NATIONAL TAIWAN UNIVERSITY
DEPARTMENT OF COMPUTER SCIENCE AND INFORMATION ENGINEERING

Robotics

Assignment III

Advisor: LI-CHEN FU

NOVEMBER 2023

Contents

Member list & Workload

No.	Full name	Student ID	Contribution
1	薛韋霖	B08902034	Code, Report
2	王濬哲	B09902107	Code, Report
3	王品文	B09902048	Report
4	紀思年	B08502187	Report

1 Part A – Camera Calibration

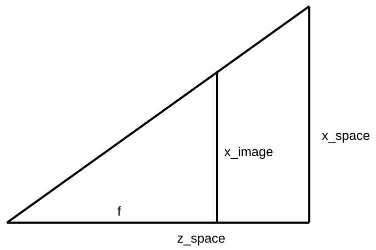
(2) The camera we used is Samsung A52 5G main camera with 12 mega-pixels, f/1.8, 26mm (wide), 1/1.7", 0.8μm, PDAF, OIS.

(3) We use the function cv2.calibrateCamera to generate the camera matrix:

$$\begin{bmatrix} a_x & 0 & x_0 & 0 \\ 0 & a_y & y_0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} = \begin{bmatrix} 3.45192788e+03 & 0.00000000e+00 & 1.31152653e+03 & 0 \\ 0.00000000e+00 & 4.07429644e+03 & 2.26852567e+03 & 0 \\ 0.00000000e+00 & 0.00000000e+00 & 1.00000000e+00 & 0 \end{bmatrix}$$

What this camera matrix does is project the coordinates relative to the camera focus in the space into the pixel coordinate in the image.

Before we see what these parameters actually do, let's see what the simple version of the camera matrix will look like if the unit in the actual space and the image point are the same. (you can assume they both use meters as a unit.), and the image z-axis is aligned to the camera z-axis, which means no shifting for the z-axis.



we can see that because these two triangles are similar, so
$\frac{\text{x\_image}}{f} = \frac{\text{x\_space}}{\text{z\_space}} => \text{x\_image} = f\frac{\text{x\_space}}{\text{z\_space}}$
Because the z coordinates of the output is still z_space, we don't need to divide it.
And the x_output = x_image $*$ z_space = $f *$ x_space.
The same rule can be applied to the y-axis, and we can get $a_x = a_y = f$.
x_0 and y_0 are zero because it requires no shifting.

Let's take a look at the actual case, the units are different, and z-axes are not aligned.

a_x: We need to do the unit transformation. The multiplier is the ratio between one unit in the actual space, and the x length of a single pixel.
In math formula, the multiplier is $\frac{\text{Length of one unit in the space}}{\text{The x length of a pixel}}$. So $a_x = f\frac{\text{Length of one unit in the space}}{\text{The x length of a pixel}}$.
a_y: We need to do the unit transformation. The multiplier is the ratio between one unit in the actual space, and the y length of a single pixel.
In math formula, the multiplier is $\frac{\text{Length of one unit in the space}}{\text{The y length of a pixel}}$. So $a_y = f\frac{\text{Length of one unit in the space}}{\text{The y length of a pixel}}$.

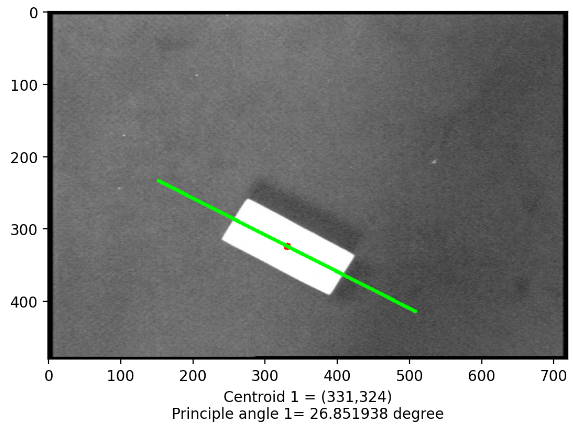
x_0,y_0: Remind that the z-axes are not aligned, we need to do a shift along the x-y-plane. The z-axis of the image passes the (0,0), while the z-axis of the camera passes the center of the image, whose coordinate is (x_0,y_0). To shift the z-axis, we need to add x_0 and y_0 to the output. Because it is the coordinate of the center of the image, the value should be half of the x maximum pixels and y maximum pixels respectively.

(4) The 21 * 2 image pairs are shown below. Each pair includes an original image (the left one), and an undistorted image (the right one).

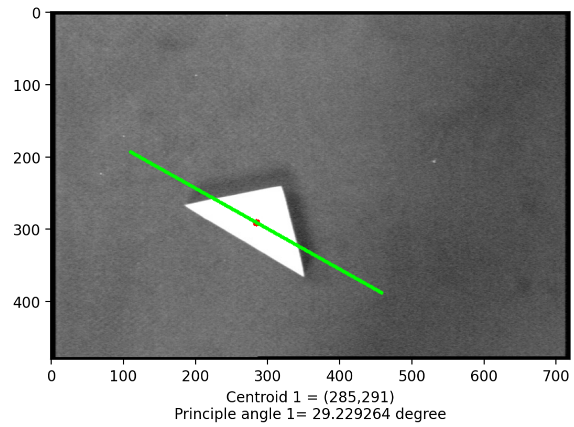
I guess our camera has a pincushion distortion, so when we undistort it, the result looks like a barrel, thats why the corners are black.

2 Part B – Object Detection

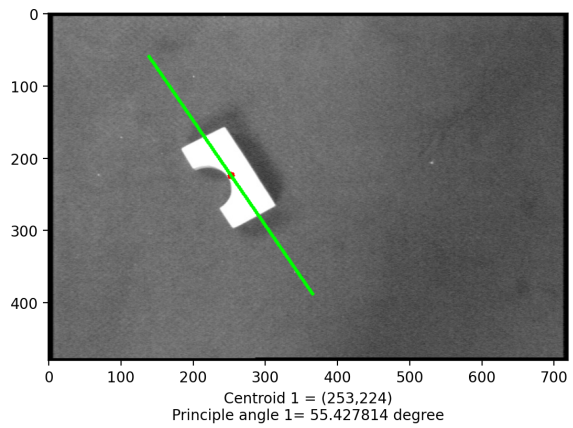
In this part, we need to do object detection with binary machine vision, and display centroid and principal line for the given input images. The centroid's coordinates and the principal angle of each image is displayed below.



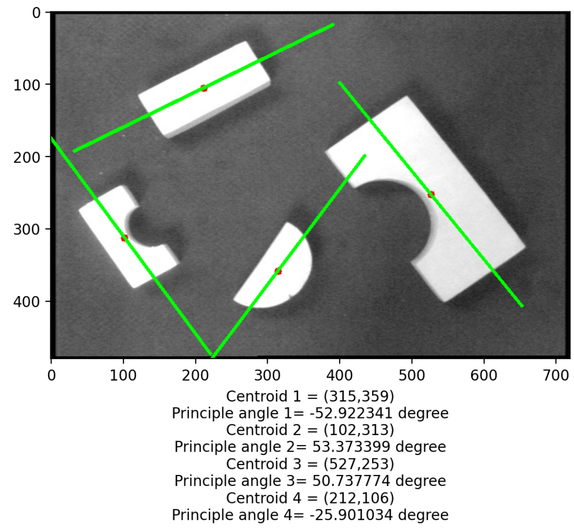
B-1



B-2



B-3



B-4

In B-1, the centroid is (331, 324); the principle angle is 26.851938 degree. In B-2, the centroid is (285, 291); the principle angle is 29.229264 degree. In B-3, the centroid is (253, 224); the principle angle is 55.427814 degree. In B-4, the highest object's centroid is (212, 106), and the principle angle is -25.901034 degree; the left-most object's centroid is (102, 313), and the principle angle is 53.373399 degree; the middle object's centroid is (315, 359), and the principle angle is -52.922341 degree; and the right-most object's centroid is (527, 253), and the principle angle is 50.737774 degree.