Change Detection of Digital Surface Model by ALOS PRISM

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Summary: Whole Shikoku island, JAPAN was selected as test area. In Shikoku, many slope failures are occurred by the torrential rain every year. The slope failures induce other serious disaster such as landslide, mudflow and debris flow. Therefore, slope failures must be found immediately. In the case of remote area, finding slope failures is very difficult.

PRISM sensor mounted on ALOS has three lines scanner with 2.5m ground sampling distance. Then, three dimensional (3D) measurements can be carried out in 2.5m spatial resolution. The 3D measurement using PRISM has a potential to detect a big scale slope failure.

For accurate 3D measurement, Ground Control Points (GCP) must be prepared. Authors established GCP database for ALOS data in Shikoku. Now, over 500 points were surveyed by GPS VRS observation. There are about 20 GCP in PRISM coverage. The GCP database is opened to the public through web site of Kochi University of Technology.

There are several geometric transformation models for 3D measurement such as RPC, 3D projection and line scanner DLT. Those geometric transformation models were evaluated using GCP database. The result showed the accurate model was 3D projection. By using 3D projection, Ortho-Mosaic imagery of 36 PRISM scenes and 9 AVNIR2 scenes was generated in whole Shikoku island. Accuracy of the Ortho-Mosaic imagery showed less than 1 pixel. Then, established GCP database has enough accuracy for registration of ALOS data.

3D measurement using PRISM was carried out using stereo matching. Image correlation method and least squares matching were combined for accurate stereo matching. The result of The 3D measurement showed 5m RMSE in 3D projection and line scanner DLT. In this study, 3D projection was also used for DSM generation. And 5 area were selected for evaluating generated DSM. The RMS error showed bigger in mountainous area rather than plane area. When GCP were prepared in high elevated area, the accuracy will be improve.

For change detection, two scenes of PRISM were used, which were acquired on 2006 and 2009 in kochi area. Digital Surface Models (DSM) of point cloud model were generated. The point cloud model was converted to 10m grid model to compare both DSM. A difference of each DSM was calculated by simple subtraction. The subtractive imagery had a striping noises. The reason of the striping noise was micro pulsation of sensor. The striping noise was eliminated by DFT. However, it was difficult to detect change. Next, Neighbor Correlation Coefficient (NCC) was calculated for change detection. This method can be neglect gentle change such as striping noise. The change detection by NCC showed noises of DSM in plane area were detected very much. For accurate change detection, noises should be eliminated.

Keywords: 3D Measurement, Slope Failure, Digital Surface Model, Disaster Monitoring

1 Introduction

Whole Shikoku island, JAPAN was selected as test area. In Shikoku, many slope failures are occurred by the torrential rain every year. The slope failures induce other serious disaster such as landslide, mudflow and debris flow. Therefore, slope failures must be found immediately. In the case of remote area, finding slope failures is very difficult. At least, $400m^2$ slope failure should be detected.

PRISM sensor mounted on ALOS has three lines scanner with 2.5m ground resolution. Then, three dimensional (3D) measurements can be carried out in 2.5m spatial resolution. Multi temporal Digital Surface Models (DSM) can be generated. A change detection of DSM will be efficient for finding slope failure in remote area. The 3D measurement using PRISM has a potential to detect a big scale slope failure.

Objectives of this study is detection of slope failure by using multi temporal DSM. Following items are research issues to achieve objectives.

- Establishment of accurate Ground Control Points Database
- Selection of Suitable geometric model for PRISM
- Evaluation of GCP and selected geometric model
- Digital Surface Model generation by using PRISM stereo imagery
- Validation of generated Digital Surface Model
- Change Detection using multi temporal Digital Surface Model

When detection method for slope failure using PRISM stereo imagery is established, second disaster such as huge mad flow or huge debris flow might be predicted.

2 Test Area

Many slope failures are occurring in Shikoku, JAPAN. Figure 2.1 shows test area where is Shikoku island.

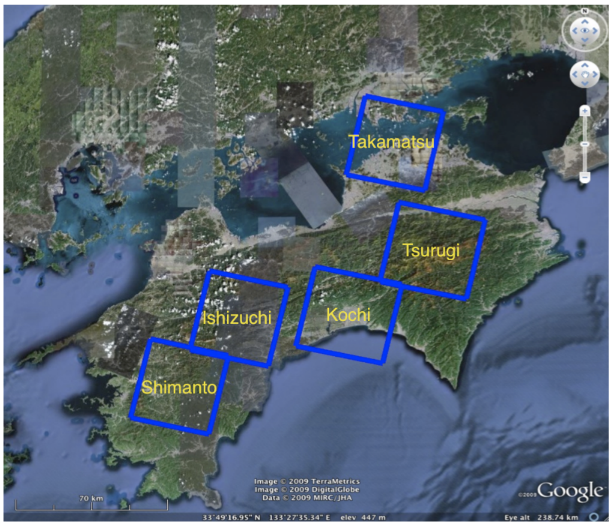

Figure 2.1 Test Area for DSM generation

GCP are prepared in whole Shikoku island. And Ortho-Mosaic imageries were generated for whole Shikoku island. DSM were generated in 5 areas where showed as rectangular symbol. The 5 ares are Kochi, Takamatsu, Shimanto, Tsurugi and Ishizuchi.

In Kochi area, change detection will be carried out and evaluated. In this study two scenes of PRISM which were acquired on 2006 and 2009. For DSM generation, nadir imagery and backward imagery were used.

3 Establishment of GCP Database

Generally, RPC model is used as geometric transformation model[1][2]. However RPC model including systematic error. Then, GCP data should be prepared for bias correction[3] of RPC.

On the other hand, basic geometric transformation model such as 3D projection transform and line scanner DLT will be derived when many GCP can be used. Number of GCP should be over 20 points which are used for calculating transformation coefficient and the validation. The total number of GCP in whole test area is over 300 to cover whole test area.

Accuracy of GCP is required 1/10 pixel which is 25 cm in the case of PRISM. Therefore, GCP should be surveyed by VRS GPS observation. The ground coordinates of GCP were measured by VRS

GPS observation which can be measured in 2cm accuracy. Measurement objects of GCP should be selected, which are intersection of road, corner of dike or center of bridge. These objects can be interpreted well in the PRISM and AVNIR2 imagery. Figure 3.1 shows established GCP database. Currently, over 500 GCP were prepared.

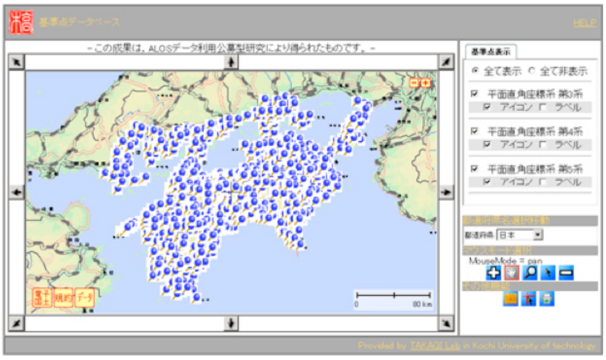

Figure 3.1 Location of GPS VRS Observation

The GCP database is opened to the public using Web GIS in Takagi Labo., Kochi university of technology. Following information are stored in the GCP database.

- Latitude, Longitude
- Altitude
- 3D coordinate in rectangular plane
- Geodetic datum and Coordinate system
- Several pictures of VRS GPS observation situation
- Chip satellite imagery of PRISM and AVNIR2 at observation point

4 Evaluation of Geometric Model

In this study, three geometric models were compared, which are RPC (rational polynomial coefficient) Model, 3D projection transform and line scanner DLT(Direct Linear Transform). Each geometric model can convert ground coordinate (x, y, z) to image coordinate (u, v). Following equation is RPC model. Function f() and g() is third order polynomial, that is provided by RESTEC, Japan.

$$\begin{cases} u = \frac{f_u(x,y,z)}{g_u(x,y,z)} \\ v = \frac{f_v(x,y,z)}{g_v(x,y,z)} \end{cases} \tag{4.1}$$

RPC model includes systematic error. Then bias correction was carried out using GCP. In this study, five GCP were used for th bias correction of RPC Model.

Following equation is 3D projective transform. There are 14 unknown coefficients which are $a_1, \cdots, a_8$ and $b_1, \cdots, b_6$.

$$\begin{cases} u &= \dfrac{a_1x + a_2y + a_3z + a_4}{b_1x + b_2y + b_3z + 1} \\ v &= \dfrac{a_5x + a_6y + a_7z + a_8}{b_4x + b_5y + b_6z + 1} \end{cases} \tag{4.2}$$

Usually, denominator of u and v coordinate in 3D projective transform is same coefficient for central projective imagery of area sensor. To apply line scanner imagery for satellite optical sensor, denominator of u and v coordinate should be separated. The unknown coefficients were derived using GCP by least squares estimation.

Following equation is line scanner DLT. There are 11 unknown coefficients which are $a_1, \cdots, a_8$ and $b_1, \cdots, b_3$.

$$\begin{cases} u &= \dfrac{a_1x + a_2y + a_3z + a_4}{b_1x + b_2y + b_3z + 1} \\ v &= a_5x + a_6y + a_7z + a_8 \end{cases} \tag{4.3}$$

The unknown coefficients were derived by same way with 3D projective transform, which were derived using GCP by least squares estimation.

Table 4.1 showed RMS(Root Mean Square) error around GCP in the case of nadir imagery. Table 4.2 showed RMS error around GCP in the case of backward imagery. From both table, each model showed almost less than one pixel.

5 Ortho-Mosaic Imagery Generation

Ortho-Mosaic imagery was generated using 36 scenes of PRISM and 9 scenes of AVNIR2. 3D projection model was selected as geometric model. for

Table 4.1 Accuracy of Geometric Model in Nadir Imagery (Unit: Pixel)

Geometric Model	Column (u)	Row (v)
Bias Corrected RPC	0.707	0.731
3D Projection	0.625	0.707
Line Scanner DLT	0.625	0.844

Table 4.2 Accuracy of Geometric Model in Backward Imagery (Unit: Pixel)

Geometric Model	Column (U)	Row (V)
Bias Corrected RPC	0.939	0.979
3D Projection	0.823	1.104
Line Scanner DLT	0.780	1.108

generating Ortho-Mosaic imagery, Digital Elevation Model (DEM) was required. In this time, 10m grid DEM was used, which is provided by Geographic Survey Institute, Japan.

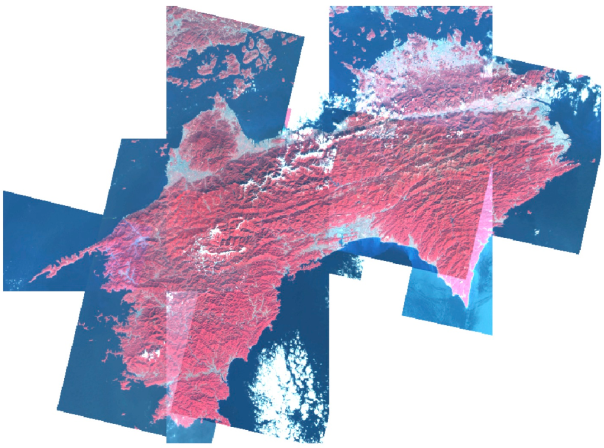

Figure 5.1 Ortho-Mosaic Imagery

Figure5.1 showed generated Ortho-Mosaic imagery.

Table?? showed RMS error in Ortho-Mosaic imagery generation. The accuracy of AVNIR2 was better than PRISM. However, RMS error of PRISM showed less than one pixel. Generated Ortho-Mosaic imagery has enough accuracy. And it will be used as base map for change detection.

Table 5.1 RMSError in Ortho. Imagery Generation (Unit: Pixel)

	RMSE	STD
PRISM u-axis	0.757	0.354
PRISM v-axis	0.883	0.327
AVNIR2 u-axis	0.545	0.211
AVNIR2 v-axis	0.641	0.166

6 DSM Generation

After the selecting geometric models, DSM generation should be carried out using stereo matching. The corresponding points in stereo matching were selected by image processing which is combined area correlation method and least square matching.

Figure6.1 showed test area for evaluating DSM generation. Red points are used GCP for deriving geometric model. Yellow rectangular area is validation area of elevation.

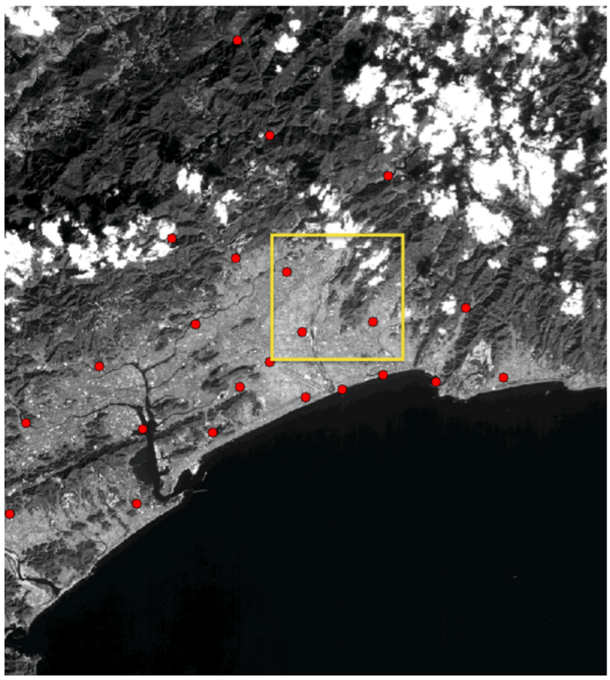

Figure 6.1 Used Image (PRISM)

When image coordinates (u, v) of the corresponding points in nadir and backward imagery are input to geometric model, unknown values are ground coordinates (X, Y, Z). The number of equations are two in each image. Then the total number of equation become four in stereo imagery. Therefore, three unknown values (X, Y, Z) can be solved.

3D projective transformation model and line scanner DLT are expressed in a linear transformation. Then, least square estimation can be applied to calculate ground coordinates (X, Y, Z). RPC model is a nonlinear expression. Therefore, the least square estimation is difficult to apply. Then, Monte Carlo Estimation could be applied. 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 projective transformation model.

After calculation of ground coordinates, Digital Surface Model (DSM) was generated in test area. The corresponding points were extracted over 185,000 points. The calculated ground coordinates were random point data which is called point cloud model. Then, the random points data should interpolated to grid data model using TIN (Triangulated Irregular Network). Thd grid interval were set to 10 meters. Figure 6.2 showed shaded images of DSM by RPC model.

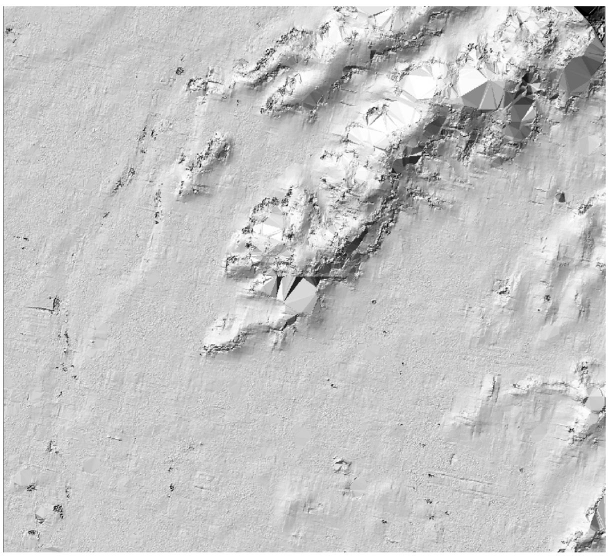

Figure 6.2 Generated DSM

Generated DSM were compared with Air borne LiDAR data for validation. Table 6.1 showed RMS error in vertical direction. In this table, line scanner DLT showed the best result in accuracy of DSM. However, the accuracy was almost same with 3D projection.

Table 6.1 RMSError in Each Model (Unit: Meter)

Model	RMS Error
Bias Corrected RPC	10.165
3D Projection	5.147
Line Scanner DLT	4.577

In 5 test areas, DSM was generated by using 3D projection model. Table6.2 showed each RMS error. The error was calculated using GCP database. In plane area, the error showed almost 3 meters. In mountainous area, the error showed over 7 meters. The results might be come from spatial distribution of GCP in Z axis. When geometric model was derived, GCP located on high elevated area were very few. Therefore, errors in mountainous area showed bigger depending on accuracy of geometric model.

Table 6.2 RMSError in each test area (Unit: m)

Scene	RMSE	Note
Shimanto	2.71	Plane Area
Kochi	3.03	Plane Area
Takamatsu	2.71	Plane Area
Mt. Ishizuchi	7.19	Mountainous Area
Mt. Tsurugi	14.0	Mountainous Area

7 Change Detection

For change detection, two scenes of PRISM were used, which are acquired on 2006 and 2009. Generated both DSM were converted to grid type in same geometric parameters. Then both DSM were compared by simple subtraction. Figure 7.1 showed subtractive imagery. In Figure 7.1, there are striping noise along scan line of PRISM imagery. The period of striping noise was approximately 1 km and the amplitude was 10m. The reason of striping noise was micro pulsation of ALOS satellite.

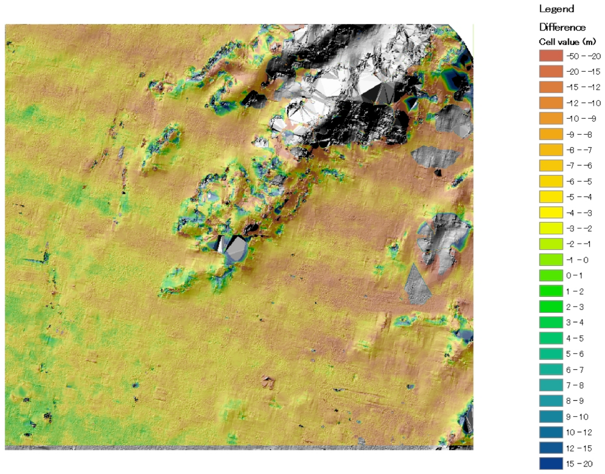

Figure 7.1 Result of Change Detection

Therefore, the striping noise should be eliminate by DFT.

Figure7.2 showed result of change detection after DFT. The striping nose was eliminated. However, changed area could not be clearly discriminated.

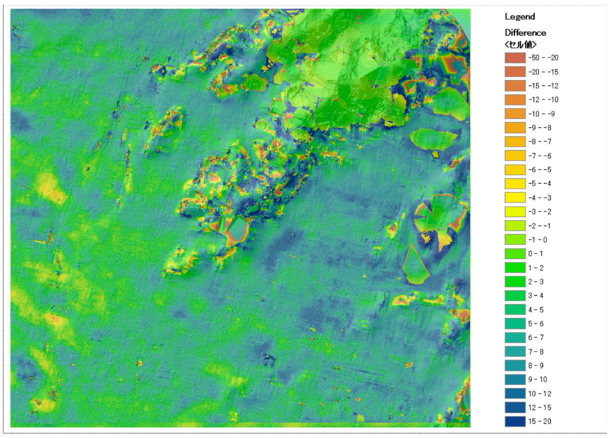

Figure 7.2 Result of Change Detection after DFT

As another change detection method, Neighbor Correlation Coefficient (NCC) was applied. This method can be neglected gentle change. Figure?? showed result of change detection by NCC. The striping noises were not detected. This method will be useful for change detection using DSM including striping noise.

The result showed many changed areas were located on plane area. Because, very small changes were occurred by mis-matching in plane area. The mis-matching should make reduce by improvement of image matching method.

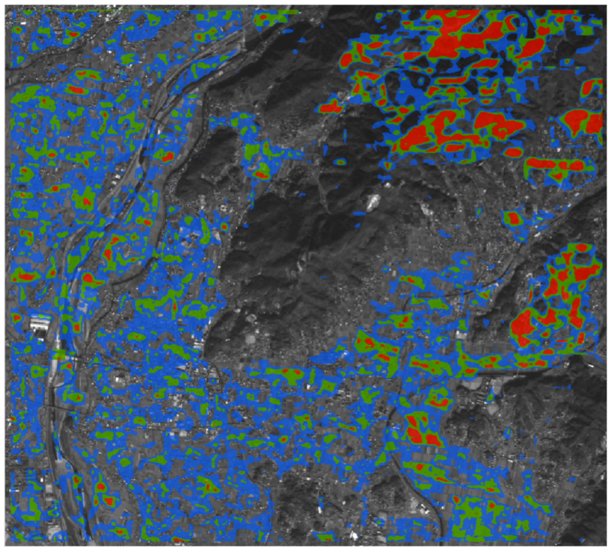

Figure 7.3 Result of Change Detection by NCC

8 Conclusions

In this study, GCP database for ALOS PRISM and AVNIR2 was established in Shikoku , JAPAN. Currently, over 500 GCP were prepared. The database will very effective to derive accurate geometric model and the validation of geometry.

By using GCP database, three geometric models were evaluated, which is bias corrected RPC, 3D projective transformation and line scanner DLT. 3D projection showed the best accuracy.

Moreover, Ortho-Mosaic imagery using 36 scenes of PRISM and 9 scenes of AVNIR2 was generated. Accuracy of both Ortho-Mosaic imagery showed less than one pixel. Specially, Ortho-Mosaic image of AVNIR2 showed less than 0.5 pixel error. Therefore, established GCP database has enough accuracy to register ALOS imagery.

By stereo matching, 3D ground coordinates were calculated. And DSM based on point cloud model was generated. In accuracy of DSM, 3D projection and line scanner DLT showed better result in RMS error that showed almos 5 meters.

For change detection, two scenes of PRISM were used, which were acquired on 2006 and 2009. A difference of each DSM was calculated by simple subtraction. The subtractive imagery had a striping noises. The reason of the striping noise was micro pulsation of sensor. The striping noise was eliminated by DFT and NCC. However, there are many small noise in the result. For detecting disaster, stereo matching method must be improved.

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