Camera calibration

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1 Introduction

A camera is a device that converts the 3D world into a 2D image. The equation $\mathbf{x} = \mathbf{PX}$ can represent a camera, where x is the 2D image point, P the camera matrix and X the 3D world point.

Calibrating a camera helps identifying the geometric characteristics of the image creation process. The camera is often categorized on the basis of a set of intrinsic parameters such as skew of the axis, focal length, and main point in these applications, and its orientation is expressed by extrinsic parameters such as rotation and translation. Linear or nonlinear algorithms are used to estimate intrinsic and extrinsic parameters utilizing known points in real-time and their projections in the picture plane.

2 Camera calibration

Camera calibration is a technique that estimates the characteristics of a camera, which are needed to establish a relationship between 3D point and its 2D projection.

In order to calibrate our camera, we took 35 images of a chessboard in different positions.

Figure 1: Images example

In order to Calibrate the camera, the first step will be to read in calibration Images of a chess board. It's recommended to use at least 20 images to get a reliable calibration.

2.1 Chessboard

Our world coordinates are fixed by this the chessboard pattern in the image, our 3D points are the corners of the squares in the chessboard.
We choose the chessboard patterns because they are distinct and easy to detect, the corners squares have sharp gradients in two directions and are located at the intersection of the chessboard lines.
OpenCV gives us an easy way to detect chessboard corners with a function calledfindChessboardCorners(), that returns the corners found in a grayscale image. So, we will convert the image to greyscale and then pass that to the findChessboardCorners() function. This function takes in a grayscle image along with the dimensions of the chess board corners. The last step, use calibrateCamera function and read the parameters. We feed our map and all the points we detected from the images. 2

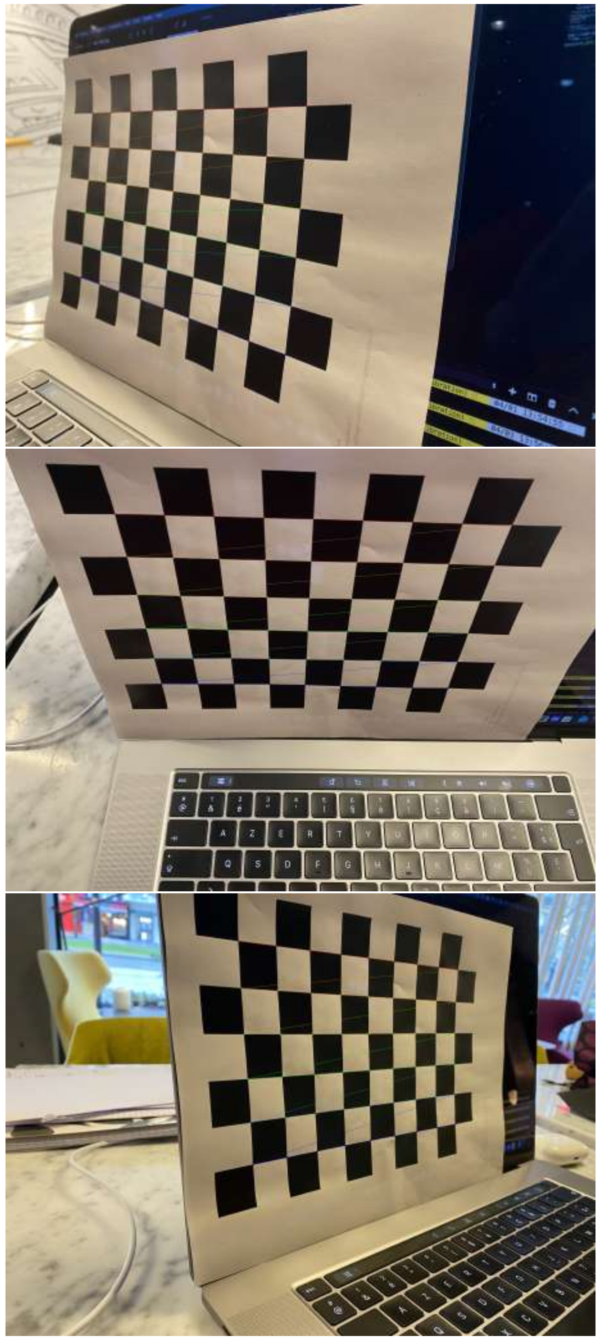

Figure 2: Chessboard corners

2.2 Intrinsic parameters

Intrinsic parameters are the parameters that allows the mapping between pixel coordinates and camera coordinates in the image frame, like the focal length, optical center and distortion coefficients. After calibrating the camera with the opencv function, we had the camera matrix shown in 3 as a result, knowing that from a camera matrix we can extract the focal length (fx,fy) and optical centers (cx,cy) 3

```
[[3.14394122e+03 0.00000000e+00 1.89490756e+03]
 [0.00000000e+00 3.13530102e+03 1.52018829e+03]
 [0.00000000e+00 0.00000000e+00 1.00000000e+00]]
```

$$\textit{camera matrix} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix}$$

Figure 3: Camera matrix

Parameter	Value
Optical center	(1894.90, 1520.18)
Focal length in pixels	(3143.94, 3135.301)
Distortion coeffs	(0.14097, -0.00982, 0.00278, -0.0106, -1.0406)

Table 1: Intrinsic parameters.

2.2.1 Focal length

We calculated the focal length of our camera in meters, thanks to the opencv function calibrationMatrixValues(), we found it equal to 15.0127 mm

2.3 Extrinsic parameters

They describes the orientation and location of the camera. This refers to the rotation and translation of the camera with respect to some world coordinate system. The rotation and translation which translates a coordinates of a 3D point to a coordinate system. Their results was given as an output from the calibration function that returns the rotation and translation vectors.

3 Radial distortion

Radial distortion is caused by unequal light bending. The rays bend more at the lens's borders than they do at the lens's center It causes straight lines to appear curved. To observe this problem, we tried to draw straight line on our chessboard lines, here is the result 4

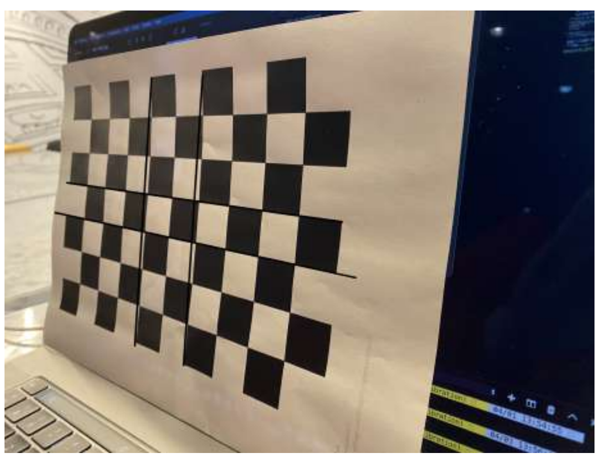

Figure 4: Radial distortion

3.1 Undistort the image

Using the camera clibration results, we control the percentage of undesired pixels in the undistorted image by fine-tuning the camera matrix (getOptimalNewCameraMatrix() function in opencv), then we used the revised camera matrix to remove distortion from the image. We obtained the result shown in 5, where the rest of the image is distorted, but the chessboard is aligned.

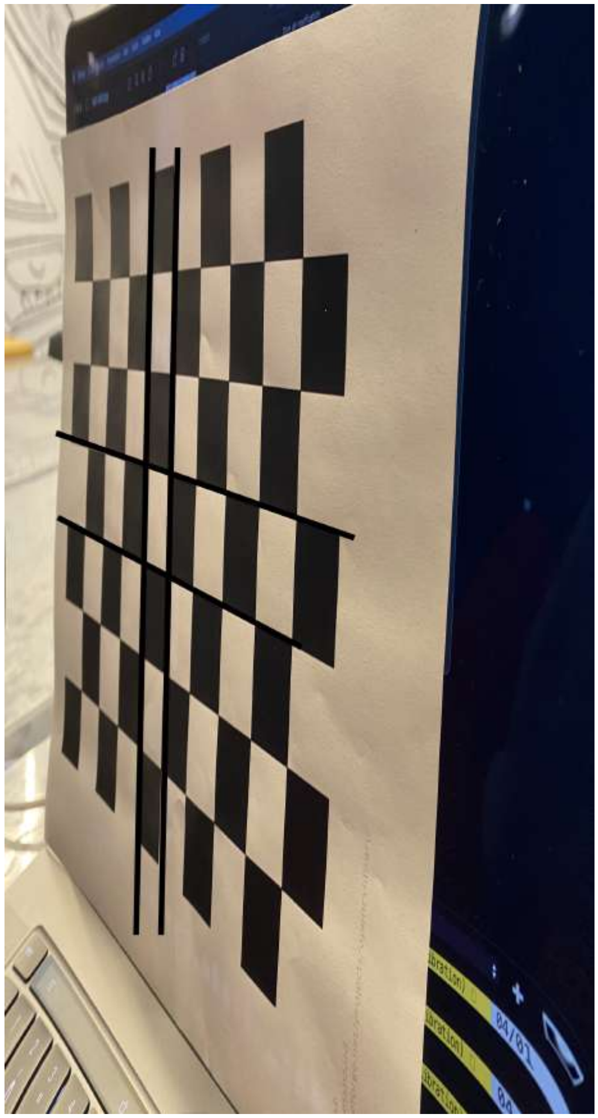

Figure 5: Radial distortion