Report on

'Robojanitor : Work Completed '

Submitted By

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Under the guidance of

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It has been a great learning experience for me on both professional and personal front. As I take on a new set of challenges in my professional journey ahead, I shall always cherish the ones I took from here.

INTRODUCTION

Robojanitor is a robot used for cleaning the bathroom related materials such as the floor and the countertop of the sink.
Being a self-cleaning robot the major challenges are faced in the computer vision side of object detection and pose estimation. The few problems which I had worked on during my internship are explained in detail as below.

ALLOTED TASKS

1. **Estimation of the distance of the dustbin from the camera**

The primary task of the robot while cleaning the floor is to locate the dustbin and estimate its distance from the camera.
There are 2 techniques which I had worked upon inorder to solve this problem.

i. Using Homography.

The task here is to first perform the experiment of homography and estimate the homography matrix.

To estimate the homography matrix we first place markers on the floor and measure its position with respect to the world coordinate system whose origin is also on the floor.
I had totally used 18 markers out of which 12 were used for obtaining the homography matrix and the remaining 6 were used for testing purposes in order to calculate the error.
Later the pixel coordinates of the points on the image plane are noted as well.
Using both the pixel coordinate and the real world coordinates we can estimate the homography matrix.

Once the homography matrix is obtained, for any pixel chosen on the image plane by multiplying it with the predetermined homography matrix we can obtain the real world coordinates of that corresponding point.
Note that the point chosen must also be on the same plane as that on which the earlier experiment was performed, which means in our case that the new point for which the real world coordinates is found must also lie on the floor.

For the task of computing the distance of the dustbin from the camera, firstly the dustbin must be segmented based on color.

Fig 1 : Original image

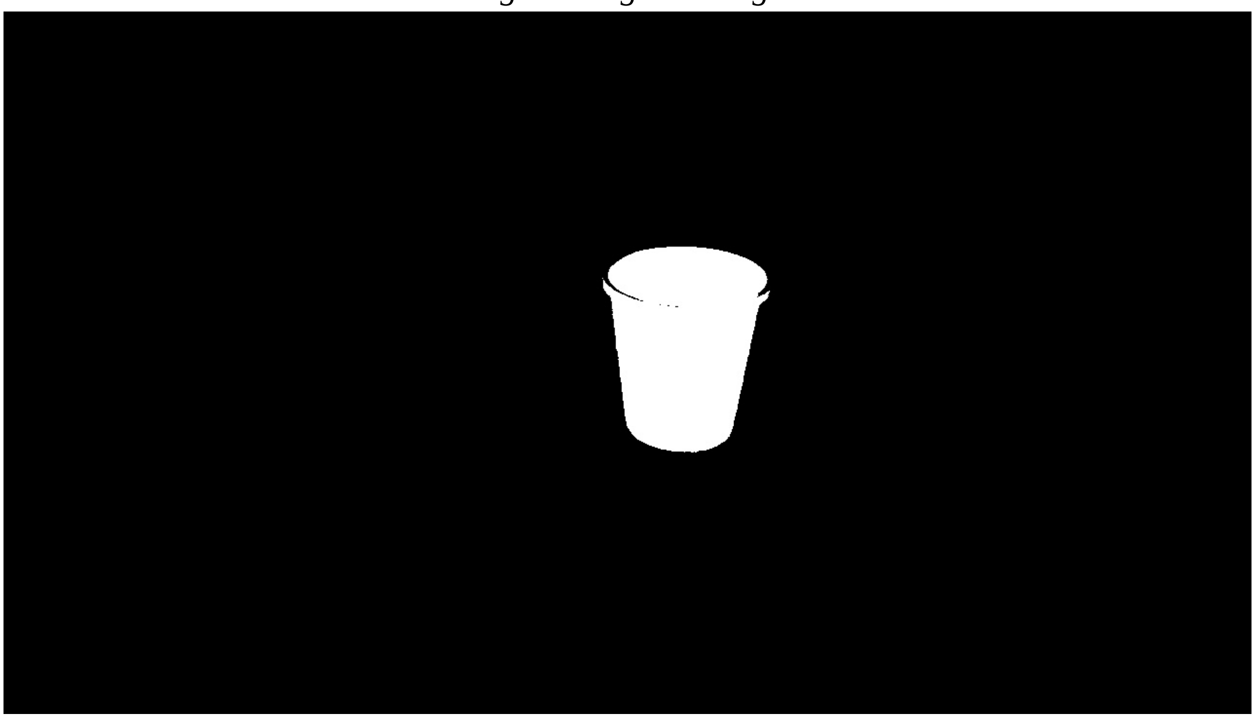


Fig 2 : Color based segmentation of the dustbin

Once the dustbin is segmented we put a bounding box to the obtained contour and get the bottom centre point of the dustbin which is assumed to lie on the floor. The distance of this particular point gives the distance of the dustbin to the camera (Blue point shown in the image below).

Once the point is obtained we find the real world coordinates of that point using the homography matrix as discussed above.
With the real world coordinates we can estimate the distance with the standard distance formula.

The result is as shown below which shows the actual distance and the calculated distance using homography.

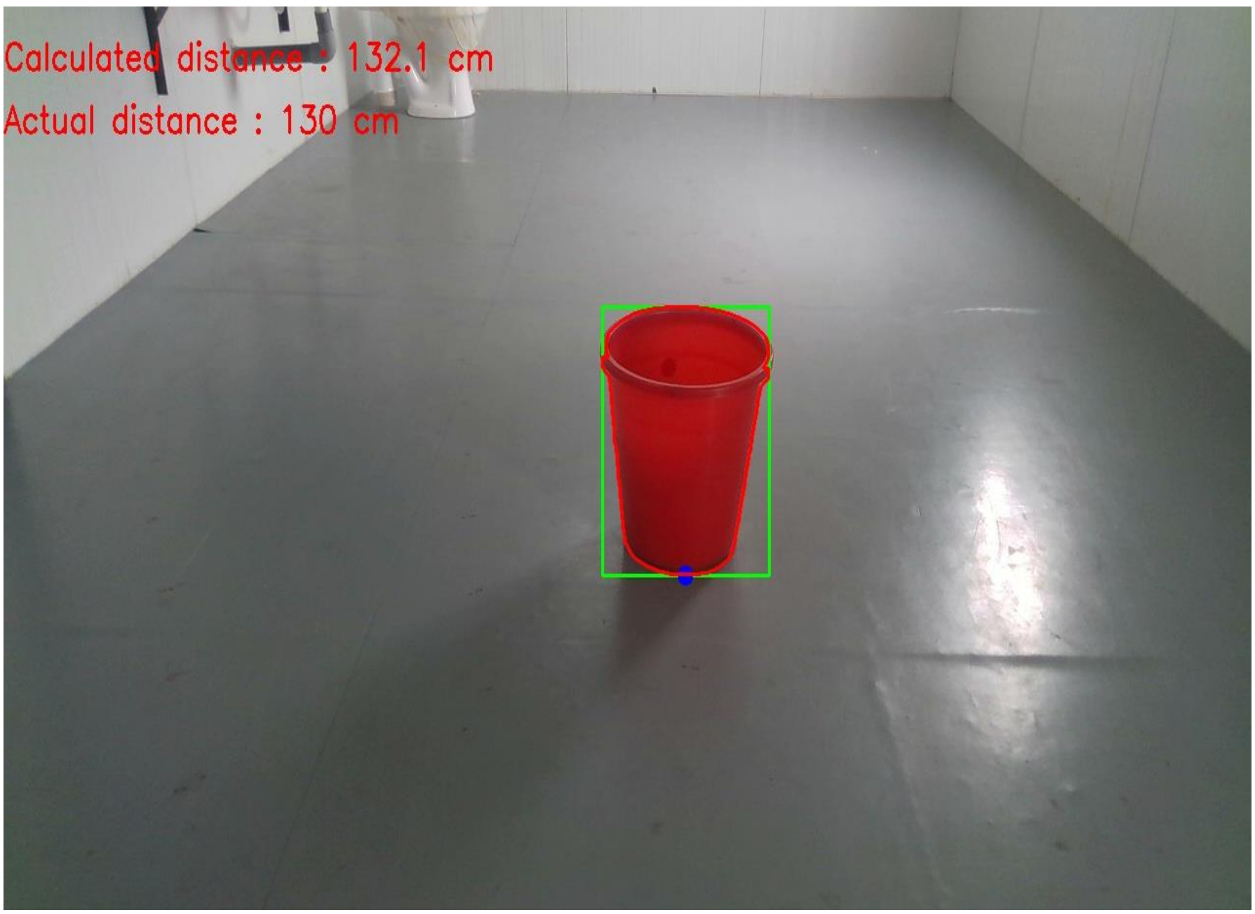


Fig 3 : Result of homography technique

However this technique is not recommendable when we have a moving camera since the same homography matrix might increase the error. The above method discussed is best suited for stationary cameras.

ii. Using the depth map of an RGBD image

The camera which is being used is Intel ReaslSense 435I which is a RGBD camera i.e. it gives the depth of any point using IR radiations.
So in order to overcome the disadvantage of the above method discussed this technique was experimented on. The depth of any point on the depth map can be obtained directly through SDK through a direct API call which then returns the depth at any point when the x and y pixel coordinates are supplied to it.

However the disadvantage of this technique is that the depth map is highly sensitive to reflections, where there are reflections caused due to light the depth of such pixels is not obtained.

Due to the above disadvantage only a single point on the dustbin would not always be guaranteed hence multiple points on the bottom of the dustbin is taken and distance is calculated at each point and the final distance is assumed to be the average of the points

Fig 4 : Multiple points from the bottom taken into consideration

Testing of the two methods :

The camera was stationary, and the dustbin was moved to different locations shown in the image below. Where the dustbin was placed at the positions marked as red.

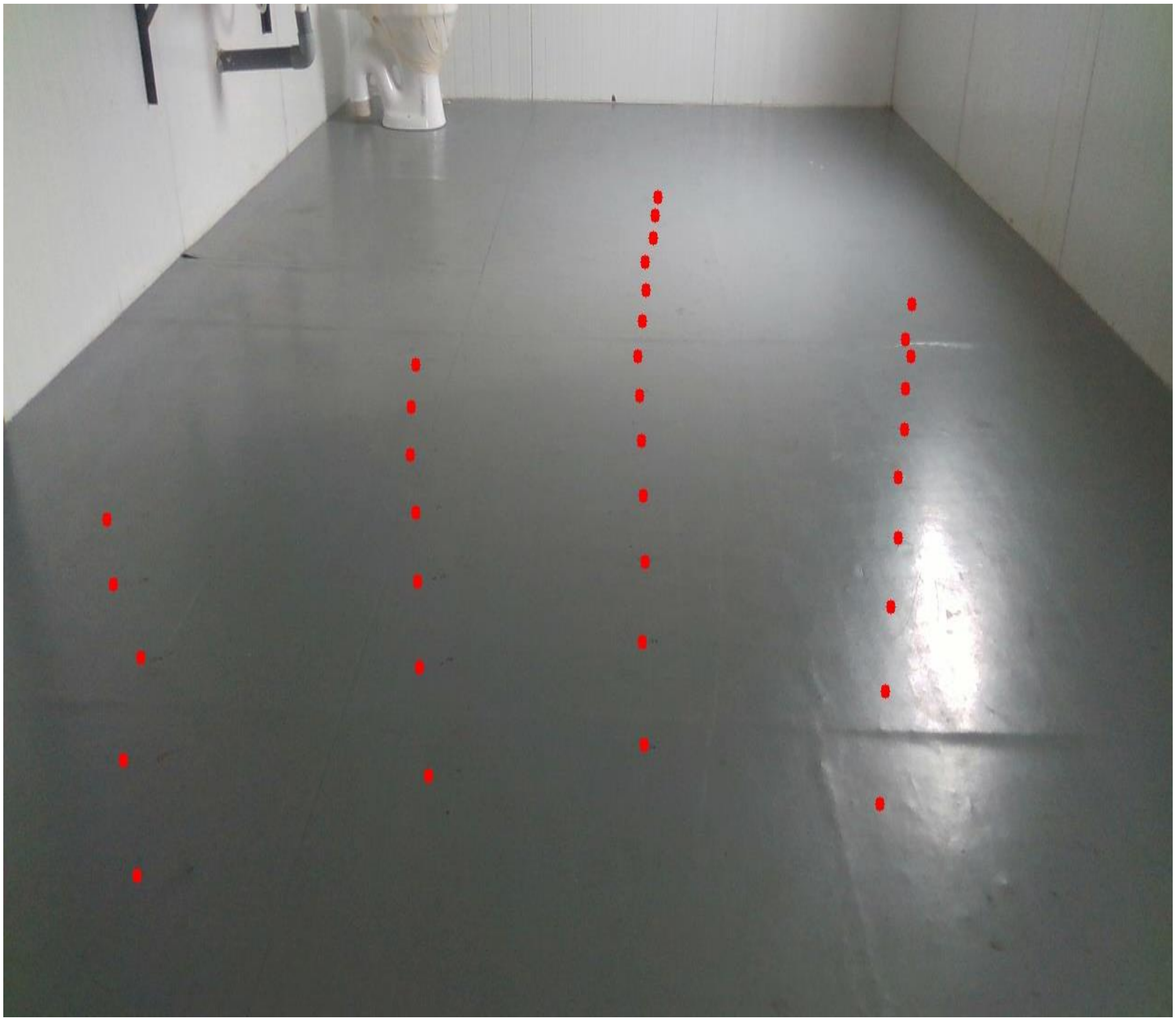


Fig 5 : Points taken for test

The ground truth distance of the points was measured, and both the techniques discussed above were tested.
The below table shows a small section of the recorded results.

Actual Distance	**Line 1**		**Line 2**	
	Homography	**Depth map**	**Homography**	**Depth map**
130	130.9	119.3	130.8	130.5
150	151.2	160.6	151	152.7
170	171.4	176.3	170.1	175.5
190	191.5	197.2	190.5	194.6
210	211.6	215.0	210.9	218.5
230	231.7	235.7	230.4	238.9
250	251.8	253.1	251	264.1
270	272	266.6	269	285.7
290			288.2	299.7
310			308.8	312.7
330			329.3	344.7
350			350.6	369.4
370			369.5	378.0
RMS error	**0.54**	**2.49**	**0.25**	**2.89**

We can conclude that in terms of performance the homography technique works better since the RMS value is least for that method. But both methods have their own advantages and disadvantages.

2. Finding the coordinates of the opening of the dustbin.

i. Using the extreme points.

Once the dustbin is segmented based on color we can select the leftmost and rightmost points of the contour and extract their depth value.

The midpoint of the two extreme points gives the centre of the dustbin. The depth of this centre point is considered to be the average of the two points.
Using the depth and the pixel coordinates of the centre hole of the dustbin the coordinates of the point can be obtained in the camera coordinate system.

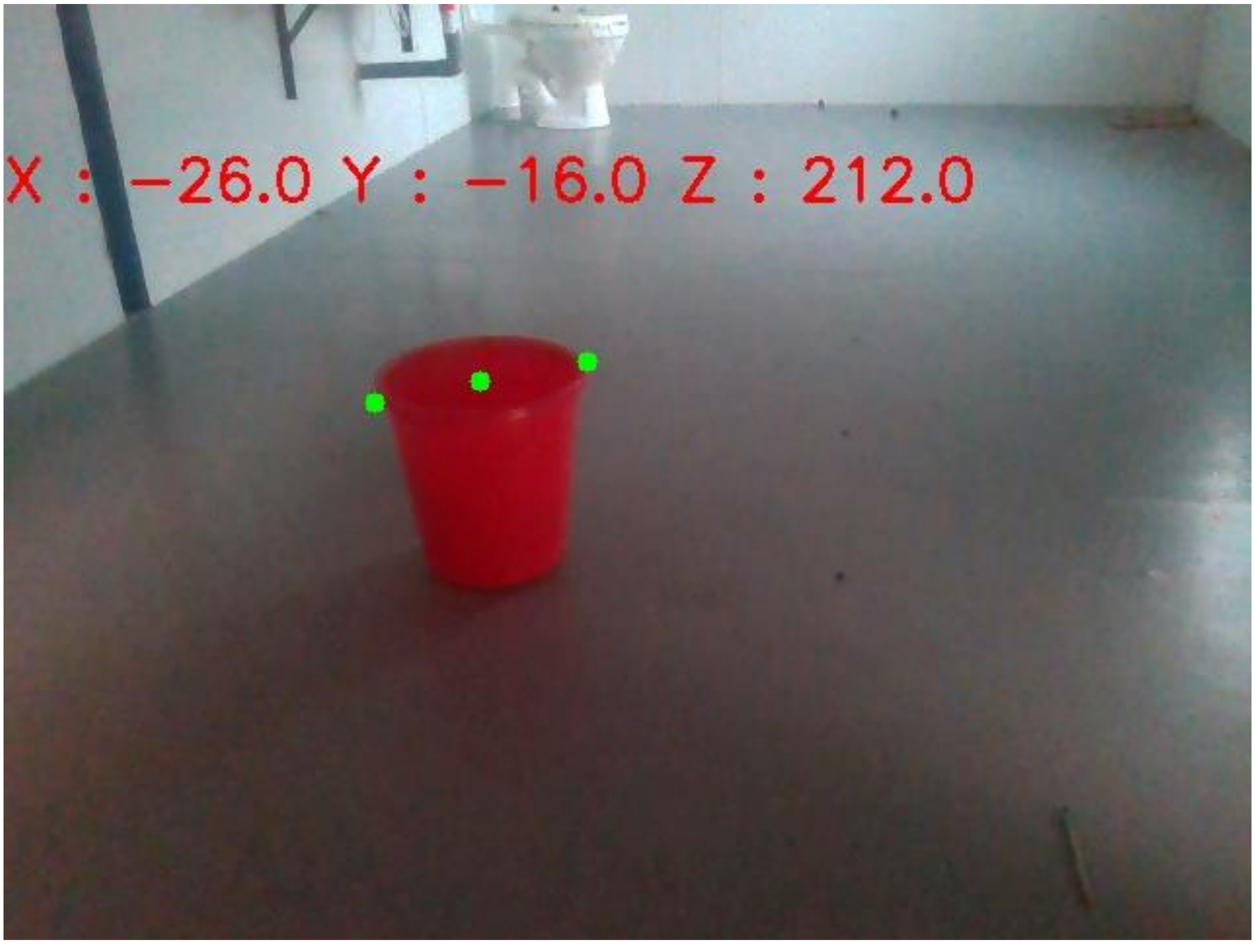
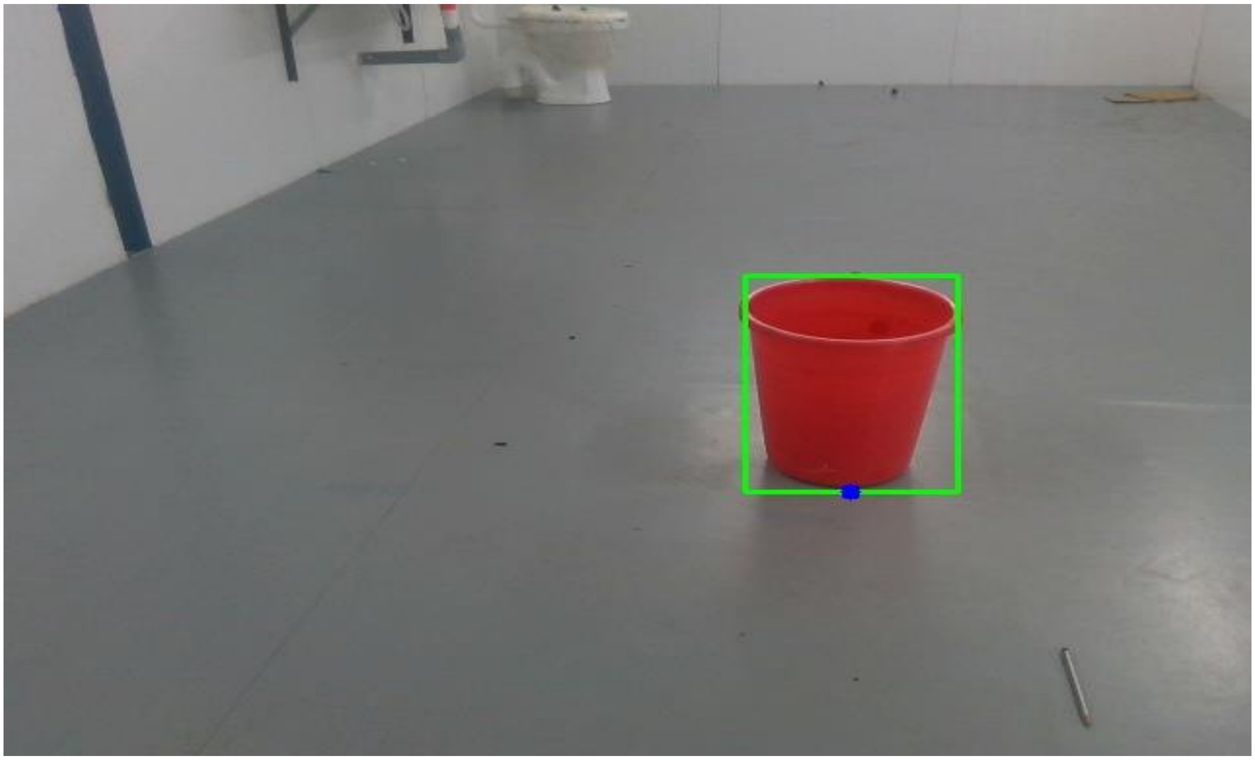


Fig 6 : Midpoint obtained through the extreme points

However using this technique cannot always give the right results since there maybe situations when the depth at the extreme points may not be known or there may be a situation when segmentation is not good other point can be taken as the extreme point

ii. Using the technique of homography

From the homography matrix obtained earlier we can also determine the centre coordinates of the dustbin since we know the physical dimensions of the dustbin.



Once we obtain the coordinates of the blue point using the earlier discussed homography method we can perform certain mathematical operations inorder to obtain the centre point

Known :
1. Height of Dustbin - 90 cm
2. Radius of Dustbin (bottom) – 9.5 cm

For example if (x,z) is the coordinate of the point obtained through homography. The Coordinates of the centre of the dustbin is given by

x_centre = x
y_centre = 90 cm
z_centre = z + 9.5

iii. Using the top rim

For this technique the top rim of the dustbin is painted with a matt black paint and the rim is segmented out based on color.

Fig 7 : original dustbin after painting the rim

Fig 8 : Top rim segmented based on color.

After obtaining the contour of the top rim the 3d coordinates of all the points on the rim with respect to the camera coordinate system can be calculated and taking the centroid of the above obtained 3d points gives the centre of the dustbin. The results obtained are as shown below.

Fig 9 : Obtained results

3. Getting the 4 corners of the countertop

i. Using the point cloud data

The point cloud is generated for the countertop followed by plane segmentation through RANSAC.
The plane segmentation is done using the pcl library.
Once the plane is segmented it is reprojected back onto the RGB image and the results are as shown below.

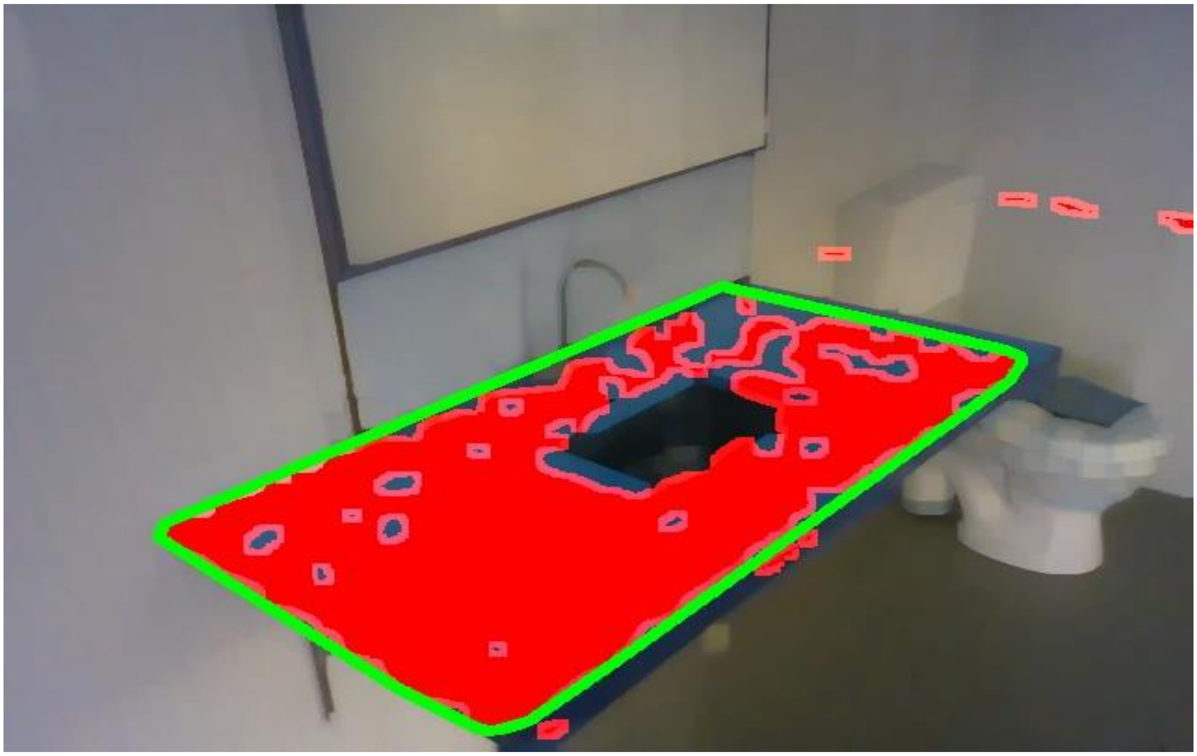


Fig 10 : Plane segmented countertop

After obtaining the plane a convex hull is fitted upon the plane contour.
Since the convex hull will not generate only 4 corners upon the convex hull cv2.aApproxPolyDP is used to reduce the number of sides of the polygon, using a parameter called epsilon the number of sides obtained can be controlled.

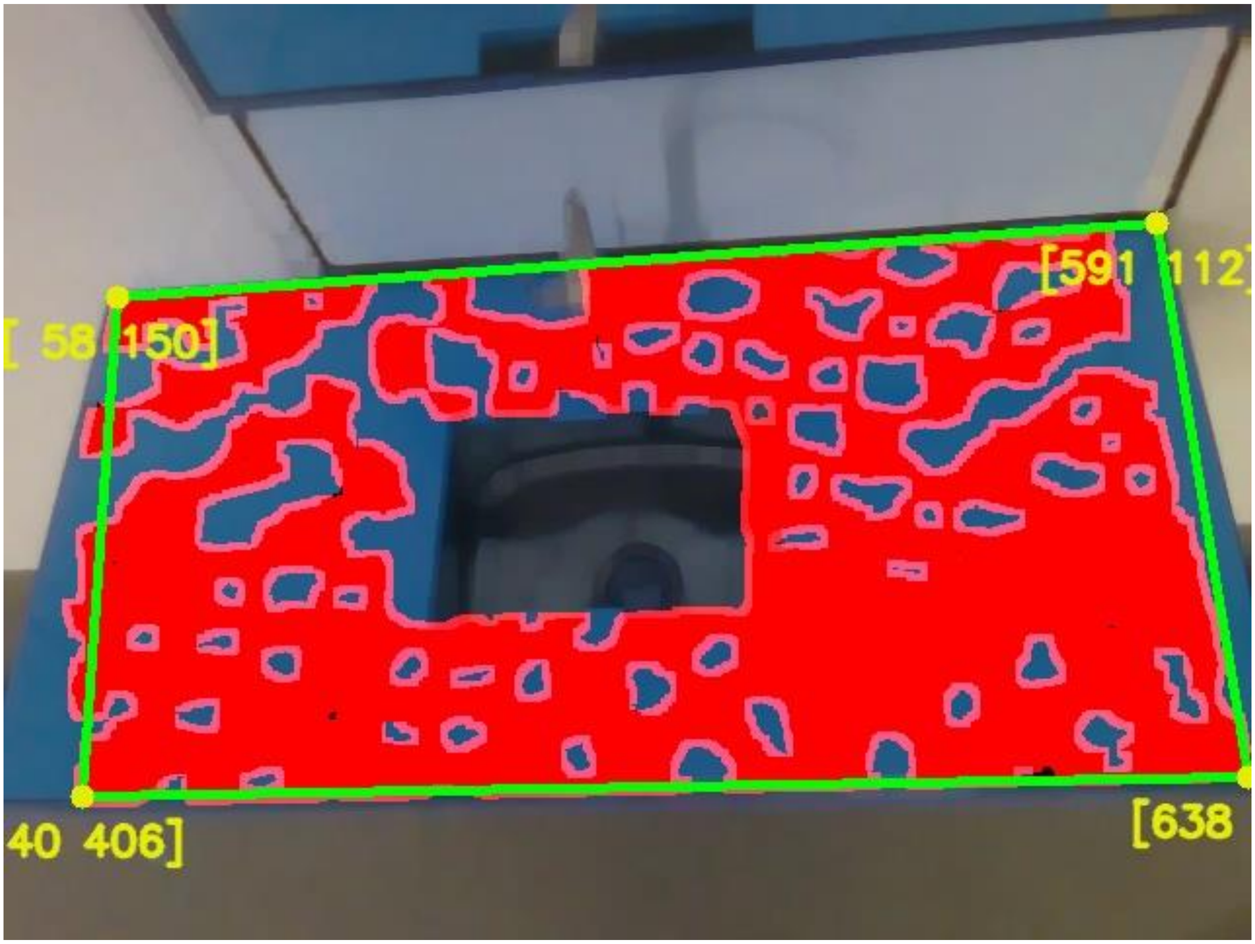


Fig 11 : Result of approxPolyDP

Here we cannot that the 4 corners actually do not coincide with the actual 4 corners of the counter top hence this method can be discarded.

ii. <u>Color segmenting the countertop</u>

The counter top is segmented based on color and the 4 corners can be obtained.

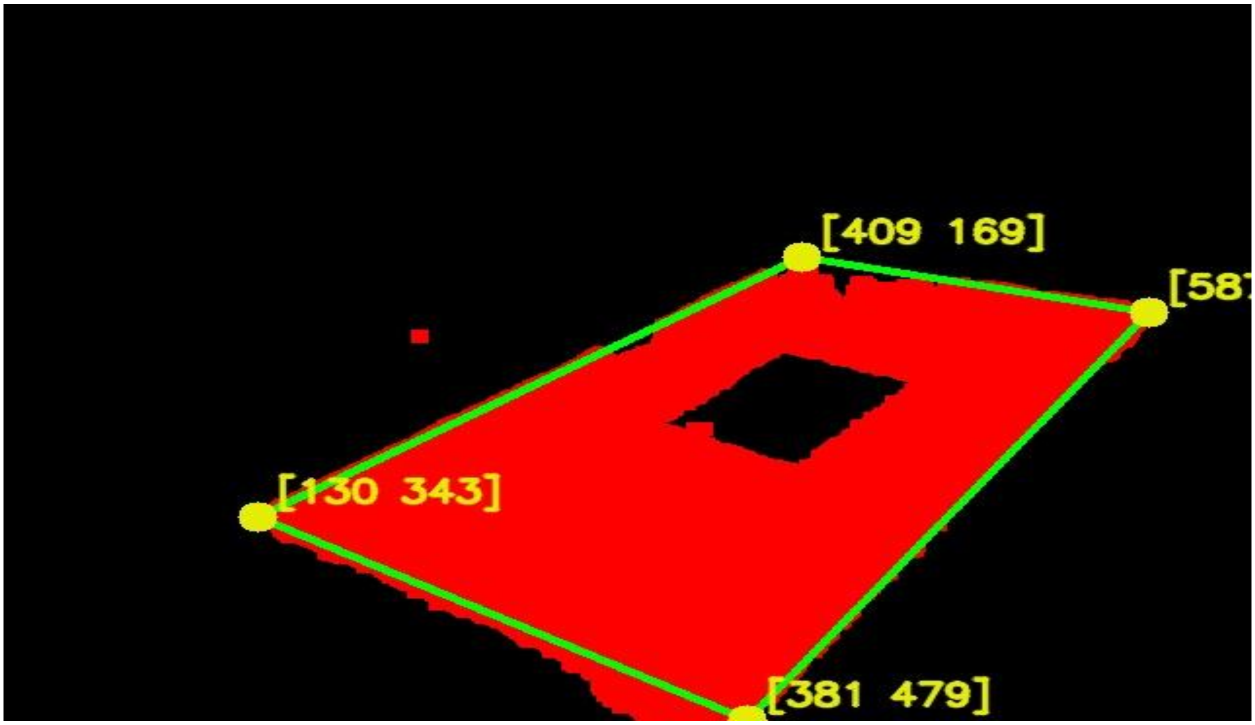
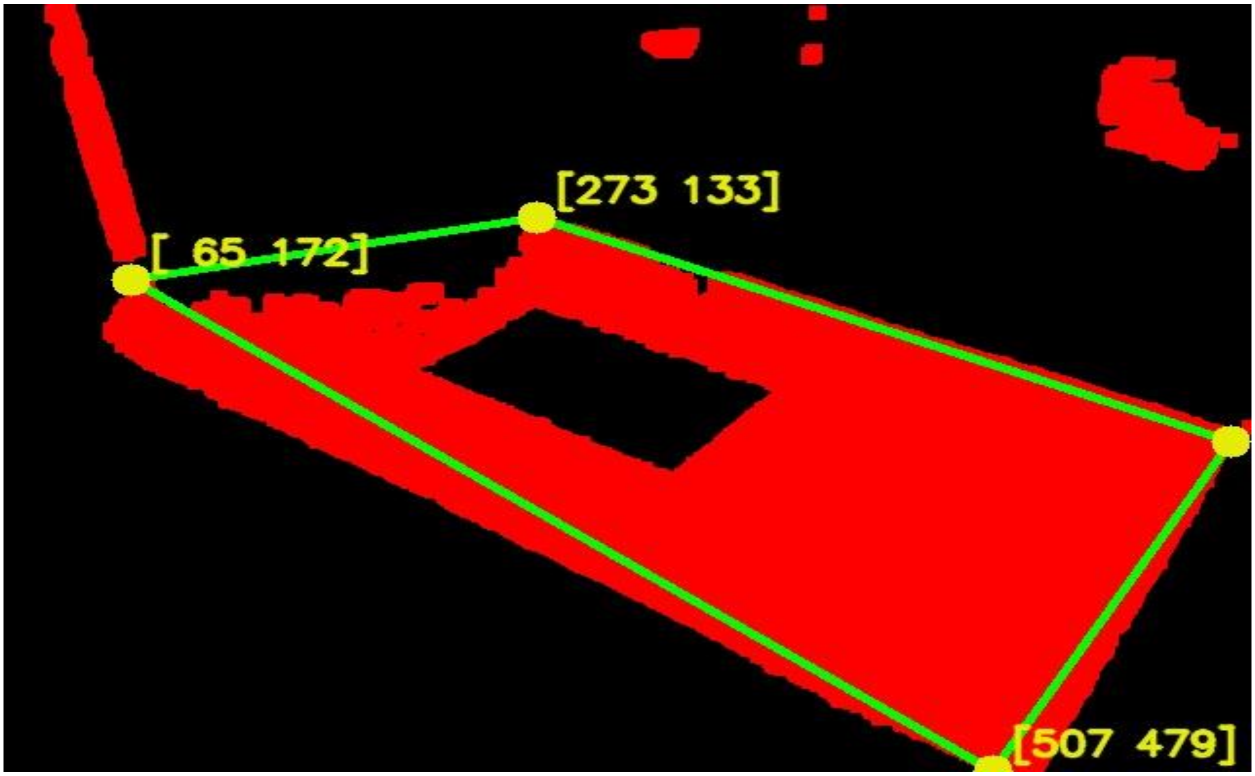


Fig 12 : Color segmentation of countertop

However this method fails when the segmentation is poor as shown below.



iii. Using markers on the countertop

Markers are placed at the corners of the countertop and are color segmented.

Fig 13 : Countertop with markers

If we are capable of segmenting the markers we can obtain the corners of the countertop. The color segmentation in the A channel of LAB color space

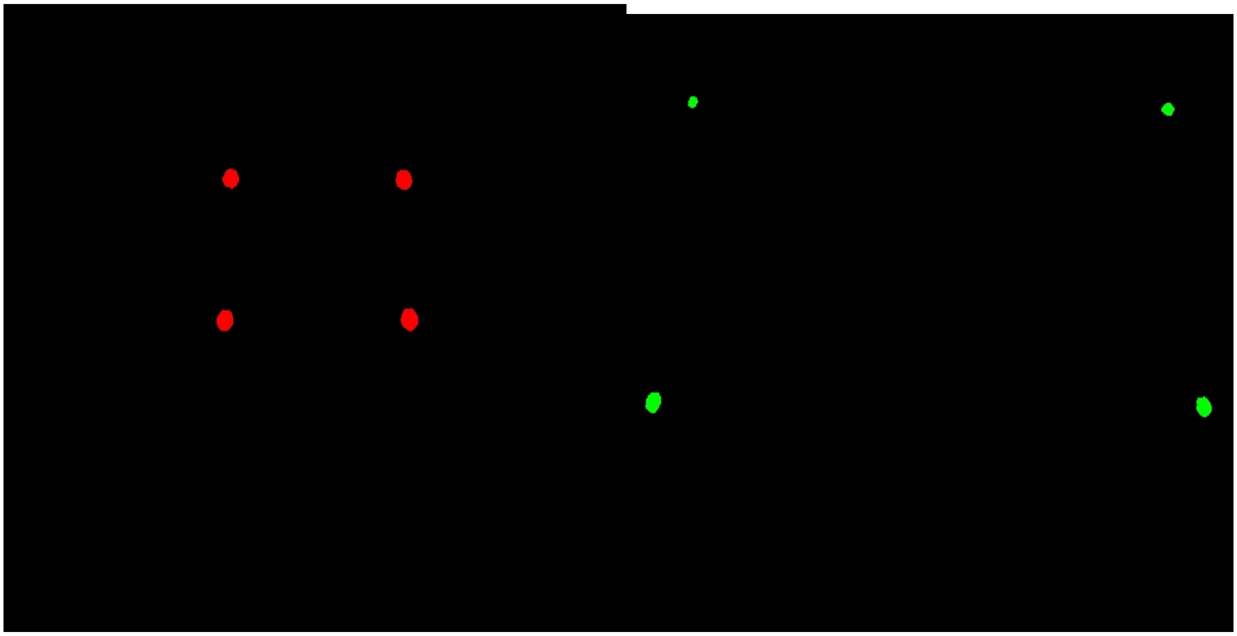


Fig 14 : Segmented markers

Once the markers are segmented the centroid of the markers are calculated as below

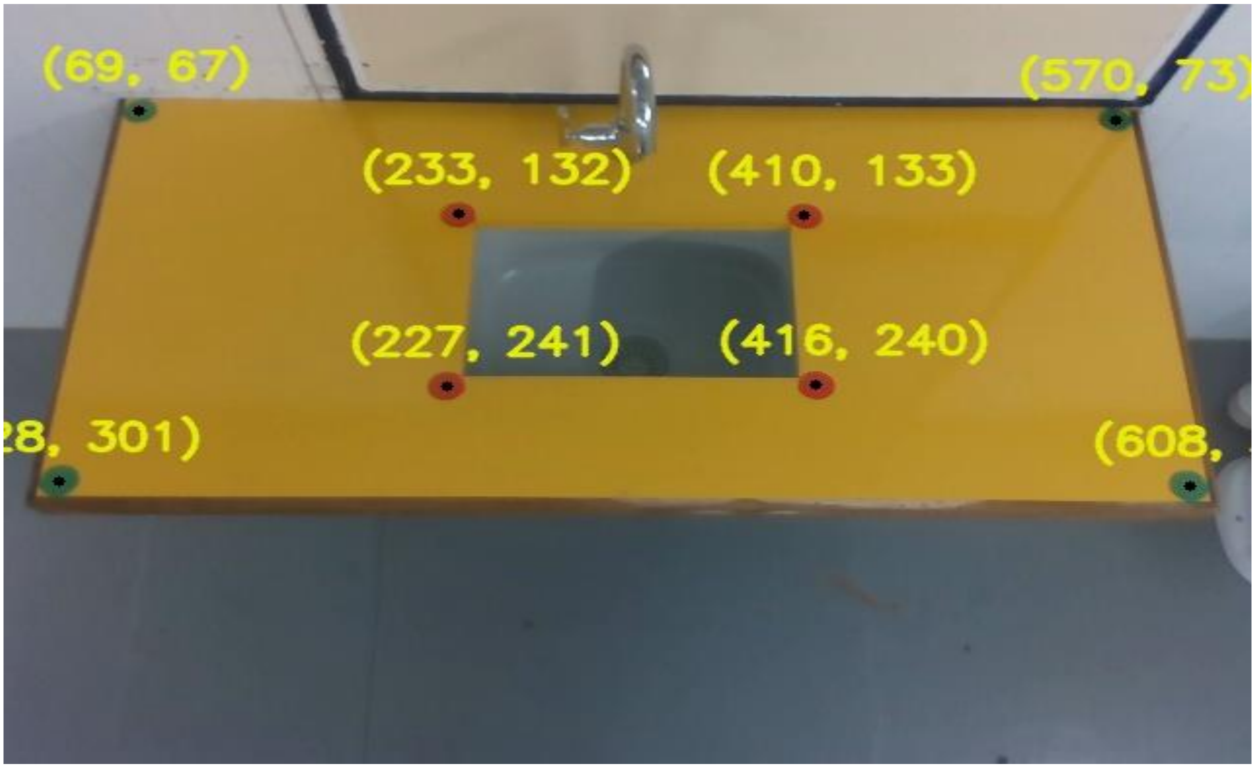


Fig 15 : Centroid of the markers

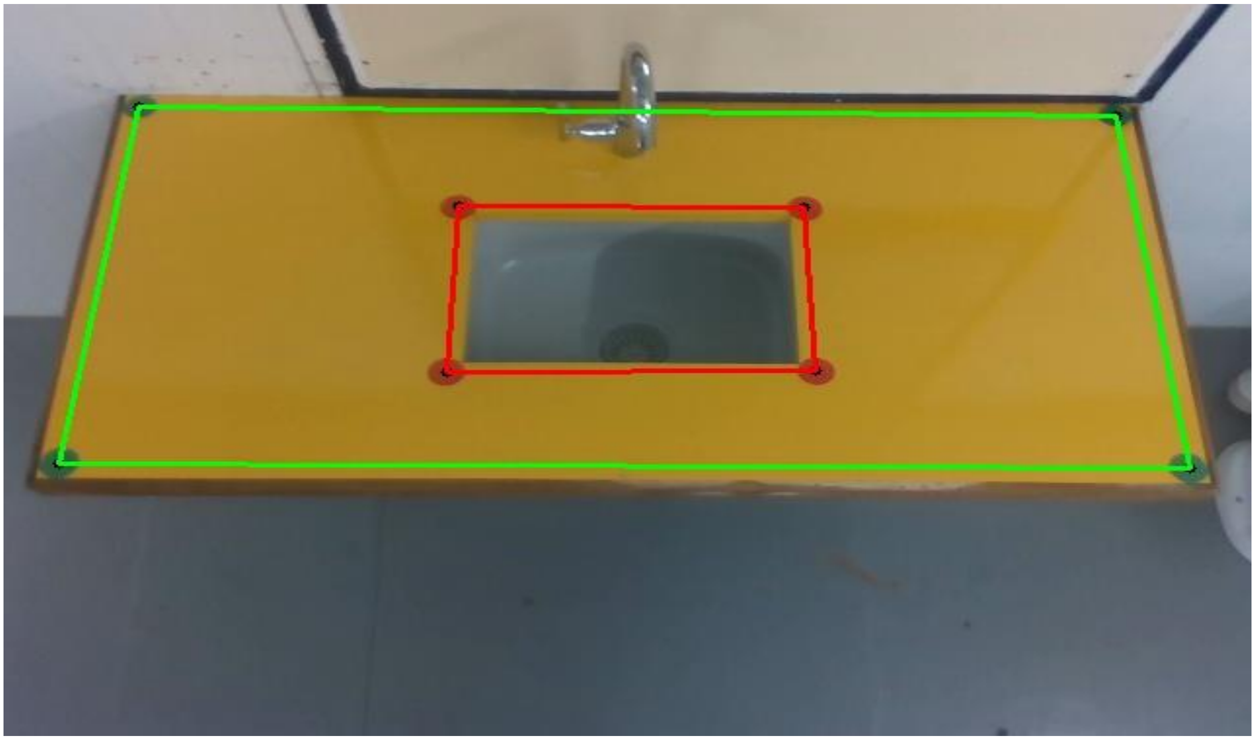


Fig 16 : Final result

4. Getting the surface normal of the countertop

To perform this we need the point cloud data after plane segmentation. RANSAC returns the equation of the plane and from the equation of the plane we can obtain the surface normal.

The surface normal is verified by the below procedure
We first extract the centroid of the countertop and the coefficients of the surface normal are added to the centroid coordinates. The new point obtained is then joined to the centroid by a line, ideally it should look like a straight line pointing out of the countertop.

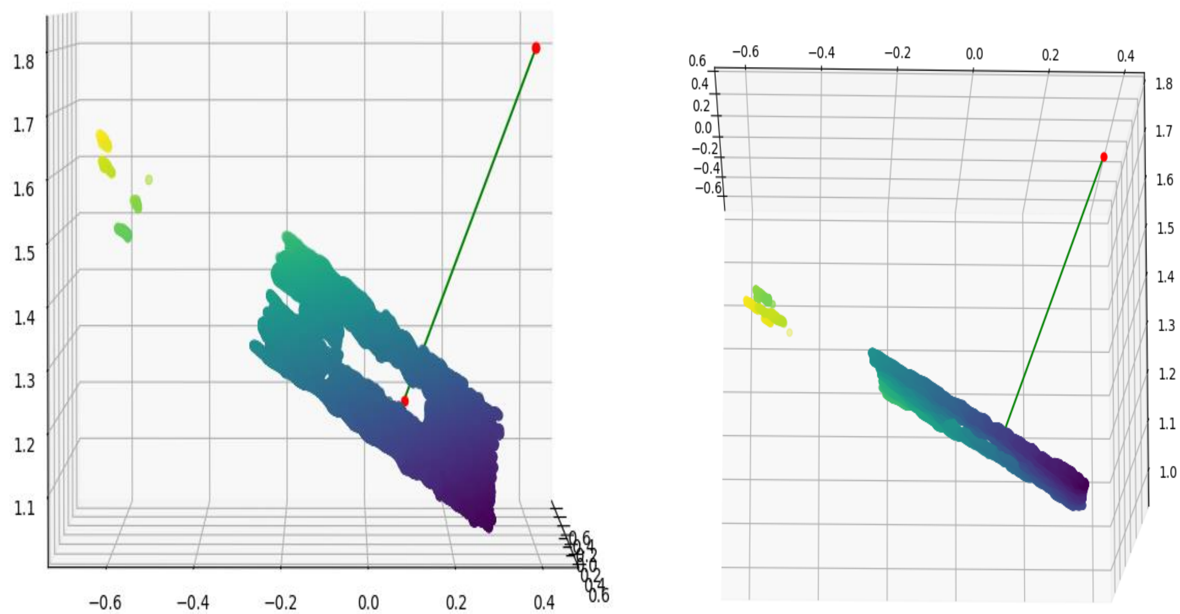


Fig 17 : Verification of the surface normal

ONGOING TASK :

Estimating the pose of the camera with respect to the countertop

CONCLUSION

The task of estimating the 4 corners of the countertop is best done using the markers where we get the best results compared to the other techniques.
Inorder to obtain the distance of the dustbin homography can be used since the error associated with this technique was least.
For the task of finding the centre of the dustbin, homography can be used which is simple along with this the segmentation of the upper rim can also be considered since it gives good results, however in the latter technique the transformation of the obtained centre of the dustbin to world coordinates is a challenging task since we need to consider the pose of the camera considering the yaw and pitch of the camera pose.

REFERENCES

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