In [1]:
```
import os
import time
import numpy as np
from matplotlib import pyplot as plt
import cv2 as cv
import mediapipe as mp
import seaborn as sns
from sklearn.model_selection import train_test_split
import tensorflow as tf
from tensorflow.keras import models
from tensorflow.keras import layers
from sklearn.metrics import confusion_matrix ,classification_report
```

In [2]:
```
tf.__version__
```

Out[2]:
```
'2.1.0'
```

In [4]:
```
tf.test.is_gpu_available('gpu')
```

Out[4]:
```
True
```

In [5]:
```
input_types = ['palm', 'fist', 'thumbsup', 'gun', 'call']
```

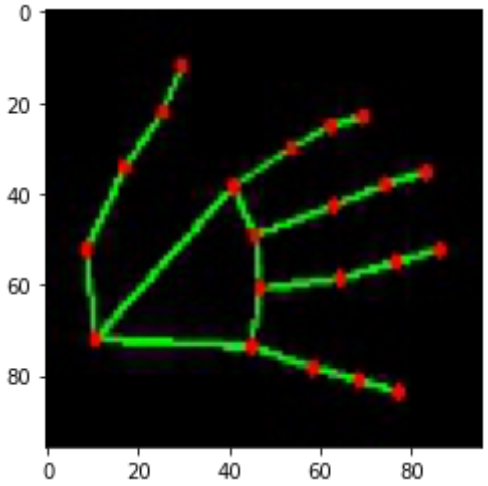
In [6]:
```
path = 'Inputs/'
data = []

for types in input_types:
    temp = path + types + '/'
    l = []
    for file in os.listdir(temp):
        if file.endswith('.jpg'):
            image_matrix = plt.imread(temp + file)
            l.append(image_matrix)
    data.append(l)
data = np.array(data)
```

In [7]:
```
data.shape
```

Out[7]:
```
(5, 2000, 96, 96, 3)
```

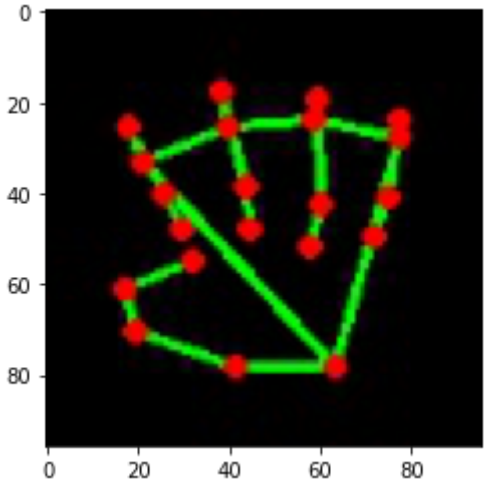
In [8]:
```
plt.imshow(data[0][30])
```

Out[8]:
```
<matplotlib.image.AxesImage at 0x1941b3c48c8>
```



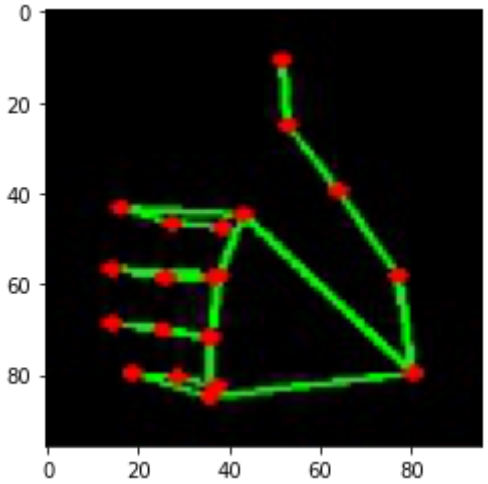
In [9]:
```
plt.imshow(data[1][70])
```

Out[9]: <matplotlib.image.AxesImage at 0x1941056ebc8>



In [10]:
```
plt.imshow(data[2][700])
```

Out[10]: <matplotlib.image.AxesImage at 0x1942be5c5c8>



In [11]:
```
data.shape
```

Out[11]:
```
(5, 2000, 96, 96, 3)
```

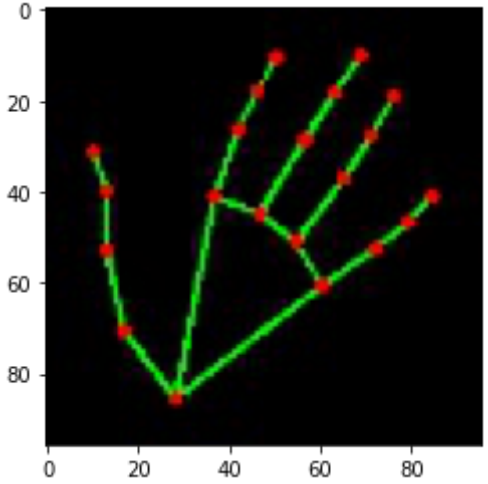
In [12]:
```
X = []
Y = []

i = 0
for class_ in data:
    for image in class_:
        X.append(image)
        Y.append(i)
    i += 1

X = np.array(X)
Y = np.array(Y)

print(X.shape)
print(Y.shape)
```

```
(10000, 96, 96, 3)
(10000,)
```

In [13]:
```
i = 77
print(Y[i])
plt.imshow(X[i])
```

```
0
```

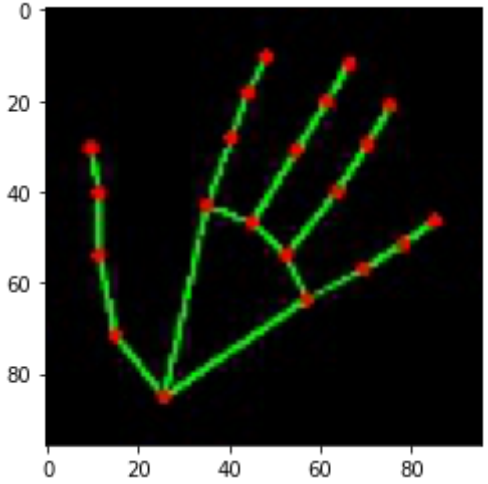
Out[13]: <matplotlib.image.AxesImage at 0x1942bf41388>



In [14]:
```
i = 1999
print(Y[i])
plt.imshow(X[i])
```

```
0
```

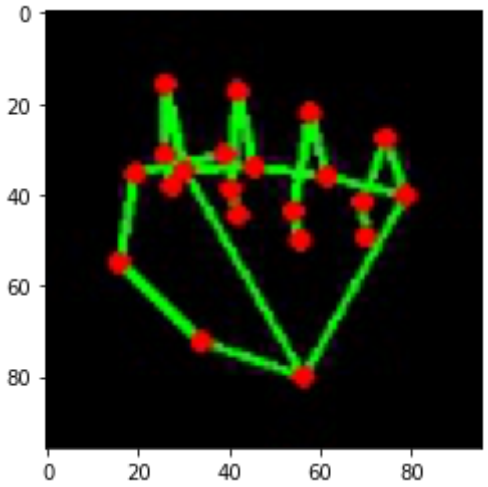
Out[14]: <matplotlib.image.AxesImage at 0x1942bedeac8>



In [15]:
```
i = 2700
print(Y[i])
plt.imshow(X[i])
```

```
1
```

Out[15]:
```
<matplotlib.image.AxesImage at 0x1943c742508>
```



In [16]:
```
X = X / 255
```

In [17]:
```
X[56]
```

Out[17]:
```
array([[[0., 0., 0.],
        [0., 0., 0.],
        [0., 0., 0.],
        ...,
        [0., 0., 0.],
        [0., 0., 0.],
        [0., 0., 0.]],

       [[0., 0., 0.],
        [0., 0., 0.],
        [0., 0., 0.],
        ...,
        [0., 0., 0.],
        [0., 0., 0.],
        [0., 0., 0.]],

       [[0., 0., 0.],
        [0., 0., 0.],
        [0., 0., 0.],
        ...,
        [0., 0., 0.],
        [0., 0., 0.],
        [0., 0., 0.]],

       ...,

       [[0., 0., 0.],
        [0., 0., 0.],
        [0., 0., 0.],
        ...,
        [0., 0., 0.],
        [0., 0., 0.],
        [0., 0., 0.]],

       [[0., 0., 0.],
        [0., 0., 0.],
        [0., 0., 0.],
        ...,
        [0., 0., 0.],
        [0., 0., 0.],
        [0., 0., 0.]],
```

```
[[0., 0., 0.],
 [0., 0., 0.],
 [0., 0., 0.],
 ...,
 [0., 0., 0.],
 [0., 0., 0.],
 [0., 0., 0.]]])
```

In [18]:
```
X_train, X_test, Y_train, Y_test = train_test_split(X, Y, test_size = 0.2, random_state = 20, shuffle = True)
```

In [19]:

```
cnn = models.Sequential([
    #conv layer 01
    layers.Conv2D(input_shape = X.shape[1:], #layer 01
                  filters = 32,
                  kernel_size = (3,3),
                  strides = (1, 1),
                  padding = 'same',
                  activation = 'relu'),

    #maxpool layer 01
    layers.MaxPooling2D(pool_size = (2, 2), #layer 02
                        strides = (2,2),
                        padding = 'same'),

    #dropout layer 01
    layers.Dropout(0.2), #layer 04

    #conv layer 02
    layers.Conv2D(input_shape = X.shape[1:], #layer 05
                  filters = 64,
                  kernel_size = (3,3),
                  strides = (1, 1),
                  padding = 'same',
                  activation = 'relu'),

    #maxpool layer 02
    layers.MaxPooling2D(pool_size = (2, 2), #layer 06
                        strides = (2,2),
                        padding = 'same'),

    #dropout layer 02
    layers.Dropout(0.2), #layer 07

    #input layer
    layers.Flatten(), #layer 08

    #hidden layer 01
    layers.Dense(units = 512, #layer 09
                 activation = 'relu'),

    #dropout layer 03
```

```
    layers.Dropout(0.2), #Layer 10

    #output layer
    layers.Dense(units = len(input_types), #layer 11
                 activation = 'softmax')
])
```

In [20]:
```
cnn.compile(optimizer = 'adam',
            loss = 'sparse_categorical_crossentropy',
            metrics = ['accuracy'])
```

In [21]:
```
start_time = time.time()
cnn.fit(X_train, Y_train,epochs = 10)
end_time = time.time()
print("total time in seconds", (end_time - start_time))
```

```
Train on 8000 samples
Epoch 1/10
8000/8000 [==============================] - 18s 2ms/sample - loss: 0.1218 - accuracy: 0.9621
Epoch 2/10
8000/8000 [==============================] - 5s 612us/sample - loss: 0.0138 - accuracy: 0.9952
Epoch 3/10
8000/8000 [==============================] - 4s 562us/sample - loss: 0.0061 - accuracy: 0.9975
Epoch 4/10
8000/8000 [==============================] - 4s 516us/sample - loss: 0.0063 - accuracy: 0.9984
Epoch 5/10
8000/8000 [==============================] - 4s 514us/sample - loss: 0.0082 - accuracy: 0.9974
Epoch 6/10
8000/8000 [==============================] - 4s 516us/sample - loss: 0.0012 - accuracy: 0.9996: 0s - loss: 9
Epoch 7/10
8000/8000 [==============================] - 4s 514us/sample - loss: 0.0012 - accuracy: 0.9998
Epoch 8/10
8000/8000 [==============================] - 4s 511us/sample - loss: 0.0059 - accuracy: 0.9977
Epoch 9/10
8000/8000 [==============================] - 4s 510us/sample - loss: 0.0049 - accuracy: 0.9983
Epoch 10/10
8000/8000 [==============================] - 4s 507us/sample - loss: 4.8045e-04 - accuracy: 1.0000
total time in seconds 55.98964047431946
```

In [22]:
```
cnn.evaluate(X_test, Y_test)
```

```
2000/2000 [==============================] - 1s 347us/sample - loss: 0.0203 - accuracy: 0.9950
```

Out[22]:
```
[0.02028128568033543, 0.995]
```

In [23]:
```
Y_pred = cnn.predict(X_test)
Y_pred_classes = [np.argmax(e) for e in Y_pred]

print("Classification Report: \n", classification_report(Y_test, Y_pred_classes))
```

```
Classification Report:
              precision    recall  f1-score   support

           0       0.99      1.00      1.00       399
           1       1.00      1.00      1.00       408
           2       0.99      1.00      0.99       373
           3       1.00      0.99      0.99       411
           4       1.00      0.99      0.99       409

    accuracy                           0.99      2000
   macro avg       0.99      1.00      0.99      2000
weighted avg       1.00      0.99      0.99      2000
```

In [24]:
```
cnn.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 96, 96, 32)        896
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 48, 48, 32)        0
_________________________________________________________________
dropout (Dropout)            (None, 48, 48, 32)        0
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 48, 48, 64)        18496
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 24, 24, 64)        0
_________________________________________________________________
dropout_1 (Dropout)          (None, 24, 24, 64)        0
_________________________________________________________________
flatten (Flatten)            (None, 36864)             0
_________________________________________________________________
dense (Dense)                (None, 512)               18874880
_________________________________________________________________
dropout_2 (Dropout)          (None, 512)               0
_________________________________________________________________
dense_1 (Dense)              (None, 5)                 2565
=================================================================
Total params: 18,896,837
Trainable params: 18,896,837
Non-trainable params: 0
_________________________________________________________________
```

In [25]:
```
cnn.get_weights()
```

Out[25]:
```
[array([[[[-4.28520143e-02,  4.36444543e-02,  1.59608930e-01,
           1.85733419e-02, -1.76627964e-01, -5.17254472e-02,
           1.54973298e-01,  1.52638137e-01, -5.96843921e-02,
           9.16987583e-02, -7.56276622e-02,  1.28879249e-01,
          -1.04584612e-01,  1.06672294e-01, -3.59708071e-03,
          -2.83434894e-02, -5.81433587e-02, -1.46537960e-01,
          -1.40992641e-01,  7.00010434e-02, -1.15938611e-01,
           1.51752919e-01,  4.53807190e-02, -3.70776281e-02,
           2.67298166e-02,  1.20139748e-01, -2.12287139e-02,
           5.76514937e-03,  3.40608172e-02,  2.66641732e-02,
           9.95498225e-02,  3.47049385e-02],
         [ 1.24757126e-01,  2.18364112e-02, -1.07748955e-01,
          -1.67609006e-01,  6.19483255e-02,  1.07955396e-01,
           1.45916596e-01,  8.77300203e-02, -4.40291055e-02,
          -3.93620431e-02,  8.53522345e-02, -7.14429617e-02,
          -4.09310609e-02,  1.11101434e-01, -6.19888566e-02,
           1.34559140e-01,  1.45799443e-01, -9.37778577e-02,
           4.06562909e-02,  4.98728603e-02,  1.39217839e-01,
           1.69269502e-01,  1.08848564e-01, -8.74814466e-02,
          -8.37267097e-03, -9.63342637e-02,  2.84434427e-02,
           1.16600014e-01, -1.46336481e-01,  2.22849566e-02,
          -5.36732487e-02,  1.41608968e-01],
         [-4.85812873e-03,  5.51559143e-02, -4.77876514e-02,
           6.68440089e-02, -1.92726299e-01,  1.39218450e-01,
           2.82772500e-02,  1.13179721e-01,  1.89193320e-02,
           1.27390832e-01, -5.07281013e-02,  2.93888021e-02,
           6.15407787e-02,  1.15959113e-02, -1.31116033e-01,
           1.02262676e-01, -5.39021902e-02, -4.15763482e-02,
           1.48542196e-01, -6.26639128e-02, -9.96292308e-02,
           1.26438931e-01,  5.79981506e-02,  7.03374892e-02,
           1.54981017e-01, -5.81746027e-02,  1.21636979e-01,
           4.84964736e-02,  1.07926615e-02,  1.03315562e-01,
          -5.19787893e-02, -3.22834635e-03]],

        [[-1.57409176e-01, -1.10887028e-01,  1.19368821e-01,
           4.24062982e-02, -1.54515788e-01, -7.97641948e-02,
          -7.76617825e-02, -1.35561332e-01,  6.85818344e-02,
           3.29237059e-02, -3.63977291e-02,  1.15845680e-01,
           8.99454951e-02,  1.59379140e-01, -7.30772838e-02,
           6.14315160e-02,  1.69435889e-02, -1.10391386e-01,
          -6.85885549e-02,  1.84984967e-01, -1.23387843e-01,
```

```
   3.92439254e-02,  2.95328014e-02,  5.05197560e-03,
  -6.68328851e-02, -3.71791283e-03,  1.50715441e-01,
   8.70548040e-02, -1.29327103e-01, -4.76575755e-02,
   1.53815359e-01, -1.18578836e-01],
 [ 3.95396724e-03,  5.49856797e-02, -3.19713764e-02,
  -1.89749181e-01,  9.24612135e-02,  7.00220317e-02,
  -5.25212027e-02,  2.02823170e-02, -6.83283284e-02,
  -1.01530634e-01, -7.31651932e-02, -1.83818936e-01,
   1.16775535e-01,  1.75797287e-03, -1.22805648e-01,
   1.22662149e-01, -8.30495283e-02,  3.93665098e-02,
   4.27106731e-02,  1.03711352e-01,  1.20188475e-01,
  -1.55766541e-02, -1.03493139e-01, -7.54922107e-02,
   3.37243229e-02, -5.19191884e-02, -5.54912984e-02,
  -2.04783194e-02, -1.65224344e-01, -4.70946431e-02,
   1.97476638e-03, -3.46633159e-02],
 [-1.24302894e-01, -1.82111248e-01,  5.62388822e-02,
  -1.25474408e-01, -2.56664045e-02, -3.60028110e-02,
  -5.74664772e-02,  1.01127021e-01, -4.74841893e-02,
   3.94921489e-02, -6.02993332e-02, -7.03132451e-02,
   1.41236484e-01,  9.56109166e-02, -9.35035050e-02,
   9.01390463e-02,  3.66556644e-03, -9.60493162e-02,
   1.17124371e-01, -2.85387579e-02, -3.10916454e-02,
   1.44075528e-01,  8.30006152e-02,  1.10915698e-01,
   1.67114120e-02, -4.11828384e-02,  1.38709366e-01,
   7.67610222e-02, -8.82508755e-02, -3.83544108e-03,
   3.02454410e-03,  8.96851812e-03]],

[[-1.22680843e-01,  9.29156691e-02,  1.24032125e-01,
  -1.56349540e-01, -5.80371395e-02,  2.47790609e-02,
   1.28605917e-01, -1.31432980e-01,  1.17688417e-01,
   3.54333185e-02, -7.29179084e-02, -1.07030243e-01,
   3.67022939e-02,  1.38840392e-01,  6.88146949e-02,
  -1.27811000e-01, -1.14382610e-01, -4.95465659e-03,
   7.00943321e-02,  1.52391613e-01, -8.78099278e-02,
  -1.55963928e-01,  5.30446768e-02, -2.06147525e-02,
  -1.37059465e-02,  1.31358564e-01,  8.29909071e-02,
   6.24938160e-02,  2.52410211e-02, -7.90996626e-02,
   9.80370492e-02,  1.44432366e-01],
 [-9.93269235e-02, -1.64214462e-01,  4.59141620e-02,
  -9.48083848e-02,  1.26117868e-02,  7.32767805e-02,
   8.88923332e-02, -1.50267988e-01, -3.89665328e-02,
   1.30762413e-01,  1.05070196e-01,  1.45238355e-01,
```

```
   -8.05041790e-02, -1.28127173e-01, -7.56547078e-02,
    8.64235610e-02, -4.24838737e-02, -2.99068488e-04,
    1.06451415e-01, -3.68188657e-02, -7.96692595e-02,
   -1.48392111e-01, -1.28999978e-01,  9.67338681e-02,
    3.46082039e-02, -5.55897467e-02,  8.63774344e-02,
   -1.42554089e-01, -1.25038788e-01,  2.72523500e-02,
   -1.62237376e-01,  5.98995201e-02],
  [ 1.17753766e-01,  7.60909021e-02,  1.31999582e-01,
   -9.08713974e-03, -6.18140586e-02,  8.04050788e-02,
   -1.29936393e-02, -3.12164351e-02, -9.68077108e-02,
   -3.54661280e-03, -6.46771863e-02,  8.92770812e-02,
    5.36139943e-02, -1.71392322e-01, -3.84497792e-02,
   -1.08272992e-02,  7.81316832e-02, -1.25815630e-01,
    2.20573856e-03, -7.72438198e-02, -5.78110442e-02,
   -4.99096997e-02, -3.65810394e-02, -4.70468439e-02,
   -7.24415928e-02,  3.82824279e-02,  1.85186490e-01,
   -9.63366479e-02, -1.01434812e-01,  8.67642462e-03,
    2.00230274e-02,  6.49010064e-03]]],


[[[ 1.56864598e-01,  1.51893914e-01, -1.44517019e-01,
    1.12386309e-01,  8.14731419e-02,  2.02344973e-02,
    8.27356279e-02,  1.22515790e-01,  8.90079420e-03,
   -1.76305324e-02,  7.09909648e-02, -4.76421043e-02,
    8.54269564e-02,  1.46211639e-01, -9.48653147e-02,
    4.02112678e-02,  8.39474201e-02, -6.58185780e-02,
   -6.06778217e-03, -1.22044213e-01, -6.08186796e-02,
    3.68744470e-02, -1.27556667e-01,  1.33689255e-01,
    5.03318012e-02, -1.04411200e-01, -1.97228212e-02,
   -8.67015719e-02,  1.79675251e-01,  4.67115790e-02,
    1.29238605e-01, -1.08463846e-01],
  [ 2.11005379e-03,  7.79224783e-02, -3.61965187e-02,
   -4.63297553e-02,  1.83684919e-02,  1.08603410e-01,
    2.00597197e-02, -1.04563661e-01, -1.84665609e-03,
   -1.06990024e-01,  1.73229296e-02,  6.73637390e-02,
   -1.26746356e-01, -5.83564378e-02, -4.35363241e-02,
   -6.99516386e-02, -8.73355381e-03,  6.99344277e-02,
    1.01653017e-01,  1.08869128e-01, -1.02209657e-01,
   -1.03588082e-01,  1.31505951e-01,  9.20896903e-02,
    1.76718619e-04, -1.07962877e-01,  9.03707519e-02,
    4.84215468e-02, -9.59647000e-02,  6.67123497e-02,
   -4.48843613e-02, -6.96909502e-02],
```

```
 [ 1.00330308e-01,  1.11114666e-01, -1.45347640e-02,
   9.46790352e-02, -8.83034393e-02,  4.69644219e-02,
   1.02333426e-01, -2.77465712e-02,  7.84563739e-03,
   7.02427700e-02, -3.97369787e-02,  1.30657583e-01,
   3.50758084e-04, -3.72191742e-02,  1.20221116e-01,
   1.20657898e-01,  7.17914104e-02, -1.13882363e-01,
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```

Saving model

In [27]:
```
if os.path.isfile("cnn.h5") is False:
    cnn.save("cnn.h5")
```

Real time acc

In [28]:
```
def Predict(img):
    class_ = np.argmax(cnn.predict(img))
    return input_types[class_]
```

In [29]:
```
mp_drawing = mp.solutions.drawing_utils
mp_holistic = mp.solutions.holistic
```

In [30]:
```
holistic = mp_holistic.Holistic()
```

In [31]:

```
R = 25
thickness = 2


webcam = 0
capture = cv.VideoCapture(webcam)

fps = int(capture.get(cv.CAP_PROP_FPS))
print("fps is "+str(fps))

_, frame = capture.read()
height, width, channel = frame.shape

while capture.isOpened():
    #time.sleep()
    if cv.waitKey(1) & 0xFF == 13:
        break

    black = np.zeros(shape = frame.shape)

    _, frame = capture.read()

    frame_rgb = cv.cvtColor(frame, cv.COLOR_BGR2RGB)

    result = holistic.process(frame_rgb)

    try:
        hand_landmarks = result.right_hand_landmarks.landmark
        if hand_landmarks:
            x_max = 0
            y_max = 0
            x_min = width
            y_min = height
            for i in range(0,21,1):
                lm = hand_landmarks[i]
                x, y = int(lm.x * width), int(lm.y * height)
                if x > x_max:
                    x_max = x
                if x < x_min:
                    x_min = x
                if y > y_max:
```

```
                y_max = y
            if y < y_min:
                y_min = y

        frame_bgr = cv.cvtColor(frame_rgb, cv.COLOR_RGB2BGR)

        mp_drawing.draw_landmarks(frame_bgr, result.right_hand_landmarks, mp_holistic.HAND_CONNECTIONS)

        cv.rectangle(frame_bgr, (x_min - R, y_min - R), (x_max + R, y_max + R), (0, 255, 0), thickness)

        result1 = frame_bgr

        mirror1 = cv.flip(result1, 1)


        '''

        '''
        mp_drawing.draw_landmarks(black, result.right_hand_landmarks, mp_holistic.HAND_CONNECTIONS)

        croped = black[y_min - R + thickness: y_max + R - thickness, x_min - R + thickness : x_max + R - thickness
]

        resized = cv.resize(croped, (96, 96))

        mirror2 = cv.flip(resized, 1)

        result2 = mirror2

        img_mat = np.array([result2])

        class_ = Predict(img_mat)

        cv.putText(mirror1, str(class_), (100, 100), cv.FONT_HERSHEY_PLAIN, 2, (255,0,0), 1)

        cv.imshow("Frame2", result2)
    except:
        result1 = frame
        mirror1 = cv.flip(result1, 1)
        #result2 = black
        pass
```

```
    cv.imshow('frame1', mirror1)

capture.release()
cv.destroyAllWindows()
```

```
fps is 30
```

In [ ]: