Assignment3: Camera Calibration

March 15, 2023

1 Part A: Intrinsics Calibration

1.1 Descriptions

We have a camera rig setup like this.

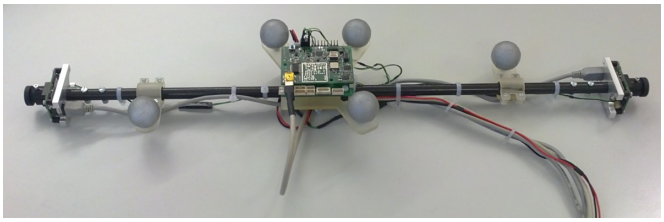

Figure 1: Illustration of the hand-eye calibration problem.

Given several checkerboard images, you need to find the intrinsics of the camera using Zhengyou Zhang's method. You also need to calculate the camera position and orientation with respect to the checkerboard calibration target. This transformation will be used in part B. You don't need to estimate the distortion parameters (for simplicity, we assume our image has no distortions).

1.2 Your goal

What we want:

- camera matrix for each camera

$$\begin{pmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{pmatrix}$$

- camera position $t_i^c \in \mathbb{R}^3$ and orientation $R_i^c \in SO(3)$ for each image i and camera c
- reprojection errors of your implementation.

2 Part B: Hand-eye Calibration

Given several checkerboard images and corresponding marker frame poses from the motion capture system, please find the transformation between the marker frame and the checkerboard frame.

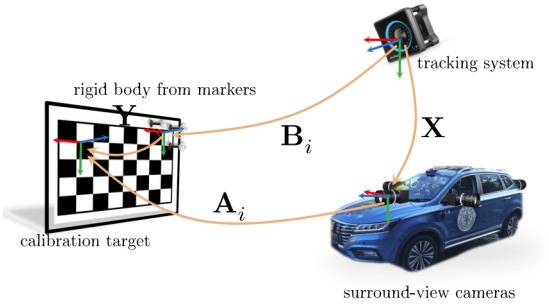

Fig. 1. Proposed surround-view camera system calibration. The target is moved individually in the front of each camera, and its position is accurately measured by an external motion capture system.

Figure 2: Illustration of the hand-eye calibration problem.

Here are some explainations for the figure above. The four rigid body transformation $A, X, Y, B \in SE(3)$ meanings

- A: transformation from the camera to the checkerboard. It can be calculated by the calibration method in part A.
- X: transformation from the tracking system to the camera. It is unknown, but a fixed value in our setup.
- Y: transformation from the marker to the checkerboard. It is also a fixed value.
- B: transformation from the tracking system to the marker. It is tracking system output in *.pose file.

So we have the relation that $A_i X = Y B_i$ for $i \in \{1\,, ..., N\}$. Meanwhile, we can also observe that $A_i A_j^{-1} Y = Y\, B_i B_j^{-1}$. To summary, what we want is Y , and our task is to solve the equation in the form of $CX = XD$.

2.1 Your goal

What we want:

- Transformation between marker frame and checkerboard frame.

- For we have camera A and camera B, the transformation between marker frame checkerboard estimated from A and from B should be consistent. You need to show that fact.

3 Data

Download All the data is in a zip file named "hw3_dataset.zip". Please download it from Piazza.

Format The zipped file contains image files named by "{cam}_{id}.png". It also contains the corresponding marker frame pose files "slam_hw3_{cam}_{id}.pose". $cam \in \{A, B\}$ and $id \in \{1, 2, 3, 4\}$.

Checkerboard The square size of our checker is 3.3cm.

Marker Pose Marker pose is represented as quaternion and its translation unit is meter.

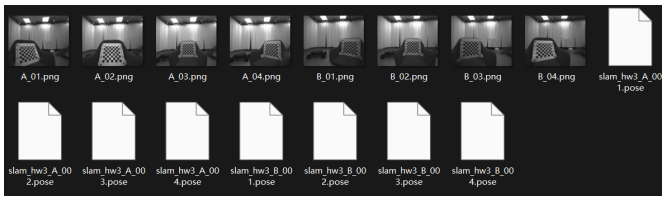

Figure 3: Hw3 data.

4 Implementation requirements

- Both C++ and Python are acceptable.
- You can only use third-party libraries for matrix computation (i.e. numpy and Eigen) and visualization(i.e. Open3D or OpenGL).
- In homework 3, you can use OpenCV to find checkerboard patterns from image data
- In homework 3, you can use OpenCV hand-eye calibration implementations. But if you can implement the method yourself, you can get a bonus point.

5 Submission requirements

- Deadline: 2nd of April 23:59.
- Submit your solution code with a one-page summary of your code (structure and usage) and results as a zip to the TA.
- Make sure the email has the header "CS284: HW3: Your Name"
- We would then arrange a meeting after the deadline in which we would ask each one of you to come in for 10 minutes to demonstrate your solution on your own computer.
- If submitted after the deadline but still within 24hrs, a 50% penalty is applied. If submitted more than 24hrs after the deadline, a zero score will be given.