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A COMPARATIVE STUDY CONCERNING THE ACCURACY OF SOME MEASURING ARRANGEMENTS FREQUENTLY USED IN CLOSE-RANGE PHOTOGRAMMETRY

Abstract

In the study a test wall was used for experimental determination of the accuracy of the results obtained with some measuring arrangements frequently used in close-range photogrammetry. The test wall was photographed with metric and non-metric cameras in a normal stereophotogrammetric way, as well as using convergent photographs. Both analogical and analytical methods were used for photogrammetric restitution. The accuracy in each case was determined by comparing the restituted model with the original check point model of the test field.

Introduction

The use of an accurate reference point network is a simple way to calibrate close-range photogrammetric systems and instruments. In Finland there are three different reference point networks of which the one used in this experiment work is a vertical planeformed test wall. The dimensions are 13,5 x 19,4 metres. The wall is constructed for an object distance of the range of about 5 to 30 metres. The reference point network consists of 39 fixed black- and white cross-shaped targets (Figure 1).

The mutual position accuracy of the points is estimated to be 0,17 mm as the standard error of one coordinate. It is e.g. equal to 0,0021 mm on the image plane when using the metric camera Carl Zeiss Jena UMK 10/1318 at a distance of 8 metres and equal to 0,0003 mm when using a 135-size amateur

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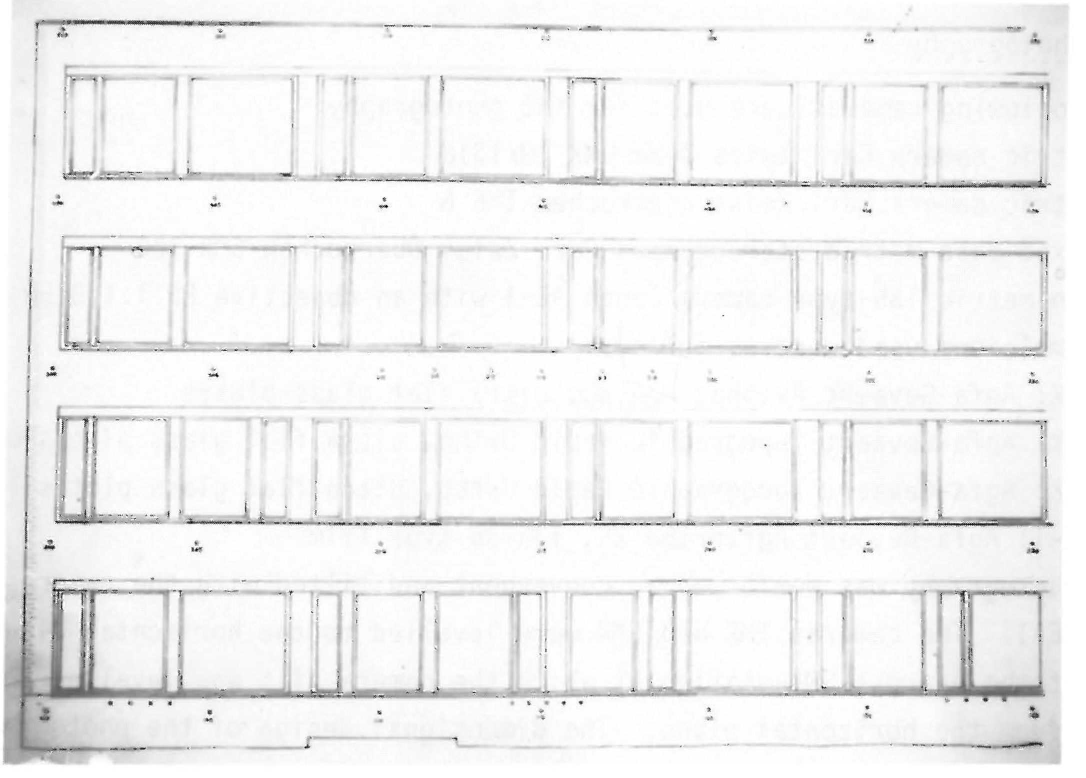


Figure 1. The test wall and the reference point network. The drawing is plotted with a stereo instrument to the original scale 1:50.

camera with f=50 mm at a distance of 25 metres. The relative accuracy of the scale can be considered about 1:100 000. The reference point network is thus suitable for most close-range photogrammetric calibrations.

At the Technical Research Centre of Finland the test wall has been successfully used for calibrating both the traditional stereophotogrammetric systems and the modern analytical ones. The most interesting results are achieved when using non-metric cameras but also metric cameras with as simple control as possible. An experiment work is described in this context.

The experiment work

The test wall was photographed for this experiment work with metric and non-metric cameras. Both stereophotogrammetric and convergent photographies were performed. All the photographs were measured with a monocomparator and in addition to it one stereopair was restituted with an analogue stereoplotter. The non-metric camera was calibrated a priori. As a result of the experiment work some close-range photogrammetric systems were calibrated.

The photography

The following cameras were used for the photography:

- metric camera Carl Zeiss Jena UMK 10/1318
- metric camera Carl Zeiss Oberkochen TMK 6
- fixed base metric stereocamera Carl Zeiss Oberkochen SMK 120
- non-metric 135-type camera Canon AE-1 with an objective FD 1:1,8/50 mm SC.

The emulsions used were as follows:

- UMK: Agfa-Gevaert Aviphot Pan 30, ultra flat glass plates
- TMK: Agfa-Gevaert Topographic Rapid Ortho, ultra flat glass plates
- SMK: Agfa-Gevaert Topographic Rapid Ortho, ultra flat glass plates
- AE-1: Agfa-Gevaert Agfaortho 25, 135-36 type film.

The photography was performed as convergent and tilted with the cameras UMK and AE-1. The cameras TMK and SMK were levelled to the horizontal plane except the nearest SMK-station at which the camera tilt was levelled to be $+30^g$ from the horizontal plane. The dimensional design of the photography is sketched in the figure below (Figure 2) and in Table 1.

In the photography three precision base rods were also used with the reference distances targeted and determined at a standard error of 0,010 mm. The

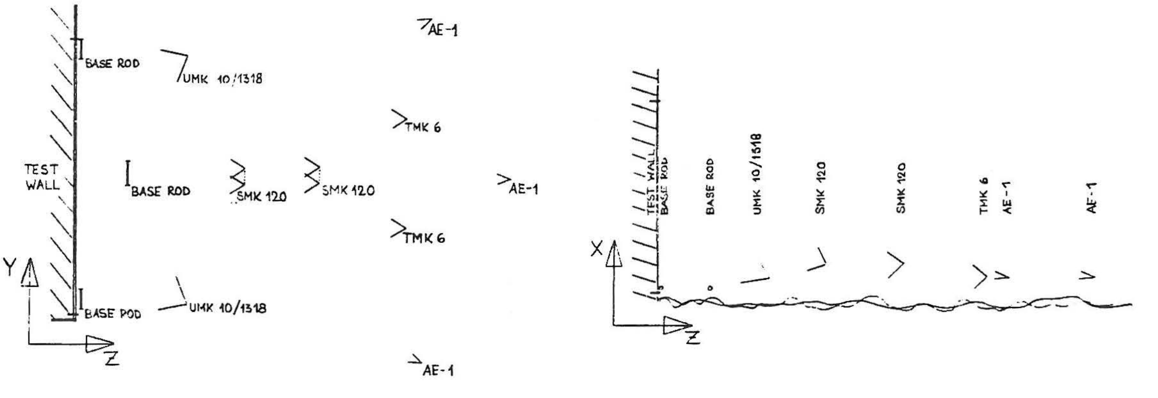


Figure 2. The sketch of the camera stations as seen from the direction of the positive X-axis (left) and the negative Y-axis (right).

rods are 1,15, 1,15 and 1,35 metres long and they were lying in front of the test wall.

The comparator measurements

All the photographs were measured with a monocomparator Carl Zeiss Oberkochen PK 1. The glass-negative photos were measured with two pointings to the fiducials and to the targeted reference points. For the determination of fiducials of the AE-1 the frame lines were measured each at nine points with two extra negatives. The negatives used for the experiment were measured with five pointings on each frame line and with one pointing to the object points.

The determination of camera coordinates

The camera coordinates were determined with the origin at the principal point. The transformation was made for the metric cameras with six parameters including affinity and non-orthogonality and for the AE-1 with four parameters. The fiducials of the AE-1 were predetermined as intersections of the frame lines which were measured each at nine points. The actual transformation to the camera coordinate system was then made by using these fiducials as standards. The standard errors of the residuals by the AE-1 after the transformation varied between 7,2 - 16,4 microns.

Camera calibration

The non-metric amateur camera Canon AE-1 was precalibrated using the reference point network and the image observations of three photographs. The data manipulation was performed with a minicomputer Hewlett Packard HP21MX. The program used was a bundle block adjustment program including the extended model for self calibrating parameters. In this case the parameters were

- affinity
- non-orthogonality
- radial distortion
- tangential distortion
- camera constant
- principal point.

As a result an image deformation mainly caused by the radial distortion of the camera objective was revealed (Figure 3). The standard error of the image observations after the adjustment was 8,7 microns.

Analytical restitution

The analytical restitution was performed using a general block adjustment program which allows the simultaneous use of geodetic and photogrammetric observations. The different control patterns used in the adjustments are

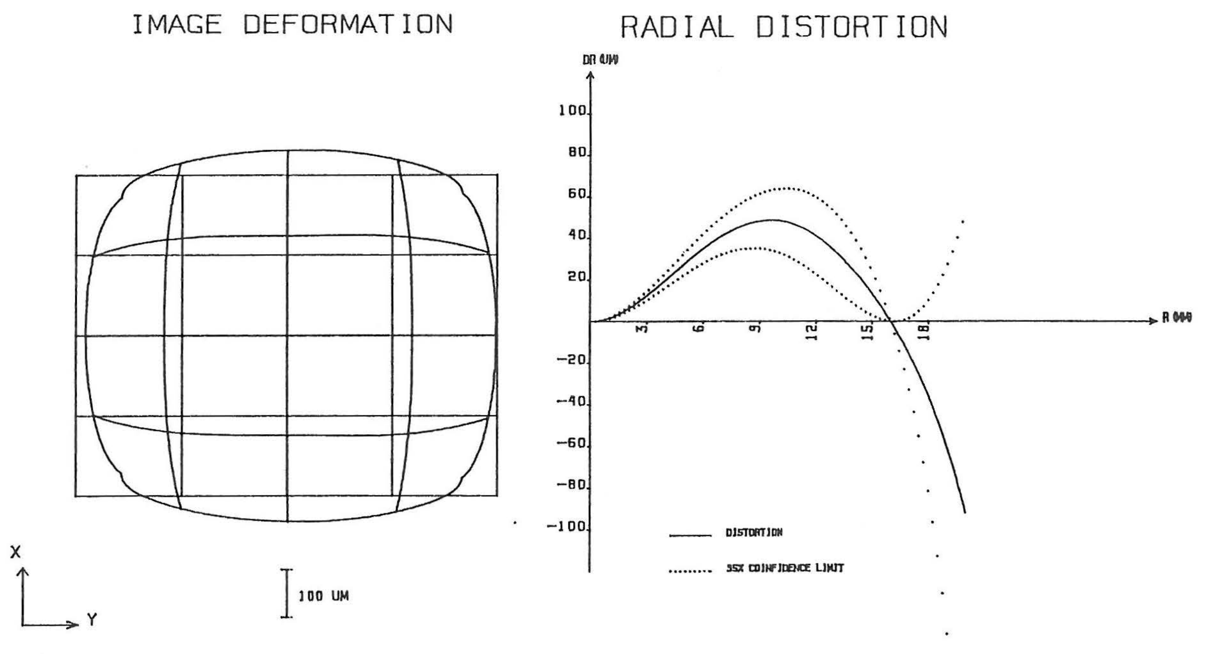


Figure 3. The image deformation and the radial distortion of the Canon AE-1.

shown in the Figure 4. The different combinations of the observations and the standard errors after the adjustments for these observations are shown in Table 1. The XYZ-control points were handled as rigorous. The accuracy of the distance observations in the quadrangle with diagonals was estimated as a standard error being $\pm$ 2 mm. The observations were weighted in the adjustment according to their estimated accuracy.

Analogue restitution

The analogue restitution was performed using the stereo instrument Carl Zeiss Jena Stereoplanigraph C5. For the restitution the original glass-plate negatives of the stereopair of the SMK 120, which was levelled to the

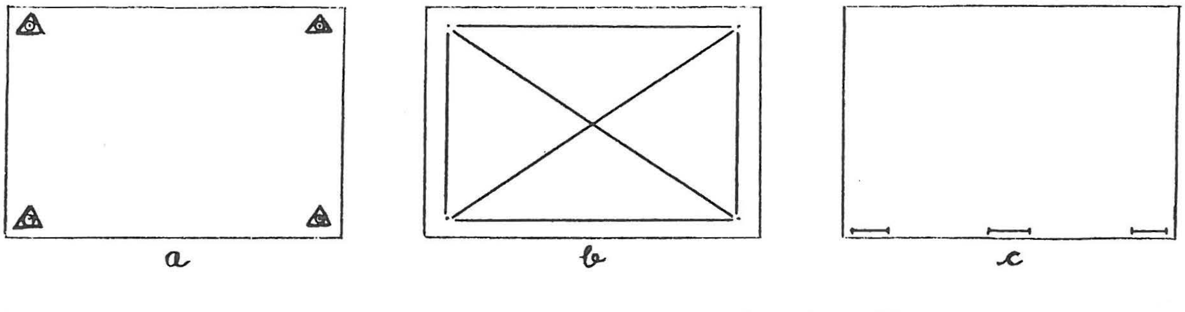


Figure 4. The different control patterns used in the adjustment: a) XYZ-control points on the block corners, b) control distances; quadrangle with diagonals, c) control distances; precision base rods.

horizontal plane, were used. The model was oriented as an affine model with the affinity coefficient being 2,5 and drawn to the scale of 1:50. The drawing was then digitized on a digitizing table Bendix / Datagrid Digitizer.

The comparison of results

The coordinates achieved in the adjustments and by the stereorestitution indicate the performing capacity of each used close-range photogrammetric system. Their resulting accuracy is then determined by comparing the coordinates with the reference point coordinates. There are two ways to perform it. Firstly, the coordinates are compared by the RMS-values of the coordinate differences in the check points. Secondly, the blocks are compared by the RMS-values of all spatial distance differences computed from coordinates of related points. Thereto the relative accuracy for each block is computed. These values show the performing capacity of the used method. The comparison of results is shown in the table below (Table 2).

Table 1. The photography performed for the experiment work

Camera	Focal lenght (mm)	No of camera stations	Appr. scale	Range (m)	Base (mm)	Base-range ratio	Photography
UMK 10/1318	100,37	2	1:130	13	17	1:0,8	convergent
TMK 6	59,81	2	1:385	23	8	1:3	normal
SMK 120	60,24 60,22	1	1:280	17	fixed	1:14	normal, levelled
SMK 120	60,24 60,22	1	1:200	12	fixed	1:10	normal, 30g tilted
AE-1	50,10	3	1:560	28	12, 23	1:2 1:1	convergent

The most interesting things to notice are

- the fulfilment of the expectations concerning the use of simple control for close-range photogrammetric measurements, e.g. the precision base rods (Figure 5),
- the good performing capacity of the 135-type non-metric camera and especially
- the stability of the accuracy in the direction perpendicular to the test

Table 2. The adjustments and the comparison of results

Block	D (m)	R (m)	S_{oi} (μm)	S_{od} (mm)	N	$RMSE_D$ (mm)	$RMSE_{Di}$ (μm)	$RMSE_{XY}$ (mm)	$RMSE_Z$ (mm)	D:$RMSE_D$
Analytical restitution										
1. XYZ-control points on the block corners										
- UMK 10/1318, convergent photographs	20	13	2,5	-	24	0,9	7	0,7	1,0	1:21200
- TKM 6, stereopair with 60 % overlap	24	23	2,2	-	38	3,8	10	2,9	7,6	1:6300
- SMK 120, fixed base stereo pair										
· levelled	24	17	1,7		39	15,4	55	11,7	25,2	1:1500
· 30^g tilted	19	12	1,4	-	26	7,8	39	6,1	11,5	1:2400
- AE-1, convergent photographs										
· original camera coordinates	22	28	5,8	-	32	48,8	87	27,3	12,9	1:450
· a priori calibrated camera coordinates	22	28	4,8	-	32	5,3	9	3,9	14,4	1:4200
· self calibrated camera coordinates	22	28	5,1	-	32	11,6	21	8,3	14,0	1:1900
2. Control distances; quadrangle with diagonals										
- UMK 10/1318, convergent photographs	22	13	1,5	1,1	24	1,2	9	0,8	0,7	1:18300
- AE-1, convergent photographs										
· a priori calibrated camera coordinates	22	28	4,7	0,3	32	5,2	9	3,5	10,9	1:4200
· self calibrated camera coordinates	22	28	4,8	0,3	32	10,2	18	6,4	11,7	1:2100
3. Control distances; precise base rods										
- UMK 10/1318, convergent photographs	22	13	1,4	0,0	24	1,6	12	1,0	0,7	1:13800
Analogue restitution										
SMK 120, fixed base stereo-pair, restituted with stereoplanigraph C5 as an affine model, Z-control on the block corners, scaling with distances	24	17	-	-	39	27,5	98	-	-	1:850

Declarations:

D	the maximum object diagonal
R	the average object distance, range
S_{oi}	the standard error of image coordinates after adjustment
S_{od}	the standard error of distances after adjustment
N	the number of the check points
$RMSE_D$	the RMS-value of the residuals of distances
$RMSE_{Di}$	$RMSE_D$ in the image scale
$RMSE_{XY}$	the RMS-value of the residuals of XY-coordinates
$RMSE_Z$	the RMS-value of the residuals of Z-coordinates
D:$RMSE_D$	the relative accuracy of the block

wall with the non-metric camera without regard to geometric calibrations of the camera coordinates.

The are some graphic drawings of the model deformations added to this context (Figures 6-11).

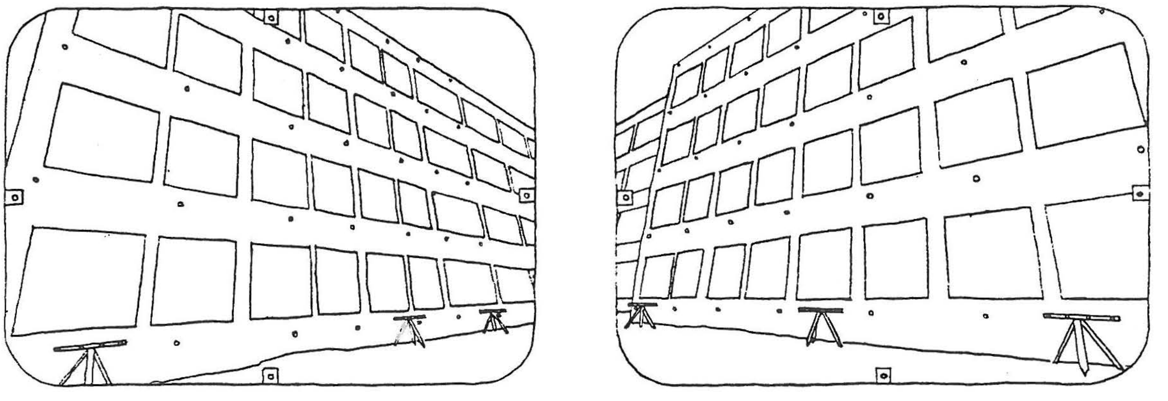
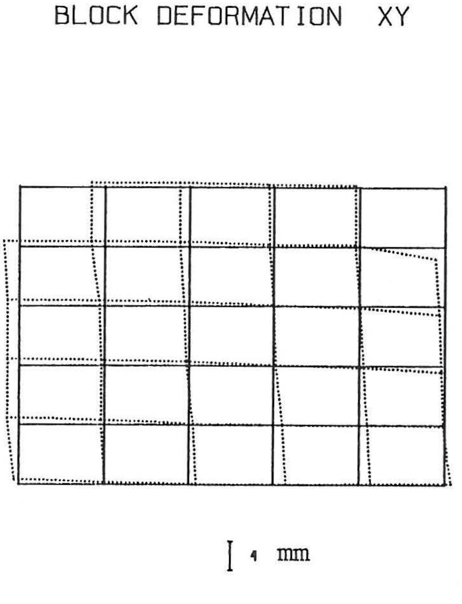


Figure 5. The two convergent photographs taken with the UMK 10/1318. By using only three precision base rods as control the RMS-value of the residuals of distances was ± 1,6 mm.



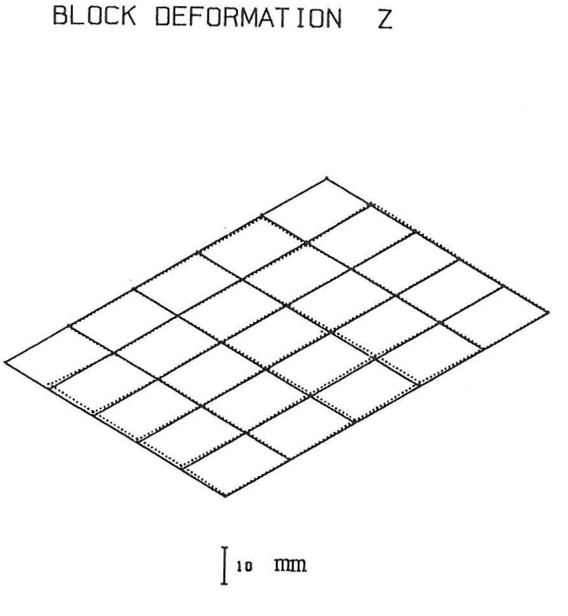


Figure 6. The block deformation by using the UMK 10/1318 and precision base rods.

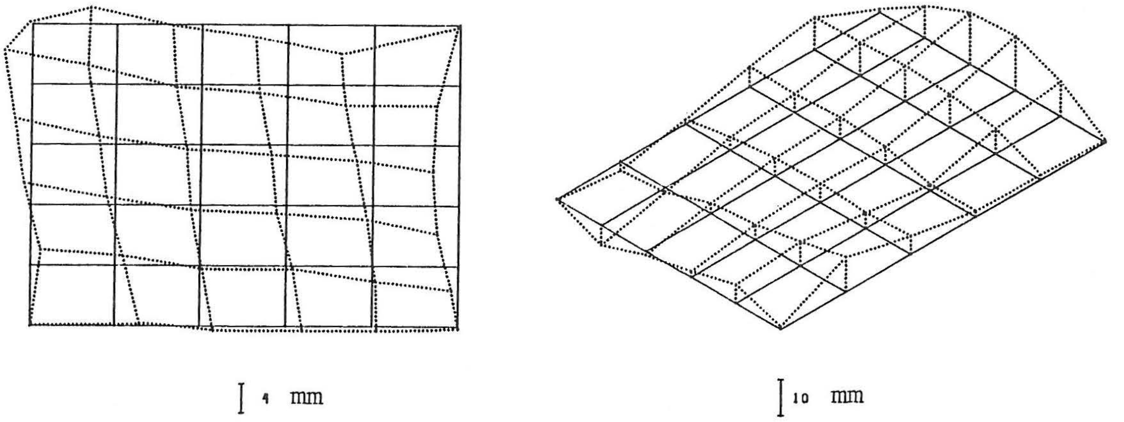


Figure 7. The block deformation by using the TMK 6 and XYZ-control points.

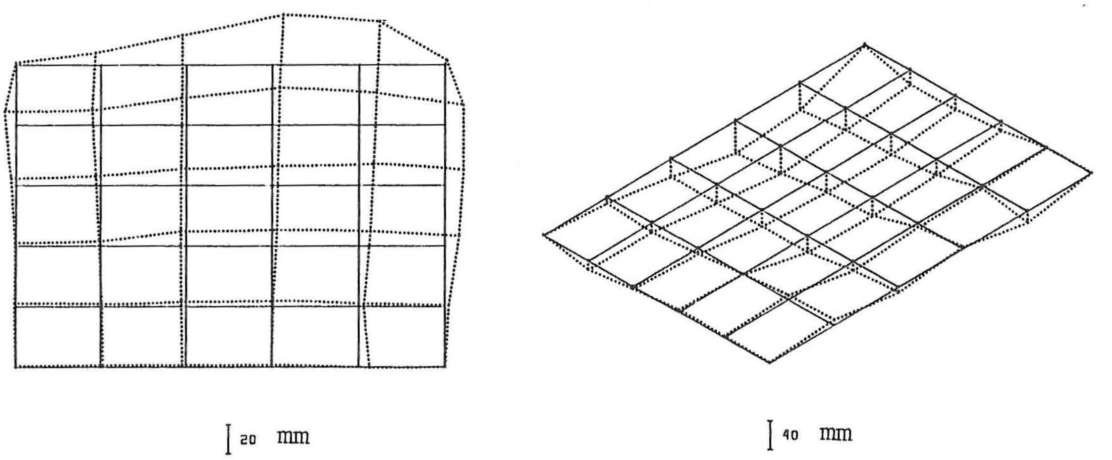


Figure 8. The block deformation by using the SMK 120 as levelled and XYZ-control points.

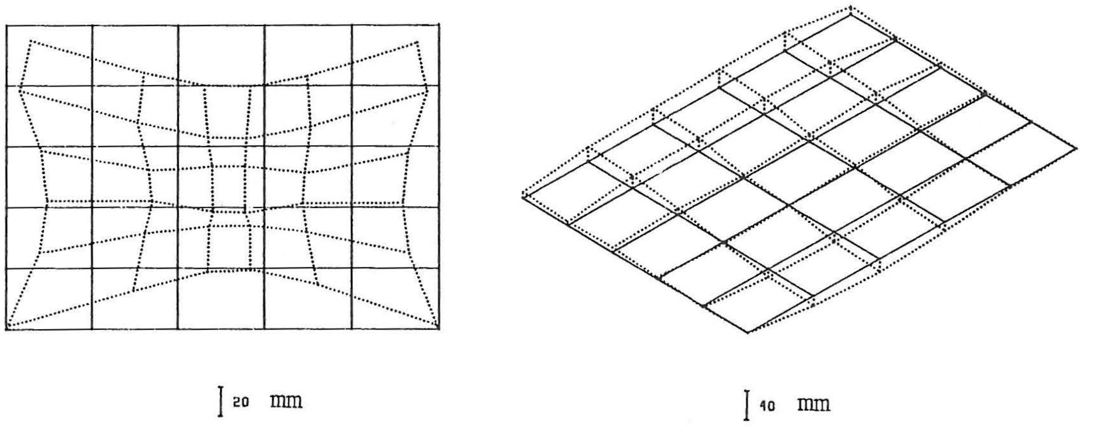


Figure 9. The block deformation by using the AE-1 without calibration and with XYZ-control.

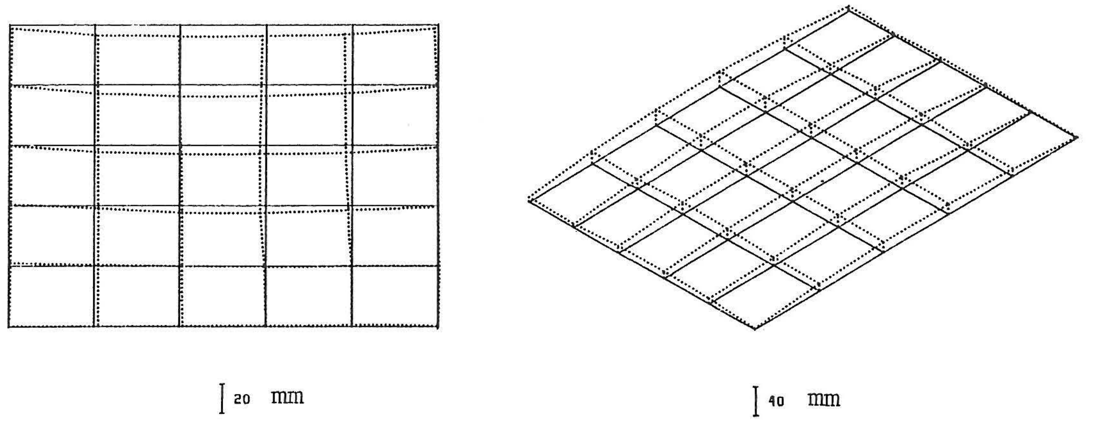


Figure 10. The block deformation by using the AE-1 with precalibration and XYZ-control.

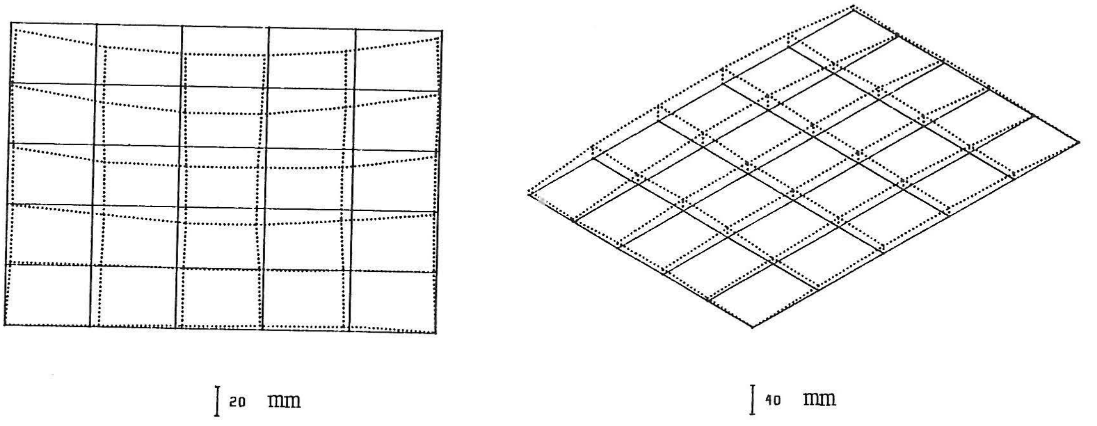


Figure 11. The block deformation by using the AE-1 with selfcalibration and XYZ-control.

Conclusions

The presented examples show the usability of a test wall in calibrating different close-range photogrammetric systems. The estimates and deductions concerning the accuracy of a measuring system are always somewhat unreliable. Now we are able to gain assurance of the performing capacity of a close-range photogrammetric system in a concrete way.

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