Effect of planimetiric correction with a few GCPs on terrain height estimation with stereo pair

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Abstract

Effect of planimetric correction with a few GCPs on terrain height estimation with stereo pair has been confirmed. It is well known terrain height estimation accuracy depends on geometric fidelity, in particular, planimetric distortion. If a few GCPs with almost same terrain height are extracted from stereo pair, planimetric distortion can be corrected results in an improvement of terrain height estimation accuracy.

1. Introduction

In Digital Elevation Model(DEM) estimation with stereo pair, estimation accuracy depends on stereo matching accuracy. It is also obvious that stereo matching accuracy depends on planimetric fidelity of stereo pair. In order to confirm it, an attempt has been conducted with system corrected SPOT/HRV of stereo pair of imagery data.

In this study, it is assumed that a few GCPs(Ground Control Points) are available with not so accurate location accuracy and with almost same height. A method for improvement of stereo matching accuracy with such a few GCPs is proposed. Effects of the proposed method is evaluated in terms of DEM estimation accuracy and planimetric accuracy.

2. The proposed method

In general, DEM is estimated with stereo pair of chip images including the point of interest through stereo matching. Before that, a geometric correction, generally, is applied to the raw images such as system correction. The proposed method is to apply a simple planimetric correction such as Affine transformation with a few GCPs of not so accurate location accuracy and of almost same sea level before the stereo matching.

System corrected images have residual geometric distortion results in low planimetric fidelity. This implies poor stereo matching accuracy. If the planimetric fidelity is improved, then stereo matching accuracy will be improved results in increasing DEM estimation accuracy. In the planimetric correction, it can not be expected that a number of GCPs with high location accuracy is existing. Because if such a number of GCPs are available, it is expected that a high accurate large scale map is available so that it is also expected that a high accurate DEM can be estimated from such a map. Assuming such a large scale map is not available and also assuming that there is only a few GCPs with not so accurate location accuracy extracted from a small scale map, a method for improvement of planimetric fidelity is proposed.

In order to improve a planimetric fidelity, the following first order Affine transformation is assumed.

$$\begin{vmatrix} L' \\ P' \end{vmatrix} = \begin{vmatrix} Ol \\ Op \end{vmatrix} + \begin{vmatrix} \cos Q & -\sin Q \\ \sin Q & \cos Q \end{vmatrix} \begin{vmatrix} 1 & -\sin R \\ 0 & \cos R \end{vmatrix} \begin{vmatrix} 1 & 0 \\ 0 & Mi \end{vmatrix} Mc \begin{vmatrix} L \\ P \end{vmatrix} \quad (1)$$

where (L, P) and (L', P') are line and pixel coordinate of GCP in the planimetrically distorted system corrected image and planimetrically corrected image, Ol, Op are offsets in line and pixel directions, Mc, Mi are magnification and aspect ratios and Q, R denote skew and rotation, respectively. Ignoring the sencond order terms from equation (1), (L', P') is expressed as follows.

$$\begin{vmatrix} L' \\ P' \end{vmatrix} = \begin{vmatrix} Ol \\ Op \end{vmatrix} + Mc \begin{vmatrix} 1 & -Mi(Q+R) \\ Q & Mi \end{vmatrix} \begin{vmatrix} L \\ P \end{vmatrix} \quad (2)$$

$$= \begin{vmatrix} A11 & A12 \\ A21 & A22 \end{vmatrix} \begin{vmatrix} L \\ P \end{vmatrix} + \begin{vmatrix} B1 \\ B2 \end{vmatrix} \quad (3)$$

The coefficients of the above equation are determined with a few GCPs so that if a few GCPs with almost same height are available, then planimetric distortion will be removed through Affine transformation with the determined coefficients.

The aim of the proposed method is to improve DEM estimation accuracy through planimetric correction.

3. Experimental consideration with SPOT/HRV stereo pair

3.1 Data used

An experiment with the following SPOT/HRV stereo pair of images was conducted.

3.2 GCP location

The following three GCPs with almost same height (around 600 m above sea level) were extracted from topological map. A portion of SPOT/HRV image and topoglaphic locations of the GCPs are shown in figure 1. Study area is stuated in a montaintanuous region of Kiso-Komagatake in the middle of Honshu in Japan. Height in this area ranges from about 600 to 2500 m above sea level.

3.3 Planimetric correction

Based on the aforementioned Affine transformation with the coefficients derived from the GCPs, planimetric distortion was removed. Assuming the following relationship between line pixel coordinates for before and after the planimetric correction, (L,P) and (La,Pa), planimetric distortion was evaluated with the selected 9 GCPs for evaluation.

$$La=a1+a2L+a3P+a7L^2+a8LP+a9P^2 +a13L^3+a14L^2P+a15P^2 \quad (4)$$
$$Pa=a4+a5L+a6P+a10L^2+a11LP+a12P^2 +a16L^3+a17L^2P+a18LP^2$$

Table 2 shows the coefficients of the above equation for before and after the planimetric correction.

3.4 Cross correlation between image chips of stereo pair

It is expected that planimetrically corrected stereo pair shows a good cross correlation. Widely distributed 8 image chips consists of 32 x 32 pixels were extracted from the stereo pair of SPOT/HRV. Cross correlations between the image chips of the stereo pair are shown in figure 2. About 0 to 98% of cross correlation was increased after the planimetric correction.

3.5 DEM estimation accuracy

9 GCPs were used for evaluation of an effect of the planimetric correction. Table 3 shows DEM derived from topological map and estimated DEM with and without planimetric correction.

RMS error of estimated DEM for the proposed method was reduced by one 14th compared to without planimetric correction.

4. Concluding remarks

The proposed method is simple and effective for improvement of DEM estimation accuracy. Just before DEM estimation, Affine transformation with 6 coefficients derived from 3 GCPs with almost same hieght is applied to the stereo pair of images. In this case with SPOT/HRV, the experimental results show that planimetric fidelity is remarkably improved, cross correlation between image chips of stereo pair is

Table 1 Data used

Acquisition date	Pointing angle	GRS	Process level	Remarks
Dec.8'86	13.6deg.	327-278	1b	Kiso-Komagatake in
Dec.12'86	20.2deg.	327-278	1b	Japan

Table 2 A comparison of the coefficients of the Affine transformation for system corrected and planimetrically corrected SPOT/HRV data

	System corrected data	Planimetrically corrected data
a1	-2.16 E 6	6.45 E 5
a2	2.04 E 3	-5.31 E 2
a3	5.44 E 2	-2.26 E 2
a4	4.96 E 6	-4.29 E 5
a5	-4.64 E 3	3.01 E 2
a6	-1.26 E 3	1.96 E 2
a7	-6.51 E 1	1.48 E-1
a8	-3.11 E-1	1.16 E-1
a9	-6.11 E-2	3.10 E-2
a10	1.48 E 0	-5.77 E-2
a11	7.21 E-1	-1.09 E-1
a12	1.42 E-1	-2.32 E-2
a13	7.63 E-5	-1.70 E-5
a14	3.17 E-5	-7.59 E-6
a15	2.68 E-5	-1.36 E-5
a16	-1.73 E-4	3.89 E-6
a17	-7.33 E-5	9.85 E-6
a18	-6.22 E-5	1.03 E-5

increased results in improvement of matching accuracy and DEM estimation accuracy is improved by factor of 14.

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Table 3 An effect of the proposed planimetric correction on DEM estimation accuracy in terms of RMS error

GCP No.	DEM from Map(m)	Estimated DEM(m) Without Correction	With Correction
33	2030	1962	2280
34	2290	1742	2266
36	2200	1528	2210
38	2841	2556	2860
39	2734	2361	2719
40	2590	2312	2621
61	2240	1826	2237
62	2405	2050	2436
63	1730	1115	1726
RMS error		438.4	31.7

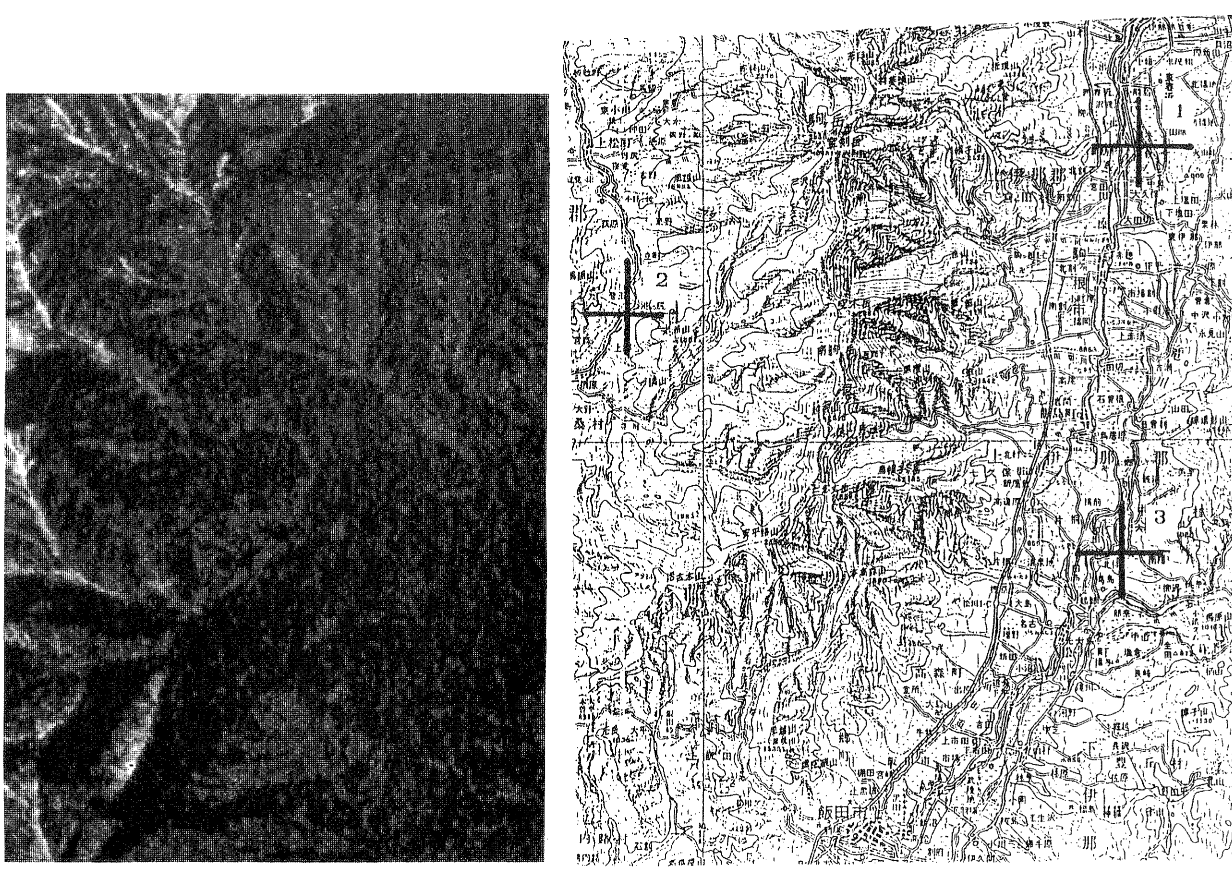
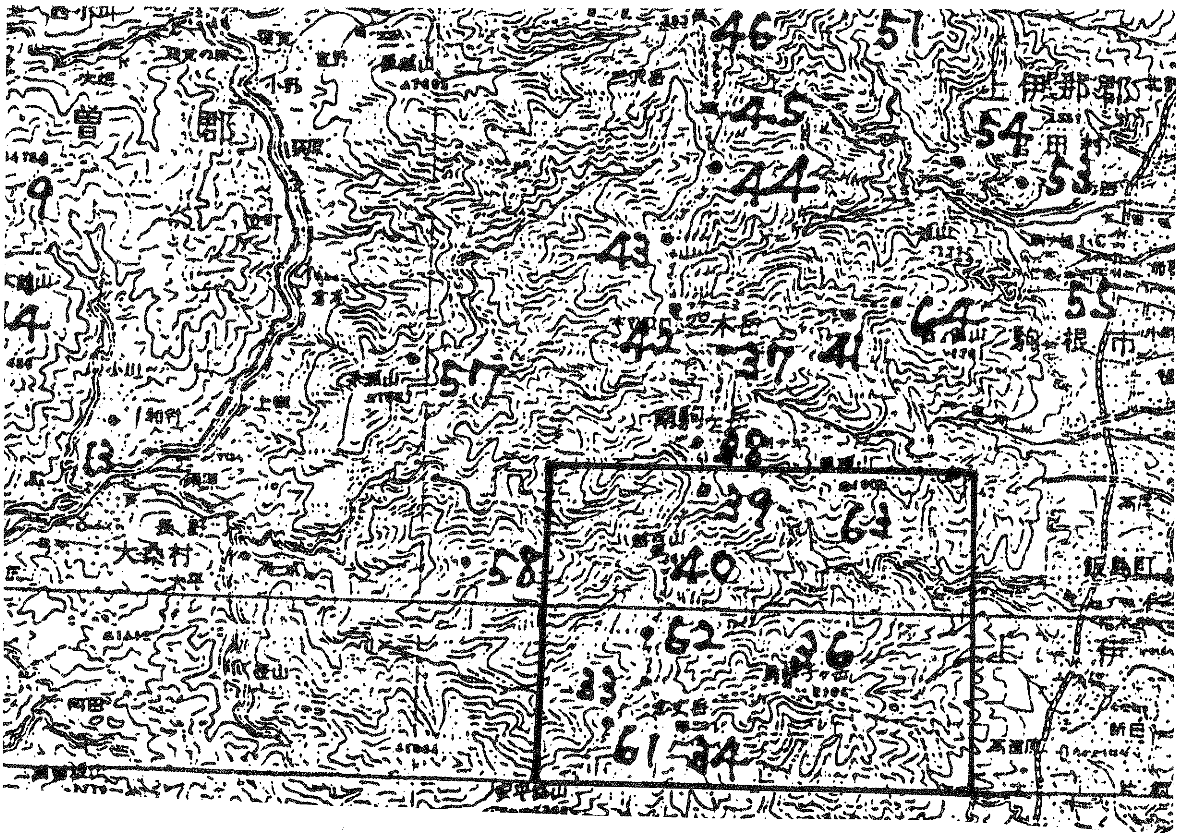


Fig.1 A portion of SPOT/HRV image and topoglaphic locations of the GCPs



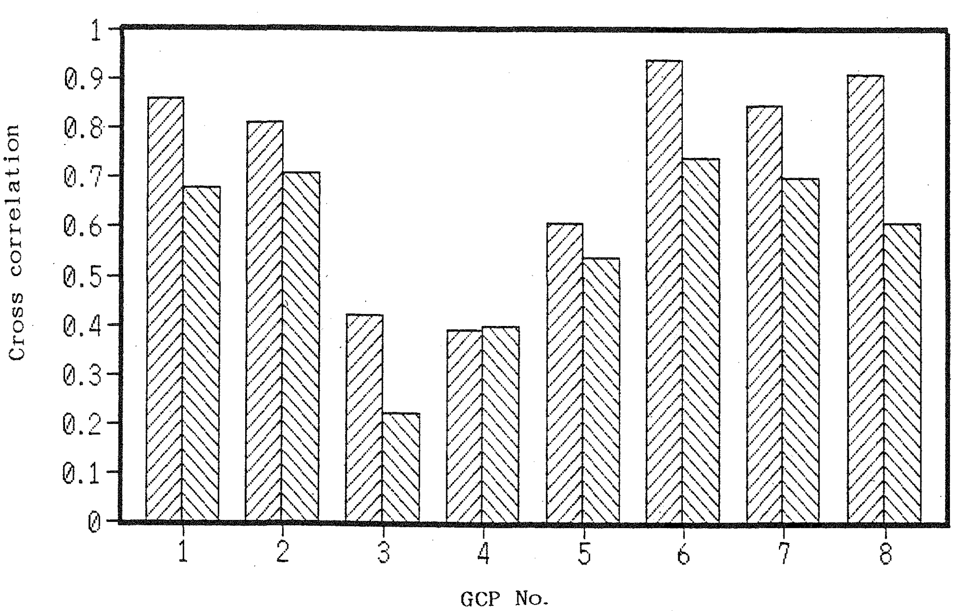


Fig. 2 Cross correlations between the image chips of the stereo pair