MULTIMEDIA TECHNOLOGY GROUP PROJECT

Correction of lens distortion for astronomical plates digitized by SLR camera

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It is necessary to carry out precise measurement of detected stellar objects in astronomy. In case of astronomical plates digitization by digital SLR (Single Lens Reflection) camera, they could be trans-illuminated and taken by the camera equipped with a suitable lens. The condition is a 100% match of an object (astronomical plate) and its image. Nevertheless, mentioned imaging system is not ideal. Various optical aberrations occur during acquisition. They introduce errors as are e.g. distortion, coma, astigmatism or chromatic aberration. Distortion influences correct positions of stellar objects and causes incorrect interpretation of taken data whether they were correct acquired using astronomical plate. Therefore, it is necessary to modify existing methods for astronomical image processing in the case of input lens with wider field of view or to remove lens distortion and apply existing algorithms. In this paper we describe a principle of image system distortion elimination using OpenCV software library.

Introduction

Optical aberrations occur during image acquisition using a real imaging system. Source of aberrations is mostly an optical part consisting of a real input lens, which cannot be modeled by pinhole camera model [1]. Images of real cameras suffer from more or less lens distortion: pincushion or barrel (Fig. 1). It causes inaccuracy of stellar object measuring using astrometry and photometry algorithms. Therefore it is necessary to correct it.

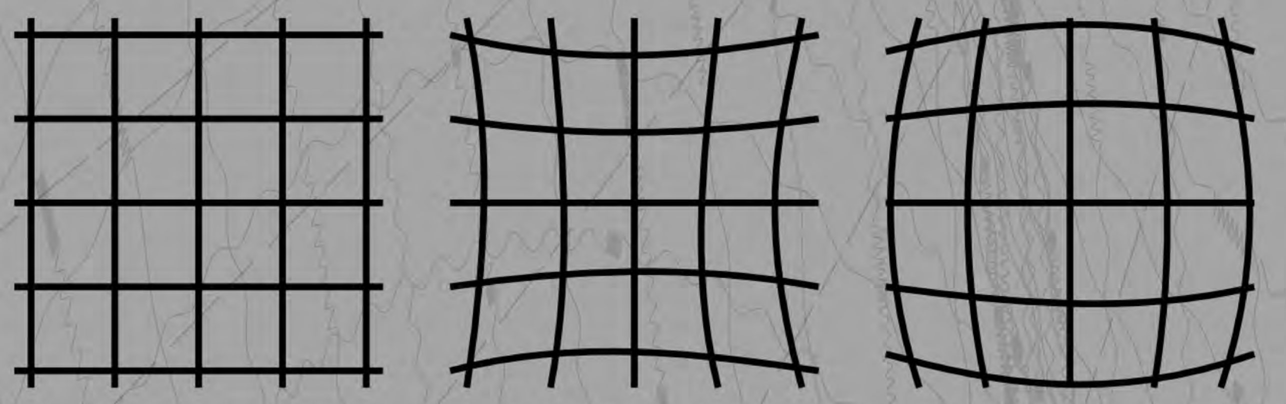

Figure 1: Examples of the pincushion (middle) and the barrel (right) distortion of the grid (left).

Correction of barrel distortion is in our case performed in C++ language using open source OpenCV library [3] containing properly software packages. The whole process consists of two steps:

1) Camera calibration
2) Correction of distortion using geometrical transformation

Camera calibration

Calibration is a process of intrinsic and extrinsic camera parameters determination.

Camera matrix (intrinsic)

$$\begin{bmatrix} x \\ y \\ w \end{bmatrix} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

Distortion coefficients (extrinsic)

$$Dist_{coef} = [k_1, k_2, p_1, p_2, k_3]$$

radial distortion (k_1, k_2, k_3) — tangential distortion (p_1, p_2)

[X, Y, Z] - coordinates of a 3D point in the world coordinate space

[x, y, w] - projection coordinates, w=0 for 2D images

[f_x, f_y] - camera focal lengths in pixels

[c_x, c_y] - optical centers in px

Camera matrix can be entered by hand or can be estimated from an input image, which should contain an object of known shape. In our case, it is a classical black-white chessboard pattern. Its image is loaded to an appropriate function, which detects internal corners - points where the black squares touch each other (see Fig. 2, yellow points).

Distortion coefficients are calculated based on taken chessboard pattern and knowledge of number of internal corners. The global Levenberg-Marquardt optimization algorithm is used for minimization of reprojection error, that is, the total sum of squared distances between the observed feature points and the projected (using the current estimates for camera parameters and the poses) object points.

Correction of distortion

On the base of detected internal corners of taken chessboard pattern, the joint undistortion and rectification transformation is computed. After that, for each pixel in the destination (corrected and rectified) image, corresponding coordinates in the source image (original image from camera) are calculated using distortion parameters. Values of pixels with non-integer coordinates are computed using bilinear interpolation method

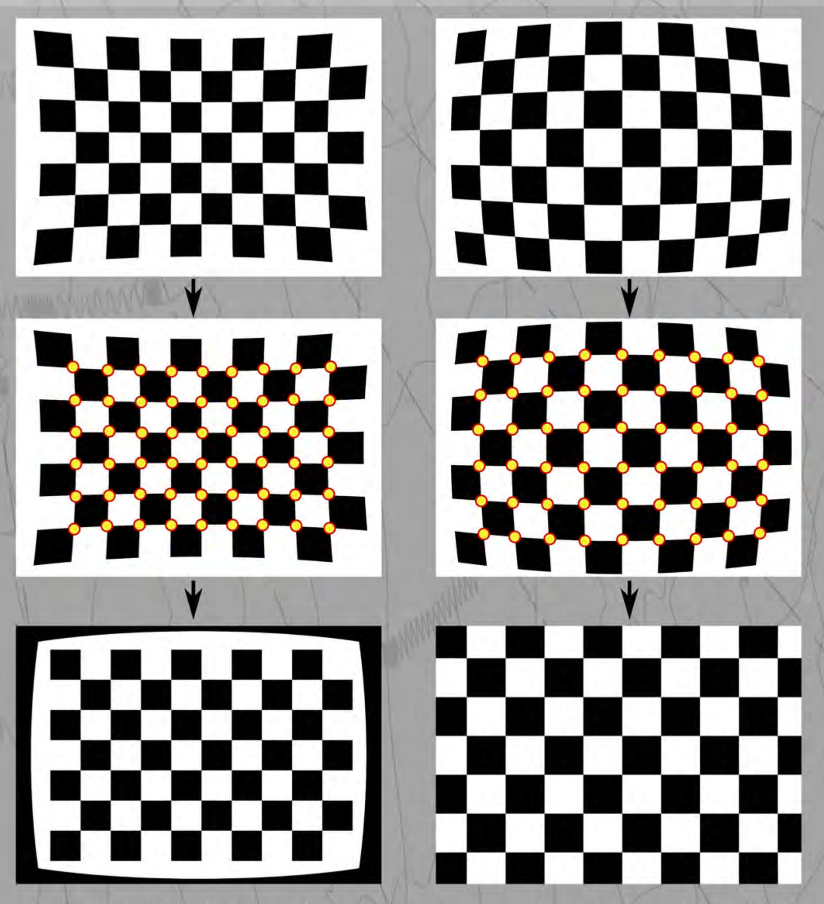

Figure 2: Internal edges detection and correction of pincushion (left) and barrel (right) distortion.

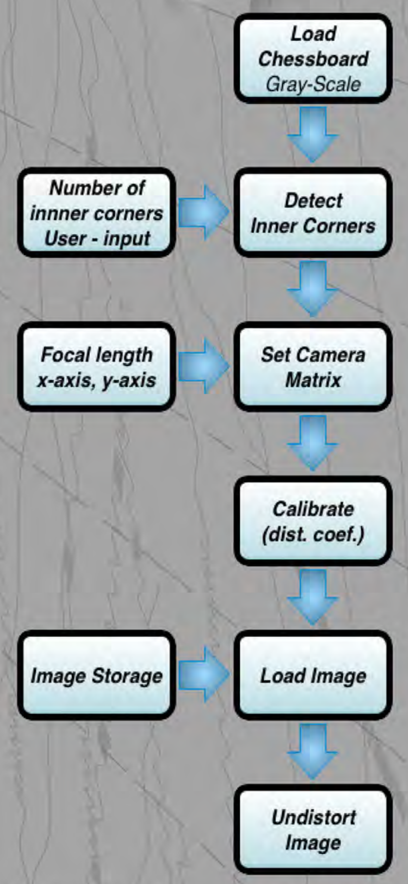

Figure 3: Process of correction of image distortion.

Fig. 3 shows the whole above described procedure of barrel distortion elimination.

Real imaging system

In our case, we have a deal with digitization of astronomical plates using digital SLR (Single Lens Reection) camera Nikon with properly lens. Information about camera and lens model is confidential jet.

Correction of barrel distortion is a part of the whole process. Fig. 4 shows an image of taken chessboard pattern by used imaging system and the same image aster correction. Difference between two images is minimal in contrast to simulated image of barrel distortion from Fig. 2. Computed distortion matrices for the real image and the simulated one are listed below

[2.89, -5.08, -0.04, 0.08, -0.002] **[0.53, -0.00, 0.001, 0.002, -3.04e-08]**

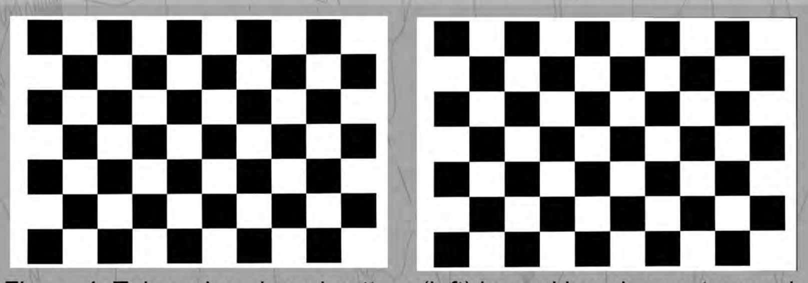

Figure 4: Taken chessboard pattern (left) by real imaging system and its correction of distortion

Mean Square Error (MSE) was used for representation of an objective criterion for comparison of coordinates change before and after correction. According to Fig. 5 and differences between input and corrected coordinates of detected internal corners of chessboard patterns expressed by MSE, we can conclude that distortion ration of taken images is very low. Therefore, it is necessary to think about necessity of this step during image processing.

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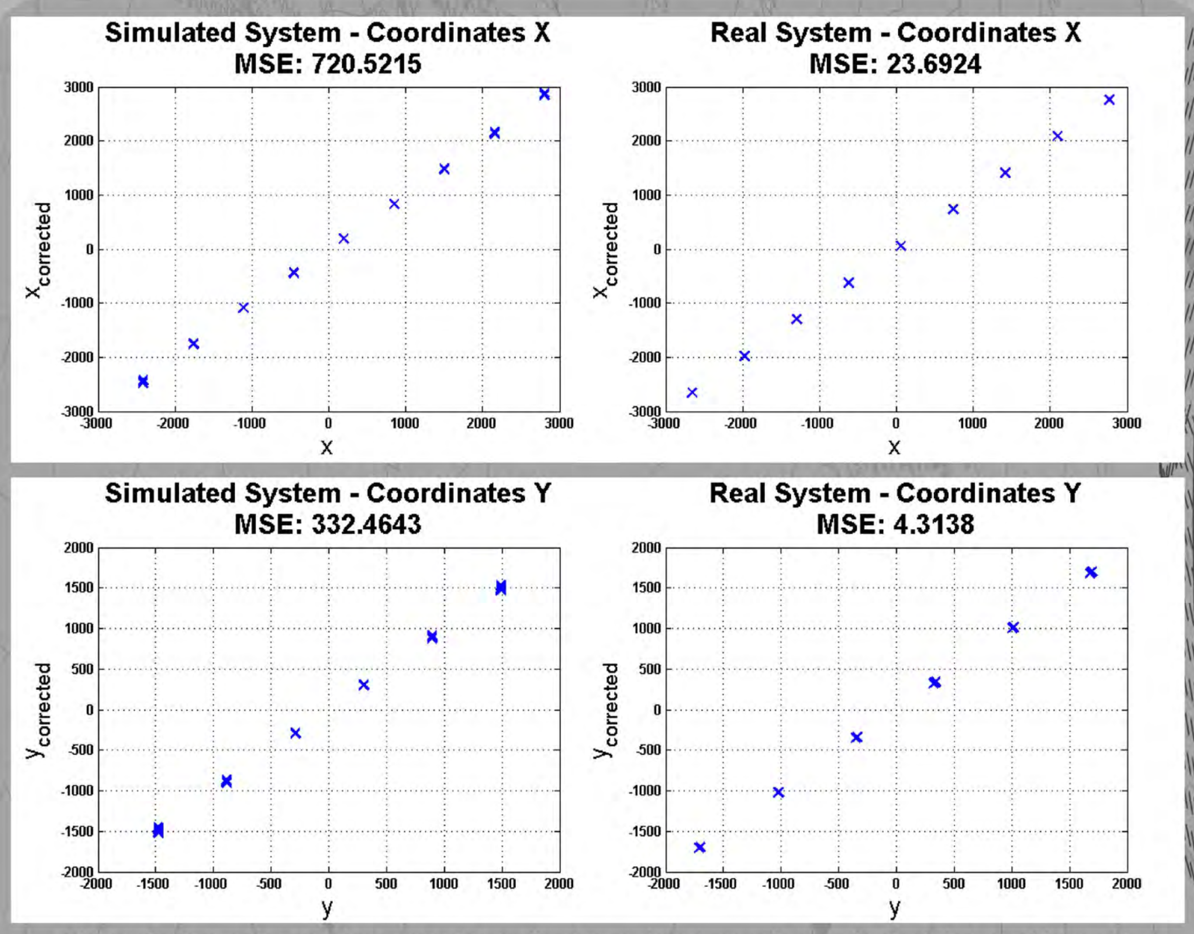

Figure 5: Dependence of corrected coordinates on input coordinates (x,y) of detected internal corners inside chessboard pattern taken by our system (right) and simulated one (left).

References

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