Camera calibration theory

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Abstract

Summary of key concepts on camera calibration theory

1 Introduction

Based on the OpenCV documentation [1].

Consider a point P in 3D with coordinates X in the world reference frame, stored in the matrix X. The coordinate vector of P in the camera reference frame is given by:

$$X_c = R \cdot X + T$$

where R is the rotation matrix corresponding to the rotation vector om, and $R = \text{rodrigues}(om)$. Let x, y, and z represent the three coordinates of X_c:

$$x = X_{c1}, \quad y = X_{c2}, \quad z = X_{c3}$$

The pinhole projection coordinates of P are $[a, b]$, where:

$$a = \frac{x}{z}, \quad b = \frac{y}{z}$$

Using the radial distance $r^2 = a^2 + b^2$, the angle $\theta = \text{atan}(r)$.

Fisheye distortion:

The angle θ_d after distortion is given by:

$$\theta_d = \theta \left(1 + k_1\theta^2 + k_2\theta^4 + k_3\theta^6 + k_4\theta^8\right)$$

The distorted point coordinates are $[x', y']$, where:

$$x' = \frac{\theta_d}{r} \cdot a, \quad y' = \frac{\theta_d}{r} \cdot b$$

Finally, converting into pixel coordinates: The final pixel coordinates vector $[u, v]$ are obtained as follows:

$$u = f_x\left(x' + \alpha y'\right) + c_x, \quad v = f_y y' + c_y$$

This represents a generic camera model [116] with perspective projection and without distortion correction.

Please note that I assumed f_x, f_y, c_x, and c_y as the focal lengths and principal point coordinates of the camera, and k_1, k_2, k_3, and k_4 as the distortion coefficients. You can replace these variables with their actual values when using the equations.

$$\begin{bmatrix} u_x \\ u_y \end{bmatrix} = \frac{\theta\left(1 + k_1\theta^2 + k_2\theta^4 + ...\right)}{r} \begin{bmatrix} f_x & 0 \\ 0 & f_y \end{bmatrix} \begin{bmatrix} x/z \\ y/z \end{bmatrix} + \begin{bmatrix} o_x \\ o_y \end{bmatrix} \tag{1}$$

References

[1] Fisheye opencv docs.