CMSC 733 Homework 1 Report AutoCalib

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Using ONE late day

I. INTRODUCTION

This report presents the implementation of Camera Calibration method as introduced by Zhengyou Zhang[1]. Their method is well suited even if the knowledge of 3D geometry is not known.

II. APPROACH

Let a 2D point on image denoted by $\tilde{m} = [u, v, 1]^T$, and a 3D point denoted by $\tilde{M} = [X, Y, Z, 1]^T$. If the camera is modelled as pinhole camera, then the relationship between a 3D point and its projection is given by

$$s\tilde{m} = A[R\,t]\tilde{M} \tag{1}$$

where s is an arbitrary scale factor, A is the intrinsic camera matrix and $[R\ t]$ is the extrinsic camera matrix containing rotation and transformation elements.

A. Step I: Detect corner points

For the given images of checkered pattern, corner points are detected using *cv2.findChessboardCorners* function of OpenCV. Corners of the Edge Boxes are not considered for calculation and there are 54 corners points $(x = 9, y = 6)$. The size of edge of one box pattern is given as 21.5 mm, which is used for calculating the world coordinates of pattern corners.

B. Step II: Homography

By assuming that the model plane is on $Z = 0$ of the world coordinates, we can write equation 1 as follows

$$s\tilde{m} = H\tilde{M} \tag{2}$$

where, $H = A[R\ t]$

C. Step III: Intrinsic Parameters

Intrinsic parameters are calculated by following the closed-form solution suggested in [1]. For initial calculation, it is assumed that distortion is not present, that is, $k = [0, 0]$ The camera intrinsic parameters for the given set of images are calculated as

$$\begin{pmatrix} 2.05335684e+03 & 0.0 & 7.66946824e+02 \\ 0.0 & 2.04491599e+03 & 1.34556729e+03 \\ 0.0 & 0.0 & 1.0 \end{pmatrix}$$

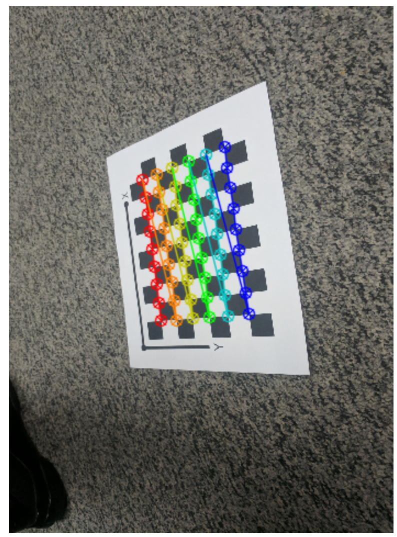


Fig. 1. Sample of detected points on the given image

D. Step IV: Extrinsic Parameters

Now, with the intrinsic parameters and Homography between points, extrinsic parameters are calculated as described in the [1] and are shown in the results file. The extrinsic parameter matrix for first image is as below

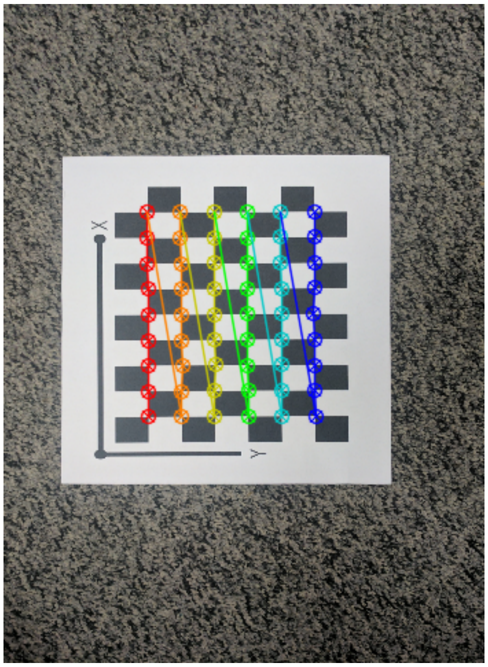
$$R = \begin{pmatrix} -1.64768892e-01 & 9.86332202e-01 & 1.43890430e-07 \\ -9.86332202e-01 & -1.64768892e-01 & 6.14741726e-08 \\ [8.43426228e-08 & -1.31794734e-07 & 1.00000000e+00 \end{pmatrix}$$

$$t = \begin{pmatrix} -1.88235818e+02 \\ 2.56636395e+02 \\ 6.19132251e-05 \end{pmatrix}$$

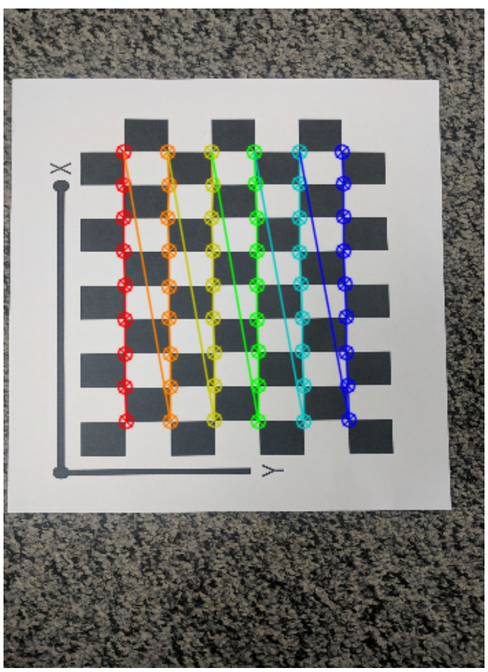
E. Step V: Radial Distortion

Ideal coordinates and the real observed coordinates of corners are used to find the distortion coefficients k_1 and k_2. The coefficients are calculated with the given method and are found to be as below

$$k = \begin{pmatrix} k_1 \\ k_2 \end{pmatrix} = \begin{pmatrix} 3.61804094e-15 \\ -1.77897535e-28 \end{pmatrix}$$



(a) Sample input image



(b) Another sample image

Fig. 2. Undistorted images

F. Step VI: Maximum Likelihood Estimation

After calculation all the above mentioned parameters, the solution is refined by minimizing the following function

$$\sum_{i=1}^{n}\sum_{j=1}^{m} \parallel m_{ij} - \hat{m}(A, k_1, k_2, R_i, t_i, M_j) \parallel^2 \tag{3}$$

where, $\hat{m}(A, k_1, k_2, R_i, t_i, M_j)$ is the projection of point M_j in image i. This is a non-linear minimization problem which is solved using Levenberg-Marquardt Algorithm.

The minimum error is found out to be 0.56

III. Conclusion

Through this assignment I have successfully implemented and tested the camera calibration algorithm as proposed by Zhengyou Zhang. The algorithm proves to effective even in the case where the physical dimensions of the points are not known, as the coordinates are normalized.

References

[1] Zhengyou Zhang. A flexible new technique for camera calibration. *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, 22:1330 – 1334, 12 2000.