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HEIGHTING ACCURACY OF SPOT IMAGERY

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ABSTRACT

The SPOT imaging system is the first sensor with stereoscopic capability and global continuous coverage. Stereopairs with overlap and base to height ratio suitable for the extraction of height information with reasonable accuracy can be obtained.

This paper summarises the results of an investigation carried out to determine the accuracy of heights derived from SPOT stereoscopic data and to assess the potential of contouring and digital terrain modelling. A stereopair, covers an area in the South West of Sinai was used to form a stereoscopic model, on the WILD-BC-2 analytical plotter. Ground control points were derived from 1:50000 topographic maps. A digital elevation model with one-kilometer spacing in the two directions and 1:100,000 scale topographic map with 20 m contour interval were produced on the BC-2. Root mean square errors in heights were computed and found to be ± 11.5 m and ± 9.4m before and after applying filtering respectively.

INTRODUCTION

The French SPOT satellite was launched in February 1986, and since then it continues to provide data for users around the world.

SPOT is a push-broom sensor system, moves in a circular synchronous orbit with altitutde of about 832 km and repeats its coverage every 26 days. The system payload includes two identical optical instruments, the HRV1 and HRV2 (High Visible Resolution).

It produces images in two modes:

(1) Panchromatic mode (P), with a single spectral band ranging from 0.51 μm to 0.73 μm, and an Instantaneous Field of View (IFOV) of 10m and

(2) Multispectral mode (XS), with three spectral bands (band − 1 : 0.50 μm to 0.59 μm, band − 2 : 0.61 μm to 0.69 μm, and band − 3 : 0.79 μm to 0.89 μm) and an IFOV of 20 m.

For each spectral band, the radiance from the ground surface picked up by the optical system is measured by an array of charge coupled detectors (CCD), (6000 for the "P" mode and 3000 for the "XS" mode), which forms rows of the image perpendicular to the Satellite track.

The acquisition of the image in the column direction (parallel to the Satellite track) is achieved by movement of the Satellite in its orbit as indicated in Figure (1), (Rodriguez 1988). Each scene covers a surface area of 60 km by 60 km.

A mirror situated in front of the HRV instrument allows modification of the look direction, making an across-track angle with the vertical that can reach ± 27°.

Thus, it is possible to record images of the same portion of ground at different look angles (including oblique viewing) from different orbits in order to record a pair of stereoscopis images, Figure (2), (Rodriguez, 1988).

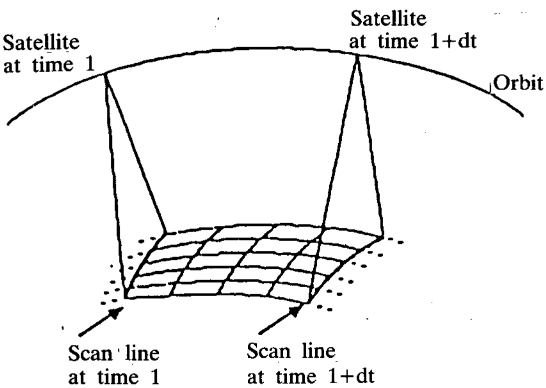

Fig. 1: Acquisition of a SPOT scene

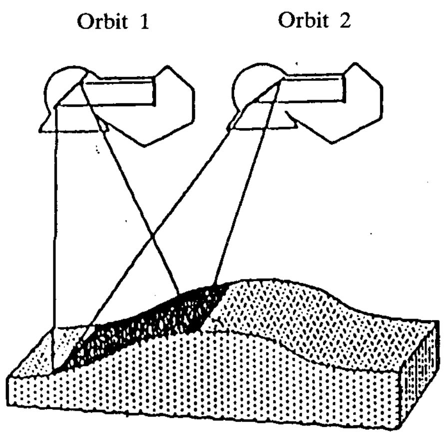

Fig. 2: Stereopair of a SPOT scene

after Rodriguez (1988)

The classical photogrammetric base-height ratio (B/H) can be defined in that case, as the ratio of the distance between the two orbits to the altitude of the satellite and is a function of the mirror tilt angles during the collection of both scenes, (B/H = 1 for + 27^0/ − 27^0, 0.50 for + 13^0/ − 13^0, and 0.5 for 0/ + 27^0) (Rodriguez, 1988).

The aim of this paper is to describe research works carried out to test the accuracy of height information obtained from SPOT stereoscopic data and to assess the possibility of topographic mapping by utilizing that data.

DATA AND OBSERVATION

Spot Images

A stereopair from the SPOT Satellite covers the area of South West Sinai (Scene No. 116291), Figure (3), was used in this investigation. The two images forming the stereoscopic pair were collected by the HRV2 Sensor and one of them was acquired on the 4th of July 1987 while the second was acquired on the 18th of July 1987. The approximate scale of the two images is 1:400,000 and the overlap between them is about 83%. The two images were collected in the panochromatic (P) mode with IFOV of 10m. Geographic co-ordinates of the center points of the two images are 29^0 28′ N and 33^0 E for the left one and 29^0 28′ N and 33^0 21′ E for the right one.

Fig. 3: The right-side image of the SPOT stereomodel used

Base to height ratio (B/H) is 1.00, and the two images have been supplied in prints and diapositives with an approximate format size of 180 mm x 180 mm as measured between the four corner marks.

Map Information

Ground control points were derived from the Egyptian Military Survey 1:50,000 scale topographic maps with 10 m contour interval. Planimetric co-ordinates of 20 ground control points were digitized on the WILD-AT-2 Plotting table. Heights of the ground control points were interpolated from the contour lines and from the spot heights appeared on the maps. Most of the ground control points are triangulation points fixed on the tops of the mountains in the area which can be identified on both the maps and the SPOT images. It is estimated that the measurement accuracy of the ground co-ordinates derived from the 1:50,000 maps is about ± 5 m for both planimetric and height co-ordinates.

Ground co-ordinates of the check points are derived with the same procedure.

STEREO-MODEL FORMATION

The two SPOT images forming the stereo-pair were manipulated on the WILD-BC-2 analytical plotter.

The procedure for the stereo-model formation was carried out as follows:

(1) Place the two diapositives on the plate carriers of the BC-2.

(2) Perform inner orientation, where the co-ordinates of the four corner marks on each image are measured and stored on the computer.

(3) Exterior orientation, in one step orientation mode, where relative and absolute orientations are performed in one step. This, normally, achieved on the BC-2 by measuring image co-ordinates of certain points, including the ground control points, in the left and in the right image simultaneously and then by applying the collinearity equations for each image individually, the six exterior orientation parameters for each image is determined. Ground co-ordinates for any point in the formed stereoscopic model, then, can be determined by applying space intersection from the two, relatively oriented, images into the ground space.

FORMATION OF A DIGITAL ELEVATION MODEL (DEM)

Ground co-ordinates of points in the stereoscopic model formed on the BC-2 are measured in a grid mode with spacing of one-kilometer in the two directions forming a digital elevation model.

Contour lines, then, been interpolated using a Contour Interpolation Program (CIP) available within the software package of the BC-2.

The contour interval is 20.00 m and the interpolated contour map plotted with scale of 1:100,000. Figure (4).

WADI GHARANDAL
(WEST SINAI)

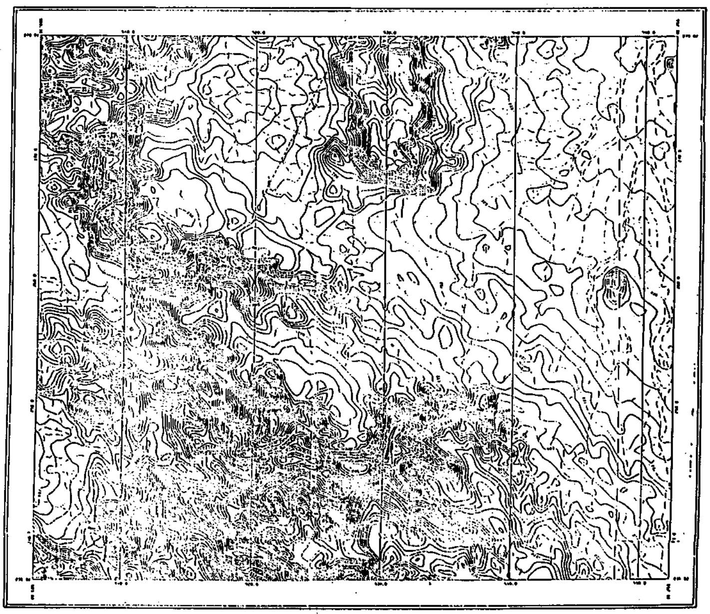

Fig. 4: Topographic map produced from SPOT stereomodel (original scale 1:100,000, reduced for printing)

TESTING THE ACCURACY OF HEIGHTS

To test the accuracy of heights derived from the formed SPOT stereomodel, heights of 66 checkpoints, identified on the 1:50,000 topograhic maps were measured on both the 1:50,000 map and the SPOT stereomodel.

Differences (residuals) between map derived and SPOT derived heights were computed, table (1).

Root mean square value of these residuals was also determined.

A filtering technique, which depends on minimizing the third difference, the sum of the squares of the third differences and on minimizing the sum of the squares of the residuals themselves was used.

Root mean square values of the residuals in the 66 checkpoints are ± 14.68 m and ± 10.99 m before and after filtering respectively, Table (2).

By removing 10 checkpoints with apparent gross heights errors, RMS values of residuals in the remaining 56 checkpoints are ± 11.99 m for raw data and ± 9.43 m after filtering, Table (3).

Table 1

Heights of the Check Points and Their Residuals in Meters

Point No.	H1 Spot	H2 Map	"D"=H1−H2
1.	754.629	750.0	+ 4.629
2.	819.369	800.0	+ 19.369
3.	423.159	420.0	+ 3.159
4.	547.479	520.0	+ 27.479
5.	340.029	325.0	+ 15.029
6.	297.669	297.0	+ 0.669
7.	291.069	285.0	+ 6.069
8.	278.949	265.0	+ 13.949
9.	259.269	250.0	+ 9.269
10.	272.259	240.0	+ 32.259
11.	259.269	240.0	+ 19.269
12.	255.669	238.0	+ 17.669
13.	248.769	230.0	+ 18.769
14.	242.349	230.0	+ 12.349
15.	778.389	765.0	+ 13.389
16.	898.929	880.0	+ 18.929
17.	959.259	917.0	+ 42.259
18.	940.539	917.0	+ 23.539
19.	904.779	904.0	+ 0.779
20.	847.869	870.0	− 22.131
21.	857.889	830.0	+ 27.889
22.	812.859	820.0	− 7.141
23.	369.609	370.0	− 0.391
24.	555.759	520.0	+ 35.759
25.	379.209	375.0	+ 4.209
26.	356.169	350.0	+ 6.169
27.	443.649	430.0	+ 13.649

Table 1 (Cont'd.)

Point No.	H1 Spot	H2 Map	"D"=H1−H2
28.	615.789	600.0	+ 15.789
29.	628.21	615.0	+ 13.21
30.	646.089	631.0	+ 15.089
31.	697.839	687.0	+ 10.839
32.	785.889	780.0	+ 5.889
33.	849.909	827.0	+ 22.909
34.	821.649	820.0	+ 1.649
35.	820.419	813.0	+ 7.419
36.	698.441	690.0	+ 8.441
37.	626.531	640.0	− 13.469
38.	622.361	631.0	+ 8.639
39.	623.471	615.0	+ 8.471
40.	625.961	620.0	+ 5.961
41.	634.721	625.0	+ 9.721
42.	645.221	630.0	+ 15.221
43.	650.861	649.0	+ 1.861
44.	665.051	659.0	+ 6.051
45.	679.481	672.0	+ 7.481
46.	766.121	745.0	+ 21.121
47.	776.501	775.0	+ 1.501
48.	820.691	820.0	+ 0.691
49.	826.901	810.0	+ 16.901
50.	805.391	794.0	+ 11.391
51.	790.271	775.0	+ 15.271
52.	768.671	764.0	+ 4.671
53.	777.221	763.0	+ 14.221
54.	768.941	755.0	+ 13.941
55.	747.851	740.0	+ 7.851
56.	726.371	720.0	+ 6.371
57.	702.641	690.0	+ 12.641
58.	680.231	680.0	+ 0.231
59.	658.631	662.0	− 3.369
60.	649.601	653.0	− 3.399
61.	637.871	626.0	+ 11.871
62.	621.671	620.0	+ 1.671
63.	618.101	608.0	+ 10.101
64.	614.351	606.0	+ 8.351
65.	806.611	603.0	+ 3.611
66.	812.041	612.0	+ 0.041

Table 2
Residuals and RMSE in Heights of the 66-Check Points Before and After Filtering (Smoothing)

Raw Data	Smoothed Data
4.629	10.172
19.369	11.298
3.259	11.836
27.159	12.012
15.029	11.957
.669	12.026
6.069	12.567
13.949	13.678
9.269	15.211
32.259	16.867
19.269	18.297
17.669	19.351
18.769	19.986
12.349	20.156
13.389	19.781
18.929	18.670
42.259	16.640
23.539	13.794
.779	10.707
−22.131	8.185
27.889	6.788
− 7.141	6.571
− .391	7.378
35.759	8.811
4.209	10.378
6.169	11.852
13.659	13.072
15.789	13.868
13.21	14.107
15.089	13.732
10.839	12.721
5.889	11.134
22.909	9.062
1.649	6.677
7.419	4.333
8.441	2.417
−13.469	1.330
− 8.639	1.315
8.471	2.267
5.961	3.781
9.721	5.417
15.221	6.822
1.861	7.860

Table 2 (Cont'd.)

Raw Data	Smoothed Data
6.051	8.589
7.481	9.076
21.121	9.417
1.501	9.720
.691	10.115
16.901	10.639
11.391	11.129
15.271	11.409
4.671	11.356
14.221	10.901
13.941	9.987
7.851	8.668
6.371	7.117
12.641	5.575
.231	4.315
− 3.369	3.608
− 3.399	3.555
11.871	4.013
1.671	4.639
10.101	5.079
8.351	5.025
3.611	4.297
.041	2.836
(RMS1)	(RMS2)
14.679	10.995

Table 3
Residuals and RMSE in Heights of the 56-Check Points Before and After Filtering (Smoothing)

Raw Data	Smoothed Data
4.629	8.737
19.369	8.546
3.159	9.180
.669	10.012
6.069	11.081
13.949	12.363
9.269	13.468
19.269	14.255
17.669	14.469
18.769	13.913
12.349	12.610
13.389	10.777
18.929	8.803
.779	6.984

Table 3 (Cont'd.)

Raw Data	Smoothed Data
− 7.141	5.808
− .391	5.555
4.209	6.115
6.169	7.394
13.649	9.082
15.789	10.662
13.21	11.793
15.089	12.356
10.839	11.989
5.889	10.971
22.909	9.353
1.649	7.265
7.419	5.235
8.441	3.637
−13.469	2.448
− 8.639	2.188
8.471	2.691
5.961	3.573
9.721	4.860
15.221	6.184
1.861	7.335
6.051	8.209
7.481	8.992
21.121	9.630
1.501	10.154
.691	10.676
16.901	11.162
11.391	11.478
15.271	11.599
4.671	11.441
14.221	10.850
13.941	9.914
7.851	8.491
6.371	6.939
12.641	5.329
.231	3.966
− 3.369	3.031
− 3.399	2.920
11.871	3.577
1.671	5.174
10.101	7.720
(RMS1)	(RMS2)
11.400	9.133

DISCUSSION AND CONCLUSIONS

The software used to handle the SPOT images on the BC-2 is normally used for processing of conventional aerial photographs with perspective geometry. To handle images with line scanner geometry, such as the SPOT image the available software has to be modified to take into account these geometrical differences.

Results obtained, however, prove that SPOT stereoscopic data can be used for topographic mapping up to a scale of 1:100,000 by utilizing conventional and analytical plotters without software modification.

By applying a modified collinearity equations program, heights accuracy of SPOT stereoscopic data may satisfy geometrical requirements of topographic mapping up to a scale of 1:50,000.

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