AutoCalib

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using 2 late days

***Abstract*—In this Homework, we calculated Camera Calibration parameters. Camera calibration consists of Extrinsic and Intrinsic parameters of the Camera and Distortion Coefficients. We find these using Zhengyou Zhang's method.**

***Index Terms*—IEEE, IEEEtran, journal, LaTeX, paper, template.**

I. Introduction

THE image points(pixels) and the world point(in meters) are related by a Homography. Homography is given by,

$$\mathbf{H} = \mathbf{A}\begin{bmatrix}\mathbf{r}_1 & \mathbf{r}_2 & \mathbf{t}\end{bmatrix} .$$

Here, r1, r2, r3 are the rotations, and t is the translation. They consist of the extrinsic parameters. The matrix A, denotes the intrinsic parameters and is given by, The relation

$$\mathbf{A} = \begin{bmatrix}\alpha & \gamma & u_0 \\ 0 & \beta & v_0 \\ 0 & 0 & 1\end{bmatrix}$$

between the camera points(image points) and world points is, Here, u,v are camera points and X, Y are world points.

$$s\begin{bmatrix}u \\ v \\ 1\end{bmatrix} = \mathbf{A}\begin{bmatrix}\mathbf{r}_1 & \mathbf{r}_2 & \mathbf{r}_3 & \mathbf{t}\end{bmatrix}\begin{bmatrix}X \\ Y \\ 0 \\ 1\end{bmatrix}$$

II. Initial Parameter Estimation

We are given a set of 13 images of a Checkerboard of size 6x9 for Calibration taken from Google Pixel XL phone with focus locked. This was printed on an A4 paper and the size of each square was 21.5mm.

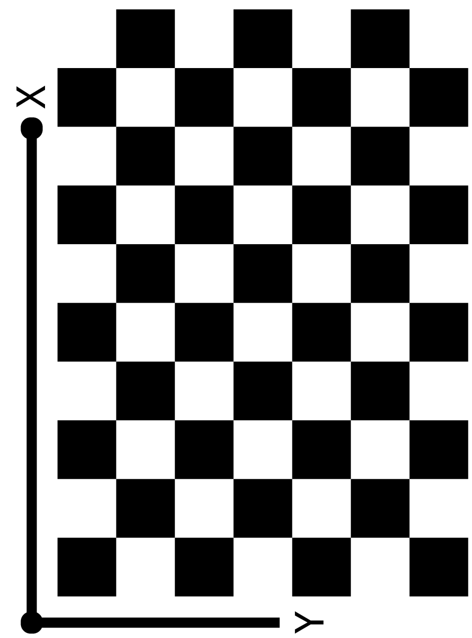

Fig. 1. The Checkerboard

A. intrinsic Parameters

1) Calculating Homography: The first step towards calculating Instrinsic Parameters is by calculating Homopgraphy which can be obtained by using cv2.findHomography() function. For this, we first need to obtain image points and world points. Image points can be obtained by using the function cv2.checkerBoardCorners(), and the world points can be formed by creating a meshgrid of the same dimensions as the given CheckerBoard.

2) Calculating A matrix: A matrix is obtained using the following relations,

We used Singular value Decomposition (SVD) for solving equation of type Ax=0.

B. Extrinsic Parameters

Extrinsic Parameters can be obtained using the following relations,

C. Distortion Coefficients and Error

We used the scipy.optimize.least_squares() function for obtaining the above. We did so by using the following relations,

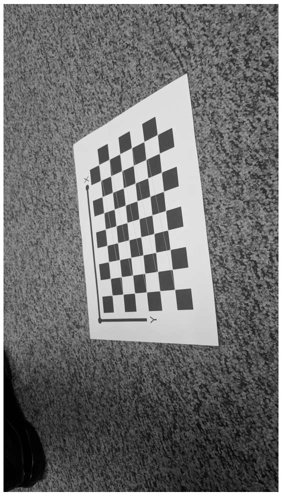

Fig. 2. the corners

$$\mathbf{B} = \mathbf{A}^{-T}\mathbf{A}^{-1} \equiv \begin{bmatrix} B_{11} & B_{12} & B_{13} \\ B_{12} & B_{22} & B_{23} \\ B_{13} & B_{23} & B_{33} \end{bmatrix}$$

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III. Results

Optimized K matrix(Intrinsic Parameters): [2.09125584e+04 -1.88382002e+04 -2.86559580e+04 2.90283073e+03 -2.12356748e+03 1.04640717e+03 6.63108747e+00 -5.46295543e+00 -5.86301344e+00]

Since the reprojection error is too large, the undistorted images obtained were blank.

$$\mathbf{b} = [B_{11}, B_{12}, B_{22}, B_{13}, B_{23}, B_{33}]^T$$

$$\begin{bmatrix} \mathbf{v}_{12}^T \\ (\mathbf{v}_{11} - \mathbf{v}_{22})^T \end{bmatrix} \mathbf{b} = \mathbf{0}$$

$$\begin{aligned} v_0 &= (B_{12}B_{13} - B_{11}B_{23})/(B_{11}B_{22} - B_{12}^2) \\ \lambda &= B_{33} - [B_{13}^2 + v_0(B_{12}B_{13} - B_{11}B_{23})]/B_{11} \\ \alpha &= \sqrt{\lambda/B_{11}} \\ \beta &= \sqrt{\lambda B_{11}/(B_{11}B_{22} - B_{12}^2)} \\ \gamma &= -B_{12}\alpha^2\beta/\lambda \\ u_0 &= \gamma v_0/\beta - B_{13}\alpha^2/\lambda \,. \end{aligned}$$

$$\begin{aligned} \mathbf{r}_1 &= \lambda\mathbf{A}^{-1}\mathbf{h}_1 \\ \mathbf{r}_2 &= \lambda\mathbf{A}^{-1}\mathbf{h}_2 \\ \mathbf{r}_3 &= \mathbf{r}_1 \times \mathbf{r}_2 \\ \mathbf{t} &= \lambda\mathbf{A}^{-1}\mathbf{h}_3 \end{aligned}$$

$$\begin{bmatrix} (u-u_0)(x^2+y^2) & (u-u_0)(x^2+y^2)^2 \\ (v-v_0)(x^2+y^2) & (v-v_0)(x^2+y^2)^2 \end{bmatrix} \begin{bmatrix} k_1 \\ k_2 \end{bmatrix} = \begin{bmatrix} \breve{u}-u \\ \breve{v}-v \end{bmatrix}$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} \|\mathbf{m}_{ij} - \hat{\mathbf{m}}(\mathbf{A}, \mathbf{R}_i, \mathbf{t}_i, \mathtt{M}_j)\|^2$$

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Optimized k Vector(Distortion): [0.00024073 0.14572058]
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Reprojection Error 12.33756625846277
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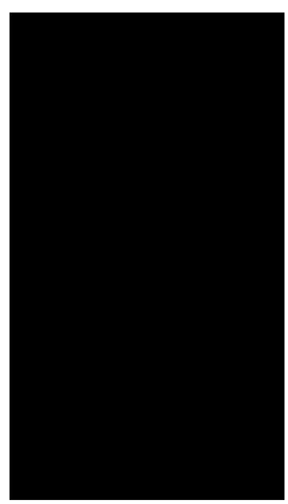

Fig. 3. Undistorted Image