BUDAPEST UNIVERSITY OF TECHNOLOGY AND ECONOMICS
Department of Geodesy and Surveying

IUGG 2019
G02p-398

MŰEGYETEM 1782

Calibration of CCD sensor on astrogeodetic measuring system

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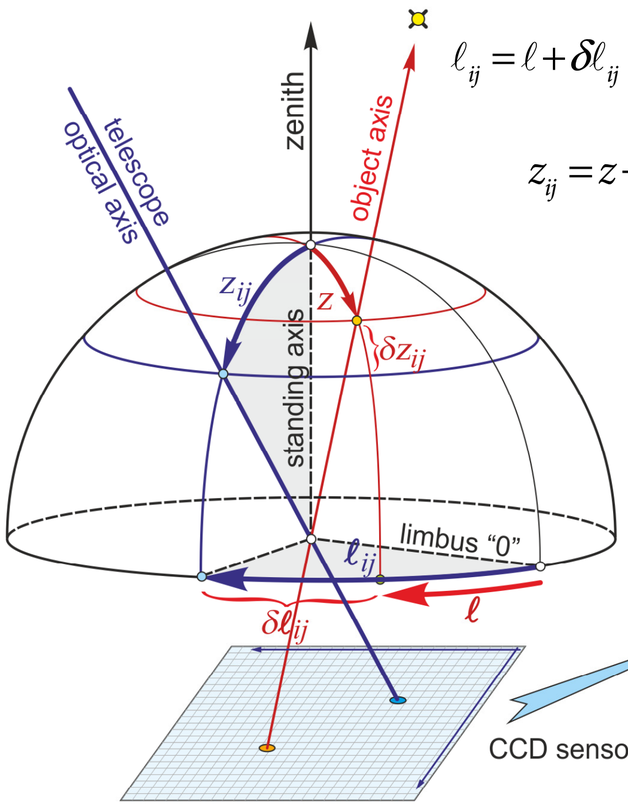
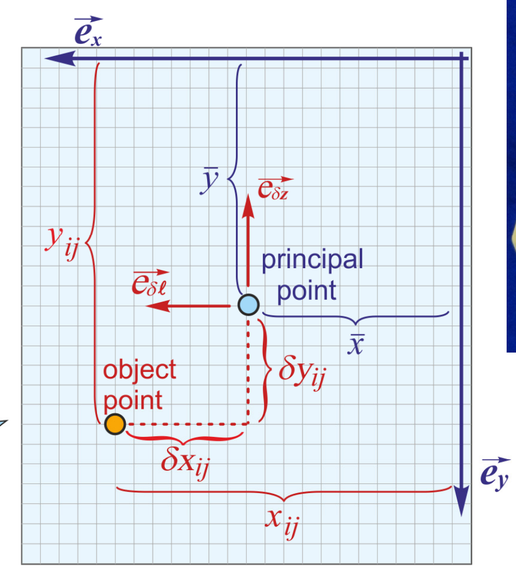
CCD sensors often substitute visual readout of geodetic instruments for various tasks. If the eyepiece of the telescope is replaced with a CCD sensor, the most important task is to calibrate the instrument. We present the Calibration of a CCD sensor on the QDaedalus astrogeodetic measuring system, which is a computer-controlled automated geodetic total station integrated with GNSS technology. Accordingly, it is necessary to establish a connection between the readings on the horizontal and vertical circles of the total station and the readings in the coordinate system of the CCD sensor. The calibration procedure at night in field conditions was rather cumbersome and did not yield the expected measurement accuracy. To solve this problem, we have developed a new method and tool for calibrating more easily and more accurately by a collimator. We tested the optimal number of calibration measurements and optimal raster size; additionally, the temperature dependence of the measurements was also investigated. Our experiences are useful in all cases when CCD sensors are mounted on geodetic instruments. (*Sponsored by NKFIH No. 124286.*)

Relationship between coordinates on the CCD sensor and angle readings on the total station:



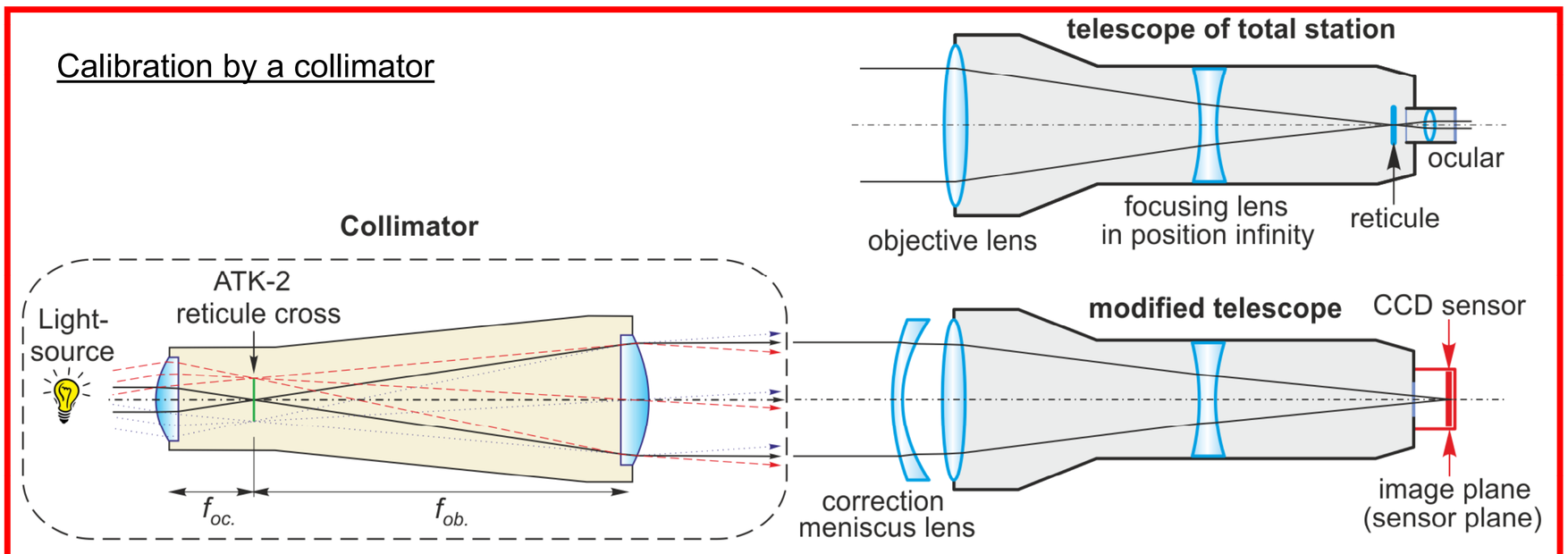
$$\ell_{ij} = \ell + \delta\ell_{ij} = \ell + \frac{1}{\sin z_{ij}}\left(a_{11}(x_{ij}-\bar{x}) + a_{12}(y_{ij}-\bar{y})\right)$$

$$z_{ij} = z + \delta z_{ij} = z + \left(a_{21}(x_{ij}-\bar{x}) + a_{22}(y_{ij}-\bar{y})\right)$$



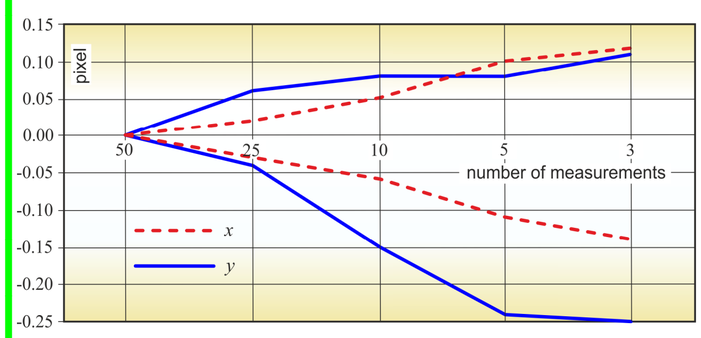
$$\left.\begin{aligned}\bar{x} &= \frac{1}{n}\sum_{i=1}^{n}\frac{x_{i1}+x_{i2}}{2}\\ \bar{y} &= \frac{1}{n}\sum_{i=1}^{n}\frac{y_{i1}+y_{i2}}{2}\end{aligned}\right\}\ \text{Principal point}$$

Calibration by a collimator

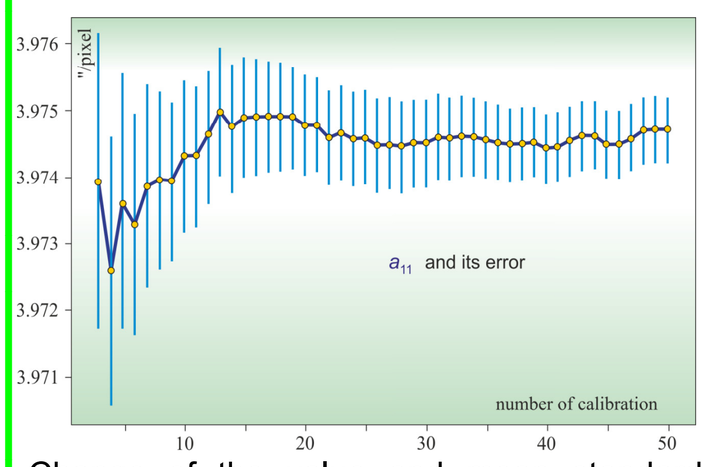


Finding optimum number of calibrations

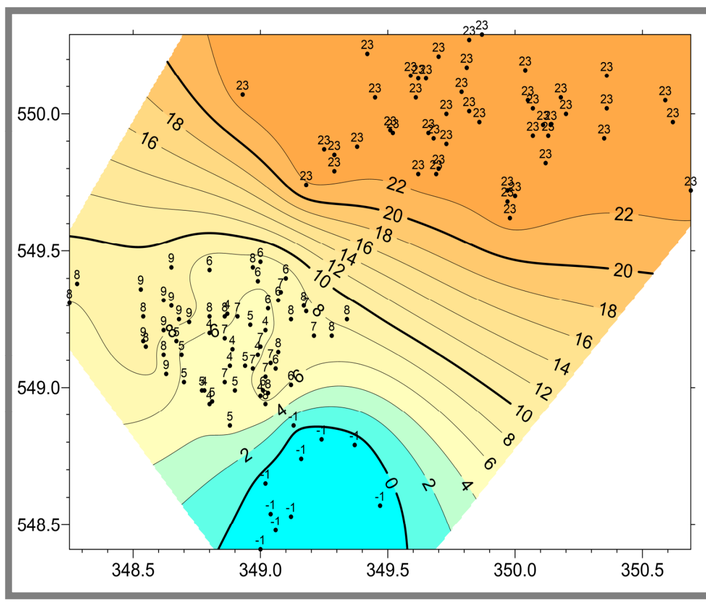
randomly selected groups of 25, 10, 5 and 3 measurements in 10 different combinations were choosed from 50 calibrations.



Growth of the largest positive and negative differences in x and y directions relative to the mean principal point of 50 calibrations as the number of calibrations decreases.

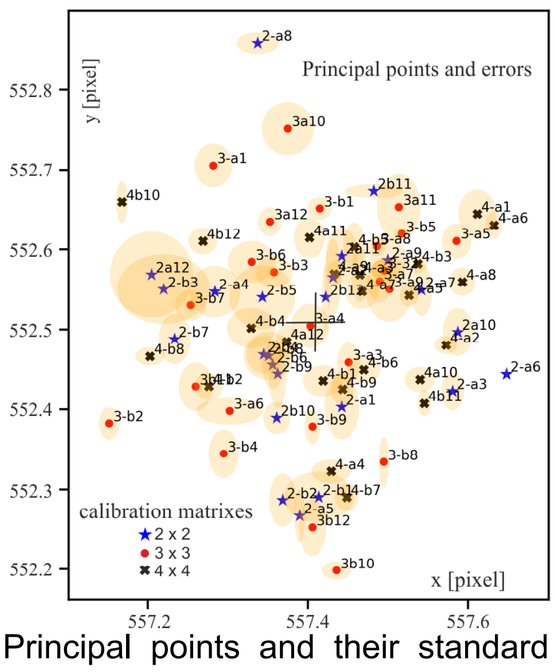


Change of the value and mean standard error of the calibration parameter a_{11} as function of the number of calibrations.

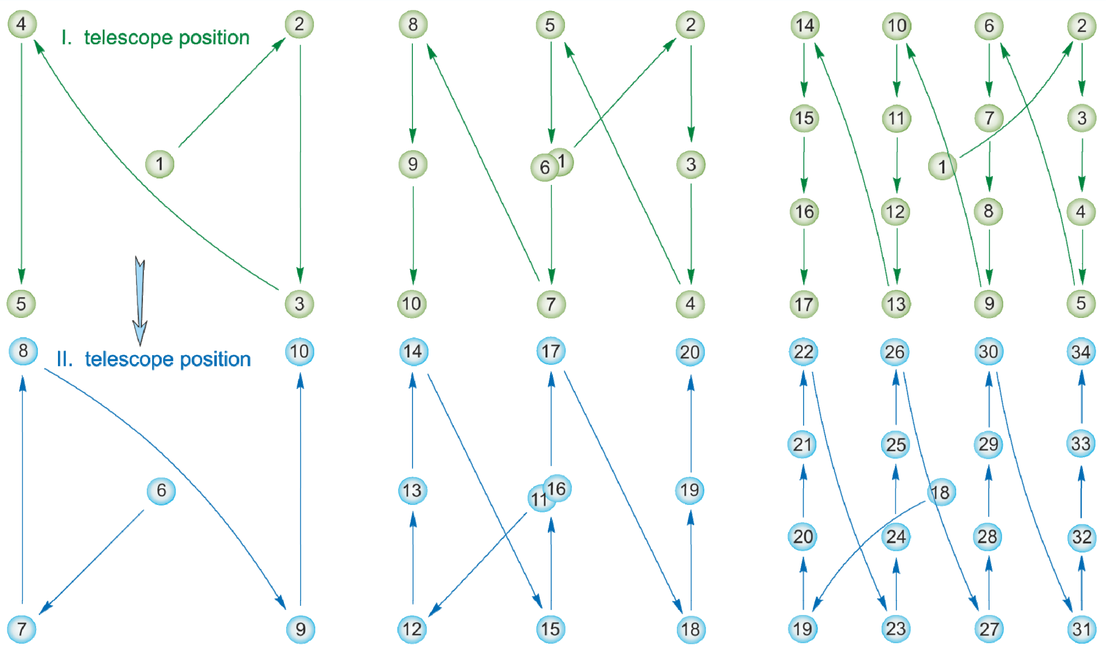


Optimal size of calibration matrix

During calibration, the total station's servomotor moves the telescope of the instrument at small steps over a specific pattern in the vicinity of the calibration target. The calibrated area of the CCD sensor depends on the size of the calibration matrix and the grid spacing.
Increasing the size of the calibration matrix, despite of the greatly increased measurement time does not significantly increase the accuracy of the principal point's position:



Principal points and their standard errors in case of 2×2, 3×3 (optimal) and 4×4 calibration matrices



Telescope movement along the corner points of 2×2, 3×3 and 4×4 matrices

Temperature dependence

Position of the principal points as a function of temperature.