BUNDLE ADJUSTMENT WITH MODEL COORDINATES

Karsten Jacobsen

University of Hannover

Abstract

Model coordinates can be transformed into quasi-photo coordinates and be used in bundle block adjustments. Also if only analog plotters are available the advantages of the bundle method can be used. But some geometric information are lost by the creation of models. So with quasi-photo coordinates computed from model coordinates only the accuracy of block adjustments with independent models can be reached. In relation to a bundle block adjustment, the accuracy of the height can be reduced in using model coordinates as original information by 100%.

Key Words: Bundle Block Adjustment, Independent Models, Model Coordinates

1. General

Even with the increasing number of analytical plotters also today not every photogrammetric company or governmental photogrammetric department is equiped with it or with comparators. In such a case a block adjustment must be based on model coordinates. A bundle block adjustment can be done only with photo coordinates but it is possible to transform model coordinates into quasi-photo coordinates. If this will be done, it is not necessary to use the method of independent models. So the bundle block adjustment can be used with the opportunity of later increase of accuracy if with new devices the data aquisition of photo coordinates will be possible.

Based on photo coordinates model coordinates have been calculated and a back transformation to quasi photo coordinates has been done. The loss of accuracy caused by this has been analysed. This is corresponding to the loss of accuracy by the block adjustment with independent models against the bundle block adjustment if photo coordinates are available. All steps of computation and analysis have been done with the Hannover program system BLUH.

2. Transformation of Model Coordinates into Quasi-Photo Coordinates

The original geometric information in photogrammetry are the bundle of rays from the projection centers over the photo points to the object points. Together with the inner orientation the measured photo coordinates are the required data for the reconstruction of the geometric situation. Model coordinates (also from analog plotters) are derived data. A back transformation from model coordinates to photo coordinates is not exactly possible. At first the y-parallax has been lost and there is no information about the orientation of the photos. But it is possible to transform neighboured models threedimensional together based on tie points and the projection centers (see figure 1).

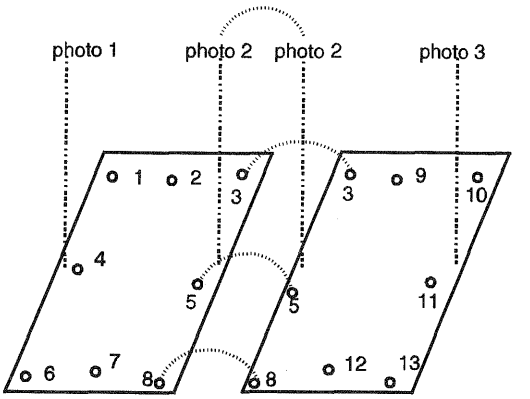

Fig. 1: 3-dimensional transformation of neighboured models

The transformation of the points in the united models to a plane with a distance of the focal length from the projection centre will deliver quasi-photo coordinates (see figure 2). With these quasi photo coordinates the original bundle of rays can be reconstructed like with the original photo coordinates.

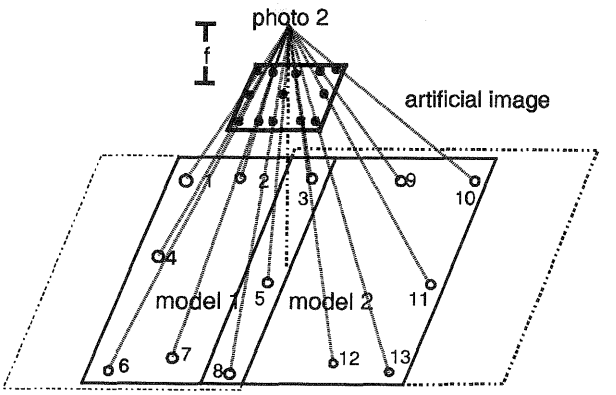

Fig. 2: transformation from united model to quasi-photo coordinates

Nevertheless there is a difference in the orientation of these artificial photos to the original photos. This will not influence directly the bundle block adjustment, but of course the adjusted

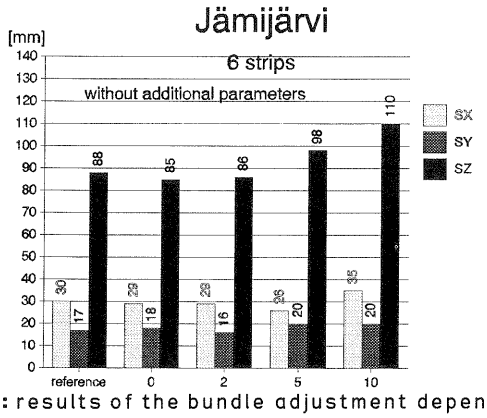

Fig. 5: results of the bundle adjustment depending upon the rotation of the quasi-photo coordinates - Jämijärvi q=60%, without selfcalibration 8+1 control points

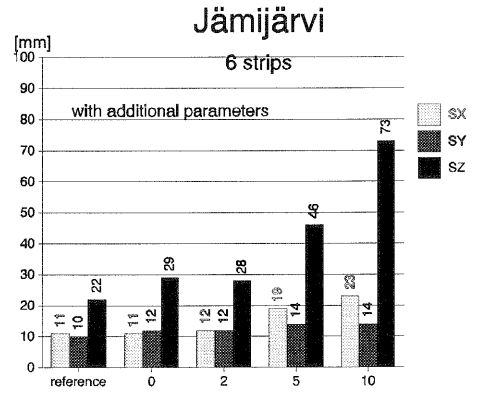

Fig. 6: Jämijärvi q=60%, with selfcalibration 8+1 control points

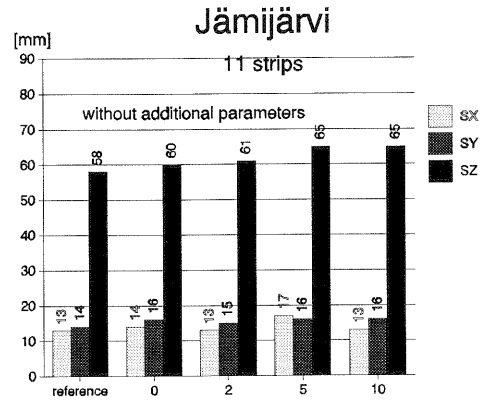

Fig. 7: Jämijärvi, crosswise q=60%, without selfcalibration, 8+1 control points

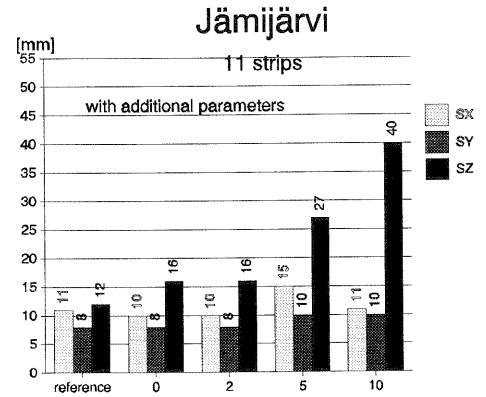

Fig. 8: Jämijärvi, crosswise q=60%, with selfcalibration, 8+1 control points

The shown results of the bundle block adjustments with the data of the block Jämijärvi are representing the results determined with independent check points. It is obvious that in the mean the adjustments with the original photo coordinates are the most accurate. But the loss of accuracy by the use of the quasi-photo coordinates without selfcalibration by additional parameters is limited. The results are demonstrating the requirement of the adjustment with selfcalibration. The standard deviation SZ will be reduced by self calibration to ~20% and SX and SY to ~50%. The systematic image errors are smeared by the transformation from model to photo coordinates, by this reason the systematic image errors cannot be determined correctly. This is causing a loss of accuracy by the block adjustment with selfcalibration with the quasi-photo coordinates. Also without artificial rotation of the quasi-photos the vertical accuracy is decreased between 10% and 30%.

With artificial rotation of the models before transformation, the loss of accuracy by block adjustment with quasi photo coordinates is raising. For a rotation of ±5grads SZ is enlarged up to 3 times, SX and SY up to 50%.

A raising number of control points is reducing the influence of the photo rotations and also the loss of accuracy by block adjustment based on model ccoordinates.

3.2 Block Blumenthal

The block Blumenthal has been used for determination of subsidences in a coal mining area.

photo scale: 1 : 3800
focal length: 152 mm
side lap: 60% + crosswise 60%
number of photos: 280
number of photos/ground point:
mean: 7 maximal: 16
22 horizontal, 109 vertical control points
area: 30 km^2

Table 3: technical data of block Blumenthal

The block adjustment has been checked with 15 horizontal independent check points to SX=±17mm, SY=±20mm and with just 4 vertical independent check points to SZ=±15mm. From corresponding block adjustments the vertical accuracy is known with approximately SZ=±27mm.

Because of the limited number of check points the block adjustments with quasi-photo coordinates have been compared with the ground coordinates of the reference adjustment.

photo orientations cannot be used for set up of the model in an analytical plotter. Caused by the uncertainty of the photo orientations it is not possible to have an exact self calibration by additional parameters. The calculated systematic image errors are smeared like in the case of the block adjustment by independent models. In addition there is a negative influence of the relative orientation in the procedure. The distribution of the points in the models are different from model to model, so in the relative orientation remaining errors are influencing also the other points in the model. The same is happening with the systematic image errors.

3. Empirical Bundle Block Adjustment with Model Coordinates

The results of different bundle block adjustments with the original and the quasi photo coordinates have been analysed. The results of two blocks are shown more in detail.

3.1 Block Jämijärvi

The test block Jämijärvi is located in Finland. The photo coordinates have been used for comparison of data handling in bundle block adjustments by the WG III/3 of the ISPRS in 1978. For the points in the center of the block ground coordinates with standard deviations better than ±1.5mm are available.

photo scale: 1 : 3300
focal length: 152mm
side lap: 60% + crosswise also 60%
number of used photos: 88
number of photos/ground point:
mean: 8 maximal: 17

Table 1: technical data test block Jämijärvi

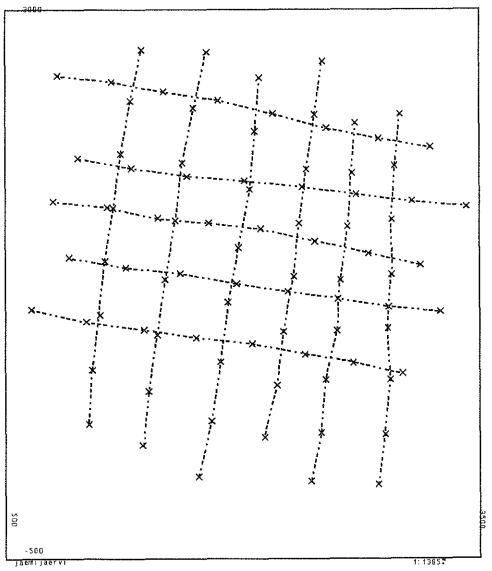

Fig. 3: configuration of block Jämijärvi

Following configurations have been used: block with 6 strips (E-W-direction 60% sidelap), 11 strips (E-W-direction 60% sidelap + N-S-direction 60% sidelap), both blocks with the control point configuration 9 (8 complete points at the periphery - 4 base length distance, + 1 vertical point in the center), with the configuration 13 (same complete control points like 9 + 5 vertical control points - raster 2 -4 base length distance) and with the configuration 36 (20 complete control points at the periphery - 2 base length distance, + 16 vertical control points - raster 2 base length distance).

If model coordinates (from analog or analytical plotters) are used, the original photo orientation for the transformation from the united models to the quasi-photo coordinates is not known. By this reason the model coordinates have been rotated before transformation to check the influence of these rotations to the block adjustment.

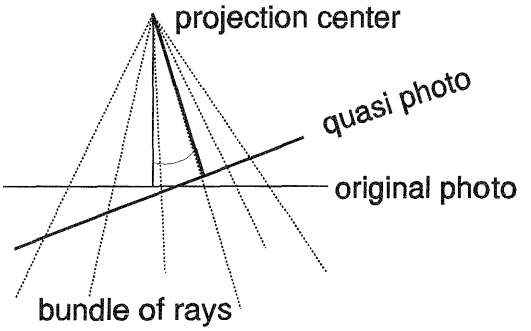

Fig. 4: relation between original and quasi photo

The transformations have been done without artificial rotation of the quasi photo, with ±2 grads, ±5grads, ±7grads and ±10grads.

rotation of photos	Jämijärvi 8 horizontal, 9 vertical control points: 6 photo strips, no self calib. Sx	Sy	Sz	6 photo strips, self calibration Sx	Sy	Sz	11 photo strips, no self calibr. Sx	Sy	Sz	11 photo strips, self calibration Sx	Sy	Sz
reference	30	17	88	11	10	22	13	14	58	11	8	12
0	29	18	85	11	12	29	14	16	60	10	8	16
2 grads	29	16	86	12	12	28	13	15	61	10	8	28
5 grads	26	20	98	19	14	46	17	16	65	15	10	27
10 grads	35	20	110	23	14	73	13	16	65	11	10	40
	Jämijärvi 8 horizontal, 13 vertical control points											
reference	28	17	42	10	10	24	13	14	32	11	8	11
0	28	17	42	12	12	28	14	17	30	11	8	14
2 grads	28	16	43	12	12	29	14	16	32	10	8	14
5 grads	26	19	48	19	14	42	17	16	36	15	10	21
10 grads	34	20	52	25	14	43	13	17	34	15	10	22
	Jämijärvi 20 horizontal, 36 vertical control points											
reference	20	12	24	8	8	15	9	9	21	7	6	11
0	19	14	25	9	9	20	10	10	19	8	7	12
2 grads	19	13	26	9	8	20	10	10	20	7	7	11
5 grads	20	16	34	13	12	28	12	11	25	10	9	17
10 grads	22	16	33	14	12	27	10	11	21	8	8	14

Table 2: accuracy of the ground coordinates [mm] determined by bundle adjustment with the original (reference) and the quasi photo coordinates depending upon the rotation of the quasi photo coordinates

rotation of photos	Blumenthal 1987					
	without selfcalibration			with selfcalibration		
	Sx	Sy	Sz	Sx	Sy	Sz
0	8	7	32	8	8	23
2 grads	13	12	37	13	13	29
5 grads	8	8	35	8	8	29
7 grads	10	9	39	9	9	35
10 grads	9	8	38	10	10	41

Table 4: mean square differences of the ground coordinates [mm] determined by bundle adjustment with the quasi photo coordinates in relation to the reference adjustment depending upon the rotation of the quasi photo coordinates

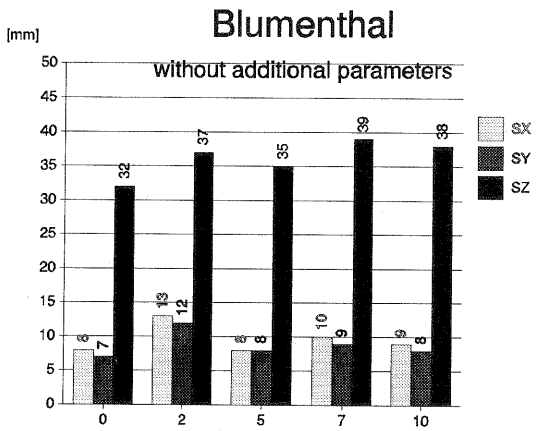

Fig. 9: mean square differences of the bundle adjustments depending upon the rotation of the quasi-photo coordinates
- Block Blumenthal without selfcalibration

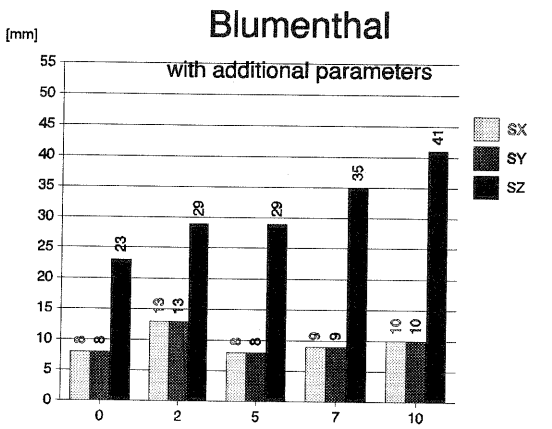

Fig. 10: mean square differences of the bundle adjustments depending upon the rotation of the quasi-photo coordinates
- Block Blumenthal with selfcalibration

Corresponding to the results of the block Jämijärvi the rotations of the quasi-photos do have the largest influence in the case of the block adjustment with selfcalibration. The effect to the horizontal coordinates is limited but nevertheless also without artificial rotations the differences of the adjustment are reaching 50% of the standard deviations of the reference adjustment. In the case of the height the differences to the reference adjustment are reaching and exceeding the size of the accuracy of the reference adjustment. This is corresponding to the loss of accuracy of block adjustments with independent models in relation to bundle block adjustments determined in practical applications.

4. Conclusion

Model coordinates can be transformed into quasi-photo coordinates by the program system BLUH and be used for a bundle block adjustment. The quality of such an adjustment is corresponding to the block adjustment by the method of independent models. Like in the case of the independent models the loss of the information of the y-parallax is reducing the reliability and also the accuracy. In addition the systematic image errors are smeared in the model and of course also in the back transformed quasi-photo coordinates. The exact information about the principal point will be lost during the calculation of the model coordinates, this is causing an additional smearing effect. Corresponding to this the loss of accuracy is increasing with the size of the random nadir distance of the photos. This effect will be seen especially by block adjustments with selfcalibration by additional parameters.

The loss of accuracy caused by the use of model coordinates for the block adjustment is unimportant in the case of a data aquisition with analog instruments - in this circumstance the limited accuracy of the data is dominating the adjustment. But if analytical plotters are used, the registration and use of model coordinates will lead to an unnecessary loss of accuracy, especially for the height. The photo coordinates should be recorded and used by bundle block adjustment with selfcalibration by additional parameters. The data handling in modern bundle block adjustment program systems is more flexible and not more complicate than the data handling with independent models.

References

Pollak, B., 1990: Bündelblockausgleichung mit Modellkoordinaten, diploma thesis University of Hannover 1990

Jacobsen, K., 1982: Attempt at obtaining the best possible accuracy in bundle block adjustment, Photogrammetria 1982, pp. 219-235

Wenck, U.-H., 1991: Einfluß unterschiedlicher Bildorientierungen auf die Bündelblockausgleichung mit Modellkoordinaten, diploma thesis University of Hannover 1992