DEM ACCURACY AND THE BASE TO HEIGHT (B/H) RATIO OF STEREO IMAGES

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Working Group IV/2

KEY WORDS: Optical Sensor, Remote Sensing, Digital Photogrammetry, Topographic Map

ABSTRACT

The adequate base to height (B/H) ratio is practically investigated with aerial photos and digital photogrammetric instruments. Very high overlap aerial photos are triangulated all at once for reducing measurement error and DEMs are created from pairs of photos at different B/H ratio. 11 pairs were selected and B/H ratio ranges from 0.1 to 1.35. Then, accuracy of each DEM is examined by ground points. Real time kinematic (RTK) GPS method, which can obtain precise position quickly, is used for acquiring ground point positions. Result is that DEM accuracy increases rapidly in proportion to the B/H ratio at lower value whereas its accuracy gradually decreased at the higher B/H ratio. In conclusion, the B/H ratio between 0.5 and 1.0 is reasonable for DEM creation.

1 INTRODUCTION

The launches of satellites, which carry optical sensors for acquiring stereo pairs along with a track, are being planned. In addition to nadir view sensors, these satellites have sidelong view sensors. The base to height (B/H) ratio differs from each satellite; B/H ratio of PRISM on ALOS is set to 1.0 (forward view + backward view) and 0.5 (sidelong view + nadir view). In case of ASTER on Terra (former EOS-AM1), it is set to 0.6. In case of OPS/VNIR on JERS-1 it was 0.3 (Miyazaki, 1995). There have been few studies focusing on this issue and executing practical tests though the B/H ratio has close relation to DEM accuracy made from a stereo pair of optical sensor images (Anko, 1996), (Shimozi, 1997). It consequently results in that the optimum ratio has not become clear. Unknownness of optimum ratio becomes a problem especially when planning along-track pair sensors that can not change the B/H ratio.

In the traditional photogrammetric registration method using aerial photos, B/H ratio between 0.35 and 0.75 (overlap ratio 50% - 75%) is needed for manual photo interpretation. Overlap ratio range from 55% to 60% is recommended for good results. However, quantitative assessment of best B/H ratio for DEM creation from automatic stereo matching method and relationship between B/H ratio and accuracy of DEM has not been done.

The purpose of this study is; making assessment of relationship with the B/H ratio and DEM accuracy of stereo pairs. Making decision of the adequate B/H ratio range suitable for automatic DEM creation from a stereo pair. A series of high overlap aerial photos was digitized and triangulated together by a digital photogrammetric workstation. Then various B/H ratios of stereo pairs were selected for DEM creation. Accuracy of DEM was examined by position of ground control points measured by GPS survey.

2 THE STUDY AREA

Terrain undulation has influence on the DEM accuracy as much as the B/H ratio has. In addition, our primary purpose is making topographic maps and DEMs from stereo images. Because of them, We have selected Kamigou area of Iwama town in Japan for the study area. This area is 3500m by 3500m in extent. This area is a rural area and influence of artificial objects to DEM is the minimum. Figure 1 shows landscape. This area is divided into 3 terrain types by its undulation. The first part is named “plain part.” This part is flat and gentle slope because Paddy field covers there. Relative height is less than 5m. The second part is named “hill part.” This part is occupied by a golf course. There are a few trees. Slope is gentle whereas relative height is about 50m. The last part is named “mountain part.” This part is wooded area and slope is relatively steep. Relative height is about 120m.

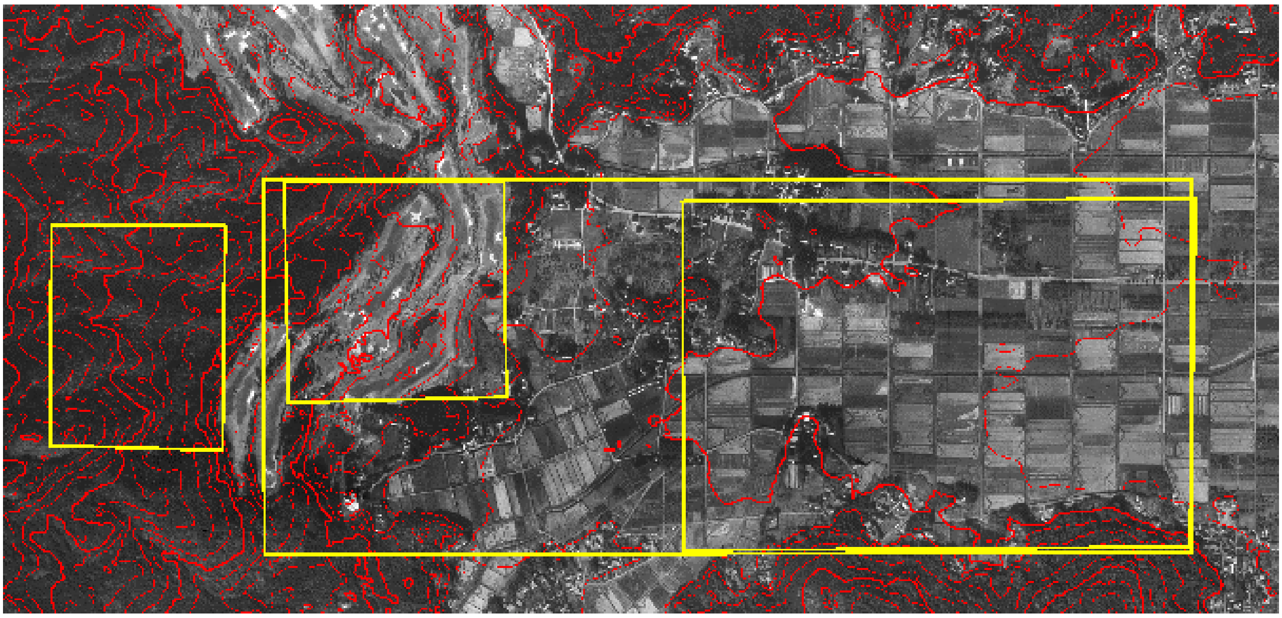

Figure 1. Ortho photo overlayed with resulted DEM and area boundary. Contour interval is set to 10m.

Ground Control Point	6
Tie Point	36
RMS residual (Image)	0.234 pixel
Max residual (Image) position accuracy of tie points	0.698 pixel
X residual (Point)	0.716 m
Y residual (Point)	0.694 m
Z residual (Point)	0.015 m

Table 1. Specification of aerial triangulation and its result.

Area	Number of Posts
Mountain	2,132
Hill	2,756
Plain	9,594
H+P	18,705

Table 3. Number of posts in an area.

Left Image	Right Image	overlap (%)	B/H
681	670	11	1.35
681	671	15	1.28
681	672	24	1.15
681	673	33	1.02
681	674	42	0.88
681	675	50	0.76
681	676	58	0.64
681	677	67	0.49
681	678	76	0.37
681	679	84	0.24
681	680	93	0.10

Table 2. Stereo pairs adopted and their B/H ratio.

Eleven high overlap aerial photos are used for the study. Photos were taken in November 19, 1996 by Wild RC30. All photos are panchromatic and their scale is 1 to 40,000. Overlap ratio between the next photos is about 90%.

3 DEM CREATION

3.1 Aerial triangulation

At first, a photogrammetric scanner DSW200 of LH systems carries out internal triangulation and scanning. Pixel size of resulted images is 20µm. Then the images are imported to SOCET SET (Softcopy exploitation Tool Set) and Aerial triangulation is executed. 6 ground control points are employed. 2 of 6 points are shown on all of photos. Position of points is obtained by quick static GPS measurement method. Measurement interval is set to 30 minutes, Measurement period is 20 minutes and measurement unit is mm. 36 tie points are used. All tie points are manually determined.

Weighted least square bundle adjustment method is employed for triangulation method. By using this method, we can assume that all of photos have same triangulation error and leave the problem out of consideration. Horizontal position accuracy of ground control points, Vertical position accuracy of ground control points, and position accuracy of tie points is set to 1.0, 0.1, and 1000.0 respectively. Triangulation result is shown on Table 1. This result satisfies our requirement.

3.2 DEM creation from stereo pairs

DEMs are created from stereo pairs after aerial triangulation. Table 2 shows list of stereo pairs. 11 pairs are adopted and the B/H ratio ranges from 0.10 to 1.35. Parameters of DEM creation are not changed from default settings for all of pairs and terrain types. Elimination of trees and artificial objects are also not applied. Considering number and density of verification point, grid of DEMs is set to 10m square.

Table 3 shows number of points included in each terrain types. Each terrain type is independently defined by squares. Total area of hill parts and plain parts do not match with that of H+P parts. Plain part occupies larget area (1200m by 900m). Both hill part and mountain part occupies 500m by 500m.

3.3 Verification points

Real time kinematic (RTK) GPS measurement method are employed for accurate position acquisition of verification points. This method is a kind of carrier phase positioning measurement using DMCA radio for transmitting phase information from a base station to an observation site. Characteristic of this method is its high accuracy and real time processing of data. Accuracy of position measurement is 3 - 5cm.

In this study, data acquisition is executed by carrying an antenna with receiver and walking around study area. In mountain part, however, because of tall trees thickly covered with leaves, we can not receive GPS signals and radio waves. It results in lack of verification points in mountain part and accuracy assessment is carried out only in plain part and hill part.

Position data for 1025 points are gathered in total. After removal of redundant points, 524 points are accepted as verification points.

4 RESULTS

Figure 2 shows relationship between average correlation coefficient and the B/H ratio. In all terrain types, coefficient decreases as the B/H ratio increases. It means that stereo matching fails when view angle difference between the left image and the right image become larger as the B/H ratio increases. When the B/H ratio is the same, correlation coefficient become smaller as undulation of terrain increases. Especially, coefficient is quite small in mountain part whereas its value keeps more than 70% in plain part and hill part. This trend is remarkable at higher B/H ratio. It means that undulation have an influence on the DEM accuracy because undulation have a relationship with parallax. As parallax become bigger in highly undulated and high relative height area, matching successful rate falls down whereas this rate does not fall down on large scale in relatively flat area.

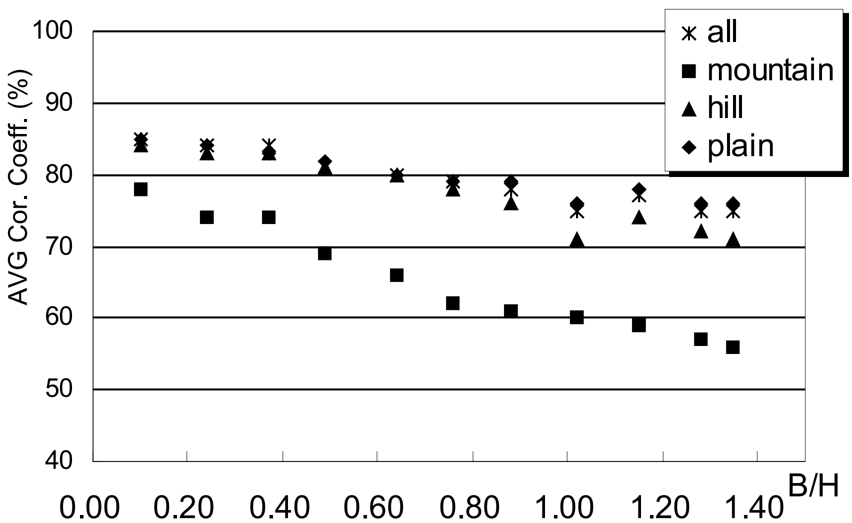

Figure 2. Average correlation coefficient of DEM creation. This rate decreases continuously as the B/H ratio increases at all terrain type.

Figure 3 shows relationship between height measurement accuracy and the B/H ratio. When the B/H ratio is lower than 0.5, accuracy continuously decreases as the B/H ratio decreases. According to photogrammetric theory, connection between height measurement accuracy δh and horizontal position matching accuracy δp can be described as follows;

$$\delta h = (H/B)\delta p$$

The result harmonize with the theory. When the B/H ratio is higher than 1.0, on the other hand, accuracy increases as the B/H ratio decreases. Curve of accuracy change at higher B/H ratio is smaller than that at lower B/H ratio. It means that height accuracy are primary determined by point matching accuracy but other facter such as matching success rate also have relationship with DEM accuracy.

Figure 4 shows relationship between height offset and the B/H ratio. Height offset is the difference of DEM height from height of check point. When the B/H ratio is 0.64, offset is smallest. When the B/H ratio is ranging from 0.5 to 0.9, offset is less than 0.5m although the connection between offset and the B/H ratio is not as clear as the connection between DEM accuracy and the B/H ratio. In all B/H ratio, offset of hill part is larger than that of plain part. It means that influence of terrain undulation can not be bypassed in case of DEM creation by automatic stereo matching method.

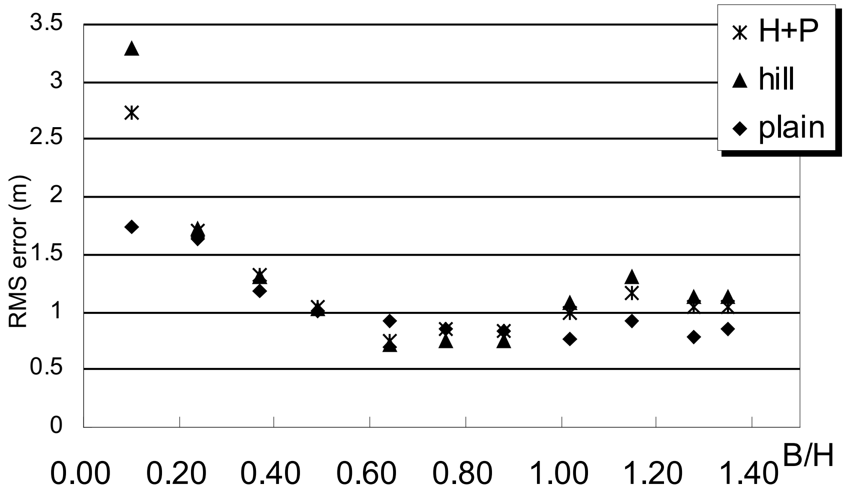

Figure 3. the B/H ratio and DEM accuracy.

5 CONCLUSION

We make the relationship between height accuracy and the B/H ratio plain in this study by comparing DEM created from high overlap aerial photos and verification points' height. When the B/H ratio is lower than 0.5, height accuracy decreases as the B/H ratio decreases. When the B/H ratio is higher than 1.0, on the other hand, the B/H ratio also decreases as the B/H ratio increases. As a result, the B/H ratio ranging from 0.5 to 0.9 is the best value for automatic DEM creation from stereo pair.

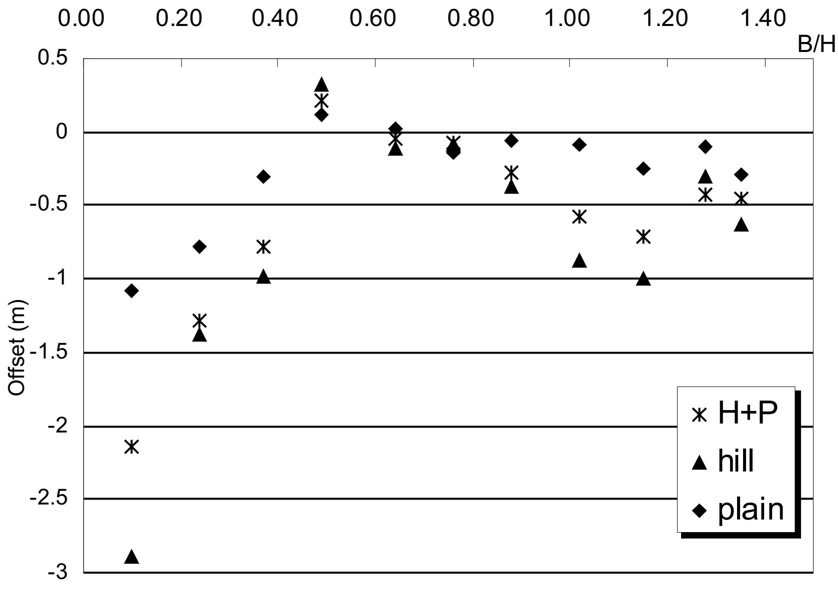

Figure 4. The relationship between height offset and the B/H ratio.

In the next stage of the study, we plan to assess height accuracy of DEM created by different methods and to determine the best B/H ratio for DEM generation from line scanner sensors.

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