Experiences in GPS Photogrammetry

Abstract

Some tests for combined block adjustment with kinematic GPS coordinates of the projection centers have been carried out by the University of Hannover. The photogrammetric data handling has been solved, but up to now the GPS data are more or less disturbed. That means that the photogrammetric data processing has to compensate for such problems. The results of the combined adjustment of disturbed data are satisfying. Due to the considerable cost reduction of the whole process — the number of control points can be reduced to just four — there is a strong request for practical application. A good organization of the photo flight and the selection of suitable hardware components is very important to avoid unnecessary problems.

Introduction

Mapping and precise point determination by photogrammetry have been shown to be an economic solution. For reference to the national net, control points are required. Based on block adjustment, the number of required control points has been reduced but the ground survey is nevertheless a not negligible part of the expenses. With crossing strips, the number of vertical control points can be reduced, but there is still a strong need for a further reduction of the control information.

Figure 1 shows a typical control point configuration for precise point determination (photo scale 1:4000; endlap 80 percent; sidelap 30 percent; 454 photos; 20 horizontal control points at the periphery, marked by double symbols in Figure 1, and 133 vertical control points equally distributed).

The ground survey for the control points took approximately 30 percent of the overall cost of precise point determination (photo flight, control point survey, photo measurements, and computations).

With crossing strips, the block adjustment can be computed with only four control points in the block corners, but the accuracy is usually not sufficient.

In Figure 2, the differences in the results of a bundle block adjustment with the Hannover program system BLUH based on just four control points in the block corners and with only two crossing strips when compared to independent check points are apparent. Differences in Z are shown by vertical vectors, and differences in X, Y by vectors in the corresponding horizontal directions.

The root-mean-square differences are as follows:

With self-calibration:

$$\text{RMS}X = \pm\ 10\text{ cm},\ \text{RMS}Y = \pm\ 8\text{ cm},\ \text{RMS}Z = \pm\ 217\text{ cm}$$

Without self-calibration:

$$\text{RMS}X = \pm\ 21\text{ cm},\ \text{RMS}Y = \pm\ 25\text{ cm},\ \text{RMS}Z = \pm\ 77\text{ cm}$$

With 20 horizontal and 133 vertical control points at independent check points, the differences in the horizontal components are ± 2 cm and the differences in height are ± 3 cm. This indicates that the results based on just four control points are not adequate. It is possible to stabilize the block adjustment with additional observations such as the projection center coordinates determined by kinematic GPS positioning.

In the past, additional observations from horizon cameras, statoscopes, shore lines, airborne profile recorder, radar altimetry, and laser distancemeter have been used for block adjustment. However, all of these observations were either inaccurate or not reliable and/or the methods were too expensive or to complicated. For this reason, they were used only for small-scale mapping in a few countries.

With kinematic GPS positioning, it is possible to determine the positions of the projection centers accurately. The rotations can be determined by block adjustment, so that theoretically a block adjustment could be made without control points. Up to now, the kinematic GPS data are usually disturbed, that is, position errors caused by an incorrect ambiguity solution — the so called cycle slips — cannot be avoided.

Photo Flight

Navigation of the photo flight with GPS positioning has become a standard procedure (Herms, 1992). In using the CCNS system, 80 percent of the photo centers are within a deviation of 70 m caused by selective availability. This is adequate also for large-scale mapping. An improvement is only possible with on-line differential GPS positioning based on broadcasting GPS reference stations. In Germany such stations are available, particularly in the coastal region. Their accuracy is limited to 10 m, acceptable for navigation but not for exact on-line calculation of the projection centers.

The exact determination of the projection centers by kinematic GPS positioning has not been established as a standard procedure. For this reason, several problems may occur such as missing cable connections, problems with the stability of the hardware components, and organizational failures. Therefore, a complete check list is absolutely necessary.

Reliable hardware components are very important. Standard PCs cannot be used in aircraft. The lower pressure and vibrations will destroy the monitors, and hard discs can be used only for a very limited time. Solid state memories are required.

Only the antenna location can be determined directly. The offset from the antenna to the projection center — the entrance nodal point — has to be accounted for. The location of the antenna has to be determined relative to the fiducial marks of the camera in the zero position. This can be done by intersection with two theodolites or more easily by close-range photogrammetry. The distance from the camera frame to the entrance nodal point has to be considered — this is not identical to the focal length (see Figure 3). The photo orientation of the bundle block adjustment will give the offset

Photogrammetric Engineering & Remote Sensing,
Vol. 59, No. 11, November 1993, pp. 1651–1658.

0099-1112/93/5911–1651$03.00/0

Karsten Jacobsen
Institute for Photogrammetry and Engineering Surveys,
University of Hannover, Nienburger Strasse 1,
D3000 Hannover, Germany.

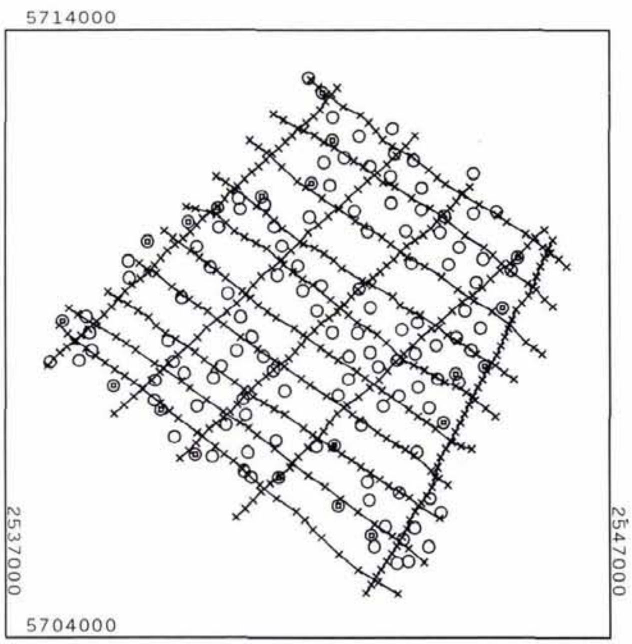

Figure 1. Block Rehinkamp: Flight lines and control points.

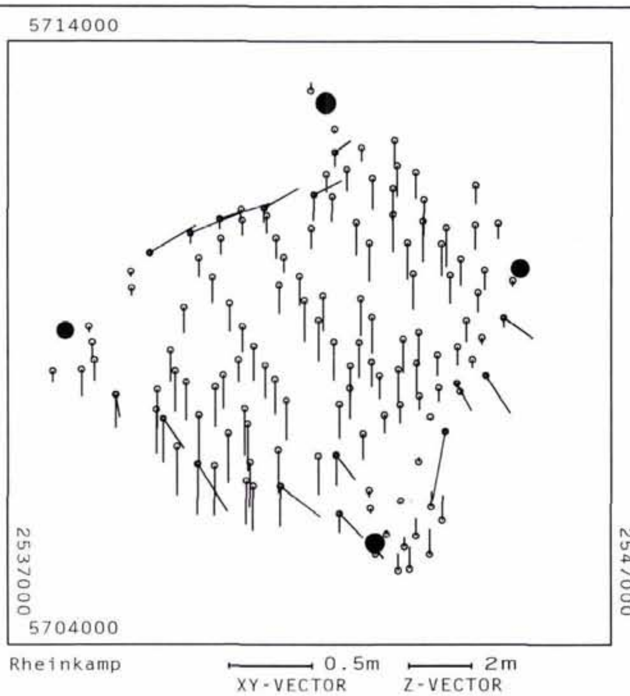

Figure 2. Differences of block adjustment based on four control points at block corners to check points.

vector orientation if the camera is fixed in the zero position. If this is not the case, the change of the camera orientation relative to the aircraft has to be recorded – this is possible with the newer model cameras. Without recording of the rotations relative to the aircraft, the orientation should not be

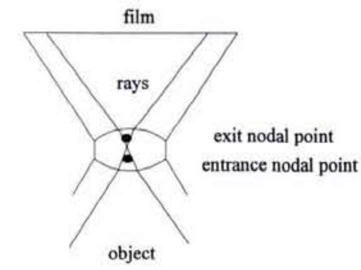

Figure 3. Camera nodal point.

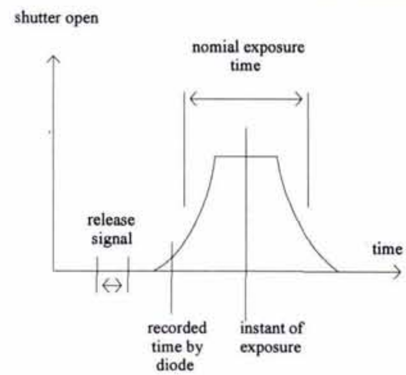

Figure 4. Instant of photographic exposure.

changed during single flight strips. Thus, only constant errors within the strips exist, which can be accounted for in the combined bundle block adjustment.

The GPS recordings are done only at constant time intervals and not at the instant of exposure. The instant of exposure has to be recorded in the time base of the GPS receivers to enable an interpolation. The newest camera models (Zeiss RMK TOP, Zeiss LMK 2000, and Wild RC30) do have the possibility to record the center time of exposure. The release signal of other cameras cannot be used because the time interval between the release signal and instant of exposure is not constant.

If the instant of exposure cannot be recorded, a diode in the image plane can be used. Of course, the recorded time of the diode has to be calibrated relative to the instant of exposure as a function of the exposure time (Figure 4). There is also a small influence of the object brightness, so it is better to use the diode just behind the shutter, but this can only be done by the camera manufacturer.

The aircraft speed during the photo flight is approximately 200 km/h, corresponding to 6cm/ms for large-scale mapping. This means that the time recording has to be done at least with an accuracy of 0.1 ms.

Interpolation of Projection Centers

The interpolation of the antenna positions as a function of the recorded time of the instant of exposure can be done linearly or by least-squares matching. This should depend on

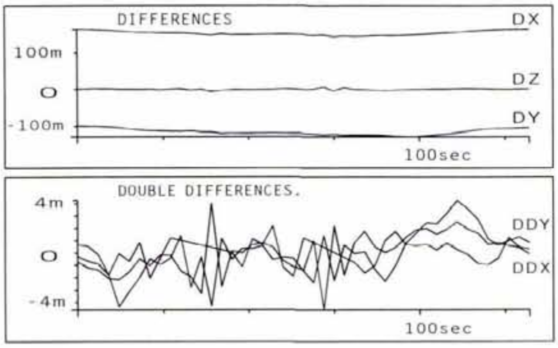

Figure 5. Coordinate differences and double differences between neighboring GPS recordings, Rheinkamp strip 1.

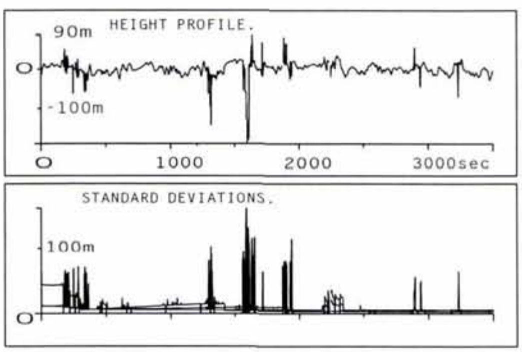

Figure 6. Upper: height profile of GPS values. Lower: standard deviations of GPS values. Test block Rheinkamp (50 percent).

the information about the photo flight (turbulence of the atmosphere) and possible problems of the GPS recordings.

In Figure 5 the coordinate differences of neighboring GPS recordings for the GPS block Rheinkamp are shown. The turbulence is reflected in the double differences which correspond to the accelerations shown in the lower part of the figure. But, of course, this is also influenced by errors in the GPS recordings.

The problems of GPS positions based on the carrier phase are illustrated in Figure 6. In the case of the test block Rheinkamp, flown in 1989, only four satellites were used. Particularly during turns from one flight strip to the next, the reference to some satellites was lost. It took some time to solve the ambiguity after loss of lock. This caused errors, visible in the height profile – an aircraft cannot go up and down as rapidly as apparently indicated by the profile. The standard deviations of the GPS positions reflect the problem. But the situation is not as bad as it appears at first sight.

The large standard deviations of the GPS positions are mainly limited to the flight path outside the block area, i.e., when the aircraft is reversing direction. Only in some cases at the beginning of the strips just inside the block area have ambiguities not been found correctly.

The height of the aircraft does not change suddenly (see Figure 7). For this reason, a polynomial interpolation of the projection centers based on neighboring GPS recordings is possible. A local polynomial fit based on four neighboring points with three unknowns indicates that 28 of the 584 projection center positions are blunders. With five unknowns, 51 positions were excluded by data snooping. But such an elimination of 9 percent of the projection centers is negligible for the bundle block adjustment with the projection center coordinates as additional observations. Also, a reduction to just 25 percent of the projection centers has a very limited influence (Jacobsen and Li, 1992). Even whole strips inside the block can be used without GPS data. Only if in block corners the projection center coordinates are not available would this cause a quality reduction.

All the positions indicated by large standard deviations were deleted by polynomial fitting. The mean square standard deviations of the interpolated values of $Sx = \pm 8$ cm, $Sy = \pm 11$ cm, and $Sz = \pm 11$ cm is realistic for the block Rheinkamp with a time interval of 3 sec for the GPS recordings. In the case of the block Blumenthal with a time interval of 1.2 sec, no blunders were detected.

The polynomial interpolation did not improve the combined block adjustment significantly over a linear interpolation. But the data handling is easier with such a polynomial matching, i.e., the blunders are identified before the start of the block adjustment.

Computation of GPS Positions

The Global Positioning System is based on passive distance measurements to satellites. Two frequencies are used for the satellite signals, the L1 frequency with a 19.05-cm wavelength and the L2 frequency with a 24.45-cm wavelength. Two different frequencies are required for a proper determination of ionospheric refraction. This is a special problem in the belt of approximately 30 degrees on either side of the geomagnetic equator and in the polar auroral zone (Figure 9).

In regions with higher ionospheric activity, a proper mathematical model for handling ionospheric refraction is required. Not all comercially available GPS programs, though adequate in the other areas, are able to solve this problem. It is not possible to transfer the experience directly to the equator and polar auroral zone.

The L1-phase is modified by two additional phases, the P-code with a wavelength of 29.31 m and the C/A-code with a

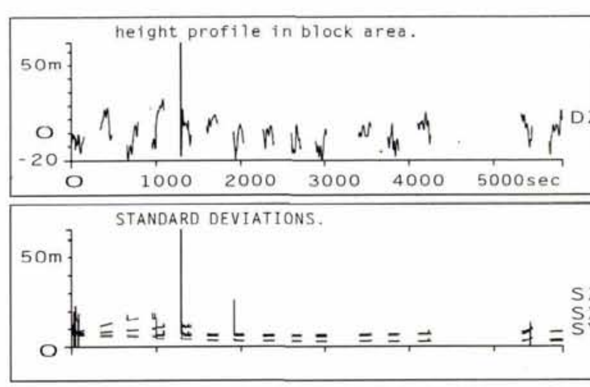

Figure 7. Upper: Height profile of computed GPS positions. Lower: Standard Deviations of GPS positions. Test block Rheinkamp, flight strips only in block area.

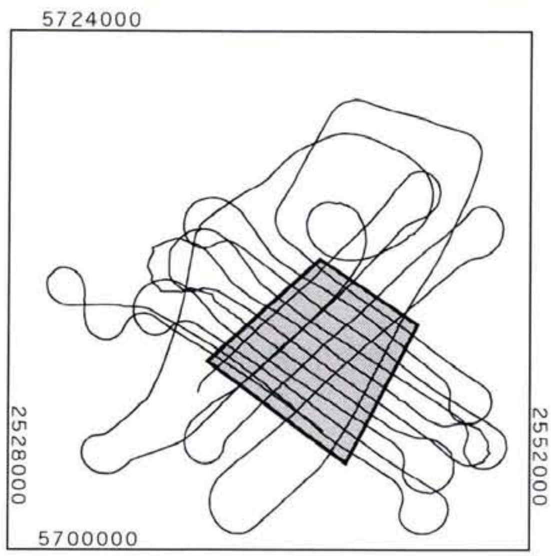

Figure 8. Flight path, GPS test block Rheinkamp.

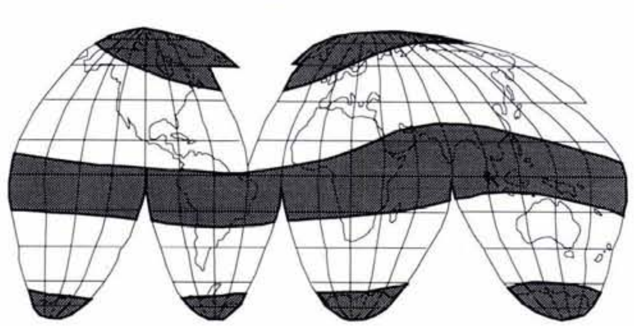

Figure 9. Regions of high ionospheric activity.

wavelength of 293.1 m. The ambiguity problem (the determination of the number of whole wavelengths from satellite to receiver) for the C/A-code is solved by a phase code. Therefore, it is simple to navigate with the C/A-code. But the wavelength of 293.1 m is too long for precise positioning. By rule of thumb, the phase can be determined with an accuracy of 1 percent of the wavelength, corresponding to 2.9 m. With smoothed phase information, positions based on the C/A-code can be as good as ± 1 m or, with several satellites, ± 0.5 m. So, for a precise block adjustment, the carrier phase has to be used for the computation of the GPS antenna location. But here the problem of the ambiguity solution exists. In the kinematic mode it is not possible, as it would be at a fixed position, to integrate the information.

The GPS positions of the tests handled by the University of Hannover were computed with the Hannover GPS program GEONAP (Seeber and Wuebbena, 1989). This program solves for the ambiguity by the "on the fly solution." With a linear combination of both frequencies LD = L1 − L2, the so called wide lane with a wavelength of 86.2 cm, and LS = L1 + L2, the narrow lane with a wavelength of 10.7 cm, together with the carrier phase, the ambiguity problem can be solved within a short time of registration, if it is not disturbed by cycle slips. The problems of cycle slips may be overcome by a combination with an inertial navigation system (INS). The drift problems of INS do not allow the use of an INS instead of the GPS for a combined block adjustment, but a short loss of reference caused by the aircraft wing obscuring one of the GPS satellites during turn around or by a multipath effect can be bridged by an INS. The traditional INS is too expensive for a standard photo flight, but new low-cost systems are now available. In 1993 the University of Hannover performed a test with a combination of GPS and an INS based on a laser gyro (price approx. $40,000) but the results are not presently available.

Because of the artificial deterioration of the GPS signals due to selective availability (SA), it is necessary to use relative positioning by establishing a reference station on the ground. By rule of thumb, the distance to the reference station will influence the results by a factor of 10^{-6}; that means that a distance of 50 km will worsen the position by a standard deviation of ± 5 cm. The situation for a combined block adjustment is a little more complicated — constant shifts of the positions in one flight strip can be compensated by the solution but, in the case of a turbulent ionosphere, the ambiguity for the reduction of the SA may be complicated. In the above-mentioned test by the University of Hannover, in addition to a reference station in the block area, three permanent recording ground stations with distances of 20 to 30 km, 40 to 50 km, and 150 to 160 km were used to get more information about possible distances to the reference station.

On-line solutions with broadcasting reference stations are not required, but they have the advantage of an on-line check of all components. Particularly in developing countries, where the complicated organization of relative kinematic GPS positioning can cause problems, the use of broadcasting guarantees that all components are working adequately. On the other hand, in some densely populated countries like Germany, no frequencies for individual broadcasting are available.

For small-scale mapping, the use of the C/A-code may be adequate. In this case, there is no problem with the ambiguity, and larger distances to the reference stations (200 km) can be accepted.

The GPS-receivers should allow for measurement on both frequencies and, at the same time, utilize a sufficient number of satellites. Low-cost systems are not an economic solution.

GPS positions are based on the World Geodetic System of 1984 (WGS84). However, this is usually not the case for the national coordinate systems. A simple transformation from one ellipsoid to the other is not sufficient. Instead, a seven-parameter transformation has to be employed. If the datum is not known exactly, a local transformation can be made with four reference points in the corners of the block. Geoid undulations usually can be neglected in relation to the height accuracy of the photogrammetric point determination.

Results of Test Blocks

Three test flights with projection centers determined by kinematic GPS positioning were carried out by the University of Hannover, and a fourth was flown but the results are not presently available.

All test blocks had enough control points for a block adjustment without the projection centers as observations. The standard deviations of the projection centers are in the range of $SXo \sim SYo = \pm$ 4 to 10 cm and $SZo = \pm$ 1 to 15 cm (see Table 1). A comparison of the projection centers determined by the bundle block adjustment based on control points with the program system BLUH and the interpolated

Table 1. GPS Test Blocks

	Blumenthal 1988	Rheinkamp 1989	Wurster Watt 1990
photo scale	1:6300	1:4000	1:4200
photos	69	454	236
camera	RMK15/23	RMK30/23	RMK15/23
endlap p	80%	80%	60%
sidelap q	60%	30%	30%
crossing strips	–	5	3
GPS-receiver	TI4100	TI4100	ELAC 8800
SXo, SYo	± 4 to 7 cm	± 4 to 7 cm	± 8 to 20 cm
SZo	± 1 to 2 cm	± 1 to 2 cm	± 3 to 15 cm
time recording	diode in image plane	diode behind shutter	diode in image plane
recording int.	1.2 sec	3 sec	1 sec

GPS positions corrected by the offset indicated systematic errors changing from strip to strip (see Figure 10). After elimination of the systematic errors of each strip, in the case of the block Blumenthal, the remaining root-mean-square differences are RMSX = ± 18 cm, RMSY = ± 19 cm, and RMSZ = ± 10 cm. Theoretically, the accuracy in Z should be less than in X and Y. The discrepancy can be explained by a limited accuracy of the time recording caused by the use of a diode in the image plane instead of the recording of the instant of exposure. The latter is possible with the modern aerial cameras.

After elimination of constant systematic errors (shift) in the strips of the block Blumenthal, systematic errors are no longer significant. This is not the case for block Rheinkamp. After data correction (see "Interpolation of Projection Centers") and stripwise preparation, root-mean-square differences in the projection centers of RMSX = ± 30 cm, RMSY = ± 23 cm, and RMSZ = ± 28 cm remain, significantly exceeding the results of Blumenthal. Figure 11 indicates that, in addition to the shifts, there are also drift values. After improvement by time dependent drift parameters, the remaining RMSX = ± 19 cm, RMSY = ± 13 cm, and RMSZ = ± 22 cm are close to the results of block Blumenthal. The larger values in Z can be explained by the larger block size of Rheinkamp (strip length ~8 km instead of ~2 km).

Theoretically, systematic errors linearly depending upon time (drift) should not exist. This can only be explained by large ambiguity errors causing second-order effects. Drift components are the first approximation of these effects. Without control points in the block center, no higher order systematic effects can be determined in the combined block adjustment.

It is not possible to combine two neighboring strips with the same shift and drift values without significant loss of accuracy. This indicates that the ambiguity problem has not been solved correctly. For all three blocks, only four satellites were available. If the elevation mask is reduced to 5 degrees, today seven to eight satellites would usually be available. Based on this, the computation of the ambiguity would be much easier. A. Leik reported at the ASPRS Convention in New Orleans (unpublished) on the latest tests of the "on the fly solution" – with seven to eight satellites, the solution is stable after 60 seconds.

The differences in the projection center coordinates determined by comparing the block adjustment based on control points with the GPS positions in the block Wurster Watt (Figure 12) are quite different from the results of the other blocks. Instead of root-mean-square differences of about 10 cm to 20 cm, values of RMSX = ± 113 cm, RMSY = ± 113 cm, and RMSZ = ± 143 cm were reached. This is caused by the use of the C/A-code instead of the carrier phase L1 and L2 for GPS positioning. These differences are not bad considering that only four satellites were used with the C/A-code.

The Hannover program system for bundle block adjustment, BLUH, can compute the combined block adjustment with projection center coordinates as observations and consider stripwise shifts and drifts (Jacobsen, 1992). In the case of block Blumenthal, the sidelap of 60 percent and the limitation to five strips allows us to determine the shifts based on just four control points and without crossing strips. In this data set, the drift parameters are not significant (see Figure 10). Therefore, a computation with just two control points would be possible, but this is not seriously considered for normal production. Based on the results of block Blumenthal, the block Rheinkamp was stabilized with five crossing strips (see Figure 8). By theory and verified by the results, a crossing strip at each block side would be sufficient. With such a geometry, the shifts and drifts can be determined by the bundle block adjustment with just four control points – one in each corner. Of course, under operational conditions single control points should not be used; for greater reliability, double control points (separated by 10 m to 100 m from each other) are required as a minimum.

The early detection of blunders is simplified by the local polynomial fitting of the GPS recordings. In addition to this,

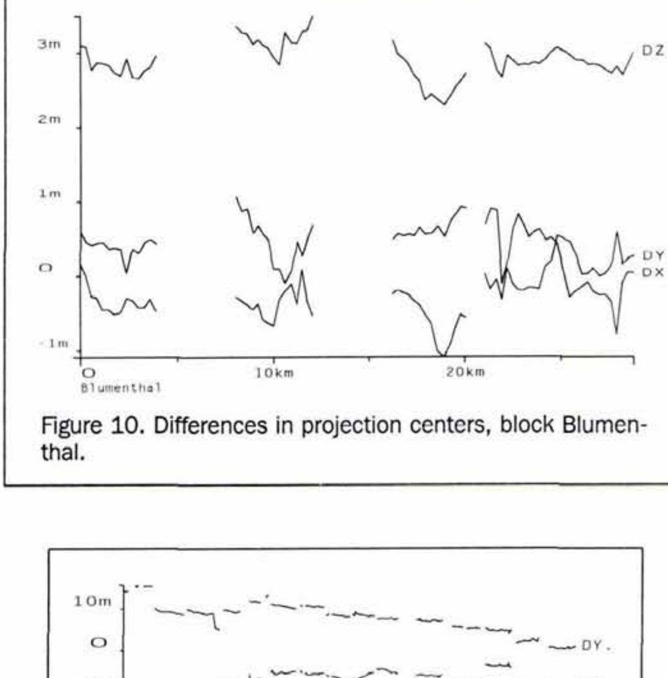

Figure 10. Differences in projection centers, block Blumenthal.

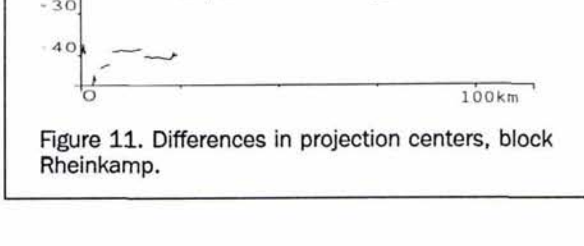

Figure 11. Differences in projection centers, block Rheinkamp.

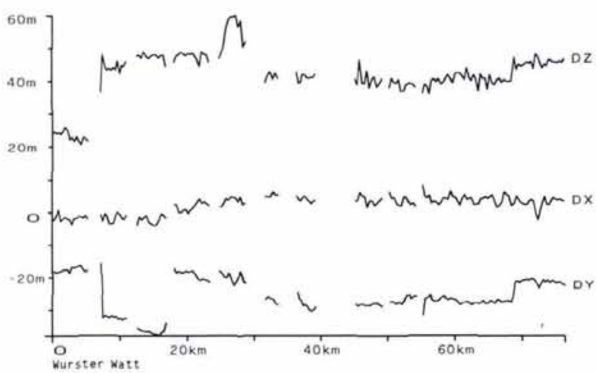

Figure 12. Differences in projection centers, block Wurster Watt.

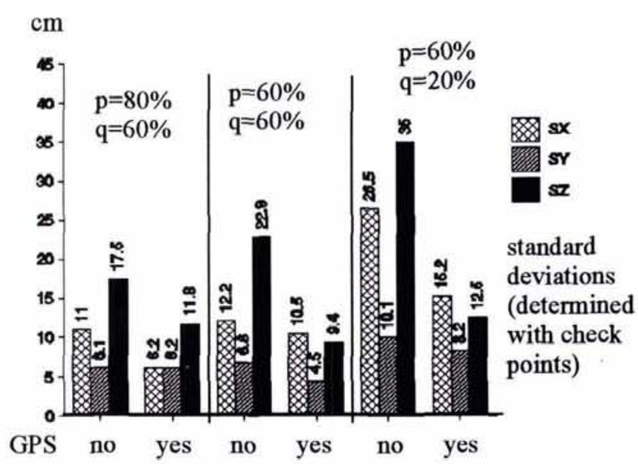

Figure 13. Results of combined bundle block adjustment. Blumenthal with four control points (p = endlap, q = sidelap).

a preliminary block adjustment without the projection center coordinates, and a check of the GPS positions against the projection centers computed by the bundle adjustment with just four control points, is performend. Without this test preceding the block adjustment, it is not so easy to determine in a combined block adjustment a group of blunders in the projection center coordinates with similar size and direction which can be caused by cycle slips.

Figure 13 illustrates the results of the combined bundle block adjustment of block Blumenthal determined with independent check points. The block with just five strips can be computed also without GPS data. In particular, the height is improved by the combined adjustment. In the case of 80 percent endlap and 60 percent sidelap, *SZ* is reduced by the GPS data from ± 17.5 cm to ± 11.8 cm and, in the case of 60 percent endlap and 20 percent sidelap, from ± 35 cm to ± 12.5 cm. The horizontal components are also improved. This is a typical result of the combined bundle block adjustment with projection center coordinates. The largest improvement is in the height, and the factor of improvement is greater for a weaker block.

A drift of the GPS positions cannot be seen in the data of block Blumenthal and the differences in the shift values are small. *For this reason, it is possible to perform the block adjustment with just one control point* (see Figure 14). Here the same trend can be seen as in the normal block adjustment — the accuracy is improved if more photos per point (higher overlap) are available. A block adjustment without control points is also possible with the projection center coordinates and at least two photo strips, but this is not reliable because of unavoidable systematic errors. For example, the focal length is not known accurately and not stable enough for precise photogrammetric point determination. Because of atmospheric pressure and temperature changes with altitude, the focal length of a wide angle camera will change by 47 micrometres at a 6-km flying height (Meier, 1978), corresponding to a 1.84-m shift of the projection center or change of ground elevation.

The same trend as in block Blumenthal can also be seen in block Rheinkamp (Figure 15). With four control points supported by the projection center coordinates and stabilized by five crossing strips, there is a loss in accuracy of only 22 percent in *X*, 27 percent in *Y*, and 21 percent in *Z* when compared with the fully controlled block. But this block is not too bad even with just four control points and not supported by crossing strips. *The improvement of the combined adjustment is mainly visible in the height — the GPS data reduce SZ* from ± 37 cm to ± 28 cm. The accuracy of the independent check points in some areas of the block is limited to *SZ* = ± 10 cm. In the center part, it is approximately *SZ* = ± 3 cm.

A sub-block of 104 photos arranged in four strips plus three crossing strips with 20 percent to 30 percent sidelap was processed separately (Figure 16). The high number of points in the sidelap area allows a computation of this sub-block without crossing strips and with just four control points. Again, the vertical component is not very precise if it is not supported by GPS (Figure 17). In this case of a block with just four strips and sufficient sidelap, the accuracy of the combined adjustment is only slightly improved by crossing strips.

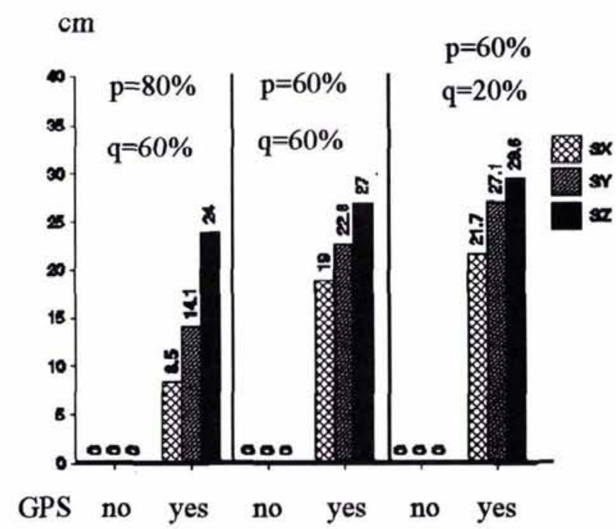

Figure 14. Results of combined bundle block adjustment, Blumenthal with one control point.

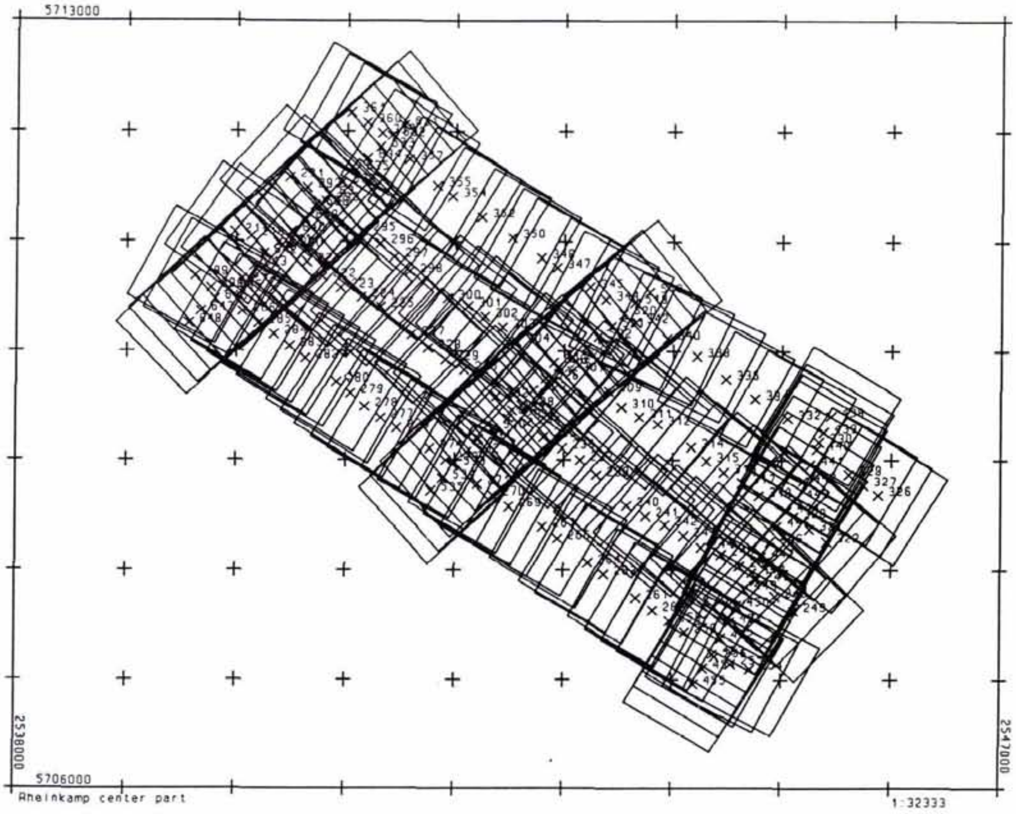

Figure 16. Photo coverage in the center part of Rheinkamp.

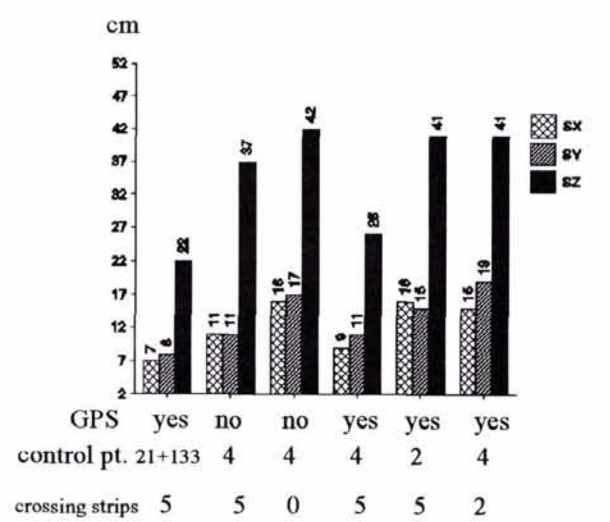

Figure 15. Results of combined block adjustment, block Rheinkamp.

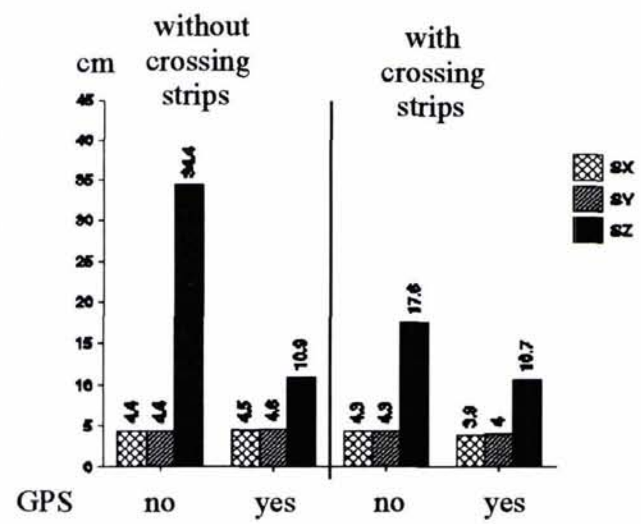

Figure 17. Results of combined bundle block adjustment, center part of Rheinkamp.

Without crossing strips, there is an improvement in the vertical accuracy from ± 34.4 cm to ± 10.9 cm and, with crossing strips, from ± 17.6 cm to ± 10.7 cm. For practical applications, crossing strips should be used; otherwise, the block may be unstable and the identification of blunders will be complicated.

The standard deviations of the projection centers of the block Wurster Watt, determined by means of the C/A-code,

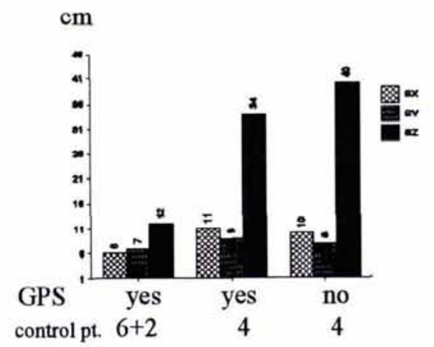

Figure 18. Results of combined block adjustment, Wurster Watt.

are too large in relation to the photogrammetric values. Therefore, the influence to the block adjustment is limited (Figure 18). The height information is improved from ± 40 cm to ± 34 cm but the horizontal component is worsened by 1 cm. In general, the C/A-code is not sufficient for this photo scale; such a block can be handled also without GPS data.

Conclusion

The power of the combined bundle block adjustment with projection center coordinates determined by kinematic GPS positioning has been demonstrated. The photogrammetric problems are solved at an operational level. The main problem today is kinematic GPS positioning itself. Based on the now available number of satellites and improved GPS receivers, GPS positioning is simplified. Stable hardware components are required for operational use in the vibrating aircraft. For small-scale mapping, all the problems have been solved if the C/A-code is acceptable. For precise point determination, the carrier phase has to be used with the requirement for an adequate ambiguity solution. Outside the area of higher ionospheric activity, it is operational today.

Selective availability requires relative positioning with respect to a ground station. The acceptable distance to the ground station is under investigation.

Cycle slips may occur; therefore, the procedure has to be able to determine and account for them. With two crossing flight strips, the block geometry allows for the computation of shifts and drifts of the projection centers individually for any strip. But such crossing strips should be used also for stabilization of regular blocks.

Combined bundle block adjustment with projection center coordinates determined by kinematic GPS positioning and the GPS-supported navigation will have in the near future a strong affect on photogrammetry because of its strong impact on the efficiency of the whole procedure.

References

Herms, P., 1982. Einsatz von GPS fuer die Navigation von Messfluegen, *Journal for Satellite-Based Positioning, Navigation and Communication*, pp. 101-103.

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

———, 1990. European progress on GPS photogrammetry, *Revista Cartografica*, pp. 71-84.

———, 1991. Trends in GPS photogrammetry, ASPRS, Baltimore.

———, 1992. Handling of disturbed kinematic GPS-data in block adjustment, ISPRS, Washington.

Jacobsen, K., and K. Li, 1992. Recent experiences in combined block adjustment with kinematic GPS-data, IUSM, Washington.

Li, K., 1992. *Empirische Untersuchungen zur GPS-gesttzten kombinierten Blockausgleichung*, doctoral thesis, University of Hannover.

Meier, H.K., 1978. The effect of environmental conditions on distortions, calibrated focal length and focus of aerial survey cameras, ISP Com I, Tokyo.

Seeber, G., 1993. *Satellite Geodesy*, de Gruyter, Berlin and New York.

Seeber, G., and G. Wuebbena, 1989. Kinematic positioning with carrier phases and 'on the way' ambiguity solution, 5th Int. Symposium on satellite positioning, Las Cruces.

List of "Lost" Certified Photogrammetrists

We no longer have valid addresses for the following Certified Photogrammetrists. If you know the whereabouts of any of the persons on this list, please contact ASPRS headquarters so we can update their records and keep them informed of all the changes in the Certification Program. Thank you.

Jack R. Anthony
Dewayne Blackburn
Gerard Borsje
Albert Brown
Eugene Caudell
Robert Denny
Franek Gajdeczka
George Glaser
William Grehn, Jr.
Louis T. Harrod
F.A. Hildebrand, Jr.
James Hogan
Lawrence Johnson
Spero Kapelas
Andre J. Langevin
Harry J. Miller
Marinus Moojen
M. David L. Morgan
Sherman Rosen
Lane Schultz
Keith Syrett
William Thomasset
Conrad Toledo
Robert Tracy
Lawrence Watson