# BLOCK ADJUSTMENT OF THE PHOTOGRAMMES WITH SINGLE OVERLAP

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ABSTRACT

This paper presents some considerations concerning a specific method for solving the aerotriangulation problem for flat terrains and especially for those difficult of acces (most of them covered by water or vegetation), at the same time avoiding the accidental stereophotogrammetric interruptions.
After the brief presentation of the principle of this method (shown in [1] ) and the description of the iterative process, some aspects referring to the formation and solving of the normal equation systems of large dimensions (implied by adjustment) are then dealt with. The solution adopted (aiming at organizing the memory of the computer as judiciously as possible) consists in generating by means of software the non-zero submatrices situated above the main diagonal of the normal equation matrix and the utilization of Cholesky algorithm to submatrices. The block-diagram and the general characteristics of the software are also presented. In the end, the results obtained with two practical examples are analysed, leading to some conclusions and recommendations concerning the efficient application of the discussed method.

## INTRODUCTION

One of the most complex problems of analytical photogrammetry is the block adjustment of aerial triangulation. It has lately been of main concern with researchers especially as regards spatial aerotriangulation. However, for approximately flat terrains which do not require stereophotogrammetric processing, specific solutions may be achieved, taking the peculiarities of the independent processing of photograms into account. Such a solution is shown in the present paper. Since the principle of the method is stated in [1] , some practical aspects regarding the application of the method will be mainly dealt with here, the other matters being treated briefly.

## 1. PRINCIPLE OF THE METHOD

Adjustment basic formulas are obtained starting from the collinearity condition equations, particularized in the case of flat terrains and linearized by applying the Taylor expansion:

$$\begin{cases} X = dX_o + xs - ye - uc + vd + (X_o^o + \lambda_o x) \\ Y = dY_o + ys + xe - vc + wd + (Y_o^o + \lambda_o y) \end{cases}$$

where:

$$s = \lambda_o d\lambda,\ c = \lambda_o d\varphi,\ d = \lambda_o d\omega,\ e = \lambda_o d\varkappa$$

$$u = f + \frac{x^2}{f},\quad v = \frac{xy}{f},\ w = f + \frac{y^2}{f}$$

Considering in the first approximation $\varphi_o = \omega_o = 0$, the approximate values of the other four parameters $(X_o^o, Y_o^o, \lambda_o, \varkappa_o)$ are determined according to the formulas of linear conformal transformation in two-dimensional space.

Hence, the adjustment will be achieved in two stages: the determination of the approximate values of the orientation elements and, respectively, the iterative determination of the corrections of these parameters. For each of the two stages, two types of equations are written: (1) for the tie points (according to the requirement that for a common point at two photograms, equally adjusted coordinates should be obtained) and (2) for the control points, respectively.

## 2. FORMATION AND SOLUTION OF NORMAL EQUATIONS

Both stages of adjustment lead to the formation and solution of normal equations which will be of large dimensions in the case of large block adjustment. Therefore, the memory of the computer should be judiciously organized, considering that most elements of the coefficient matrix are zero. The solution adopted consists in generating by software the non-zero submatrices situated above the main diagonal of the normal equation matrix. With that end in view, a general numbering has been adopted for the tie points (two on each side of the photogram), as well as for the control points (located all along the perimeter of the block).

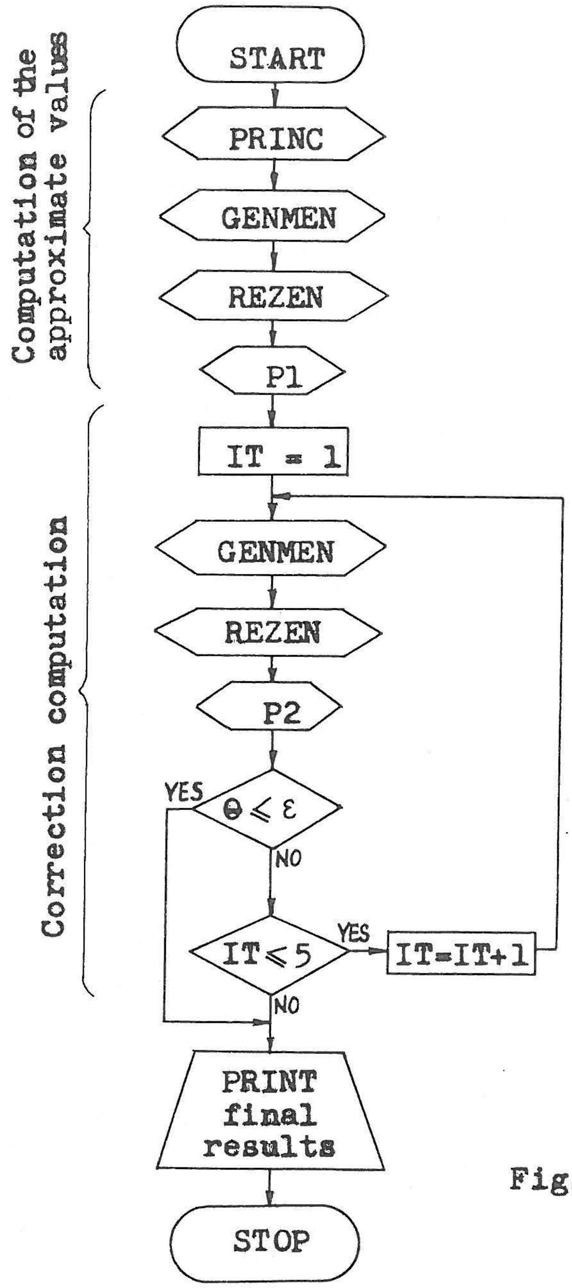
The matrix of the normal equations has a band-type structure, identical for both adjustment stages, with only the dimensions of the submatrices differing (4x4 in the first stage and 6x6 in the second one).

As for the solution of normal equations implied by adjustment, the structure of the coefficient matrix has been taken into account as well as the mode of storage in the memory of the computer, resulting consequent to the preceding stage. Hence, the root square method (Cholesky algorithm) was chosen, but it was applied to submatrices (as a computing element). Taking into account that the structure of the normal equation matrix is the same in both adjustment stages, the solution of the corresponding equation systems can be reached according to the same algorithm.

## 3. DESCRIPTION OF COMPUTER PROGRAM

For the practical solving of the problem, a FORTRAN program has been achieved and run with a FELIX computer having 128 K bytes of core storage. By using only the core memory of the computer (90 K bytes - at the user's disposal) blocks containing up to 50 photograms can be adjusted. Taking into account that it exceeds 64 K bytes, the program has been segmented. Mention can be also made that in order to perform various matrix operations, some scientific subroutines of the program library have been adapted.

The main stages of the computer program may be followed up by means of the block-diagram presented in Fig.1.




PRINC = main subroutine (performs data reading, transformations of coordinates and printing of intermediate results);

GENMEN = subroutine generating normal equation matrix;

REZEN = soubroutine solving normal equations;

P1,P2 = entry points to the main subroutine;

$\theta \leq \varepsilon$ - test for ending the iterations (when corrections become insignificant);

$IT \leq 5$ - the number of iterations is limited to 5 (sufficient for normal conditions).

Fig.1 Block-diagram of the computer program

4. PRACTICAL EXAMPLES

To illustrate the method, two practical examples have been achieved: a block 9 photograms (with single overlap) taken over a flat area and a 50 photograms block from a deltaic zone. The first example, run with two variants (with and without applying relief correction) is meant to point out the importance of applying this correction (whenever possible), even for smaller blocks.

As regards the nature of the control points utilized, specification must be made that we have used points, the ground coordinates of which were determined by spatial aerotriangulation. This will obviously have to be taken into account, when evaluating the results obtained.

With the first example, the photograms, having the format 18x18 cm and the average scale of approximately 1:11,000 have been recorded with a Wild RC8 camera, f=115 mm.

For the first variant (without application of the relief corrections), the mean square errors obtained have the following values: $\sigma = \pm 0{,}014$ mm (on the photogram scale), $m_R = \pm 0{,}12$ m, $m_L = \pm 0{,}05$ m (the following notations have been used: $\sigma$ = standard error of unit weight, $m_R$ = mean square error determined on the basis of all the corrections at the control points, $m_L$ = mean square error determined on the basis of all the corrections at the tie points.

For the second variant, the mean square errors decrease approximately by half: $\sigma = \pm 0{,}008$ mm, $m_R = \pm 0{,}06$ m, $m_L = \pm 0{,}03$ m. The point heights have been approximately determined, by means of a map with contour lines. Altitude differences with respect to a average reference plane do not exceed 10 m, but, as can be noticed, by applying the relief correction the results are highly improved.

In the second example, the block is made up of 50 photograms in 10 strips, five photograms on each strip. The photograms, having a 23x23 cm format and a average scale of approximately 1:27,000 recorded with a Wild RC8 camera, f=153 mm. Taking into account that throughout the considered zone the altitude differences are less than 3 m and the photogram scale is comparatively small, the relief correction was not applied. The mean square errors obtained in this case are: $\sigma = \pm 0{,}04$ mm (on the photogram scale), $m_R = \pm 0{,}87$ m, $m_L = \pm 0{,}54$ m and can be considered satisfactory under the above-mentioned conditions.

## CONCLUSIONS

The application of the described method offers particular advantages especially for terrains difficult of access, mostly covered by water or vegetation, where regular ground control work is sometimes impossible. Moreover, under these circumstances, another method can seldom be used because of the impossibility of determining central points. At the same time, the accidental stereophotogrammetric interruptions are avoided, the method implying single overlaps (of approximately 25%).

Although flat terrains are the main application field, the method may be also used for the planimetric adjustment of aerial triangulation in rough terrains, provided the height of tie points is known. Likewise, as shown in the first example, even for approximately flat terrains, the relief correction should be applied whenever information - if only approximate - regarding the point heights can be obtained.

As for the arrangement of photograms within the block, it would be desirable that the differences between adjacent photograms in succesive strips should not be too large. If photograms are taken with single forward overlap, then the flight design will have to be precisely observed in order to meet this requirement. From a practical point of view, it could be easier, however, to take photograms with larger overlaps and then to choose those photograms which better satisfy the above-mentioned requirement. Besides, the photograms should be numbered so that the number of photograms on the strip should at most be equal to the number of strips, thus implying a saving in the storing space all the more so as the block is more elongated.

On the other hand, the facility of achieving initial data may be pointed out, considering the limited number of points to be read in a photogram (most tie points being common for several photograms). The selection, marking and transferring of points is advisable to be carried out by a precision device.

An increased accuracy can be obtained if the control points are premarked. At the same time the premarking of control points may be particularly useful when the evolution in time of certain phenomena is aimed and aerial photography is repeated and consequently also the adjustment at certain time intervals, using the same control points.

On the other hand, mention must be made that on the basis of the orientation elements of each photogram determined by adjustment, the analytical processing of photograms may be achieved, establishing the ground coordinates for a certain number of terrain details whose images were measured on photograms.

REFERENCES

[1] Turdeanu L., "Un procédé de compensation en bloc des photogrammes à recouvrement simple, pour le cas des terrains plans". Paper presented at the 13-th Congress of the International Society for Photogrammetry, Helsinki, 1976.

[2] Turdeanu L., "Block adjustment of the photogrames with single overlap". Doctorat thesis, 1978; 105 pp, Bucharest.