

ASSESSMENT OF SPOT 5 IMAGE POSITIONING ACCURACY WITH SPARE GCPs

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ABSTRACT:

SPOT 5 satellite was launched on May, 4th, 2002. It has some new distinguished characteristics, for example that its ephemeris and attitudes on orbit can be accurately measured, recorded and distributed within DIMAP format which is a newly designed format for SPOT 5 imagery. DIMAP's metadata, usually named Metadata.dim, contains plenty of detailed information of imagery acquisition, satellite ephemeris and attitudes, view directions of each CCD and line sample intervals, etc. All of those data make it reach reality to perform image positioning with few GCPs and rigorous satellite physical model.

Based on the built rigorous satellite physical model by authors, they carried out image positioning experiments and accuracy assessment with one scene of SPOT HRG image and two scenes of SPOT HRS image, in order to determine the suitability of the built model to few GCPs and the accuracy that SPOT 5 image positioning can achieve.

The content in the paper includes two experiments, one is SPOT 5 image positioning accuracy assessment, whose aim is to test SPOT 5 image positioning accuracy basing on the built model, another one is model suitability test whose aim is to test the ability of the model under diverse GCPs and different coordinate systems. Finally some important conclusions are drawn.

1. INTRODUCTION

Image rectification with few GCPs(Ground Control Points) has been one of the utmost targets and research hotspots that is pursued by all scientists in surveying and mapping field. Although lots of research work has been done to prompt the advancement to the target, the throughout has failed until now. The launching of SPOT 5 satellite brought an opportunity to reach the technology of image rectification with sparse GCPs. SPOT 5 satellite was launched on May 4, 2002. Its distinguished character is that it can precisely measure satellite's ephemeris and attitudes and distribute to users in DIMAP format file with imagery. The details with DIMAP about imagery and satellite, such as ephemeris, attitude values and velocities, viewing angles of each CCD and time interval of each line, etc., make it possible for SPOT5 image rectification to be performed with sparse GCPs.

Based on the rigorous model established by ourselves, the authors performed image positioning and planimetric accuracy assessment of one scene of SPOT 5 HRG image and one stereo-pair of SPOT HRS images with sparse GCPs and within different coordinate systems(CS). The capability of the model to fit sparse GCPs and different CS was verified. At meanwhile some important conclusions have been drawn through the experiments of image positioning and accuracy assessment.

The experiments include:

(1) image positioning and accuracy assessment: using the model established by authors to rectify one scene of SPOT HRG image of Mianyang, Sichuan province and one stereo-pair SPOT HRS images of Baoji, Shaanxi province in order to analysis the accuracy of image positioning.

(2) assessment of suitability of the model: analysis and verify the suitability of the model to sparse GCPs and different coordinate systems through image positioning with various

GCPs and within different coordinate systems in order to demonstrate SPOT 5 imagery's usage under sparse GCPs.

2. TEST DATA

2.1 Dataset of Mianyang, Sichuan province

(1)The image is the first scene of HRG image in China after SPOT 5 satellite was launched, which was acquired in Oct., 2002 and whose resolution is 2.5 meter, scope is 60×60km².

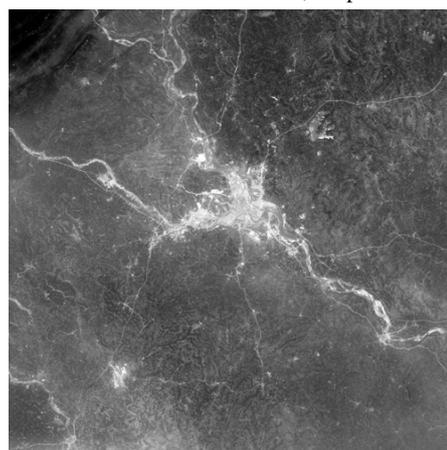


Fig. 1 SPOT HRG image of Mianyang

(2)99 GCPs, which were measured with GPS and got the accuracy 0.5 m in planimetry, 0.25m in elevation.

(3)Paper airophotos with illustrating points



Fig 2 Paper airophoto

2.2 Dataset of Baoji, Shaanxi province

(1) One stereo-pair of HRS images, which were acquired on Sep. 23, 2003, with 10 meter resolution and scope of 60×60km².

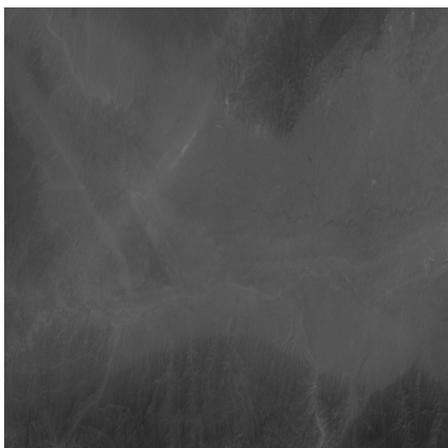
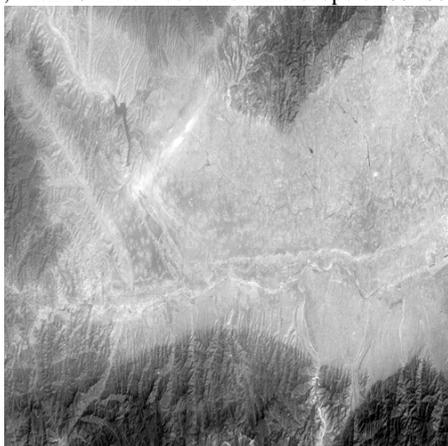


Fig. 3 SPOT5 HRS stereo-pair

(2) 384 sheets of 1:10,000 scale maps

3. ANALYSIS PROCEDURE

3.1 Measurement of GCPs and Check Points

(1) Mianyang, Sichuan Province

Selecting 2-6 points as GCPs and all the points as check points. According to the airophoto, measuring their image coordinates

(2) Baoji, Shaanxi province

According to 1:10000 scale maps, selecting 43 points and measuring their ground coordinates and image coordinates. Selecting 2-6 points as GCPs and all the points as check points.

3.2 Analysis of Image positioning accuracy

The rigorous physical model, which is flexible for different CSs. has been established by authors. Then the image points' ground coordinates can be computed according to the model. Comparing the computed coordinates with real ground coordinates, the image positioning errors can be got as following tables.

① Image positioning results of SPOT HRG image of Mianyang within Xi'an-80 CS and Orbital CS.

Table 1 image positioning errors

CS	RMS	meter	pixel
Xi'an-80	X	4.15	1.66
	Y	5.73	2.29
	Xmax	12.54	5.02
	Ymax	14.15	5.66
	XY	7.07	2.83
Orbit	X	3.55	1.42
	Y	5.75	2.30
	Xmax	10.17	4.07
	Ymax	16.80	6.72
	XY	6.78	2.71

Analyzing the errors can get the distribution of image positioning errors in pixel.

Tbale 2 statistic of image positioning errors

Error(pixel)	number	percent (%)
0-1	14	14.141
1-2	30	30.303
2-3	24	24.242
3-4	19	19.192
4-5	7	7.071
5-6	2	2.020
6-7	1	1.010
7-8	2	2.020
Total	99	100.00

From the error distribution, we can see 44 points (44.44%) with error of 0-2 pixels, 43 points(43.43%) with error of 2-4 pixels and 12 points (12.12%) with more than 4 pixel errors. It was found that the 12 points have difficulties to identify because they all locates in the intercross of roads.

② Experiments of SPOT HRS image positioning of Baoji, Shaanxi province in Beijing-54 CS

Table 3 Experiment results of SPOT HRS 281 stereo-pair image positioning

281-2			281-1		
error (pixel)	num.	%	error (pixel)	num	%
0-1	6	13.953	0-1	12	27.907
1-2	14	32.558	1-2	9	20.930
2-3	10	23.256	2-3	9	20.930
3-4	4	9.302	3-4	7	16.279
4-5	5	11.628	4-5	2	4.651
5-6	4	9.302	5-6	2	4.651
Total	43	100.00	6-7	2	4.651

From the experiment results of 3 scenes of image, the distribution of image positioning errors can be got as following.

Table 4 statistic of image positioning errors of 3 scenes

error image	error		
	0-3pixel (%)	3-4pixel (%)	>4pixel (%)
Mianyang	68.686	19.192	12.121
Baoji281-2	69.767	9.302	20.930
Baoji281-1	69.767	16.279	13.953
Ave.(%)	69.407	14.924	15.671

The statistic data show that 70% points have errors of 0-3 pixels while 84% points' errors are within 4 pixels. Although the average error is about 7 meter for HRG images, there is still large errors caused by manually selecting points which give great affect on image positioning accuracy.

3.3 Analysis of the suitability of the model

The analysis of the model's suitability is to verify whether the model meets two requirements, sparse GCPs and different CS. The GCPs can be 2 at minimum and 6 at maximum. The CS can be of Beijing-54, Xi'an-80 or WGS 84. The model can directly perform the image positioning within different CSs to overcome the difficulties of extra CS transformation.

The experiments were carried out within Xi'an-80 CS and WGS 84 CS separately using HRG image of Mianyang. 2-6 GCPs were selected to input into the model. The results are as following.

Table. 5 Results of image positioning with different GCPs

CS	RMS (m)	num. of GCPs			ave. RMS
		6	4	2	
Xi'an-80	RMS of GCPs	2.45	2.15	1.02	1.87
	X	4.15	3.94	4.30	4.13
	Y	5.73	5.61	5.64	5.66
	Xmax	12.51	13.43	13.76	13.23
	Ymax	14.15	15.16	14.63	14.65
	RMS	7.07	6.85	7.09	6.96
WGS84	RMS of GCPs	1.96	1.94	0.95	1.62
	X	5.08	4.90	5.01	4.97
	Y	1.88	1.92	1.89	1.90
	Xmax	16.47	15.95	16.21	16.21
	Ymax	4.72	6.59	5.18	5.50
	RMS	6.39	6.25	6.41	6.35

The results shown in the above table prove that the model only use 2-6 GCPs to get the planimetric accuracy of 3 pixels of image positioning. And the accuracy doesn't be affected by the GCPs number. Further more the model has well suitability to different CSs, which is demonstrated by the similar results in Xi'an-80 CS and WGS 84 CS.

4. CONCLUSION

From the experiments, some conclusions can be drawn as following:

(1) Under the situation of manually selecting GCPs on image, the planimetric positioning accuracy is about 2.8 pixel in RMS at 70%, which means 7 meter for HRG image, and about 4 pixel at 85%.

(2) The model established by authors can use the detailed information in the Dimap document of the image to carry out image positioning with sparse GCPs and within different CSs directly rather than with CS transformation. The needed GCPs is 6 at maximum and only 2 at minimum. For large scale production, 4 GCPs are proposed and locate evenly in whole image.

(3) Manually selecting points in image often brings large errors to image positioning. If the points measurement is improved, the accuracy of the image positioning can be enhanced. So stereo-match measurement of points instead of mono-match measurement is recommended.

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