Research on the Layout of Ground Control Points in Plain area 1:10000 DLG Production Using POS Technique

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***Abstract*—**POS (also been called DGPS/IMU) technique can obtain the Exterior Orientation Elements of aerial photo, so the triangulation and DLG production using POS can save large numbers of ground control points (GCP), and this will improve the produce efficiency of DLG and reduce the cost of collecting GCP. This paper mainly research on POS technique in production of 1:10 000 scale DLG on GCP distribution. We designed 23 kinds of ground control points distribution schemes, using integrated sensor direction method to do the triangulation experiments, based on the results of triangulation, we produce a map with the scale of 1:10 000 and test its accuracy. This paper put forward appropriate GCP distributing schemes by experiments and research above, and made preparations for the application of POS technique on photogrammetry 4D data production.

***Keywords*—**POS; IMU; DGPS; DLG; ground control point; triangulation

I. Introduction

POS (position and orientation system) is an assembly system of IMU and DGPS. aero photography by POS may obtain the exterior orientation elements (X, Y, Z, ω, Φ, κ), POS assistant aerial triangulation which is called "Integrated sensor orientation" can save large number of ground control points(GCPs), and shorten production time, increasing productivity, decreasing the production cost[1]. Many studies have been carried on integrated sensor orientation[1,2]. The experiments of OEEPE in 1999 showed that, the integrated sensor orientation can improve the accuracy of orientation while no GCP been used, and can reach the conventional photogrammetry adjustment accuracy while using one GCP. However, the reliability of the integrated sensor orientation is doubtable, few GCPs are necessary in aerial triangulation. CASM(China Academy of Surveying and Mapping) carried out large-scale experiments using AERO control of IGI company in 2003, the outcome indicate that the accuracy of 1:10000 and 1:50000 DLG produced by the method of integrated sensor orientation can comply with the requirement of criterion. This paper mainly researches on the layout schemes of GCPs in the production of plain area 1:10000 DLG by POS technique.

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In this research, the POS data was obtained by POS AV system of APPLANIX Company in Canada, 23 kinds of layout schemes of GCPs of different density were designed, and do aerial triangulation on each scheme by integrated sensor orientation. By comparison and analysis to the accuracy of schemes, conclusion of least GCPs schemes(the most economical scheme) were drew, and make preparation for the large-scale application of POS technique on DLG production.

II. Brief Introduction to Experiment Area

Experiments were held in the plain area of Beijing, the scale of photograph is 1:35000, and the scale of DLG is 1:10000, scanned with resolution 21μ, 6 airline, 151 photos, covered 160km² area. The quality check to POS data indicates the accuracy under the accuracy restriction of criterion [3].

III. The Layout Schemes of GCPs and Triangulation Experiments

A. Accuracy Limits

Criterion[4] has stipulate the accuracy limits of aerial triangulation as TABLE I, and the accuracy limits of DLG GCPs as TABLE II. This paper's experiments meet the requirements of this criterion.

TABLE I. ACCURACY LIMITS OF 1:10 000 AERIAL TRIANGULATION (UNIT: METER)

Accuracy limits / Sort of points	Planar limits	Elevation limits
Orientation point	3.0	0.25
Check point	3.5	0.3

TABLE II. ACCURACY LIMITS OF 1:10 000 DLG CHECK POINTS (UNIT: METER)

Planar limits	Elevation limits	
	Elevation Point	Contour Line
5.0	0.35	0.5

B. The Layout Schemes of GCPs and Triangulation Experiments

As the exterior orientation elements had been obtained By POS technique, the span of baseline can be increased and the density of GCPs can be decreased comparing with routine means in aerial triangulation [5]. The distribution and density of GCPs will affect not only the accuracy of outcome, but also the workload of surveying. While the density of GCPs is too high, the workload of surveying is heavier, but the accuracy is not necessarily higher; while the density of GCPs is too low, although the workload of surveying is lower, the accuracy may go beyond the limits. This paper does experiments on block division and the layout of GCPs by means of integrated sensor orientation, and draw conclusion of the best GCPs layout scheme.

There are 50 GCPs distributed in the block as figure1, solid dot represents principle point， triangle represents planar and height GCP, circle represents height GCP, as Figure 1.

Fig. 1 Layout figure of GCPs

- Triangulation experiments and analysis to layout schemes of GCPs in different size of blocks

Three kinds of blocks and nine layout schemes of GCPs are designed, respectively irregular blocks, standard blocks and small blocks, as Figure 2.

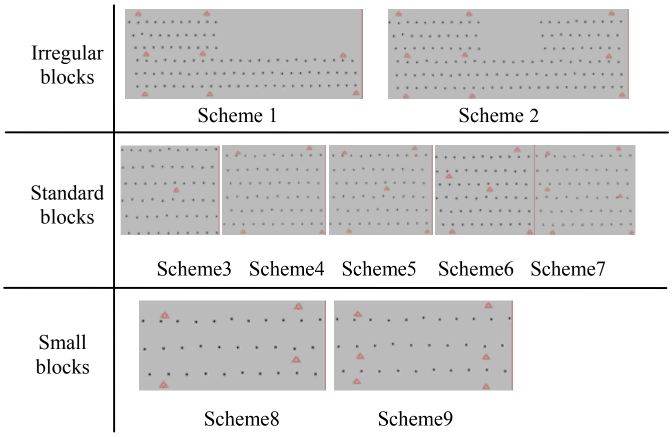

Fig. 2 Layout schemes of GCPs in different kinds of blocks

Among the schemes above, scheme 2 is a block of concave shape, in conventional aerial triangulation, GCPs must be layout in every corner of block to ensure the accuracy, while there are two corners haven't GCPs in scheme 2; In scheme 6, there is one corner hasn't GCP.

Triangulation by Intergraph SSK, the experiments results are as TABLE III.

TABLE III. ACCURACY COMPARISON OF EXPERIMENTS TO LAYOUT SCHEMES OF GCPS IN DIFFERENT SIZE OF BLOCKS（UNIT: METER）

Schemes		**Mean Square Error of GCPs**			**Mean Square Error of Check Points**		
		Num	**Planar**	**Height**	**Num**	**Planar**	**Height**
Irregular blocks	1	8	0.366	0.049	42	0.695	0.229
	2	9	0.38	0.044	41	0.738	0.203
standard blocks	3	1	2.302	0.103	18	9.203	6.388
	4	4	0.226	0.024	17	0.873	0.189
	5	5	0.279	0.024	16	0.868	0.232
	6	5	0.262	0.023	16	0.814	0.316
	7	5	0.316	0.018	15	0.799	0.184
Small blocks	8	4	0.434	0.018	9	0.850	0.158
	9	6	0.411	0.013	7	0.863	0.180

1) In table 3, there are 15 planar check points and 15 height check points error of scheme3 over the accuracy restriction, so the triangulation with only one GCP can't meet the accuracy restriction.

2) Scheme1 and scheme2 has the similar density of GCPs, the accuracy of check points are similar too. In the experiment of scheme2, there needn't each corner with GCPs, and the accuracy of check points not over the restriction.

3) Scheme4, scheme5 and scheme7 use 4,5 and 6 GCPs respectively to do triangulation, the accuracy of the check points are all under restriction. Scheme8 and scheme9 use 4 and 6 GCPs respectively, the accuracy under restriction, too.

4) Scheme6 use 5 GCPs, the up left outer corner hasn't put GCP, there're 2 height check points' error over the restriction. So, four outer corner of a block must have GCPs to insure the accuracy under restriction.

5) Scheme 8 and scheme 9 respectively use 4 and 6 GCPs, the accuracy of the check points are all under restriction, and the difference of the accuracy between the small blocks and the standard blocks are slight.

- Experiments and analysis to layout schemes of GCPs in different density

Regular block is the common used shape of block. The experiments thereinafter are based on one regular block, with different density of GCPs, 14 kinds of layout schemes of GCPs are designed, from scheme10 to scheme23. Thereinto, scheme22 and scheme23 are the same layout, the difference is, scheme22 use POS data and scheme23 do not use POS data to do triangulation. The schemes are as Figure 3.

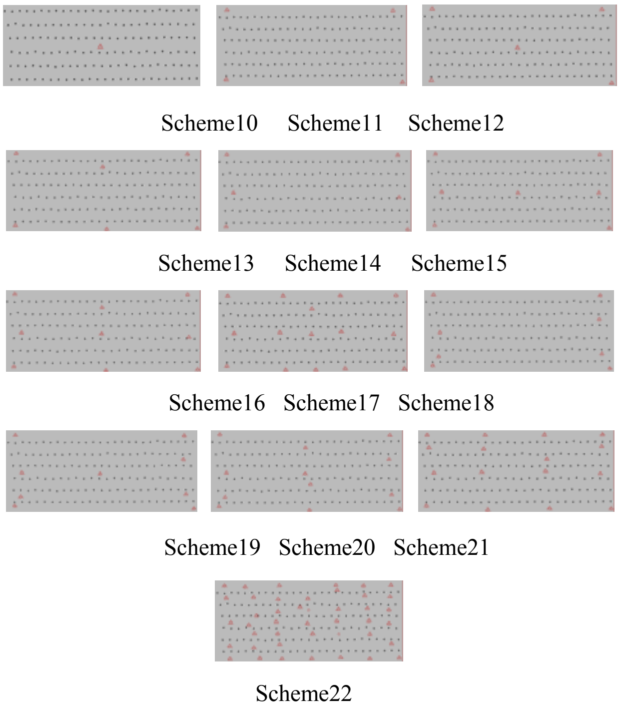

Fig. 3 Layout schemes of GCPs in different density

The results of experiments are as TABLE IV.

TABLE IV. ACCURACY COMPARISON OF EXPERIMENTS TO LAYOUT SCHEMES OF GCPS IN DIFFERENT DENSITY (UNIT: METER)

Schemes		mean square error of GCPs			mean square error of Check Points		
		Num	Planar	Height	Num	Planar	Height
Experiment block(two times in area of standard block)	10	1	1.932	0.089	49	7.552	5.028
	11	4	0.311	0.023	46	0.755	0.195
	12	5	0.31	0.04	45	0.771	0.177
	13	6	0.307	0.033	44	0.793	0.164
	14	6	0.319	0.023	44	0.776	0.208
	15	7	0.331	0.04	43	0.735	0.189
	16	9	0.312	0.039	41	0.762	0.186
	17	15	0.448	0.065	35	0.68	0.208
	18	8	0.435	0.081	42	0.776	0.184
	19	9	0.411	0.038	41	0.741	0.164
	20	12	0.385	0.037	38	0.76	0.165
	21	16	0.467	0.059	34	0.687	0.194
	22	43	0.449	0.053	7	0.672	0.141
Without POS	23	43	0.416	0.058	7	0.681	0.235

1) The check points mean square error of scheme10 is overrun the accuracy restriction, so the triangulation with only one GCP can't meet the requirement of 1:10 000 triangulation.

2) The highest accuracy is scheme 22, where the number of GCPs is most and take POS in calculation; the lowest accuracy is scheme 23, where the number of GCPs is as same as scheme 22, while not take POS in calculation.

3) Scheme 11 and scheme 12 respectively take 4 and 5 GCPs to do triangulation, the accuracy of check points of both schemes are under the restriction. While, because both schemes have few GCPs, accuracies of triangulation are affected by the few GCPs largely. Slight deviation of each GCP may lead to the offset of check points in error distribution region, and the mathematical expectation non-zero, even lead to some check points' accuracy overrun the restriction , as Figure 4. So, scheme 11 and scheme 12 require the measurement to GCPs very accurate, and we don't suggest using them in large-scale triangulation production.

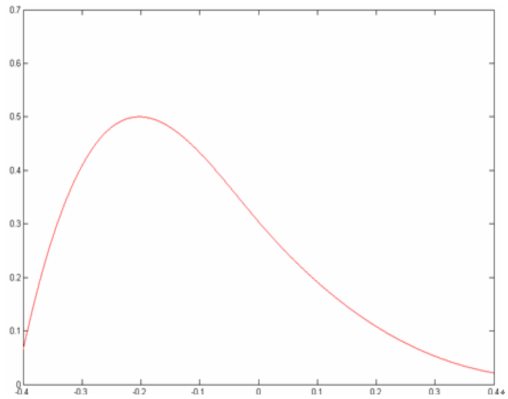

Fig. 4 The distribution curve of height error of check points

4) Scheme13 to scheme21 respectively take 6 to 16 GCPs in triangulation, the accuracy of check points are all under restriction, and the difference of accuracy between each scheme is slight.

IV. DLG PRODUCTION AND ACCURACY MEASUREMENT

Export the outcome of triangulation of scheme 15 to Intergraph ISDM, and draw 1:10 000 DLG, which covered 80 km²area, 51 check points are laid, the coordinates of them are obtained by GPS measurement. The distribution of the check points as Figure 5.

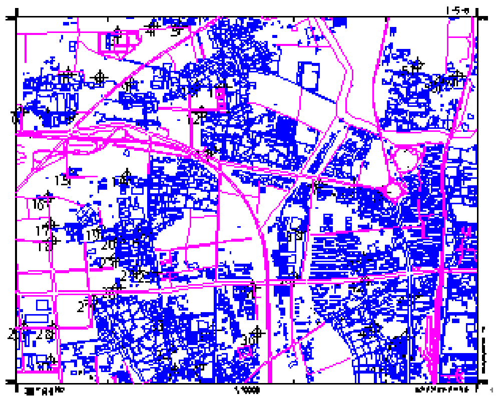

Fig. 5 The distribution of check points in DLG

The mean square error of Check Points is 1.008 meter in plane, which is under the restriction. The distribution of the mean square error of check points as Figure 6.

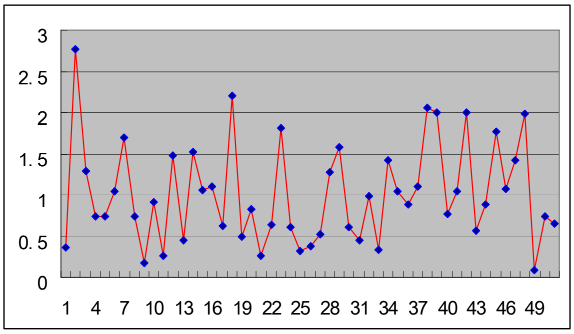

Fig. 6 The distribution of the mean square error of check points

The DLG accuracy measurement experiments indicate that the exportation of the outcome of integrated sensor orientation can meet the requirements of the Criterion [4].

V. CONCLUSION

This paper designed 23 kinds of GCPs layout schemes, to search for appropriate schemes by integrated sensor orientation experiments. Conclusions are drawn as follows:

1) Comparing with conventional triangulation, the integrated sensor orientation can decrease the GCPs in large number, and the accuracy under restriction of 1:10000 DLG of planar area.

2) Any blocks, regardless of size or area, should put at least 4 GCPs at outer corner. It's not necessary to put GCPs on every inner corner of irregular blocks.

3) The accuracy of integrated sensor orientation won't improve with the increase of GCPs. This paper do experiment on blocks of three kinds of size, the must amount of GCPs won't decrease according with the size decrease of block, so the block shouldn't be too small.

4) The error of check points over restriction in some experiments, while the error of control points never overrun the restriction, so integrated sensor orientation should put some check points to estimate the accuracy truthfulness. We suggest 4 to 6 check points put in a block.

5) Scheme13, scheme14, scheme15 and scheme16 are suggested to apply in the production of 1:10000DLG in plain area.

This paper's research made preparation for the application of POS technique on plan area 1:10 000 DLG production, and provide reference for other scale DLG production by POS technique.

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