# Camera Calibration with OpenCV

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*Cameras have been around for a long time and its quality varies among different brands or prices. Cheap cameras are indeed more affordable for most people, but its cheapness comes with a cost: significant distortion. Fortunately, there are camera constants and with a calibration and some remapping we can correct its distortion. Furthermore, with calibration we may also determine the relationship between the camera's natural units (pixels) and the real-world units (e.g. millimetres).*

For the distortion OpenCV takes into account the radical and tangential factors. For the radical factor one uses the following formula:

$$x_{dis} = x(1 + k_1 r^2 + k_2 r^4 + k_3 r^6)$$
$$y_{dis} = y(1 + k_1 r^2 + k_2 r^4 + k_3 r^6)$$

So, corresponding to every pixel point at (x, y) its position in the distorted image is ($x_{dis}$, $y_{dis}$). The presence of the radical distortion usually manifests in form of the "barrel" and "fish-eye" effect.

Tangential distortion occurs because the image taking lenses are not perfectly parallel to the imaging plane. It can be represented via the formula:

$$x_{dis} = x + 2p_1 xy + p_2(r^2 + 2x^2)$$
$$y_{dis} = y + [p_1(r^2 + 2y^2) + 2p_2 xy)$$

We consequently have five distortion parameters that in OpenCV are presented as one row matrix with five columns:

$$distortion_{coefficients} = (k_1\ k_2\ p_1\ p_2\ k_3)$$

Now for the unit conversion the following formula is applied:

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

Hence the presence of w is explained using homograph coordinate system (and w = Z). The unknown parameters are fx and fy (camera focal lengths) and (cx, cy) that are the optical centres expressed in pixels' coordinates. If for both axes a common focal length is used with given a aspect ratio (usually 1), then fx = fy*a and in the upper formula we will have a single focal length f. The matrix containing these four parameters is referred to as the camera matrix. While the distortion coefficients are the same regardless of the camera resolutions used, these should be scaled along with the current resolution from the calibrated resolution.

The process of determining these two matrices is the calibration. Calculation of these parameters is done through basic geometrical equations. The equations used depend on the chosen calibrating objects. Currently OpenCV supports three types of objects for calibration:

- Classical black-white chessboard
- Symmetrical circle pattern
- Asymmetrical circle pattern

Basically, every image or every frame of video capture results in a new equation. To solve the equation, it is necessary to predetermine number of frames to form a well-posed equation system (25 frames in project). Theoretically this number is higher for the chessboard pattern and less for the circle ones.

Reference:

OpenCV Tutorials, *Camera calibration with OpenCV*, http://docs.opencv.org/3.1.0/d4/d94/tutorial_camera_calibration.html [online]