Auto Calibration

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I. Initial Parameter Estimation

In a camera, there are two types of parameters, Intrinsic and Extrinsic parameters. Intrinsic parameters consists of unique camera properties like focal length in x and y axes, centre of image plane. Extrinsic parameters are parameters that change, with reference to each image, like rotational and translation parameters. For initial guessing, we try to compute parameters as closed form solution.

A. Intrinsic parameter estimation

For initial parameter estimation, original paper by Zhang tries to use the constraint 3 and 4, which is dependent on the fact that r1 and r2 are orthonormal vectors. This, leads to solving for eigen vector of vector V, corresponding to smallest eigen value. As, we find B matrix, Intrinsic matrix is computable.

$$\text{Initial Intrinsic matrix=} \begin{bmatrix} 2056.11 & -1.018 & 761.65 \\ 0.00 & 2040.51 & 1351.31 \\ 0.00 & 0.00 & 1.00 \end{bmatrix}$$

B. Extrinsic parameter estimation

Homography matrix is product of extrinsic and intrinsic parameter matrix. We have computed intrinsic parameters, now extrinsic parameter has to be computed. Since, we know the object points and image points, by using opencv function cv2.find homography and passing 54 points for each 13 image, we get unique homography matrix for each of the image.

Now extrinsic matrix can be computed by inverting intrinsic matrix and multiplying it to homography matrix, explained in Zhang's paper with respect to each rotational vector computation. Below, are initial extrinsic matrix [r1,r2,T] for image 1 and image2.

$$\text{Initial Extrinsic matrix 1=} \begin{bmatrix} -0.011 & 0.996 & -2.686 \\ -0.99 & -0.0095 & 2.38 \\ 0.0358 & 0.0198 & 14.631 \end{bmatrix}$$

$$\text{Initial Extrinsic matrix 2=} \begin{bmatrix} 0.035 & 0.996 & -2.686 \\ -0.99 & -0.27 & 0.38 \\ 0.187 & 0.35 & 17.631 \end{bmatrix}$$

C. Approximate Distortion coefficient estimation

In this part, we only consider radial distortion coefficients k1 and k2. Initially, their values are assumed as zero.

II. Non-linear Geometric Error Minimization

What we have guessed as initial parameters or extrinsic parameters are initial closed form solution. There are optimization techniques that could approximate parameters more correctly. One of the ways author describes as closed form solution is to guess distortion coefficient for initial guessing instead of assuming them as zero.

Another way, is to proceed with distortion coefficient as 0, this is the method that I have followed. For optimization, Levenberg-Marquardt algorithm can be followed for complete maximum likelihood estimation, where a function needs to be written in code that needs to be optimized. *scipy* library provides optimize library that has variety of function to choose, for least square there are least_sq and curve_fit functions.

After optimization, my intrinsic parameter and extrinsic parameter have slight changes and reprojection error when no estimate is used, is 0.67 and when only intrinsic parameter estimate is used, is 3.5 but when intrinsic and extrinsic parameters are used, is 6.92. This, shows significant amount of distortion, and distortion values are close to Zhang's paper results. Output from the program, below.

('Estimated Intrinsic Matrix', array ([[1.92137454e+03, -1.46973408e+00, 7.19732593e+02], [-3.66242478e-02, 2.05002640e+03, 1.35287062e+03], [-3.27080134e-03, -1.51247633e-02, 9.98293165e-01]]))

('Estimated Radial distortion coefficients', array([[0.16582558, -0.7264315]], dtype=float32))

Reprojection error: 6.92793946072

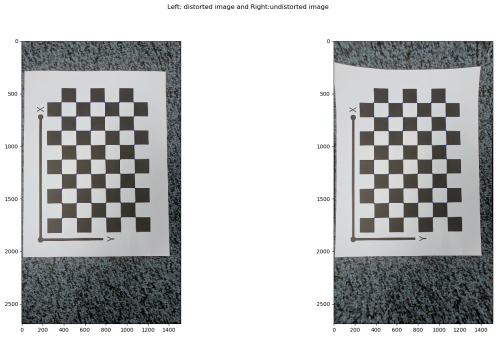

Fig. 1. Image 1

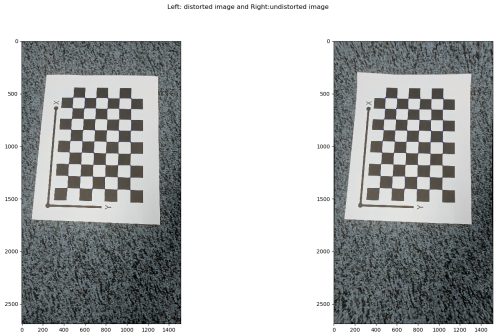

Fig. 2. Image 2

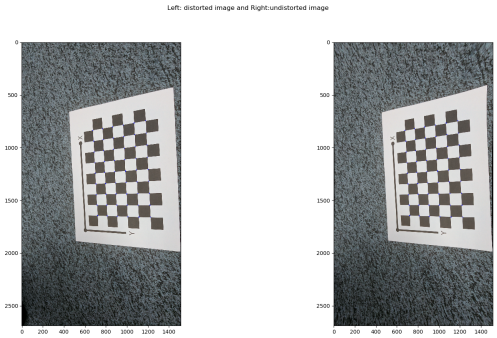

Fig. 3. Image 3

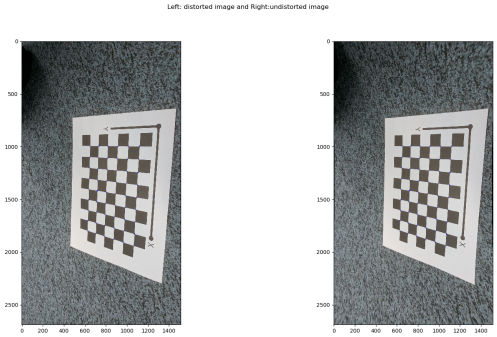

Fig. 4. Image 4

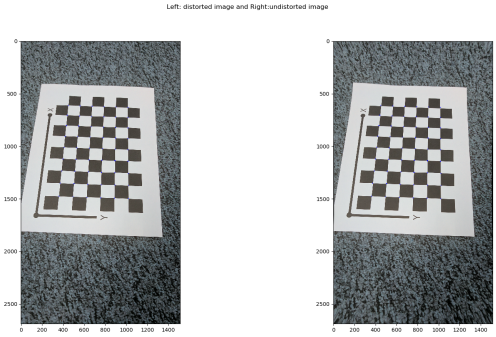

Fig. 5. Image 5

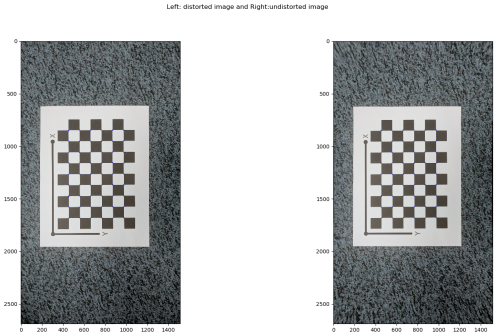

Fig. 6. Image 6

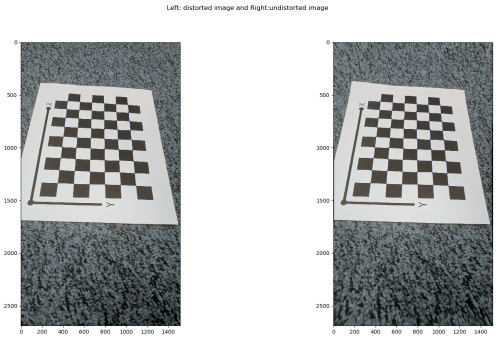

Fig. 7. Image 7

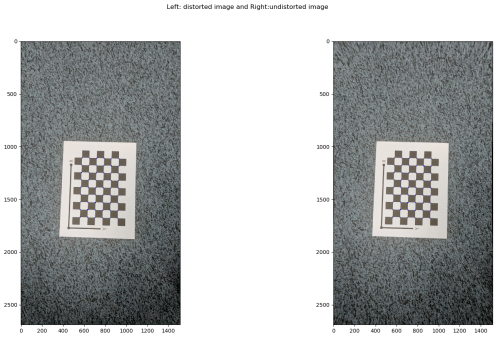

Fig. 8. Image 8

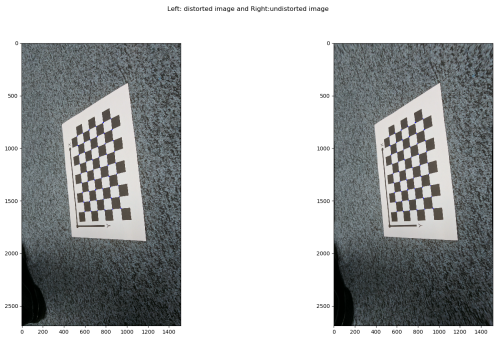

Fig. 9. Image 9

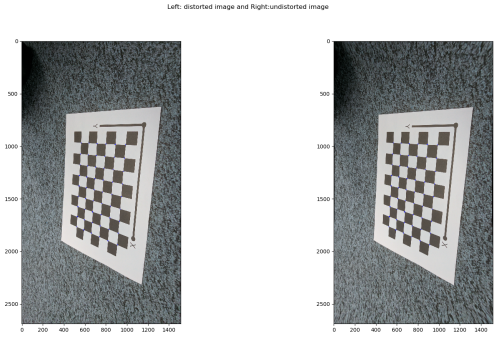

Fig. 10. Image 10

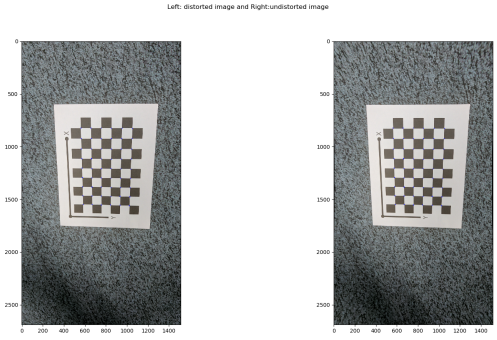

Fig. 11. Image 11

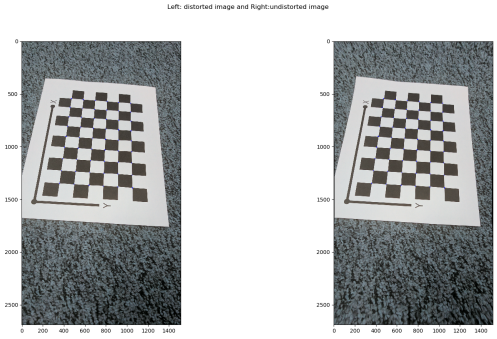

Fig. 12. Image 12

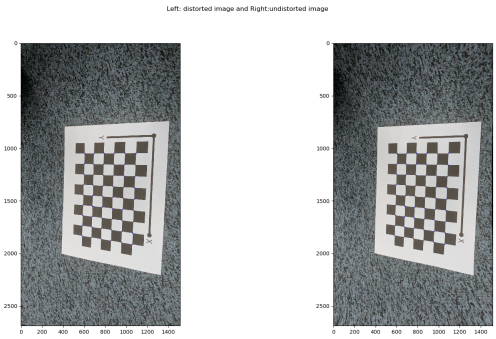

Fig. 13. Image 13

REFERENCES

[1] Zhengyou Zhang, *A Flexible New Technique for Camera Calibration*, Microsoft Research, 1998