Calibrating an optical tracking system

José Carlos Mayoral Baños
Chaitanya Hebbal

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Definitions

From [2]:

- Principal point: optical center of the camera or intersection of optical axis and image plane.
- Focal Length: corresponds to the distance from the center of the camera lens to the image plane.
- Principal Point Error: "this error can be visualized and interpreted as the standard error of the estimated principal point".
- Radial distortion are the coefficients of the distortion of the image based on.
- Radial Distortion error indicate the distortion which come from the camera lens.
- Tangential Distortion error is different to zero in those camera which the lens and the image plane are not parallel.
- Reprojection errors is the distance between a pattern keypoint detected in a calibration image, and a corresponding world point projected into the same image, shown at figure 3.

Calibration Process

The current calibration process was using the Camera Calibration Toolbox for Matlab.
The calibration process consists on:

- Having a patter 1, a set of images of this must be taken with the camera that is wanted to be calibrated changing distance to the pattern and orientation.

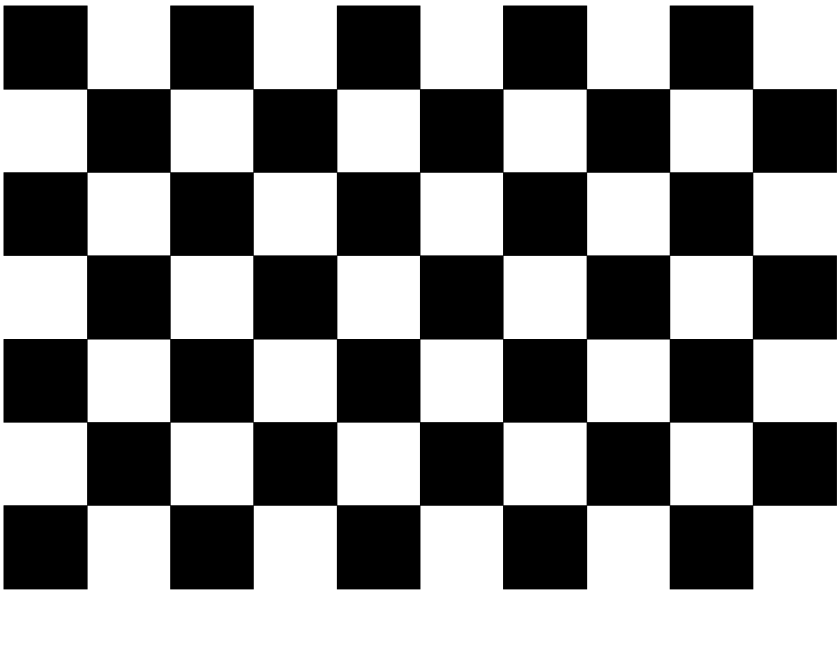

Figure 1: Example of Coordinates Frame Pattern

- At Matlab, the images must be added to the toolbox, for this example 40 images were added.
- The toolbox input is just the size of the square of the pattern (in this case 72 mm).
- For each image the patter will find the corners of the patter, i.e figure 2.

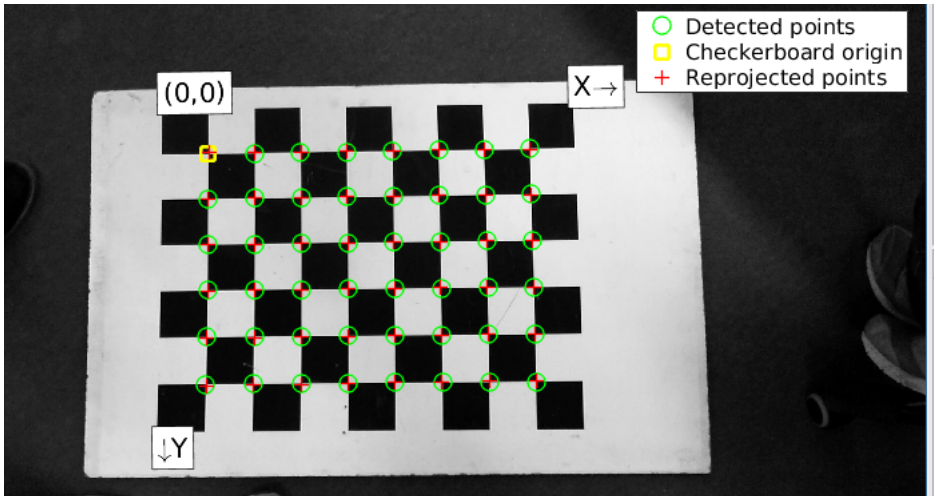

Figure 2: Border Detection

- In addition, the toolbox also find the Reprojection Error per Image 3

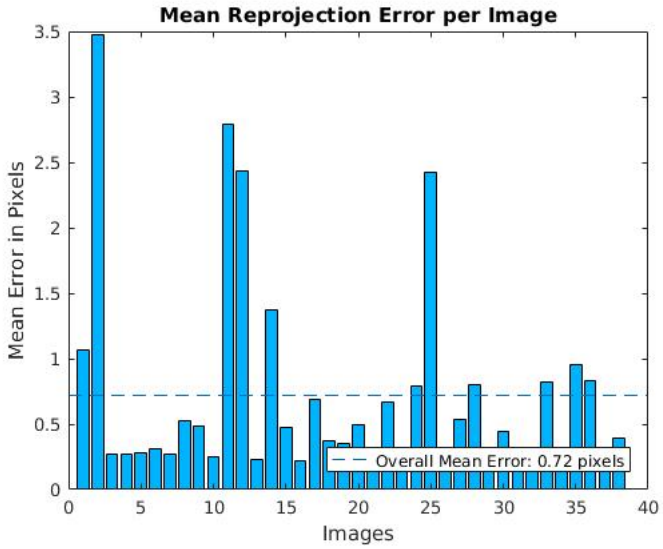

Figure 3: Mean Reprojection Error per Image

- The calibration also allow to find the exact location of the pattern for each camera (shown at figure 4. It is important to notice that might be a good idea to skip some of the image in order to have an smaller error.

The parameters provided at calibration are shown in the next sections.

Camera Parameters

Intrinsic Matrix

Intrinsic Matrix =

$$\begin{bmatrix} 1460.7 & 0 & 0960.9 \\ 0 & 1463.9 & 548.6 \\ 0 & 0 & 1 \end{bmatrix}$$

Focal length (fx,fy) at pixels are: $[1460.7, 1463.9]$
Where the principal point coordinates are $[960.9, 548.6]$ in pixels.
Skew (row 0 col 1) indicates the perpendicularity of the axis of the image plane.

Radial Distortion

Radial Distortion Coefficients are $[k1 = 0.0063, k2 = 0.0215]$. This coefficients comes from an arbitrary unknown function that is normal modeled by Taylor Expansion the radial distortion model [**?**]:

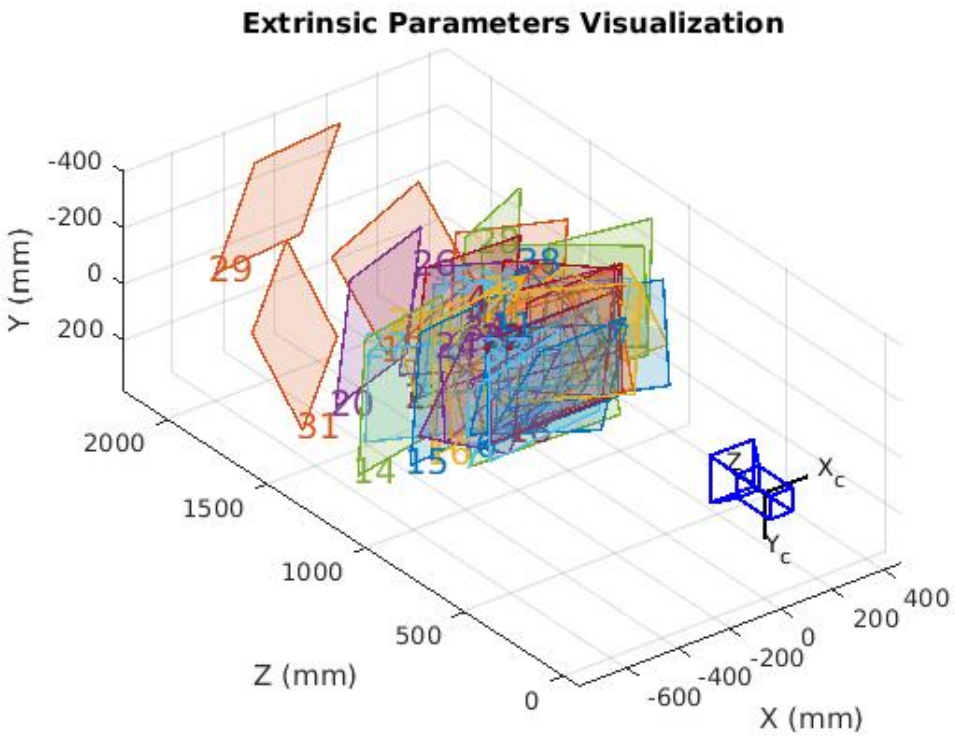

Figure 4: Extrinsic Parameters Visualization

$$L(r) = 1 + k_1 r + k_2 r^2 \cdots$$

Which is used to get the correct coordinates from an image using:

$$\hat{x} = x_c + L(r)(x - x_c)$$

$$\hat{y} = y_c + L(r)(y - y_c)$$

Whiere (x,y) are measured coordinates, $(\hat{x}, \hat{y})$ are corrected coordinates and (x_c, y_c) is the center of the radial distortion. And r is the distance from the center of radial distortion.

Camera Errors

SkewError: 0
FocalLengthError: [4.13894.1263]
PrincipalPointError: [1.58771.4350]
RadialDistortionError: [0.00460.0155]
TangentialDistortionError: [00]

Experiment Design

- If the position of the camera is known then the problem can be simplify.
- With one single camera is not possible in general to locate the position of one point in the camera in world frames, however is possible to obtain a distance to it if the size of the object is known.
- Having the focal length, the pixel where is the center of the camera could be known.
- Taking one point to calculate the distance in pixels can be known.
- A scale factor could be calculated if the area or size of the object is known, then multiplied this factor to the distance in pixels a distance from principal point in longitude is obtained.
- It can be transformed using a Homogeneous transform to the World Frame.

Possible Problems

- The size of the marker must be known to estimate scale factor.
- Detection of the marker could be an issue if the illumination is not optimal.
- Accuracy of measurement relies on the quality of the calibration.

References

[1] Matlab Documentation Link

[2] Robot Perception Course Slides. Prof. Paul Plöger. Hochschule Bonn Rhein Sieg..