Color block color sorting

1. Content Description

This function enables the program to obtain images through the camera, select the color of the color block to be sorted according to the key input, and the program will identify the color block that meets the requirements and clamp it with the lower claw, and finally place it in the set position.

This section requires entering commands in the terminal. The terminal you open depends on your motherboard type. This lesson uses the Raspberry Pi 5 as an example. For Raspberry Pi and Jetson-Nano boards, you need to open a terminal on the host computer and enter the command to enter the Docker container. Once inside the Docker container, enter the commands mentioned in this section in the terminal. For instructions on entering the Docker container from the host computer, refer to this product tutorial **[Configuration and Operation Guide]--[Enter the Docker (Jetson Nano and Raspberry Pi 5 users, see here)]**.

Simply open the terminal on the Orin motherboard and enter the commands mentioned in this section.

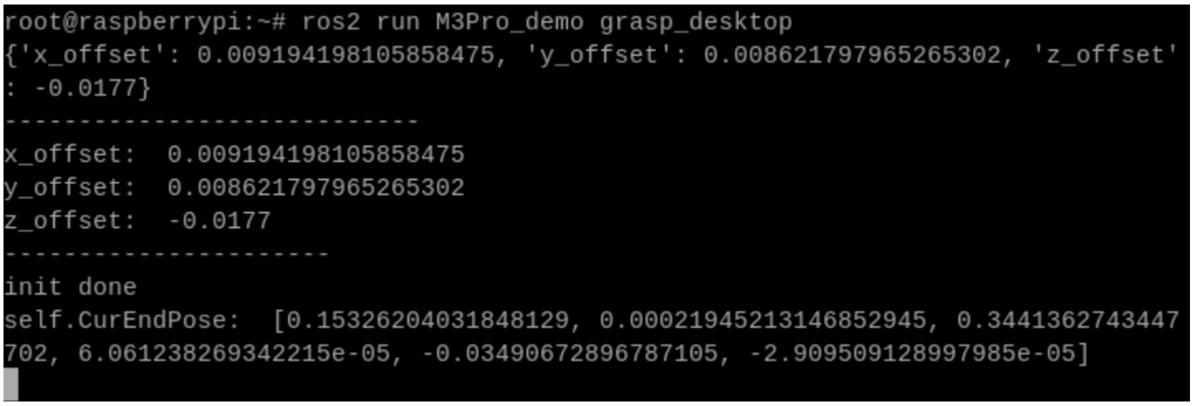
2. Program startup

First, open the terminal and enter the following command to start the robot arm solver and camera driver,

```
ros2 launch M3Pro_demo camera_arm_kin.launch.py
```

Then, open another terminal and enter the following command to start the robotic arm gripping program:

```
ros2 run M3Pro_demo grasp_desktop
```

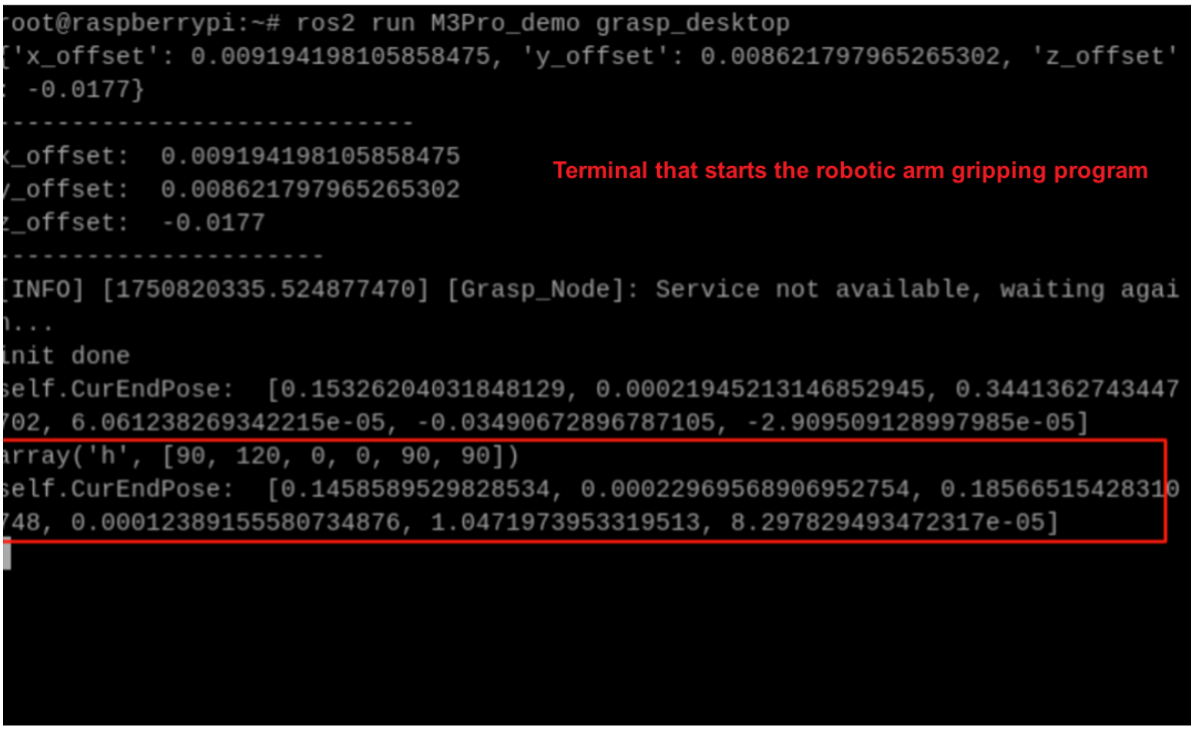


```
root@raspberrypi:~# ros2 run M3Pro_demo grasp_desktop
{'x_offset': 0.009194198105858475, 'y_offset': 0.008621797965265302, 'z_offset'
: -0.0177}
----------------------------
x_offset:  0.009194198105858475
y_offset:  0.008621797965265302
z_offset:  -0.0177
----------------------
init done
self.CurEndPose:  [0.15326204031848129, 0.00021945213146852945, 0.3441362743447
702, 6.061238269342215e-05, -0.03490672896787105, -2.909509128997985e-05]
```

Finally, open the third terminal and enter the following command to start the color sorting program:

```
ros2 run M3Pro_demo color_recognize
```

After starting this command, the second terminal should receive the current angle topic information sent in one frame and calculate the current posture once, as shown in the figure below.



```
root@raspberrypi:~# ros2 run M3Pro_demo grasp_desktop
{'x_offset': 0.009194198105858475, 'y_offset': 0.008621797965265302, 'z_offset'
: -0.0177}
---------------------------
x_offset:  0.009194198105858475
y_offset:  0.008621797965265302
z_offset:  -0.0177
---------------------
[INFO] [1750820335.524877470] [Grasp_Node]: Service not available, waiting agai
n...
init done
self.CurEndPose:  [0.15326204031848129, 0.00021945213146852945, 0.3441362743447
702, 6.061238269342215e-05, -0.03490672896787105, -2.909509128997985e-05]
array('h', [90, 120, 0, 0, 90, 90])
self.CurEndPose:  [0.1458589529828534, 0.00022969568906952754, 0.18566515428310
748, 0.00012389155580734876, 1.0471973953319513, 8.297829493472317e-05]
```

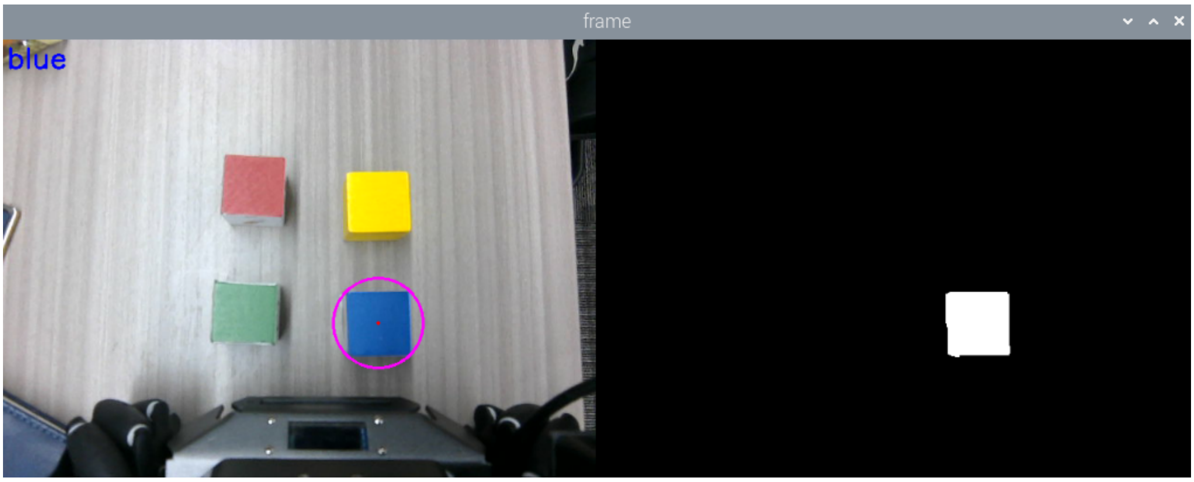
Terminal that starts the robotic arm gripping program

If the current angle information is not received and the current posture is not calculated, the gripping posture will be inaccurate when the coordinate system is converted. Therefore, you need to close the color sorting program by pressing ctrl+c and restart the color sorting program until the robot gripping program obtains the current angle information and calculates the current end position.

After the color block color sorting program is started, it will subscribe to the color image and depth image topics. Place the color block provided by the product under the camera. When the color block appears in the image, use the following buttons to select the color of the color block or calibrate the color of the color block:

- Press R or r: sort red blocks
- Press G or g: sort the green blocks
- Press B or b: sort blue blocks
- Press Y or y: sort the yellow blocks
- Press C or c: calibrate the color of the selected color block

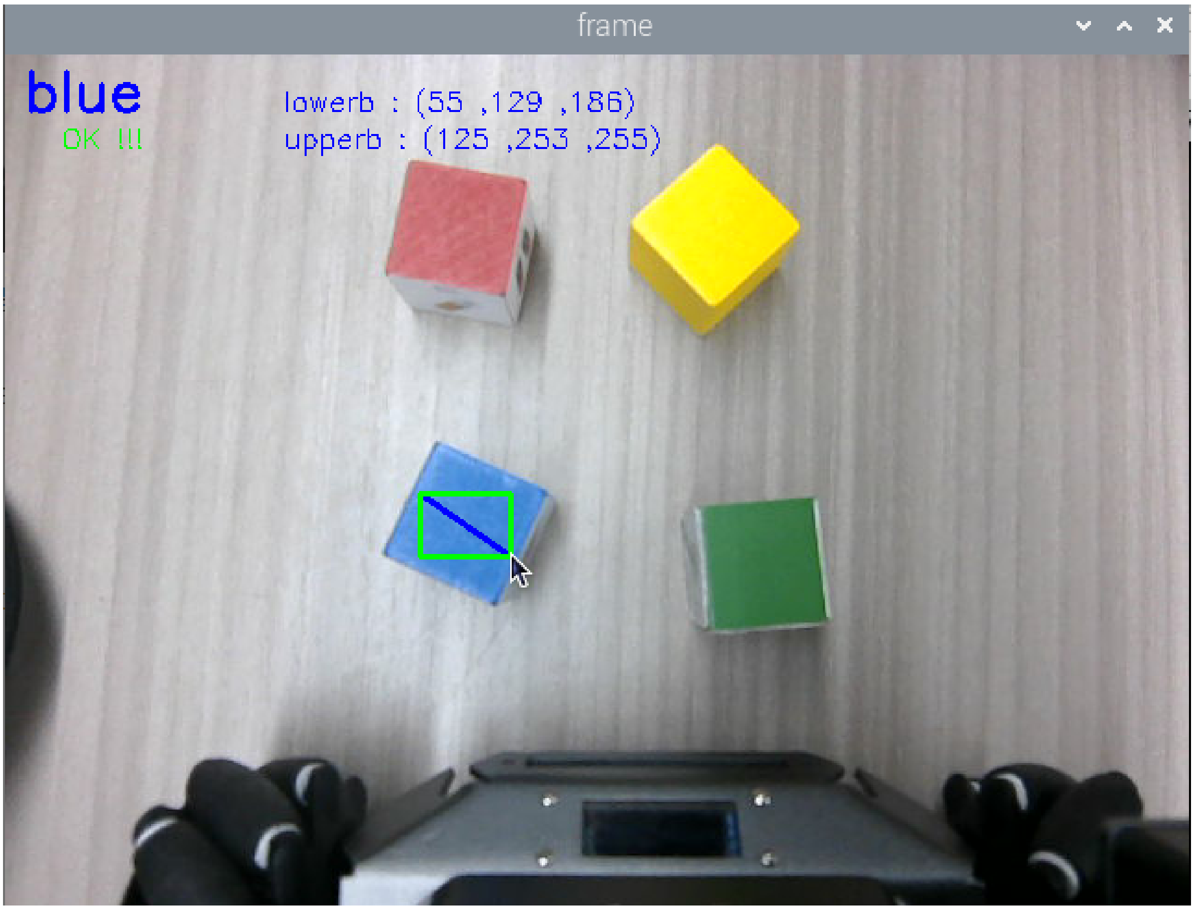
After pressing the button to select the color block, the selected color will be printed in the upper left corner of the image, and a binary image will appear on the right side of the image, showing the blue block that appeared in the left image, as shown in the figure below. Assuming that b is pressed to select the blue block,



At this point, press the spacebar to begin the gripping process. Similarly, the program determines the distance between the blue block and the robot's base_link. If the distance is within [215, 225], the robot arm directly lowers its gripper to grab the block and place it at the set location. If the distance is outside [215, 225], the robot first moves the robot block to within [215, 225] based on the distance between the robot code block and the robot's base coordinate system (base_link), then lowers its gripper to grab the block and place it at the set location.

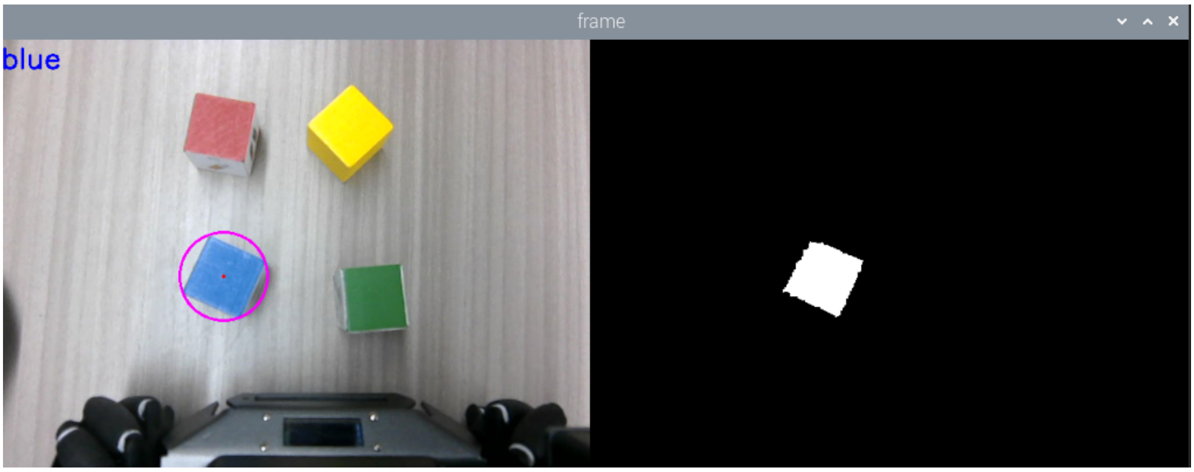
2.1. Color block color calibration

Due to lighting reasons, the HSV value preset by the program may not be able to accurately distinguish the color blocks. At this time, you can press the c key or the C key, and then use the mouse to select the color of the color block to recalibrate the HSV value of the color block. As shown in the figure below, suppose you press b or B to select blue first, but the binary image on the right cannot distinguish the blue. Then we need to press the c key or the C key to enter the calibration model and use the mouse to select the area of the blue block. The program will obtain the HSV value in the green box.



```
blue
  OK !!!
lowerb : (55 ,129 ,186)
upperb : (125 ,253 ,255)
```

Release the mouse to complete the calibration. Press the b or B key to identify. The binary image on the right can distinguish the blue block very well.



3. Core code analysis

3.1、color_recognize.py

Program code path:

- Raspberry Pi and Jetson-Nano board

  The program code is in the running docker. The path in docker is /root/yahboomcar_ws/src/M3Pro_demo/M3Pro_demo/ color_recognize.py

- Orin Motherboard

  The program code path is /home/jetson/yahboomcar_ws/src/M3Pro_demo/M3Pro_demo/color_recognize.py

Import the necessary library files,

```
import cv2
import os
import numpy as np
from sensor_msgs.msg import Image
from cv_bridge import CvBridge
import cv2 as cv
from M3Pro_demo.Robot_Move import *
#Import color recognition library
from M3Pro_demo.color_common import *
from arm_interface.srv import ArmKinemarics
from arm_interface.msg import AprilTagInfo,CurJoints
from arm_msgs.msg import ArmJoints
from std_msgs.msg import Bool,Int16
import time
import transforms3d as tfs
import tf_transformations as tf
import yaml
import math
from rclpy.node import Node
import rclpy
from message_filters import Subscriber,
TimeSynchronizer,ApproximateTimeSynchronizer
from geometry_msgs.msg import Twist
from ament_index_python.packages import get_package_share_directory
import threading
from M3Pro_demo.compute_joint5 import *
```

程序初始化以及创建发布者和订阅者，

```
def __init__(self, name):
    super().__init__(name)
    self.init_joints = [90, 100, 0, 0, 90, 0]
    self.rgb_bridge = CvBridge()
    self.depth_bridge = CvBridge()
    #Define the flag for publishing color block information. When the value is
True, it means publishing. When it is False, it means not publishing.
    self.pub_pos_flag = True
    #Define the array that stores the current end pose coordinates
    self.CurEndPos = [0.1279009179959246, 0.00023254956548456117,
0.1484898062979958, 0.00036263794618046863, 1.3962632350758744,
0.00033332603981328959]
    #Dabai_DCW2 camera internal parameters
    self.camera_info_K = [477.57421875, 0.0, 319.3820495605469, 0.0,
477.55718994140625, 238.64108276367188, 0.0, 0.0, 1.0]
    #Rotation matrix from the end to the camera
    self.EndToCamMat = np.array([[ 0 ,0 ,1 ,-1.00e-01],
                                 [-1  ,0 ,0  ,0],
                                 [0  ,-1  ,0 ,4.82000000e-02],
                                 [ 0.00000000e+00 , 0.00000000e+00 ,
0.00000000e+00 , 1.00000000e+00]])
    self.rgb_image_sub = Subscriber(self, Image, '/camera/color/image_raw')
    self.sub_grasp_status =
self.create_subscription(Bool,"grasp_done",self.get_graspStatusCallBack,100)
    self.depth_image_sub = Subscriber(self, Image, '/camera/depth/image_raw')
    self.CmdVel_pub = self.create_publisher(Twist,"cmd_vel",1)
    self.pub_cur_joints = self.create_publisher(CurJoints,"Curjoints",1)
    self.pos_info_pub = self.create_publisher(AprilTagInfo,"PosInfo",1)
    self.pub_SixTargetAngle = self.create_publisher(ArmJoints, "arm6_joints",
10)
    self.client = self.create_client(ArmKinemarics, 'get_kinemarics')
    self.pub_beep = self.create_publisher(Bool, "beep", 10)
    self.TargetJoint5_pub = self.create_publisher(Int16, "set_joint5", 10)
    self.pubCurrentJoints()
    self.pubSixArm(self.init_joints)
    #Get the current robot arm end pose coordinates
    self.get_current_end_pos()
    self.ts = ApproximateTimeSynchronizer([self.rgb_image_sub,
self.depth_image_sub], 1, 0.5)
    self.ts.registerCallback(self.callback)
    #Get the compensation values in the xyz directions in the offset table
    self.x_offset = offset_config.get('x_offset')
    self.y_offset = offset_config.get('y_offset')
    self.z_offset = offset_config.get('z_offset')
    self.adjust_dist = False
    self.linearx_PID = (0.5, 0.0, 0.2)
    self.linearx_pid = simplePID(self.linearx_PID[0] / 1000.0,
self.linearx_PID[1] / 1000.0, self.linearx_PID[2] / 1000.0)
    self.target_color = 0
    #Read the HSV values of four colors
    self.red_hsv_text = os.path.join(package_pwd, 'red_colorHSV.text')
    self.green_hsv_text = os.path.join(package_pwd, 'green_colorHSV.text')
    self.blue_hsv_text = os.path.join(package_pwd, 'blue_colorHSV.text')
    self.yellow_hsv_text = os.path.join(package_pwd, 'yellow_colorHSV.text')
    #Define the variable to store hsv, which will eventually be passed to the
color recognition function
    self.hsv_range = ()
    #Select the color block area flag. When the value is True, it means that the
mouse selects the area in the color block.
    self.select_flags = False
    self.windows_name = 'frame'
    #Define state variables, there are three values: init, select, identify
    self.Track_state = 'init'
    #Define storage of mouse coordinates
    self.Mouse_XY = (0, 0)
    self.cols, self.rows = 0, 0
    #Define the region of interest, here refers to the area on the selected color
block
    self.Roi_init = ()
    #Create a color recognition object
    self.color = color_detect()
    #Define a variable to record the current color
    self.cur_color = None
    #Define the RGB value of the currently selected color
    self.text_color = (0,0,0)
    #The center x coordinate of the target color block
    self.cx = 0
    #The center y coordinate of the target color block
    self.cy = 0
    #The radius of the minimum circumscribed circle of the target color block
    self.circle_r = 0
    #Valid distance flag, the value is True means the current distance is valid
    self.valid_dist = True
    self.joint5 = Int16()
    self.corners = np.empty((4, 2), dtype=np.int32)
    #Define the color value of the current target color block, 1-4 represents
red, green, blue, and yellow respectively
    self.cur_target_color = 0
    #Indicates the update HSV value flag. When the value is True, it means that
the HSV value of the selected color can be updated.
    self.updata_flag = False
```

callback image topic callback function,

```
def callback(self,color_frame,depth_frame):
    #Get color image topic data and use CvBridge to convert message data into
image data
    rgb_image = self.rgb_bridge.imgmsg_to_cv2(color_frame,'rgb8')
    rgb_image = cv2.cvtColor(rgb_image, cv2.COLOR_RGB2BGR)
    result_image = np.copy(rgb_image)
    #Get the deep image topic data and use CvBridge to convert the message data
into image data
    depth_image = self.depth_bridge.imgmsg_to_cv2(depth_frame, encoding[1])
    frame = cv.resize(depth_image, (640, 480))
    depth_to_color_image = cv2.applyColorMap(cv2.convertScaleAbs(depth_image,
alpha=1.0), cv2.COLORMAP_JET)
    depth_image_info = frame.astype(np.float32)
    key = cv2.waitKey(10)& 0xFF
    #Call the defined process function to perform key processing and image
processing
    result_frame, binary = self.process(rgb_image,key)
    #Call thread function to display image
    show_frame = threading.Thread(target=self.img_out, args=
(result_frame,binary,))
    show_frame.start()
    show_frame.join()
    if key == 32:
        self.adjust_dist = True
    #If self.cx and self.cy are not 0, it means that a color block of the target
color has been detected. At the same time, the radius of the minimum
circumscribed circle of the current color block must be greater than 30. This is
to filter out some small areas that are misidentified.
    if self.cx!=0 and self.cy!=0 and self.circle_r>30:
        cx = int(self.cx)
        cy = int(self.cy)
        dist = depth_image_info[int(cy),int(cx)]/1000
        #Calculate the position of the color block in the world coordinate
        pose = self.compute_heigh(cx,cy,dist)
        #Calculate the distance between the center of the color block and the
base coordinate base_link
        dist_detect = math.sqrt(pose[1] ** 2 + pose[0]** 2)
        dist_detect = dist_detect*1000
        #If the distance is less than 130 mm, it is considered invalid
        if dist_detect<130:
            print("Invalid dist.")
            self.valid_dist = False
        dist = 'dist: ' + str(dist_detect) + ' mm'
        print("dist: ",dist)
        #If the distance is valid and outside the range [215, 225], then control
the chassis to adjust the distance
        if abs(dist_detect - 220.0)>5 and  self.valid_dist == True:
            if self.adjust_dist==True:
                self.move_dist(dist_detect)
        #If the distance is valid and within the range [215, 225], then extract
the coordinates of the center point of the color block, calculate the depth
information of the center point of the color block, and then publish it
        elif abs(dist_detect - 220.0)<5 and self.valid_dist == True:
            print("------------------------------------")
            self.pubVel(0,0,0)
            self.adjust_dist = False
            cx = int(self.cx)
            cy = int(self.cy)
            #Calculate the depth information of the center point of the color
block
            dist = depth_image_info[int(cy),int(cx)]/1000
        #print("dist: ",dist)
            #If the depth distance of the center point of the color block is not
0, it means it is valid
            if dist!=0:
                #Calculate the rotation angle of the color block based on the
corner coordinates
                vx = self.corners[0][0][0] - self.corners[1][0][0]
                vy = self.corners[0][0][1] - self.corners[1][0][1]
                target_joint5 = compute_joint5(vx,vy)
                self.joint5.data = int(target_joint5)
                pos = AprilTagInfo()
                pos.id = self.target_color
                pos.x = float(cx)
                pos.y = float(cy)
                pos.z = float(dist)
                if self.pub_pos_flag == True:
                    self.pub_pos_flag = False
                    #Publish color block location information topic
                    self.pos_info_pub.publish(pos)
                    self . pos_info_pub . publish ( pos )
                    #Publish the topic of No. 5 servo angle
                    self.TargetJoint5_pub.publish(self.joint5)
    else:
        self.pubVel(0,0,0)
```

process button image processing function,

```
def process(self,rgb_img,key):
    rgb_img = cv.resize(rgb_img, (640, 480))
    binary = []
    #Judge the value of the button and assign values to self.target_color and
self.cur_target_color according to the value of the button
    if key == ord('c') or key == ord('C'):
        self.target_color = 0
        self.Reset()
        self.updata_flag = True
    elif key == ord('r') or key == ord('R'):
        self.target_color = 1
        self.cur_target_color = self.target_color
    elif key == ord('g') or key == ord('G'):
        self.target_color = 2
        self.cur_target_color = self.target_color
    elif key == ord('b') or key == ord('B'):
        self.target_color = 3
        self.cur_target_color = self.target_color
    elif key == ord('y') or key == ord('Y'):
        self.target_color = 4
        self.cur_target_color = self.target_color
    elif key == ord('i') or key == ord('I') or self.target_color!=0:
self.Track_state = "identify"
    #Judge the value of self.Track_state. If it is init, it is in initialization
mode.
    if self.Track_state == 'init':
        cv.namedWindow(self.windows_name, cv.WINDOW_AUTOSIZE)
        cv.setMouseCallback(self.windows_name, self.onMouse, 0)
        if self.select_flags == True:
            cv.line(rgb_img, self.cols, self.rows, (255, 0, 0), 2)
            cv.rectangle(rgb_img, self.cols, self.rows, (0, 255, 0), 2)
            if self.Roi_init[0] != self.Roi_init[2] and self.Roi_init[1] !=
self.Roi_init[3]:
                rgb_img, self.hsv_range = self.color.Roi_hsv(rgb_img,
self.Roi_init)
                self.dyn_update = True
            else: self.Track_state = 'init'
    #If it is identify, it is identification mode, which reads the hsv file
according to the target color value of self.target_color and assigns it to
self.hsv_range
    elif self.Track_state == "identify":
        if self.target_color == 1:
            self.hsv_range = read_HSV(self.red_hsv_text)
            self.cur_color = "red"
            self.text_color = (0, 0, 255)


        elif self.target_color == 2:
            self.hsv_range = read_HSV(self.green_hsv_text)
            self.cur_color = "green"
            self.text_color = (0, 255, 0)


        elif self.target_color == 3:
            self.hsv_range = read_HSV(self.blue_hsv_text)
            self.cur_color = "blue"
            self.text_color = (255, 0, 0)

        elif self.target_color == 4:
            self.hsv_range = read_HSV(self.yellow_hsv_text)
            self.cur_color = "yellow"
            self.text_color = (255, 255, 0)

        else:
            self.Track_state = 'init'
    #If the current self.Track_state is not init, then enter the color
recognition mode
    if self.Track_state != 'init':
        #Judge whether self.hsv_range is empty. If it is not empty, it means the
current identify recognition model
        if len(self.hsv_range) != 0:
            #Call the object_follow function in the color recognition object.
The function is to filter out objects that meet the HSV standard in the image
based on the HSV value and color image passed in. The returned content includes
the processed color image, binary image, minimum circumscribed circle and corner
coordinates
            rgb_img, binary, self.circle,_,self.corners=
self.color.object_follow(rgb_img, self.hsv_range)
            #Get the center x coordinate of the minimum circumscribed circle
            self.cx = self.circle[0]
            #Get the center y coordinate of the minimum circumscribed circle
            self.cy = self.circle[1]
            #Get the radius of the minimum circumscribed circle
            self.circle_r = self.circle[2]
            #If the value of self.updata_flag is true, it means that the hsv
parameter file needs to be updated and modified. According to the current target
color block color, select the corresponding hsv parameter file for modification
            if self.cur_target_color == 1 and self.updata_flag == True:
                write_HSV(self.red_hsv_text, self.hsv_range)
            elif self.cur_target_color  == 2 and self.updata_flag == True:
                write_HSV(self.green_hsv_text, self.hsv_range)
            elif self.cur_target_color == 3 and self.updata_flag == True:
                write_HSV(self.blue_hsv_text, self.hsv_range)
            elif self.cur_target_color == 4 and self.updata_flag == True:
                write_HSV(self.yellow_hsv_text, self.hsv_range)
            self.updata_flag = False
    #Finally, the color name of the current target color block is displayed in
the upper left corner of the image
    rgb_img = cv2.putText(rgb_img, self.cur_color, (10, 30),
cv2.FONT_HERSHEY_SIMPLEX, 1, self.text_color, 2)
    return rgb_img, binary
```

3.2, color_common

The source code path of the library:

- Raspberry Pi 5 and Jetson motherboard

  The program code is in the running docker. The path in docker is /root/yahboomcar_ws/src/M3Pro_demo/M3Pro_demo/ color_common.py

- Orin Motherboard

  The program code path is /home/jetson/yahboomcar_ws/src/M3Pro_demo/M3Pro_demo/color_common.py

object_follow color recognition function

```
def object_follow(self, img, hsv_msg):
    src = img.copy()
    # 由颜色范围创建NumPy数组
    # Create NumPy array from color range
    src = cv.cvtColor(src, cv.COLOR_BGR2HSV)
    lower = np.array(hsv_msg[0], dtype="uint8")
    upper = np.array(hsv_msg[1], dtype="uint8")
    # 根据特定颜色范围创建mask
    # Create a mask based on a specific color range
    mask = cv.inRange(src, lower, upper)
    color_mask = cv.bitwise_and(src, src, mask=mask)
    # 将图像转为灰度图
    # Convert the image to grayscale
    gray_img = cv.cvtColor(color_mask, cv.COLOR_RGB2GRAY)
    # 获取不同形状的结构元素
    # Get structure elements of different shapes
    kernel = cv.getStructuringElement(cv.MORPH_RECT, (5, 5))
    # 形态学闭操作
    # Morphological closed operation
    gray_img = cv.morphologyEx(gray_img, cv.MORPH_CLOSE, kernel)
    # 图像二值化操作
    # Image binarization operation
    ret, binary = cv.threshold(gray_img, 10, 255, cv.THRESH_BINARY)
    # 获取轮廓点集(坐标)
    # Get the set of contour points (coordinates)
    find_contours = cv.findContours(binary, cv.RETR_EXTERNAL,
cv.CHAIN_APPROX_SIMPLE)
    if len(find_contours) == 3:
        contours = find_contours[1]
    else:
        contours = find_contours[0]
    if len(contours) != 0:
        areas = []
        for c in range(len(contours)): areas.append(cv.contourArea(contours[c]))
        max_id = areas.index(max(areas))
        max_rect = cv.minAreaRect(contours[max_id])
        self.max_box = cv.boxPoints(max_rect)
        #print("max_box: ",max_box)
        self.max_box = np.int0(self.max_box)
        #print("max_box: ",max_box)
        #计算一组二维点的最小外接圆，返回的是这个圆的圆形坐标xy和这个圆的半径、
        #Calculate the minimum circumscribed circle of a set of two-dimensional
points, and return the circular coordinates xy and radius of the circle
```

```
        (color_x, color_y), color_radius = cv.minEnclosingCircle(self.max_box)
        # 将检测到的颜色用原形线圈标记出来
        # Mark the detected color with the original shape coil
        self.Center_x = int(color_x)
        self.Center_y = int(color_y)
        self.Center_r = int(color_radius)
        perimeter = cv.arcLength(contours[max_id], True)
        self.approx = cv.approxPolyDP(contours[max_id], 0.035 * perimeter, True)
        cv.circle(img, (self.Center_x, self.Center_y), self.Center_r, (255, 0,
255), 2)
        cv.circle(img, (self.Center_x, self.Center_y), 2, (0, 0, 255), -1)
    else:
        self.Center_x = 0
        self.Center_y = 0
        self.Center_r = 0
    return img, binary, (self.Center_x, self.Center_y,
self.Center_r),self.max_box,self.approx
```