Retraction

Retraction: Block Adjustment of Large-scale Domestic Optical Satellite Remote Sensing Imagery without GCP in Antarctic (IOP Conf. Ser.: Earth Environ. Sci. 428 012082)

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Block Adjustment of Large-scale Domestic Optical Satellite Remote Sensing Imagery without GCP in Antarctic

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Abstract. Aiming to the difficult area of surveying and mapping, such as Antarctic, it is difficult to guarantee favourable observation condition for traditional mapping methods. Large-scale block adjustment (BA) without ground control point (GCP) is carried out by using domestic high-resolution satellite remote sensing imagery. The key technologies of BA model construction based on virtual control point (VCP), gross error detection and elimination, and robust and fast method of large-scale BA are studied in this paper. On this basis, the experimental analysis and validation of 13 pairs (39 images) of ZY-3 satellite imagery in Antarctic are carried out. The results show that the sparse matrix technology can effectively reduce the memory requirement. The combined matrix block and GPU parallel technology can solve the problem of large-scale BA computational efficiency. In addition, after BA, the maximum residual is 3.920 pixel, the root mean square error (RMSE) is 0.169 pixel in the X (flight) direction, the maximum residual error is 5.933 pixel, and the RMSE is 0.191 pixel in the Y (scan) direction. The proposed method has certain accuracy and stability in large-scale BA without GCP using high-resolution satellite remote sensing imagery in Antarctica. The relative positioning accuracy can reach sub-pixel level, which can meet the requirements of cartographic splicing.

1. Introduction

Due to climate change, it is difficult for traditional mapping methods to guarantee favorable observation conditions. Therefore, large-scale surveying and mapping of Antarctica can be carried out by means of photogrammetric [1-2]. In recent years, many countries have substantially increased their investment in scientific investigation of Antarctica and used various advanced surveying and mapping methods to survey the Antarctic region. China's Antarctic scientific investigation started late, but from a relatively high starting point, and achieved remarkable results [3]. Surveying and mapping geographic information products are an important support and guarantee for the development of polar scientific research in China and an indispensable part of the scientific research field. After decades of rapid development, remote sensing technology has become a practical and advanced space exploration technology in the field of geographic information. Carrying out surveying and mapping research in Antarctica is the need of China's polar scientific research. It can provide basic surveying and mapping support for polar scientific research and provide services for research and application of glaciers, geology, oceanography and other disciplines. [4]

With the continuous improvement of the resolution of optical satellite remote sensing images [5] and the development of data processing technology [6-7], it is very important to improve the image positioning accuracy. Foreign countries, such as spot-5, IKONOS, QuickBird and other common high resolution optical satellite images, direct positioning accuracy is not high. The original RPC parameters contained relatively large system errors, and the corresponding error compensation model...
should be established for correction [8-9]. Literature [10] systematically analyzed the system error of RPC model, and used affine transformation model to effectively correct the influence of system error of RPC model. Literature [11] used the adjustment method of regional network to improve the plane accuracy and elevation accuracy of the no. 3 image of large area resource to 13-15 m. Literature [12] used regional network adjustment to improve the accuracy of spot-5 product from 13.7 m to 5m, and elevation accuracy from 9 m to 5m. In literature [13-14], DEM data were introduced into the adjustment model for joint adjustment under the condition of weak intersection of images, which solved the problem that the modified equation could not converge and the result was not reliable. References [15] adopted the adjustment method of uncontrollably area network with multi-coverage satellite images to improve the positioning accuracy of satellite images without control. Literature [16] used high-resolution satellite images with higher positioning accuracy (such as Geoeye, WorldView, etc.) or aerial images as control conditions, and also achieved better geometric positioning effects. In addition, existing geographic information data, such as digital orthography (DOM) and digital elevation model (DEM) can also be used as control data for joint adjustment of satellite image regional network [17]. Literature [18] used SRTM data to interpolate the elevation of the object square corresponding to the connection point as the initial adjustment value, effectively improving the image elevation positioning accuracy of large-scale regional network adjustment. Literature [19] used the satellite image of resource-3 to conduct the adjustment experiment verification of regional network, and the experimental results showed that its positioning accuracy could meet the requirements of 1:50,000 scale mapping, but the adjustment process was relatively complex, and the adjustment process of regional network under the condition of no control was constrained by the size of the experimental area [20]. Literature [21] used the zy-3 three-wire array stereoscopic image of 8802 scene covering China to conduct adjustment of uncontrollably area network, and the accuracy of uncontrollably measured map was better than 5m.

In this paper, the domestic high-resolution optical satellite stereo image is used for satellite mapping, and mapping research is carried out in Antarctica to explore the technical route to solve the basic mapping data. This article first analyzes the problems existing in the traditional adjustment methods, studied the adjustment model building based on virtual control points, the gross error detection and eliminate net adjustment the steady, rapid and massive area calculating, the key techniques such as overcome countless control case adjustment model caused by high degrees of freedom adjustment not convergent, accuracy and reliable, and appeared in the process of image matching coarse almost cause the deformation of the regional network of problems. Finally, the zy-3 satellite image of the South Pole strip 13 (39 images) was used for experimental analysis and verification. The results showed that the maximum residual error of the adjusted result in the X (flight) direction was 3.920 pixels, with a median error of 0.169 pixels, and the maximum residual error in the Y (scan) direction was 5.933 pixels, with a median error of 0.191 pixels. The method used in this paper for adjustment of large-scale uncontrollable area-net using high-resolution satellite remote sensing images in the Antarctic region has certain accuracy and stability, and the relative positioning accuracy can reach sub-pixel level, which meets the requirements of mapping edges.

2. Theory

2.1. RFM Model

Rational function (RFM) model represents the image coordinate of image square as the ratio of a polynomial with the three-dimensional ground coordinate of the corresponding object as the independent variable. In essence, it is a highly mathematical fitting of a rigorous model, which can achieve almost the same geometric positioning accuracy. Its form is shown in equation (1).

\[
\begin{align*}
\; & x_n = \frac{\text{Num}_x(P_n, L_n, H_n)}{\text{Den}_x(P_n, L_n, H_n)} \\
\; & y_n = \frac{\text{Num}_y(P_n, L_n, H_n)}{\text{Den}_y(P_n, L_n, H_n)} \\
\; & e_n = \frac{\text{Num}_z(P_n, L_n, H_n)}{\text{Den}_z(P_n, L_n, H_n)}
\end{align*}
\]
Where, \((r_n, c_n)\) \((P_0, L_0, H_0)\) represent the regularized coordinates of image point coordinates and ground point coordinates respectively, which vary in \((1~+1)\). Regularization can improve the stability of the solution of each coefficient in RPC model, and also help reduce the rounding error caused by the large difference of data series in the calculation process. Regularization is achieved by translation and scaling, and the regularization formula is shown in (2).

\[
\begin{align*}
    r_n &= \frac{r - r_0}{r_s} , c_n = \frac{c - c_0}{c_s} \\
    P_n &= \frac{P - P_0}{P_s} , L_n = \frac{L - L_0}{L_s} , H_n = \frac{H - H_0}{H_s}
\end{align*}
\]

(2)

Where, \(r_0, c_0, P_0, L_0, H_0\) are the regularized translation parameters, and \(r_s, c_s, P_s, L_s, H_s\) are the regularized scaling factors.

The image square correction model is used to correct the systematic error of the rational function model. According to equation (1), the following equation can be obtained:

\[
\begin{align*}
    r + \Delta r &= F_r(P, L, H) \\
    c + \Delta c &= F_c(P, L, H) \\
    \Delta r &= a_0 + a_1 r + a_2 c + a_3 rc \\
    \Delta c &= b_0 + b_1 r + b_2 c + b_3 rc
\end{align*}
\]

(3)

(4)

Where, \(\Delta r, \Delta c\) represent the correction number of system errors of satellite image uplink direction and column direction respectively, \((a_0, a_1, a_2, a_3, b_0, b_1, b_2, b_3)\) represents the compensation coefficient of the system error.

Regional network adjustment is an important step in photogrammetry, which uses a small number of ground control points to calculate affine transformation coefficients of all images in the whole survey area and ground coordinates of all encryption points. The original RPC parameters of optical satellite images have a large systematic error. The systematic error of the RFM model is compensated through the constraint relationship between the connection points between the images, so as to improve the geometric positioning accuracy of the target.

Equation (3) can be further written as follows:

\[
\begin{align*}
    R &= r + \Delta r - F_r(P, L, H) \\
    C &= c + \Delta c - F_c(P, L, H)
\end{align*}
\]

(5)

\[
\begin{align*}
    F_r(P, L, H) &= \frac{\text{Num}_r(P, L, H)}{\text{Den}_r(P, L, H)} \\
    F_c(P, L, H) &= \frac{\text{Num}_c(P, L, H)}{\text{Den}_c(P, L, H)}
\end{align*}
\]

Where, \(F_r(P, L, H)\) \(F_c(P, L, H)\) represents the compensation coefficient of the system error.

After linearization of equation (5),
For every JingYing like, evenly divided on the image plane according to certain spacing rules grid (each scene can be divided into nine grid), for each of the center of the grid, the use of the JingYing as initial RPC model, in object space height datum (general settings for the image in the initial RPC model elevation offset), get the virtual ground control points by forward intersection. 

\[
\n\begin{align*}
\frac{\partial R}{\partial a_0} \cdot \Delta a_0 + \frac{\partial R}{\partial a_1} \cdot \Delta a_1 + \frac{\partial R}{\partial a_2} \cdot \Delta a_2 + \frac{\partial R}{\partial b_0} \cdot \Delta b_0 + \frac{\partial R}{\partial b_1} \cdot \Delta b_1 + \frac{\partial R}{\partial b_2} \cdot \Delta b_2 + \\
\frac{\partial R}{\partial P} \cdot \Delta P + \frac{\partial R}{\partial L} \cdot \Delta L + \frac{\partial R}{\partial H} \cdot \Delta H - (R - R^0)
\end{align*}
\]

\[
\begin{align*}
\frac{\partial C}{\partial a_0} \cdot \Delta a_0 + \frac{\partial C}{\partial a_1} \cdot \Delta a_1 + \frac{\partial C}{\partial a_2} \cdot \Delta a_2 + \frac{\partial C}{\partial b_0} \cdot \Delta b_0 + \frac{\partial C}{\partial b_1} \cdot \Delta b_1 + \frac{\partial C}{\partial b_2} \cdot \Delta b_2 + \\
\frac{\partial C}{\partial P} \cdot \Delta P + \frac{\partial C}{\partial L} \cdot \Delta L + \frac{\partial C}{\partial H} \cdot \Delta H - (C - C^0)
\end{align*}
\]

For every JingYing like, evenly divided on the image plane according to certain spacing rules grid (each scene can be divided into nine grid), for each of the center of the grid, the use of the JingYing as initial RPC model, in object space height datum (general settings for the image in the initial RPC model elevation offset), get the virtual ground control points by forward intersection. \(P (b, l, h)\) [21], such as fig.1 shown.

For each join point (or virtual control point), a set of error equations such as equation (6) can be listed, which contains two kinds of unknowns, \(t\) and \(x\). \(T\) represents the sum of the transformation coefficients of image square correction of all images, and \(x\) represents the coordinate correction of all ground points.

\[
\begin{align*}
V_w &= A_w \cdot x - L_w, P_w \\
V_p &= A_p \cdot x + B_p t - L_p, P_p
\end{align*}
\]

It can be further written as follows,

\[
V = Ax + Bt - L, P
\]

The corresponding formula is

\[
\begin{bmatrix}
A^T PA & A^T PB \\
B^T PA & B^T PB
\end{bmatrix}
\begin{bmatrix}
x \\
t
\end{bmatrix} =
\begin{bmatrix}
A^T PL \\
B^T PL
\end{bmatrix}
\]

In general, the number of coordinates \(x\) of the ground point is much larger than the number of directional unknowns \(t\). The solution of \(t\) can be obtained by eliminating \(x\)
\[ t = N_i^{-1} \cdot R_i \quad (9) \]

Where

\[ N_i = A^T PA - A^T PB (B^T PB)^{-1} (B^T PA) \quad R_i = A^T PL - A^T PB (B^T PB)^{-1} (B^T PL) \]

Adjustment of regional network is a process of gradual convergence of iteration. When the result of two calculations is less than the given threshold, the iterative calculation process ends.

2.2. Adjustment Technology of Large-scale Uncontrollably Area Network

2.2.1. Sparse Matrix Technique

The coefficient matrix of the normal equation in the regional network adjustment model is generally sparse, and the distribution of non-zero elements in the coefficient matrix is related to the distribution relationship between the original images. This paper adopts the data storage structure of sparse matrix [22]. The data storage structure adopts a ternary data structure to record and store the non-zero elements in each row of the matrix, and each row contains the number of non-zero elements in the row, the column coordinates of each non-zero element and their corresponding values. With this data structure, the original image can be numbered freely regardless of whether the LAN has regular airlstrip structure or not, and only the non-zero elements in the matrix can be stored and calculated, thus the arbitrary operation on the zero elements can be completely avoided. After storing non-zero elements in the coefficient matrix, the robust and efficient solution of the unknowns in the higher order normal equation is another key problem that needs to be solved urgently.

2.2.2. GPU Parallel Computing Technology

In the calculation process of the modified equation in the RFM model in this paper, it is a real symmetric matrix, which can be solved by block iteration method, and its formula is as follows:

\[ N_t = \begin{bmatrix} N_{t-1} & r_t^T \\ r_t & \beta_t \end{bmatrix} \quad (10) \]

Where, \( t(t \leq n) \) is the number of iterations, \( N_{t-1} \) is \( t-1 \) square matrix, \( r_t \) is the former \( t-1 \) row of \( N_t \), \( r_t^T \) is the front column of the t-th row element of the matrix, the transpose of the \( r_t \), \( \beta_t \) is the t-th row of \( N_t \) , and the t-th column element of the matrix.

According to the block iterative inverse algorithm using \( N_{t-1}^{-1} \) recursion \( N_t^{-1} \), set

\[
\begin{align*}
    b_t &= -N_{t-1}^{-1}r_t \\
    \beta_t &= \rho_t + r_t^T b_t
\end{align*}
\]  

(11)

Then the matrix \( N_t \) inverse formula is

\[
N_t^{-1} = \begin{bmatrix} N_{t-1}^{-1} + \frac{1}{\beta_t} (b_t b_t^T) & \frac{1}{\beta_t} b_t \\
\frac{1}{\beta_t} b_t^T & \frac{1}{\beta_t} \end{bmatrix}
\]  

(12)

When \( t = n \), \( N_n^{-1} \) is \( N_t \)'s inverse matrix.

Large real symmetric matrix inverse problem can be realized by block iterative method. The process of block iterative method of modifying the coefficient matrix of the equation belongs to the calculation process of cyclic iteration, but each cycle contains a large number of matrix multiplication...
and addition operations, and they are independent of each other. Therefore, it can be optimized and computed in parallel. The specific process is shown in figure 2.

![Flow Chart of Block Parallel Inversion of Real Symmetric Matrix](image)

**Figure 2.** Flow Chart of Block Parallel Inversion of Real Symmetric Matrix

After calculating the correction number of affine transformation coefficient of each image, according to the calculation result of the modified algorithm, the correction number of the object coordinate corresponding to the connection point is solved by the algorithm (8). Since the matter-squared coordinates corresponding to the join points are independent of each other, the matter-squared coordinates can be optimized in parallel.

2.2.3. Coarse Error Detection and Elimination Technique

The coefficient matrix of the normal equation in the regional network adjustment model is generally sparse, and the distribution of non-zero elements in the coefficient matrix is related to the distribution relationship between the original images. This paper adopts the data storage structure of sparse matrix [22]. The data storage structure adopts a ternary data structure to record and store the non-zero elements in each row of the matrix, and each row contains the number of non-zero elements in the row, the column coordinates of each non-zero element and their corresponding values. With this data structure, the original image can be numbered freely regardless of whether the LAN has regular airstrip structure or not, and only the non-zero elements in the matrix can be stored and calculated, thus the arbitrary operation on the zero elements can be completely avoided. After storing non-zero elements in the coefficient matrix, the robust and efficient solution of the unknowns in the higher order normal equation is another key problem that needs to be solved urgently.
3. Analyses

3.1. Data
In this paper, a 13-scene three-line array stereo image pair (a total of 39 images, as shown in figure 3) of the long strip belt in the Antarctic region obtained by the resource 3 satellite was used to carry out the adjustment test of the uncontrolled regional network. The zy-3 satellite image of the region was captured in 2014, and each image was accompanied by RPC parameter files. There was a certain degree of overlap between adjacent images, and the total amount of image data was about 52 GB. The test area covers an area of about 50 km×450 km, and the test area contains mountain, mountain and other types of terrain, with the maximum and minimum elevation fluctuation up to 1000 m.

![Image of Taihu](image)

**Figure 3. Images distribution of Taihu**

3.2. Experiment
Experiments using software environment for 10 64 - bit operating system, Windows R2017a professional numerical calculation software MATLAB, the hardware environment for DELL high-performance graphics workstations (the graphics workstations configured with a 12 CPU core i7-8700, 32 gb of memory and NVIDIA Quadro P2000 professional graphics), using PCI GEOMATICA 2015 version of about 12657 in the whole measuring range automatic matching uniform distribution and the junction of high reliability, total cost about 1 h. The distribution of join points is shown in figure 4. The image square space of each image is evenly divided into 3×3 grids, and virtual control points are generated for the center of each grid. 9 virtual control points are generated on each image, and a total of 342 virtual control points are generated. The joint adjustment experiment is carried out between the generated virtual control points and the matching connection points. The experimental results show that the introduction of virtual control points into the traditional free network adjustment model and the weighted observation can effectively improve the state of the adjustment model and make the adjustment model more robust.
3.3. Results
The application memory space of the method in this paper is much less than that of the traditional method. When the number of images in the experiment reached 39, the traditional method required at least 16 gigabytes of memory space for adjustment calculation, while the method in this paper only required 1778m of memory (1126M of which was occupied by the free state of MATLAB software), which was relatively small. At the same time, the time spent in the adjustment process of this method and other operation methods is shown in Table 1. As can be seen from Table 1, the traditional method failed the memory application and adjustment calculation could not be performed. In the adjustment using preconditioned conjugate gradient method [25], the adjustment part takes 129.942s; in the parallel computing using GPU, the adjustment part takes 24.834s; in the joint matrix block and GPU parallel computing, the adjustment part takes the least time, only 11.096s.

Statistical analysis was conducted on the backproyection residual of the connection points after adjustment, and the comparison was made with the backprojection residual of the connection points intersecting directly in front of the original RPC parameters. The adjustment effect and stability of the regional network could be evaluated, and the residual could also reflect the relative position accuracy of the images to a certain extent. The residual results of the connection points before and after adjustment are shown in Table 2. As can be seen from Table 2, the original RPC orientation directly results in the direction of the X (flight) maximum residual error is 11.954 pixel, the error of 1.845 pixels, Y (scan) the direction of the maximum residual error is 14.362 pixel, the error of 2.654 pixels, this suggests that using original RPC parameters directly to forward intersection calculation result there is a big error, need further correction; Through regional net adjustment result in the X direction (flight) the maximum residual error is 10.711 pixel, the error of 0.301 pixels, Y (scan) the direction of the maximum residual error is 12.378-pixel, the error of 0.367 pixels, compared with the original RPC calculation results, the connection point of the projection residual got better improvement, it shows that through regional net adjustment after the relative positioning precision of image can be effectively improved.

| Table 1. Adjustment Time Cost of Different Algorithms |
|--------------------------------------------------------|
| **Methods** | **Iterations** | **Time-costing** | **Accuracy** |
|-------------|---------------|-----------------|--------------|
| Traditional method | / | / | / |
| PCG         | 2             | 129.942s(Sparse)| Tab. 2       |
| GPU parallel technology | 2 | 24.834s(Sparse) | Tab. 2       |
| Combined block matrix and GPU parallel technology | 2 | 11.096s(Sparse) | Tab. 2       |
Table 2. Image Points Residues of Different Solutions (Unit: Pixel)

| Solutions              | X_max   | X_min  | X_mean | X_RMSE | Y_max   | Y_min  | Y_mean | Y_RMSE |
|------------------------|---------|--------|--------|--------|---------|--------|--------|--------|
| Forward intersection   | 11.954  | 0.001  | 0.576  | 1.845  | 14.362  | 0.001  | 0.638  | 2.654  |
| Bundle adjustment      | 10.711  | 0.001  | 0.001  | 0.301  | 12.378  | 0.001  | 0.003  | 0.367  |

Figure 5. Residual Distribution of Image Points (Gross error elimination)

Table 3. Image points residues of different solutions (Unit: Pixel)

| Solutions                  | X_max   | X_min  | X_mean | X_RMSE | Y_max   | Y_min  | Y_mean | Y_RMSE |
|----------------------------|---------|--------|--------|--------|---------|--------|--------|--------|
| Forward intersection      | 11.954  | 0.001  | 0.576  | 1.845  | 14.362  | 0.001  | 0.638  | 2.654  |
| Bundle adjustment         | 10.711  | 0.001  | 0.001  | 0.301  | 12.378  | 0.001  | 0.003  | 0.367  |
| Forward intersection (Gross error elimination) | 6.061  | 0.001  | 0.371  | 1.548  | 8.906   | 0.001  | 0.192  | 1.699  |
| Bundle adjustment (Gross error elimination) | 3.920  | 0.001  | 0.001  | 0.169  | 5.933   | 0.001  | 0.001  | 0.191  |

According to the method mentioned above, the gross error was detected and eliminated, and a total of 1105 gross errors were eliminated in this experiment. The relative positioning accuracy before and after adjustment is shown in figure 5. After the coarse error is eliminated by the algorithm in this paper, the residual results of the connecting points before and after adjustment are shown in table 3. As can be seen from table 3, after rough error elimination, the maximum residual of the result of direct orientation of original RPC in the X (flight) direction is 6.061 pixels, and the median error is 1.548 pixels. The maximum residual in the Y (scan) direction is 8.906 pixels, and the median error is 1.699 pixels. Compared with the result before rough error elimination, the relative positioning accuracy is further improved. After adjustment of the regional network, the maximum residual in the X (flight) direction is 3.920 pixels, with a median error of 0.169 pixels, and the maximum residual in the Y (scan) direction is 5.933 pixels, with a median error of 0.191 pixels. Compared with the coarse error before elimination, the relative positioning accuracy is also improved to some extent.
4. Conclusions
In view of the difficult area of Antarctic mapping, a large scale uncontrolled regional network adjustment is carried out by using domestic high resolution satellite remote sensing images. The method in this paper has certain accuracy and stability, and the relative positioning accuracy can reach sub-pixel level to meet the requirements of drawing edge. Due to the limitation of experimental data, the correctness and feasibility of the method in this paper still need to be further verified by using a large number of different types of optical satellite images, and how to make full use of the existing geographic information data to assist the adjustment of vllan will be the next research direction of this paper.

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6. References
[1] D R, Yuan X X. Bundle block adjustment with small format air photographs on surveying and mapping on Antarctic[J]. Antarctic Research, 1992, 4(2): 27-35.
[2] Ai S T. Chinese Antarctic Spatial of Surveying and Mapping Database and Its Key Technology[D]. Wuhan University, 2003.
[3] Yang Y D, Er D C, Wang H H, et al. Sea ice concentration over the Antarctic Ocean from satellite pulse altimetry[J]. Sci China Earth Sci, 2010 (12): 1759-1764.
[4] Wang T J, Zhang Y J, Su G R, et al. Production tests of Surveying and mapping products for Antarctic based on high-resolution satellite images[J]: Remote sensing information, 2014 (5): 58-61.
[5] Ma R H, Zhu F, Wu Q X, et al. Dense stereo matching algorithm based on image segmentation [J]. Acta Optica Sinica, 2019, 39 (03): 0315001.
[6] Liu X, Liu Y, Zhang C, et al. Study on Resolution Improvement and Data Processing of Remote Sensing Image [J]. Laser & Optoelectronics Progress, 2019, 56 (08): 081002.
[7] Li Y Y, Wu H, Chang X L, et al. Multi-View stereo positioning error analysis based on spaceborne optics and SAR images [J]. Acta Optica Sinica, 2018, 434 (05): 0528003.
[8] Zheng M, Zhang Y, Zhou S, et al. Bundle block adjustment of large-scale remote sensing data with Block-based Sparse Matrix Compression combined with Preconditioned Conjugate Gradient[J]. Computers & Geosciences, 2016, 92:70-78.
[9] Cheng C Q, Zhang J X, Huang G M. RFM-Based Block Adjustment for Spaceborne Images with Weak Convergent Geometry[J]. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2015, XL-7/W4:1-6.
[10] Grodecki J, Dial G. Block Adjustment of High-Resolution Satellite Images Described by Rational Polynomials[J]. Photogrammetric Engineering & Remote Sensing, 2003, 69(1):págs. 59-70.
[11] Bouillon A, Bernard M, Gigord P, et al. SPOT 5 HRS geometric performances: Using block adjustment as a key issue to improve quality of DEM generation[J]. ISPRS Journal of Photogrammetry and Remote Sensing, 2006, 60(3):134-146.
[12] Zhang H, Zhang G, Jiang Y H, et al. A SRTM-DEM-controlled Ortho-rectification Method for Optical Satellite Remote Sensing Stereo Images[J]. Acta Geodaeticaet Cartographica Sinica, 2016, 45(3): 326-331.
[13] Wang T Y, Zhang G, Li D R, et al. Comparison between Plane and Stereo Block Adjustment for ZY-3 Satellite Images[J]. Acta Geodaeticaet Cartographica Sinica, 2014, 43(4):389-395,403.
[14] Zhang Y, Wan Y, Huang X, et al. DEM-Assisted RFM Block Adjustment of Pushbroom Nadir Viewing HRS Imagery[J]. IEEE Transactions on Geoscience and Remote Sensing, 2016, 54(2):1025-1034.
[15] Yao X H, You H J. Multi-Observed Block Adjustment for Satellite Images Without Ground Control Points. Remote Sensing Technology and Application, 2018, 33(3): 555-562.
[16] Li H H, Cao H, Shi J. High-precision Orientation Algorithms of High-resolution Satellite
Imagery[J]. Geospatial Information, 2018, v.16;No.105(05):8+11-18.

[17] Zhang Z X, Tao P J. An Overview on "Cloud Control" Photogrammetry in Big Data Era. Acta Geodaetica et Cartographica Sinica, 2017, 46(10): 1238-1248.

[18] Zhou P, Tang X M, Cao N, et al. SRTM-aided Stereo Image Block Adjustment without Ground Control Points. Acta Geodaetica et Cartographica Sinica, 2016, 45(11): 1318-1327.

[19] Wang T, Zhang G, Li D, et al. Geometric Accuracy Validation for ZY-3 Satellite Imagery[J]. IEEE Geoscience and Remote Sensing Letters, 2014, 11(6):1168-1171.

[20] Zhang Y, Zheng M, Xiong X, et al. Multistrip Bundle Block Adjustment of ZY-3 Satellite Imagery by Rigorous Sensor Model Without Ground Control Point[J]. IEEE Geoscience and Remote Sensing Letters, 2015, 12(4):865-869.

[21] Yang B, Wang M, Pi Y D. Block-adjustment without GCPs for Large-scale Regions only Based on the Virtual Control Points. Acta Geodaetica et Cartographica Sinica, 2017, 46(7): 874-881.

[22] Wu J P, Wang Z H, Li X M. Efficient Solution and Parallel Computing of Sparse Linear Equations [M]. Hunan Science and Technology Press, 2004: 43-46.

[23] Huo Y Q, Wang W X, Peng C F, et al. CUDA-based parallel matrix inverse algorithm of large-scale real symmetric matrix[J]. Computer Engineering and Design, 2015 (8): 2133-2137.

[24] Li D R. Gross Error Location by means of the Iteration Method with variable Weights. Geomatics and Information Science of Wuhan University, 1984, 9(1):46-68.

[25] Zheng M T, Zhou S P, Xiong X D, et al. GPU Parallel Bundle Block Adjustment. Acta Geodaetica et Cartographica Sinica, 2017, 46(9): 1193-1201.

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