

GEOMETRIC AND AUTOMATIC MOSAIC METHOD WITH COLLINEAR EQUATION FOR AVIATION TWICE-IMAGING DATA

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ABSTRACT:

Due to more than one hundred of traditional film aerial cameras and too expensive digital ones in China, new type aerial camera with large format becomes the focus of researchers on remote sensing and Photogrammetry in both film and digital aerial camera. The key innovation for this program is twice-imaging proposal. In this paper, a geometric and automatic mosaic method is mainly developed for twice-imaging data. This method is able to efficiently present whole images with large format and high resolution through secondary imaging data during a mapping assignment. Experiments are carried out to validate this method.

1. INTRODUCTION

Due to more than one hundred of traditional film aerial cameras and too expensive digital ones in China, a new type of aerial camera with large format becomes the focus of researchers on remote sensing and Photogrammetry in both film and digital aerial camera. The key innovation for this program is twice imaging proposal. In this paper, a geometric and automatic mosaic method is mainly developed for twice-imaging data. This method can efficiently present whole images with large format and high resolution through secondary imaging for a mapping assignment. Experiments are carried out to validate this method.

2. TWICE-IMAGING MODEL

Twice-imaging scheme (in Fig.1) is one of the key innovations in an aerial camera system. Here, the dotted line part is original Lens module of the film aerial camera, and we directly use it with no improvement. In the original aerial camera structure, the film plate is fixed to the focal plane. However, the twice-imaging method replaces the film with a special glass fixed in the focal plane with same size. Through the shot of film aerial camera, the first imaging presents ground scene on the first imaging plane. Then, with 2×2 CCD (charge-coupled device) array cameras behind the focal plane, four parts of the intact first imaging data are obtained synchronously. Based on the overlap between the four partial secondary images and an appropriate algorithm, a whole image can be formed into large format and high resolution one.

3. ALGORITHMIC APPROACH

A geometric and automatic mosaic method is developed in twice-image data process. All of the secondary imaging sensors use the array CCD chips to capture part of the first image respectively. With same format of traditional aerial camera, the imaging pattern of area CCD is fit to central projection. All pixels in a CCD have the same principal point of photograph and same photo plane. In a word, they share same parameters of

exterior orientation. Therefore, they have same imaging principle with traditional film aerial cameras. The relationship between photo and ground point can be described by the classical Central Projection Imaging Collinear Equation, which includes many elements such as photo point coordinates, offset, camera focus, relative ground point coordinates and orientation cosine values. The equation not only shows the imaging construction for remote sensing, but also demonstrates that the image geometric distortion. Due to interior and exterior

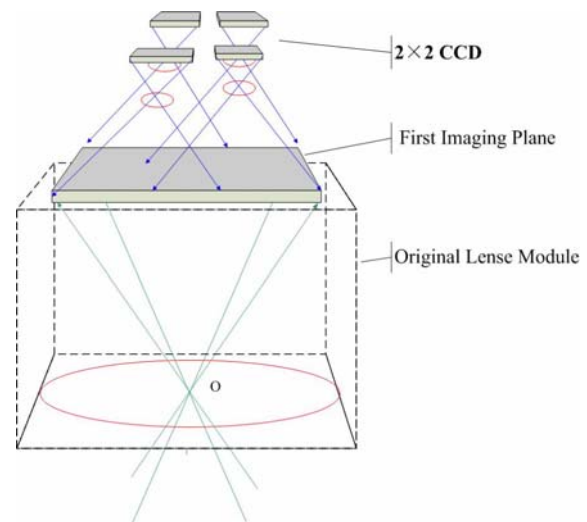


Figure 1. Twice imaging based aerial camera construction

distortion elements of the photograph camera, the equation is used in image geometric rectification. Here is the collinear equation.

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$$x - x_0 = -f \frac{a_1(X - X_s) + b_1(Y - Y_s) + c_1(Z - Z_s)}{a_3(X - X_s) + b_3(Y - Y_s) + c_3(Z - Z_s)} \quad (1)$$

$$y - y_0 = -f \frac{a_2(X - X_s) + b_2(Y - Y_s) + c_2(Z - Z_s)}{a_3(X - X_s) + b_3(Y - Y_s) + c_3(Z - Z_s)}$$

$$\left. \begin{aligned} a_1 &= \cos \varphi \cos \kappa - \sin \varphi \sin \omega \sin \kappa \\ a_2 &= -\cos \varphi \sin \kappa - \sin \varphi \sin \omega \cos \kappa \\ a_3 &= -\sin \varphi \cos \omega \\ b_1 &= \cos \omega \sin \kappa \\ b_2 &= \cos \omega \cos \kappa \\ b_3 &= -\sin \omega \\ c_1 &= \sin \varphi \cos \kappa + \cos \varphi \sin \omega \sin \kappa \\ c_2 &= -\sin \varphi \sin \kappa + \cos \varphi \sin \omega \cos \kappa \\ c_3 &= \cos \varphi \cos \omega \end{aligned} \right\} \quad (2)$$

By the collinear equations, the parameters of interior and exterior orientation can be expressed the relationship of center projection between secondary and first imaging plane. With ground point coordinates directly obtained through photo point ones, the secondary imaging data can be rectified. Due all rectified secondary images in same coordinate system, they can mosaic automatically and quickly. Here, A geometric and automatic mosaic method with the collinear equation is presented for secondary imaging data. As the first imaging plane is quite flat, the equation can be simplified. Through calibrating the cameras and measuring the spatial position relationship between CCD camera and first imaging plane, the parameters of interior and exterior orientation can be obtained. Based on the rigorous mathematical transition between photo point and relative ground point coordinates, this method has high precision in geometric rectification.

When the digital imaging module has been fixed, there are definite translation and revolution between CCD sensor and the first image plane, which should be measured. Relative to the first image, the four CCD sensors can be identified as exposures at four positions, which form a 2x2 photography block with two flight strips. In that case, both the exterior and the interior orientation parameters are different in each camera. The relationship among the four exposure positions are shown in Fig.2. After CCD imaging sensors have been rectification, the images correction can be carried out through interior and exterior orientation parameters of the twice-imaging system. The geometric and automatic mosaic algorithm approaches as follows in Fig.3.

Firstly, the parameters of interior and exterior orientation must be obtained by strictly calibrating the four CCD cameras. And the spatial position relationship also needs to be measured accurately between the cameras and the first imaging plane. On the first image plate, we use the collimation mark and draw a fine waffle slab to limit all errors. In Fig.2, the object space coordinate is set up, whose base point of X-Y plate is located at the left lower corner of the first image, and the Z axis is vertical and up rising to the plate. The coordinates of each net point are (X_i, Y_i, Z_i) , $i=1, 2, 3, \dots$, which Z_i is zero due to

the first image plate flat enough that the plate fluctuation can be neglected.

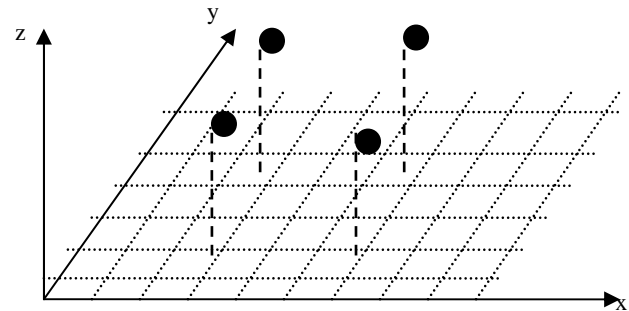


Figure 2. the relationship among the four exposures positions

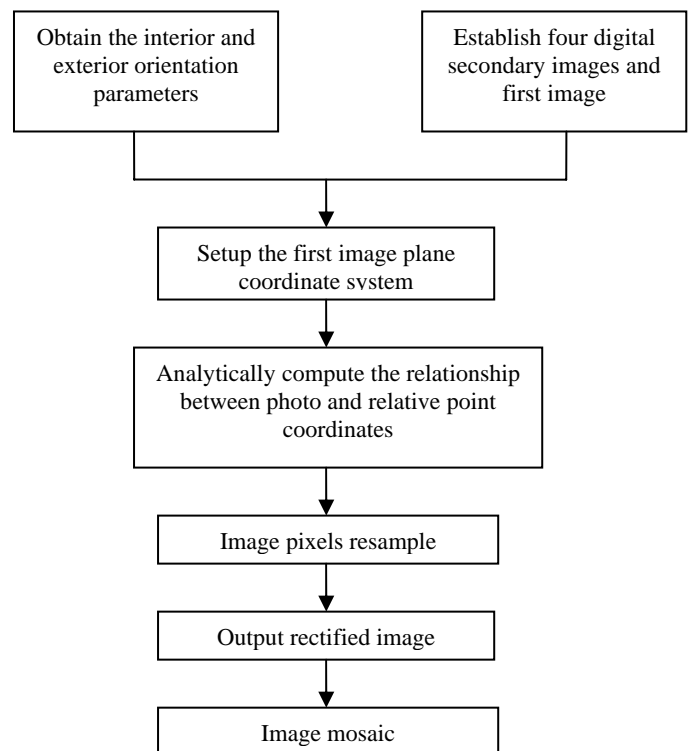


Figure 3. route of the geometric and automatic mosaic algorithm

Secondly, four digital secondary images have overlapping among each other. Therefore, they can be rectified and mosaic.

After that, the transform matrix for projection transform process can be obtained from the exterior orientation parameters. In this process, it is assumed that the first image plane coordinate is X_i, Y_i, Z_i , and the image coordinate is X'_{jk}, Y'_{jk} after distorting correction. The projection center of each CCD sensor coordinate is X_{sj}, Y_{sj}, Z_{sj} , and the traverse matrix is R_j , in which $i = 1, 2, \dots; j = 1, 2, 3, 4; k = 1, 2, \dots$. And then, the formulation can be expressed as follows:

$$\begin{bmatrix} X_i \\ Y_i \\ Z_i \end{bmatrix} = R_j \begin{bmatrix} x_{jk} \\ y_{jk} \\ -f_j \end{bmatrix} + \begin{bmatrix} X_{sj} \\ Y_{sj} \\ Z_{sj} \end{bmatrix} \quad (3)$$

With analytically computing the relationship between photo point and relative point coordinates on the first imaging plane, we can resample pixel value of rectified secondary image with bilinear interpolation. Because the first image point coordinate is known, the gray resample can be done from the first image to the secondary image.

4. EXPERIMENTS

For proving the feasibility of the algorithm, several experiments are carried out. As shown in Fig.4, An original remote sensing image is used as ideal image on the first imaging plane. The four secondary images are obtained from the ideal image by arbitrarily setting their parameters of interior and exterior orientation. Then these secondary images are processed with the collinear equation method. In Fig.4, the eight control points on the first image are arranged uniformly. Based on the intact remote sensing image, its four parts are generated to simulate four CCD secondary images in the experiments, which are shown in Fig.5.

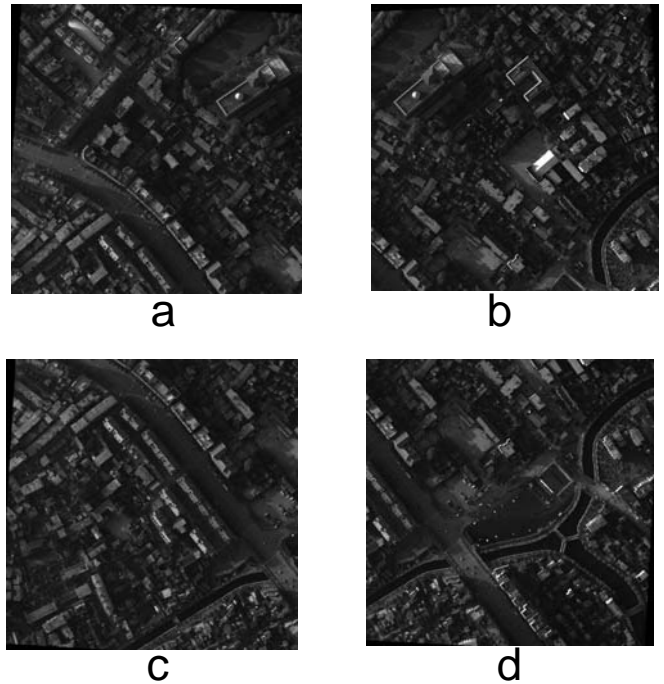


Figure 5. the four simulation image obtained from original remote sensing image



Figure 4. original remote sensing image and control point distribution

The twice-imaging optical system is design with Tab.1 parameters. The CCD imaging sensor performance is the key element in twice-imaging scheme, which affects the geometric and automatic mosaic algorithm, and the parameters are shown in Tab.2. Here, the exterior orientation parameters include m_phi, m_omega and m_kapa as angle elements, and Xs, Ys and Zs as position elements.

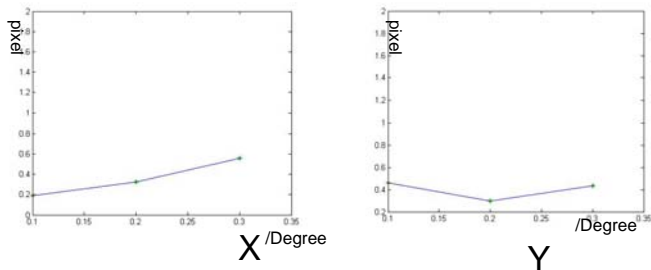
Each CCD sensor resolution	4K×2.7K
Distance between first and second image	346mm
Focal length of CCD sensor lens	70mm
FOV of each CCD sensor lens	28.8°

Table 1. the optical parameters

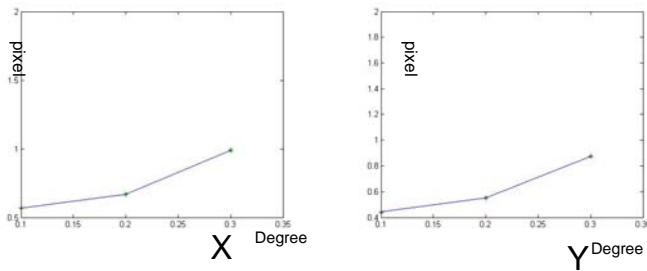
m_phi	0.251°
m_omega	0.215°
m_kapa	3.2103°
Xs	0.01152 m
Ys	0.025344 m
H	0.0160 m
f	0.008 m

Table 2. the original CCD image sensor parameters

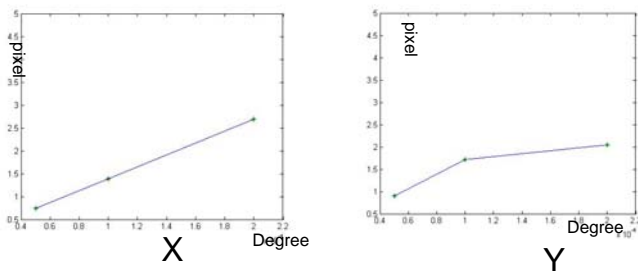
In the experiment, artificial interior and exterior orientation errors are added in the original image data. And the algorithm is realized by MATLAB. The error affection for m_phi, m_kapa and height H has been shown in Fig.6.



(a) the error of m_phi effect



(b) the error of m_kapa effect



(c) the error of height H effect

Figure 6. the error analysis

CONCLUSIONS

1. Twice-imaging aerial camera system is new style aerial equipment.
2. The results show that the algorithm can produce whole images with large format and high resolution through processing secondary imaging data efficiently and the error can be controlled in less than one pixel error .

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