# Calibration of Long Focal Length Cameras

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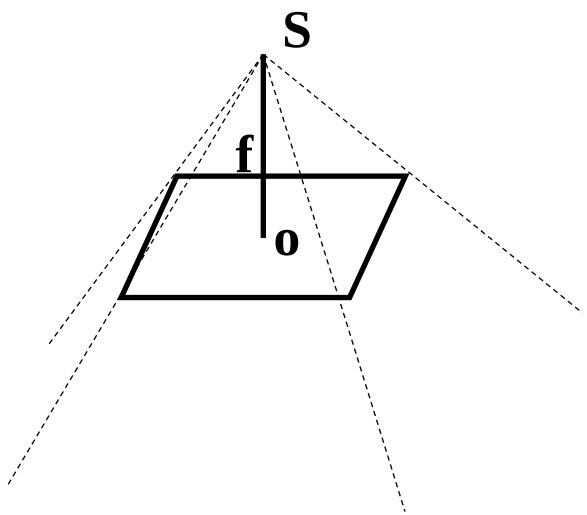
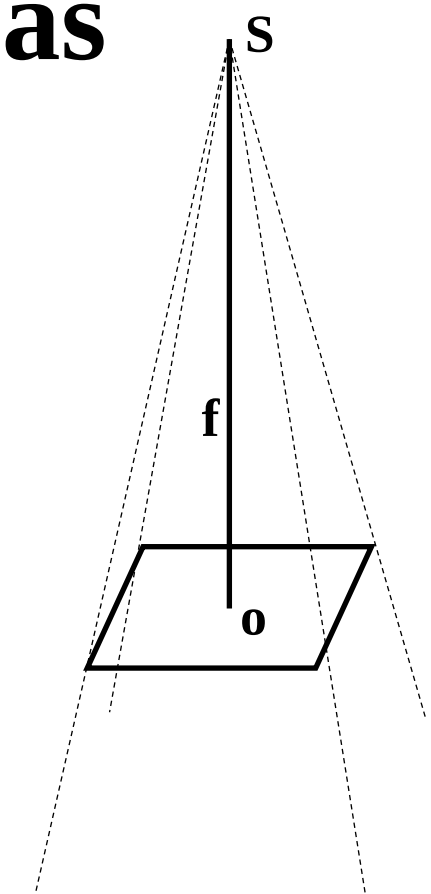
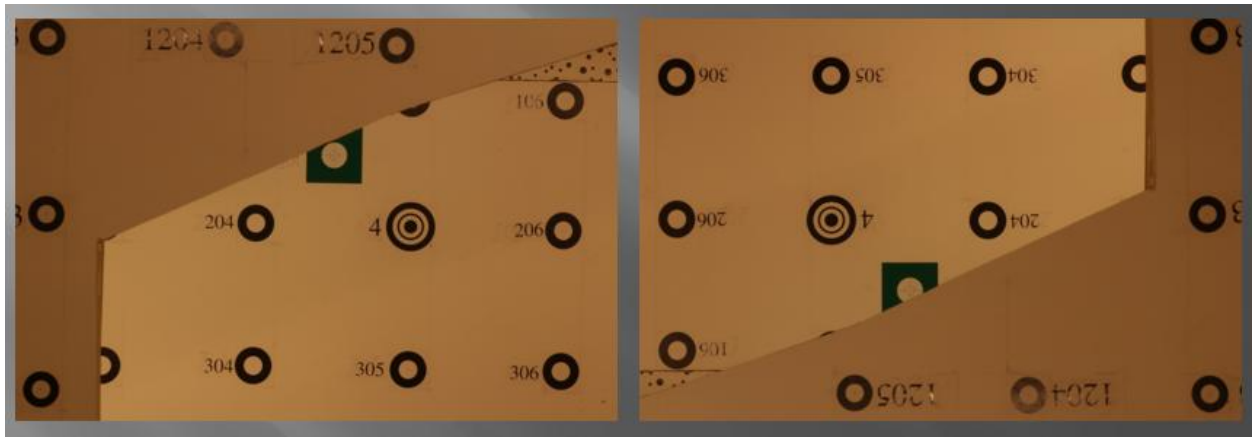
# The main problem of calibration of long-focus cameras

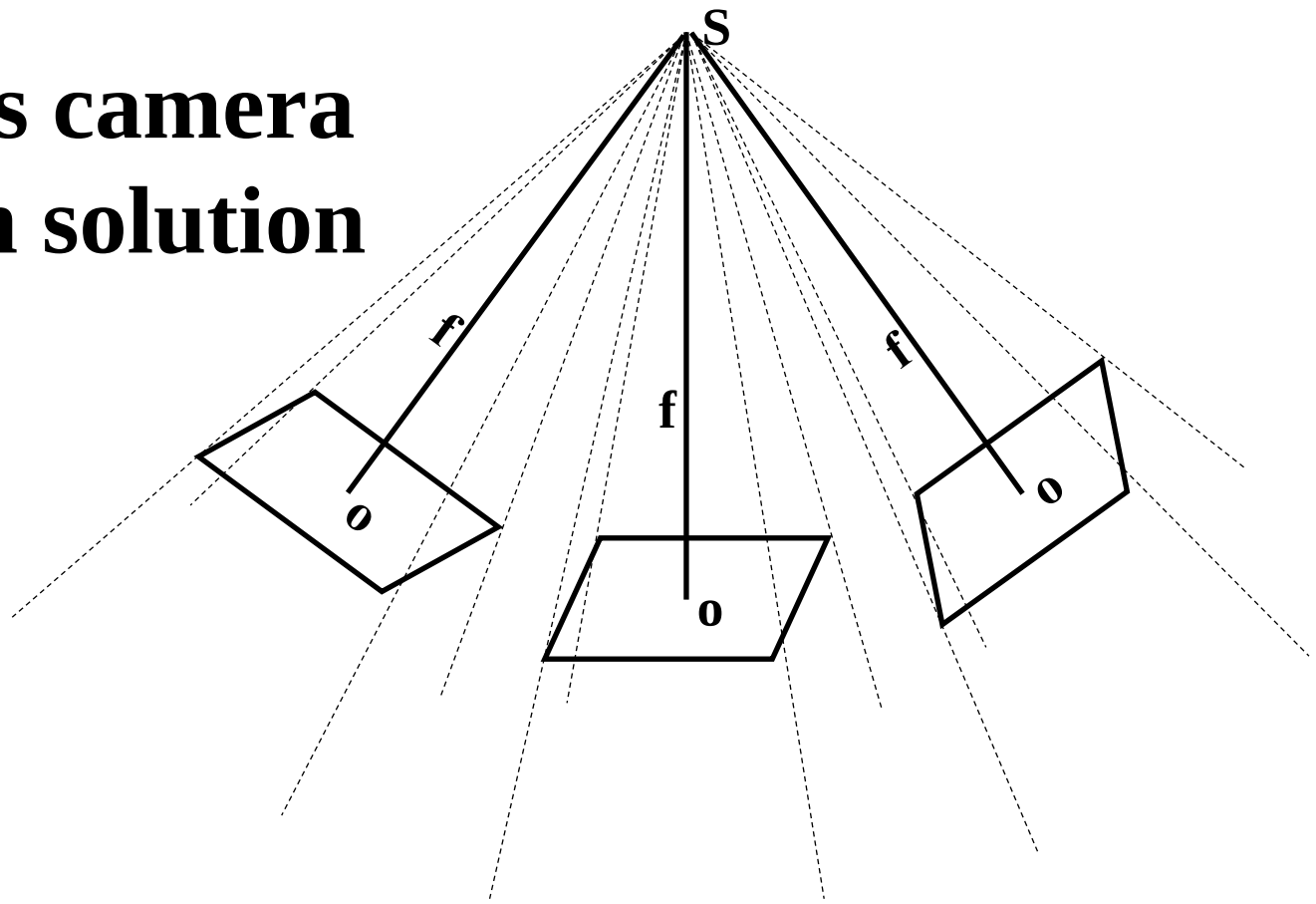


# Test-object

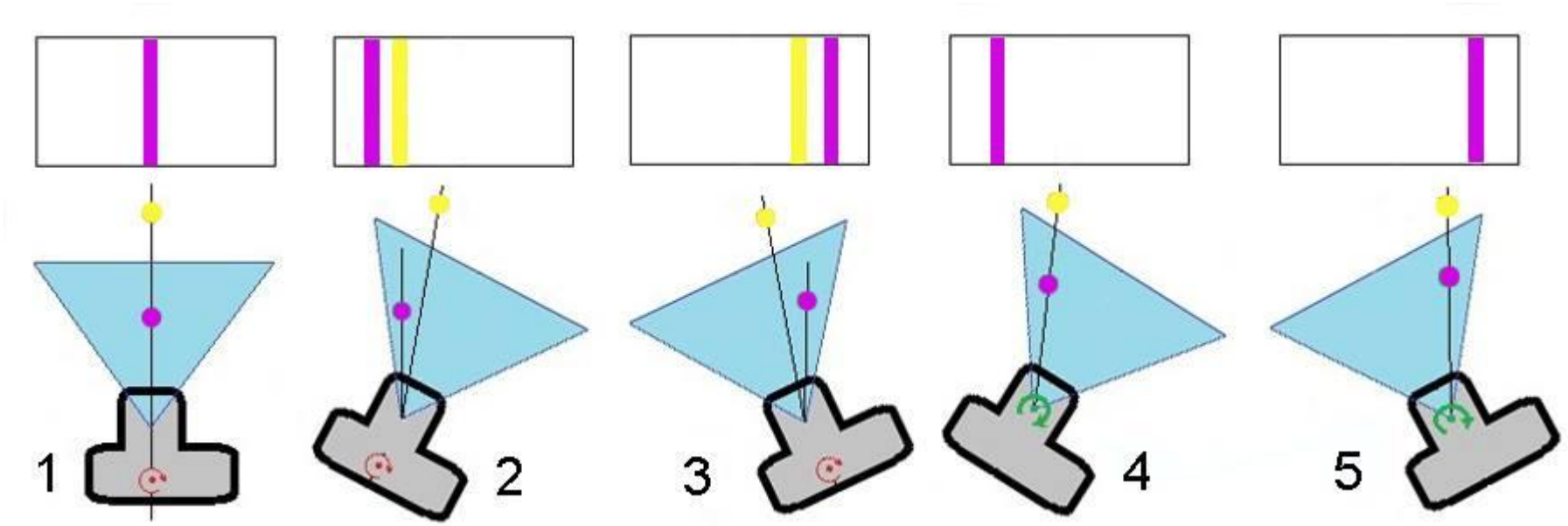


# Long-focus camera calibration solution

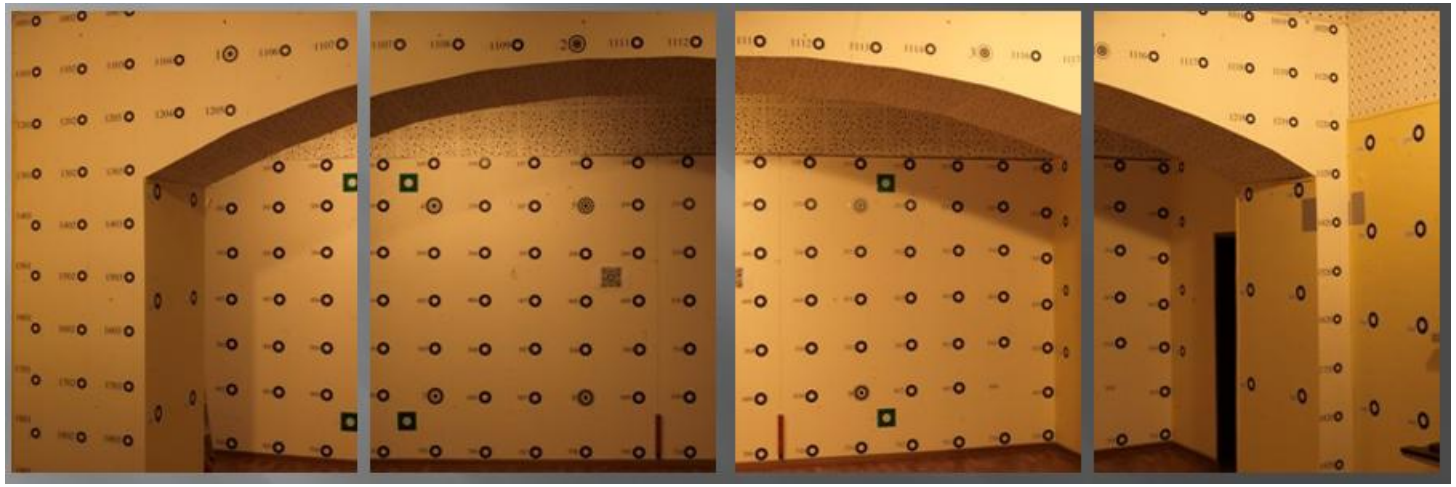


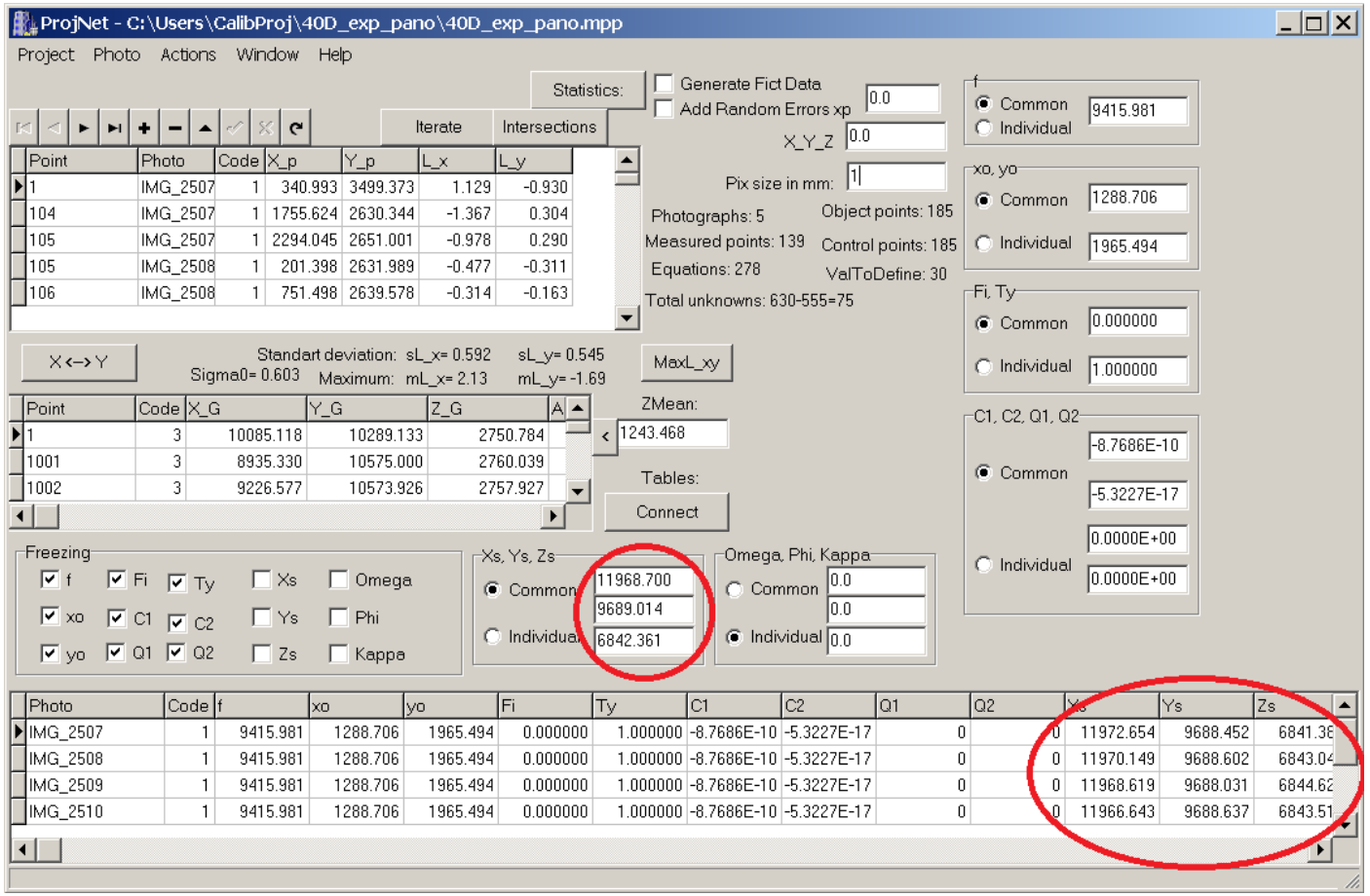
# Panoramic head

# Finding the front nodal point



# Example of shooting a test-object with a long-focus camera




ProjNet - C:\Users\CalibProj\40D_exp_pano\40D_exp_pano.mpp
Project Photo Actions Window Help
Statistics:
Generate Fict Data
Add Random Errors xp
0.0
X_Y_Z
0.0
Pix size in mm:
1
Iterate
Intersections
Photographs: 5
Object points: 185
Measured points: 139
Control points: 185
Equations: 278
ValToDefine: 30
Total unknowns: 630-555=75
f
Common
Individual
9415.981
xo, yo
1288.706
1965.494
Fi, Ty
0.000000
1.000000
C1, C2, Q1, Q2
-8.7686E-10
-5.3227E-17
0.0000E+00
0.0000E+00
X<->Y
Standart deviation: sL_x= 0.592 sL_y= 0.545
Sigma0= 0.603 Maximum: mL_x= 2.13 mL_y= -1.69
MaxL_xy
ZMean:
1243.468
Tables:
Connect
Freezing
f Fi Ty Xs Omega
xo C1 C2 Ys Phi
yo Q1 Q2 Zs Kappa
Xs, Ys, Zs
11968.700
9689.014
6842.361
Omega, Phi, Kappa
0.0
0.0
0.0
Point Photo Code X_p Y_p L_x L_y
1 IMG_2507 1 340.993 3499.373 1.129 -0.930
104 IMG_2507 1 1755.624 2630.344 -1.367 0.304
105 IMG_2507 1 2294.045 2651.001 -0.978 0.290
105 IMG_2508 1 201.398 2631.989 -0.477 -0.311
106 IMG_2508 1 751.498 2639.578 -0.314 -0.163
Point Code X_G Y_G Z_G
1 3 10085.118 10289.133 2750.784
1001 3 8935.330 10575.000 2760.039
1002 3 9226.577 10573.926 2757.927
Photo Code f xo yo Fi Ty C1 C2 Q1 Q2 Xs Ys Zs
IMG_2507 1 9415.981 1288.706 1965.494 0.000000 1.000000 -8.7686E-10 -5.3227E-17 0 0 11972.654 9688.452 6841.38
IMG_2508 1 9415.981 1288.706 1965.494 0.000000 1.000000 -8.7686E-10 -5.3227E-17 0 0 11970.149 9688.602 6843.04
IMG_2509 1 9415.981 1288.706 1965.494 0.000000 1.000000 -8.7686E-10 -5.3227E-17 0 0 11968.619 9688.031 6844.62
IMG_2510 1 9415.981 1288.706 1965.494 0.000000 1.000000 -8.7686E-10 -5.3227E-17 0 0 11966.643 9688.637 6843.51

# Evaluation of accuracy by simulated data

| RMS (mm) | Individual projection centers | Common projection center |
|---|---|---|
| f | 0.047 | 0.017 |
| xo | 0.372 | 0.352 |
| yo | 0.280 | 0.284 |

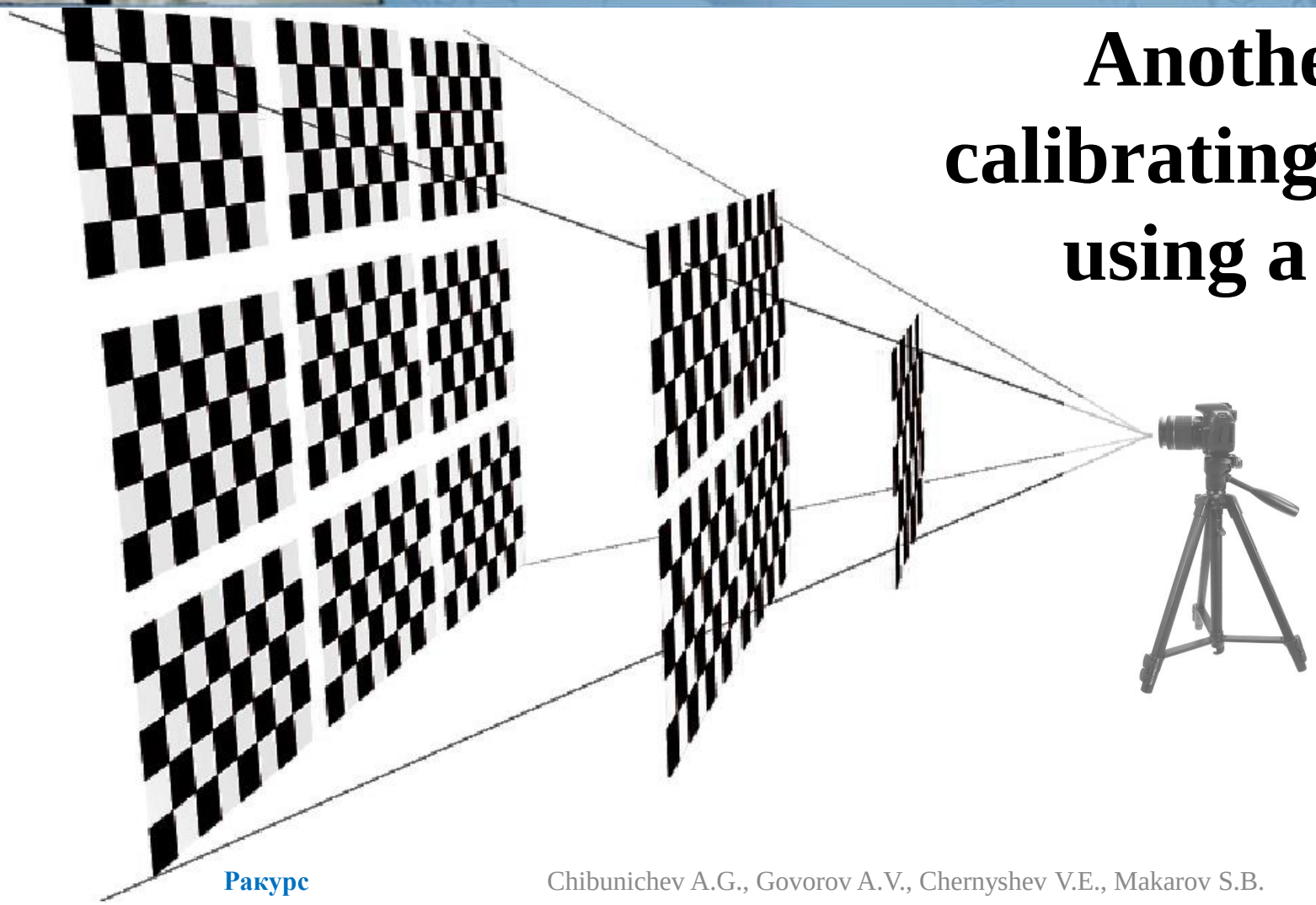
# The results of camera calibration - Hasselblad H4D-60, f = 100 mm.

| | Individual projection centers | Common projection center |
|---|---|---|
| f, pix | 16663.77 +/- 2.34 | 16656.360 +/- 1.44 |
| xo, pix | 3363.18 +/- 2.32 | 3360.727 +/- 2.39 |
| yo, pix | 4522.66 +/- 2.50 | 4532.29 +/- 1.92 |
| $K_1$ | -1.8614E-10 +/- 9.8780e-12 | -2.0206E-10 +/- 9.9394e-12 |
| $K_2$ | -1.1706E-18 +/- 3.2410e-19 | -7.8066E-19 +/- 3.3487e-19 |

# Results of photogrammetric processing of the stereopair (49 points of the test-object)

| RMS | Individual projection centers | Common projection center |
|---|---|---|
| X, mm | 0.17 | 0.16 |
| Y, mm | 0.22 | 0.11 |
| Z, mm | 0.50 | 0.31 |

# Another approach to calibrating digital cameras is using a flat test-object



# Calibration of digital camera by flat test-object

$$\left.\begin{aligned} x_0 - f\frac{a_{11}(X-X_S)+a_{21}(Y-Y_S)+a_{31}(Z-Z_S)}{a_{13}(X-X_S)+a_{23}(Y-Y_S)+a_{33}(Z-Z_S)} - x + d_x = 0 \\ y_0 - f\frac{a_{12}(X-X_S)+a_{22}(Y-Y_S)+a_{32}(Z-Z_S)}{a_{13}(X-X_S)+a_{23}(Y-Y_S)+a_{33}(Z-Z_S)} - y + d_y = 0 \end{aligned}\right\}$$

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} X_{0i} \\ Y_{0i} \\ Z_{0i} \end{pmatrix} + A_i \begin{pmatrix} X_i \\ Y_i \\ Z_i \end{pmatrix}$$

$$\left.\begin{aligned} d_x = x(r^2k_1 + r^4k_2 + r^6k_3) + (r^2 + 2x^2)p_1 + 2xyp_2 \\ d_y = y(r^2k_1 + r^4k_2 + r^6k_3) + 2xyp_1 + (r^2 + 2y^2)p_2 \end{aligned}\right\}$$

*i* - number of flat test-object

# Thanks so much

# Большое спасибо