Analytical Processing of Non-metric Images Taken from Low Altitude by Radio-controlled Model

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1. Introduction

The photography from radio-controlled models is carried out by several institutions in the CSSR. The Geographical Institute of the Czechoslovak Academy of Sciences in Brno has dealt with this problem already from the year 1965. The images from low altitude are taken by non-metric cameras mostly for interpretation and documentation. In the present time the Department of Geodesy of the Technical University in Brno cooperates with the Geographical Institute in the field of processing non-metric images taken from low altitude by the methods of analytical close-range photogrammetry.

2. Test Field, Photography

A test field 240 x 300 m in size in the form of approx. a square net with a side 60 m in length was made and photographed. The points were marked with white targets 30 x 30 cm in size. The greatest elevation difference between the points was 16 m. The points were determined in the local coordinate system with an accuracy $m_{x,y} = 0.02$ m, $m_z = 0.01$ m. The image size of the non--metric camera was 57 x 57 mm and the lens was 3.5/80. 11 images were taken in two rows, five and six images each.
The average flight altitude was 380 m and the altitude range was between 334 to 419 m. The plane was not navigated by means of any instrument, the place of exposure and the flight altitude were determined by experience of the operator.

3. Methods of Processing

The images were measured by the Stecometer Zeiss Jena comparator. The corners of the images were taken for fiducial marks. For processing the measured data three methods were used :
1. The method based on complanarity condition.
2. The method based on colinearity condition.
3. The method of direct linear transformation.
The first step of the first method is the solution of relative orientation of image pairs according to the complanarity condition.

$$\begin{vmatrix} bx & by & bz \\ x' & y' & z' \\ x'' & y'' & z'' \end{vmatrix} = 0. \qquad (1)$$

The determination of the elements of relative orientation is followed by the computation of model coordinates which are transformed in the geodetic coordinate system. The absolute orientation is given by the relation.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} x & y & z & 0 & 1 & 0 & 0 \\ y & -x & 0 & z & 0 & 1 & 0 \\ z & 0 & -x & -y & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} d\lambda \\ d\alpha \\ d\beta \\ d\gamma \\ dX \\ dY \\ dZ \end{bmatrix} \quad (2)$$

The second method is based on the colinearity condition.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \lambda . R . \begin{bmatrix} x' \\ y' \\ -f \end{bmatrix} + \begin{bmatrix} X_c \\ Y_c \\ Z_c \end{bmatrix} \quad (3)$$

In the first place the computation determines the elements of exterior orientation X_c, Y_c, Z_c, φ, ψ, ω (6 elements) or the elements of exterior and interior orientation f, x_0, y_0 (9 elements). The coordinates of the points are determined by resection. Eq.(3) is arranged to a known formula

$$x' = \frac{L_1 X + L_2 Y + L_3 Z + L_4}{L_9 X + L_{10} Y + L_{11} Z + 1} \qquad z' = \frac{L_5 X + L_6 Y + L_7 Z + L_8}{L_9 X + L_{10} Y + L_{11} Z + 1} \quad (4)$$

After computation of the transformation coefficients L_i for both the images of the pair the geodetic coordinates of the determined points are computed by solving the equation system. The distotion was eliminated by the application of the formula

$$dr = k_1 r^3 + k_2 r^5 + k_3 r^7 \quad (5)$$

Two variants of programmes were made for the methods (2) and (3). The first variant marked A uses no correction of distortion. The second variant B uses coefficient k_1 from formula (5) only. The programmes for the methods were written in FORTRAN and were computed by means of computers EC 1045 and ADT 4500.

4. Evaluation of Results
It was found out that it was not necessary to introduce a distortion correction for the used type of lens.
The calculated elements of exterior orientation make it possible to determine the accuracy of navigation. The average deviation from the planned place of exposure was 22 m, the greatest deviation was 40 m. The camera axis deviated from the vertical 6.5 degrees at max. in case of 10 images. In case of one image the angle ω was equal to 17 degrees. The camera was gimbal--mounted. The base-height ratio b/h was between 1/6 and 1/2.5. The results for two typical stereopairs are shown in Table 1. The quoted errors are computed from the deviations at the check points.

Tab.1

pair	σx	σy (m)	σz	method	number control points	variant
M – 10	0.03	0.06	0.88	2	6	9 parameters
b/h = 1/6	0.02	0.05	0.36	2	6	6
h = 390 m	0.04	0.04	0.27	2	12	9
	0.05	0.06	0.30	2	12	6
	0.14	0.18	0.45	3	6	A
	0.04	0.06	0.45	3	8	A
	0.14	0.23	0.84	3	6	B
	0.07	0.05	0.42	3	8	B
M – 6	0.09	0.07	0.15	1	10	
b/h=1/2,5	0.03	0.02	0.10	2	10	9
h = 380 m	0.05	0.04	0.14	2	10	6
	0.07	0.06	0.58	3	6	A
	0.04	0.01	0.13	3	8	A
	0.17	0.09	1.01	3	6	B
	0.03	0.01	0.15	3	8	B

The results show that it is suitable to use more control points
for the methods (2) and (3) than required. This will increase
the accuracy and reliability of the results. The accuracy of
the method based on complanarity condition depends on the deter-
mination of the focal length and the position of the principal
point. A higher accuracy of determining the point elevation
can be obtained by using a camera with a shorter focal length.
It can be expected that the accuracy at unmarked points will
be lower. The obtained results show that it is possible to use
these methods for thematical mapping.