Scientific Experimentation and Evaluation

Assignment: 04
Calibrating an Optical Tracking System

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24-May-2018

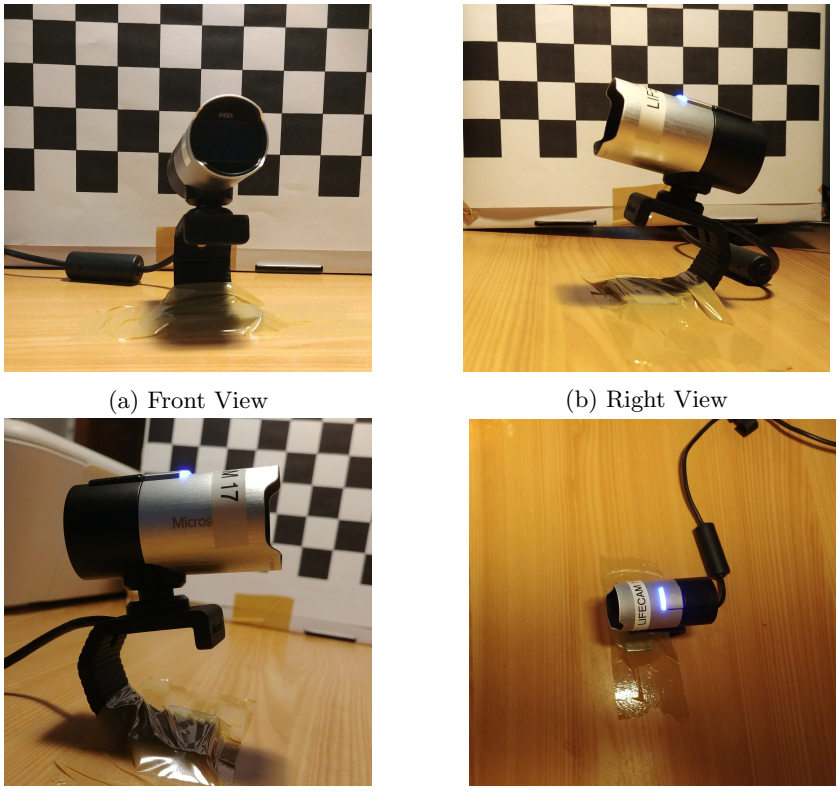
Contents

1 Relevant Aspects of Experiment

1.1 Setup

1.1.1 Measurement Instruments and Tools

- We use a standard 10×7 chessboard pattern pasted on a flat board as our calibration grid.
- Each grid is of the size 23 mm $\times$ 23 mm.
- A Microsoft LiteCam is used to capture the images for calibration.
- Camera is mounted on a surface to make sure that it remains stable during operation.
- Camera is connected with the laptop through a USB cable.
- Calibration is done by the camera calibration toolbox for Matlab [1].



(a) Front View (b) Right View

(c) Left View (d) Top View

Figure 1: Camera Setup

1.1.2 Image Description

- Images are taken such that the grid appears at different positions and orientation in the field of view of the camera.

- The process is repeated multiple times to capture 26 images.

1.2 Description of Parameters

- The details of the parameters have been given in the documentation of the toolbox. [2]
- **Intrinsic Parameters**:
  - *Focal length*: The focal length in pixels is stored in the 2×1 vector fc.
  - *Principal point*: The principal point coordinates are stored in the 2×1 vector cc.
  - *Skew coefficient*: The skew coefficient defining the angle between the x and y pixel axes is stored in the scalar $alpha\_c$.
  - *Distortions*: The image distortion coefficients (radial and tangential distortions) are stored in the 5×1 vector kc.
  - *Camera Matrix*, K, is given by:

$$\begin{bmatrix} fc(1) & alpha\_c \times fc(1) & cc(1) \\ 0 & fc(2) & cc(2) \\ 0 & 0 & 1 \end{bmatrix}$$

    this denotes the intrinsic camera parameters.
- **Extrinsic Parameters**: Is a collection of *rotation matrices* and *translation vectors* corresponding to each image.

1.3 Possible Problems or error sources that can disturb the calibration process

- Errors might arise because of blurred image capture.
- Image captured might not sufficiently cover the field of view of the camera.
- The lighting condition while capturing the images might not be ideal and may result in non-uniform illumination of the chessboard.
- While marking the corners manually during the first stage of calibration,inaccuracies might arise.

2 Observations and Data

2.1 Image Poses Used

2.2 Procedure

Following the guidelines described in the toolbox documentation, we went through the below steps:

1. Using all the 26 images we manually identified the corners of each image and ran the calibration script.

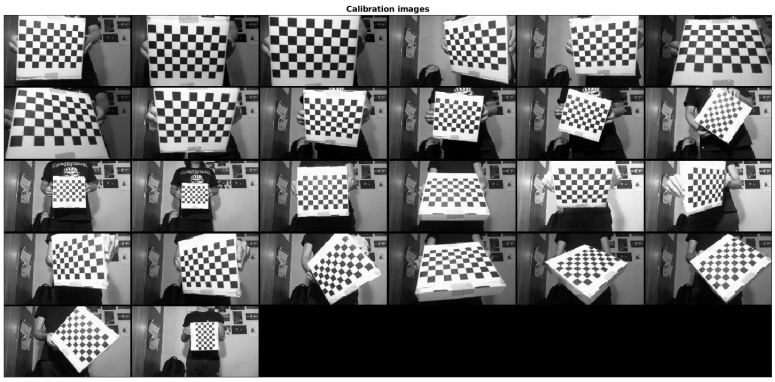


Figure 2: Calibration Images

2. Now, we re-project the calibrated corners onto the original images re-compute the corners again using different figure size as suggested in the documentation.

3. On analyzing the re-projection error (image below), we observe many outliers.

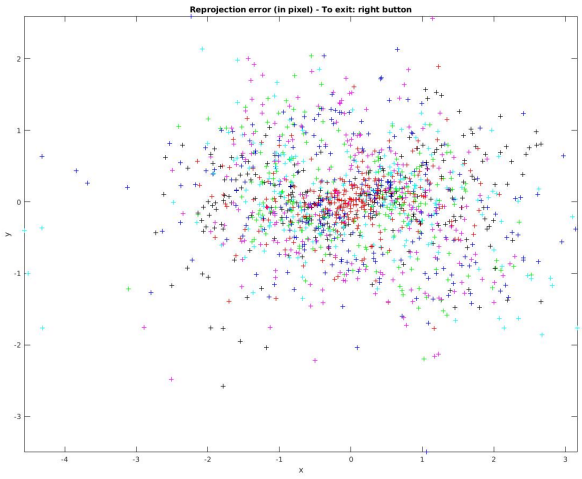


Figure 3: Initial Re-projection Error

4. After identifying the images corresponding to these outliers we remove 6 images and recompute the corners again and calibrated.

5. The final re-projection error after this has been found to be significantly improved. The image below has been scaled to similar range as in the previous image.

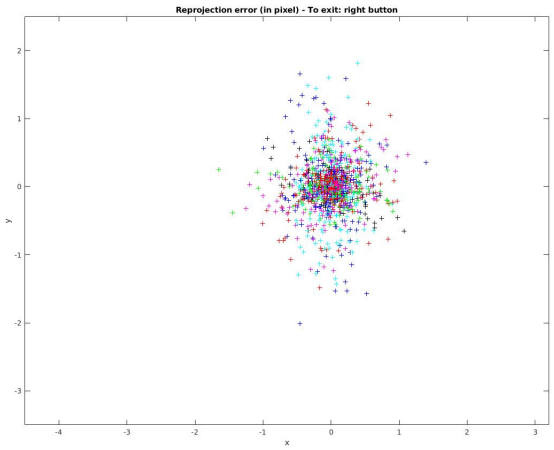


Figure 4: Final Re-projection Error

2.3 Camera Parameters

Calibration results after optimization (with uncertainties):

- Focal Length:

$$fc = \begin{bmatrix} 975.67762 & 980.32442 \end{bmatrix} +/- \begin{bmatrix} 4.01158 & 4.18425 \end{bmatrix}$$

- Principal point:

$$cc = \begin{bmatrix} 614.92103 & 373.68816 \end{bmatrix} +/- \begin{bmatrix} 6.43647 & 4.62420 \end{bmatrix}$$

- Skew:

$alpha_c = \begin{bmatrix} -0.00139 \end{bmatrix} +/- \begin{bmatrix} 0.00079 \end{bmatrix} \implies$ angle of pixel axes = 90.07972+/−0.04505 degrees

- Distortion:

$$kc = \begin{bmatrix} 0.01491 & -0.00391 & 0.00133 & -0.00133 & -0.00000 \end{bmatrix} +/- \begin{bmatrix} 0.01137 & 0.03009 & 0.00166 & 0.00231 & 0.00000 \end{bmatrix}$$

- Pixel error:

$$err = \begin{bmatrix} 0.33413 & 0.41325 \end{bmatrix}$$

  The two values are the standard deviation of the re-projection error (in pixel) in both x and y directions respectively.

- The extrinsic parameters are included in the 'Calib_Results.mat' file.

- The above parameters were chosen as they provided least pixel error. The procedure to arrive to this has been described in the previous section.

References

[1] Camera calibration toolbox for matlab. `http://www.vision.caltech.edu/bouguetj/calib_doc/index.html`. Accessed: 2018-05-28.

[2] Description of the calibration parameters. `http://www.vision.caltech.edu/bouguetj/calib_doc/htmls/parameters.html`. Accessed: 2018-06-05.