GPS & AEROTRIANGULATION

COMMISSION I

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ABSTRACT:

Recent developments in GPS navigation offer the possibility of determining dynamic positioning and attitudes of an aerial camera, during photographic coverage flights, with an accuracy of 1-2 meters and a 3' arc, respectively.

Looking toward the future, when field control will no longer be necessary, this paper shows the results of analytical aerial triangulations performed with camera stations and attitude constraints.

KEY WORDS: Accuracy, Aerotriangulation, GPS.

1. INTRODUCTION

The rapid development of navigation offered by NAVSTAR-GPS, and the combination of these data with the adjustment of a photogrammetric block by the bundle method, allows one to consider the prospect of reducing, or even eliminating ground control, taking into account the fact that it is now possible to obtain navigation data with an accuracy on the order of 1 to 2 meters in the coordinates of the perspective centers, and of 3' on the Eulerian angles. Therefore, this study was performed to find out whether ground control may be ignored in whole or in part, when the coordinates of the perspective center and the Eulerian angles of the air camera, of all exposure stations of an aerophotogrammetric coverage, are obtained with this accuracy and used as constraints in aerotriangulation.

2. MATERIALS AND METHODS

This study was carried out with simulated data as described below, for the purpose of verifying whether it is possible to attain the objectives proposed.

Using a software in FORTRAN language, developed by Andrade (1977), a photogrammetric block with 16 photos distributed through four equal-sized strips was generated. This software was supplied with the following data:

a) focal length of the 153mm camera;

b) coordinates of the perspective centers of the 16 exposure stations, so that the longitudinal and lateral overlaps are respectively 60% and 20%;

c) equal value of the Eulerian angles of the 16 exposure stations equal to 0 rd;

d) value of ground point coordinates; and

e) accuracy of 5μm to generate the points in the photo coordinates.

This data is used by the program to calculate the photo coordinates, and presents a listing of the respective elements of exterior orientation at the end of processing.

During the input data for this program to generate the photo coordinates of the synthetic block, the parameters listed below were taken into account:

a) number of ground points, 36;

b) scale of photo, 1/10.000;

c) mean height of flight on the order of 1,640m;

d) mean difference in elevation 25m; and

e) picture format 23 x 23cm.

In figure 1 the photogrammetric block and respective ground points are presented schematically.

With software in FORTRAN language developed by MAGRO (1990), is possible to do analytical aerotriangulation. The aerotriangulation uses the bundle method and the observations are adjusted by least squares. The solution of the system of normal equations is developed by the iterative method of successive overrelaxations. This computation program does, or does not, accept as constraints altimetric, planimetric or planialtimetric ground control points, as well as the elements of exterior orientation.

At present it is possible to achieve an accuracy on the order of 2m to 2m for the coordinates of the perspective center and 3' for the Eulerian angles of the air camera exposure station, using navigation with GPS. A statistical algorithm was used so that they would reflect the accuracy given above. This algorithm generates normally distributed numbers with a zero average and a mean square error equal to the accuracies which way be obtained in the field. The randomly generated values were added algebraically to the elements of exterior orientation of the photogrammetric block.

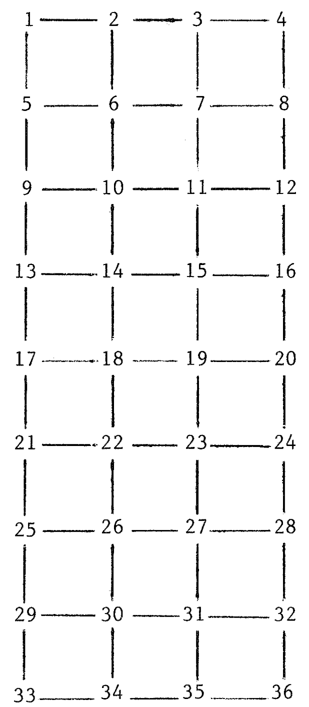

Fig. 1 - Distribution of the ground points

3. RESULTS AND DISCUSSION

Several aerotriangulations were performed with the photogrammetric block defined above. Three of these experiments will be discussed here, since they are related to the objectives of this study.

In the first experiment, constraints were applied to the ground points as follows: one planialtimetric point in each corner of the block (points 1, 4, 33, and 36), and another two altimetric points at the far ends of the strips so as to connect the second to the third strip (points 17 and 20), see figure 1. The accuracy attributed to these points was 0,01m. In the second experiment, constraints identical to those of the previous experiment were also applied to the elements of exterior orientation. In the third experiment the constraints were applied only to the exterior orientation elements.

In each of the experiments the mean values of the coordinates of the ground points were calculed, besides the two longest distances between those which had not been used as constraints, for the purpose of finding deformations in the block. The results may be seen in tables 1 and 2.

Experiment	x (m)	y (m)	z (m)
1st	11500,206	32000,128	111,26
2nd	11500,206	32000,128	111,26
3rd	11500,292	32000,288	113,37

Table 1 - Mean ground points coordinate

The results shown in Table 1 do not present any significant differences in the mean values of coordinate x of the ground points. However, regarding the values of coordinate y and coordinate z, a significant difference is found when the third experiment is compared with the other two. This fact leads to assume that ground control can not be entirely ignored. The significance value used here was three times the mean square error of the photo coordinates, considering the scale in relation to the ground.

The occurrence of longer distances in the third experiment, where ground control was not taken into account, denotes that the area covered by aerotriangulation was expanded, see table 2. Once again it is believed that ground control can not be entirely ignored.

Experiment	2 - 35 (m)	3 - 34 (m)
1st	8.062,668	8.062,872
2nd	8.062,668	8.062,872
3rd	8.098,053	8.098,168

Table 2 - Distances between ground points

Furthermore, the direct examination of the ground point coordinates obtained at the third adjustment are significantly different from those obtained during the other two adjustments. Table 3 shows the altimetric coordinates (z) of the points obtained in all three adjustments, which were nearest to those used for control.

Point	1st	2nd	3rd
2	107,111	107,109	118,001
3	110,897	110,894	123,585
18	111,442	111,442	103,432
19	115,386	115,386	107,226
34	114,992	114,992	131,790
35	119,083	119,083	133,849

Table 3 - Altimetric coordinates of ground control

Is is know that seven is the minimum number of constraints to materialize a three-dimensional reference. In aerotriangulation, geometrical rigidity problems occur, which require an additional number of constraints to ensure consistent results. For this purpose, experiments were performed with this photogrammetric block. First of all, the altimetric ground points 17 and 20, which connect the second to the third strip were eliminated. The results obtained did not present significant changes. Then, ground point 36 was eliminated leaving only planialtimetric points 1, 4 and 33. Once again, the results obtained did not show any difference in relation to those obtained with the adjustment of the first experiment. Then ground point 1 was considered altimetric, 4 and 33 planialtimetric, and a new adjustment was made. Again, the results did not show significant difference when compared with those of the adjustment of the first experiment. However, the solution of the system of normal equations took double the time until it attained the convergence criteria used in the first adjustment, considered the standard for this work. From then on, as new adjustments were performed and as the already mentioned ground points were reduced, until the third experiment was reached, in which there are no ground points, significant differences began to appear as compared with those of the first or second experiment. Several experiments were carried out, and many results were obtained for these experiments which presented the situations described here.

4. CONCLUSIONS

This study was performed for the purpose of finding out whether the ground points may be ignored in whole or in part, when the coordinates of the perspective centers and the Eulerian angles of the air camera of all the exposure stations of an aerophotogrammetric coverage are obtained, with an accuracy of 2m and 3', respectively, and used as constraints in aerotriangulation.

Considering the experiments carried out and the results obtained for the synthetic photogrammetric block, mentioned previously, if may be concluded that:

a) Ground control points may not be entirely eliminated in an aerotriangulation procedure;

b) The minimum number of ground control points in the field should be 2 planimetric and 3 altimetric non-colinear ones,but, depending on the solution algorithm of the system of normal equations, problems may occur with processing time due to bad block geometry or to the strong correlation of the parameters.

One ground control point in each corner of the photogrammetric block is recommended as the minimum required.

ACKNOWLEDGMENTS

The authors wish to thank FAPERGS - Fundação de Amparo à Pesquisa do Estado do Rio Grande do Sul for the finacial support provided by funding a scientific initiation fellowship (file 90.2307.0) and Prof. Hedy Lorraine Hofmann for translating this paper into english.

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