Calibration of a Smartphone Camera using Zhang's Method

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Abstract

This report describes the process and outcomes of calibrating the intrinsic and extrinsic parameters of a smartphone camera using Zhang's method. The objective was to enhance the accuracy of 3D object placements in images and compare the estimated focal lengths with the manufacturer's specifications.

1 Introduction

Goal: The goal of this project is to calibrate the camera of a smartphone to accurately estimate its intrinsic and extrinsic parameters using Zhang's method, and to validate these parameters by overlaying 3D objects onto the captured images. Additionally, this project aims to compare the focal lengths obtained through calibration with those provided in the smartphone's specifications.

2 Method

2.1 Equipment

I used my personal smartphone a Google Pixel 6a. I used his front camera (also called selfie camera). Further details about the camera specifications are provided when needed below.

2.2 Estimation of Intrinsic Parameters

Zhang's method was utilized to estimate the intrinsic parameters of the smartphone camera. This method involves capturing multiple images of a chessboard under various orientations, which is then used to compute the camera matrix and distortion coefficients. I followed the provided tutorial: link

2.3 Estimation of Extrinsic Parameters

With the world coordinate system defined by the chessboard, the extrinsic parameters of the camera were estimated. These parameters define the camera's position and orientation with respect to the world coordinates. These parameters are needed to find the projection matrix that map real world 3D point into the image 2D plane.

2.4 Undistortion

Undistortion was used to remove the distortion effect caused by inaccuracies in the lens position and other manufacturer errors. We used the method undistort(...) from OpenCV.

2.5 Drawing 3D Objects

Using the calibrated camera parameters, 3D objects such as XYZ axes and boxes were projected onto the calibration images to assess the accuracy of the calibration. To do that we had to define points in the real world 3D coordinates and then map then into 2D image coordinates using the before estimated projection matrix. We did not use any libraries other than OpenCV for the visualization, we simply joined points with the line command from OpenCV.

3 Results

A series of images were captured, processed, and analyzed. The intrinsic camera matrix, distortion coefficients, and extrinsic parameters were computed. The projection of 3D objects onto the images was also successfully achieved.

4 Discussion

The focal length obtained from the calibration process, defined in pixel units, was compared with the actual focal length in millimeters as specified by the smartphone manufacturer. The estimation of intrinsic parameters matrix give us a value of focal length equals to:

$$f_p = 846 pixels \tag{1}$$

To convert the focal length from pixel to millimeters we need to calculate the conversion factor, called m_x. This can be calculated as:

$$m_x = p_w^- 1 \tag{2}$$

where the single pixel width is equal to $p_w = s_w / img_w$ [meters / pixel], where s_w is the sensor width in mm, and img_w is the image width as a number of pixels.

From the datasheet found here the pixel width is equal to: $p_w = 1.12 \mu m$. Thus the estimated focal length in mm is

$$f_m m = f_p / m_x = f_p * p_w = \ 0.943 mm \tag{3}$$

Now let's calculate the nominal focal length. From this resource link, we get the nominal focal length: $f_n = 2.5mm$. In some resources the nominal focal length is given in 35 mm equivalent standard as $f_{n35mm} = 24mm$. This standard map the camera's focal length to the equivalent of a full-frame 35mm camera, with 24mm height and 36mm width. We can convert the 35mm standard to the actual focal length by using this equation:

$$f_{nactual} = f_{n35mm} / cropratio \tag{4}$$

where the crop ratio is:

$$cropratio = diag_{35mm} / diag_{camera} = 43.3/4.6 = \ 9.4 \tag{5}$$

Thus,

$$f_{nactual} = f_{n35mm} / cropratio = 24/9.4mm = \ 2.5mm \tag{6}$$

The difference is quite large, this could be caused by distortion.

On the other hand, we did not achieve a satisfying distortion correction with the undistort(...) method: as we can see in picture4 the undistortion considerably vary the position of the chessboard computed corners thus we could not draw the 3D objects as required.

5 Conclusion

The calibration of the smartphone camera using Zhang's method proved to be effective for estimating the required camera parameters. The comparison between the calibrated focal length and the manufacturer's specification highlighted the differences that can arise from such methodologies.

6 images

Even though I used 9 images for the process, here I provide only one for each type as a proof of concept to avoid making the document too long. Further images are provided at this link.

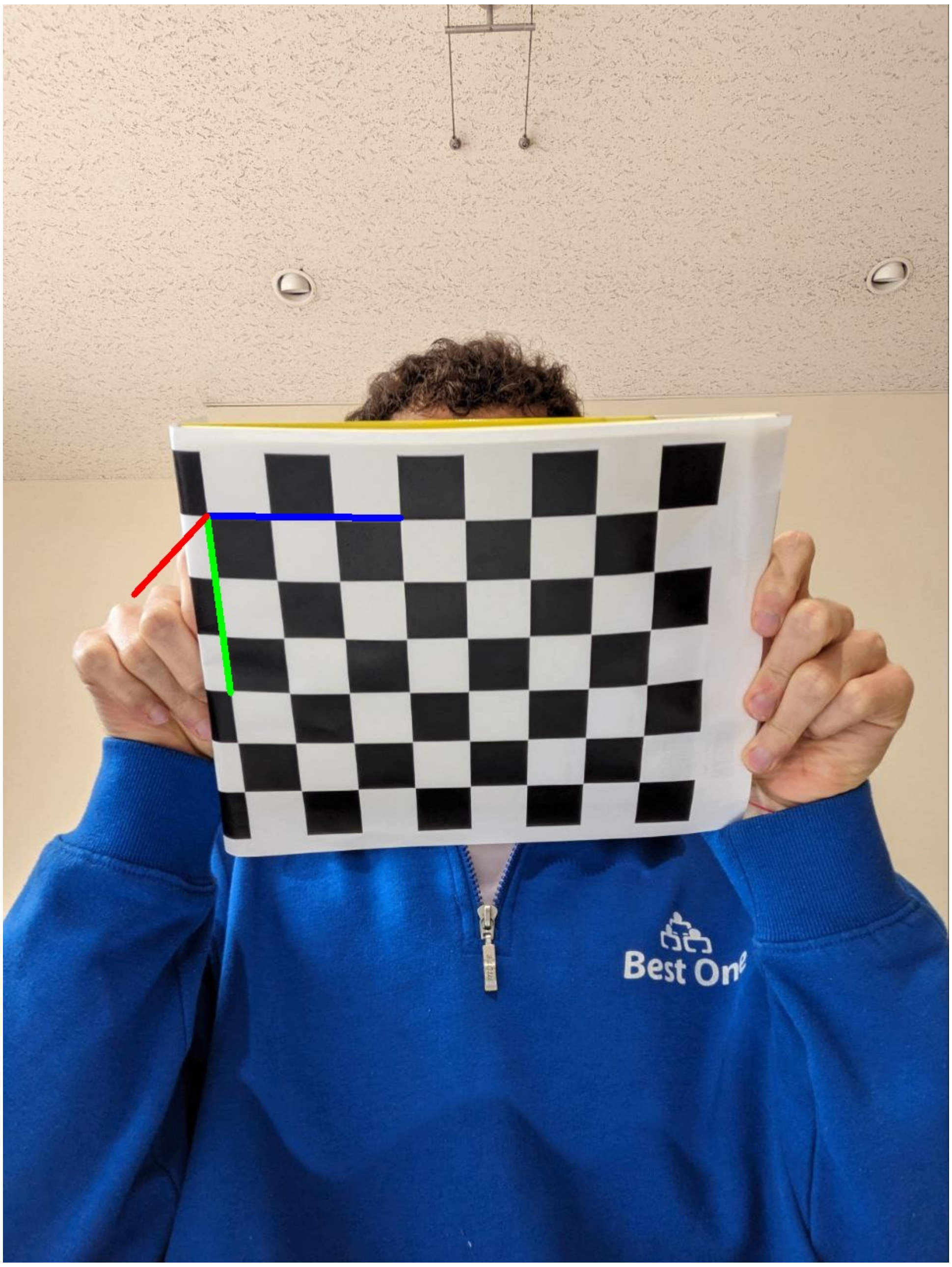

Figure 1: Example of 3D axis projected onto a calibration image.

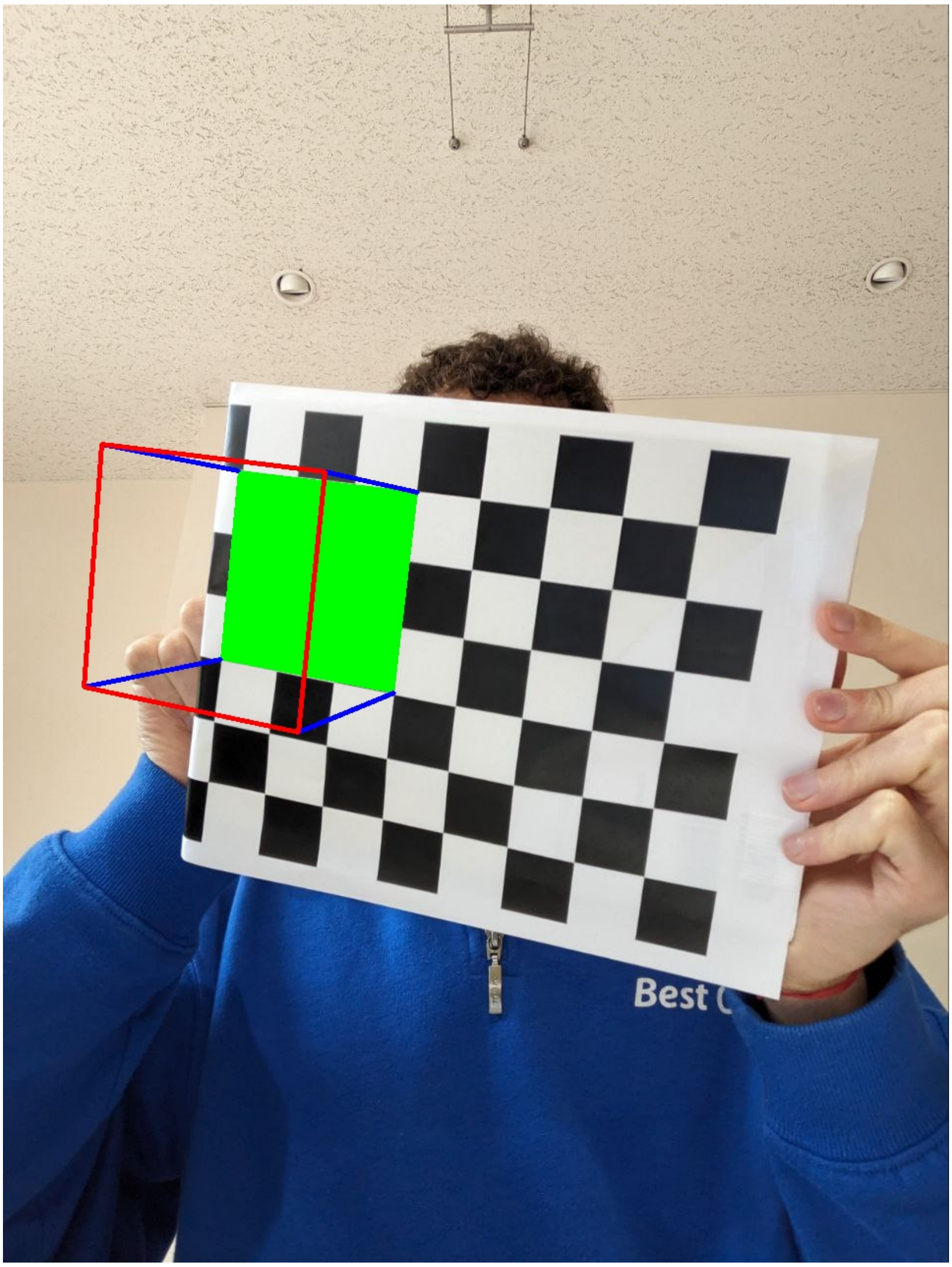

Figure 2: Example of 3D box projected onto a calibration image.

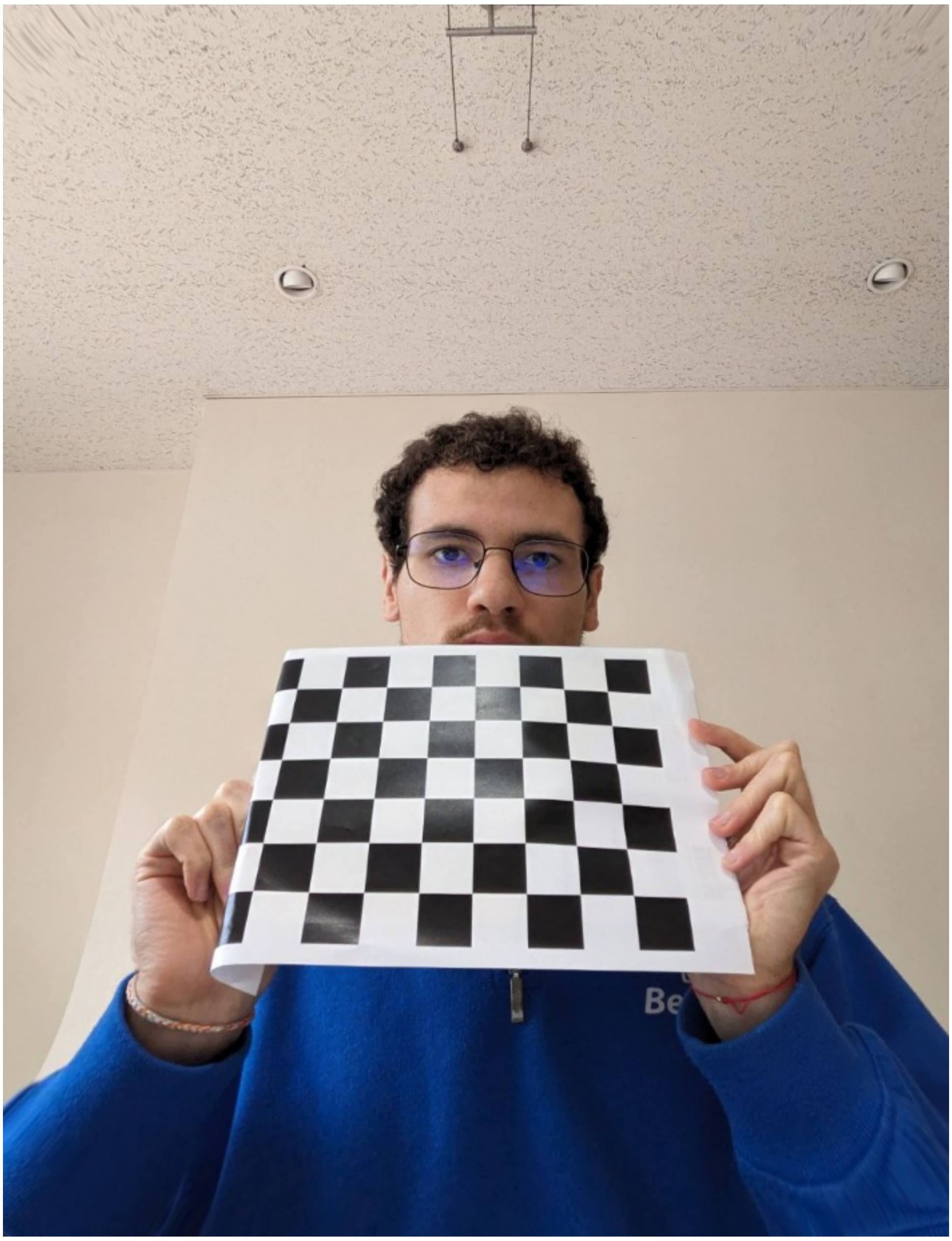

Figure 3: Example of an image undistorted

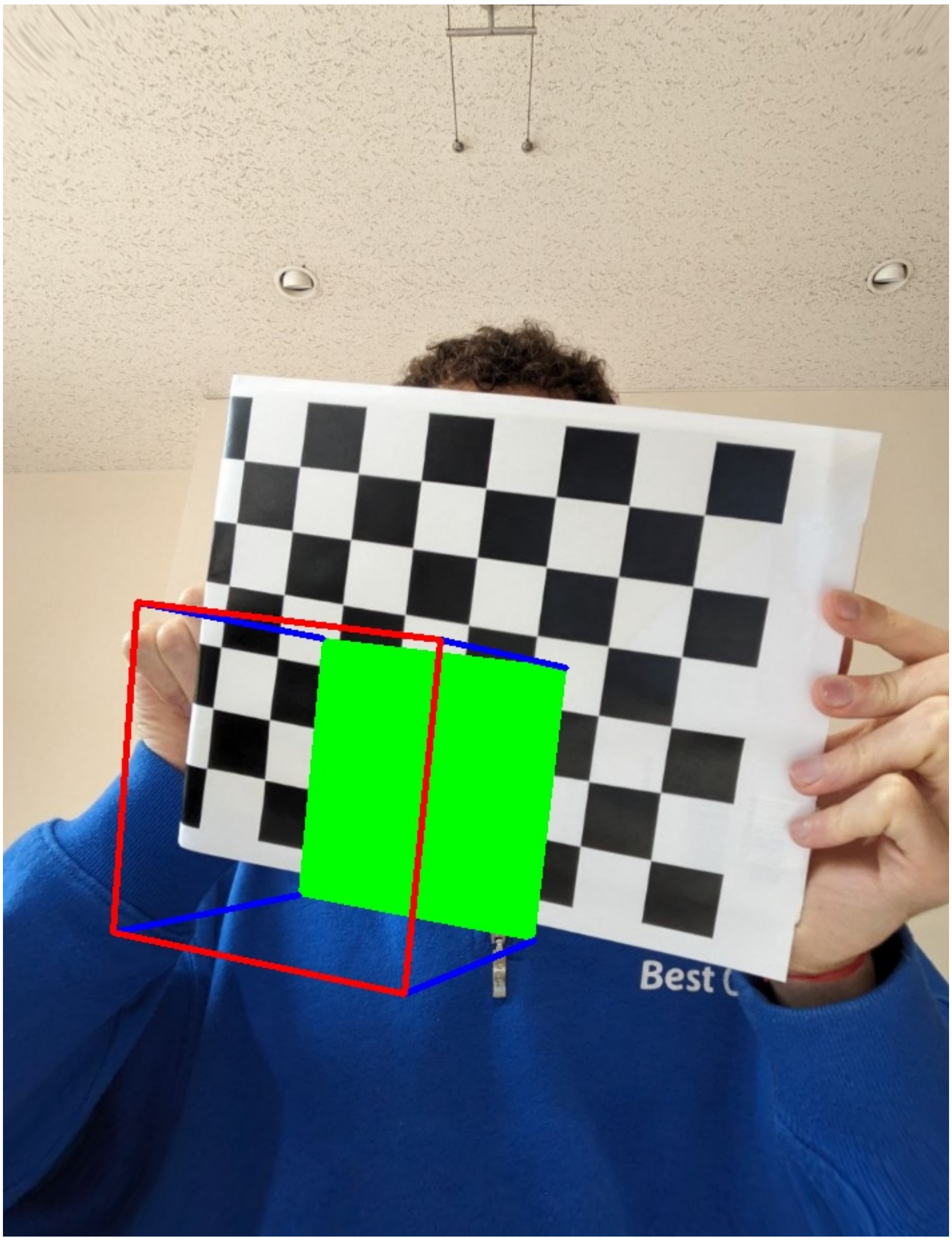

Figure 4: Example of 3D box projected onto a undistorted calibration image.