Data Collection for Bundle Block Adjustment on Analytical Plotters

Karsten Jacobsen
University Hannover
FR of Germany
Commission III

1. Introduction

Up to two years ago, the photo measurements for bundle block adjustment of the University Hannover have been done with comparators. The measurements have been time consuming and no online check was possible. Caused by this, a photo arrangement of 60 % endlap and 20 % to 35 % sidelap was used and a lot of blunders have been included in the data. In addition, the reliability of the computed object point coordinates was poor, because of the small number of photos for each object point.
Now the use of modern analytical plotters has changed the data collection and this also has influenced the block constellation. If a point was measured in a photo or model, this information can be used for an automatic accurate or approximate pointing in other photos or models. So the use of photos with a higher overlap will raise the time for data collection not so much.
The topic of this paper is only the data collection for high accurate bundle block adjustments. That means, the object points are signalised or they are well defined topographic objects.

2. Program for Data Collection

The advantage of analytical plotters is depending upon the software. Usual the standard software is limited in the possibilities. By this reason, a program for supported measurement of photo coordinates for bundle block adjustment was made for the Zeiss Planicomp with the computer HP 1000. This program has following main possibilities:

- measurement of fiducial marks or reseau points with automatic approximate pointing;
- measurement of photo points, partially with approximate or accurate automatic pointing;
- optional second measurement of the photo points in reverse sequence;
- second measurement of fiducial marks or reseau points;
- computation of relative orientation including statistical tests and transformation of the model to the approximate computed block.

Only numbers of points which have not been measured before or for which no approximate position is available, have to be typed.
The fiducial marks or the reseau points are numbered corresponding to their location in the camera. That means, the same fiducial mark can be sometimes on the left hand side and sometimes on the right hand side in the analytical plotter, depending upon the flight direction of the individual strip. The automatic numbering will be done corresponding to the answer to

the dialog question for the location of the photo side information. So the photo coordinate system is unique and the additional parameters can be computed without any problem in the bundle block adjustment.
The automatic approximate pointing can be done by using photo coordinates of models before, approximate photo coordinates from a digitizer or approximate ground coordinates. If accurate photo coordinates are available - in one photo of the new model in the overlapping area of the models or in the case of a second measurement - these points are measured again, but for getting independent values, no exact automatic pointing will be done. The floating mark will go 50 microns beside the centre. Only in the case of not well defined topographic points, the exact location will be pointed to make a point transfer possible.
A changing of the temperature can have a remarkable influence to the measured plate coordinates. To eliminate this and to have an independent pointing, which also can be used as first quality control, a second measurement of each point in the model should be done in the reverse sequence. This second measurement can be done very fast, because the operator only has to do the exact pointing. In any case a second measurement of the fiducial marks or reseau points should be done. So temperature effects and a lost of the coordinate reference can be checked. If the difference to a measurement before exceeds a limit, a warning is comming immediately and the operator has to choose whether he can accept the difference or not.
The photo coordinates of the whole model are tested by the computation of a relative orientation. This includes the computation of the partial redundance r and the normed correction w. The partial redundance can be very different from point to point, so no conclusion can be made without the normed correction.

$$v_i = - r_i \cdot \varepsilon_i$$

v_i = residual
ε_i = error of the observation

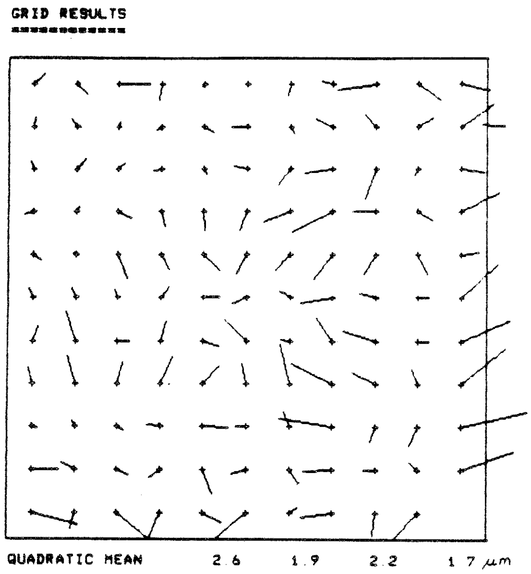
$$r_i = (\underline{Q}_{vv} \cdot \underline{P}_{ee})_{ii}$$

$\underline{Q}_{vv}$ = cofactor matrix of observations
$\underline{P}_{ee}$ = weight matrix of observations

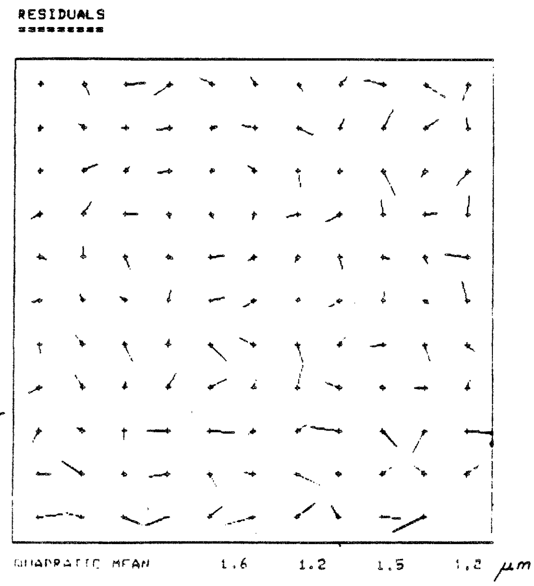
$$w_i = \frac{v_i \cdot \sqrt{P_i}}{\sqrt{v_i} \cdot \sigma_o}$$

w_i = normed correction
P_i = weight of the observation
σ_o = a posteriori standard deviation of unit weight

If more than one blunder or not accurate measurement is included in the model, it can be difficult to analyse the result. For this reason, the computation can be repeated without some points, but they are still available in the data set.
After acceptance or remeasurement of points, the corrected photo coordinates are stored. The correction can include the radial symmetric distortion, refraction and a correction of the photo carrier coordinates. The Planicomp is working with spindels and they can have systematic errors. Intensive tests have shown, the errors of the photo carrier system can be reproduced. So a correction is possible.
With correction of the photo carrier coordinates on the base of grid measurements, the Planicomp can reach a standard deviation of $\pm$ 2.0 microns. Also for high accurate bundle block adjustments this is sufficiant.



Planicomp calibration



residuals after transformation

3. Experience in Data Collection

The described program and the standard program of the Zeiss Planicomp, and the standard program of the Kern DSR1 have been used for photo measurements.
The comparison of the different methods had following results:

- A relative orientation should not have an influence to the photo measurements. Even if the measurements for the relative orientation are done very careful, the standard deviation of pointing the y-component will raise 50 % and more. Inevitable discrepancies in pointing and at this stage unknown systematic image errors will have an influence. In addition the y-components of both photos are not independent.
- The computer directed sequence of observation - one photo, than other photo, than stereoscopic control - has been optimal. In this case both pointings are independent and the not signalised points can be corrected stereoscopic.
- The measurement of one model should not be disturbed by data organisation done by the operator. The best results are achieved if each model can be measured fast and without interrupt. Every interrupt will raise the number of blunders, number of wrong point numbers and number of forgotten measurements, if there is no automatic pointing by the program.
- A second measurement of the points in a model is not time consuming if the approximate pointing will be done by the program, but the operator will be led to a more careful pointing if he can see the differences of a second measurement and he will get a better feeling to the pointing accuracy of the different point groups, what can be used for different weights in the block adjustment.
- Especially for not signalised points the first data test with the computation of a relative orientation is important. Unaccurate or wrong points can be remeasured immediately, supported by automatic pointing.

The number of blunders has not exceed 2 %. More often unaccurate measurements have been detected.
In the case of few points in a model, the partial redundance can be very small. Also the normed correction is not in every case able to locate blunders. But it is not economic to include more points if this is not necessary for bundle block adjustment. The power of the test of the final block adjustment is in every case better than any partial pre adjustment and it is better to remeasure later some photos than to raise the number of points in the photos.

4. Experiences with Bundle Block Adjustments

The advantage of automatic pointing has led to a changed block configuration for high accurate bundle block adjustment, which is necessary for net densification and cadastre. In this case now an endlap of 80 % to 90 % and also crossed strips at the block boundary are used (see appendix). In the average, in these blocks, each object point is measured in approximate 7 photos. The high reliability and the method of the robust estimators in the block adjustment uncovers every blunder. On this basis no more than one per mille blunders have been included in the data, collected with the self developed program. Because of the high number of observations per object point, no photo had to be remeasured and every point was determined. This result was achieved in blocks with 90 % signalised points and 10 % well defined topographic points but with low quality photos.

5. Need of Online Triangulation?

The self developed program for data collection does not include a bundle block adjustment. Intensive offline investigations have shown the low advantage of an adjustment of subblocks against a stripwise computation. The model, which shall be tested and which is placed in the analytical plotter, in any case is located at the corner of the subblock measured up to that stage. So the power of the test is limited.
The low advantage of a bundle block adjustment does not justify the time for the computation. On mini computers also optimised programs for bundle block adjustment do not have a negligible computing time, and the operator has to wait for the result.
If the online triangulation is defined as a really online computation after each single measurement for test purposes, the question for the need can be answered with no. If the online triangulation is defined as a mathematic correct computation of subblocks after the completion of a model, the question has to be answered - it is not economic on mini computers. But if the online triangulation is defined as online computation for automatic approximate pointing and test after the completion of a model with strip methods, which can be computed very fast, there is no doubt of the need. The possibilities of the analytical plotters should be used in this way.

Reference

K. Jacobsen: Experience in Blunder Detection for Aerial Triangulation
ISP Rio de Janeiro, 1984, Com. III

Photo Arrangement