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BLUH Bundle Block Adjustment Method applied for large size project in Middle East

by

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ABSTRACT

Some advantage and disadvantage of various methods of aerial triangulation have been studied and discussed since they were introduced. "BLUH" Bundle block adjustment method was applied for KUDAMS (Kuwait Utility Data Management System) project which was aiming to establish a land information system containing topographic data, property cadastre data and utility cadastre data covering 580 sq.Km of urban area in the state of Kuwait.

In this report, method of quality control to obtain the required accuracy in the real large size project is discussed.

Comparison of results by using Bundle Block Adjustment and Independent Model Block Adjustment for real project data is also presented.

1. Introduction

It is only the way to represent the accuracy of the adjustedblock by root mean square (RMS) of descripancies of check points , and therefor , usually it is difficult to detect the accuracy of the block adjustment in actual project since known points are often used for control points and check points are not usually provided for the actual project. Therefore we can assume the accuracy of block adjustment only from experience or / and from theoritical investigation. In this sense , the results of experimentation which were performed at Oberschwaben Test Field and the results of research by Prof. Ackerman and others are significant for us. And we can consider that this results are standard. But it is special condition that all of the tie-points were signalized, in actual project.

Bundle Block Adjustment with self-calibration was applied in KUDAMS (Kuwait Utility Data Management) project. The aim of this project was to establish a Land Information system containing topopraphic data , property cadastre data and utility cadastre data hence high accuracy was required. Normal Angle Camera (f=30cm) was used to minimize the dead angle of tall building, however it was believed that normal angle photographs have some disadvantage for block adjustment in accuracy point of view.

This study was started to investigate the accuracy of the block adjustment in actual project. The accuracy of the block adjustment depend upon control distribution and upon the method used for adjustment. Up to now the accuracy of block adjustment using Normal Angle Camera is not reported and it is one the major subject of this report.

With this study the effect of the control distribution on the accuracy was investigated. The determination of accuracy relation of different methods (Bundle and Independent Model) of adjustment , based on the exactly same materials was also investigated.

On the othier hand the following condition in this study have to be noticed whichis due to a reason that materials of the study were obtained from real project but not from scientific research program.

-- Tie-pionts were not signalized
-- Check points were not sufficient (small number, poor distribution)
-- It is flat terrain

2. Scope of Block Adjustment of KUDAMS

Total number of photos to be adjusted		5365 photos
Block size	average	335 photos
	maxmum	572 photos
	minimum	128 photos
Photo scale		1:3400
Camera		Normal Angle (f=302mm)
Relative flying height		1020 m
Over-lapping	forword	60 %
	side	35 %
Base-length		306 m

UNIVAC 1100/71-II computer at Asia Air Survey Co., Ltd. was used for this computation. The planimetric control points distribution only along the perimeter of each blocks. The distance of control points are denoted by i and expressed in multiple of the base-length. The average distance of control points on the perimeter is two times as base-length. The bridging distance which is the distance between chains of height control points is also 2 times as base-length. Error of terrestrial control is supposed to be negligible.

3. Bundle Block Adjustment

The bundle block adjustment was performed at Asia Air Survey Co., Ltd. in Atsugi, Japan using UNIVAC 1100/71-II computer and the program BLUH (Bundle Block Adjustment University Hannover). The original image coordinates were measured using analytical stereo plotter Kern DSR-1 with aerial triangulation system to avoid less accuracy and to detect large descripancies of tie-points between the neighbored models during measurement.

The BLUH includes a set of 24 different additional parameters (24 different formulas for the correction of the photo coordinates). In BLUH, the blunders of the data can be detected and considered by the method of robust estimators and 4 different statistical test (correlation,student test,total correlation and student test of a posteriori orthogonalized additional parameter) are used for checking the necessity of the single additional parameters,but these involves much extra work.

The weight 1 was applied for all image coordinates.

In order to obtain optimum results, at first the blunders should be detected. The blunder detection should be done at first in the adjustment without additional parameters. After that,all additional parameters should be included in the adjustment. Then additional parameters which have to be excluded in to the following adjustment are discriminated by program itself.

4. Real Job Step of Adjustment of KUDAMS

The original colour positive films were used to avoid less accuracy for measurement. All measurements were performed by the analytical stereo plotter Kern DSR-1 and the coordinates were transformed in to the plate coordinate system by Affine transformation (6-parameters transformation) . The radial lens distortion , refraction and earth curvature were not corrected at this stage.

The actual adjustments consist of following 3 steps.

Step 1. Preliminary check by PDP version of BLUH

Because of the limited memory of PDP, each block were subdivided in small blocks that consist of 80 photos. This step was carriedout to detect the gross errors of measurements.

The criteria of this check were as follows.

-- Descripancy between photo coordinates of common points of neighbored photos		:	20 microns
— RMS of relative orientation		:	10 microns
-- Residuals of control points	planimetry	:	5 cm
	height	:	15 cm

This adjustment included a set of 12 different additional parameters with the robust estimator.

Step 2. Intermediate check by UNIVAC version of BLUH

The following criteria were applied for this check.

— Difference of photo coordinates measured in neighboured photos		:	20 microns
— RMS of relative orientation		:	10 microns
-- Sigma 0 of photo coordinates		:	6 microns
-- Residuals of control points	planimetry	:	5 cm
	height	:	15 cm

This adjustment included a set of 24 different additional parameters with the robust estimator.

Step 3. Final adjustment by UNIVAC version of BLUH

Final adjustment was excuted with unit weight of image coordinates of 1, with parameters obtained of step 2 result and without robust estimator. Criteria of the residuals of control points for planimetry was 5 cm and for height was 15 cm, and sigma 0 of photo coordinates was 8 microns.

Any points exceeding the criteria mentioned above were remeasured.

5. Result of Block Adjustment

A block which most number of check points are available was chosen to investigate the accuracy of the block adjusted and it was performed using exactly same materials as actual adjustment. No addition/deletion of measurement was carried out for this investigation.

Results of this investigation are shown as follows.

-- Shape of block		nearly rectangular
-- Number of strips		13 strips
-- Number of photos		475 photos
-- Number of points per photo in average		22.3 points
-- Sigma 0 of image coordinates		4.61 microns
-- RMS of residuals of control points	X	0.012 m
	Y	0.014 m
	H	0.029 m
-- RMS of residuals of check points	planimetry	0.062 m
	height	0.058 m

Control distribution

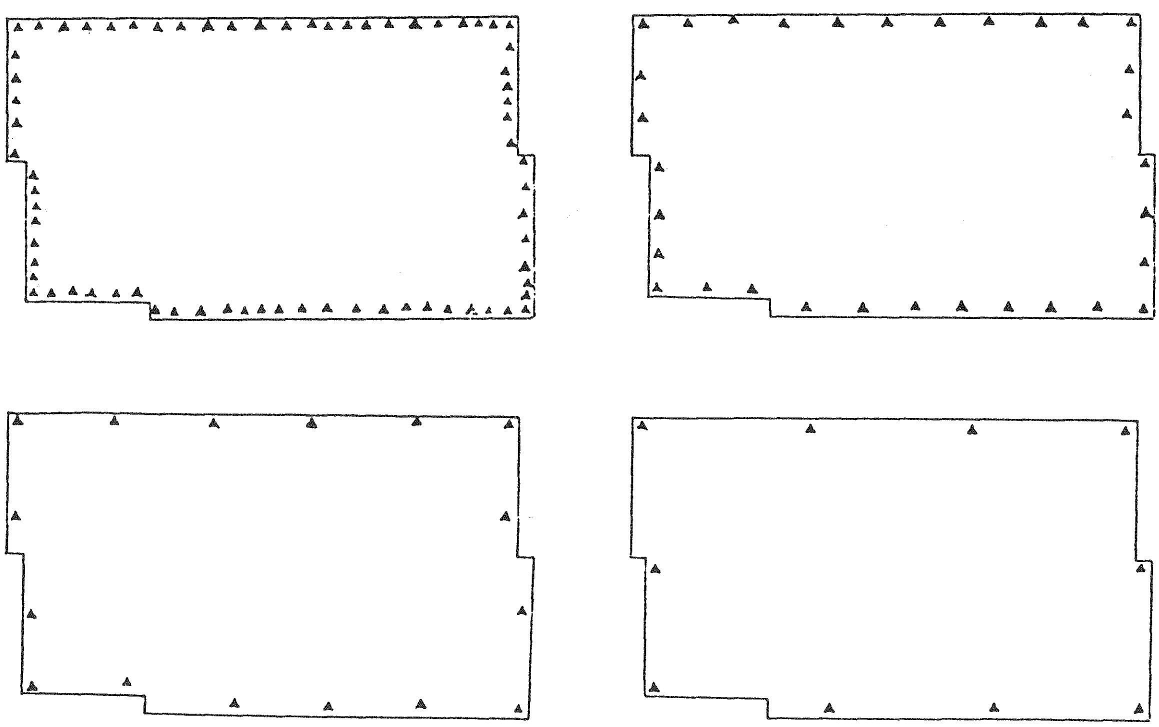

Figure - 1

Sigma 0 represents standard deviation of image coordinates in unit weight. RMS of the errors of the coordinates of check points are expressed by μ_{xy} and μ_z , where $\mu_{xy}=\sqrt{\mu_x^2+\mu_y^2}$. The control points distributions both planimetry and height are described in section 2 of this paper. RMS of check points in height is equal to 0.06 ‰ of relative flying height. It is high accuracy in spite of the normal angle camera was used.

6. Compensation of the systematic image error by the additional parameters

Bundle block adjustment without parameter were also carried out using actual block of KUDAMS that is shown on section 5 to investigate the effort of additional parameters. The control distribution that are represented in figure 1 and 2 were adjusted without and with additional parameters. The mathematical model for compensation of systematic error of BLUH were formerly reported by Dr. H. K. Jacobsen, Hannover university.
The results of both adjustment are compared in Table 1. Table 1 contains the accuracy ratios between corresponding adjustments. When additional parameters are applied into the block adjustment σ_0 becomes considerably smaller and the dependency oh control distribution disappears.The accuracy obtained by bundle block adjustment with additional parameters is compared with bundle block adjustment without additional parameter in figure 2 and 3. In both figures corresponding results are plotted.

Comparison of without and with additional parameters in bundle block adjustment

control distribution		with add. param.			without add. param.			accuracy ratio		
plan	height	sigma 0	μ_{xy}	μ_z	sigma 0	μ_{xy}	μ_z	sigma 0	μ_{xy}	μ_z
		um	m	m	um	m	m			
i= 2	i= 2	4.61	0.062	0.053	5.93	0.066	0.063	1.29	1.06	1.09
4	4	4.52	0.068	0.058	5.78	0.096	0.101	1.28	1.41	1.74
8	8	4.48	0.071	0.091	5.56	0.142	0.257	1.24	2.00	2.82
12	12	4.47	0.137	0.177	—	—	—	—	—	—

Table - 1

With 4.5 um sigma 0 is close to the noise limit (random error) that we can expect todays photogrammetry.

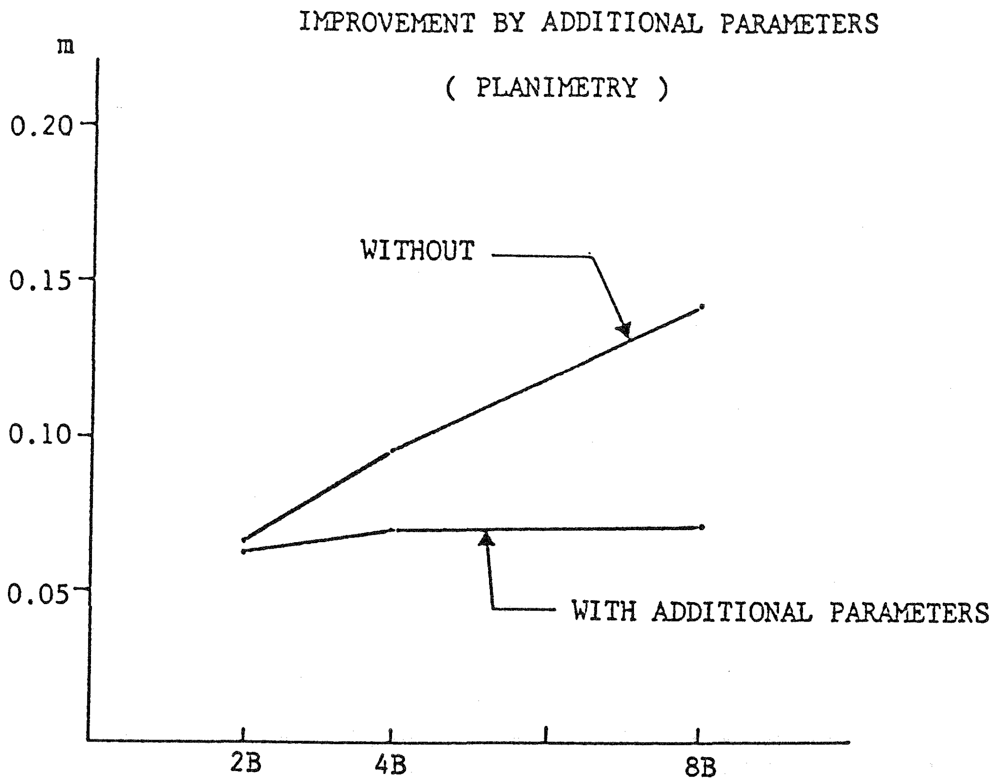

Figure - 2

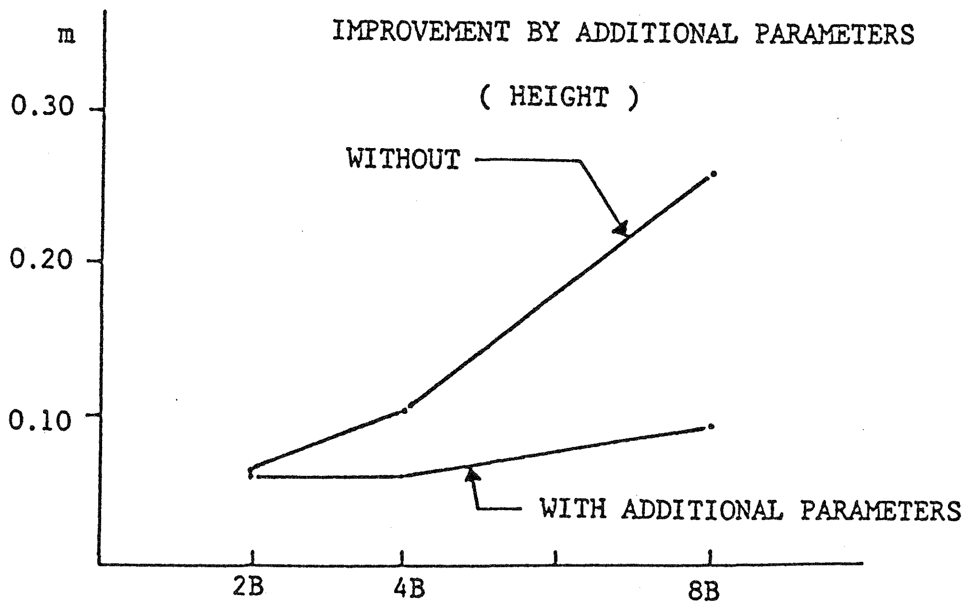

Figure - 3

7. Comparision of different method of Block Adjustment

The data used in this study is part of actual data collected for KUDAMS project. The detailed information of this block is described on section 2 and 5 in this paper.

Control points distributions that are presented in figure 1 were used. To allow for a valid comparison of different methods of block adjustment, exactly same control points were used with independent models and bundles. It should be mentioned here that no priori correction of image or model coordinates was performed. The independent model adjustment were also performed at Asia Air Survey Co., Ltd. using a UNIVAC 1100/71-II computer and program PAT-M43 without self-calibration.

For independent model adjustment the input data were weighted as follows.

-- coordinates of model points
x,y weight 1 , z weight 1
-- coordinates of perspective centers
x,y weight 0.25 , z weight 1
-- coordinates of control points
X,Y weight 100000 , H weight 100000
-- coordinates of check points
X,Y weight 0 , H weight 0

It is recommended by Prof. Ackerman in his paper.

The radial lens distortion , refraction and earth curvature were corrected during block adjustment.

Independent model block adjustments were also performed for the four cases of the control distributions which are shown in figure 1. The accuracy obtained by bundle block adjustment without and with additional parameters are compared with the accuracy after independent model block adjustment in Table 2 and 3. In both Tables contain the accuracy ratios of both methods. In figure 4 and 5 the accuracies obtained by bundle block adjustments with additional parameters are graphically compared with independent model block adjustments. In both figures the corresponding results are plotted.

With independent model block adjustment the corresponding σ_{0XY} and σ_{0Z} , represent the accuracy of model coordinates in planimetry and height, were not influenced by the control distributions.

Comparison of independent model and bundle without additional parameter

control distribution		bundle without addi. param.			independent model				accuracy ratio	
plan	height	sigma 0	μ_{xy}	μ_z	sigma 0_{xy}	μ_{xy}	sigma 0_z	μ_z	μ_{xy}	μ_z
		um	m	m	um	m	um	m		
i= 2	i= 2	5.93	0.066	0.063	6.47	0.055	30.88	0.068	0.83	1.08
4	4	5.78	0.096	0.101	6.18	0.065	31.47	0.102	0.68	1.01
8	8	5.56	0.142	0.257	6.18	0.083	31.18	0.266	0.58	1.04

Table - 2

Comparison of independent model and bundle with additional parameters

control distribution		bundle with addi. param.			independent model				accuracy ratio	
plan	height	sigma 0	μ_{xy}	μ_z	sigma 0_{xy}	μ_{xy}	sigma 0_z	μ_z	μ_{xy}	μ_z
		um	m	m	um	m	um	m		
i= 2	i=2	4.61	0.062	0.058	6.47	0.055	30.88	0.068	0.89	1.17
4	4	4.52	0.068	0.058	6.18	0.065	31.47	0.102	0.96	1.76
8	8	4.48	0.071	0.091	6.18	0.083	31.18	0.266	1.17	2.92
12	12	4.47	0.137	0.177	6.18	0.118	30.59	0.597	0.86	3.37

Table - 3

8. Concluding Remarks

— Accuracies both in height and in planimetry are improved by simultaneous self-calibration.

— Accuracy improvement by self-calibration in planimetry is smaller than in height.

— Self-calibration improves the accuracy more with poorer the control distribution.

— Independent model block adjustments gives a higher accuracy in planimetry however slightly a lower accuracy in height than bundle block adjustments without additional parameter.

— The not higher results in planimetry of the bundle block adjustment without additional parameter are suprising. From this fact , we can consider that the systematic errors impair the bundles block adjustment more then independent models.

— Bundle block adjustments with additional parameters give a much higher accuracy in height than independent model block adjustments.

— Up to today, it was considered that the normal angle cameras are not useful for block adjustment. However, from this investigation it can be used for block adjustment. This fact is great advantage for specially large scale mapping in urban area which are made up tall buildings.

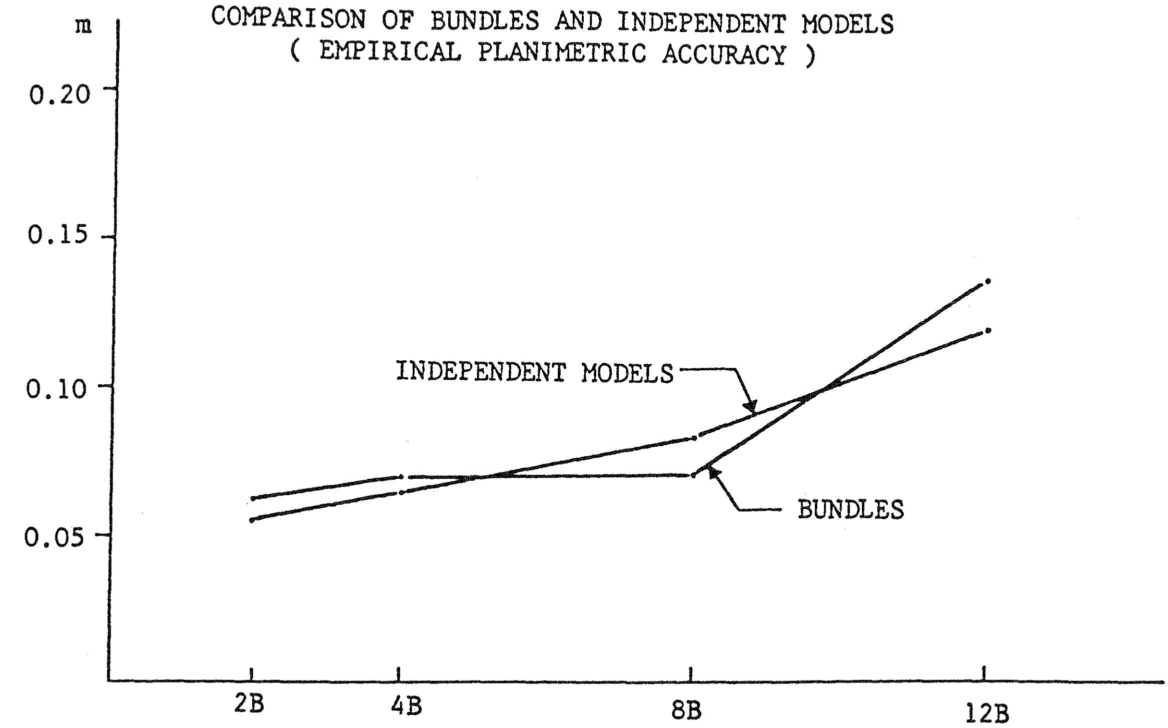

Figure - 4

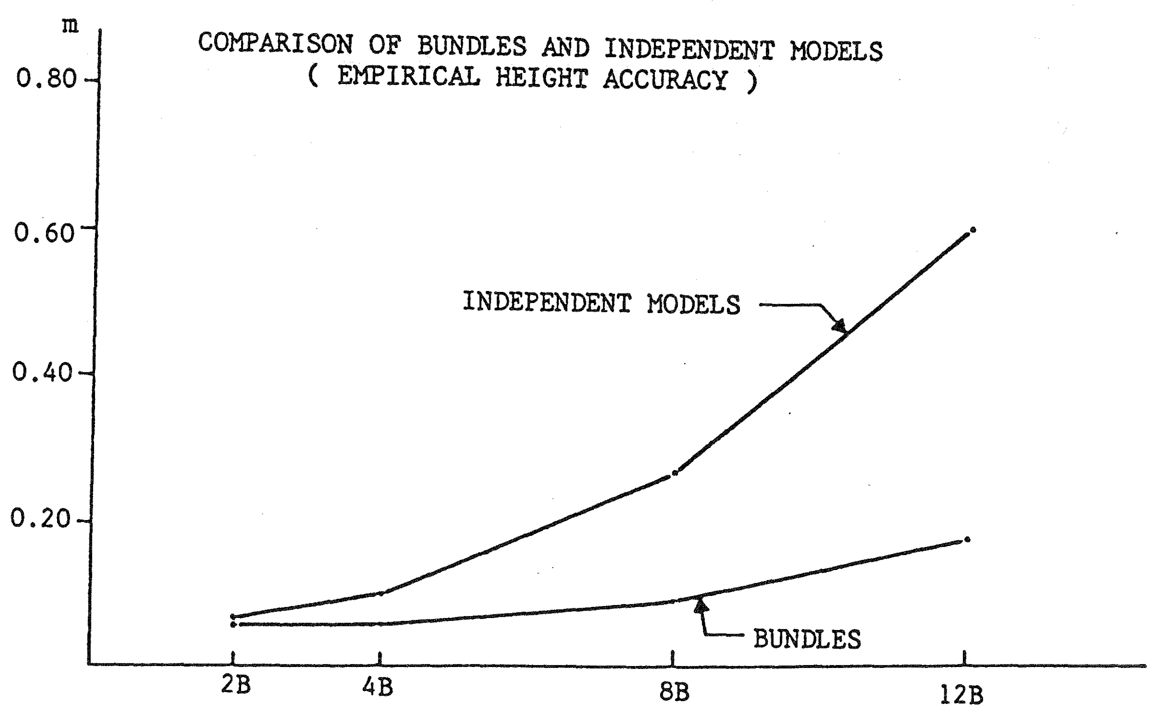

Figure - 5

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