Research on relative orientation method of oblique aerial photography based on basic matrix

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ABSTRACT: After the oblique aerial photography technology is used to collect the stereo image, it is necessary to use the relative orientation method to check the image parameters. After the rectification process is completed, the 3D software is used to draw the 3D model to meet the subsequent application requirements. The author of this paper analyzes the difficulty of the matching and aerial photography, including affine transformation cannot successful transformation, influence there covered phenomenon and characteristic finishing is difficult, the combination of fundamental matrix tilt aerial photography as a method of relative orientation, through the study of oblique aerial photography based matrix as precision control points, its aim is to continuously optimize tilt aerial photography as the content, improve the use value of collation results.

1. Introduction
With the continuous improvement of digital photogrammetry technology system, the ways of regional image acquisition are also expanding. At the same time, affected by the quality of the photography platform, the height of the flight path, air flow, aircraft attitude and other factors, the attitude angle of the acquired image also fluctuates greatly, which affects the application quality of the final image. Based on the relevant content of the basic matrix, a reliable relative orientation method is adopted to process it, which can not only improve the quality of the collected image in the initial state, but also improve the quality of the image, so as to meet the requirements of subsequent operation.

2. Difficulties in oblique aerial photography matching
2.1. Affine transformation cannot be smoothly converted
Based on previous practical experience, it can be known that in conventional aerial photography, affine transformation can be approximated as similarity transformation since the attitude of the aerial photography flight platform is relatively stable and vertical photography is maintained. However, affine transformation between oblique aerial images cannot be approximated as similar transformation. In the incline aerial photography system integrated by multiple lenses, there is a large photographic Angle difference between side-looking camera, down-looking camera and side-looking camera, as shown in Figure 1. When using the image matching method based on gray scale, the similarity measure between the same image points is an uncertain value if the image matching window is not pre-corrected in advance. On the other hand, most of the current feature point extraction operators can only guarantee the similarity invariance. Therefore, when the transformation relation between adjacent images is affine
transformation, it is difficult to extract repeated feature points, and the image matching theory is invalid at this time.

FIG. 1 Geometric relation of image taken by tilting aerial camera on the same ground object

2.2. The impact is covered
At present, the application of tilting aerial photography is mainly concentrated in urban areas, where there are a large number of high-rise buildings and obvious occlusion interference exists. Meanwhile, the shooting area of image is mainly artificial features, which will directly affect the progress of image feature extraction. And in the process of technology application, because the system block phenomenon, this also makes the feedback image by the number of covered area, in carries on the processing, even using the affine invariant feature extraction operator, but there are still 30% - 40% of the fuzzy feature points, and cannot be these feature points are uniformly distributed, this will directly affect the final image processing quality, affect the smooth progress of follow-up operations.

2.3. Feature sorting is difficult
After feature acquisition data are obtained by oblique aerial photography, these data will be directly applied to the 3d modeling of the city, playing a role of complementing and improving the model. In the actual modeling, the feature points mainly used for natural features show a strong stable repetition rate in the image processing activities, while the artificial features have regular shapes and strong high-frequency components in the edge of the image processing, but this kind of features are in a poor stability in the application. In addition, as mentioned above, there is also a relatively obvious problem of shading during urban survey, and the geometric characteristics of inclined aerial photography itself aggravate the difficulty of image matching, thus affecting the final mapping effect and the smooth progress of subsequent operations.

3. Analysis of relative orientation method of oblique aerial photography based on basic matrix

3.1. Relatively directional processing

3.1.1. Geometric analysis of double images
For two stereo image pairs of the same scene obtained from different locations, the coplanar condition should be satisfied between the same image points, and the formula is written as

\[
\begin{bmatrix}
Ax & Ay & Az \\
x & y & z \\
x' & y' & z'
\end{bmatrix} = 0.
\]
Among them, \( A= \begin{bmatrix} Ax \\ Ay \\ Az \end{bmatrix} \) belongs to the baseline vector used in the photographic image, and \( a= \begin{bmatrix} x \\ y \\ z \end{bmatrix} \) belongs to the baseline vector used in the photographic image, and \( a'= \begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} \) are also set to facilitate subsequent matrix calculation. Among them, \((x,y)\) and \((x',y')\) are the image plane coordinates of the same image point on the left and right images; \(-f\) and \(-f'\) are the main distance between the two images; The matrix \( R= \begin{bmatrix} 3 & 3 & 3 \\ 2 & 2 & 2 \\ 1 & 1 & 1 \end{bmatrix} \) is the orthogonal transformation matrix of the right image relative to the left image.

The basic matrix expresses the geometric constraint relation between two 2d image planes, which is the matrix expression form of kernel line geometric relation, and reflects the mathematical relation between two image points with the same name. Starting from coplanar conditions, the above equation can be abbreviated as the following formula: \( a \cdot (A \times a') = a^T \cdot A \{x\} \times a' = 0 \). In kernel geometry, to simplify the model, the camera is generally considered to be the ideal case, that is, the main point of the image is in the center of the image, but the main distance of the image is variable (especially for close-range images). Therefore, there are 7 independent parameters of the basic matrix, that is, 5 relative position parameters and 2 principal distances. The basic matrix is usually used to describe the correspondence between two images with unknown internal azimuth parameters and is an important concept in computer vision dual-view geometry.

### 3.1.2. Solving relative directional parameters

After the formulation of the above formula, it enters the stage of solving relative directional parameters. In the specific solving process, the solving process can be divided into the following two stages: First, export processing for relative orientation elements, in practice, due to the size of the photography baseline weight does not directly influence on three-dimensional model building will not, have \( A_{\{x\}} \) degrees of freedom can return \( A \) value of 2, and the degrees of freedom as 3 \( R \) matrix, and had mentioned in this paper, the formula of the need to solve of eight elements, At the same time, there are necessary correlations between elements, which is easy to cause structural instability and reduce the progress of solving results. Based on this situation, it is necessary to build a relative orientation model in the application, so that after the rank deficiency constraint ends, the obtained essential matrix will also be used as the initial value, so as to improve the accuracy of the solution results of relatively oriented elements. Secondly, formulate the relative orientation model and refine the corresponding parameters in the model. Theoretically, the vertical and downward parallax value generated by the stereo image with the same image point after relatively oriented processing is 0, and the specific calculation formula is as follows: \( Q = NY - N'Y' - Ay \), where \( N \) and \( N' \) represent the corresponding point projection coefficients of the same image points on the left and right images respectively. Then the error equation is used to sort out the applied parameters, so as to improve the accuracy of the analysis results.

### 3.1.3. Processing of relative directional accuracy

In the process of processing relative directional accuracy, the following should also be paid attention to: First, determine the specific values of model baseline \( Ax \), when determine the three-dimensional model, its size can be arbitrarily assigned according to the actual situation, according to the above numerical can learn, model of vertical parallax will also keep the proportional relationship between baseline and model, and in order to better for calculation, the measurement precision of image point
The calculation formula is also simplified to improve the stability and rationality of numerical results. Second, for vertical parallax weighting processing, according to the related parameters of images has been the precision image point measuring results can be determined, and on this basis, to complete the unit error calculation, the initial value and relative orientation elements as the basic conditions, using the error propagation law to deal with vertical parallax precision of calculation accuracy control at more than 99.2%. Third, the unit weight and the upper and lower parallax weight are changed, and the least square adjustment is used to carry out iterative processing in the specific application. After each iterative processing, the weight error will also be calculated, and accurate calculation results will be obtained according to the law of pixel points after the iterative convergence [1].

3.2 Absolute directional processing

3.2.1 Expression of rotation matrix

In dealing with the absolute orientation, will handle, using the rotation matrix expression in specific processing link, will create a 3 d rotation matrix, the matrix that belong to a 3 x 3 in the application of orthogonal matrix, only can accurately express the two groups in the application of rotation between the coordinates of the relationship, and based on this to review the basic characters of three-dimensional moment. First, in the three-dimensional matrix \( R = \begin{bmatrix} x_1 & y_1 & z_1 \\ x_2 & y_2 & z_2 \\ x_3 & y_3 & z_3 \end{bmatrix} \), there is \( RRT = E \), then it has the following properties: 
1. \( x_1^2 + y_1^2 + z_1^2 = 1 \), and \( x_1x_2 + y_1y_2 + z_1z_2 = 0 \);
2. \( x_2^2 + y_2^2 + z_2^2 = 1 \), and \( x_2x_3 + y_2y_3 + z_2z_3 = 0 \);
3. \( x_3^2 + y_3^2 + z_3^2 = 1 \), and \( x_3x_1 + y_3y_1 + z_3z_1 = 0 \).
In the case of \( R^T = E \), the following properties also exist:
1. \( x_1^2 + x_2^2 + x_3^2 = 1 \), \( x_1y_1 + x_2y_2 + x_3y_3 = 0 \);
2. \( y_1^2 + y_2^2 + y_3^2 = 1 \), \( x_1z_1 + x_2z_2 + x_3z_3 = 0 \);
3. \( z_1^2 + z_2^2 + z_3^2 = 1 \), and \( z_1y_1 + z_2y_2 + z_3y_3 = 0 \). Second, the resulting rotation matrix, the existence of \( |R| = 1 \), this is the basis for the subsequent calculation activities smoothly. Thirdly, in the process of element calculation, each group maintains the same relationship with the remainder algebraic cofactors [2].

3.2.2 Rotation matrix solution processing

When the rotation matrix is solved in the process, often used in processing method is as follows: first, direct linear method, the method in the application, would have been the application of the elements in the rotation matrix as a relatively independent elements, the linear solution method can be used to organize each element corresponding numerical, and on the basis point equation can also be successfully listed three applications. In its calculation, the least square method is used to solve the parameters, so that in the process of solving, the content can be quickly solved, so as to obtain the initial value of the unknown parameters. Second, singular value decomposition constraint method, which can offset the accuracy error of the error to a certain extent in the application, thus improving the accuracy of the solution result to more than 99%. Third, unit quaternion method, for solving three dimensional vector rotation, can be seen as will vector to expand as the quaternion and unit between the four elements of mixed product, measuring several points according to the requirement, also be able to get the best solution formula, according to the requirements for finishing the content, so as to improve the precision of the processing result of [3].

3.2.3 Absolute directional processing

After completing the above processing, it enters the stage of absolute directional processing. In this process, the commonly used processing methods are as follows: First, spatial similarity transformation processing, in specific orientation calculation, can according to the requirements for space auxiliary coordinate calculation of model, and in order to calculate the coordinates of the corresponding absolute position, this also needs in the application, to optimize the space coordinates, obtained the corresponding transformation, increase the use value of the results of the analysis. Second, based on
the requirements for absolute orientation elements, in absolute orientation of small swing Angle image processing, in order to further simplification of the corresponding calculation process, using center of gravity of the three-dimensional space coordinates to the more similarity transformation processing, and in the application, also use empirical formula for a specific parameters, so as to get the absolute orientation parameters, The accuracy was controlled above 99% [4].

4.Control points of oblique aerial photography accuracy of basic matrix

4.1.Accuracy index determination

4.1.1.Theoretical accuracy

Combined with the relevant requirements of basic matrix, when analyzing the theoretical accuracy, the reference content is obtained from the covariance matrix of unknowns obtained by adjustment, which can be written as the following formula: \( a_i = s_0 \sqrt{Q_{ii}} \), in which \( Q_{ii} \) represents the element on the ith diagonal of the matrix \( Q_x \), and \( s_0 \) represents the median error corresponding to the observed value of unit weight. It can be verified according to the actual situation and calculated using the variance value, so as to improve the accuracy of numerical calculation results. Moreover, in the calculation of theoretical accuracy, the corresponding covariance propagation law also maintains a good application relationship with the regional network, and the error propagation law within the regional network also maintains a direct proportional relationship with the pixel measurement accuracy. It can be seen that in numerical calculation, the theoretical accuracy can also directly represent the internal accuracy of regional net adjustment [5].

4.1.2.Actual accuracy

Correspondingly, after determining the theoretical accuracy value, the actual accuracy also needs to be calculated. As a direct embodiment of the accidental error distribution, the theoretical accuracy also has a good correlation with the point-position distribution. From the perspective of practical application, the complexity of the whole process is relatively high, and the established adjustment model will also have some systematic errors in the application. The comprehensive effect of these contents and accidental errors will also increase the difference between theoretical accuracy and actual accuracy. In general, the application accuracy of adjustment content will be directly feedback between the real coordinates and the difference coordinates of the redundant control points involved in the region. The specific calculation formula is as follows:

\[
\begin{align*}
\alpha_x &= \sqrt{\frac{\sum (x_{true} - x_{adjustment})^2}{n}}; \\
\alpha_y &= \sqrt{\frac{\sum (y_{true} - y_{adjustment})^2}{n}}; \\
\alpha_z &= \sqrt{\frac{\sum (z_{true} - z_{adjustment})^2}{n}}
\end{align*}
\]

4.2.Estimation of positioning accuracy

4.2.1.Conventional image positioning accuracy

Based on the data obtained in the past, in numerical calculation, the unit weight error value of adjustment is relatively close to the estimated measuring accuracy of image points, which can also confirm that the estimated measuring accuracy of image points has strong value significance. At the same time, the actual accuracy of adjustment was analyzed, and the average accuracy of the measured data was close to 0.1m, which was twice the size of GSD after being converted into images. In addition, in the image positioning, the accuracy of the flat area is relatively high, with an average accuracy of 0.090m, while that of the hilly area is at a lower level, with an average accuracy of 0.116m. The accuracy of elevation also conforms to the above application rules, so that error elimination can be completed on this basis in calculation, so as to improve the accuracy of analysis results [7].

4.2.2.Unconventional image positioning accuracy

Based on previous data information, in the numerical calculation, due to the irregular aerial
photography as corresponding as point coordinates of measurement accuracy in the low position, and the adjustment of the corresponding overall is in the condition of relatively low precision, the error in the unit weight of adjustment will be closer to 0.3 pixels, at this time and the estimated image point coordinate measurement accuracy is in the condition of close to, it can meet the basic requirements of daily data analysis. And unconventional in the application of aerial photography as the plane precision and elevation of position precision is in a state of relatively large, the key causes of such problems is that the unconventional aerial photography as geometric relationships between, make the image point coordinate measurement accuracy is in a state of decline, and the adjustment of the whole precision control in the low state, Thus, the estimated value of the accuracy estimation result is improved [8].

5.Conclusion
To sum up, based on the basic characteristics of the basic matrix, analyzing the relative orientation method of inclined aerial photography can not only improve the accuracy of image processing results, but also lay a foundation for the smooth advancement of subsequent operations.

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