Lab 05: OpenCV and Depth Sensing

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The objective of this tutorial is to introduce the concept of point cloud, depth camera, and examples for OpenCV.
In topic 1, you will learn how to use Realsense camera SR300 or D435 and understand the the content of published topics.
In topic 2, we will use OpenCV functions and detect objects with HSV color space.

Hardware and software setup

Laptop setup

Update the latest repo to laptop

laptop$ cd ~/sis_lab_all_2020 (If you haven't clone repo, please clone it first.)
laptop$ git checkout devel-[student_id] (create and switch to your branch)
laptop$ git stash
laptop$ git pull origin master
laptop$ git stash pop
laptop$ cd ~/sis_lab_all_2020/05-Opencv_and_Depth_Sensing/Dockerfiles/PC
laptop$ docker build -t="lab5" .
^ there is a dot here.

Nano setup

Please turn on Nano and plug your Realsense Camera into Nano.
Then, open a terminal and SSH into Nano.
laptop$ ssh arg@[hostname].local
First, set Jetson Nano from 5 Watt mode into 10 Watt mode to increase the computational speed
Nano$ sudo nvpmodel -m 0
Delete all the docker images, containers on Nano
Nano$ docker rm -vf $(docker ps -a -q)
Nano$ docker rmi -f $(docker images -a -q)
Nano$ cd ~/sis_lab_all_2020 (If you haven't clone repo, please clone it first.)
Nano$ git checkout master
Nano$ git stash && git pull
Nano$ cd ~/sis_lab_all_2020/05-Opencv_and_Depth_Sensing
Nano$ docker build -t="lab5" -f=Dockerfiles/Nano/Dockerfile .
^ there is a dot here.

Overview

Estimated Time to Finish: 1.3 hours

After completing this tutorial you should

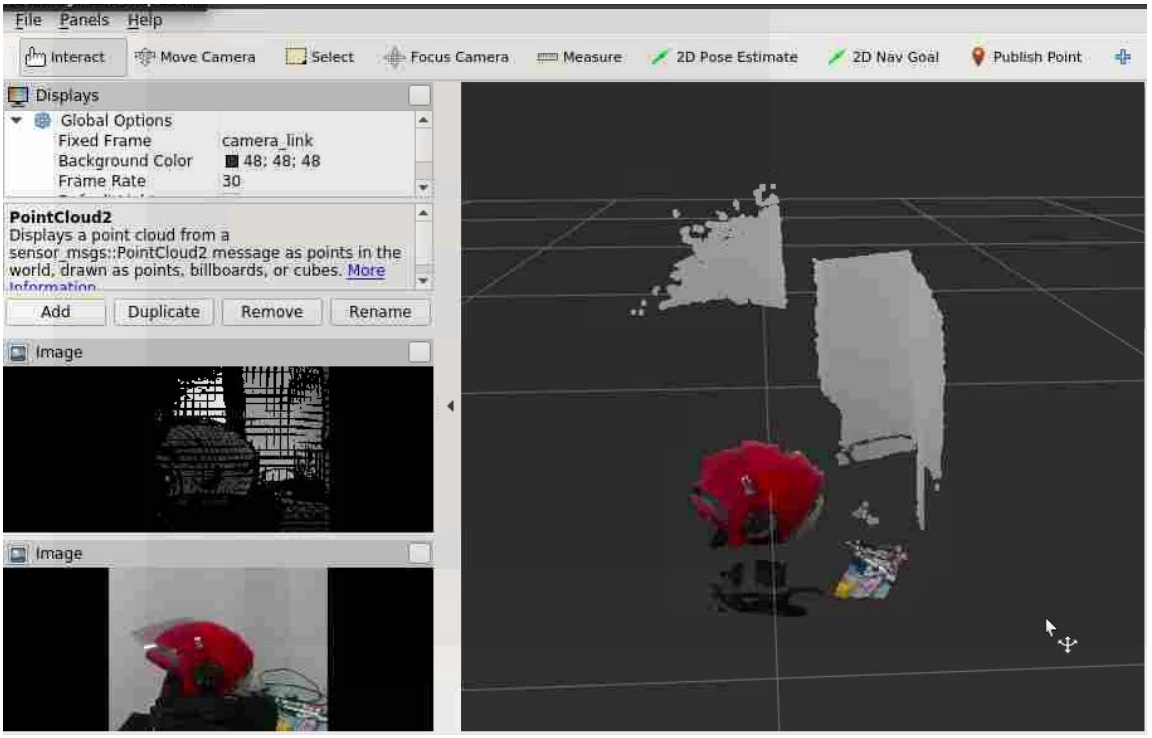
- be able to
  - run RealSense Camera
  - use ROS topics from RealSense Camera
  - use OpenCV
- know
  - how pointcloud is generated.
  - what is Morphological Image Processing
  - what is camera matrix
  - what is HSV color space

Topics and Activities

Topic 1: Use RGB-D Camera

Open a terminal and SSH into Nano.
Laptop$ ssh arg@ [your nano hostname].local
Nano$ export DISPLAY=:0 && xrandr --fb 1800x900 (Resolution depends on your screen)
Nano$ /usr/lib/vino/vino-server
Open the other terminal
laptop$ vncviewer -quality 5 -encodings "tight" [your nano hostname].local
Open a terminal in Nano
Nano$ xhost +
Nano$ source ~/sis_lab_all_2020/05-Opencv_and_Depth_Sensing/Dockerfiles/docker_run_nano.sh
Nano Container$ source devel/setup.bash
Nano Container$ roslaunch realsense2_camera rs_rgbd.launch
Open the second terminal in Nano
Nano$ rviz
Please set fixed frame as camera_link
Add topic "/camera/depth_registered/points", "/camera/aligned_depth_to_color/iamge_raw/raw", "/camera/color/image_raw/raw"

You need to modify fixed frame from map to camera_link, otherwise, you won't see the point cloud.



Open the third terminal in Nano

Nano$ docker exec -it lab5 bash (Enter container bash)
Nano Container$ rostopic list (List all ROS topics)

```
root@tx2-14:/home/nvidia/sis_lab_all# rostopic list
/camera/camera_nodelet_manager/bond
/camera/depth/camera_info
/camera/depth/disparity
/camera/depth/image
/camera/depth/image/compressed
/camera/depth/image/compressed/parameter_descriptions
/camera/depth/image/compressed/parameter_updates
/camera/depth/image/compressedDepth
/camera/depth/image/compressedDepth/parameter_descriptions
/camera/depth/image/compressedDepth/parameter_updates
/camera/depth/image/theora
/camera/depth/image/theora/parameter_descriptions
/camera/depth/image/theora/parameter_updates
/camera/depth/image_raw
/camera/depth/image_raw/compressed
/camera/depth/image_raw/compressed/parameter_descriptions
/camera/depth/image_raw/compressed/parameter_updates
/camera/depth/image_raw/compressedDepth
/camera/depth/image_raw/compressedDepth/parameter_descriptions
/camera/depth/image_raw/compressedDepth/parameter_updates
/camera/depth/image_raw/theora
/camera/depth/image_raw/theora/parameter_descriptions
/camera/depth/image_raw/theora/parameter_updates
/camera/depth/image_rect
/camera/depth/image_rect/compressed
/camera/depth/image_rect/compressed/parameter_descriptions
/camera/depth/image_rect/compressed/parameter_updates
/camera/depth/image_rect/compressedDepth
/camera/depth/image_rect/compressedDepth/parameter_descriptions
/camera/depth/image_rect/compressedDepth/parameter_updates
```

Nano Container$ rostopic echo /camera/color/camera_info

```
header:
  seq: 18348
  stamp:
    secs: 1538712625
    nsecs: 435345569
  frame_id: "camera_rgb_optical_frame"
height: 480
width: 640
distortion_model: "plumb_bob"
D: [0.0, 0.0, 0.0, 0.0, 0.0]
K: [620.5628662109375, 0.0, 314.2391052246094, 0.0, 620.5629272460938, 240.24301147460938, 0.0,
0.0, 1.0]
R: [1.0, 0.0, 0.0, 0.0, 1.0, 0.0, 0.0, 0.0, 1.0]
P: [620.5628662109375, 0.0, 314.2391052246094, 0.0, 0.0, 620.5629272460938, 240.24301147460938,
0.0, 0.0, 0.0, 1.0, 0.0]
binning_x: 0
binning_y: 0
roi:
  x_offset: 0
  y_offset: 0
  height: 0
  width: 0
  do_rectify: False
```

Discussion and Check point

1. Show depth image, rgb image, and pointcloud in RVIZ
2. Please explain the definitions of image rectification and registration and compare them to the ROS image topic "**/camera/aligned_depth_to_color/image_raw/raw**" and "**/camera/depth/image_raw/raw**" (hint: http://wiki.ros.org/rgbd_launch)
3. Please explain the data in topic "**/camera/color/camera_info".** You only need to explain "D", "K", and "R" (hint: sensor_msgs/CameraInfo Messag , https://silverwind1982.pixnet.net/blog/post/153218861-pinhole-camera%3A-相機校正-%28camera-calibration%29)

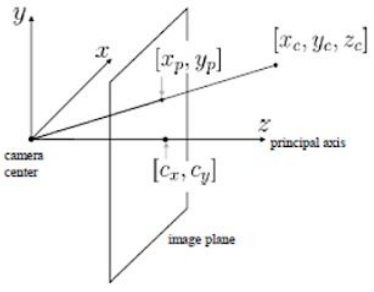
Note: After you finished topic 1, please exit docker container, so the docker container will be automatically removed.

Topic 2: Pinhole projection

Topic 2.1: Get point 3D coordinate from depth

Suppose we have a depth image, the value of each pixel represents the real depth between camera and the captured point in the real world. Now we get random pixel of the image. With algorithm 1, we can get 3D coordinate from point depth.

Algorithm 1



Pin hole projection illustration.

$$\begin{bmatrix} x_p \\ y_p \\ 1 \end{bmatrix} = K \begin{bmatrix} x_c/z_c \\ y_c/z_c \\ 1 \end{bmatrix} \qquad \mathbf{K} = \begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix}$$

Transform matrix

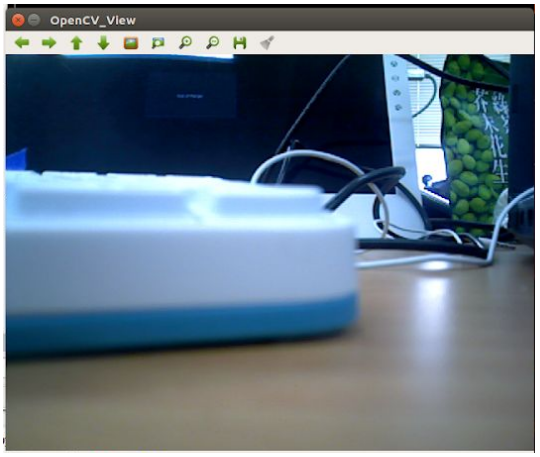
Open a terminal in Nano vncviewer

Nano$ source ~/sis_lab_all_2020/05-Opencv_and_Depth_Sensing/Dockerfiles/docker_run_nano.sh

You can go to checkout the information in this file

Nano Container$ source devel/setup.bash
Nano Container$ roslaunch realsense2_camera rs_rgbd.launch
Open a terminal in Nano vncviewer
Nano$ cd ~/sis_lab_all_2020/05-Opencv_and_Depth_Sensing/catkin_ws
Nano$ catkin_make
Please ignore the error
Nano$ source devel/setup.bash
Nano$ rosrun me212cv object_detection.py

You will see the the following image:
OpenCV View: RGB image



Discussion.

1. Show the results of the topic 2.1
2. Please explain the code in function “getXYZ”

3. Given a depth image, in image(20,20), the value is 0.5. Please use algorithm 1 and parameters from ROS topic “/camera/color/camera_info” to calculate the real world coordinate (x,y,z)

Topic 3.1: HSV filtering

HSV filtering is a common and easy method to detect colored objects. In topic 3.1, we will filter red object by using HSV color space. Then, we will use morphology image process skills to denoise and make mask complete. Finally, with separate object mask, we can get object contour and its bounding box.

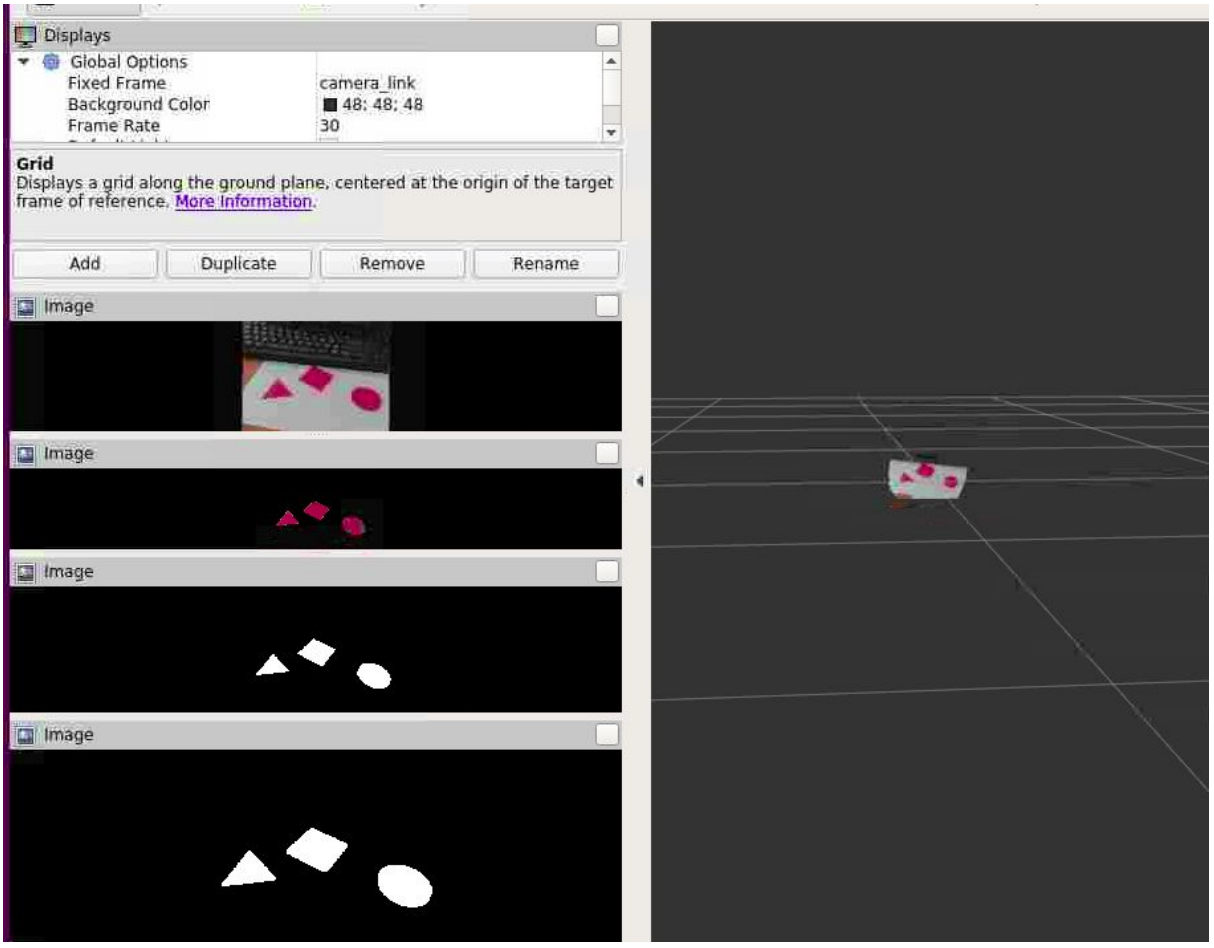
In Nano container, change the variables in 05-Opencv_and_Depth_Sensing/catkin_ws/src/me212cv/scripts/object_detection.py "useHSV" as True, "useDepth" value as False

Open a camera launch file in Nano container

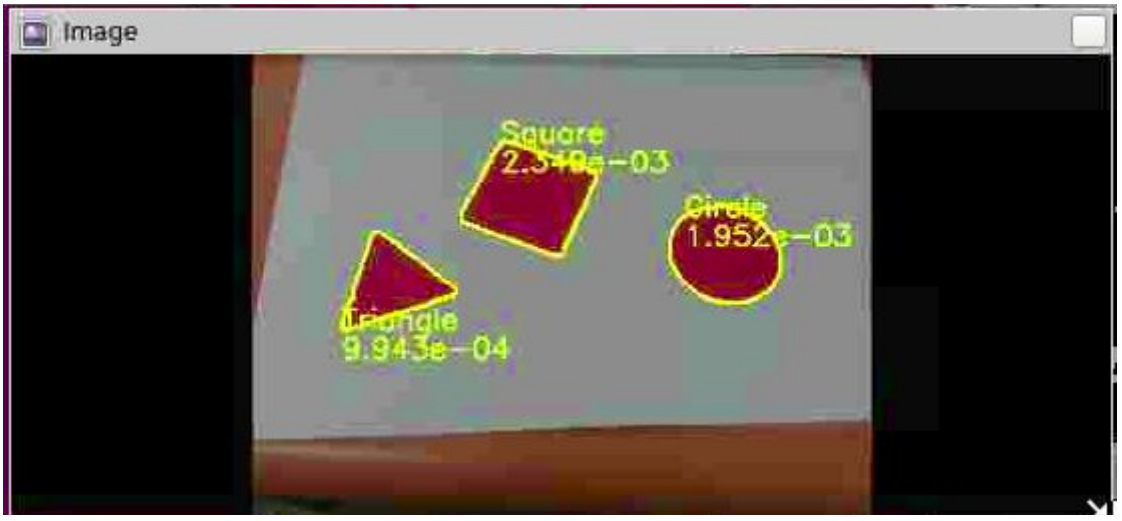
Nano Container$ rosrun me212cv object_detection.py
Add the topic "**/camera/color/image_rect_color**", "**/object_detection/mask_eroded**", "**/object_detection/mask_eroded_dilated**", "**/object_detection/img_result**"

You wiil see the the following image:

Rviz: the detected object



Bonus. Analyze detected object



In tutorial, we are able to detect objects by using HSV color space. In bonus, we will start to analyze objects. Each group will be given a paper where red square, equilateral triangle, circle are printed. Our mission is to detect each object, get the shape, and calculate the area.

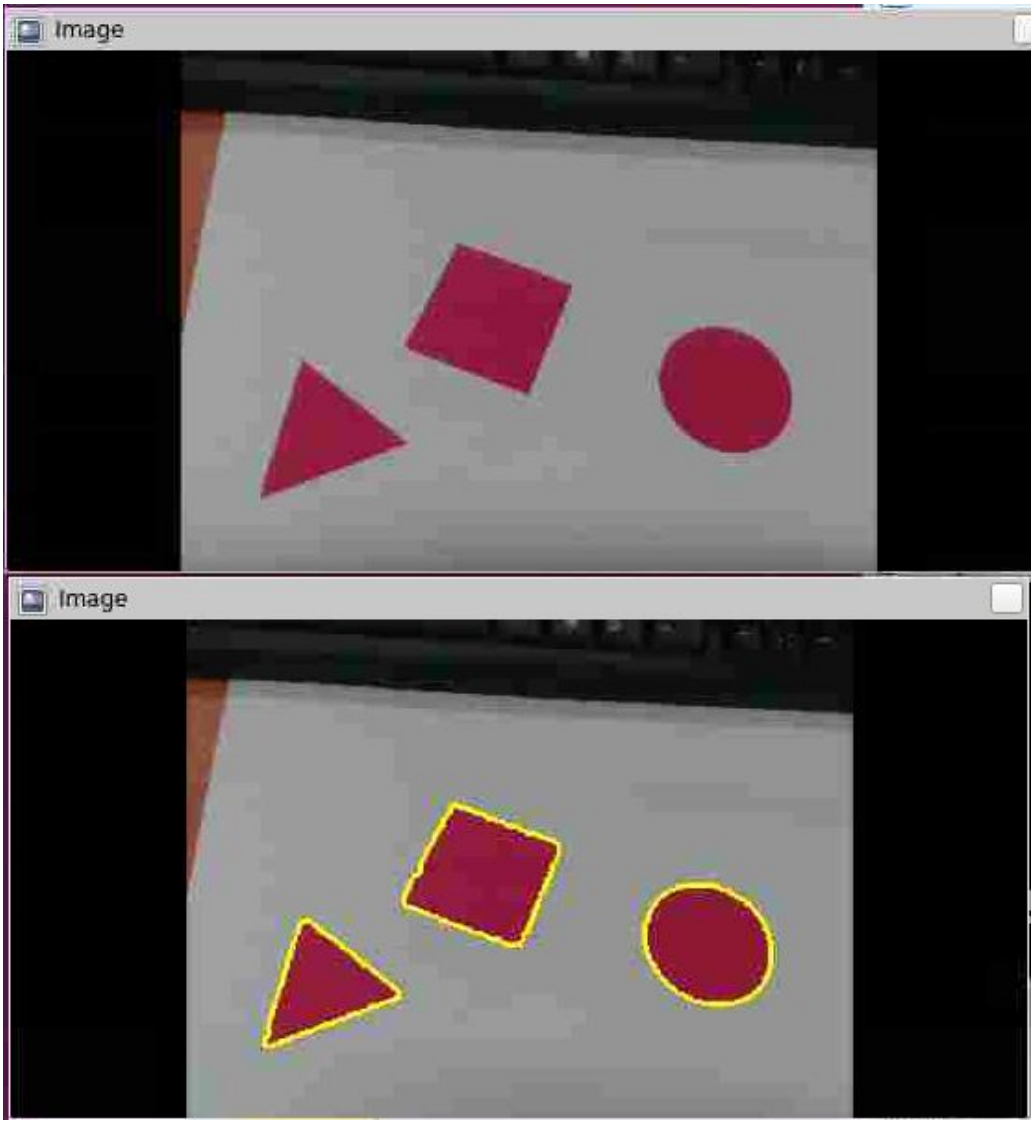
In task 1, we will detect objects by using the same method as tutorial, but we will draw the contours instead of bounding box.

In task 2, the shape of object needs to be determined. That is, you need to get the number of object vertex. Now you have had the contours of the object. All you need to do is approximate the contours as polygon. (hint: use opencv function **approxPolyDP**)

In task 3, after determining the object shape, we can know which formula to use to calculate object area. Your mission is to get side length or radius and then you can use the already prepared function to calculate object area. (You don't need to implement algorithms for calculating area.)

Task 1: Detect multi objects and draw contours

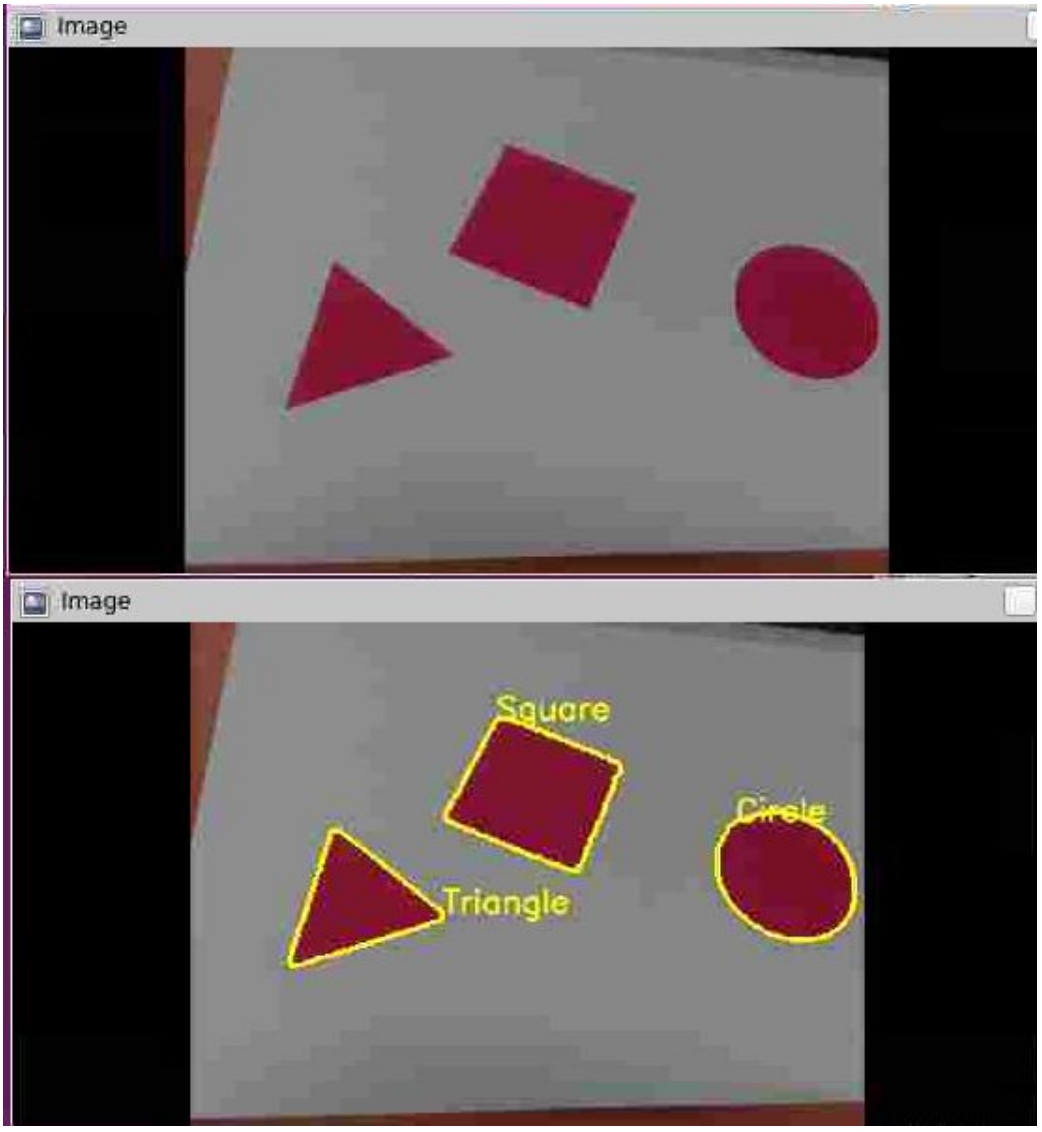
In task 1, you will revise object_detection.py and finish line 144 - 148. You also need to set variable “draw_contours” as “True” if you want to demo.



Topic “/object_detection/img_result”

Task2: Determine object shape

In task 2, you need to detect object shape for each object (contour). You also need to set variable “draw_contours” and “detect_shape” as “True” if you want to demo.



Topic “/object_detection/img_result”

Task3: Calculate object size

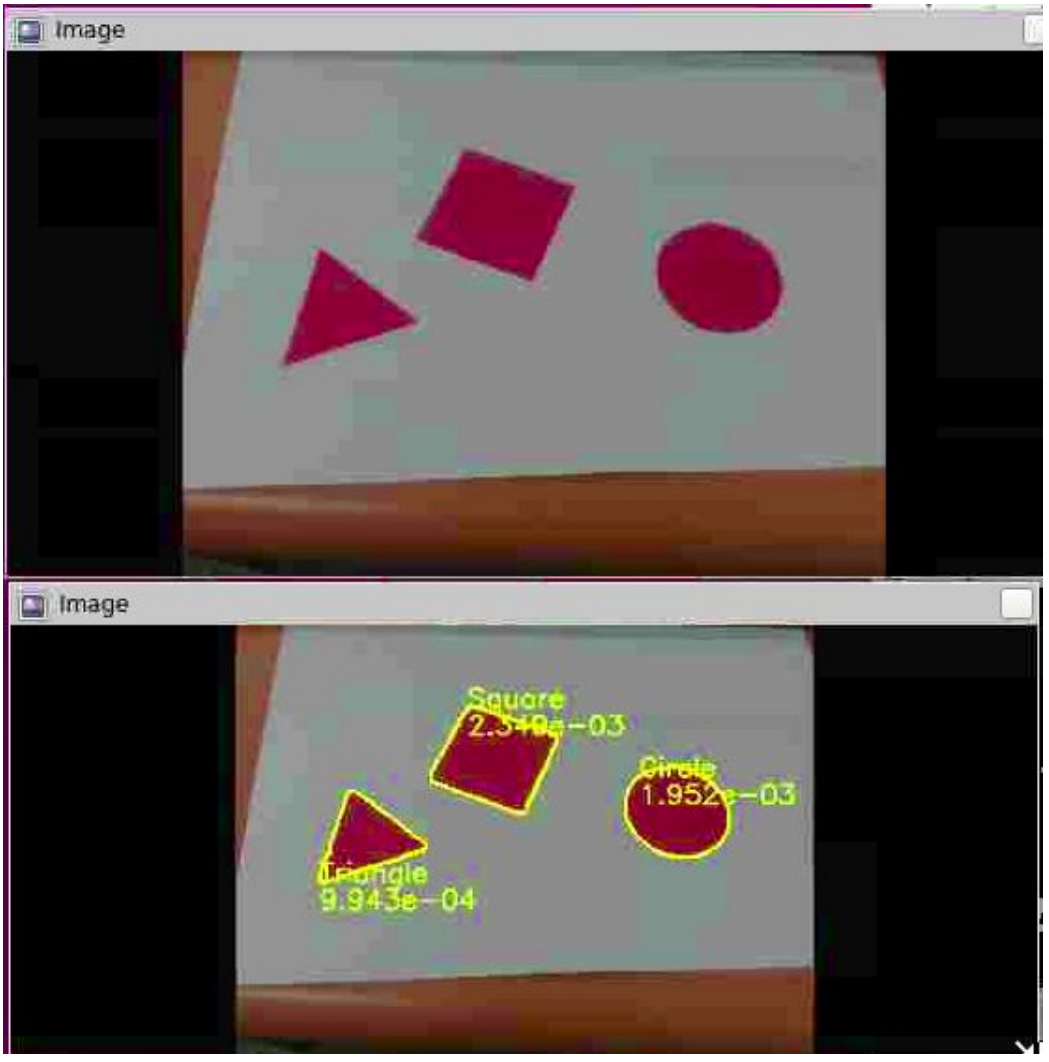
In task 3, we offer the methods to calculate area. If you want to use the method TA offers, you will need to assign vertex list of single object to variable "vtx_list" and finish functions "get_side_length", "get_radius". You can also write your own code to calculate area. If so, please ignore and comment the line 193 - 218.

You also need to set variable “draw_contours”, “detect_shape”, and “calculate_size” as “True” if you want to demo.

(Note: The area doesn’t need to be the same as expected result. The result will be regarded to be successful if error is lower than 10%.)

Groundtruth:

Equilateral triangle: 0.0010825m^2
Square: 0.0025 m^2
Circle: 0.0019635 m^2



Topic “/object_detection/img_result”

Grading rule

The homework template will be announced on New E3

Reference

- https://www.jetsonhacks.com/2019/04/10/jetson-nano-use-more-power/
- http://people.csail.mit.edu/peterkty/teaching.htm
- http://docs.opencv.org/2.4/modules/calib3d/doc/camera_calibration_and_3d_reconstruction.html?highlight=calibratecamera
- http://wiki.ros.org/rgbd_launch
- http://docs.ros.org/api/sensor_msgs/html/msg/CameraInfo.html