Computer Vision - Homework1 - AutoCalib

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***Abstract*—This project 'AutoCalib' focuses on calibrating a camera automatically, by implementing Zhengyou Zhang's work on the same. Camera calibration is one of the fundamental steps of any computer vision project. We find the multiple calibration parameters contained by the matrix 'K'.**

I. Initial Parameter Estimation

The methodology of Zhang's work is that an initial estimation of parameters is found so that it can later be refined using a nonlinear optimizer. We need two sets of corners for each image- the 'world points' and the 'image corners'. image corners are subpixel positions of each corner of the provided chessboard image. The world points are calculated using simple math. The side of each square of the chessboard pattern is 21.5mm. Using that, the position of all the corners can be calculated. These coordinates or pixels are called the world points.

A. Homographies

Next, we find the homography for each image w.r.t the world points. We do this with calculating the single value decomposition, and then reshaping the result to a 3x3 matrix. After calculating the homographies for all the images, we store them in an array.

B. Intrinsic Parameters

We use the above closed-form relation to calculate the intrinsic parameters. B is a symmetric matrix. Hence the unique elements present on the top half of the matrix can be turned into a vector 'b'.

$$\mathbf{B} = \mathbf{A}^{-T}\mathbf{A}^{-1} \equiv \begin{bmatrix} B_{11} & B_{12} & B_{13} \\ B_{12} & B_{22} & B_{23} \\ B_{13} & B_{23} & B_{33} \end{bmatrix}$$

Fig. 1

We calculate a matrix 'V' of the size (2x13, 6), by calculating and appending the following matrix for each image:

$$\mathbf{b} = [B_{11}, B_{12}, B_{22}, B_{13}, B_{23}, B_{33}]^T$$

Fig. 2

The relation between V and b vector is as follows:

$$\mathbf{v}_{ij} = [h_{i1}h_{j1}, h_{i1}h_{j2} + h_{i2}h_{j1}, h_{i2}h_{j2}, \\ h_{i3}h_{j1} + h_{i1}h_{j3}, h_{i3}h_{j2} + h_{i2}h_{j3}, h_{i3}h_{j3}]^T$$

Fig. 3

We use Singular Value Decomposition to estimate the value of b vector. Finally, to calculate the intrinsic parameters, we use the outlined relations in Appendix B of Zhang's work.

$$\begin{aligned} v_0 &= (B_{12}B_{13} - B_{11}B_{23})/(B_{11}B_{22} - B_{12}^2) \\ \lambda &= B_{33} - [B_{13}^2 + v_0(B_{12}B_{13} - B_{11}B_{23})]/B_{11} \\ \alpha &= \sqrt{\lambda/B_{11}} \\ \beta &= \sqrt{\lambda B_{11}/(B_{11}B_{22} - B_{12}^2)} \\ \gamma &= -B_{12}\alpha^2\beta/\lambda \\ u_0 &= \gamma v_0/\beta - B_{13}\alpha^2/\lambda\ . \end{aligned}$$

Fig. 4

Using the found parameters, we just plug them into the camera intrinsic matrix 'A':

$$\mathbf{A} = \begin{bmatrix} \alpha & \gamma & u_0 \\ 0 & \beta & v_0 \\ 0 & 0 & 1 \end{bmatrix}$$

Fig. 5

The calculated Intrinsic matrix is:

```
[[ 4.80084007e-10 -9.27100648e-23 -6.10627105e-17]
 [ 0.00000000e+00  4.80084007e-10  3.25059706e-16]
 [ 0.00000000e+00  0.00000000e+00  1.00000000e+00]]
```

Fig. 6

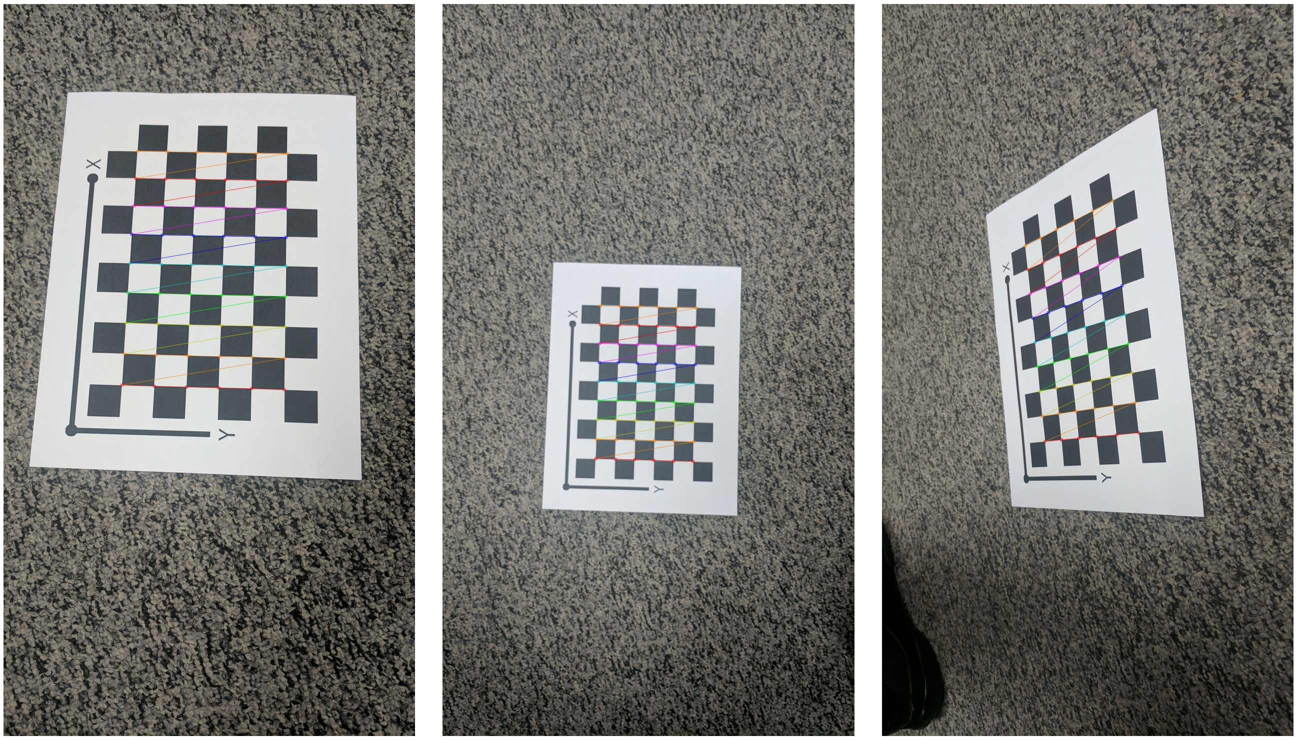

Fig. 7: Detected corners in chessboard images

REFERENCES

- A Flexible New Technique for Camera Calibration, Microsoft Research-Zhengyou Zhang
- https://docs.opencv.org/

REFERENCES