Finger trajectory recognition

1. Introduction

MediaPipe is an open-source data stream processing machine learning application development framework developed by Google. It is a graph-based data processing pipeline used to build data sources in various forms, 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 cross-platform, customizable ML solutions for real-time and streaming media.

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

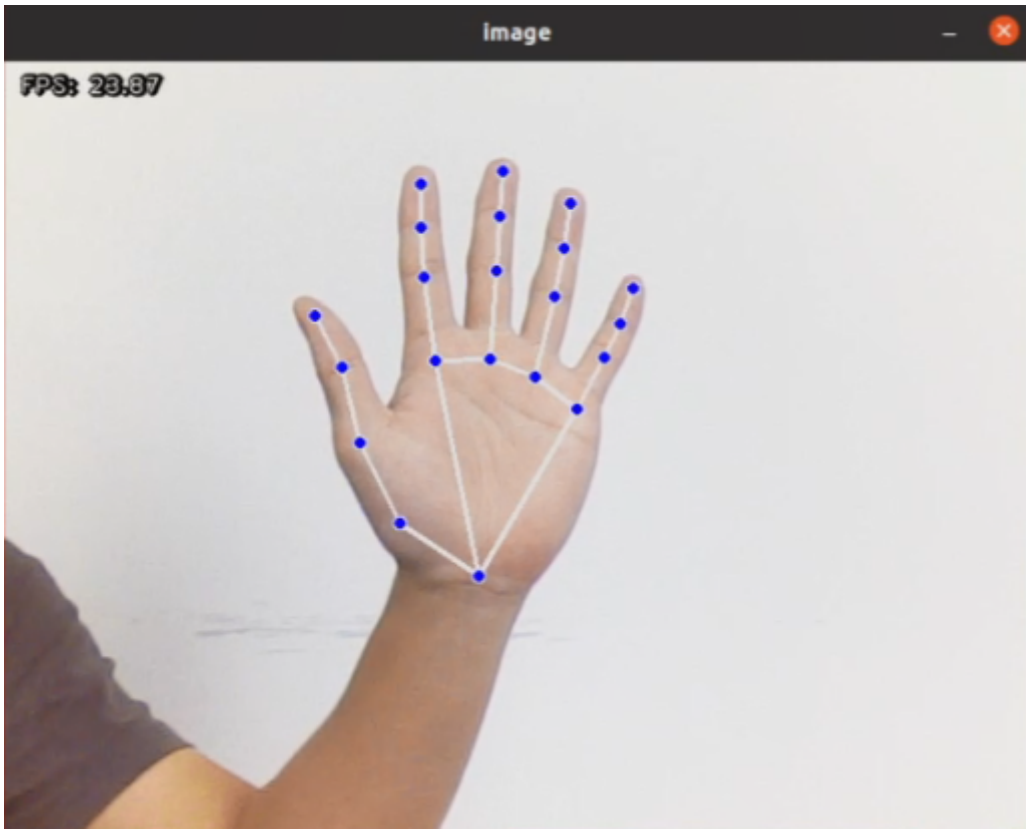
Features of MediaPipe:

- End-to-end acceleration: built-in fast ML inference and processing can be accelerated even on ordinary hardware.
- Build once, deploy anywhere: unified solution for Android, iOS, desktop/cloud, web and IoT.
- Ready-to-use solution: cutting-edge ML solution that demonstrates the full capabilities of the framework.
- Free and open source: framework and solution under Apache2.0, fully extensible and customizable.

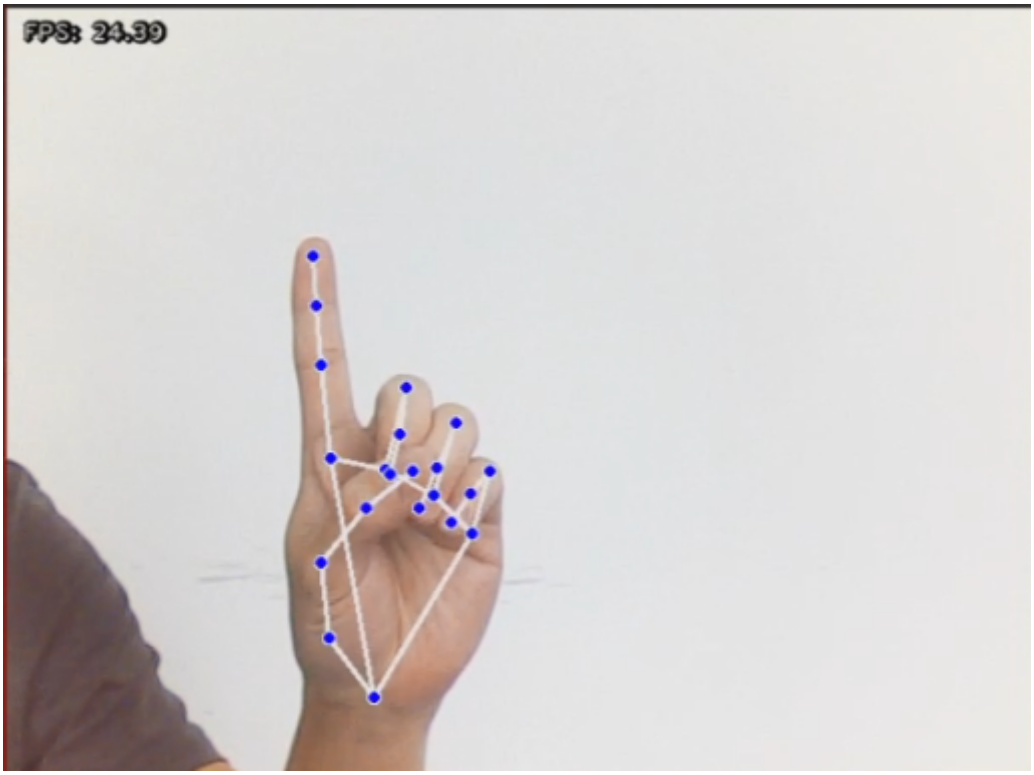
2. Startup

2.1. Program description

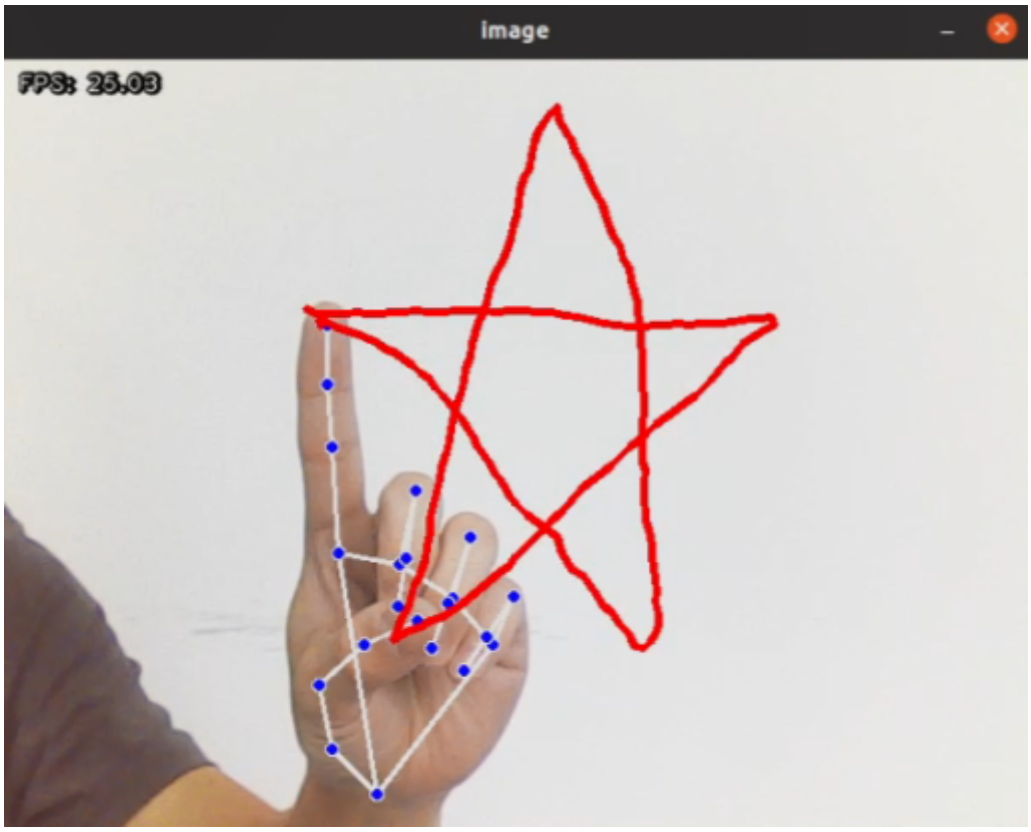
After the program is started, the camera captures the image, put your palm flat on the camera screen, open your fingers, and face the palm of your hand to the camera, similar to the gesture of the number 5, and the image will draw the joints on the entire palm. Adjust the position of your palm and try to be in the upper middle part of the screen.



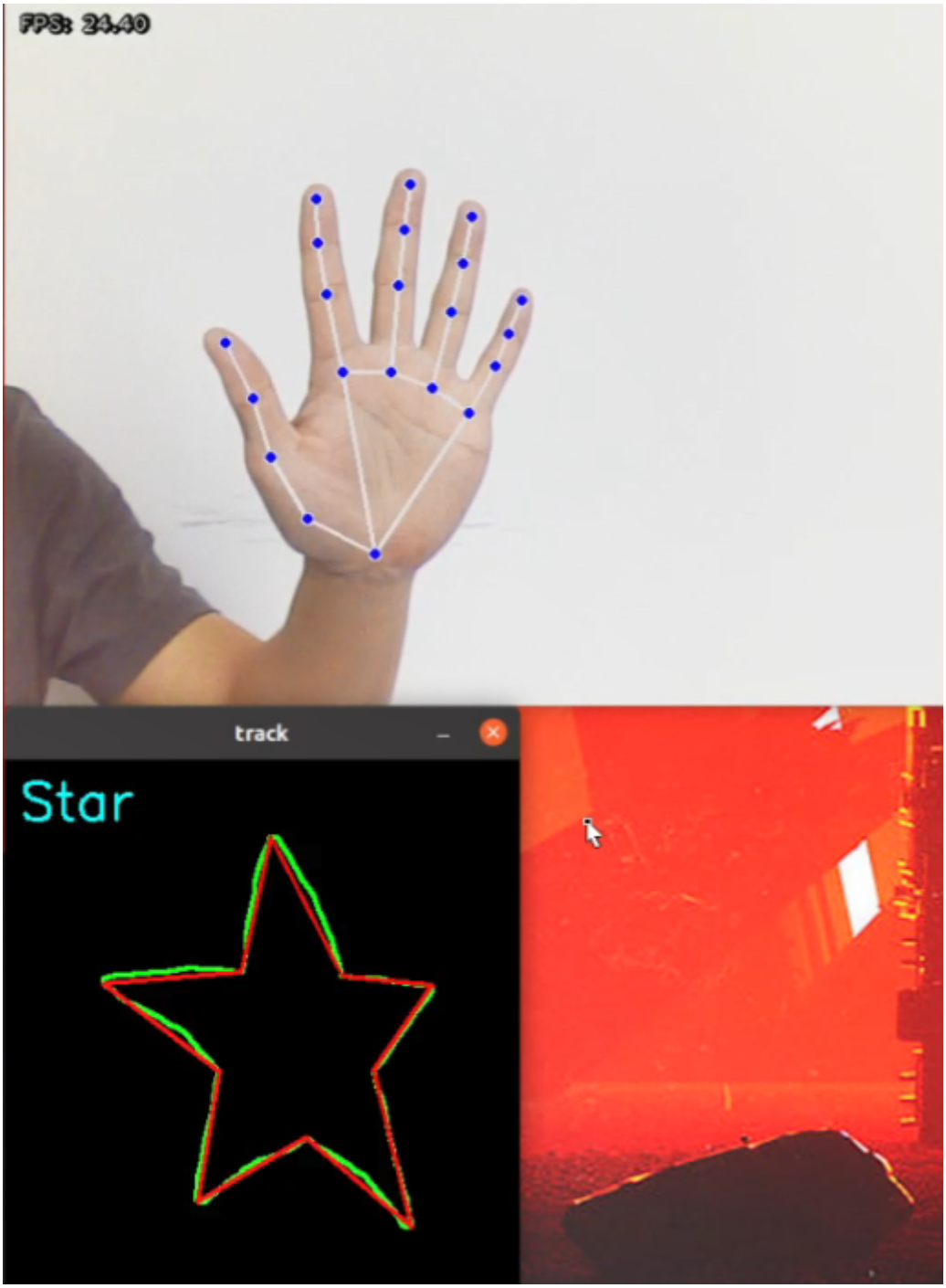
At this time, the index finger remains unchanged, and the other fingers are retracted, similar to the gesture of the number 1.



Keep the gesture 1 unchanged, move the finger position, and a red line will appear on the screen to draw the path of the index finger.



When the figure is drawn, open all fingers, and the gesture similar to the number 5 will generate the drawn figure below.



Note: The drawn figure needs to be closed, otherwise part of the content may be missing.

There are currently four trajectory figures that can be recognized, namely: triangle, rectangle, circle, and five-pointed star.

2.2, Program Startup

- Enter the following command to start the program

```
ros2 run dofbot_pro_mediapipe 15_FingerTrajectory
```

Press the q key in the image or press Ctrl+c in the terminal to exit the program.

3, Source Code

Code path:

```
~/dofbot_pro_ws/src/dofbot_pro_mediapipe/dofbot_pro_mediapipe/15_FingerTrajectory
.py
```

```
#!/usr/bin/env python3
# coding: utf8
import os
import enum
import cv2
import time
import numpy as np
import mediapipe as mp
import rclpy
from rclpy.node import Node
import queue
from sensor_msgs.msg import Image
from dofbot_utils.fps import FPS
import gc
from dofbot_utils.vutils import distance, vector_2d_angle, get_area_max_contour
from cv_bridge import CvBridge


def get_hand_landmarks(img, landmarks):
    """
    将landmarks从medipipe的归一化输出转为像素坐标
    :param img: 像素坐标对应的图片
    :param landmarks: 归一化的关键点
    :return:
    """
    h, w, _ = img.shape
    landmarks = [(lm.x * w, lm.y * h) for lm in landmarks]
    return np.array(landmarks)


def hand_angle(landmarks):
    """
    计算各个手指的弯曲角度
    :param landmarks: 手部关键点
    :return: 各个手指的角度
    """
    angle_list = []
    # thumb 大拇指
    angle_ = vector_2d_angle(landmarks[3] - landmarks[4], landmarks[0] -
landmarks[2])
    angle_list.append(angle_)
    # index 食指
    angle_ = vector_2d_angle(landmarks[0] - landmarks[6], landmarks[7] -
landmarks[8])
    angle_list.append(angle_)
    # middle 中指
```

```
    angle_ = vector_2d_angle(landmarks[0] - landmarks[10], landmarks[11] -
landmarks[12])
    angle_list.append(angle_)
    # ring 无名指
    angle_ = vector_2d_angle(landmarks[0] - landmarks[14], landmarks[15] -
landmarks[16])
    angle_list.append(angle_)
    # pink 小拇指
    angle_ = vector_2d_angle(landmarks[0] - landmarks[18], landmarks[19] -
landmarks[20])
    angle_list.append(angle_)
    angle_list = [abs(a) for a in angle_list]
    return angle_list


def h_gesture(angle_list):
    """
    通过二维特征确定手指所摆出的手势
    :param angle_list: 各个手指弯曲的角度
    :return : 手势名称字符串
    """
    thr_angle, thr_angle_thumb, thr_angle_s = 65.0, 53.0, 49.0
    if (angle_list[0] < thr_angle_s) and (angle_list[1] < thr_angle_s) and
(angle_list[2] < thr_angle_s) and (
            angle_list[3] < thr_angle_s) and (angle_list[4] < thr_angle_s):
        gesture_str = "five"
    elif (angle_list[0] > 5) and (angle_list[1] < thr_angle_s) and (angle_list[2]
> thr_angle) and (
            angle_list[3] > thr_angle) and (angle_list[4] > thr_angle):
        gesture_str = "one"
    else:
        gesture_str = "none"
    return gesture_str


class State(enum.Enum):
    NULL = 0
    TRACKING = 1
    RUNNING = 2


def draw_points(img, points, tickness=4, color=(255, 0, 0)):
    """
    将记录的点连线画在画面上
    """
    points = np.array(points).astype(dtype=np.int32)
    if len(points) > 2:
        for i, p in enumerate(points):
            if i + 1 >= len(points):
                break
            cv2.line(img, tuple(p), tuple(points[i + 1]), color, tickness)

def get_track_img(points):
    """
    用记录的点生成一张黑底白线的轨迹图
    """
```

```
    points = np.array(points).astype(dtype=np.int32)
    x_min, y_min = np.min(points, axis=0).tolist()
    x_max, y_max = np.max(points, axis=0).tolist()
    track_img = np.full([y_max - y_min + 100, x_max - x_min + 100, 1], 0,
dtype=np.uint8)
    points = points - [x_min, y_min]
    points = points + [50, 50]
    draw_points(track_img, points, 1, (255, 255, 255))
    return track_img


class FingerTrajectoryNode(Node):
    def __init__(self):
        super().__init__('finger_trajectory')
        self.drawing = mp.solutions.drawing_utils
        self.timer = time.time()

        self.hand_detector = mp.solutions.hands.Hands(
            static_image_mode=False,
            max_num_hands=1,
            min_tracking_confidence=0.05,
            min_detection_confidence=0.6
        )

        self.fps = FPS()  # fps计算器
        self.state = State.NULL
        self.points = []
        self.start_count = 0
        self.no_finger_timestamp = time.time()

        self.gc_stamp = time.time()
        self.image_queue = queue.Queue(maxsize=1)
        self.bridge = CvBridge()

        # Initialize video capture device
        self.cap = cv.VideoCapture(0, cv.CAP_V4L2)
        self.cap.set(cv2.CAP_PROP_FRAME_WIDTH, 640)
        self.cap.set(cv2.CAP_PROP_FRAME_HEIGHT, 480)
        if not self.cap.isOpened():
            self.get_logger().error("Error: Could not open video device.")
            rclpy.shutdown()

    def image_proc(self):
        ret, frame = self.cap.read()
        if not ret:
            self.get_logger().error("Error: Could not read frame from video
device.")
            return

        rgb_image = cv2.cvtColor(frame, cv2.COLOR_BGR2RGB)
        rgb_image = cv2.flip(rgb_image, 1) # 水平翻转
        result_image = np.copy(rgb_image)
        result_call = None
        if self.timer <= time.time() and self.state == State.RUNNING:
            self.state = State.NULL
        try:
```

```
            results = self.hand_detector.process(rgb_image) if self.state !=
State.RUNNING else None
            if results is not None and results.multi_hand_landmarks:
                gesture = "none"
                index_finger_tip = [0, 0]
                self.no_finger_timestamp = time.time()  # 记下当期时间，以便超时处理
                for hand_landmarks in results.multi_hand_landmarks:
                    self.drawing.draw_landmarks(
                        result_image,
                        hand_landmarks,
                        mp.solutions.hands.HAND_CONNECTIONS)
                    landmarks = get_hand_landmarks(rgb_image,
hand_landmarks.landmark)
                    angle_list = (hand_angle(landmarks))
                    gesture = (h_gesture(angle_list))
                    index_finger_tip = landmarks[8].tolist()

                if self.state == State.NULL:
                    if gesture == "one":  # 检测到单独伸出食指，其他手指握拳
                        self.start_count += 1
                        if self.start_count > 20:
                            self.state = State.TRACKING
                            self.points = []
                    else:
                        self.start_count = 0

                elif self.state == State.TRACKING:
                    if gesture == "five": # 伸开五指结束画图
                        self.state = State.NULL

                        # 生成黑白轨迹图
                        track_img = get_track_img(self.points)
                        contours = cv2.findContours(track_img, cv2.RETR_EXTERNAL,
cv2.CHAIN_APPROX_NONE)[-2]
                        contour = get_area_max_contour(contours, 300)
                        contour = contour[0]
                        # 按轨迹图识别所画图形
                        # cv2.fillPoly在图像上绘制并填充多边形
                        track_img = cv2.fillPoly(track_img, [contour,], (255,
255, 255))
                        for _ in range(3):
                            # 腐蚀函数
                            track_img = cv2.erode(track_img,
cv2.getStructuringElement(cv2.MORPH_RECT, (5, 5)))
                            # 膨胀函数
                            track_img = cv2.dilate(track_img,
cv2.getStructuringElement(cv2.MORPH_RECT, (5, 5)))
                        contours = cv2.findContours(track_img, cv2.RETR_EXTERNAL,
cv2.CHAIN_APPROX_NONE)[-2]
                        contour = get_area_max_contour(contours, 300)
                        contour = contour[0]
                        h, w = track_img.shape[:2]

                        track_img = np.full([h, w, 3], 0, dtype=np.uint8)
                        track_img = cv2.drawContours(track_img, [contour, ], -1,
(0, 255, 0), 2)
```

```
                        # 对图像轮廓点进行多边形拟合
                        approx = cv2.approxPolyDP(contour, 0.026 *
cv2.arcLength(contour, True), True)
                        track_img = cv2.drawContours(track_img, [approx, ], -1,
(0, 0, 255), 2)

                        print(len(approx))
                        # 根据轮廓包络的顶点数确定图形
                        if len(approx) == 3:
                            cv2.putText(track_img, 'Triangle', (10,
40),cv2.FONT_HERSHEY_SIMPLEX, 1.2, (255, 255, 0), 2)
                        if len(approx) == 4 or len(approx) == 5:
                            cv2.putText(track_img, 'Square', (10,
40),cv2.FONT_HERSHEY_SIMPLEX, 1.2, (255, 255, 0), 2)
                        if 5 < len(approx) < 10:
                            cv2.putText(track_img, 'Circle', (10,
40),cv2.FONT_HERSHEY_SIMPLEX, 1.2, (255, 255, 0), 2)
                        if len(approx) == 10:
                            cv2.putText(track_img, 'Star', (10,
40),cv2.FONT_HERSHEY_SIMPLEX, 1.2, (255, 255, 0), 2)

                        cv2.imshow('track', track_img)

                    else:
                        if len(self.points) > 0:
                            if distance(self.points[-1], index_finger_tip) > 5:
                                self.points.append(index_finger_tip)
                            else:
                                self.points.append(index_finger_tip)

                        draw_points(result_image, self.points)
                else:
                    pass
            else:
                if self.state == State.TRACKING:
                    if time.time() - self.no_finger_timestamp > 2:
                        self.state = State.NULL
                        self.points = []

        except BaseException as e:
            self.get_logger().error("e = {}".format(e))

        self.fps.update_fps()
        self.fps.show_fps(result_image)
        result_image = cv2.cvtColor(result_image, cv2.COLOR_RGB2BGR)
        cv2.imshow('image', result_image)
        key = cv2.waitKey(1)

        if key == ord(' '): # 按空格清空已经记录的轨迹
            self.points = []
        if time.time() > self.gc_stamp:
            self.gc_stamp = time.time() + 1
            gc.collect()


def main(args=None):
```

```
    rclpy.init(args=args)
    finger_track_node = FingerTrajectoryNode()
    try:
        while rclpy.ok():
            finger_track_node.image_proc()
    except KeyboardInterrupt:
        pass
    finally:
        finger_track_node.cap.release()
        cv2.destroyAllWindows()
        rclpy.shutdown()


if __name__ == "__main__":
    main()
```