Computer vision

Camera Calibration

Matteo Marturini

MAT. SM3500484

M.Sc. Data Science and Scientific Computing

University of Trieste

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Contents

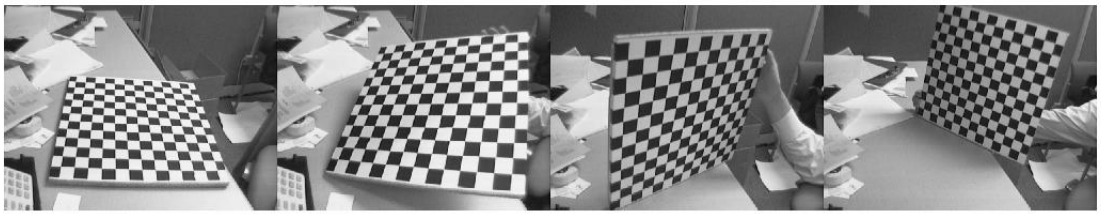

Figure 1: Example of the images used for the Zhang calibration procedure.

1 Problem statement

The camera is an object which converts the 3D world into a 2D image. Assuming the pinhole camera as a mathematical model for our camera, we can characterize it as a matrix $P = K[R|t]$, where the elements of the matrix K are called *intrinsic* parameters, while the elements of the matrix R and the vector t are called *extrinsics*. Camera calibration refers to the process of estimating these parameters given a set of images taken with the camera to calibrate. This project aims at estimating the parameters of a camera given a set of images of a checkerboard using the Zhang calibration procedure.

2 Camera calibration

2.1 Zhang calibration procedure

The Zhang calibration procedure (Zhang, 2000) is a method for estimating camera parameters which uses different homographies between a plane in the real world and its perspective projection image created by the camera. In particular, given a picture of a checkerboard with a known size of the unit square, a correspondence between the pixels of the perspective image and the "real" world points of the checkerboard can be found, and from these correspondences estimate the homography. This process is repeated for different pictures of the same checkerboard taken such that the plane formed by the checkerboard has a different orientation; from the set of estimated homographies, the *extrinsics* and *intrinsics* are estimated. In figure 1 are reported examples of images used in this procedure. The details and the implementation choices are reported in the file `Calibration.mlx`.

2.2 Reprojection error

Given an image, for every detected point of the checkerboard, the reprojection error can be estimated: it is defined as the difference between the estimated and the measured projection. The total reprojection error can be then found by summing up the squared differences, as the following

$$\epsilon(P) = \sum_{i=1}^{n} \left(\frac{p_1^T m_i}{p_3^T m_I} - u_i \right)^2 + \left(\frac{p_1^T m_i}{p_3^T m_I} - v_i \right)^2 \tag{1}$$

In figure 2 is reported the first image of the set with the red circles representing the points projected with the perspective projection matrix P estimated using the Zhang calibration procedure, while in green the points detected with the Matlab built-in function `detectCheckerboardPoints()`. It can be seen qualitatively that the estimated P is able to correctly project points into the image plane.

Figure 2: In red, the reprojected points using the perspective projection matrix estimated with the Zhang calibration procedure, in green, points detected by Matlab built-in function detectCheckerboardPoints().

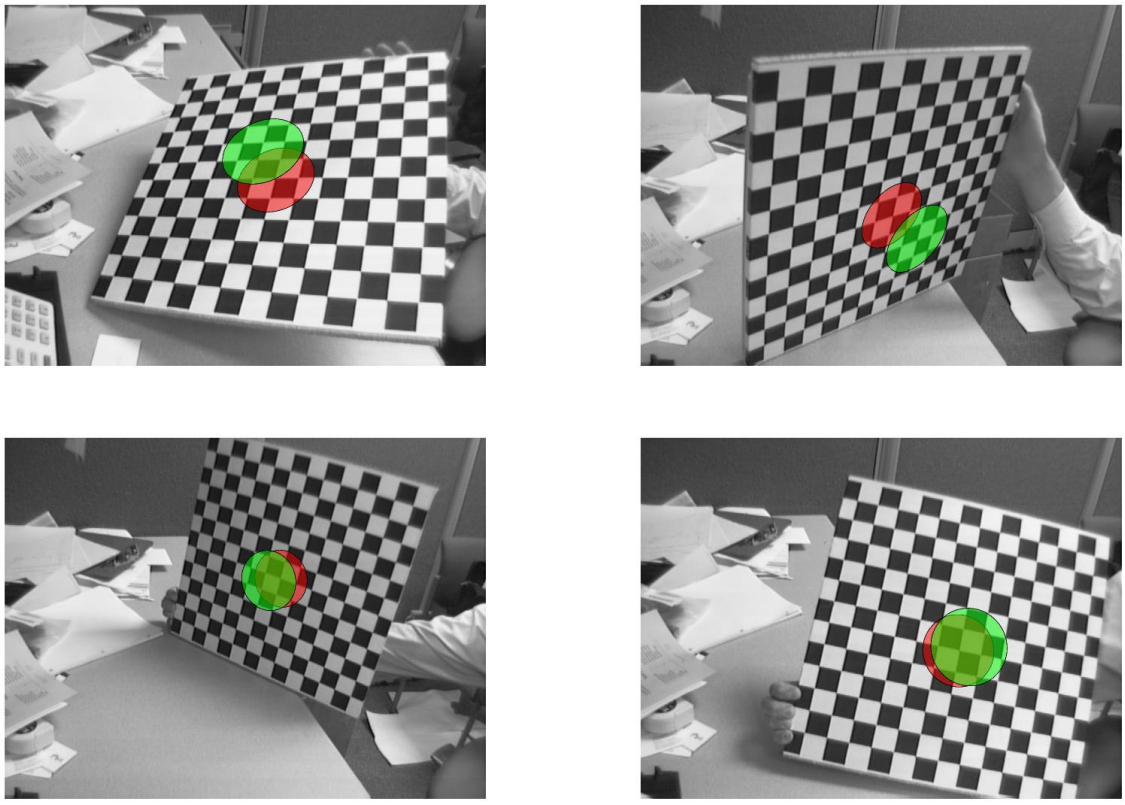

Figure 3: Examples of a cylinder superimposed to the calibration plane of different images.

2.3 Superimposing a cylinder

Another way to test that the matrix P projects points into the image plane in the correct way, is to check the way it projects a solid. In particular, a cylinder in real world coordinates is constructed; then, by applying P to its homogenous coordinates, the cylinder is projected into the image plane and plotted using the inhomogenous coordinates. An example of the same cylinder superimposed to different images of the checkerboard is reported in figure 3. As it can be observed from the images, the cylinder, which consists in 2 circles taken at different heights from the plane of the checkerboard, is projected and plotted correctly.

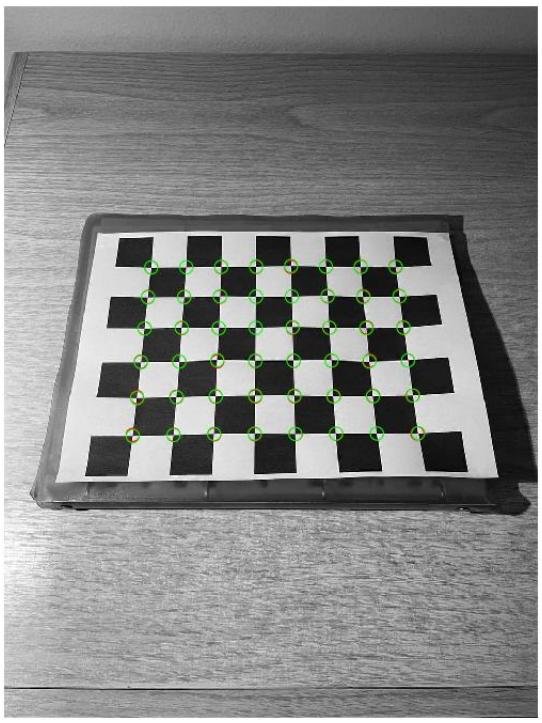

Figure 4: Reprojection errors: in red, the projected points found with P estimated using Zhang procedure, in green, the points detected with Matlab built-in function detectCheckerboardPoints().

3 Smartphone camera calibration

The same procedure is applied to images taken with my smartphone in order to establish the parameters of its camera. The images hsve 1280x960 pixels and the checkerboard has a 30 mm square and 8x6 vertices.

In figure 4 is reported an example image with the reprojection errors for every point detected in the checkerboard.

In figure 5 are reported examples of a cylinder superimposed to the calibration plane of different images.

The implementation details and choices are reported in the file `myCalibration.mlx`.

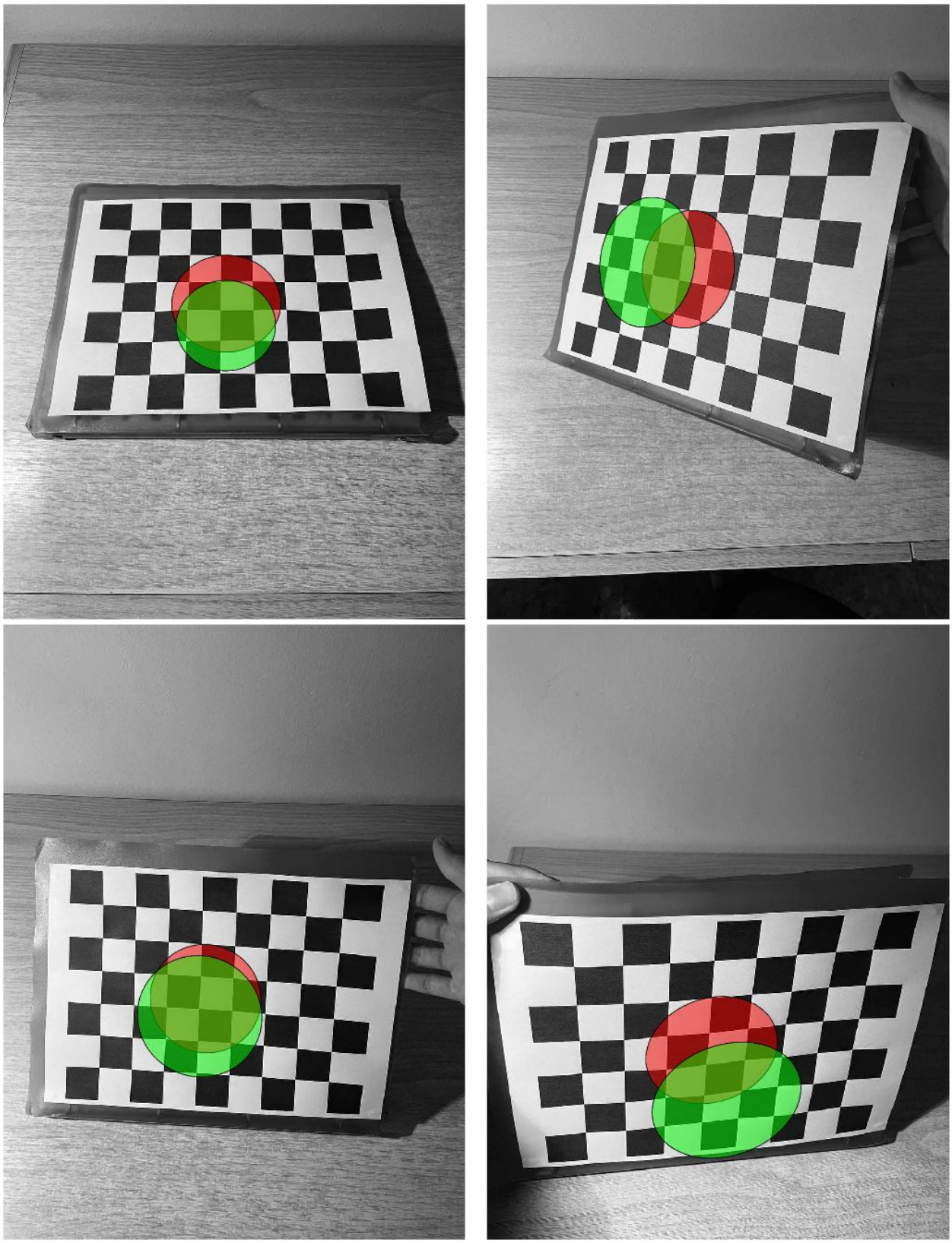

Figure 5: Cylinder superimposed to the calibration plane of different images.

References

Z. Zhang. A flexible new technique for camera calibration. *IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 22, no. 11, pp. 1330-1334*, 2000.