SPATIAL LOCATION ON CITY 3D MODELING WITH CLOSE-RANGE STEREO IMAGES

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Commission V, WG V/2

KEY WORDS: Close-range, Free network, Bundle adjustment, Relative control

ABSTRACT:

This paper chooses close-range target stereo image data as main topic of 3DCM, and carries through comprehensive and systemic study on photogrammetry of free network bundle adjustment from theory to practice. On the data processing of spatial model location, free network bundle adjustment is introduced to solve the base of spatial location. Photogrammetry and non-photogrammetry information are integrated to develop a union adjustment system with self-calibration parameter. Simultaneously solve problems of the big angle linked of different models that take photo around a building, and none-control point and only relation controls used to carry out free network adjustment. Process of realization and results are given.

1. INTRODUCTION

The 3DCM(three dimension city modeling) is hotspot of digital photogrammetry, computer vision, GIS and other correlation study. The basic geography data and methods are utilized by model create tools such as GIS systems, image processing to create three dimensions model. Measures of target acquiring include photography, laser scanning and video-theodolite, etc. Highly effective works are presented in spatial 3D modeling. But 3D create tools are different from automatic and half-automatic modeling in GIS field. Remote sensing images applied in three dimensions modeling are effective measures. But this measure cannot solve shelter from high building, the side face, complex construction, and special working face of building. Cannot satisfy high scale, accuracy (cm) necessity of city and engineering. As technology supplement of remote sensing, there are significance researching on methods of high speed data acquiring and processing to close-range target, and realizing real-time, automatic, and modeling to closed-range objects.

Acquiring of three dimensions spatial information of close-range object include fusion of multi-source informs, correlation matching of image, and processing of digital photogrammetry etc. On the basis of reviewing the current research status of 3DCM， based on multi-resource information, this paper chooses close-range target stereo image data as main topic of 3DCM, and carries through comprehensive and systemic study on photogrammetry of free network bundle adjustment from theory to practice. On the data processing of spatial model location, classic network and especially free network bundle adjustment is introduced to solve the base of spatial location. Photogrammetry and non-photogrammetry information are integrated to develop a union adjustment system with self-calibration parameter. Simultaneously solve problems of the big angle linked of different models that take photo around a building, and none-control point and only relation controls used to carry out free network adjustment.

2. CONSTRUCT CLOSE-RANGE FREE NETWORK

In close-range photogrammtry, absolute orientation of the target objects with respect to control points does not play a significant role. What is important is to measure the relative positions of points on surface of an object, and determine its size, shape and volume according to desired accuracy, especially on 3d modeling in city close-range photogrammtry. Three dimension objects reconstructed and recovered from images, inner oriented data and relate control condition need mathematic models and algorithms to realize multi-resource spatial data integration under universal coordinate system.

2.1 Coordinate System Select

The independent image pair coordinate system is selected as basic coordinate system. S1, S2 being the projection centres, and the direction of the baseline B is taken as the X axis of a temporary coordinate system, and the direction of the Y axis is perpendicular to the principle epipolar plane of the left-hand photograph (see Fig 2-1 image pair). The elements of inner orientation, focal, and pixel size of image can be acquired through calibration in laboratory. Automatic matching or semiautomatic measure can acquire coordinates of image points of photo pair.

2.2 Solution Model Coordinates

In the case of the rotation system in which the Y axis is taken as the primary axis, the elements of relative orientation of the photo pair are τ_1 , κ_1 (left photo), $\varepsilon, \tau_2, \kappa_2$ (right photo). When S1 is taken as the origin, the locations of S1 and a1 with respect to S1 can be determined from the vectors $\overrightarrow{S_1S_2}$ and $\overrightarrow{S_1a1}$ (see Fig. 2-1), whereas the location of image point a2 with respect to S2 can be determined from the vector $\overrightarrow{S_2a_2}$. Since these three vectors are in the same epipolar plane, they are coplanar, which means their scalar-vector product of is zero:

$$\overrightarrow{S_1S_2} \bullet (\overrightarrow{S_1a_1} \times \overrightarrow{S_2a_2}) = 0 \tag{1}$$

Which, express in coordinates, is:

$$\begin{vmatrix} Y & Z \\ Y' & Z' \end{vmatrix} = 0 \tag{2}$$

* Jia sheng-ju, PhD. Study on digital close-range photogrammetry and 3d visualization.

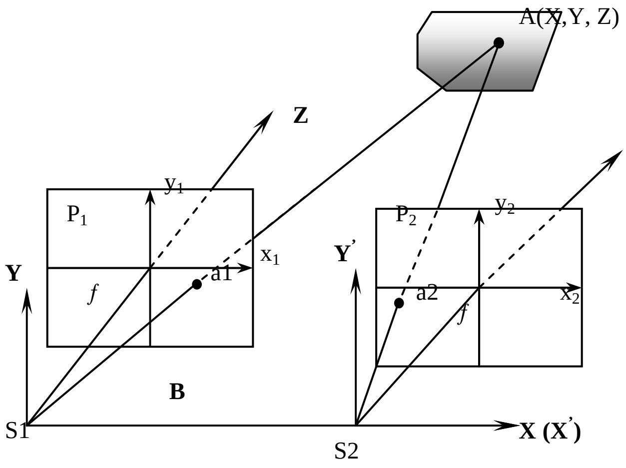

Fig.2-1

(X, Y, Z) and $(X^{'}, Y^{'}, Z^{'})$ are corresponding photo pair coordinates of baseline coordinate system.

2.3 Connection of Free Network Models

The elements of relative orientation of respect photo pair under baseline coordinate system can be acquired after each photo pair relative orientation. For providing initial values to block adjustment, the elements of respect model relative orientation and point's coordinates must calculate under universal coordinate system, namely connection of models.

After the relative orientation and the solution for the model points of the second image pair, model connection can be carried out with respect to the first model based upon the points in the overlap area of the deferent models. This same procedure is to be carried out for the other succeeding models. As to the first image pair, the model scale is arbitrary; therefore, the scale of the first model determines the free scale of the whole close-range strip. From movement, rotation and scaling, the independent models can be connected a whole close-range strip. The S1 is origin of first model baseline coordinate system. The analogous transformation is:

$$\begin{bmatrix} \tilde{X} \\ \tilde{Y} \\ \tilde{Z} \end{bmatrix}_{ij} = \lambda_j M_j \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{ij} + \begin{bmatrix} \tilde{X}_s \\ \tilde{Y}_s \\ \tilde{Z}_s \end{bmatrix}_j \qquad (3)$$

where $\begin{bmatrix} X & Y & Z \end{bmatrix}_{ij}^T$ = any model point vector; M_j = model rotation matrix; λ_j = scale coefficient; $\begin{bmatrix} \tilde{X}_s & \tilde{Y}_s & \tilde{Z}_s \end{bmatrix}_j^T$ =No. j model coordinate vector under first baseline coordinate system; $\begin{bmatrix} \tilde{X} & \tilde{Y} & \tilde{Z} \end{bmatrix}_{ij}^T$ = No. j model any i point coordinate vector under corresponding baseline coordinate system. Based on first model, the close-range independent models can be connected as whole strip (see Fig. 2-2).

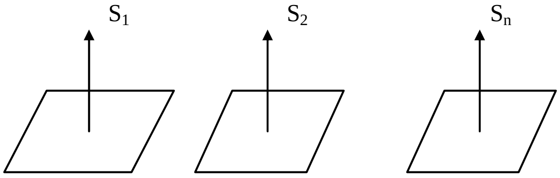

Fig.2-2 close-range strip

2.4 Solution of Connection of Big Angular Orientation

There are connections of big angular problems when taking photo around building in convergent photography mode (see

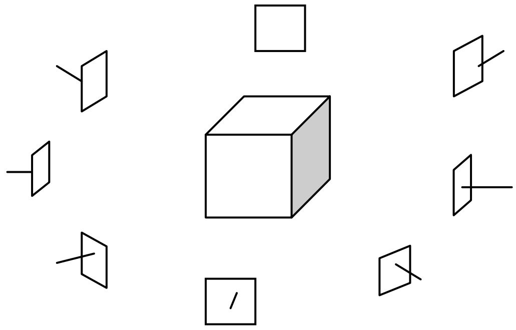

Fig.2-3 Big angle photography

Fig.2-3). When the case of the independent image pair method is adopted, the coordinate system is right hand system, and axis of independent model coordinate is not parallel. The circumstances of approximate vertical angular occur in the change of direction, it need transform the model coordinate system as follows: transform the former model tie points to next model coordinate system. Through rotating 90 degree anticlockwise solve the coordinates in current independent model. The solution process is as above. Simultaneously, considering starting values of exterior orientation element transfer between two models. The connection of angular orientation is depend on the results of relative orientation calculated elements $\varphi, \kappa, \varphi', \omega', \kappa'$ and left photo exterior orientation elements $\varphi_l, \omega_l, \kappa_l$, the right photo orientation $\varphi_r, \omega_r, \kappa_r$, the primary relation is:

$$R_{\tau\nu} = R_{\varphi_l \omega_l \kappa_l} \cdot R_{\varphi\kappa}^T \qquad (4)$$

it can be written as:

$$R_\tau R_\nu = R_{\varphi_l} R_{\omega_l} R_{\kappa_l} \cdot R_\kappa^T R_\varphi^T \qquad (5)$$

τ, ν Represent direction angular of photography baseline.

$$R_{\varphi_r \omega_r \kappa_r} = R_{\tau\nu} R_{\varphi' \omega' \kappa'}$$

Known $R_{\varphi_r \omega_r \kappa_r}$ can be solved $\varphi_r, \omega_r, \kappa_r$. The independent model initial values of left image $\varphi_l, \omega_l, \kappa_l$ are 0. Then the results can be taken into baseline coordinate system.

3. FREE NETWORK BUNDLE ADJUSTMENT

Under non-control point condition, only utilize relative control condition solution spatial position of free network, which involving not enough initiative data to carry out adjustment calculation within part network, can result in rank defect. How to eliminate the rank defect, is base of free network solution. Using least squares operation can solve the free network adjustment determine relative position of net figure, and smallest norm condition give Helmert conversion under given approximate coordinate system so that determine absolution position of network, and build centroid as relative reference coordinate system. Because normal equation matrix is not complete rank, rank defect is 7, which include the seven freedoms of basis of adjustment calculation, must be ensured to solve rank defect problems.

3.1 Fictitious Equation Eliminate the Rank Defect

In close-range photogrammetry, the collinearity equations are used to build mathematical model to carry out free network adjustment. The bundle freedom network adjustment utilizes fictitious observation values to overcome lacking of observation function. The least square and smallest norm condition determines point positions. The numbers of auxiliary observation data are equal to network necessary number of initial data so that added auxiliary observation function is in complete rank status. Mathematical model as follows:

$$\begin{aligned} G^T G &= I \\ AG &= 0 \end{aligned} \tag{6}$$

$$\begin{bmatrix} l \\ 0 \end{bmatrix} = \begin{bmatrix} A \\ G^T \end{bmatrix} X \tag{7}$$

$\begin{bmatrix} A \\ G^T \end{bmatrix}$ column complete rank，exclusive result can gotten.

$$X = (A^T PA + GG^T)^{-1} A^T Pl \tag{8}$$

To determine G matrix is ensure $\begin{bmatrix} A \\ G^T \end{bmatrix}$ in complete rank state, the row of G matrix make up coefficient vector X a group of basis. The seven conditions process Helmert conversion to eliminate rank defect. S is G matrix normalization matrix. S matrix as follows:

$$S = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & \cdots & 1 & 0 & 0 & \cdots & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & \cdots & 0 & 1 & 0 & \cdots & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & \cdots & 0 & 0 & 1 & \cdots & 0 & 0 & 1 \\ 0 & -Z_{01} & Y_{01} & a_{11} & b_{11} & c_{11} & \cdots & 0 & -Z_1 & Y_1 & \cdots & 0 & -Z_r & Y_r \\ Z_{01} & 0 & -X_{01} & a_{21} & b_{21} & c_{21} & \cdots & Z_1 & 0 & -X_1 & \cdots & Z_r & 0 & -X_r \\ -Y_{01} & X_{01} & 0 & a_{31} & b_{31} & c_{31} & \cdots & -Y_1 & X_1 & 0 & \cdots & -Y_r & X_r & 0 \\ X_{01} & Y_{01} & Z_{01} & 0 & 0 & 0 & \cdots & X_1 & Y_1 & Z_1 & \cdots & X_r & Y_r & Z_r \end{bmatrix} \tag{9}$$

where:

$$\begin{aligned} a_{11} &= \cos\kappa_1 / \cos\phi_1 ; a_{21} = \sin\kappa_1 / \cos\phi_1 \\ a_{31} &= b_{31} = 0; b_{11} = \sin\kappa_1 ; b_{21} = \cos\kappa_1 ; \\ c_{11} &= \tan\phi_1 \cos\kappa_1 ; c_{21} = -\tan\phi_1 \sin\kappa_1 ; c_{31} = 1; \end{aligned} \tag{10}$$

3.2 Relative control condition

In order to make full use of various kinds of information present in the object space at the time of photographing, relative control is often used particularly in close-range photogrammetry. There are some additional observation data, relative control information easy to add into condition equations to carry out whole adjustment calculation. Two kinds of method deal with in detail:

3.2.1 Observation values include measured data

Relative control including observation values, construct error equation from condition equation as follows:

$$V_\theta = BX - D \tag{11}$$

With collinearity equation's linearized as follows:

$$V = AX - L \tag{12}$$

indirect adjustment methods apply in whole solve process.

3.2.2 Relative control as restrict term

Not including observation values in the relative control factor, relative control factor provide a restrict term for collinearity equation (13), and indirect adjustment model with additional conditions as follows:

$$\begin{aligned} CX + W &= 0 \\ V &= AX - L \end{aligned} \tag{13}$$

where: X = rectify vector of exterior orientation elements and object point coordinates;
B = coefficient of error equation of relative control factor;
D =constant vector of error equation of relative control factor;
A = coefficient of image point coordinates error equation;
L = constant vector of image point coordinates error equation;
C=coefficient of restrict condition of relative control factor;
W = constant vector of restrict condition of relative control.

Relative control factor applied in adjustment system can partly change coefficient vector X status of rank defect, and can make the adjustment network more stably.

4. RESULT AND CONCLUSION

For testing and verifying correction of theory and method, author developed software that solve close-range model and three dimensions visualization based on OpenGL. Using CCD camera takes photo around an office building and teaching building to acquire dynamic sequence image data, which form stereo photo pair. Then carry out digital close-range photogrammetry process and part tests of three modeling with non-control point only relative control factors. Camera is NIKON D1X, 3008*1960 pixel, focal length: 28.9mm, resolution: 7.88 um, image file: TIFF, JPEG.

4.1 Result

The digital close-range photogrammetry free network bundle adjustment processing includes image points measure with stereo photo pairs, inner orientation, relative orientation of model, and connection of model and bundle adjustment. The system interface (see Fig 3-1), calculation results (see sheet 3-1) and three dimensions visualize result as shown (see Fig 3-2).

Fig.3-1 Software interface

Fig.3-2 Visualize result

Sheet 3-1 Calculation results

Test scheme	1# building	3# building
Station number	55	30
Photography scale	1：1000	1：1000
Photography mode	Normal photography	Convergence photography
Object coordinate means of error (mm) X Y Z P	 0.52 0.54 0.53 0.53	 0.47 0.45 0. 48 0.46
Relative means of error	10000	12000
Model connection error (pixel)	<10	<8
Means of reliability	0.63	0.65
Note: Distance and self calibration parameters added into adjustment system		

4.2 Conclusion

a.Building free network based on the first model of independent coordinate system, the stance of first model affect sequence processing, normal photography is a better ways.
b. Connection of free network consist of individual models, the error is transmitted inevitability. Systemic error rectification and relative control condition carried out can intensify the intensity of photogrammetry network..
c. Free network take centriod as reference coordinate system, known directions and coordinates under corresponding coordinate system can easy to transfer to other coordinate system.
d. Finite iterative algorithm used to solve spatial coordinates of model.
e. Comparing with classic bundle adjustment, advantages of free network bundle are: coordinate estimate values and precise are not affected by accuracy of starting point, the errors are even equality and small.

REFERENCE:

[1] Feng wenhao. Close-range photogrammetry, wuhan university press, China,2002

[2] Zhang zhuxun, zhang jianqing. Digital Photogrammetry, wuhan university press, China,1996

[3] Ma songde, zhang zhengyou. Computer Vision. Science press, China, 1998

[4]Robert T．Collins．The Ascender System：Automate Site Modeling from Multiple Aerial Images. Computer Vision And Image Understanding，1998，Vol.72

[5] Tanimoto S, Pavilidis T. Hierarchical Data Structure for Picture Processing. Computer Graphics and Image Process, 4:104-119

[6] Shao xihui. Military Engineer Photogrammetry, PLA press, China, 1991

[7] Tao benzao. Free Network Adjustment and Distort Analysis. Mapping and Surveying Press, China.1984

[8] Huang weibin. Recent Adjustment Theory and Application. PLA Press, China,1992

[9] Jia shengju. Study on Three-Dimension Modelling of Close-range Objects. Tongji University, Doctoral Thesis，2003.4