EVALUATION OF DSM GENERATED FROM QUICKBIRD STEREO IMAGERY

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KEYWORDS: High-resolution-Satellite, Quickbird, DSM/DEM/DTM, orthorectified image, Cartography

ABSTRACT:
GSI (Geographical Survey Institute) is researching to apply high-resolution satellite imagery to topographical mapping. Previous studies with IKONOS and SPOT5 show its effectiveness. QuickBird has the highest resolution among the commercial satellites. According to prior studies, QuickBird mono image with DEM gave good results for horizontal accuracy and discrimination. We confirmed the accuracy of 3D model from QuickBird stereo imagery is suitable for topographical mapping and the shift contained in the 3D model was decreased with a simple correction. In this study, we try to generate the digital surface model from QuickBird stereo images and compare the results with products from aerial photographs and aerial laser scanner. We also generate the orthorectified images from QuickBird images and evaluate the quality.

1. INTRODUCTION

The Geographical Survey Institute (GSI) is researching on the application of high-resolution satellite imagery to topographical mapping, especially for 1:25,000 topographic maps, which are the base maps of Japan.

The studies of the application of IKONOS and SPOT5 imagery for mapping were already published. They showed that high-resolution satellite imagery was effective for mapping (Iida et al., 2001, Iida et al., 2002, Kobayashi et al., 2002, Iida et al., 2003). The 3D accuracy and bias compensation of IKONOS imagery were already studied (Fraser et al., 2002, Fraser et al., 2003). The evaluation of discrimination of features and the horizontal spatial accuracy for a QuickBird mono image with DEM was also published (Noguchi et al., 2003). It indicates the discrimination ability is good, but the image has a constant positional shift. Other studies of the spatial accuracy of the 3D model of QuickBird stereo images were also published (Oki et al). In the study, we evaluated the accuracy and tried to correct the distortion of the 3D model of QuickBird Stereo Imagery. The results show that a few GCP are enough for the correction in the purpose of topographical mapping. Considering the previous study on the discrimination of feature, QuickBird satellite imagery is effective for topographical mapping.

In this study, we used stereo-pairs of QuickBird imagery of Yokosuka City and Tokyo, JAPAN. We generated DSM (Digital Surface Model) automatically from these images by using a digital photogrammetry software and compared them with DSM generated from aerial photographs and with DSM obtained by using an aerial laser scanner. We also generated orthorectified images of QuickBird images by using the DSM generated from QuickBird stereo imagery and evaluated them.

2. EVALUATION Of 3D model

In previous study, we evaluated the accuracy of the 3D model of QuickBird Stereo Imagery by using a stereo-pair with 60 check points (measured by GPS) arranged densely.

The coordinates of sixty check points measured from imagery (coordinates A) are compared with those of GPS survey results (coordinates B). Fig.1 shows the distribution of check points.

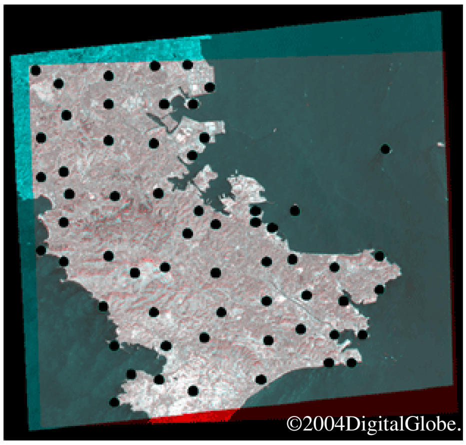

Fig. 1 Distribution of check points
(Overlaid are QuickBird stereo images)

2.1 Test field

We selected Yokosuka City and its surroundings nearby Tokyo as a test field. It is located in a hilly district. The terrain elevation ranges from 0m to 241m (Fig. 2).

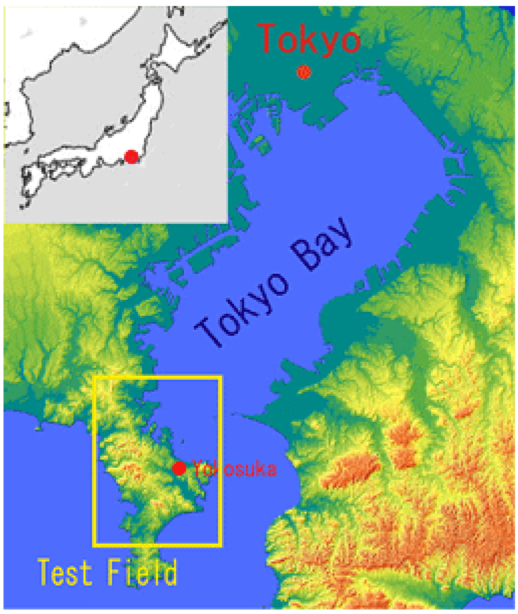

Fig. 2 Location of test field

2.2 Image data

Evaluated images are ‘QuickBird panchromatic basic imagery’ with a radiometric correction and a sensor characteristic correction. The observation date of images is April 22, 2003 and their ground resolution is 0.78m. The area of each image is 450km^2 (21.2km*21.2km). The off-nadir angle of the forward view is 28.7 degree and that of the backward view is 27.2 degree. The overlap is about 90%.

2.3 3D model

The evaluated 3D model is an RPC model by using parameters distributed with images.

2.4 Image measurement

The 60 check points were selected from obvious objects in images (*e.g.,* an intersection of lines at parking lot, Fig. 3). Then 3 dimensional coordinates are measured on the 3D model by stereoscoping at a digital photogrammetry software. Each point is measured twice and calculated the average as the coordinates A. The standard deviation of the differences between the two measurements is 0.19m in easting, 0.15m in northing and 0.23m in vertical.

Fig. 3 An example of check points
(Left: forward-view, Right: backward-view)

2.5 GPS survey

The check points were also surveyed by fast-static GPS (Fig. 4) and coordinates B were obtained. The reference station is one of permanent GPS stations of the GEONET (GPS Earth Observation Network of the GSI, Hatanaka et al., 2003). The observation time of each point is 30 minutes and PDOP of each observation is less than 6.

Fig.4 GPS survey

2.6 Evaluation of horizontal spatial accuracy

The horizontal component of error vectors (coordinates A – coordinates B) are indicated in Fig. 5.

An apparent westbound shift is observed at all points. The average of the easting component of the shifts is 13.13 m and that of the northing component is 2.78m. The standard deviation of the easting component is 0.73 m and that of the northing component is 0.93 m.

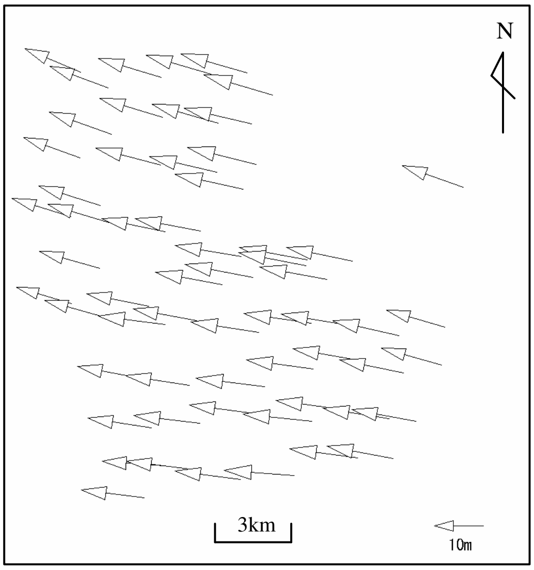

Fig.5 Horizontal component of error vectors

Since all vectors have the same tendency, we tried to correct the shifts by fixing one point as a ground control point (GCP). Fig. 6 shows a correction result in which the center point of images is used as a GCP. The average of the easting component of shifts decreased to 0.74m and that of the northing component decreased to 0.79m.

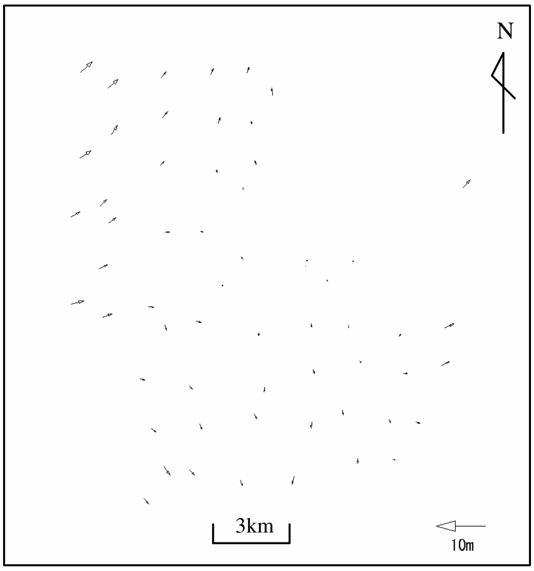

Fig.6 Horizontal component of error vectors
(after correction)

2.7 Evaluation of vertical accuracy

The average of vertical differences between coordinates A and coordinates B is 1.38m and the standard deviation of that is 1.42m. Fig. 7 displays the error as a gradation map. It shows a south-north tilt of –1.90m to 2.90m.

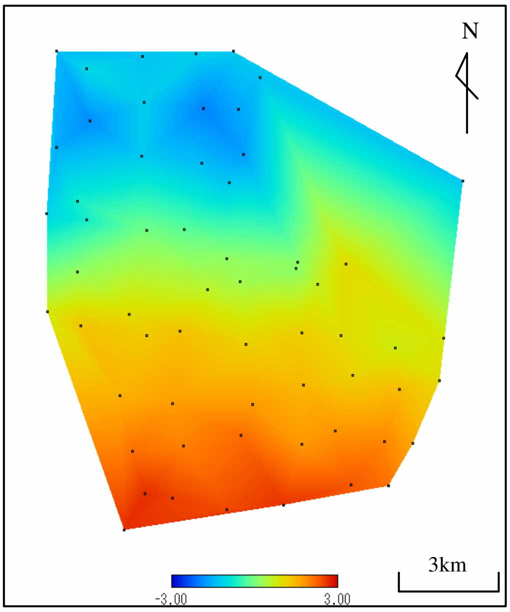

Fig.7 Vertical errors

Fig. 8 is a gradation map after a tilt correction of the whole model using 3 points on the coastline as GCPs to perform of the correction without a ground survey. We obtain a good result that the average error is 0.33 m and the RMS is 0.44 m.

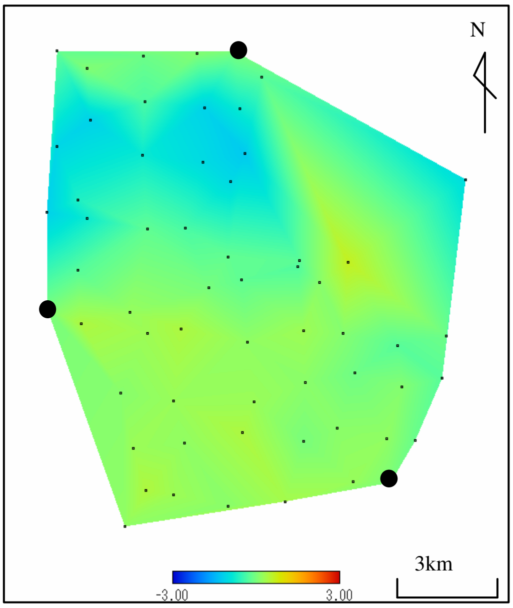

Fig.8 Vertical errors after correction with 3 GCPs taken from coastline (•: GCP)

2.8 Conclusion of the evaluation of 3D model

In the study, accuracy of QuickBird basic stereo images is evaluated and the distortion of the 3D model is limited. A few GCP are sufficient when we use those images for topographical mapping.

3. EVALUATION Of DSM

In this study we evaluated DSM generated from QuickBird stereo imagery.

We generated DSMs of two test fields. One is Yokosuka City and its surroundings nearby Tokyo. The other is Central Tokyo.

3.1 Test field 1 (Yokosuka City and its surroundings)

This test field is the same as that of the previous study where we evaluated the accuracy of the 3D model from QuickBird stereo imagery. We use the same QuickBird panchromatic imagery. For the evaluation, we used DSM from color aerial photographs as reference data.

3.1.1 Specification of aerial photographs

The aerial photographs were taken using the RC30 camera with GPS/IMU. The date of acquisition is December 2003. It is only 6 months after the observation of the QuickBird imagery. The scale is 1:30,000 and the flight altitude is 4690m. These photographs were scanned at a resolution of 20 microns (2540dpi) by using a digital scanner. Its ground resolution is 0.60m. It is almost equal to that of QuickBird imagery.

3.1.2 Orientation

In the previous study mentioned above, we confirmed that a few GCPs are necessary for the accurate orientation of QuickBird stereo imagery. In this study we used five GCPs (GPS survey results) and about 40 tie points generated automatically, and corrected the RPC model by 3rd order polynomials. The result of orientation was very good. The RMS of horizontal and vertical residuals at the GCPs and ten check points were about one pixel respectively.

3.1.3 DSM generation

We generated DSM from QuickBird stereo imagery and aerial photographs respectively (Fig. 9 and Fig. 10) by using a digital photogrammetry software (LPS). The area is 5km*5km and located in the middle of the QuickBird stereo pair scenes. The elevation range of this area is about 200m. The grid interval of both DSMs is 5m. Therefore, the number of points is 1 million.

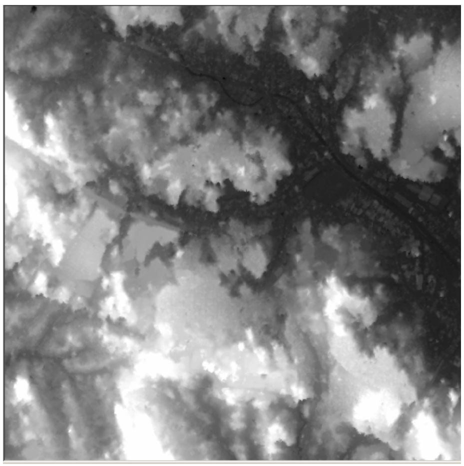

Fig. 9 DSM from QuickBird

Fig. 10 DSM from aerial photographs

3.1.4 Evaluation result

We compared the height at each point where the horizontal coordinates of two DSMs are the same. The average of vertical differences (absolute values) of 1 million points is 13.6m. The standard deviation of that is 26.5m. The maximum of that is 164.1m. Fig. 11 shows the distribution of differences.

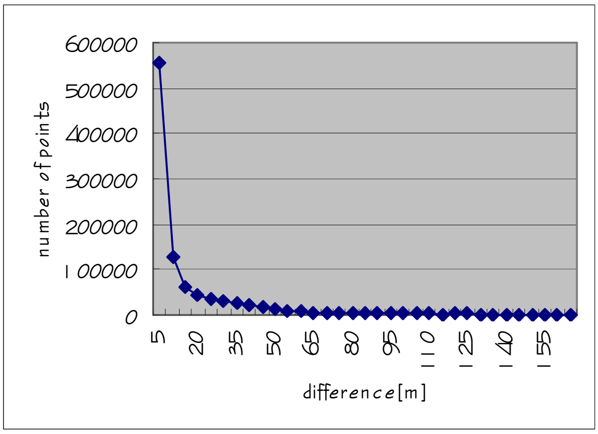

Fig. 11 the comparison between two DSMs

About 20 thousand points (2% of whole points) have the difference of more than 100m.

We checked the height of some wrong points by stereo-scoping. The height values from aerial photographs and QuickBird imagery at each point are almost the same and these values are near the values of DSM from aerial photographs. Then it is probable that the DSM from QuickBird is not good.

3.2 Test field 2 (Central Tokyo)

We used another stereo pair of QuickBird. The images are also panchromatic basic imagery with radiometric correction and sensor characteristic correction. The observation date of images is May 5, 2003. The off-nadir angle of the forward view is 29.8 degree and that of the backward view is 30.7 degree. For the evaluation, we use DSM from the aerial laser scanner as reference data.

3.2.1 Orientation

The method of orientation was the same as that of the test field 1. In this case, the horizontal coordinates of GCPs are obtained from Numerical Map 2500 published by GSI. Accuracy of the Numerical Map is declared as 1.75m in horizontal. The vertical coordinates of GCPs are from 1:25000 topographic map of GSI, and the accuracy is 3.3m. The coastal line is also used to determine sea level (0m). The horizontal and vertical residuals for 12 GCPs were less than 0.5 pixels.

3.2.2 DSM generation

We generated DSM from QuickBird stereo imagery (Fig. 12) by using the same digital photogrammetry software as above. DSM of the same area from the aerial laser scanner is shown in Fig. 13. The area is 2km*1.5km and located in the middle of the QuickBird stereo pair scenes. The elevation range of this area is about 180m. The grid interval of both DSMs is 5m. Therefore, the number of points is 120 thousand.

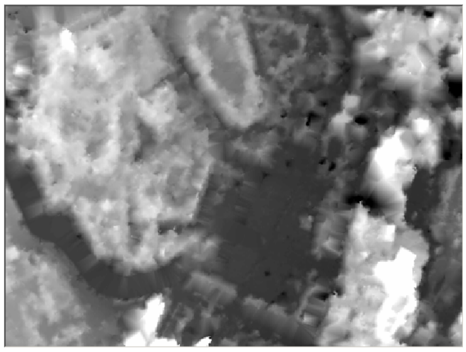

Fig. 12 DSM from QuickBird

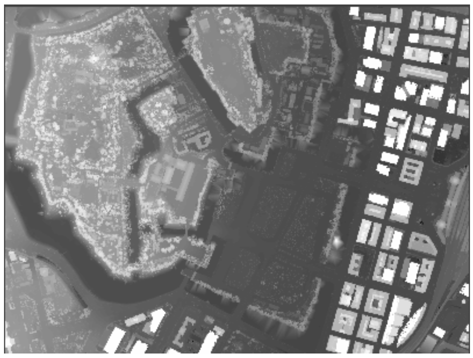

Fig. 13 DSM from aerial laser scanner

3.2.3 Evaluation result

We compared the height at each point where the horizontal coordinates of two DSMs are the same. The average of vertical differences (absolute values) of 120 thousand points is 10.1m, the standard deviation of that is 18.0m, the maximum of that is 167.6m. Fig. 14 shows the distribution of differences.

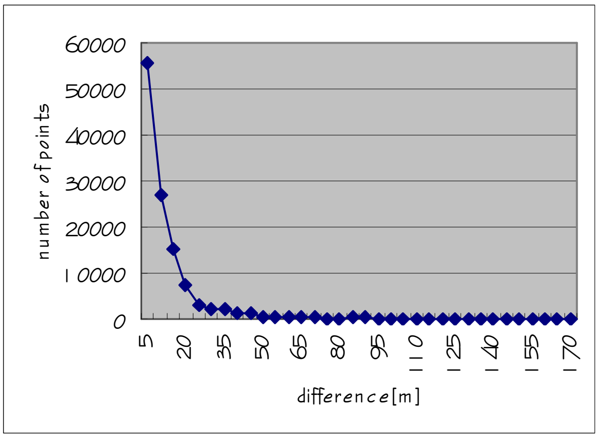

Fig. 14 the comparison between two DSMs

About 6 hundred points (0.5% of whole points) have the difference of more than 100m.

4. EVALUATION Of Orthorectified Image

We generated DSM from QuickBird stereo imagery of Yokosuka City and its surroundings automatically. The grid interval of DSM is also 5m. Then we orthorectified QuickBird stereo imagery by using this DSM and obtained two orthoimages, one is from the forward view image (Fig. 15) and the other is from the backward view image.

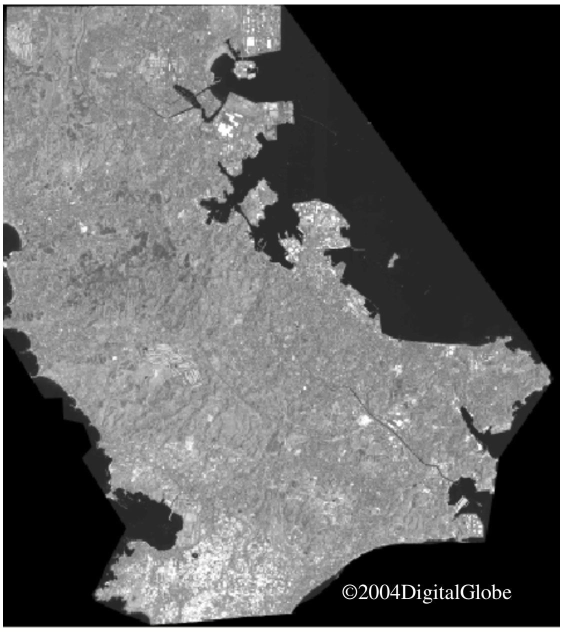

Fig. 15 orthoimage from QuickBird imagery

In order to evaluate the orthoimages, we measured the horizontal coordinates of 57 check points from two images. Then we compared the coordinates with each other and the result of the GPS survey. The result is shown in Table.1. In the table "Forward", "Backward" and "GPS" mean the coordinates measured from an orthoimage of the forward view image, those of the backward view image and the GPS survey results respectively. The difference is absolute value in meter.

Table.1 the comparison between horizontal coordinates

Unit : m

Differece Between: / of Differece	Forward and Backward	GPS and Forward	GPS and Backward	GPS and Average of Backward and Forward
Maximum	50.6	27.7	27.1	4.1
RMS	11.5	6.2	5.6	1.4
Average	3.8	2.7	2.2	1.1
Maximum in northing	49.5	27.0	27.0	2.6
RMS in northing	11.3	5.9	5.6	1.1
Average in northing	3.7	2.5	2.1	0.8
Maximum in easting	10.4	8.2	2.2	3.1
RMS in easting	2.2	1.9	0.7	0.8
Average in easting	0.9	0.8	0.5	0.5

The differences in northing are much larger than those in easting. The offnadir angle of QuickBird imagery is large in the north-south direction, then the software probably sometimes cannot find true matching points for DSM generation along the north-south direction and the images cannot be corrected appropriately.

Accurate coordinates were obtained by calculating the average of coordinates measured from the orthoimages. However, these orthoimages are not applicable for topographical mapping.

5. Conclusion

In this study the DSM and the orthoimages from QuickBird imagery are evaluated. The 3D model from QuickBird imagery is accurate. However, the DSM contains the large error and the orthoimage is not satisfied for topographical mapping. QuickBird imagery has high potential, and if we create DSM from QuickBird imagery manually, the DSM and the orthoimages will be accurate. The result shows the status of the automatic generation of the DSM and orthoimages using satellite imagery.

Acknowledgements

Hitachi Software Engineering Co., Ltd. offered the images evaluated in this paper. We express our appreciation.

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