POSITIONING ACCURACY ANALYSIS AND APPLICATION FOR WORLDVIEW-1 STEREO IMAGERY

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ABSTRACT:

This article introduced the progress of processing the WorldView-1 satellite image by using the air triangulation method. And different adjustment models were used to improve the vendor provided RPC (Rational Polynomial Coefficients) accuracy.WorldVfew-1 images in Beijing are used to test the correction accuracy of these adjustment models. Results show that the systematic errors of RPC model can be eliminated using a small amount of control points. The planar RMSE can reach 1.6 pixels(0.9 meter).

1. INTRODUCTION

Digital Globe Company successfully launched a new generation of high resolution imaging satellite - WorldView-1 in September 18, 2007. After launching, WorldView-1 became the highest resolution, and fastest responsive commercial satellite around world. This satellite is running at a height of 450 kilometres the sun synchronous orbit, and inclination 98 degrees, cycle 93.4min.The average revisit period is 1.7 days, satellite panchromatic image system with very large capacity to crab 0.5m resolution image around 50000 km2 every day. The satellites also can rapid aim the targets and effectively get the same track stereo-imaging. The satellite can not only obtain the resolution of 0.5m images, but also make positioning accuracy up to 6.5m without the ground control points [1].

But some technical security problems, WorldView-1 provides a non-rigorous geometric sensor model to user – the RPC model, which is replaced the strict collinear geometric model [2]. Obviously, this strategy reduces the professional standards of users, but because it's a non-strict geometric model, the stereo positioning accuracy has been affected. So, how to improve the accuracy has been a focus of attention. This paper used WorldView-1 image data and a large number of high precision control point data of Beijing area to estimate the stereo positioning and regional adjustment accuracy of RPC stereo-pair model for WorldView-1. And according to the analysis results, we explored the practical ability for different adjustment model under various conditions.

2. INTRODUCTION OF WORLDVIEW-1 STEREOTACTIC

WorldView-1 does not provide orbit parameters, and not provide the original image and not provide rigorous geometric model strategy. It only provides the rational polynomial coefficient RPC (Rational Polynomial Coefficients), which is used by the rational function model. Generally, we use the RPC model to do the photogrammetric processing for WorldView-1 data. The essence of RPC model is the rational function model, through regularization pre-processing, object and image coordinates of RPC model are located in [-1, 1] which is in order to improve the stability of the model. RPC file is the important data files for WorldView-1 stereo pair model, unfortunately, core parameter information of sensor has been hidden. There are 90 RPC parameters in total (80 for rational function coefficient, 10 for the regularization parameters).They constitute together a WorldView-1 satellite images of the rational function model[3]. Usually you can use the rational function model (RPC) as WorldView-1 image data imaging geometric model to process the photogrammetric, such as orthophoto correction, stereo mapping, DEM extraction.

In general, WorldView-1 remote sensing image can't meet the application positioning precision

requirements of urban surveying and mapping without ground control. Usually we require the ground control points to correct the error of RPC system using a polynomial adjustment model, in order to improve the directional accuracy.

3. WORLDVIEW-1 ORIENTED MATHEMATICAL MODEL

Polynomial adjustment model depends on the deformation characteristics of image and RPC expression. In this experiment, we use to analyze the adjustment mathematical model for translation and the way for RPC + 2D affine transformation. We will do a simple introduction for the RPC model[4], translation transformation, affine transformation[5] and the corresponding adjustment mathematical model.

3.1 RPC model

$$X = \frac{Num_S(B,L,H)}{Den_S(B,L,H)}$$

$$Y = \frac{Num_L(B,L,H)}{Den_L(B,L,H)}$$

In up formulas, (B,L,H) are the regularization of terrestrial coordinates; (X,Y) are the normalized image coordinates.

3.2 Translation transforms

The coordinate origin of the two Cartesian coordinates do the simple translation.

$$x = s + a_0$$

$$y = l + b_0$$

In up formulas, (x,y) as the control points in the image of the measured coordinates; (s,l) as projection value of ground control point using RPC projection onto the image plane.

3.3 2Dimensional affine transformation

Affine transformation takes into account the inconsistency in two direction scale between transverse axis and longitudinal axis. We divide coefficient of transverse and longitudinal axis into two directions of scaling coefficients, while increase the horizontal axis and the vertical axis vertical system error correction. The affine transformation completely is a polynomial transform, can be used to correct translation, scale and rotation, affine deformation linear deformation error. It is a commonly used in remote sensing image geometric correction method.

$$x = a_0 + a_1 s + a_2 l$$

$$y = b_0 + b_1 s + b_2 l$$

(x,y) as the measured coordinates in the control points of image; (s,l) for ground control point using RPC projection onto the image plane. This transformation parameters and the parameters of RPC model are the satellite parameters of strict imaging geometric model.

4. RESULTS AND ANALYSIS

4.1 Platform and test data

In this study, we chose two scene WorldView-1 image data on July third in 2008 in Beijing area, the data for a stereo image pair. Data level is the basis of stereoscopic imaging products (stereo 1B). Table 1 is the image data of some acquisition parameters.

Table 1 Data parameter of test image

Image Data	08JUL03032443
Time	July,03,2008
Size of image	35180×21444
GSD	0.561m
Trackside Perspective	33.8°
Vertical Trackside Perspective	61.74°

The major topographic features in this area are urban and mountains. We used 48 points as ground control points, as orientation and inspection points according to schemes. These points are evenly distributed on the plane and elevation, elevation ranges from about 30.33m to 55.11m. Orientation and inspection points were obtained from aerial control points in 2008, accuracy in cm level. Precision of coordinates by Digital Photogrammetry Workstation can reach sub-pixel level.

4.2 Test scheme

This paper chooses the translational transformation and affine transformation model to improve accuracy of WorldView-1 images RPC imaging geometric model. And in accordance with the control points and check points in the plane and elevation, we distribute

situation of groups, designed 6 different control points and check point combination for test precision plan (See table 2), the remain points as the check points. These test schemes were used to evaluate RPC accuracy for different polynomial adjustment models in different control conditions and improve the applicability, provide the evidence for the practical application.

Table 2 the scheme for control points and check point

Scheme	No. of GCP	Position description
1	None	Using RPC parameter
2	1	In the center of image
3	5	One in the center of image，other 4 points
4	15	around 4 corners 5×3
5	16	4×4
6	25	5×5

4.3 Result and analysis

According to the design schemes of test, this paper did different combinations of test data for the control points and check points in the different distributions, and using translational transformation and affine transformation model to improve the WorldView1 image RPC imaging geometric model accuracy, table 3-5 respectively listed RMSE statistical data under these test schemes of check points. Units are meter.

Table 3 The result of RPC model directly position

Scheme	Position description	Accuracy of control points						Accuracy of check points					
		Actual accuracy			Max. residual error			Check accuracy			Max. residual error		
		X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
Scheme 1	RPC							32.07	59.06	9.61	-33.02	-60.15	10.64

Table 4 The result of translation transform model

Scheme	Position description	Accuracy of control points						Accuracy of check points					
		Actual accuracy			Max. residual error			Check accuracy			Max. residual error		
		X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
Scheme 2	1							0.48	0.88	0.92	1.19	1.55	1.28
Scheme 3	4+1	0.27	0.36	0.57	0.86	0.48	-0.97	0.50	0.57	0.63	0.87	0.83	0.92
Scheme 4	5×3	0.32	0.46	0.52	0.77	0.63	-0.81	0.35	0.53	0.61	0.80	0.79	1.00
Scheme 5	4×4	0.24	0.33	0.58	0.58	0.42	0.82	0.55	0.46	0.59	0.72	0.67	0.94
Scheme 6	5×5	0.35	0.51	0.42	0.73	0.79	-0.91	0.38	0.45	0.50	0.68	-0.78	-1.02

Table 5 the result of 2Dimensional affine transformation model

Scheme	Position description	Accuracy of control points						Accuracy of check points					
		Actual accuracy			Max. residual error			Check accuracy			Max. residual error		
		X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
Scheme 3	4+1	0.38	0.25	0.44	-0.79	-0.65	0.81	0.46	0.50	0.42	-0.82	-0.89	-0.94
Scheme 4	5×3	0.26	0.29	0.30	0.71	-0.69	0.77	0.48	0.52	0.51	-1.00	0.81	-1.22
Scheme 5	4×4	0.36	0.38	0.35	0.68	0.72	0.85	0.40	0.45	0.47	0.84	0.82	-0.97
Scheme 6	5×5	0.38	0.41	0.38	-0.83	-0.76	0.86	0.29	0.43	0.48	0.68	-0.78	-1.02

Affine transformation requires more than 3 control points, so it only gives the Scheme 3-6.

According to results of table 3-5, we can draw the following conclusions:

1. Without control points, ground positioning accuracy of WorldView-1 is about 60m, the height precision is about 10m.
2. Adding a few control points (1 or 5), the system error of RPC model was been effectively eliminated. The plane orientation point accuracy of WorldView-1 is 0.7 ~ 0.9m (2 pixels). The height precision at around is 0.8m (2 pixels).
3. Two adjustment schemes almost have the same accuracy and results remain stable. This verify that RPC model error is the main source of systematic error. Using a simple object translation Scheme has basically satisfied the usual location requirements.

5. CONCLUSIONS

RPC model of WorldView-1 image replaces the strict geometric model based on collinear equation. Since satellite observations have certain errors, so the accuracy of original RPC parameter positioning is limited. It needs to do correct to satisfy the requirements of application in mapping. This paper used two kinds of indirect optimization algorithm: translation transformation and affine transformation model as the RPC model, and applied to the WorldView-1 stereopair adjustment calculation, research the different accuracy of positioning. The test results show that, the RPC model has better stability, with only a few ground control points which can effectively eliminate the systematic errors in the RPC model. The plane of orientation error of WorldView-1 image can reach +0.70M, elevation is better than 1m. From the experimental results, the translational transformation model is a simple and good adaptability, high precision for processing WorldView-1 image data adjustment model. In practical field work operation, especially the less control point, poor distribution, or difficult terrain conditions, such as the border, islands, mountains, coast, mountains, alpine, lakes, forests, deserts and other regions, we recommend to use translation model for WorldView-1 image data processing.

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