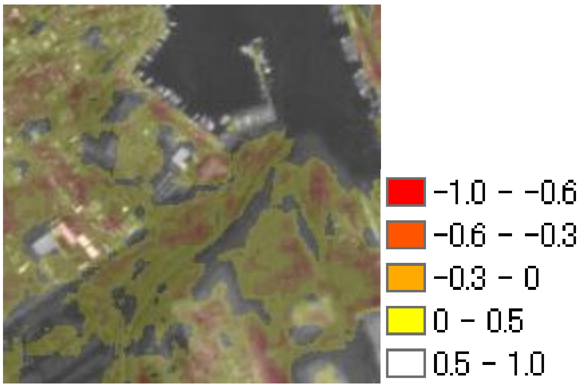
Test area 2

August 15 2007 Imagery April 11 2011 Imagery

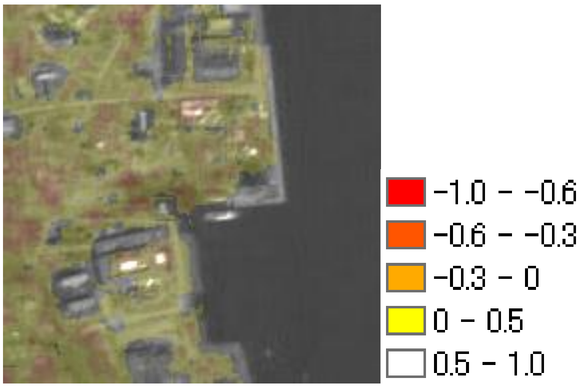
Test area 3

August 15 2007 Imagery April 11 2011 Imagery

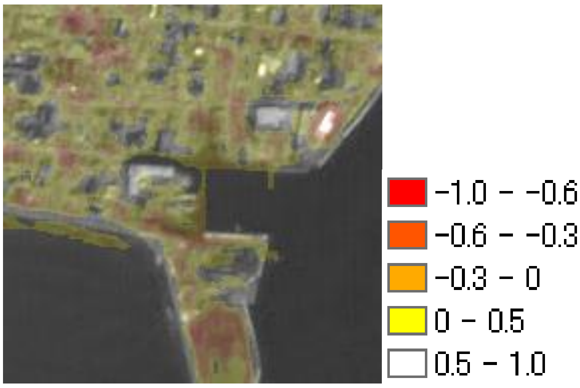
Figure 3.3 Result of Landform Change Detection



Test area 1



Test area 2



Test area 3

Figure 3.4 Change detection of Test area

Table 3.1 Accumulation of area on changed pixel

Correlation	Test area1 (m^2)	Test area2 (m^2)	Test area3 (m^2)
-1.0 ~ -0.6	1000	206	1581
-1.0 ~ -0.3	11331	6925	15594
-1.0 ~ 0.0	34650	36406	52656
~ 0.5	99381	102556	134638

Table 3.2 Accumulation of ratio on changed pixel

Correlation	Test area1 (%)	Test area2 (%)	Test area3 (%)
-1.0 ~ -0.6	0.73	0.15	0.88
-1.0 ~ -0.3	8.23	4.92	8.65
-1.0 ~ 0.0	25.17	25.86	29.21
~ 0.5	72.18	72.84	74.69

4. CONCLUSION

In this study, Method of 3D measurement using stereo satellite imagery was established. The stereo matching with Coarse to Fine Method was applied. However, accuracy of stereo matching was not enough. Currently, feature extraction method is revised.

The change in the geographical features after a huge earthquake been detected with original satellite imagery using neighborhood correlation method. The correlation showed 70% or more were changed in each test area. The results should verified aerial photograph or field survey in near future.

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