Gesture Recognition

1. Content Description

MediaPipe is an open-source data stream processing framework developed by Google for machine learning applications. It is a graph-based data processing pipeline used to build applications that consume a variety of data sources, such as video, audio, sensor data, and any time series data.

MediaPipe is cross-platform and can run on embedded platforms (such as Jetson Nano), mobile devices (iOS and Android), workstations, and servers, and supports mobile GPU acceleration. MediaPipe provides a cross-platform, customizable ML solution for real-time and streaming media.

The core framework of MediaPipe is implemented in C++, with support for languages such as Java and Objective C. Key concepts in MediaPipe include packets, streams, calculators, graphs, and subgraphs.

MediaPipe Features:

- End-to-end acceleration: Built-in fast ML inference and processing accelerates even on commodity hardware.
- Build once, deploy anywhere: A unified solution for Android, iOS, desktop/cloud, web, and IoT.
- Ready-to-use solution: A cutting-edge ML solution that demonstrates the full capabilities of the framework.
- Free and open source: The framework and solution are licensed under Apache 2.0 and are fully extensible and customizable.

Gesture recognition is designed for right-hand use and accurately recognizes gestures when specific conditions are met. Recognizable gestures include: Zero, One, Two, Three, Four, Five, Six, Seven, Eight, Ok, Rock, Thumb_up (like), Thumb_down (thumbs down), Heart_single (heart gesture)—a total of 14 categories.

This section requires entering commands in a terminal. The terminal you choose depends on your motherboard type. This section 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 section 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 section.

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]).

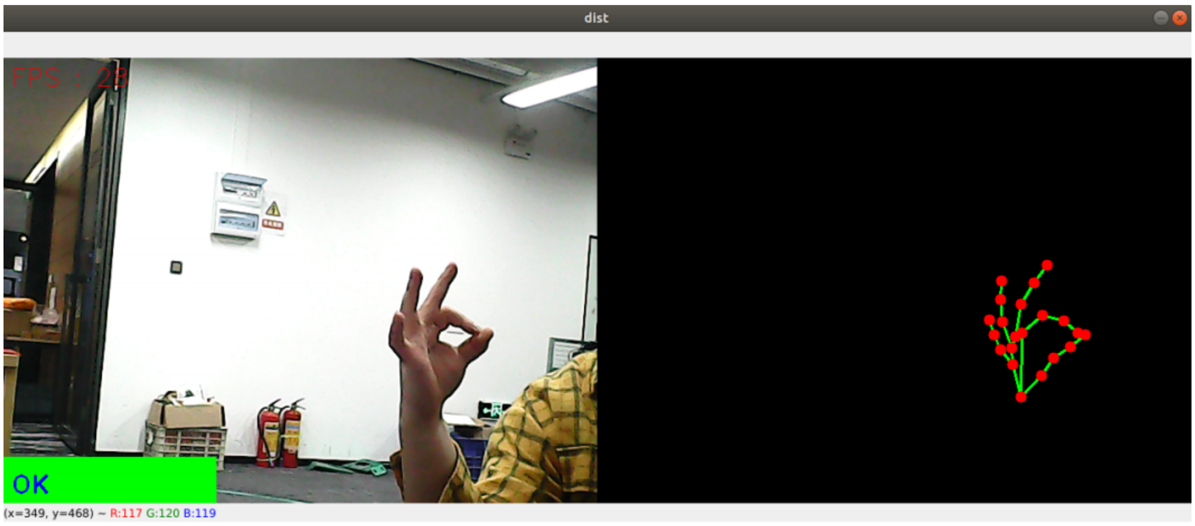
All of the following Docker commands must be executed from the same Docker container **(for steps, see [Docker Course] --- [3. Docker Submission and Multi-Terminal Access]).**

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 gesture recognition program.

```
ros2 run yahboomcar_mediapipe 10_GestureRecognition
```



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/10_GestureRecognition.py`

- Orin motherboard

  The program code path is `/home/jetson/yahboomcar_ros2_ws/yahboomcar_ws/src/yahboomcar_mediapipe/yahboomcar_mediapipe/10_GestureRecognition.py`

`pubHandsPoint` function

```
def pubHandsPoint(self, frame, draw=True):
    """检测手部关键点并返回可视化结果 \ Detect hand key points and return
visualization results
    Args:
        frame: 输入BGR图像 \ Input BGR image
        draw: 是否在原图绘制关键点（默认True） \ Whether to draw key points in the
original image (default True)
    Returns:
        tuple: (带标记的原图, 纯关键点图像 \ Original image with markers, pure
keypoint image)
    """
    img = np.zeros(frame.shape, np.uint8)  # Create a blank canvas
    img_RGB = cv.cvtColor(frame, cv.COLOR_BGR2RGB)  # Convert color space

    self.results = self.hands.process(img_RGB)  # MediaPipe Processing

    if self.results.multi_hand_landmarks:  # When a hand is detected
        for hand_landmarks in self.results.multi_hand_landmarks:
            if draw:  # Draw on the original image
                self.mpDraw.draw_landmarks(
                    frame, hand_landmarks, self.mpHand.HAND_CONNECTIONS,
                    self.lmDrawSpec, self.drawSpec)

            # Key point skeleton in blank picture
            self.mpDraw.draw_landmarks(
                img, hand_landmarks, self.mpHand.HAND_CONNECTIONS,
                self.lmDrawSpec, self.drawSpec)

    return frame, img
```

`frame_combine` function

```
def frame_combine(self, frame, src):
    """水平拼接两个图像 \ Horizontally stitch two images
    Args:
        frame: 左侧图像 \ Left image
        src: 右侧图像 \ Right image
    Returns:
        numpy.ndarray: 拼接后的图像 \ Stitched image
    """
    if len(frame.shape) == 3:  # Color image processing
        h, w = frame.shape[:2]
        dst = np.zeros((h, w*2, 3), np.uint8)
        dst[:, :w] = frame
        dst[:, w:] = src
    else:  # Grayscale image processing
        h, w = frame.shape[:2]
        dst = np.zeros((h, w*2), np.uint8)
        dst[:, :w] = frame
        dst[:, w:] = src
    return dst
```

`image_callback` function

```
def image_callback(self, msg):
    """ROS图像订阅回调函数 \ ROS image subscription callback function
    Args:
        msg: sensor_msgs/Image 类型的ROS消息  \  ROS message of sensor_msgs/Image
type
    """
    frame = self.bridge.imgmsg_to_cv2(msg, 'bgr8')  # ROS to OpenCV
    frame, img = self.pubHandsPoint(frame)  # Keypoint detection
    combined = self.frame_combine(frame, img)  # Image stitching
    cv.imshow('HandDetector', combined)  # Display results
    cv.waitKey(1)  # Refresh display
```