Block Adjustment and Orthorectification for Multi-Orbit Satellite Images

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Abstract: The objective of this investigation is to establish a simple yet effective block adjustment procedure for the orthorectification of multi-orbit satellite images. The major works of the proposed scheme are: (1) adjustment of satellite's orbit accurately, (2) calculation of the error vectors for each tie point using digital terrain model and ray tracing technique, (3) refining the orbit using the Least Squares Filtering technique and (4) generation of the orthophotos. In the process of least squares filtering, we use the residual vectors on ground control points and tie points to collocate the orbit. In orthorectification, we use the indirect method to generate the orthoimage. Test areas cover northern Taiwan. Test images are from SPOT 5 satellite. Experimental results indicate that proposed method improves the relative accuracy significantly.

Keywords: Orbit Adjustment, Least Square Filtering, Tie Points, Orthoimage

1. Introduction

Satellite images need geometric corrections for combining with other spatial data. In various applications, areas of interest sometimes cover two or more satellite images, thus mosaicking for those images becomes important. Orthoimages are frequently used in the mosaicking process. While orbit adjustment is a prerequisite in the image orthorectification. Scene-based orbit adjustment could yield geometric discrepancies between images. That could cause image discontinuity along the seam line during mosaicking. Thus, block adjustment is preferable.

A traditional block adjustment is performed in three dimensions. The base-to-height ratio of multi-orbit satellite images is, frequently, not large enough. Hence, those tie points need elevation control in the block adjustment procedure. In this investigation, we use GCPs (Ground Control Points), tie points, and DTM (Digital Terrain Modal) to adjust satellite's orbit using the Least Squares Filtering technique [3]. This process can reduce geometric discrepancies between images acquired from different orbits.

2. Methodology

The proposed method of block adjustment comprises two major parts. The first part is to adjust satellite's orbit by using the GCPs. The second one is to refine the orbit using the least squares filtering with GCPs and tie points.

1) Least Squares Adjustment

Because the on-board data include errors to a certain degree, GCPs are needed to adjust the orbit parameters. The observation vector provided by the satellite will not pass through the corresponding GCP due to errors in the on-board data. Thus, correction of the orbit data may be performed least squares adjustment [1].

2) The Residual Vectors for Each Tie Point

In the process of least squares filtering, we use the residual vectors on GCPs and tie points to collocate the orbit. So we need to calculate the residual vectors for tie points. First we use the orbit parameters and the image coordinates of a tie point to calculate the observation vector. Given a DTM, the ray tracing technique is applied to determine the ground position of a tie point. The procedure is repeated for its counterpart in the other image. Referring to Fig. 1, a pair of tie point has two ground corresponding points. The middle of two ground points would be used as a constraint. The residual vector on each tie point is the vector from one ground position to the middle of the two points.

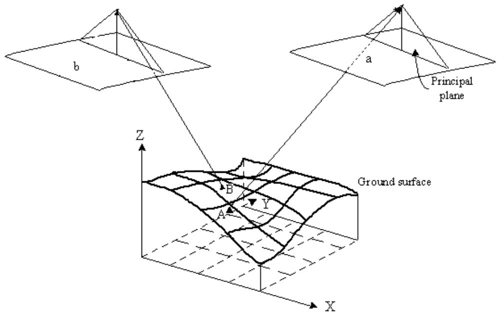


Fig. 1. Illustration of error vector on tie point

3) Least Squares Filtering

Because the least squares adjustment is a global treatment, it cannot correct for the local errors. Therefore, the least squares filtering [1] has to be used to fine tune the orbit. In the process of least squares filtering, reference points include GCPs and tie points. That means the refinement will count on the residual error vectors for GCPs and pairs of tie points.

4) Orthorectification

In this paper, we select the indirect method to do the orthorectification [1]. Once the orientation parameters are determined and a DTM is given, the corresponding image position for a ground point may be determined by the indirect method.

3. Experiments

The experiments include two parts of validation. The first one is to examine the accuracy of the generated orthoimages. The second one is to check the geometrical consistency.

1) Test Data

The test data include two strips of SPOT 5 panchromatic images. These two strips are with about 50% overlap. Related information of the test images is shown in Table 1. Strip 1 is the image of standard mode while Strip 2 is a supermode image. The test area is in the Northern part of Taiwan as shown in fig 2. The elevation rang of the test area is about 1 to 2200 meter.

Table 1. Related information of test images

	Strip 1	Strip 2
Data	2002/12/5	2003/3/15
GSD	5m	2.5m
Image Size(pixels)	12000*24000	24000*48000
Incidence Angle	14.510434	-26.541398
Elevation Range	1~2200m	1~2200m

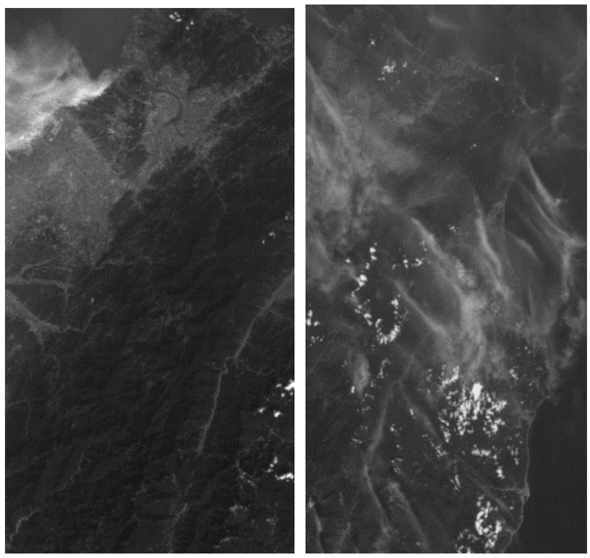


Fig. 2. The test images

There are two tests in this experiment. Both tests include the generation of orthoimages. In the process of least squares filtering, Test 1 only use residual vector of GCPs. Test 2 use residual vector of GCPs and tie points.

2) Relative Accuracy Evaluation

One pair of tie points will appear in two orthoimages, we check ground positions of tie point in the orthoimages. Distance between these two ground positions can evaluate the orbit relative accuracy. Some tie point pairs are used for least squares filtering, while the remaining are used to check the relative accuracy. Table 2 illustrates the accuracy performance of tie points. In Test 1, the RMSE of tie points (check) is about 12m and 8m in E and N directions. In Test 2, the RMSE of tie points (check) is about 7.9m and 5.5m in E and N directions. Significant improvement of relative accuracy is demonstrated when tie points are employed in the adjustment.

Table 2. Root-mean-square error (RMSE) of relative accuracy

	RMSE E (meter)	RMSE N (meter)
Test 1		
Tie points(control)	13.43	7.7
Tie points(check)	12.02	7.93
Test 2		
Tie points(control)	9.93	6.28
Tie points(check)	7.86	5.5

3) Absolute Accuracy Evaluation

We evaluate the absolute accuracy by measuring ground position of GCPs and CHKPs in the orthoimage.

Table 3 illustrates the accuracy performance of GCPs and CHKPs. In Test 1, the RMSE of CHKPs in Strip1 is about 7.5m and 6.5m in E and N directions, and the RMSE of CHKPs in Strip2 is about 5.7m and 4.6m in E and N directions. In Test 2, the RMSE of CHKPs in Strip1 is about 8.5m and 7m in E and N directions, and the RMSE of CHKPs in Strip2 is about 6.2m and 4.6m in E and N directions. The absolute accuracy does not improve when tie points are included in the adjustment.

Table 3. Root-mean-square error (RMSE) of orbit adjustment

	Strip 1 (5m)		Strip 2 (2.5m)	
	RMSE E (meter)	RMSE N (meter)	RMSE E (meter)	RMSE N (meter)
Test 1				
GCPs	5.95	6.16	7.08	4.94
CHKPs	7.48	6.46	5.74	4.59
Test 2				
GCPs	7.97	7.00	6.8	5.07
CHKPs	8.55	7.01	6.16	4.55

4) Mosaic Images

In order to check the geometrical consistency, we compare the mosaicking results for the two tests. The generated mosaics from those two images are shown in fig 3. The mosaic images of Test 1 and Test 2 are different along the seam line due to different relative accuracies. There are two sample enlargements as shown in fig 4 and fig 5 for a comparison. In Test 1, we find obvious discontinuity along the seam line. This condition is significantly improved in Test2.

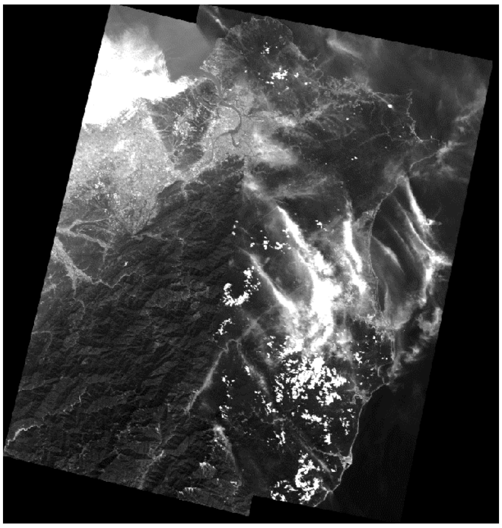
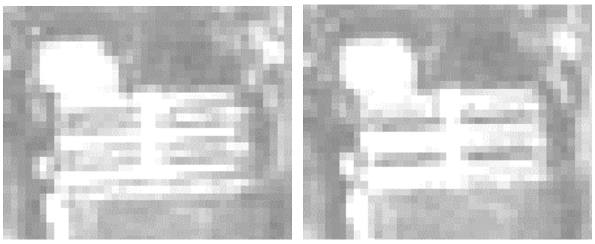
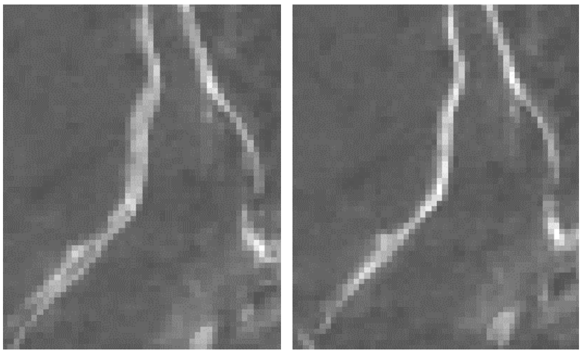


Fig. 3 Mosaic image



(a) (b)

Fig. 4. Mosaic image (a) Test1, (b) Test 2



(a) (b)

Fig. 5. Mosaic image (a) Test 1, (b) Test 2

5. Conclusions

This paper proposes a simple yet effective block adjustment procedure for multi-orbit satellite images. In the process of least squares filtering, we use GCPs and tie points to increase the relative accuracy between orthoimages of different strips.

Experimental results indicate that, block adjustment can improve the relative accuracy between orthoimages. It is also demonstrated that the mosaicked image is better seamed when tie points are employed in the adjustment.

6. References

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