Calibration

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September 2020

1 Data Normalization

To normalize the data, we simply need to compute the mean and the standard deviation of the data and transform the data by: $\tilde{x} = \frac{x-\bar{x}}{\sigma}$ where $\sigma = \frac{1}{n}\sum_{i=1}^{n} ||x_i - \bar{x}||$.

2 Implementation

To make the result of Direct Linear Transform and Gold Standard comparable, we picked eight points. We use all points in both Direct Linear Transform and Gold Standard algorithms. We used the same axis notation and cell size as in the exercise statement (we took meter unit and therefore the cell size is 0.027), and followed the steps as summarized as follows:

- To get the projection matrix, we need use the trick $x = PX$ such that $x \times PX = 0$. Vectoring the matrix P and plugging into all correspondences, we can solve for P, and map it back to the original data scale;
- Based on the fact that $P = K[R| - RC]$ and QR decomposition, we can roughly get the rotation matrix R and intrinsic matrix K, and then adjust them to make sure they are the matrix we actually want. For the camera position C, we then use the trick $PC = 0$ to solve for it;
- Gold Standard refined the matrix computed by DLT by minimizing the Euclidean square error between projected points and real points on image among all points;

3 Results

3.1 Intrinsic parameters

We get the intrinsic matrix (we use the result of Gold Standard method)

$$K = \begin{bmatrix} 1332.2 & 9.400 & 786.3 \\ 0 & 1334.3 & 571.3 \\ 0 & 0 & 1 \end{bmatrix} \tag{1}$$

The skew angle is rather small, and two focal lengths are close, so the image is close to square.

3.2 Extrinsic parameters

The rotation matrix and the translation of the camera (with GS method) is shown as follows:

$$R = \begin{bmatrix} -0.8582 & 0.5134 & -0.0046 \\ -0.1673 & -0.2881 & -0.9429 \\ -0.4853 & -0.8084 & 0.3331 \end{bmatrix} \tag{2}$$

and $t = [0.0210; 0.1471; 0.3515]$

3.3 Average projection Error

We define the average projection error as the average Euclidean distance between the real position and the projected position on the image among all points.

	DLT	GS	(DLT) Not normalized
error	1.2793	1.2416	1.2903

As we can see, GS has better performance than DLT, as the solution of DLT is just one potential solution to GS, therefore the error of DLT is no less than GS. We also found that normalization helped improve the performance.

3.4 Projection Matrix

We also provide the projection matrix based on GS method:

$$P = 1e3 \begin{bmatrix} -2.4910 & 0.0744 & 0.4031 & 0.4991 \\ -0.8168 & -1.3808 & -1.7424 & 0.6480 \\ -0.0008 & -0.0013 & 0.0005 & 0.0006 \end{bmatrix} \tag{3}$$

3.5 Visualization

AS is shown in Fig. 1, those are the points we manually picked from the image. Fig. 2 and 3 are visualization results from the DLT and GS methods respectively. From the images we cannot really tell the difference as they both did a great job in this case.

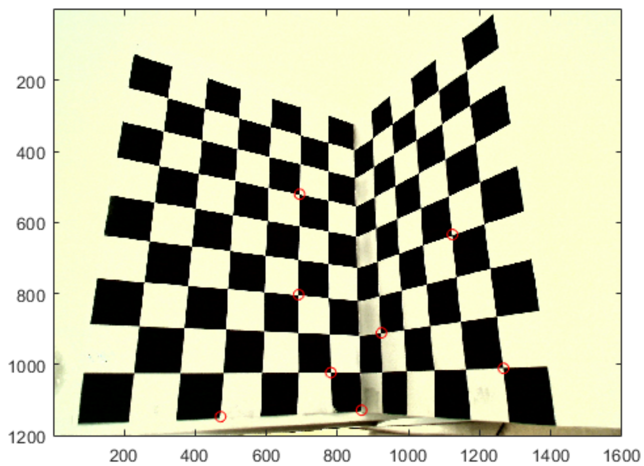

Figure 1: before being calibrated

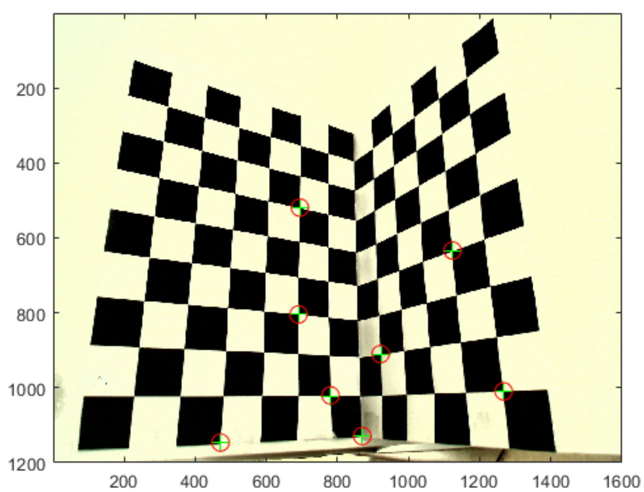

Figure 2: after being calibrated: direct linear transform

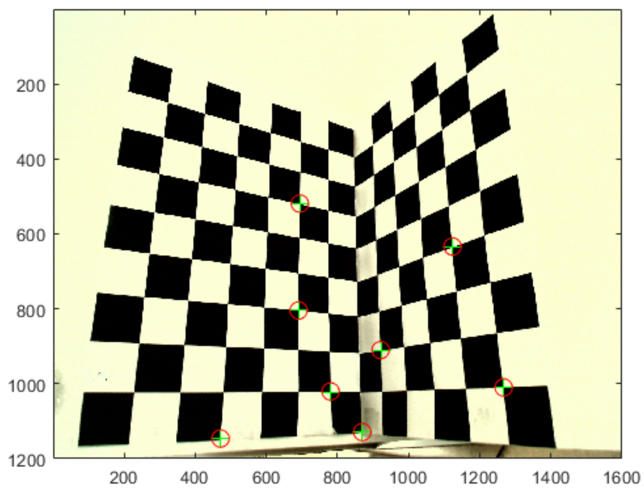

Figure 3: after being calibrated: gold standard