Finger control

1. Content Description

This course implements color imaging and uses the MediaPipe framework to detect fingers. It then calculates the angle between the thumb tip, wrist joint, and index finger tip to modify the image processing effect. This course uses a 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 course in the terminal. For instructions on entering the Docker container from the host computer, refer to **[01. Robot Configuration and Operation Guide] --[5.Enter Docker (For JETSON Nano and RPi 5)]**.

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

2. Program Startup

For the Raspberry Pi 5 controller, you must first enter the Docker container. For the Orin controller, this is not necessary.

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

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

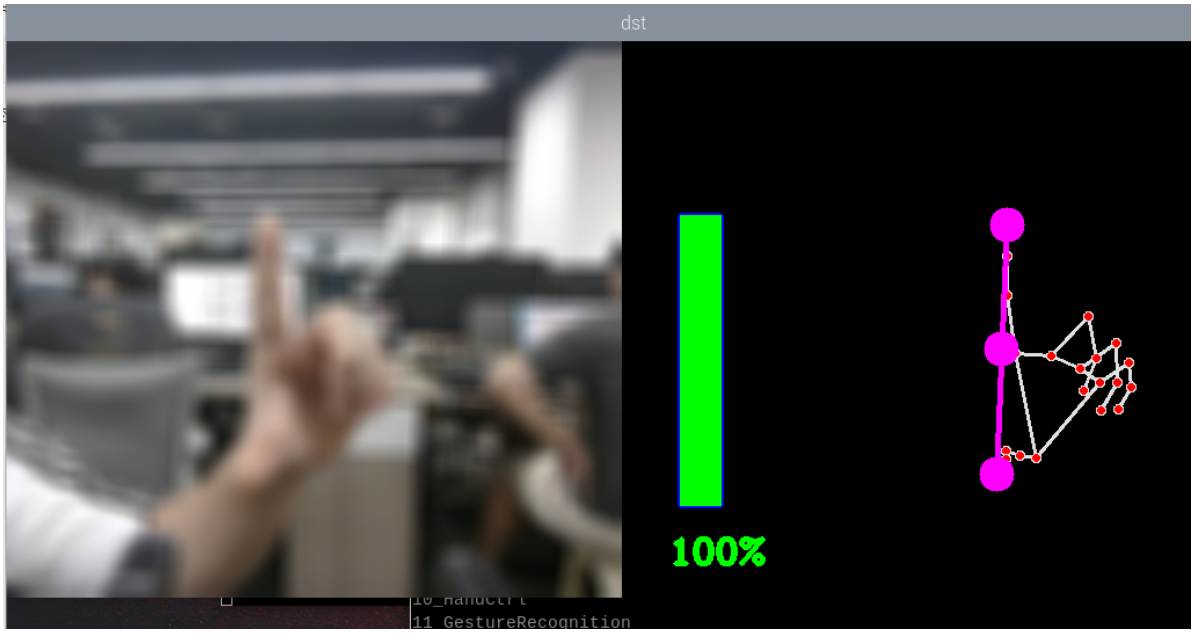
First, enter the following command in the terminal to start the camera.

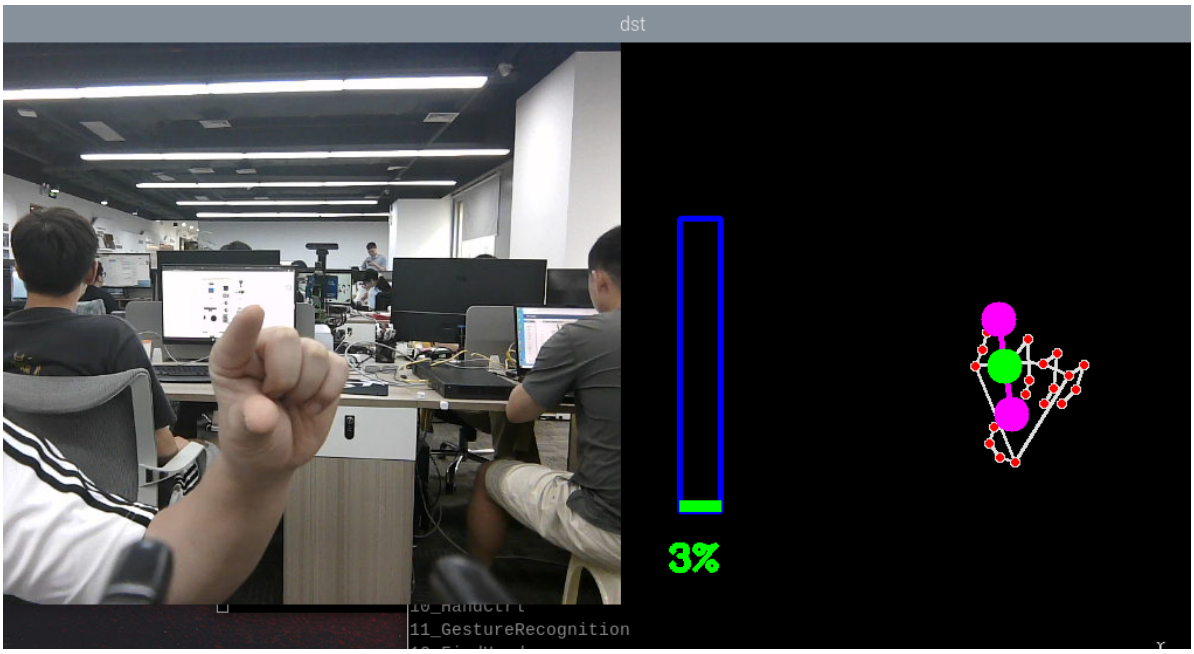
```
#usb camera
ros2 launch usb_cam camera.launch.py
#nuwa camera
ros2 launch ascamera hp60c.launch.py
```

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

```
ros2 run yahboomcar_mediapipe 09_FingerCtrl
```

After running the program, press the F key to toggle the image processing effect. Then, adjust the angle between your thumb and index finger to control the image processing effect.





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/09_FingerCtrl.py`

- Orin motherboard

The program code path is `/home/jetson/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_mediapipe/yahboomcar_mediapipe/09_FingerCtrl.py`

Import the necessary library files.

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

Initialize data and define publishers and subscribers,

```
def __init__(self):
    super().__init__('hand_effects_node')
    #Define a list of image processing effects
    self.effect = ["color", "thresh", "blur", "hue", "enhance"]
    self.volBar = 400
    self.pTime = self.cTime = self.volPer = self.value = self.index = 0
    #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=0.5,
        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')
    action = cv.waitKey(1) & 0xFF
    #Call the function to detect the palm and draw the palm joint connection
diagram
```

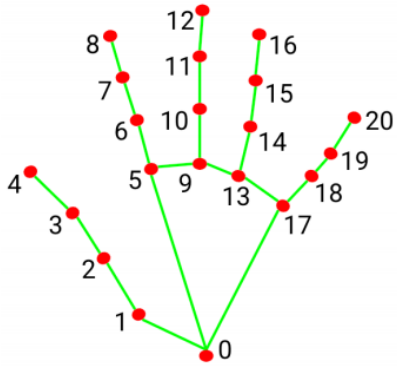
```
    img = self.hand_detector.findHands(frame)
    #Call findPosition to get the coordinates of the finger joint list
    lmList = self.hand_detector.findPosition(frame, draw=False)
    if len(lmList) != 0:
        #Calculate the angle
        angle =  self.calc_angle(4, 0, 8)
        x1, y1 = lmList[4][1], lmList[4][2]
        x2, y2 = lmList[8][1], lmList[8][2]
        cx, cy = (x1 + x2) // 2, (y1 + y2) // 2
        cv.circle(img, (x1, y1), 15, (255, 0, 255), cv.FILLED)
        cv.circle(img, (x2, y2), 15, (255, 0, 255), cv.FILLED)
        cv.line(img, (x1, y1), (x2, y2), (255, 0, 255), 3)
        cv.circle(img, (cx, cy), 15, (255, 0, 255), cv.FILLED)
        if angle <= 10: cv.circle(img, (cx, cy), 15, (0, 255, 0), cv.FILLED)
        #calculate
        self.volBar = np.interp(angle, [0, 70], [400, 150])
        self.volPer = np.interp(angle, [0, 70], [0, 100])
        self.value = np.interp(angle, [0, 70], [0, 255])
        # print("angle: {},value: {}".format(angle, value))
    #Perform a threshold binarization operation. Values ••greater than the
threshold value are represented by 255, and values less than the threshold value
are represented by 0.
    if self.effect[self.index]=="thresh":
        gray = cv.cvtColor(frame, cv.COLOR_BGR2GRAY)
        frame = cv.threshold(gray, self.value, 255, cv.THRESH_BINARY)[1]
    # Perform Gaussian filtering, (21, 21) means that the length and width of the
Gaussian matrix are both 21, and the standard deviation is value
    elif self.effect[self.index]=="blur":
        frame = cv.GaussianBlur(frame, (21, 21), np.interp(self.value, [0, 255],
[0, 11]))
    # Color space conversion, HSV to BGR
    elif self.effect[self.index]=="hue":
        frame = cv.cvtColor(frame, cv.COLOR_BGR2HSV)
        frame[:, :, 0] += int(self.value)
        frame = cv.cvtColor(frame, cv.COLOR_HSV2BGR)
    # Adjust contrast
    elif self.effect[self.index]=="enhance":
        enh_val = self.value / 40
        clahe = cv.createCLAHE(clipLimit=enh_val, tileGridSize=(8, 8))
        lab = cv.cvtColor(frame, cv.COLOR_BGR2LAB)
        lab[:, :, 0] = clahe.apply(lab[:, :, 0])
        frame = cv.cvtColor(lab, cv.COLOR_LAB2BGR)
    #Press the F key to switch the processing effect
    if action == ord('f'):
        self.index += 1
        if self.index >= len(self.effect): self.index = 0

    cv.rectangle(img, (50, 150), (85, 400), (255, 0, 0), 3)
    cv.rectangle(img, (50, int(self.volBar)), (85, 400), (0, 255, 0), cv.FILLED)
    cv.putText(img, f'{int(self.volPer)}%', (40, 450), cv.FONT_HERSHEY_COMPLEX,
1, (0, 255, 0), 3)
    #Merge images
    dst = self.hand_detector.frame_combine(frame, img)
    cv.imshow('dst', dst)
```

findPosition obtains the id of each joint and the xy coordinates of each joint.

```
def findPosition(self, frame, draw=True):
    #Create a test list and store the test results
    self.lmList = []
    if self.results.multi_hand_landmarks:
        #Traverse the test results and add the test results to the self.lmList
list, which represents the ID of each person's joint and the xy coordinates of
the joint detected
        for id, lm in enumerate(self.results.multi_hand_landmarks[0].landmark):
            # print(id,lm)
            h, w, c = frame.shape
            cx, cy = int(lm.x * w), int(lm.y * h)
            # print(id, lm.x, lm.y, lm.z)
            self.lmList.append([id, cx, cy])
            if draw: cv.circle(frame, (cx, cy), 15, (0, 0, 255), cv.FILLED)
    return self.lmList
```

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



0. WRIST
1. THUMB_CMC
2. THUMB_MCP
3. THUMB_IP
4. THUMB_TIP
5. INDEX_FINGER_MCP
6. INDEX_FINGER_PIP
7. INDEX_FINGER_DIP
8. INDEX_FINGER_TIP
9. MIDDLE_FINGER_MCP
10. MIDDLE_FINGER_PIP
11. MIDDLE_FINGER_DIP
12. MIDDLE_FINGER_TIP
13. RING_FINGER_MCP
14. RING_FINGER_PIP
15. RING_FINGER_DIP
16. RING_FINGER_TIP
17. PINKY_MCP
18. PINKY_PIP
19. PINKY_DIP
20. PINKY_TIP

calc_angle calculates the angle between the thumb tip, wrist joint, and index finger tip.

```
def calc_angle(self, pt1, pt2, pt3):
    point1 = self.lmList[pt1][1], self.lmList[pt1][2]
    point2 = self.lmList[pt2][1], self.lmList[pt2][2]
    point3 = self.lmList[pt3][1], self.lmList[pt3][2]
    a = self.get_dist(point1, point2)
    b = self.get_dist(point2, point3)
    c = self.get_dist(point1, point3)
    try:
        radian = math.acos((math.pow(a, 2) + math.pow(b, 2) - math.pow(c, 2)) /
(2 * a * b))
        angle = radian / math.pi * 180
    except:
        angle = 0
    return abs(angle)
```