OPTIMIZING DESIGN AND ANALYSIS OF INDUSTRIAL PHOTOGRAMMETRIC NETWORK

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ABSTRACT:

Mainly task of optimizing design of *Industrial Photogrammetric Network with Variant Interior Elements* (IPNVIE) is to provide a schema for a set of interior relatively problems in a photographic task. It includes: how to choose cameras, design measure marks, choose obtaining data schema, choose measurement method of image coordinates and schema of analytic process of photographic measurement, and so on. The paper discussed some problems of optimizing design problems and effective factors about IPNVIE; brought forward some principle methods to solve these problems; Analyzed basic requests about optimizing selecting some factors of setting IPNVIE. Experimentations were given about IPNVIE geometric configuration. The research results can be used for advancing the quality of Industrial photogrammetry and software design of optimize design of IPNVIE.

1 INTRODUCTION

In high precision industrial object measurement, it is a regular work method to set up a Photogrammetric Network with convergent photography and multi cameras around a measurement object. When we use ordinary non-metric digital camera to finish the photogrammetric task, especially interior elements (position of principal point, principal distance, parameters of distortion model, resolution of images) due to variant focus of the camera or using different cameras, can cause photography joining in the photogrammetric network to have different computing interior element separately. All these prompt to "*Industrial Photogrammetric Network with Variant Interior Elements* (IPNVIE)". In aspect of external dimensions and shape measurement of object, in order to get high accuracy measurement result, design of IPNVIE plays an important role.

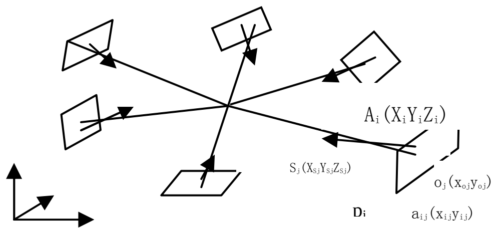

Figure 1. Multi-station Industrial photogrammetric network

2 CONCEPT AND PROCESS METHOD OF IPNVIE

Different type cameras used to shoot images are set around the object measured, principal axis points to central point of the object measured. Multi cameras (or single camera as multi-station) process photography around object points A_i (i=1,2,….n). the measurement marks will not always picture on every image p_j (j=1,2,…m). Photography angle high convergent (cameras set around object as 360º), distance of photography or scale of photography all may be different. For digital cameras, principal distance, resolution and image distortion may also be different (Figure1).

Shooting several or hundreds of images, and doing the same accuracy level of photographic coordinate measurement about tens or hundreds of object points (almost are artificial texture marks) distributed separately on the object measured, using coordinate of the object space control points provided by control area, we usually adopt Least Squares Estimation(LSE) (always has tens to thousands of additional parameters) to calculate the object space coordinate of every mark point by using co-linearity equations (1a and 1b).

$$x_{ij}-x_{0j}+\Delta x_j=-f_j\frac{a_{1j}(X_i-X_{Sj})+b_{1j}(Y_i-Y_{Sj})+c_{1j}(Z_i-Z_{Sj})}{a_{3j}(X_i-X_{Sj})+b_{3j}(Y_i-Y_{Sj}+c_{3j}(Z_i-Z_{Sj})} \quad 1a$$

$$y_{ij}-y_{0j}+\Delta y_j=-f_j\frac{a_{2j}(X_i-X_{Sj})+b_{2j}(Y_i-Y_{Sj})+c_{2j}(Z_i-Z_{Sj})}{a_{3j}(X_i-X_{Sj})+b_{3j}(Y_i-Y_{Sj})+c_{3j}(Z_i-Z_{Sj})} \quad 1b$$

Considering that interior element such as principal distance *f* of every camera (or variant focus of every camera), principal point (x_0,y_0) and image distortion caused by coordinate shift (△x, △y) are all different. If there exists different image scale in directions of x and y, principal distance should be considered separately as (*f*x, *f*y).

3 DESIGN PROBLEMS AND FACTORS OF IPNVIE

Design of photogrammetric network is aimed at improving the ability of processing photographic measurement. So three aspects of problems should be solved (K.B.Atkinson, 1996):

(1)Problem of data is to eliminate faults of photographic data. This problem involves design and usage of measurement mark, method of data measurement and accuracy, and correctly identity of homologous image points and coding, and so on.

(2)Problems of geometry setting mainly mean exploring the most excellent Photogrammetric Network，namely can realize intersection precision of Photogrammetric Network. This problem involves choice of camera type, layout and number of Photography station, angle of Photography, scale of Photography, layout of control points, and so on.

(3)Problems of LSE calculation is how to choose computing method, distortion parameters and calibration method, set suitable weight of observation value, eliminate blunders of observation value, optimizing computing scheme, and so on, according to different calculation condition.

Vision metric system that has no function of optimizing of photogrammetric network is not a perfect system. In this area, Fraser (Fraser ， 1992) did a research systematically on processing of design of photogrammetric network and system of target evaluation. Mason(Mason,s.,1986)，Bammek(Bammeke A.A. & Baldwin R.A.,1987) had built conception model of design of Photogrammetric Network., and discussed and tried solutions based on an expert system to solve problems of optimizing design of Photogrammetric Network. Brown, Mason, Shortis & Fraser developed the software based on CAD environment, and prototype system or experiment system, and used them in some industrial photogrammetric measurement task separately (Fraser, 1995). It is mainly used in choice of cameras, design of network, mark point and calculation of performance of photogrammetric network.

4 ANALYSIS OF OPTIMIZING DESIGN EXPERIMENT

The following experiments did analysis for building a optimized IPNVIE, mainly from effect of calculation precision of station configuration，number of station, position of camera, number and layout of control points used ,and so on.

4.1 Experiment Analysis on Precision Change Influence of Layout of Station and Number of Station

Ordinary non-metric digital camera of KODAK DCS4800 was used, range of automatic focusing is 28~84 mm, resolution is 2156×1440. Function of automatic focusing was used. Six experiments had been done, two image of every station are used. Area of photography is 80cm×80cm, 81 known points in total, using control point distributed dense around(Figure 2). Partial object images used in experiment are shown as Figure 3. Process of image and coordinate measurement uses corresponding methods told above. Some similar methods are used in the following other experiments, no more details (Li, 2001, 2002, Feng, 2004).

Applying bundle adjustment, distortion model uses Brown model with 18 parameters, Results as table 1. Precision change trend is shown as Figure 4.

Comparing these experiments above,photography mode of four angles, four angles and center, four angles and four edges, and four edges and four angles and center can provide the best measurement precision than other methods.

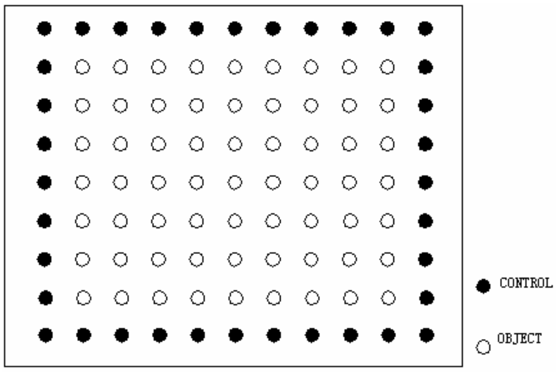

Figure 2. Dense layout of control points on edge

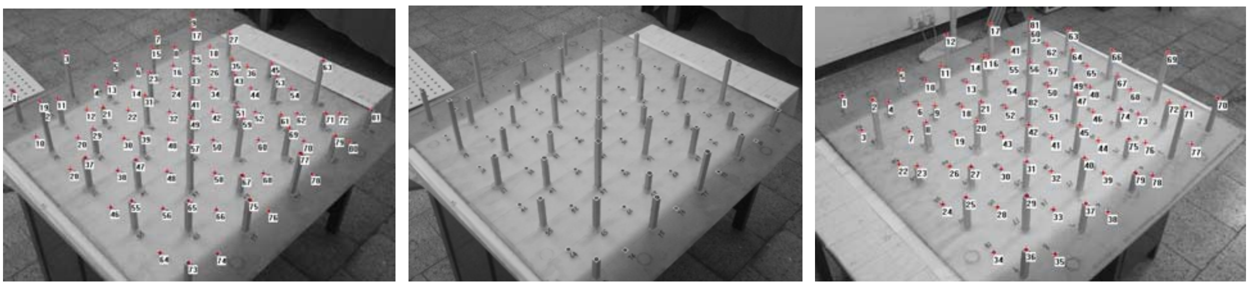

Figure 3. Partial images in experimentation

Name of shooting	**Position of camera**	**MX(mm)**	**MY(mm)**	**MX,Y(mm)**	**MZ(mm)**	σ **(pixel)**
		Theory **practice**	**Theory** **practice**	**Theory** **practice**	**Theory** **practice**	
Four edges	·S_2 S_1· ·S_3 ·S_4	0.04 0.21	0.04 0.10	0.06 0.23	0.08 0.24	0.14
Four angles	S_1· ·S_2 S_3· ·S_4	0.05 0.12	0.05 0.11	0.07 0.16	0.09 0.14	0.17
Four angles and center	S_1· ·S_2 ·S_5 S_4· ·S_3	0.05 0.14	0.05 0.11	0.07 0.18	0.09 0.13	0.16
Four edges and center	·S_2 S_1· ·S_5 ·S_3 ·S_4	0.04 0.20	0.04 0.09	0.06 0.22	0.08 0.24	0.14
Four edges and four angles	S_1· ·S_2 ·S_3 S_4· ·S_5 S_6· ·S_7 ·S_8	0.05 0.12	0.05 0.08	0.07 0.13	0.09 0.12	0.15
Four edge, four angles and center	S_1· ·S_2 ·S_3 S_4· ·S_9 ·S_5 S_6· ·S_7 ·S_8	0.04 0.12	0.04 0.09	0.06 0.12	0.09 0.15	0.15

Tab.1 Relationship between the accuracy and photography mode

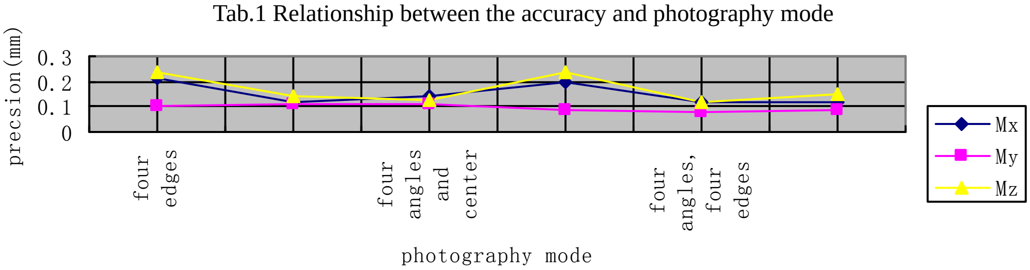

Figure 4. The relationship between precision and photography mode

4.2 Experiment Analysis of Effect on Precision Change by Adding Number of Every Station Image

Numbers of photo	M_X(mm)	M_Y(mm)	$M_{X,Y}$(mm)	M_Z(mm)	σ (pixel)
	theory practice	theory practice	theory practice	theory practice	
1	0.07 0.39	0.07 0.21	0.09 0.44	0.12 0.42	0.15
2	0.05 0.12	0.05 0.11	0.07 0.16	0.09 0.14	0.17
3	0.05 0.12	0.05 0.13	0.06 0.18	0.08 0.16	0.17
4	0.04 0.10	0.04 0.13	0.06 0.16	0.07 0.12	0.18
5	0.04 0.07	0.04 0.10	0.05 0.12	0.06 0.11	0.18
6	0.04 0.09	0.04 0.09	0.05 0.13	0.06 0.13	0.19

Tab.2 Relationship between the accuracy and number of every station image

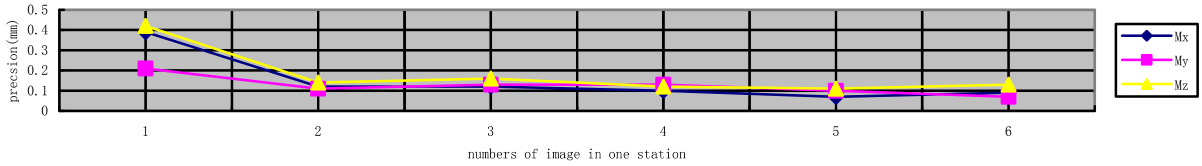

Figure 5. Relationship between the accuracy and number of every station image

This experiment is based on four angles station, control points are set as Figure 2, number of object is 18, 14 check points, freedom focusing shooting, applying bundle adjustment, distortion model using Brown model. Increasing number of every station image, calculation results shown in table 2. Precision change trend is shown as Figure 5.

Synthetic analyzing the experiment results above, we know that, in form of two images per station, results have nearly the same precision in three coordinate directions. Keeping increasing image number based on this, range of precision change is not large, but workload of coordinate measurement will increase apparently.

4.3 Experiment Analysis on Affection of Changes Caused by Control Points Location and Numbers

Numbers of control points are 9, 32, 41 and 33 separately (Figure 6,Figure 7), using four angles station, twice shooting per station, freedom focusing photography.

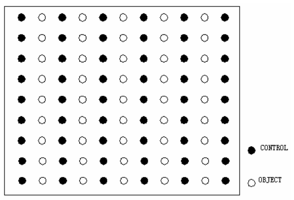

Figure 6. Symmetrical layout

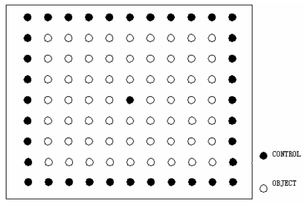

Figure 7. Density around edge and center

Applying bundle adjustment, distortion model using Brown model, Calculation results are shown in table 3. Precision change trend is shown as Figure8.

Analyzing the experiment results above, calculation can be drawn as : in practical job of industrial measurement, setting control points dense around can easily be done, and excellent precision can also be reached. It is not very necessary to set central point. Mode of setting points Symmetrical can't reach excellent precision. Layout with 9 control points is not suitable.

Mode of layout	M_X(mm) theory / practice	M_Y(mm) theory / practice	$M_{X,Y}$(mm) theory / practice	M_Z(mm) theory / practice	σ (pixel)
Nine points	0.03 / 0.92	0.03 / 0.39	0.05 / 1.00	0.06 / 0.44	0.15
Density around edge	0.04 / 0.10	0.04 / 0.12	0.06 / 0.16	0.07 / 0.16	0.18
Density around edge and center	0.04 / 0.10	0.04 / 0.11	0.06 / 0.15	0.07 / 0.20	0.18
Symmetrical layout	0.04 / 0.42	0.05 / 0.17	0.06 / 0.45	0.08 / 0.20	0.19

Tab.3 Relationship between accuracy and number and location of control points

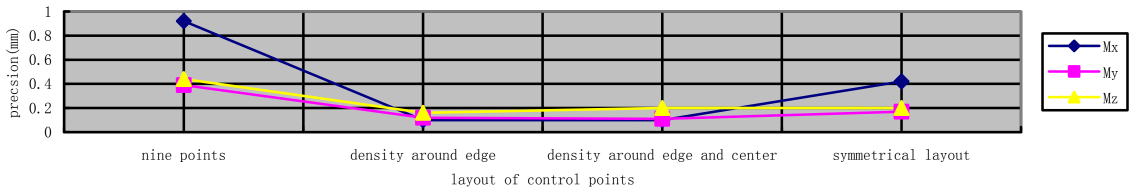

Figure 8. Relationship between accuracy and number and location of control points

4.4 Experiment Analysis on Effect of Changes Caused by Photography of Vertical Convergent Angle

When four angles station was used, vertical convergent angle is around 90. In order to research influence on precision caused by variant vertical convergent angle, different vertical convergent angle photography is adopted separately, shown as Figure 9.

Twice shooting per station, freedom focusing. Applying bundle adjustment, Distortion model using Brown model. Calculation results are shown in table 4. Precision change trend is shown as Figure 10.

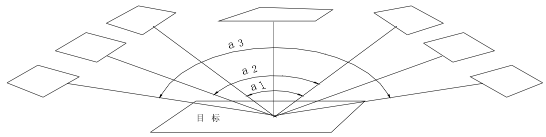

Figure 9. vertical convergent angle

Vertical convergent angle (a/2)	M_X(mm) Theory practice	M_Y(mm) Theory practice	$M_{X,Y}$(mm) Theory practice	M_Z(mm) Theory practice	σ (pixel)
0° Around	0.06 0.15	0.05 0.16	0.08 0.22	0.22 0.63	0.17
10° Around	0.06 0.19	0.06 0.19	0.08 0.27	0.06 0.17	0.19
20° Around	0.05 0.12	0.05 0.11	0.07 0.16	0.09 0.14	0.17
30° Around	0.06 0.06	0.06 0.10	0.08 0.12	0.08 0.11	0.18
40° Around	0.13 0.26	0.13 0.21	0.18 0.33	0.15 0.21	0.38
50° Around	0.08 0.20	0.08 0.29	0.11 0.35	0.09 0.18	0.23

Tab.4 Relationship between accuracy and vertical convergent angle

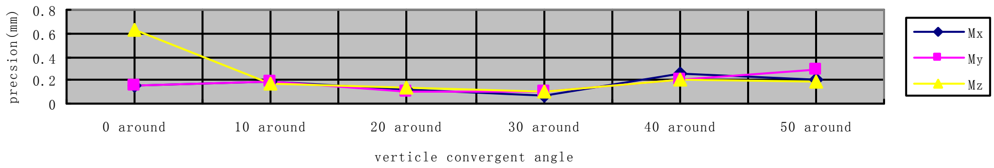

Figure 10. Relationship between accuracy and vertical convergent angle

From analysis, we know that: in vertical photography, precision is poor in direction Z, and precision distinction between plane and direction Z is a little great. When we don't care precision in direction Z, we can adopt the form of vertical photography, but plane precision will be lower than vertical convergent angle of 40°～60°, and be higher than other angle. When vertical convergent angle is between 40°～60°. Precision in plane and direction Z will be the almost the same. Increasing vertical convergent angle further, precision will on reduce trend. Synthetic analyzing the experiment result above, conclusions are: when vertical convergent angle is around 40°～60°, horizontal convergent angle is around 40°～60°, network of four angles station is the most suitable.

5 CONCLUSION

Factors determining final results quality of a photographic task are multi-sided, but optimizing design factors of phtogrammetric network is a main measure to improve measurement precision. From analyzing effect of calculation results caused by way of photography , layout of station, precision of control points, number, layout and so on, the experiment reach at some important conclusions. Results can be used as references to optimize of IPNVIE and improve results of photographic measurement.

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