Line patrol and obstacle removal

1. Content Description

This function enables the program to acquire images through the camera and recognize the color of the patrol line. The program controls the robot to move along the line. During this process, the lidar scans for obstacles on the path. If an obstacle is encountered, the robot stops. If a machine code appears on the route, the robot adjusts its posture, grabs the machine code with its lower claw, puts it aside, and continues patrolling the line.

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
```

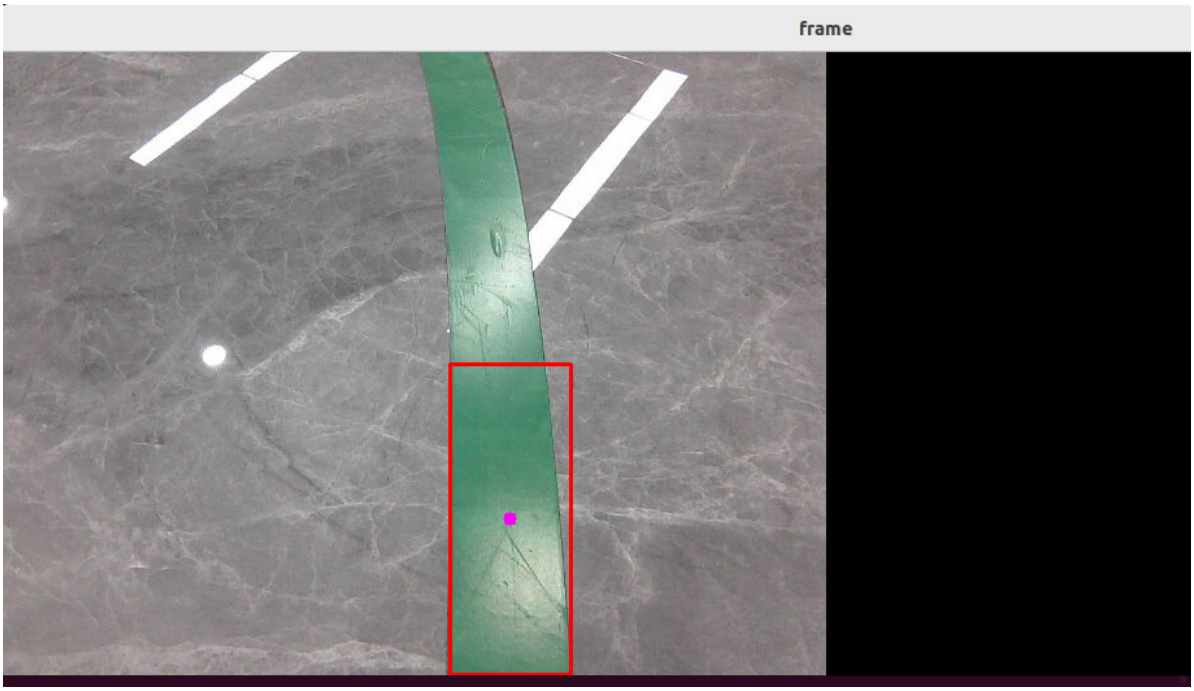
Then, open another terminal and enter the following command to start the robotic arm gripping program:

```
ros2 run M3Pro_demo grasp_desktop
```

Finally, open the third terminal and enter the following command to start the line inspection and obstacle removal program:

```
ros2 run M3Pro_demo follow_line
```

After the start command, a graphic window titled " **frame"** will be opened . The marking box in the screen will mark the landmark line. Press the spacebar to start the robot moving along the landmark line. If an obstacle appears in front of it, the robot stops patrolling and the buzzer sounds an alarm. After the obstacle is removed, the robot continues to move until the landmark line ends and the terminal prompts " **Not Found** ", indicating that no landmark line was found.

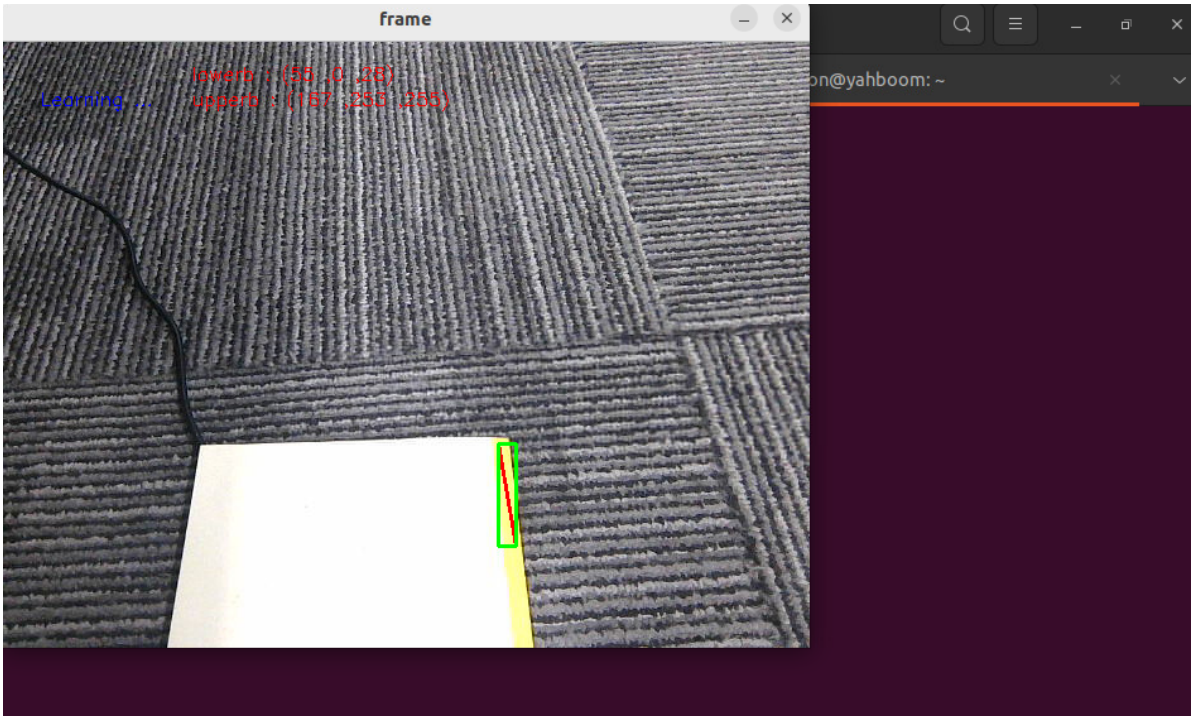


If it encounters a machine code, the car will stop and adjust the distance between the car body and the machine code according to the position of the machine code. After adjusting to the distance set by the program, the robotic arm will lower its claws to clamp the machine code and place it aside, and then continue to move along the line.

2.1. Color calibration

The robot has been calibrated with a specific color when it leaves the factory. If you find that the color recognition of road markings is not ideal during line patrol, or you need to change the color of the road markings, you need to change the line patrol color.

After the frame graphics window appears after the previous step `ros2 run M3Pro_demo follow_line`, press the R key on the keyboard to select the color, hold down the left mouse button and drag a rectangular box in the color area (make sure the rectangular box is within the color range), and it will automatically confirm after releasing the left mouse button.



After recalibrating the color, the terminal prompts **Reset success!!!** , and the color calibration is completed.

3. Core code analysis

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/ follow_line.py

- Orin Motherboard

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

Import the necessary library files,

```
#ros lib
import rclpy
from rclpy.node import Node
from std_msgs.msg import Bool,Int16,UInt16
from geometry_msgs.msg import Twist
from sensor_msgs.msg import LaserScan, Image
#common lib
import os
import threading
import math
from M3Pro_demo.follow_common import *
RAD2DEG = 180 / math.pi
import cv2
from arm_msgs.msg import ArmJoints
from message_filters import Subscriber,
TimeSynchronizer,ApproximateTimeSynchronizer
from cv_bridge import CvBridge
encoding = ['16UC1', '32FC1']
from dt_apriltags import Detector
from M3Pro_demo.vutils import draw_tags
import numpy as np
from arm_interface.msg import AprilTagInfo,CurJoints
from M3Pro_demo.compute_joint5 import *
```

Program initialization and creation of publishers and subscribers

```
def __init__(self,name):
    super().__init__(name)
    #create a publisher
    self.pub_cmdVel = self.create_publisher(Twist,"/cmd_vel",1)
    self.pub_rgb = self.create_publisher(Image,"/linefollow/rgb",1)
    self.pub_Buzzer = self.create_publisher(UInt16,'/beep',1)
    #create a subscriber
    self.sub_JoyState =
self.create_subscription(Bool,"/JoyState",self.JoyStateCallback,1)
    self.sub_laser =
self.create_subscription(LaserScan,"/scan",self.registerScan,1)
    self.sub_JoyState = self.create_subscription(Bool,'/JoyState',
self.JoyStateCallback,1)
```

```
    self.rgb_image_sub = Subscriber(self, Image, '/camera/color/image_raw')
    self.depth_image_sub = Subscriber(self, Image, '/camera/depth/image_raw')
    self.pub_SixTargetAngle = self.create_publisher(ArmJoints, "arm6_joints",
10)
    self.pos_info_pub = self.create_publisher(AprilTagInfo,"PosInfo",1)
    self.TargetJoint5_pub = self.create_publisher(Int16, "set_joint5", 10)
    self.TargetJoint6_pub = self.create_publisher(Int16, "set_joint6", 10)
    self.pub_cur_joints = self.create_publisher(CurJoints,"Curjoints",1)
    while not self.client.wait_for_service(timeout_sec=1.0):
        self.get_logger().info('Service not available, waiting again...')
    self.get_current_end_pos()

    while not self.pub_SixTargetAngle.get_subscription_count():
        self.pubSixArm(self.init_joints)
        time.sleep(0.1)
    self.pubSixArm(self.init_joints)

    while not self.pub_cur_joints.get_subscription_count():
        self.pubCurrentJoints()
        time.sleep(0.1)
    self.pubCurrentJoints()

    self.sub_grasp_status =
self.create_subscription(Bool,"grasp_done",self.get_graspStatusCallBack,100)
    self.ts = ApproximateTimeSynchronizer([self.rgb_image_sub,
self.depth_image_sub], 1, 0.5)
    self.ts.registerCallback(self.callback)


    self.init_joints = [90, 90, 12, 20, 90, 0]
    self.rgb_bridge = CvBridge()
    self.depth_bridge = CvBridge()

    self.at_detector = Detector(searchpath=['apriltags'],
                                families='tag36h11',
                                nthreads=8,
                                quad_decimate=2.0,
                                quad_sigma=0.0,
                                refine_edges=1,
                                decode_sharpening=0.25,
                                debug=0)
    self.move_flag = True
    self.pubPos_flag = True
    self.declare_param()
    self.Joy_active = False
    self.img = None
    self.circle = ()
    self.hsv_range = ()
    self.Roi_init = ()
    self.warning = 1
    self.Start_state = True
    self.dyn_update = False
    self.Buzzer_state = False
    self.select_flags = False
    self.Track_state = 'identify'
    self.windows_name = 'frame'
    self.cols, self.rows = 0, 0
```

```
        self.Mouse_XY = (0, 0)
        #Store the hsv value of the patrol line color
        self.hsv_text =
"/root/yahboomcar_ws/src/M3Pro_demo/M3Pro_demo/LineFollowHSV.text"
        self.color = color_follow()
        self.scale = 1000
        #Line patrol PID control parameters, mainly used to calculate the angular
velocity value
        self.FollowLinePID = (50, 0, 10)
        #PID control parameters when adjusting the distance when machine code
obstacles are found
        self.RemovePID = (40, 0, 15.0)
        #Line speed of the line patrol
        self.linear = 0.2
        self.PID_init()
        self.img_flip = False
        self.refresh  = False
        self.tags = []
        self.depth_image_info = []
        self.joint5 = Int16()
        self.joint6 = Int16()
        self.joint6.data = 120
        self.Start_ = False
        self.start_time = time.time()
        self.count = True
        self.front_warning = 0
        self.Joy_active = False
        self.declare_parameter("LaserAngle",60.0)
        self.LaserAngle =
self.get_parameter('LaserAngle').get_parameter_value().double_value
        self.declare_parameter("ResponseDist",0.8)
        self.ResponseDist =
self.get_parameter('ResponseDist').get_parameter_value().double_value
        print("Init Done.")
        print("----------------------------")
        print("self.LaserAngle: ",self.LaserAngle)
        print("self.ResponseDist: ",self.ResponseDist)
```

callback color image topic callback function,

```
def callback(self,color_frame,depth_frame):
    # Convert the image to opencv format
    rgb_image = self.rgb_bridge.imgmsg_to_cv2(color_frame,'rgb8')
    rgb_image = np.copy(rgb_image)

    depth_image = self.depth_bridge.imgmsg_to_cv2(depth_frame, encoding[1])
    depth_img = cv2.resize(depth_image, (640, 480))
    self.depth_image_info = depth_img.astype(np.float32)
    # Check the machine code
    self.tags = self.at_detector.detect(cv2.cvtColor(rgb_image,
cv2.COLOR_RGB2GRAY), False, None, 0.025)
    self.tags = sorted(self.tags, key=lambda tag: tag.tag_id)
    draw_tags(rgb_image, self.tags, corners_color=(0, 0, 255), center_color=(0,
255, 0))
    frame = cv2.resize(depth_image, (640, 480))
    action = cv2.waitKey(1)
    if self.count==True and self.Start_==True:
```

```
        if (time.time() - self.start_time)>3:
            self.Track_state = 'tracking'
            self.count = False
    #Enter the image processing function process
    result_img,bin_img = self.process(rgb_image,action)
    result_img = cv2.cvtColor(result_img, cv2.COLOR_RGB2BGR)
    if len(bin_img) != 0: cv.imshow('frame', ManyImgs(1, ([result_img,
bin_img])))
    else:cv.imshow('frame', result_img)
```

process image processing function,

```
def process(self, rgb_img, action):
    #print("**********************************")
    binary = []
    rgb_img = cv.resize(rgb_img, (640, 480))

    if self.img_flip == True: rgb_img = cv.flip(rgb_img, 1)
    #Run the program according to the key value 32 means the spacebar is pressed,
and the line patrol mode is started.
    if action == 32: self.Track_state = 'tracking'
    #Press i to enter the recognition mode and load the hsv file to identify the
color of the line
    elif action == ord('i') or action == 105: self.Track_state = "identify"
    #Press r to reselect color and enter init mode
    elif action == ord('r') or action == 114: self.Reset()
    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'
    elif self.Track_state == "identify":
        if os.path.exists(self.hsv_text): self.hsv_range =
read_HSV(self.hsv_text)
        else: self.Track_state = 'init'
    if self.Track_state != 'init' and len(self.hsv_range) != 0:
        rgb_img, binary, self.circle = self.color.line_follow(rgb_img,
self.hsv_range)
        if self.dyn_update == True:
            write_HSV(self.hsv_text, self.hsv_range)
            self.Hmin  =
rclpy.parameter.Parameter('Hmin',rclpy.Parameter.Type.INTEGER,self.hsv_range[0]
[0])
            self.Smin  =
rclpy.parameter.Parameter('Smin',rclpy.Parameter.Type.INTEGER,self.hsv_range[0]
[1])
```

```
            self.Vmin  =
rclpy.parameter.Parameter('Vmin',rclpy.Parameter.Type.INTEGER,self.hsv_range[0]
[2])
            self.Hmax  =
rclpy.parameter.Parameter('Hmax',rclpy.Parameter.Type.INTEGER,self.hsv_range[1]
[0])
            self.Smax  =
rclpy.parameter.Parameter('Smax',rclpy.Parameter.Type.INTEGER,self.hsv_range[1]
[1])
            self.Vmax  =
rclpy.parameter.Parameter('Vmax',rclpy.Parameter.Type.INTEGER,self.hsv_range[1]
[2])
•

            all_new_parameters =
[self.Hmin,self.Smin,self.Vmin,self.Hmax,self.Smax,self.Vmax]
            self.set_parameters(all_new_parameters)
            self.dyn_update = False
    #If you enter the tracking mode, then execute the execute function
    if self.Track_state == 'tracking' :
        if len(self.circle) != 0:
            threading.Thread(target=self.execute, args=(self.circle[0],
self.circle[2])).start()
    else:
        if self.Start_state == True:
            #self.pub_cmdVel.publish(Twist())
            self.Start_state = False
    if len(self.tags)>0 and self.Track_state!="Remove":
        self.Track_state = "identify"
        self.pub_cmdVel.publish(Twist())
        print("Find the apriltag.")
        self.Track_state = "Remove"
    if  self.Track_state == "Remove":
        print("len(tags) = ",len(self.tags))
        if len(self.tags)>0 :
            #Get the center coordinates of the machine code
            center_x, center_y = self.tags[0].center
            #If the center coordinate of the machine code is not within the
center range, then execute remove_obstacle to control the car according to the
center value of the machine code and adjust the distance between the car and the
machine code
            if (abs(center_x-320) >10 or abs(center_y-400)>10) and
self.move_flag == True:
                print("adjusting.")
                self.remove_obstacle(center_x, center_y)
            if abs(center_x-320) <10 and abs(center_y-400)<10:
                self.pubVel(0.0, 0.0)
                print("start crawling.")
                #Get the depth value of the center point coordinates of the
machine code
                c_dist = self.depth_image_info[int(center_y),int(center_x)]/1000
                #If the current center coordinate value is valid and the value of
self.pubPos_flag is True, it means that the position information of the machine
code can be published.
                if c_dist!=0 and self.pubPos_flag == True:
                    self.move_flag = False
                    self.pubPos_flag = False
                    pos = AprilTagInfo()
```

```
                    pos.id = self.tags[0].tag_id
                    pos.x = center_x
                    pos.y = center_y
                    pos.z = c_dist
                    #Get the corner coordinates of the machine code and
calculate the reference value of the No. 5 servo based on the corner coordinates
                    vx = int(self.tags[0].corners[0][0]) -
int(self.tags[0].corners[1][0])
                    vy = int(self.tags[0].corners[0][1]) -
int(self.tags[0].corners[1][1])
                    target_joint5 = compute_joint5(vx,vy)
                    print("target_joint5: ",target_joint5)
                    self.joint5.data = int(target_joint5)
                    print("tag_id: ",self.tags[0].tag_id)
                    print("center_x, center_y: ",center_x, center_y)
                    print("depth: ",c_dist)
                    self.pos_info_pub.publish(pos)
                    self.TargetJoint5_pub.publish(self.joint5)
                else:
                    print("Invalid distance.")
    return rgb_img, binary
```

execute line patrol function,

```
def execute(self, point_x, color_radius):
    #If the R2 button on the remote control is pressed, then return directly and
press it again to modify self.Joy_active to False
    if self.Joy_active == True:
        if self.Start_state == True:
            self.PID_init()
            self.Start_state = False
        return
    self.Start_state = True
    #If there is no identification line, then publish the parking speed
    if color_radius == 0:
        print("Not Found")
        self.pub_cmdVel.publish(Twist())
    else:
        twist = Twist()
        b = UInt16()
        #Calculate the angular velocity
        [z_Pid, _] = self.PID_controller.update([(point_x - 320)*1.0/16, 0])
        if self.img_flip == True: twist.angular.z = -z_Pid #-z_Pid
        else: twist.angular.z = +z_Pid

        twist.linear.x = self.linear
        #If the radar detects an obstacle ahead, it will issue a stop command
and a buzzer command
        if self.front_warning > 10:
            print("Obstacles ahead !!!")
            self.pub_cmdVel.publish(Twist())
            self.Buzzer_state = True
            b.data = 1
            self.pub_Buzzer.publish(b)
        else:
            if self.Buzzer_state == True:
                b.data = 0
```

```
                for i in range(3): self.pub_Buzzer.publish(b)
                self.Buzzer_state = False
            if abs(point_x-320)<40:
                twist.angular.z=0.0
            if self.Joy_active == False:
                self.pub_cmdVel.publish(twist)
            else:
                twist.angular.z=0.0
```