RBE 549 Homework 1: AutoCalib

Aabha Tamhankar
Masters in Robotics Engineering
Worcester Polytechnic Institute
astamhankar@wpi.edu

***Abstract*—The paper follows Camera Calibration method described by Zhengyou Zhang, in the paper ”A Flexible New Technique for Camera Calibration.” This method estimates all extrinsic and intrinsic parameters of the camera using real world points, and the image points .**

I. Introduction

Camera calibration is a necessary step in 3D computer vision in order to extract metric information from 2D images. Camera calibration includes calculation of intrinsic and extrinsic parameters of the camera using homography between real point and image points. The camera calibration matrix is given by 1, which composes of intrinsic camera parameters.

$$A = \begin{bmatrix} f_x & \gamma & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix} \tag{1}$$

Here, f_x, f_y are focal lengths and c_x, c_y are principle points, while γ describes the skewness of two image axes. This is assuming an ideal image without any distortion. However, radial distortion is also applied, which is given by the values k_1 and k_2. Zhengyou Zhang has described a method to estimate the parameters f_x, f_y, c_x, c_y, k_1 and k_2 through his paper. The steps are explained in details below.

II. Technique for Camera Calibration

A. Obtaining the Data

The Zhang's paper relies on a calibration target (checkerboard in our case) to estimate camera intrinsic parameters. Thus, a checkerboard was printed as an object in the world frame in which size of each square was 21.5mm. 13 images of this checkerboard were taken at different angle from a Google Pixel XL phone.

1) World Points: Since the dimensions of real checkerboard pattern were known, the values of world coordinates were readily calculated. Since only the inner grid is considered as common practice, only 9X6 world points were considered.

2) Image Points: The image coordinates are calculated using *cv2.findChessboardCorners*, which detects corners of inner grid of a checkerboard. Thus, 9X6 image points were obtained

B. Finding Homography

After finding both image points and world point, the homography between image and real object is calculated. For this, *cv2.findHomography()* is used as a basic method to find homography. This function requires atleast four points to get homography, but all available points have been used. We can say that a model point M and its image m is related by a homography such that

$$sm = HM \tag{2}$$

with

$$H = A \begin{bmatrix} r1 & r2 & t \end{bmatrix}$$

C. Finding B matrix

B is given by

$$B = A^{-T} A^{-1}$$

Since A is an upper triangular matrix (having right bottom elements as zeroes) as shown in 1, we get B as a symmetric matrix. The B matrix is found using b given by $b = \begin{bmatrix} B_{11}, B_{12}, B_{22}, B_{13}, B_{23}, B_{33} \end{bmatrix}$ as explained in Section 3.1 of [1]. The B found by following the steps was:

$$\begin{bmatrix} -1.47686373e-07 & -1.56139825e-10 & 1.10449865e-04 \\ -1.56139825e-10 & -1.49238371e-07 & 2.03623512e-04 \\ 1.10449865e-04 & 2.03623512e-04 & -9.99999973e-01 \end{bmatrix}$$

D. Finding A matix

The camera calibration matrix A was then found by refering to the same Section 3.1 of [1].

E. Finding Extrinsic Parameters

After getting the intrinsic parameter matrix, the extrinsic parameters of the camera are also calculated.

$$r1 = A^{-1} h1$$

$$r2 = A^{-1} h2$$

$$r3 = r1 \times r2$$

$$t = A^{-1} h3$$

Thus, we get an RT matrix such that $RT = \begin{bmatrix} r1, r2, r3, t \end{bmatrix}$.

F. Distortion Parameters

The radial distortion parameters *k1* and *k2* are initialized as 0 at first.

III. Results

A. Camera Matrix Values

$$A = \begin{bmatrix} -2.08152692e+03 & -2.18920030e+00 & 7.46425989e+02 \\ 0.00000000e+00 & 2.07067640e+03 & 1.36363700e+03 \\ 0.00000000e+00 & 0.00000000e+00 & 1.00000000e+00 \end{bmatrix}$$

B. Values of k1 and k2

$$k1 = 0.0165701552600425$$

$$k2 = -0.05601774829284805$$

C. Rectified Images

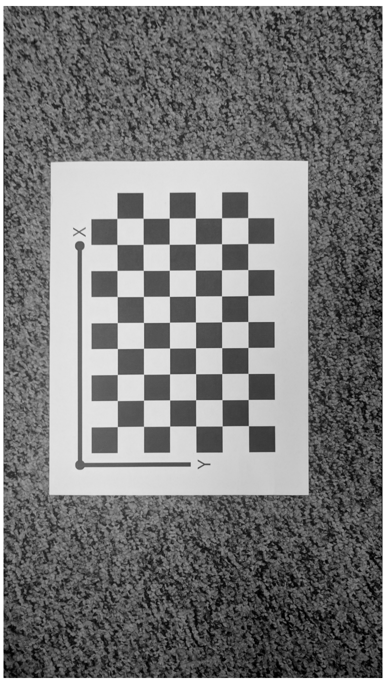

Fig. 1. Rectified Image 1

References

[1] Zhengyou Zhang, "A Flexible New Technique for Camera Calibration"
[2] https://learnopencv.com/camera-calibration-using-opencv/

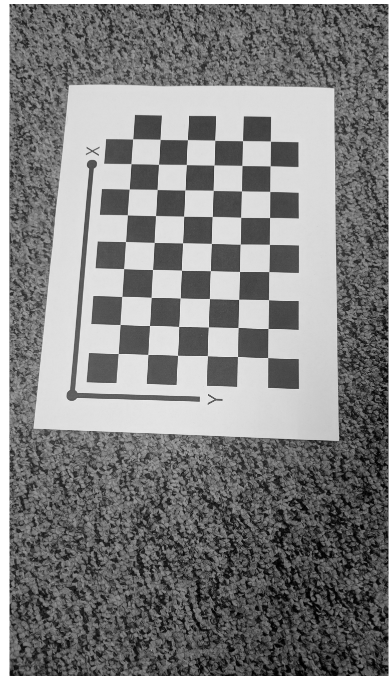

Fig. 2. Rectified Image 2

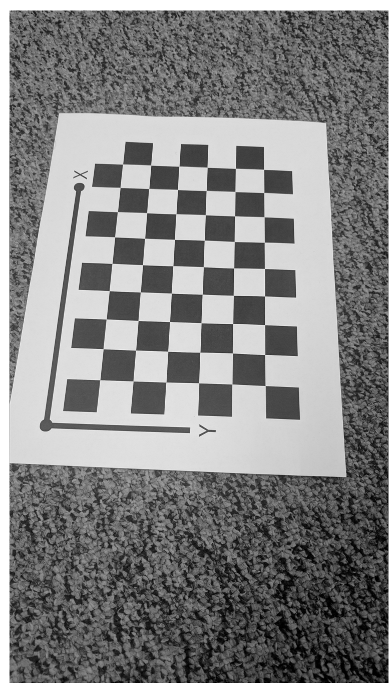

Fig. 3. Rectified Image 3

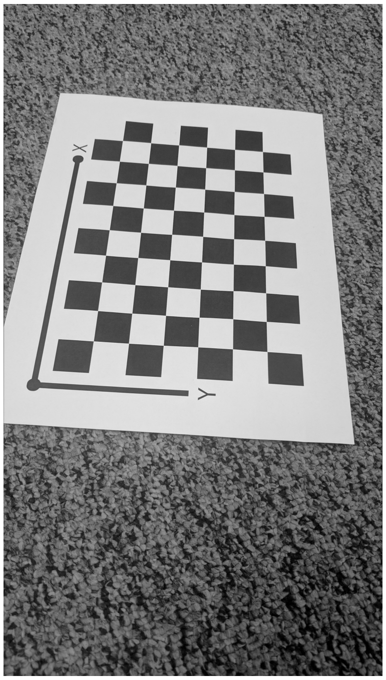

Fig. 4. Rectified Image 4

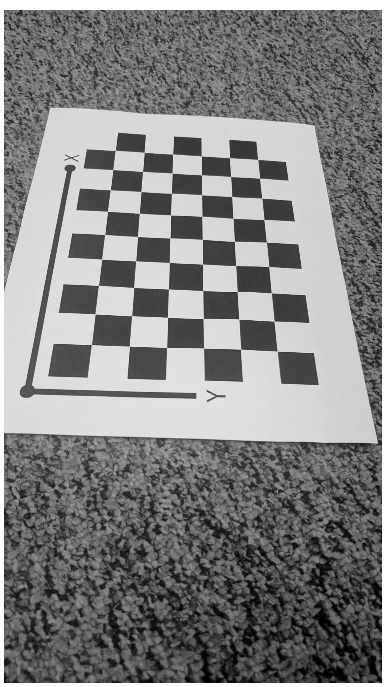

Fig. 5. Rectified Image 5

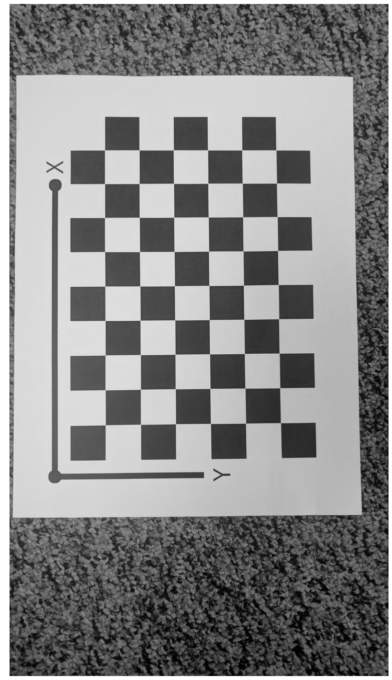

Fig. 6. Rectified Image 6

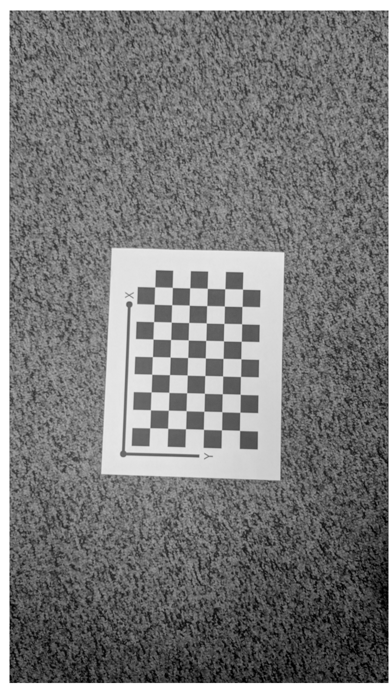

Fig. 7. Rectified Image 7

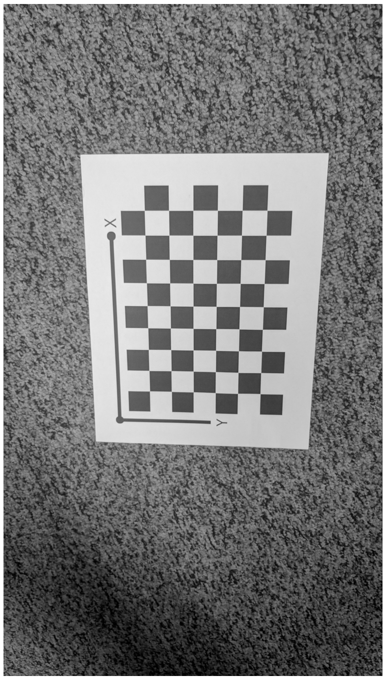

Fig. 8. Rectified Image 8

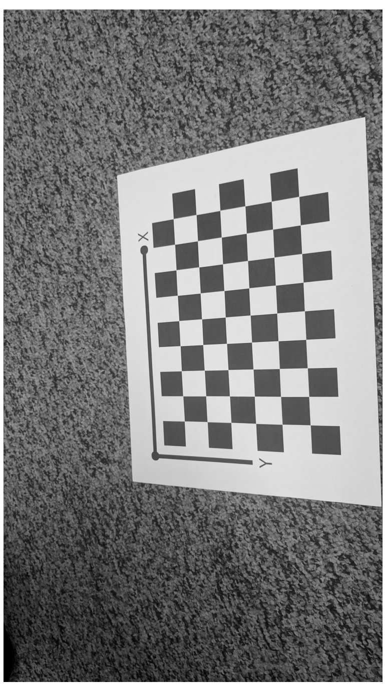

Fig. 9. Rectified Image 9

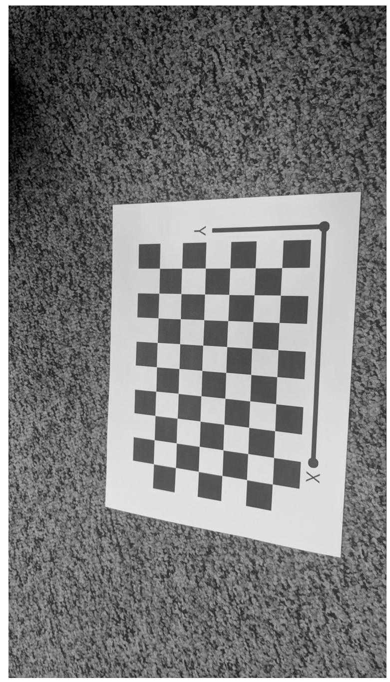

Fig. 10. Rectified Image 10