Brush

1. Content Description

This course implements color image acquisition and finger detection using the mediapipe framework. It then selects a color and draws a trajectory on the image based on the detected finger movement. This section requires entering commands in a terminal. The terminal you open depends on your board type. This lesson uses the Raspberry Pi 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 lesson in the terminal. For instructions on entering the Docker container from the host computer, refer to **[01. Robot Configuration and Operation Guide] -- [4.Enter Docker (For JETSON Nano and RPi 5)]**.

For RDKX5 and Orin boards, simply open a terminal and enter the commands mentioned in this lesson.

2. Program Startup

For Raspberry Pi and Jetson-Nano boards, you need to enter the Docker container first. For RDKX5 and Orin controllers, this is not necessary.

Enter the Docker container (see [Docker course] --- [4. Docker Startup Script] for steps).

All the following commands must be executed within the same Docker container **(see [Docker course] --- [3. Docker Submission and Multi-Terminal Access] for steps).**

First, enter the following command in the terminal to start the camera.

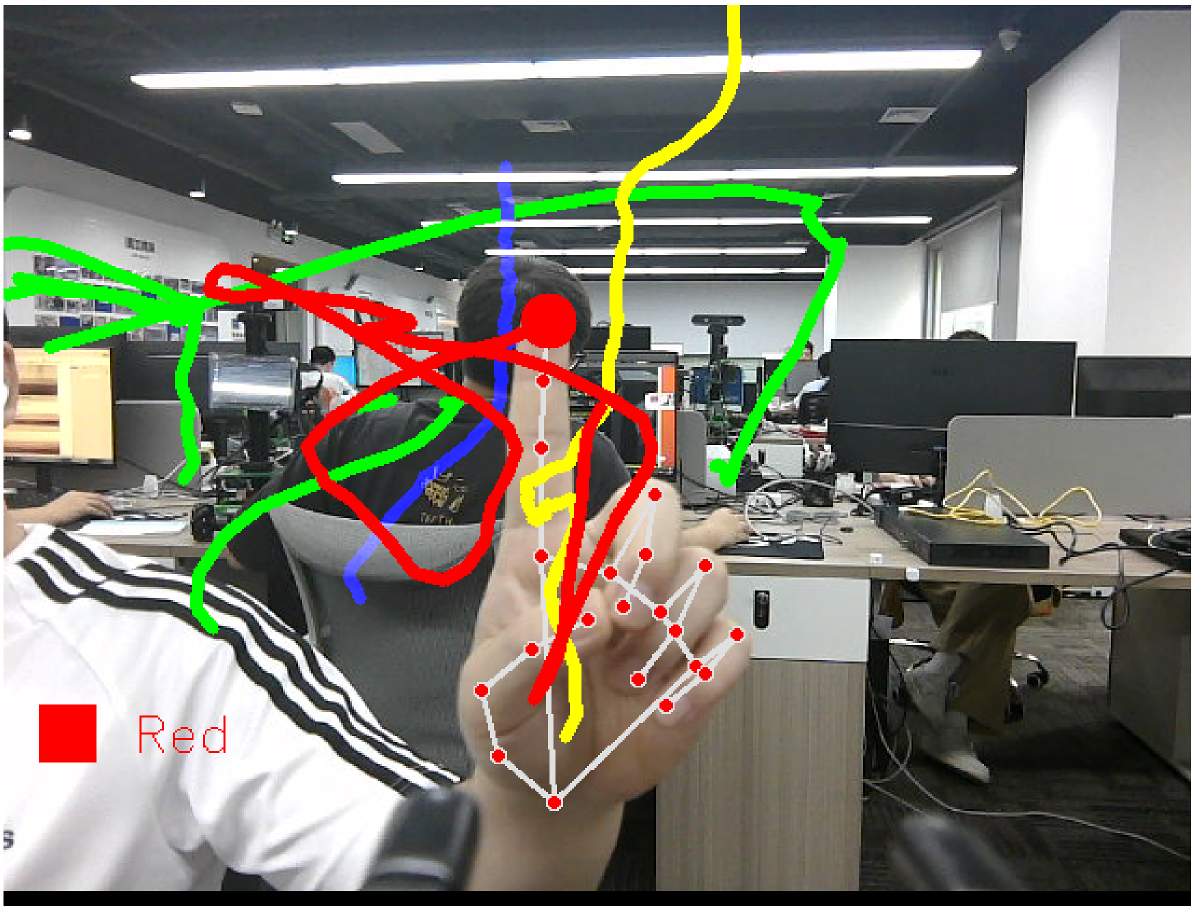
```
#usb camera
ros2 launch usb_cam camera.launch.py
#nuwa camera
ros2 launch ascamera hp60c.launch.py
```

After successfully starting the camera, open another terminal and enter the following command to start the paintbrush program.

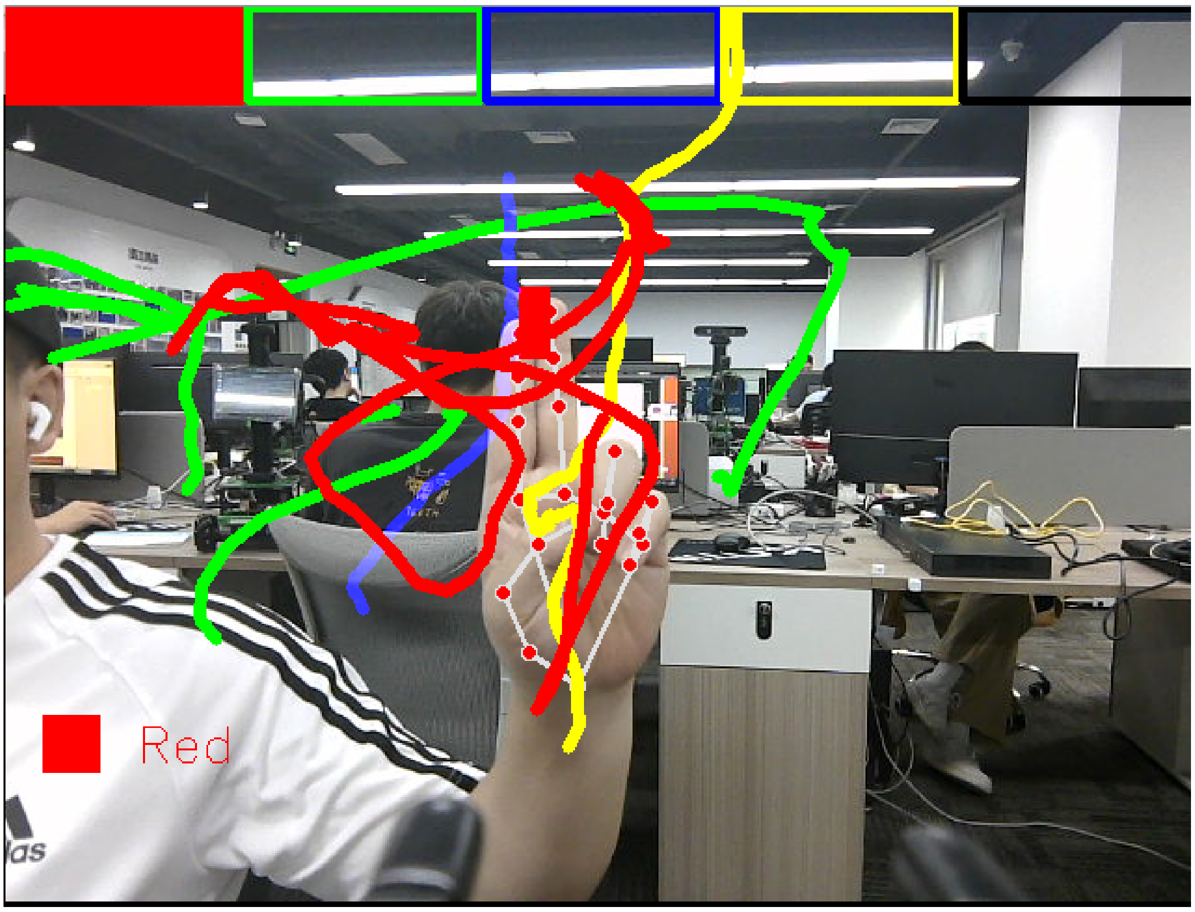
```
ros2 run yahboomcar_mediapipe 08_VirtualPaint
```

After running the program, as shown in the image below, the default fingertip color is red. When you move your right index and middle fingers together, you're in the selection mode, and a color selection box pops up. Move your fingertips to the corresponding color position to select that color (black acts as an eraser). When you move your index and middle fingers apart, you're in the drawing mode, allowing you to draw freely on the canvas.

The index and middle fingers start drawing separately.



Put your index and middle fingers together to enter color selection mode.



3. Core Code Analysis

Program Code Path:

- Raspberry Pi 5 and Jetson Nano Board

  The program code is running in Docker. The path in Docker is `/root/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_mediapipe/yahboomcar_mediapipe/08_VirtualPaint.py`

- Orin board

  The program code path is `/home/jetson/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_mediapipe/yahboomcar_mediapipe/08_VirtualPaint.py`

- RDK X5

  The program code path is `/home/sunrise/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_mediapipe/yahboomcar_mediapipe/08_VirtualPaint.py`

Import the library files used.

```
import math
import time
import cv2 as cv
import numpy as np
import mediapipe as mp
import rclpy
from rclpy.node import Node
from sensor_msgs.msg import Image
from cv_bridge import CvBridge
import os
```

Initialize data and define publishers and subscribers,

```
def __init__(self):
    super().__init__('hand_painting_node')
    #Create an empty image with a resolution of 480*640
    self.imgCanvas = np.zeros((480, 640, 3), np.uint8)
    #Define the thickness of the brush (red, green, blue and yellow)
    self.brushThickness = 5
    #Define the thickness of the eraser (black)
    self.eraserThickness = 100
    #The y-coordinate threshold at the bottom of the color selection box. If it
is less than this value, it means entering the color selection mode.
    self.top_height = 50
    self.Color = "Red"
    #Define the brush color list followed by the RGB value of each color
    self.ColorList = {
    'Red': (0, 0, 255),
    'Green': (0, 255, 0),
    'Blue': (255, 0, 0),
    'Yellow': (0, 255, 255),
    'Black': (0, 0, 0),
    }
    #Define the ID of each fingertip, which will be used later to determine which
fingers are straightened
```

```
    self.tipIds = [4, 8, 12, 16, 20]
    #Use the class in the mediapipe library to define a hand object
    self.mpHand = mp.solutions.hands
    self.mpDraw = mp.solutions.drawing_utils
    self.hands = self.mpHand.Hands(
    static_image_mode=False,
    max_num_hands=2,
    min_detection_confidence=0.85,
    min_tracking_confidence=0.5 )
    #Define the properties of the joint connection line, which will be used in
the subsequent joint point connection function
    self.lmDrawSpec = mp.solutions.drawing_utils.DrawingSpec(color=(0, 0, 255),
thickness=-1, circle_radius=15)
    self.drawSpec = mp.solutions.drawing_utils.DrawingSpec(color=(0, 255, 0),
thickness=10, circle_radius=10)

    self.bridge = CvBridge()

    #Define subscribers for the color image topic
    camera_type = os.getenv('CAMERA_TYPE', 'usb')
    topic_name = '/ascamera_hp60c/camera_publisher/rgb0/image' if camera_type ==
'nuwa' else '/usb_cam/image_raw'

    self.subscription = self.create_subscription(
        Image,
        topic_name,
        self.image_callback,
        10)
```

Color image callback function,

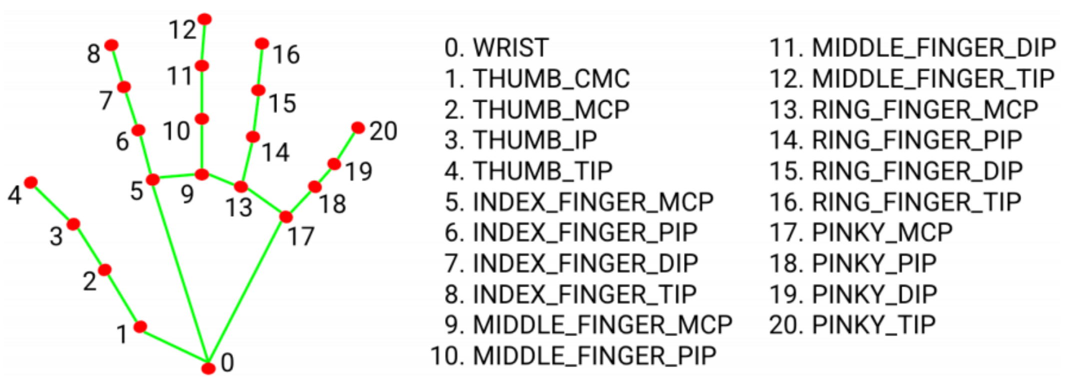
```
def image_callback(self, msg):
    #Use CvBridge to convert color image message data into image data
    frame = self.bridge.imgmsg_to_cv2(msg, desired_encoding='bgr8')
    #Get the size of the color image to facilitate subsequent color selection
based on the coordinates of the fingertip
    h, w, c = frame.shape
    frame, lmList = self.hand_detector.findHands(frame, draw=False)
    if len(lmList) != 0:
        # print(lmList)
        # tip of index and middle fingers
        #Get the coordinate values of the index and middle finger tips
        x1, y1 = lmList[8][1:]
        x2, y2 = lmList[12][1:]
        #Call the fingersUp function to return a list of extended fingers
        fingers = self.fingersUp()
        #If the index and middle fingers are straight
        if fingers[1] and fingers[2]:
            # print("Seclection mode")
            if y1 < self.top_height:
                #Determine the selected color based on the coordinates of the
index finger and the size of the image
                if 0 < x1 < int(w / 5) - 1:
                    self.boxx = 0
                    self.Color = "Red"
                if int(w / 5) < x1 < int(w * 2 / 5) - 1:
                    self.boxx = int(w / 5)
                    self.Color = "Green"
                elif int(w * 2 / 5) < x1 < int(w * 3 / 5) - 1:
                    self.boxx = int(w * 2 / 5)
                    self.Color = "Blue"
                elif int(w * 3 / 5) < x1 < int(w * 4 / 5) - 1:
                    self.boxx = int(w * 3 / 5)
                    self.Color = "Yellow"
                elif int(w * 4 / 5) < x1 < w - 1:
                    self.boxx = int(w * 4 / 5)
                    self.Color = "Black"
            cv.rectangle(frame, (x1, y1 - 25), (x2, y2 + 25),
self.ColorList[self.Color], cv.FILLED)
            cv.rectangle(frame, (self.boxx, 0), (self.boxx + int(w / 5),
self.top_height), self.ColorList[self.Color], cv.FILLED)
            #Draw a color selection box for each color
            cv.rectangle(frame, (0, 0), (int(w / 5) - 1, self.top_height),
self.ColorList['Red'], 3)
            cv.rectangle(frame, (int(w / 5) + 2, 0), (int(w * 2 / 5) - 1,
self.top_height), self.ColorList['Green'], 3)
            cv.rectangle(frame, (int(w * 2 / 5) + 2, 0), (int(w * 3 / 5) - 1,
self.top_height), self.ColorList['Blue'], 3)
            cv.rectangle(frame, (int(w * 3 / 5) + 2, 0), (int(w * 4 / 5) - 1,
self.top_height), self.ColorList['Yellow'], 3)
            cv.rectangle(frame, (int(w * 4 / 5) + 2, 0), (w - 1,
self.top_height), self.ColorList['Black'], 3)
            #If the index finger and middle finger are not straightened at the
same time and the distance between the fingertips is greater than 50 pixels, it
means they are in the open state and enter the drawing mode.
        if fingers[1] and fingers[2] == False and math.hypot(x2 - x1, y2 - y1) >
50:
            # print("Drawing mode")
            if self.xp == self.yp == 0: self.xp, self.yp = x1, y1
            #If black, it is an eraser model that erases the painted track; if
not, it draws the track on the image according to the selected color
            if self.Color == 'Black':
                cv.line(frame, (self.xp, self.yp), (x1, y1),
self.ColorList[self.Color], self.eraserThickness)
                cv.line(self.imgCanvas, (self.xp, self.yp), (x1, y1),
self.ColorList[self.Color], self.eraserThickness)
            else:
                cv.line(frame, (self.xp, self.yp), (x1, y1),
self.ColorList[self.Color], self.brushThickness)
                #Draw a line of the selected color on the created canvas
                cv.line(self.imgCanvas, (self.xp, self.yp), (x1, y1),
self.ColorList[self.Color], self.brushThickness)
            cv.circle(frame, (x1, y1), 15, self.ColorList[self.Color],
cv.FILLED)
            self.xp, self.yp = x1, y1
        else: self.xp = self.yp = 0
    #Convert the canvas's color space to grayscale for easier image processing
    imgGray = cv.cvtColor(self.imgCanvas, cv.COLOR_BGR2GRAY)
    #Thresholding is a process that divides the pixel values ••of a grayscale
image into two categories (for example, foreground and background) based on a set
threshold. It is one of the core methods of image binarization.
    _, imgInv = cv.threshold(imgGray, 50, 255, cv.THRESH_BINARY_INV)
    #Convert the color space to convert the grayscale image into a color BGR
image space
    imgInv = cv.cvtColor(imgInv, cv.COLOR_GRAY2BGR)
```

```
    #Perform AND and OR operations on images to combine them
    frame = cv.bitwise_and(frame, imgInv)
    frame = cv.bitwise_or(frame, self.imgCanvas)
    #Draws the currently selected color box and color
    cv.rectangle(frame, (20, h - 100), (50, h - 70), self.ColorList[self.Color],
cv.FILLED)
    cv.putText(frame, self.Color, (70, h - 75), cv.FONT_HERSHEY_SIMPLEX, 0.9,
(0, 0, 255), 1)
    cv.imshow('frame', frame)
```

fingersUp finger straightening finger detection function,

```
def fingersUp(self):
    fingers=[]
    # Thumb: Check whether the angle of each joint of the thumb is greater than
150 degrees. If so, the thumb is considered straight.
    if (self.calc_angle(self.tipIds[0],
                        self.tipIds[0] - 1,
                        self.tipIds[0] - 2) > 150.0) and (
            self.calc_angle(
                self.tipIds[0] - 1,
                self.tipIds[0] - 2,
                self.tipIds[0] - 3) > 150.0): fingers.append(1)
    else:            fingers.append(0)
    # 4 finger The remaining four fingers
    for id in range(1, 5):
        #Here we check whether the y value of the fingertip joint is smaller
than that of the middle joint. If so, the finger is straight (the origin of the
image is in the upper left, the y value increases as it goes down, and the x
value increases as it goes to the right)
        if self.lmList[self.tipIds[id]][2] < self.lmList[self.tipIds[id] - 2]
[2]:
            fingers.append(1)
        else:
            fingers.append(0)
    return fingers
```

As shown in the image below, the IDs for each finger joint are:



The findHands function detects palms.

```
def findHands(self, frame, draw=True):
    #Create a test list and store the test results
    self.lmList = []
    img_RGB = cv.cvtColor(frame, cv.COLOR_BGR2RGB)
    #Call the process function in the mediapipe library to process the image.
During init, the self.hands object is created and initialized.
    self.results = self.hands.process(img_RGB)
    if self.results.multi_hand_landmarks:
        for handLms in self.results.multi_hand_landmarks:
            if draw: self.mpDraw.draw_landmarks(frame, handLms,
self.mpHand.HAND_CONNECTIONS, self.lmDrawSpec, self.drawSpec)
            else: self.mpDraw.draw_landmarks(frame, handLms,
self.mpHand.HAND_CONNECTIONS)
        #Traverse the detection results and add them to the self.lmList list,
which represents the ID of each person's joint and the xy coordinates of the
joint.
        for id, lm in enumerate(self.results.multi_hand_landmarks[0].landmark):
            h, w, c = frame.shape
            cx, cy = int(lm.x * w), int(lm.y * h)
            # print(id, cx, cy)
            self.lmList.append([id, cx, cy])
    return frame, self.lmList
```