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CALIBRATION OF NON-METRIC CAMERAS FROM A SINGLE PHOTOGRAPH AND PAIR OF PHOTOGRAPHS

Abstract:

In this study, calibration procedure for non-metric cameras is investigated by two different approaches: In the first approach collinearity equations including 12 unknown parameters are solved numerically by the use of Marguardt algorithm and the interior and exterior orientation elements are obtained from a single photograph. The second approach involves the use of the main equations of Parallax Photogrammetry and similarly interior orientation elements together with the systematic errors $\Delta x, \Delta y$ are determined by the Marquardt algorithm.

A special apparatus is also developed to make the stereo-camera- and object axes parallel. The applicability and the precision of this apparatus is also tested as part of the study.

INTRODUCTION:

The methods of the calibration of non-metric cameras from a single photograph and pair of photographs were established using "an algorithm for least-squares estimation of nonlinear parameters", which was developed by D.W. Marquardt, 1963. It was established a direct linear relationship between the comparator coordinates and object space coordinates. As such, it did not require fiducial marks in the photographs. These can also be applied to metric cameras.

The photograph pair required in this study were obtained by a specially designed sliding system readily adaptable to practical studies, enabling photograph taking at different bases. The respective tilting and rotations of the stereo photograph obtained by the system were adjusted to be zero.

A Hasselblad 500 C/M camera is used for the application example. The results clearly showed that the calibration approaches can be successfully used Architectural Photogrammetry.

ESTABLISHMENT OF THE TEST FIELD FOR CALIBRATION OF NON-METRIC CAMERA

The test field has been established for the calibration works in the Topographic Laboratory at the Technical University of Istanbul, M.M.F. In this test field 121 targets were established and a base bar of 2 meters length was provided (Fig.1). In this test field 5 and 10 mm. diameters steel bars were used with ends (targets) prepared as shown in (Fig.2).

These steel bars were painted black and the ends (targets) of these bars which were 1 mm. diameter were painted white for better contrast and sharper image.

Since the steel bars were cut in various lengths, the targets were on different space planes. The optical projections of the targets on a single picture plane will be used for calibration processing. The targets are numbered on a column and row system.

The space coordinates of targets were determined with intersection method by measuring vertical and horizontal angles WILD T 2 Theodolite.

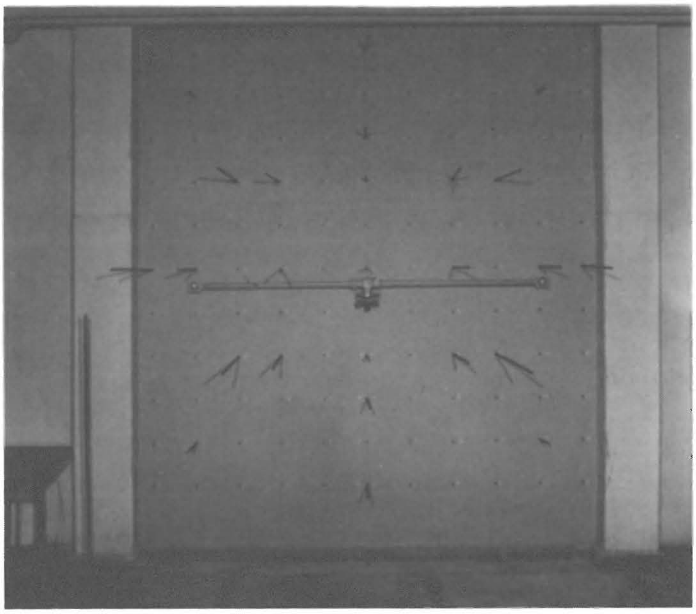

Figure 1. General layout of test field.

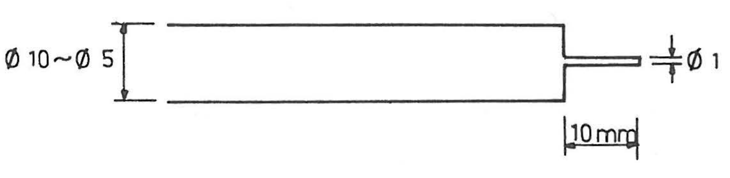

Figure 2. Detail of a target.

THE SYSTEM, DEVELOPED FOR THE STEREO PAIRS OF PHOTOGRAPHS AND TAKING PHOTOS

It was developed a system to obtain stereo pairs with non-metric cameras. This system has a camera carrier that is sliding on two parellel stell bars, readily adaptable to practical studies, enabling photograph taking at different bases. The respective tilting and ratations of the stereo photographs obtained by this system are adjusted approximately zero (Fig.3-4.)

Figůre 3. A specially designed sliding system.

The single and the stereophotographs were taken with Hasselblad 500 C/M camera for the calibration processing. This camera exposes 70 mm. roll film and has a magazine capacity for 12 exposures. Hasselblad 500 C/M camera has a format of 55 mm. x 55 mm. the camera has a slow-action focal plane shutter and high-speed lens shutter.

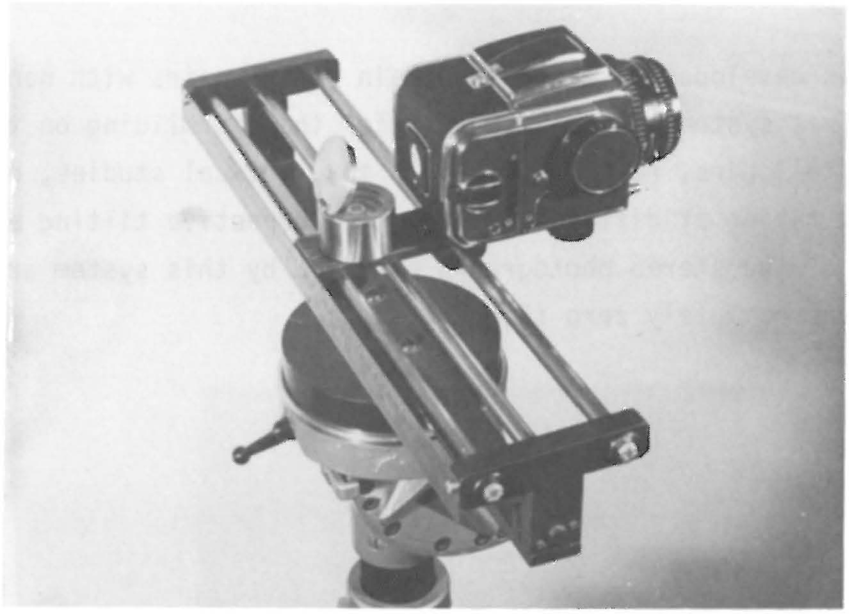

Figure 4. A specially designed sliding system.

The camera lens, planar, has 1:2.8, f=80 mm. and it is Carl Zeiss Nr.5783264. Its exposures speeds are B and from 1 to 1/500 seconds.

The photographic material were ORWO NP 20 film and KODAK Microdol-X was used as developing both.

The camera station was selected about 6 meters away from the test field. The camera was fixed on the system shown in the (Fig.-3-4), and all system was leveled.

Then the base axis was made parellel to the object plane with a special apparatus shown in (Fig.-5). This apparatus mainly consist of a prism and two rods and which are parellel to each other and normal to the base. A rod is held at any point of the direction which is perpendicular to the object plane and passes from the camera station. The image of this rod must fit into the images of two rods on the apparatus in thi prizm. In order to secure of fitting those images the system, shown (Fig.3-4), must be turned round of its vertical axis.

Left-hand and right-hand pictures was taken with 40 cm. base and same camera constant.

The comparator coordinates of the targets on the stereo-negatives were observed at the Stereocomparator ZEISS PSK 2 Nr.124033. The coordinate transformations were made by using the coordinates of the two targets of base bar.

A CALIBRATION METHOD FROM A SINGLE PHOTOGRAPH

The interior and exterior orientation elements were obtained from colinearity condition equations. The left-hand side colinearity equations was taken in the form,

$$\begin{aligned} \bar{x} - x_p &= x_K + x - x_o \\ \bar{z} - Z_p &= z_K + z - z_o \end{aligned} \qquad (1)$$

and rearranged

$$x_K = x_o - x + c_x \frac{a_1(X-X_o)+a_2(Y-Y_o)+a_3(Z-Z_o)}{b_1(X-X_o)+b_2(Y-Y_o)+b_3(Z-Z_o)} \qquad (2)$$

$$z_K = z_o - z+c_z \frac{c_1(X-X_o)+c_z(Y-Y_o)+c_3(Z-Z_o)}{b_1(X-X_o)+b_2(Y-Y_o)+b_3(Z-Z_o)} \qquad (3)$$

where

$\bar{x},\bar{z}$ = refined photo coordinates of a point
x_p, z_p = photo coordinates of the pricipal point of the photograph
x_K, z_K = observed comparator coordinates
x_o, z_o = coordinates of the principal point referred to the comparator coordinate system.
$\Delta x, \Delta z$ = systematic errors in coordinates.
c_x, c_z = camera principal distance
X,Y,Z = object space coordinates of the point

X_o, Y_o, Z_o = object space coordinates of the camera perspective center.

There 12 unknown parameters in the equations (2) and (3). To reduce the number of the unknowns the elements of the transformation matrice was written in the function of φ, ω, $\varkappa$ and the number of the unknowns wüs reduced to 9.

$$D = D_{\varkappa} \cdot D_{\omega} \cdot D_{\varphi} = \begin{pmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{pmatrix} \tag{4}$$

where

$$D_{\varkappa} = \begin{pmatrix} \cos\varkappa & 0 & -\sin\varkappa \\ 0 & 1 & 0 \\ \sin\varkappa & 0 & \cos\varkappa \end{pmatrix}$$

$$D_{\omega} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & \sin\omega \\ 0 & -\sin\omega & \cos\omega \end{pmatrix}$$

$$D_{\varphi} = \begin{pmatrix} \cos\varphi & \sin\varphi & 0 \\ -\sin\varphi & \cos\varphi & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

The nonlinear colinearity equations were solved with Marqardt algorithm and the following values were obtained.

x_o = 510.9849 mm	φ = 0.000681 radyan	Y_o = 8.061908 m
z_o = 500.4323 mm	ω = 0.021237 "	Z_o = 10.03897 m
c_x = 80.0398 mm	$\varkappa$ = 0.000002 "	Δx = 0.1601 mm
c_z = 80.0478 mm	X_o = 11.664244 m	Δz = 0.1603 mm

A CALIBRATION METHOD FROM STEREO PAIRS

The stereo pairs was taken with the system which is shown in (Fig 3-4). In those stereo pairs of negatives $\varphi, \omega, \varkappa$ were equal each other respectively and they were aproximately zero.

For the calibration procedure of the stereo pairs the following equations are used

$$X = \frac{b.x'}{p_x}$$

$$Y = \frac{b.c}{p_x} \qquad (5)$$

$$Z = \frac{b.z'}{p_x}$$

were

$$p_x = x' - x''$$

$$x' = x_{Kleft} + \Delta X_1 - X_{oleft} \qquad (6)$$

$$x'' = x_{Kright} + \Delta X_2 - X_{oright} \qquad (7)$$

Δx_1 and Δx_2 were taken aproximately equal in these equations.

$$X = \frac{b\,(X_{Kleft} + \Delta x - X_{oleft})}{X_{Kleft} - X_{oleft} - X_{Kright} + X_{oright}} \qquad (8)$$

$$Y = \frac{b\,.\,c}{X_{Kleft} - X_{oleft} - X_{Kright} + X_{oright}} \qquad (9)$$

$$Z = \frac{b\ (z_{Kleft} + \Delta z - z_{oleft})}{X_{Kleft} - X_{oleft} - X_{Kright} + X_{oright}} \tag{10}$$

were obtained.

From the equations (8), (9), 10

$$\Delta X = X_{n+1} - X_n \tag{11}$$

$$\Delta Y = Y_{n+1} - Y_n \tag{12}$$

$$\Delta Z = Z_{n+1} - Z_n \tag{13}$$

can be found. From those equations, interior oriention parameters of camera can be determined by using Marquardt algorithm.

The precision of this method is less than from a single photographs method.

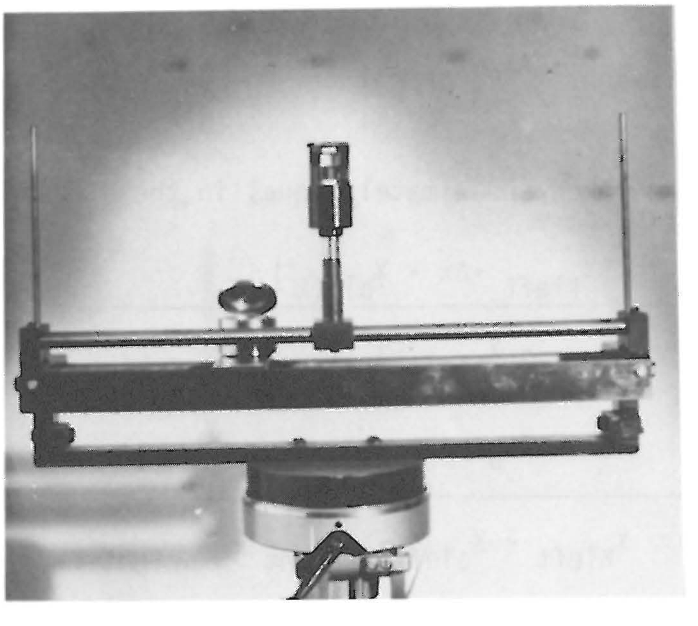

Figure 5. The base axis was made parellel to the object plane with this apparatus.