EVALUATION OF SPOT DATA FOR TOPOGRAPHIC MAPPING WITHOUT GCP

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ABSTRACT

Stereo triplet of Level 1A SPOT panchromatic CCT images were studied to compute three dimensional coordinates of the corresponding points on the earth surface using no ground control point. Only geometric data such as satellite position, velocity and look direction were used for the computation of the coordinates. It is found out that the absolute accuracy (mean) is more than several hundred meters but that the relative accuracy (standard deviation) is less than 10 meters in all X, Y and Z directions. This study shows the potential of SPOT data to produce relative topographic map in the areas where GCP is not available.

1. Introduction

Since SPOT stereo images were available, there have been many researches on cartographic application using SPOT images both by wholly digital method and by photogrammetric instruments. Under the tendency that most researches in both methods use GCP, this paper aims to study the potential of SPOT data for topographic mapping by digital method without GCP at the view point of accuracy.

2. SPOT images

The following stereo triplet images covered Mt. Fuji in Japan were used in this study. Fig.1 shows viewing angles and angles between vertical lines from three satellite positions.

	(1)	(2)	(3)
Spectral mode	: Panchromatic	Panchrimatic	Panchromatic
Sensor	: HRV2	HRV2	HRV1
Obsevation date	: March 7 '86	March 8 '86	March 17 '86
Viewing angle	: 4.3 degree East	23.8 degree West	15.4 degree East
Processing level	: 1A	1A	1A
Path-row	: 329-279	329-279	329-279

3. Check points

The corresponding points in the three images and topographic map with the scale of 1:2,500 were collected manually. 22 good corresponding points were selected for check points from the originally collected 63 points. Fig. 2 shows the locations of the check points in the image. Plane rectangular coordinates, elevation and image coordinates of the check points were read from the map and images.

4. Methodology

4.1 Computation of three dimensional coordinates of the check points

Basically, three dimensional coordinates of the check points are computed as the intersection of the viewing line which is defined by satellite position and viewing direction.

(1) Viewing line

The satellite position and viewing direction(look direction) of a specific pixel in a image in the geocentric coordinate system are derived from the image coordinates of the pixel and geometric data recorded in SPOT CCT by the flow shown in Fig. 3.

(2) Intersection

The intersection of two viewing lines in stereo pair is defined as the middle of the shortest line segment between the two viewing lines.

The intersection of three viewing lines in stereo triplet was defined by the following three methods in this study.

a) Mean method

b) Weighted mean mehod

c) Least square mehod

By the method a), intersection is defined as

$((X_1+X_2+X_3)/3 , (Y_1+Y_2+Y_3)/3 , (Z_1+Z_2+Z_3)/3)$

where $(X_i,Y_i,Z_i)(i=1,3)$ is the intersection of two viewing lines in three combinations of stereo pairs.

By the method b), intersection is defined as

$((W_1*X_1+W_2*X_2+W_3*X_3)/(W_1+W_2+W_3) , (W_1*Y_1+W_2*Y_2+W_3*Y_3)/(W_1+W_2+W_3) ,$
$(W_1*Z_1+W_2*Z_2+W_3*Z_3)/(W_1+W_2+W_3))$

where W_i $(i=1,3)$ are the weights which are equivalent to B/H ratios of three combinations of stereo pairs.

By the method c), intersection is defined as the point which has the least square value of three distances to the three viewing lines.

4.2 Use of collinearity equations

By using collinearity equations at the corresponding points, satellite positions and viewing directions are adjusted relatively and accuracy of intersection is expected to become better. There are many ways to assume unknown parameters which are included in satellite position and viewing direction. One can assume time-variant parameters. However we assume here very simple time-invariant parameters of (dX_i, dY_i, dZ_i) and (k_i, p_i, w_i) (i=1,3 : image No.) as follows.

(dX_i, dY_i, dZ_i) : parallel shift of satellite position

$X_i = X_{icct} + dX_i$
$Y_i = Y_{icct} + dY_i$
$Z_i = Z_{icct} + dZ_i$

(X_i, Y_i, Z_i) : relatively adjusted satellite position used for the computation of intersection

$(X_{icct}, Y_{icct}, Z_{icct})$: satellite position from SPOT CCT in the geocentric coodinate system

(k_i, p_i, w_i) : attitude angle in the local orbital coordinate system

Three cases (P1-P3) for stereo pair and three cases (T1-T3) for stereo triplet were considered as is shown in Table 1.

Table 1 Unknown parameters for relative adjustment

Case	Parameters																	
	1st image						2nd image						3rd image					
	dX_1	dY_1	dZ_1	k_1	p_1	w_1	dX_2	dY_2	dZ_2	k_2	p_2	w_2	dX_3	dY_3	dZ_3	k_3	p_3	w_3
P1	0	0	0	0	0	0	1	1	1	1	1	1	-	-	-	-	-	-
P2	0	0	0	0	0	0	1	1	1	0	0	0	-	-	-	-	-	-
P3	0	0	0	0	0	0	0	0	0	1	1	1	-	-	-	-	-	-
T1	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
T2	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1	0	0	0
T3	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	1	1	1

0 : Parameters are fixed and not considered for relative adjustment. The value of these parameters is zero.
1 : Unknown parameters for relative adjustment

P1-P3 : Cases for stereo pairs
T1-T3 : Cases for stereo triplet

5. Results

Computed intersections of the 22 check points in the geocentric coordinate system by various methods were transformed to the map coordinates and elevations and calculated location errors compared with the map coordinates from 1:2,500 topographic map. The horizontal errors in the map coordinate system were transformed to X_c(cross track direction : approximately east) and Y_a(along track direction

: approximately south) coordinates.

Table 2 shows absolute accuracy (mean) and relative accuracy (standard deviation) in the case of stereo pairs without using collinearity equations. Table 3 shows the one in the case of stereo triplet without usig collinearity equations.

Worse accuracies were obtained by the method using collinearity equations than the method not using collinearity equations.

6. Conclusions

(1) In the case of stereo pairs, fairly good relative accuracies were obtained. The relative accuracies in the X_c and Y_a directions are independent on B/H ratio, while the one in the Z_e direction is dependent on B/H ratio.

(2) In the case of stereo triplet, very good relative accuracies within 10 meters in all X_c, Y_a and Z_e directions were obtained by the least square method or the weighted mean method.

(3) Though the method using collinearity equations would be considered to have a possibility to improve relative accuracy, worse relative accuracies were obtained.

(4) The relative accuracies obtained by stereo triplet shows the potential of SPOT data to produce relative topographic map in the area where GCP in not available.

Reference

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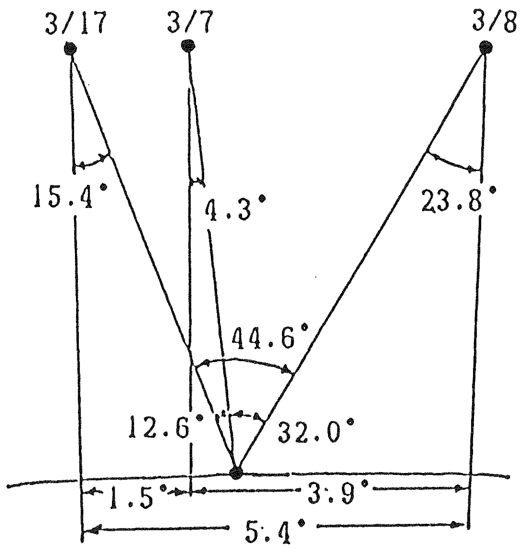

Fig. 1 Viewing angles of stereo triplet images

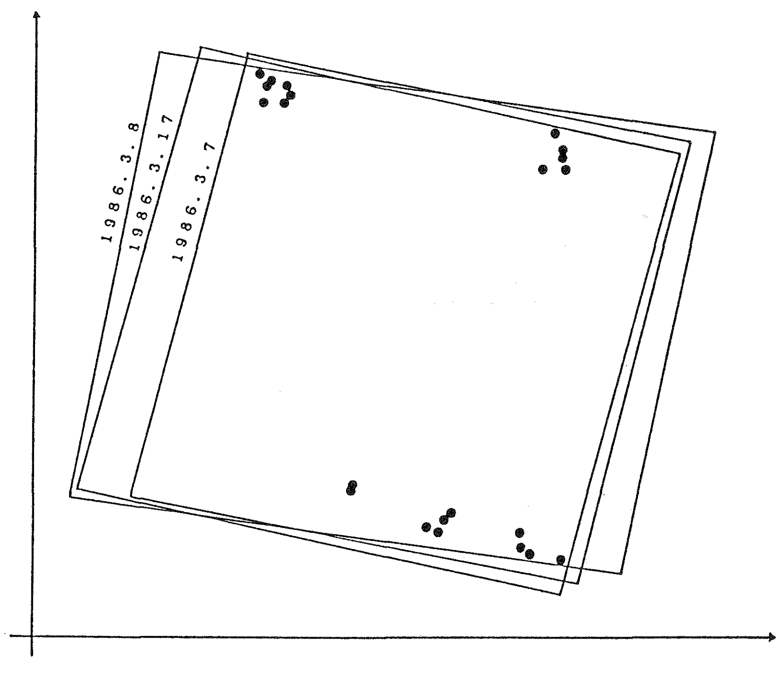

Fig. 2 Locations of check points

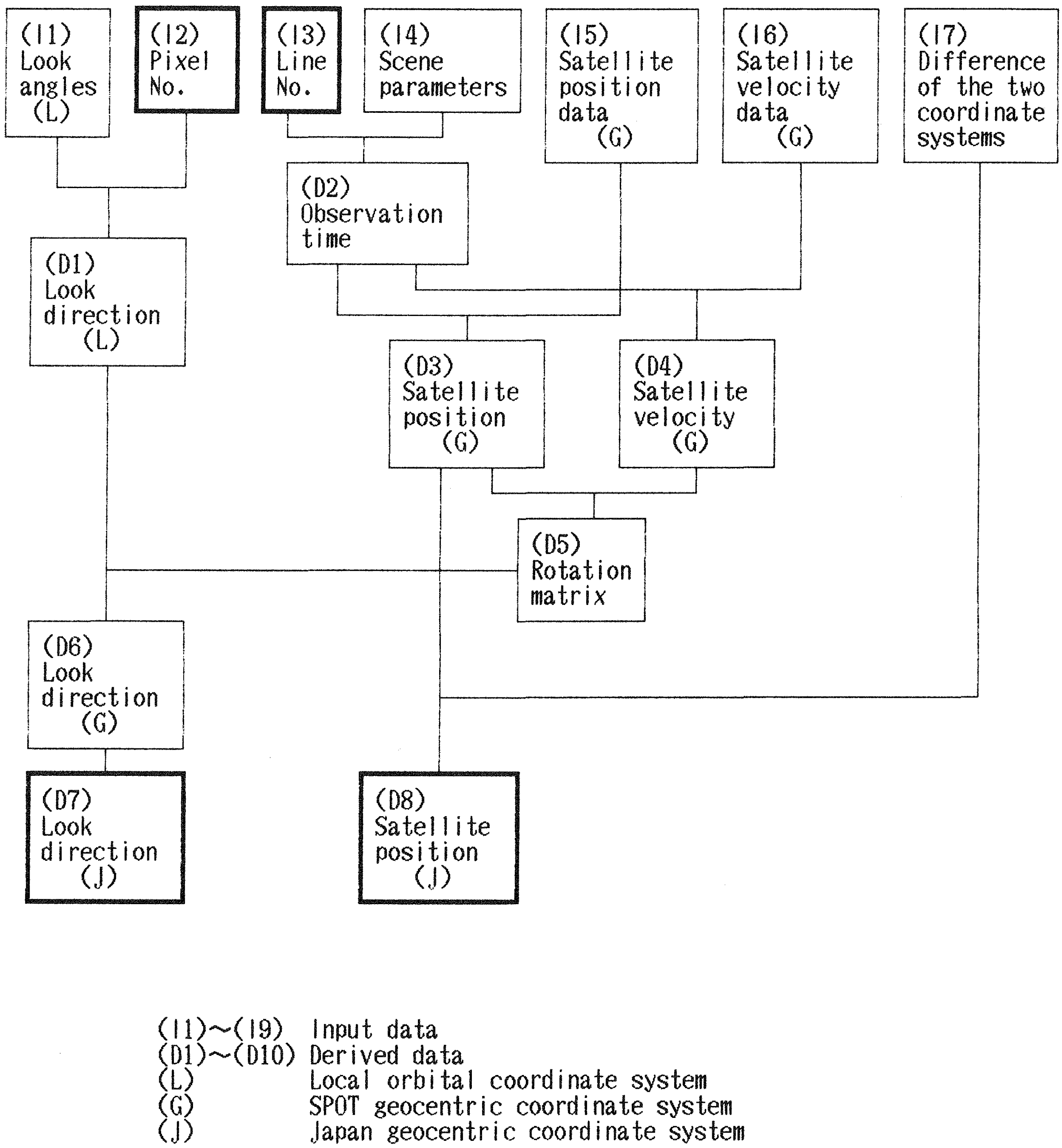

Fig. 3 Flow of computing satellite position and viewing direction

Table 2 Absolute and relative accuracy in the case of stereo pairs

Viewing angles (degree)	B/H ratio	Absolute accuracy / Relative accuracy (mean) (standard deviation)		
		X_c(east)	Y_a(south)	Z_e(elevation)
+23.8, -15.4	0.7	-653 / 11.1	-26 / 7.0	-1217 / 7.4
+23.8, -4.3	0.5	-587 / 10.2	-102 / 9.3	-1368 / 13.1
-4.3, -15.4	0.2	-836 / 10.1	-179 / 9.5	-829 / 38.0

unit : meter

Table 3 Absolute and relative accuracy in the caseof stereo triplet

Viewing angles (degree)	Method	Absolute accuracy / Relative accuracy (mean) (standard deviation)		
		X_c(east)	Y_a(south)	Z_e(elevation)
+23.8, -4.3 and -15.4	a)	-693 / 8.8	-100 / 6.4	-1138 / 12.0
	b)	-656 / 9.7	-77 / 6.2	-1216 / 7.6
	c)	-719 / 8.9	-112 / 6.2	-1225 / 8.4

unit : meter

a) : Mean method
b) : Weighted mean method
c) : Least square method