1. Hand Detection

1.1. 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 (Raspberry Pi, etc.), 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:

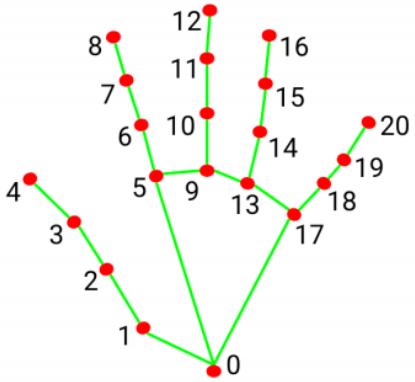
- End-to-end acceleration: built-in fast ML inference and processing can be accelerated even on commodity hardware.
- Build once, deploy anywhere anytime: unified solution for Android, iOS, desktop/cloud, web and IoT.
- Ready-to-use solutions: cutting-edge ML solutions that showcase the full capabilities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

1.2. MediaPipe Hands

MediaPipe Hands is a high-fidelity hand and finger tracking solution. It uses machine learning (ML) to infer 21 3D coordinates of the hand from a frame.

After palm detection for the entire image, the 21 3D hand joint coordinates in the detected hand region are accurately localized by regression based on the hand marker model, i.e. direct coordinate prediction. The model learns a consistent internal hand pose representation that is robustness even to partially visible hands and self-occlusion.

To obtain ground truth data, about 30K real-world images were manually annotated with 21 3D coordinates, as shown below (Z values are obtained from the image depth map, if there is a Z value for each corresponding coordinate). To better cover possible hand poses and provide additional supervision on the properties of hand geometry, high-quality synthetic hand models are also rendered against various backgrounds and mapped to their corresponding 3D coordinates.



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

1.3, Hand detection

1.3.1, Startup

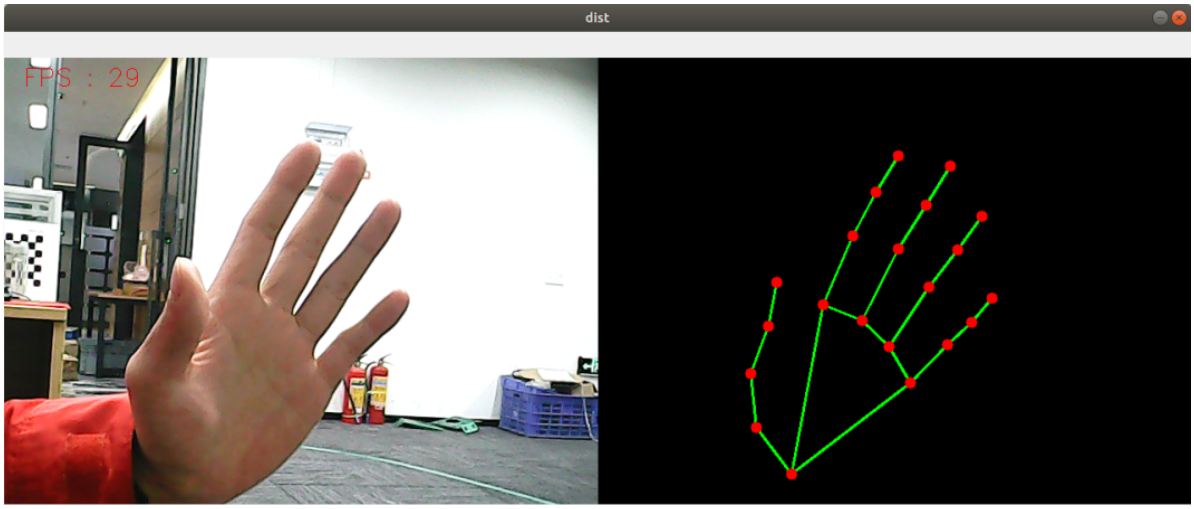
- Host input

Please do this step before running the program

```
sudo supervisorctl stop ChassisServer #Shut down the self-starting chassis service
#Indoor version of NAVROBO-astra_pro2 camera executes this command
/home/yahboom/YBAMR-COBOT-EDU-00001/start/OBColorViewer #Release color stream video100
#[info][722318][Pipeline.cpp:251] Start streams done!
#[info][722318][Pipeline.cpp:234] Pipeline start done!
#[warning][722318][Pipeline.cpp:327] Wait for frame timeout, you can try to increase the wait time! current timeout=100
```

```
roslaunch yahboom_navrobo_mediapipe cloud_Viewer.launch # Point cloud viewing: supports 01~04
```

```
roslaunch yahboom_navrobo_mediapipe 01_HandDetector.launch # Hand detection
```



1.3.2, Source code

Source code location: /home/yahboom/YBAMR-COBOT-EDU-00001/src/yahboom_navrobo_mediapipe/scripts/01_HandDetector.py

```
#!/usr/bin/env python3
# encoding: utf-8
import rospy
import time
import cv2 as cv
import numpy as np
import mediapipe as mp
from geometry_msgs.msg import Point
from yahboomcar_msgs.msg import PointArray

class HandDetector:
```

```
    def __init__(self, mode=False, maxHands=2, detectorCon=0.5, trackCon=0.5):
        self.mpHand = mp.solutions.hands
        self.mpDraw = mp.solutions.drawing_utils
        self.hands = self.mpHand.Hands(
            static_image_mode=mode,
            max_num_hands=maxHands,
            min_detection_confidence=detectorCon,
            min_tracking_confidence=trackCon )
        self.pub_point = rospy.Publisher('/mediapipe/points', PointArray,
queue_size=1000)
        self.lmDrawSpec = mp.solutions.drawing_utils.DrawingSpec(color=(0, 0,
255), thickness=-1, circle_radius=6)
        self.drawSpec = mp.solutions.drawing_utils.DrawingSpec(color=(0, 255,
0), thickness=2, circle_radius=2)

    def pubHandsPoint(self, frame, draw=True):
        pointArray = PointArray()
        img = np.zeros(frame.shape, np.uint8)
        img_RGB = cv.cvtColor(frame, cv.COLOR_BGR2RGB)
        self.results = self.hands.process(img_RGB)
        if self.results.multi_hand_landmarks:
            '''
            draw_landmarks(): Draws landmarks and connections on an image.
            image: A three-channel RGB image represented as a numpy ndarray.
            landmark_list: A list of normalized landmarks to be annotated on the
image.
            connections: A list of landmark index tuples specifying how the
landmarks are connected in the drawing.
            landmark_drawing_spec: A drawing parameter for specifying the drawing
settings of landmarks, such as color, line thickness, and circle radius.
            connection_drawing_spec: A drawing parameter for specifying the
drawing settings of connections, such as color and line thickness.
            '''
            for i in range(len(self.results.multi_hand_landmarks)):
                if draw: self.mpDraw.draw_landmarks(frame,
self.results.multi_hand_landmarks[i], self.mpHand.HAND_CONNECTIONS,
self.lmDrawSpec, self.drawSpec)
                self.mpDraw.draw_landmarks(img,
self.results.multi_hand_landmarks[i], self.mpHand.HAND_CONNECTIONS,
self.lmDrawSpec, self.drawSpec)
                for id, lm in
enumerate(self.results.multi_hand_landmarks[i].landmark):
                    point = Point()
                    point.x, point.y, point.z = lm.x, lm.y, lm.z
                    pointArray.points.append(point)
        self.pub_point.publish(pointArray)
        return frame, img

    def frame_combine(slef,frame, src):
        if len(frame.shape) == 3:
            frameH, frameW = frame.shape[:2]
            srcH, srcW = src.shape[:2]
            dst = np.zeros((max(frameH, srcH), frameW + srcW, 3), np.uint8)
            dst[:, :frameW] = frame[:, :]
            dst[:, frameW:] = src[:, :]
        else:
            src = cv.cvtColor(src, cv.COLOR_BGR2GRAY)
            frameH, frameW = frame.shape[:2]
```

```
            imgH, imgW = src.shape[:2]
            dst = np.zeros((frameH, frameW + imgW), np.uint8)
            dst[:, :frameW] = frame[:, :]
            dst[:, frameW:] = src[:, :]
        return dst

if __name__ == '__main__':
    rospy.init_node('handDetector', anonymous=True)
    capture = cv.VideoCapture(6)
    capture.set(6, cv.VideoWriter.fourcc('M', 'J', 'P', 'G'))
    capture.set(cv.CAP_PROP_FRAME_WIDTH, 640)
    capture.set(cv.CAP_PROP_FRAME_HEIGHT, 480)
    print("capture get FPS : ", capture.get(cv.CAP_PROP_FPS))
    pTime = cTime = 0
    hand_detector = HandDetector(maxHands=2)
    while capture.isOpened():
        ret, frame = capture.read()
        # frame = cv.flip(frame, 1)
        frame, img = hand_detector.pubHandsPoint(frame, draw=False)
        if cv.waitKey(1) & 0xFF == ord('q'): break
        cTime = time.time()
        fps = 1 / (cTime - pTime)
        pTime = cTime
        text = "FPS : " + str(int(fps))
        cv.putText(frame, text, (20, 30), cv.FONT_HERSHEY_SIMPLEX, 0.9, (0, 0,
255), 1)
        dist = hand_detector.frame_combine(frame, img)
        cv.imshow('dist', dist)
        #cv.imshow('frame', frame)
        # cv.imshow('img', img)
    capture.release()
    cv.destroyAllWindows()
```