Task No. 01

Calibration Section

Maker and Model of the phone:

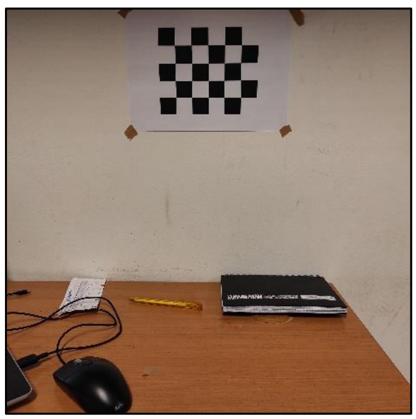
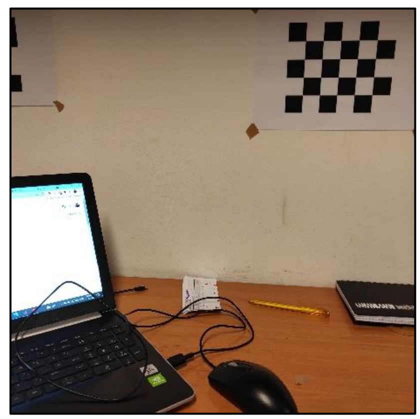
- Xiaomi Redmi Note 9 Pro 6/128gb

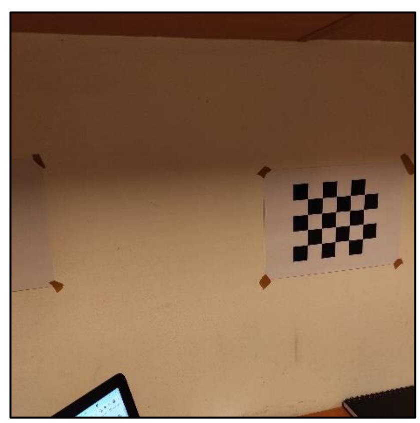
Picture information:

- The resolution ratio = 1:1.
- The focus was fixed.
- The settings were default.

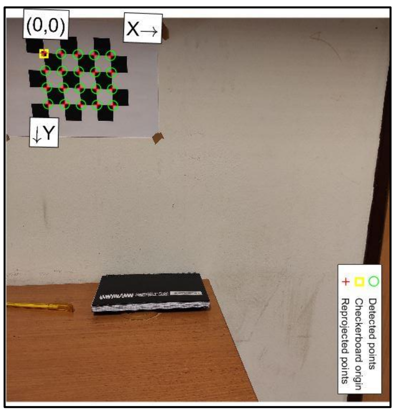
Miniature of calibration photos:

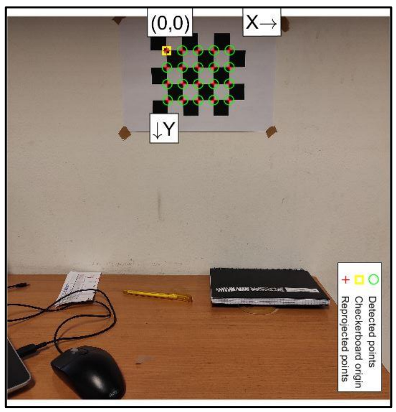
The photos taken from the camera are attached below in sequence. At every position, two photos were captured which are identical to each other. Therefore, total of 18 photos were the input to the calibration app. The size of the box is 20x20mm.

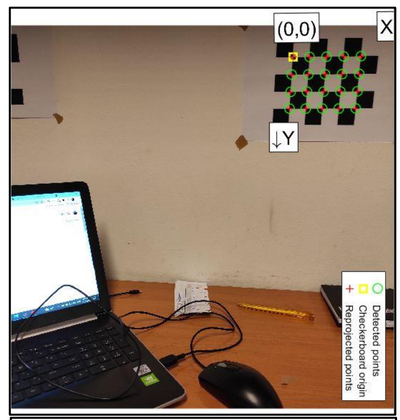




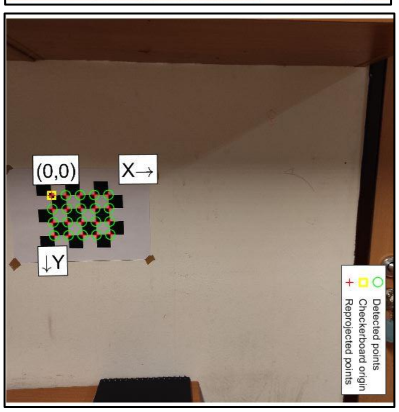



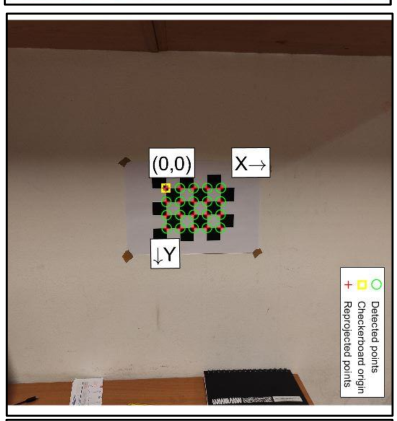
Calibration App Photos:

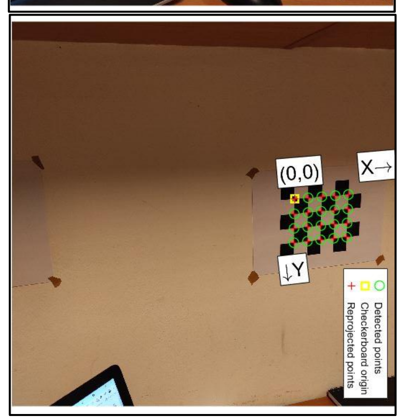


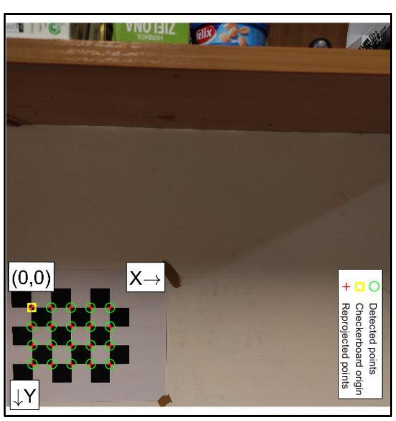


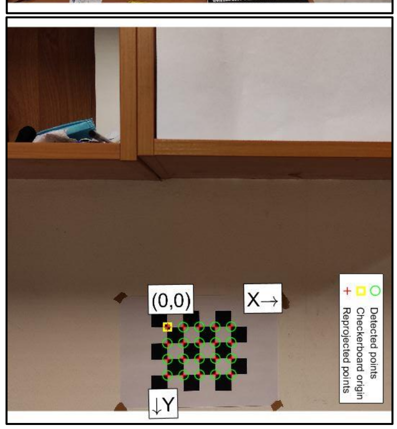


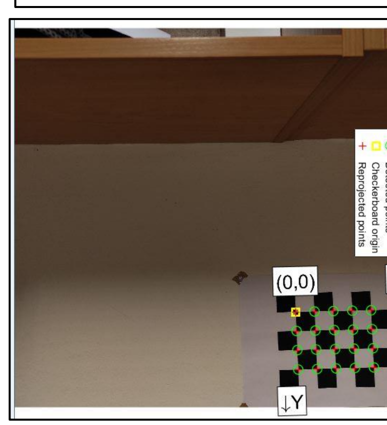






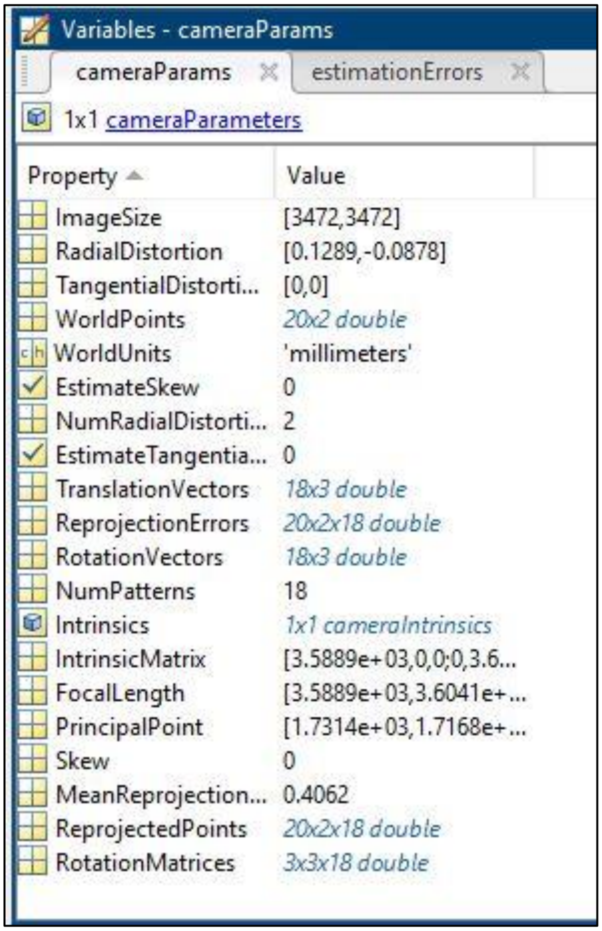






Camera parameters:

The camera parameters are shown in figure below:



The required parameters are:

$$f_x = 3.5889 \times 10^3 \ pixels$$

$$f_y = 3.6041 \times 10^3 \ pixels$$

$$c_x = 1.7314 \times 10^3 \ pixels$$

$$c_y = 1.7168 \times 10^3 \ pixels$$

Task 2

Distance Measurement Section

The intrinsic equation is stated under, where z distance between camera and the object should remain same in one picture:

$$u = f_x \frac{x}{z} + c_x$$

$$v = f_y \frac{y}{z} + c_y$$

For two points x_0 and x_1, we can write

$$u_0 = f_x \frac{x_0}{z} + c_x$$

$$u_1 = f_x \frac{x_1}{z} + c_x$$

Subtracting the two equations

$$u_0 - u_1 = f_x \frac{x_0}{z} + c_x - f_x \frac{x_1}{z} - c_x$$

Cancelling out c_x

$$u_0 - u_1 = f_x \frac{x_0}{z} - f_x \frac{x_1}{z}$$

We can write the equation in simplified way as under:

$$u_0 - u_1 = f_x . \frac{1}{z} . (x_0 - x_1)$$

We can rewrite the equation as under:

$$\boldsymbol{z = f_x . \left(\frac{x_0 - x_1}{u_0 - u_1}\right)}$$

Similarly for y axis, we can write the equation as

$$\boldsymbol{z = f_y . \left(\frac{y_0 - y_1}{v_0 - v_1}\right)}$$

Target Pattern

The pictures of target pattern at different distance are provided below. It should be noticed that the picture from z=1 was captured more precisely than the other two.

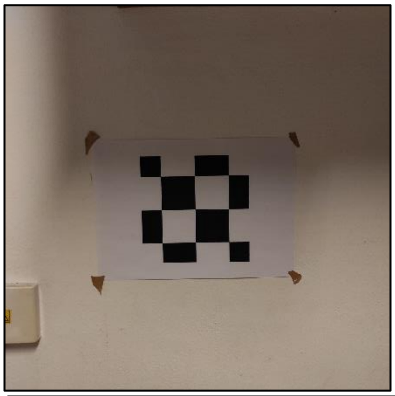
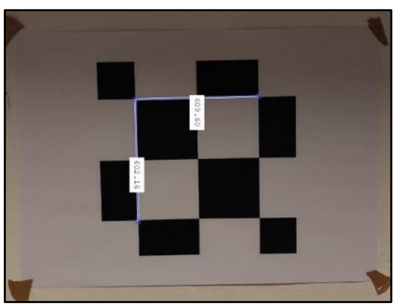
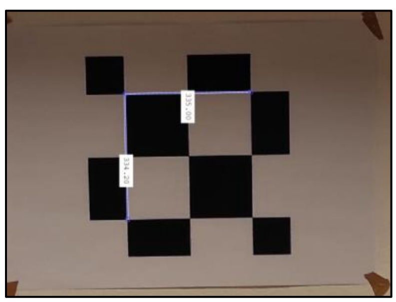


Fig: Z ≈ 0.5	Fig: Z = 1	Fig: Z ≈ 1.5

Measured Pattern:

The u and v camera parameters were measured using the Image Viewer in Matlab. The u value is in the direction of x which is vertical in the figures below, and y axis is horizontal because the apps flip the image.





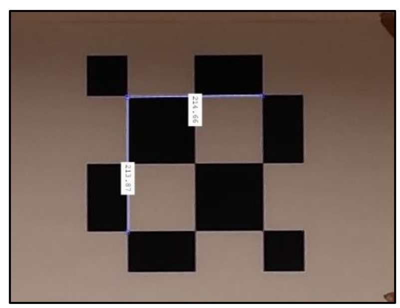


Fig: Z ≈ 0.5	Fig: Z = 1	Fig: Z ≈ 1.5

Results:

The calculation for the z using the measurements along x and u axis.

Measurement Distances z (cm)	x_0 (cm)	x_1 (cm)	u_0 (pixels)	u_1 (pixels)	f_x (pixels) $x10^3$	$z = f_x \cdot (\frac{x_0 - x_1}{u_0 - u_1})$ (cm)	Absolute Error (cm)	Relative Error
50	0	10	0	609.6	3.5889	58.8730	8.8730	0.1775
100	0	10	0	335	3.5889	107.1313	7.1313	0.0713
150	0	10	0	214.66	3.5889	167.1900	17.1900	0.1146

The calculation for the z using the measurements along y and v axis.

Measurement Distances z (cm)	y_0 (cm)	y_1 (cm)	v_0 (pixels)	v_1 (pixels)	f_y (pixels) $x10^3$	$z = f_y \cdot (\frac{y_0 - y_1}{v_0 - v_1})$ (cm)	Absolute Error (cm)	Relative Error
50	0	10	0	602.16	3.6041	59.8529	9.8529	0.1971
100	0	10	0	334.2	3.6041	107.8426	7.8426	0.0784
150	0	10	0	213.87	3.6041	168.5183	18.5183	0.1235

Impact of Measurement Error

By adding one pixel error in u_1 and v_1, the calculations are given below:

Measurement Distances z (cm)	x_0 (cm)	x_1 (cm)	u_0 (pixels)	u_1 (pixels)	f_x (pixels) $x10^3$	$z = f_x \cdot (\frac{x_0 - x_1}{u_0 - u_1})$ (cm)	Absolute Error (cm)	Relative Error
50	0	10	0	610.6	3.5889	58.7766	8.7766	0.1775
100	0	10	0	336	3.5889	106.8125	6.8125	0.0681
150	0	10	0	215.66	3.5889	166.4147	16.4147	0.1094

Measurement Distances z (cm)	y_0 (cm)	y_1 (cm)	v_0 (pixels)	v_1 (pixels)	f_y (pixels) $x10^3$	$z = f_y \cdot (\frac{y_0 - y_1}{v_0 - v_1})$ (cm)	Absolute Error (cm)	Relative Error
50	0	10	0	603.16	3.6041	59.7536	9.7536	0.1951
100	0	10	0	335.2	3.6041	107.5209	7.5209	0.0752
150	0	10	0	214.87	3.6041	167.7340	17.7340	0.1182

The relative and absolute errors are reduced slightly by adding one pixel.