Pattern recognition

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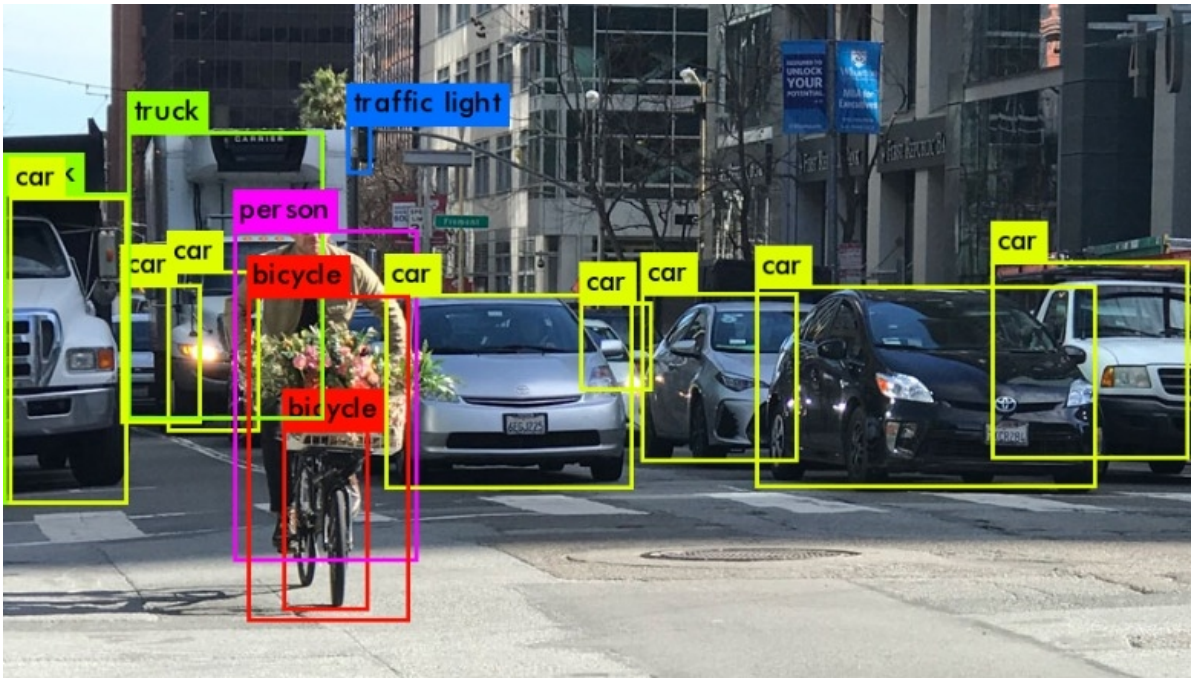
- Pattern recognition
- `cvzone` and `mediapipe`

Pattern recognition



- Template matching is one of the most primitive and basic pattern recognition methods. It studies where the pattern of a specific object is located in the image, and then recognizes the object. This is a matching problem
- The principle of template matching is very similar to that of convolution
- The template ***slides*** from the origin on the original image, and the difference between the template and the image covered by the template is calculated.

cv.TM_SQDIFF

$$R(x,y)=\sum_{x',y'}\left(T\left(x',y'\right)-I\left(x+x',y+y'\right)\right)^2$$

cv.TM_SQDIFF_NORMED

$$R(x,y)=\frac{\sum_{x',y'}\left(T\left(x',y'\right)-I\left(x+x',y+y'\right)\right)^2}{\sqrt{\sum_{x',y'}T(x',y')^2\cdot\sum_{x',y'}I(x+x',y+y')^2}}$$

cv.TM_CCORR

$$R(x,y) = \sum_{x',y'} \left(T\left(x',y'\right) \cdot I\left(x+x',y+y'\right) \right)$$

cv.TM_CCORR_NORMED

$$R(x,y) = \frac{\sum_{x',y'} \left(T\left(x',y'\right) \cdot I\left(x+x',y+y'\right) \right)}{\sqrt{\sum_{x',y'} T\left(x',y'\right)^2 \cdot \sum_{x',y'} I\left(x+x',y+y'\right)^2}}$$

cv.TM_CCOEFF

$$R(x,y) = \sum_{x',y'} \left(T'\left(x',y'\right) \cdot I'\left(x+x',y+y'\right) \right)$$

$$T'\left(x',y'\right) = T\left(x',y'\right) - 1/(w \cdot h) \cdot \sum_{x'',y''} T\left(x'',y''\right)$$

$$I'\left(x+x',y+y'\right) = I\left(x+x',y+y'\right) - 1/(w \cdot h) \cdot \sum_{x'',y''} I\left(x+x'',y+y''\right)$$

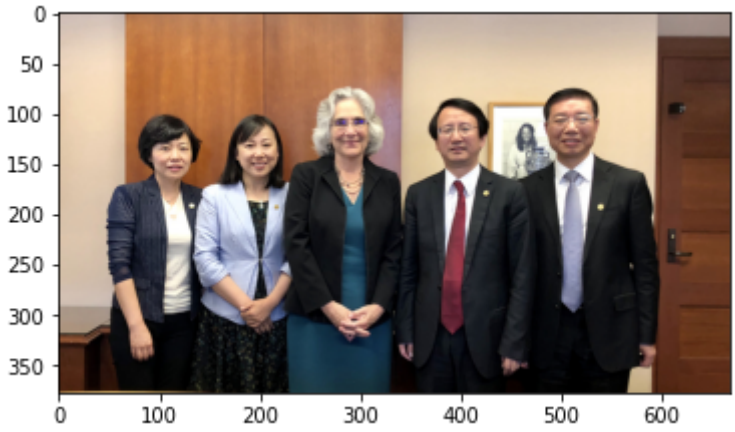
cv.TM_CCOEFF_NORMED

$$R(x,y) = \frac{\sum_{x',y'} \left(T'\left(x',y'\right) \cdot I'\left(x+x',y+y'\right) \right)}{\sqrt{\sum_{x',y'} T'(x',y')^2 \cdot \sum_{x',y'} I'(x+x',y+y')^2}}$$

```
import cv2
from matplotlib import pyplot as plt
import numpy as np
import matplotlib.colors as mat_color

def read_image(path="./images/wu.jpg", flags=cv2.IMREAD_COLOR):
    img_bgr = cv2.imread(path)
    img_rgb = cv2.cvtColor(img_bgr, cv2.COLOR_BGR2RGB)
    print(img_rgb.shape)
    return img_rgb

no_norm = mat_color.Normalize(vmin=0, vmax=255, clip=False)
img_wu = read_image()
plt.imshow(img_wu, norm=no_norm)
```

```
(378, 668, 3)
```

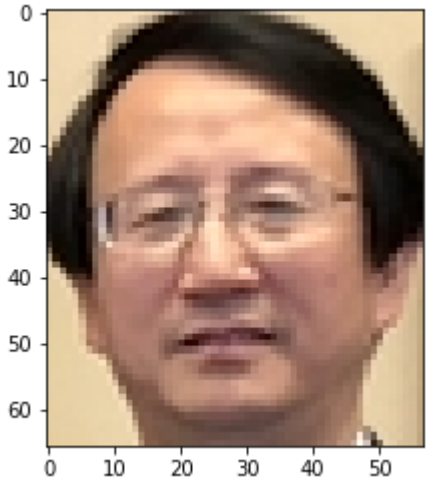
```
<matplotlib.image.AxesImage at 0x1a01f818a90>
```




```
img_wu_tem = read_image("./images/wu_tem.jpg")
plt.imshow(img_wu_tem, norm=no_norm)
```

```
(66, 57, 3)
```

```
<matplotlib.image.AxesImage at 0x1a01f92791O>
```

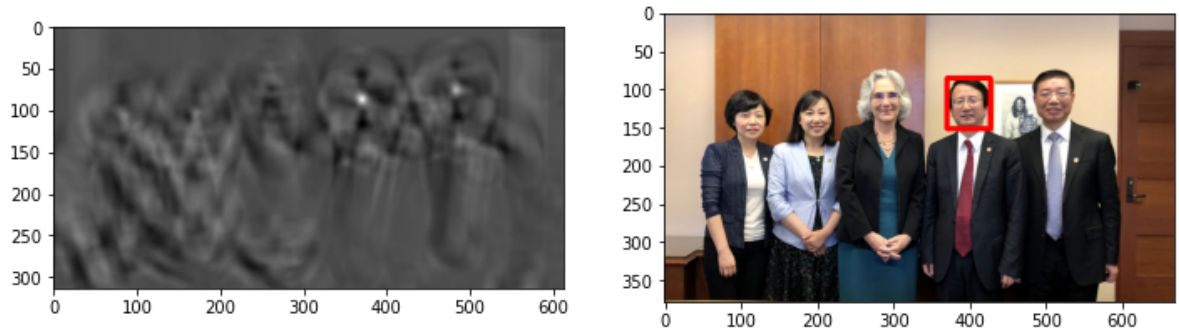



```
width, height = img_wu_tem.shape[0], img_wu_tem.shape[1]

methods = [cv2.TM_CCOEFF, cv2.TM_CCOEFF_NORMED, cv2.TM_CCORR,
```

```
            cv2.TM_CCORR_NORMED, cv2.TM_SQDIFF, cv2.TM_SQDIFF_NORMED]

def show_wu_face(mathod, color=(255, 0, 0)):
    plt.figure(figsize=(12, 4))
    res = cv2.matchTemplate(img_wu, img_wu_tem, mathod)
    plt.subplot(1, 2, 1)
    plt.imshow(res, cmap = 'gray')
    plt.subplot(1, 2, 2)
    min_val, max_val, min_loc, max_loc = cv2.minMaxLoc(res)
    print(min_val, max_val, min_loc, max_loc)
    top_left = min_loc if mathod in [cv2.TM_SQDIFF, cv2.TM_SQDIFF_NORMED]
else max_loc
    bottom_right = (top_left[0] + height, top_left[1] + width)
    img_wu_detect = cv2.rectangle(np.copy(img_wu),
                                  top_left, bottom_right, color, 5)
    plt.imshow(img_wu_detect, norm=no_norm)
```

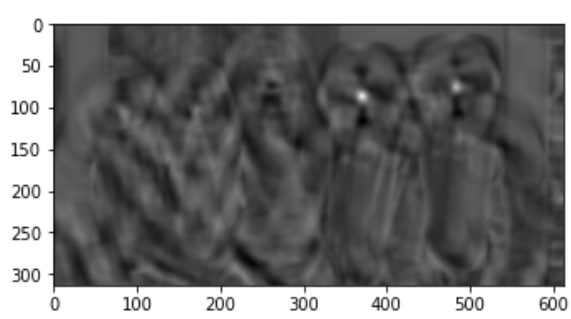
```
show_wu_face(methods[0])
```

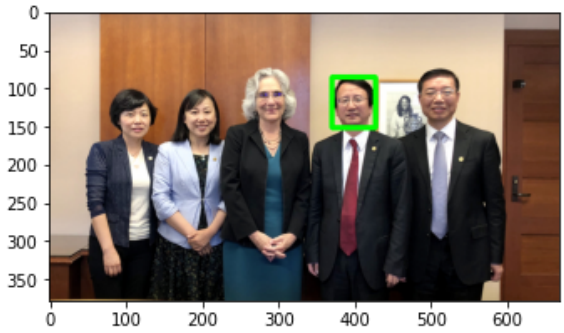
```
-21032008.0 47274936.0 (370, 116) (370, 86)
```




```
show_wu_face(methods[1], (0, 255, 0))
```

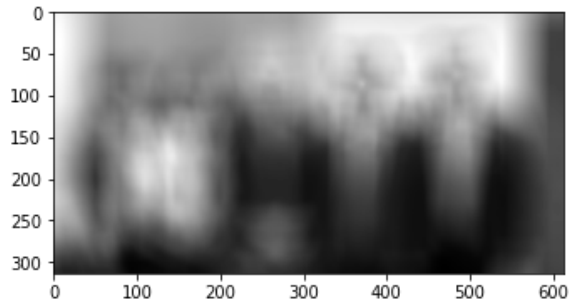
```
-0.4156877100467682 0.9993270635604858 (370, 116) (370, 86)
```

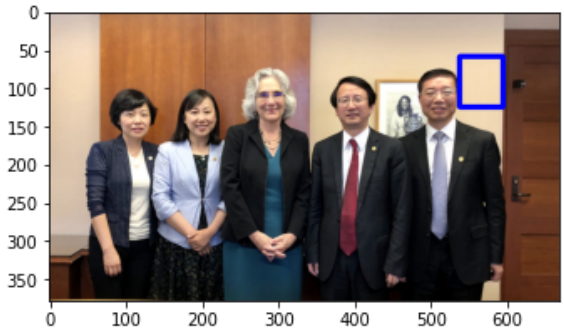




```
print("This is a bad algorithm")
show_wu_face(methods[2], (0, 0, 255))
```

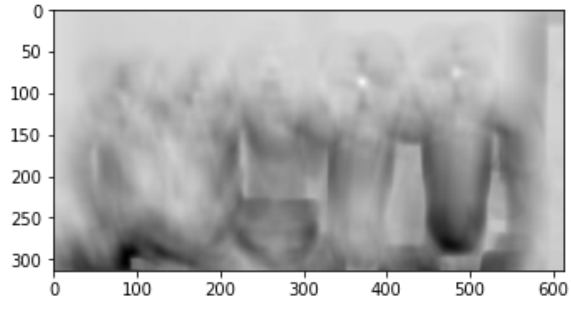
```
This is a bad algorithm
7438519.5 326176640.0 (470, 312) (537, 59)
```

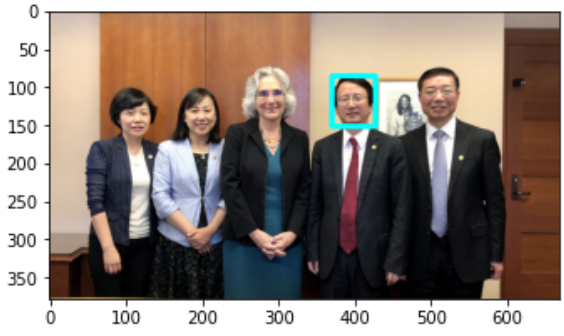




```
show_wu_face(methods[3], (0, 255, 255))
```

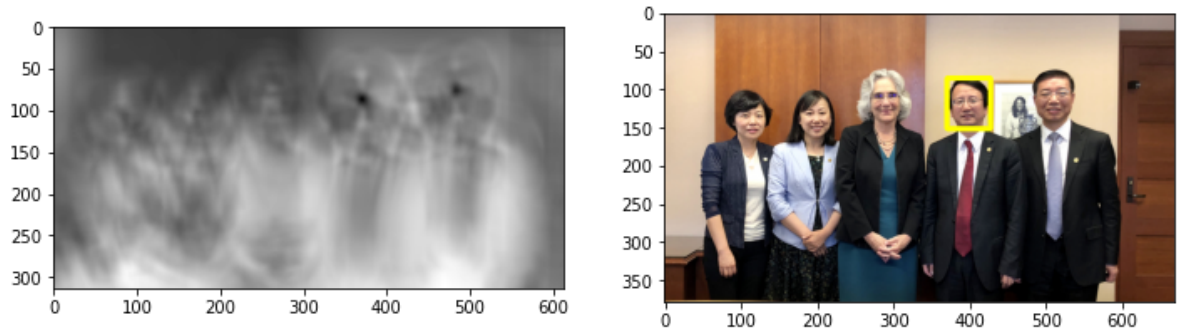
```
0.29923704266548157 0.9998716115951538 (88, 292) (370, 86)
```





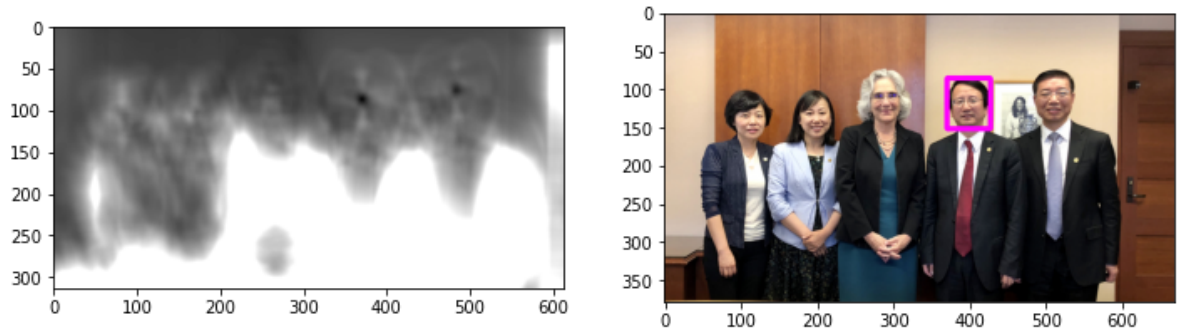
```
show_wu_face(methods[4], (255, 255, 0))
```

```
63684.0 233722720.0 (370, 86) (470, 312)
```



```
show_wu_face(methods[5], (255, 0, 255))
```

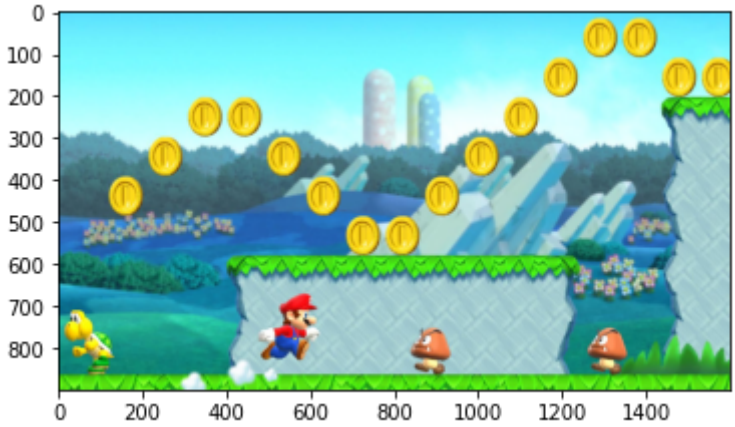
```
0.0002567677292972803 1.0 (370, 86) (607, 22)
```



```
img_ma = read_image("./images/mario.jpg")
plt.imshow(img_ma, norm=no_norm)
```

```
(900, 1600, 3)
```

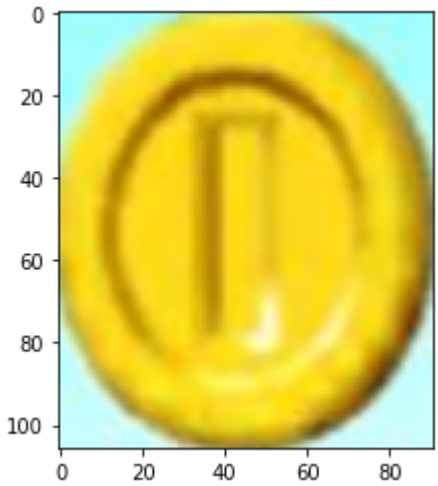
```
<matplotlib.image.AxesImage at 0x1a021e2550>
```




```
img_tem = read_image("./images/coin.png")
plt.imshow(img_tem, norm=no_norm)
```

```
(106, 91, 3)
```

```
<matplotlib.image.AxesImage at 0x1a0227f37f0>
```

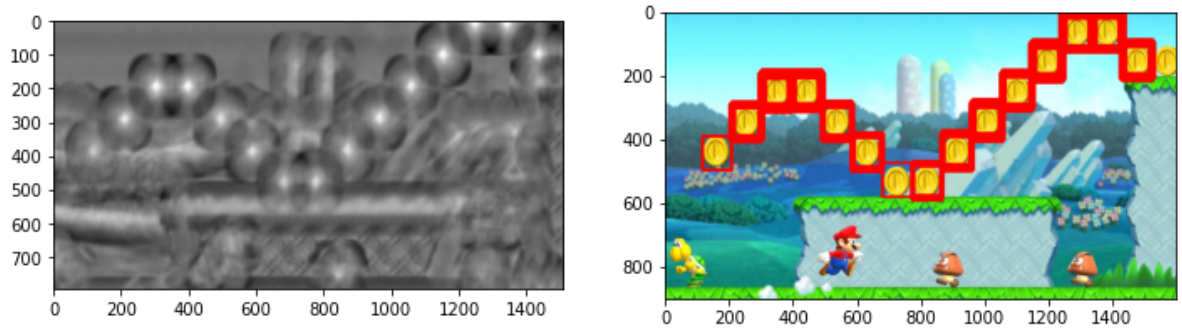



```
width, height = img_tem.shape[0], img_tem.shape[1]

res = cv2.matchTemplate(img_ma, img_tem, cv2.TM_CCOEFF_NORMED)
threshold = 0.4
loc = np.where(res >= threshold)
```

```
img_ma_copy = np.copy(img_ma)
print(loc)
for pt in zip( * loc[::-1]):
    cv2.rectangle(img_ma_copy, pt, (pt[0] + height, pt[1] + width), (255,
0, 0), 3)

def show_mario(res, img):
    plt.figure(figsize=(12, 7))
    plt.subplot(1, 2, 1)
    plt.imshow(res, cmap = 'gray')
    plt.subplot(1, 2, 2)
    plt.imshow(img, norm=no_norm)
```

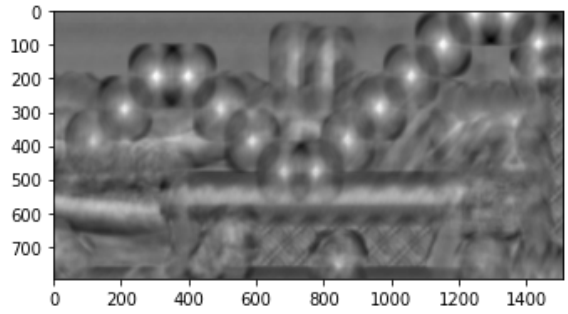
```
(array([  0,   0,   0, ..., 488, 488, 488], dtype=int64), array([1238,
1239, 1240, ...,  774,  775,  776], dtype=int64))
```

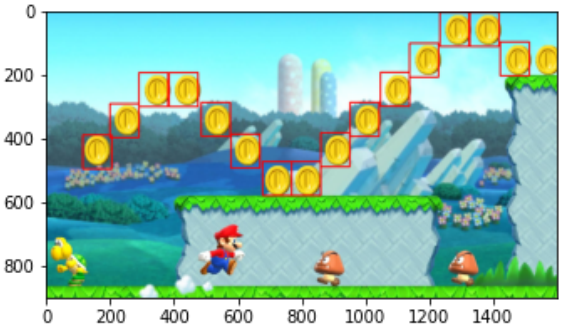
```
show_mario(res, img_ma_copy)
```




```
img_ma_copy = np.copy(img_ma)
last_width = 0
points = [pt for pt in zip( * loc[::-1])]
points = sorted(points, key=lambda x:x[0])
last_width = 0
for pt in points:
    if np.abs(pt[0] - last_width) < 50:
        continue
    last_width = pt[0]
    cv2.rectangle(img_ma_copy, pt, (pt[0] + height, pt[1] + width), (255,
0, 0), 3)
```

```
show_mario(res, img_ma_copy)
```





Solve by Image Gradient?

- All the above algorithms compare the similarity by calculating the pixel value
  - Too rigid, inflexible, sometimes naive
  - Not universal
  - Not robust
- Use image gradient to illustrate similarity
  - More robust and universal

```
img_wu_2 = read_image("./images/wu_2.jpeg")
plt.imshow(img_wu_2, norm=no_norm)
```

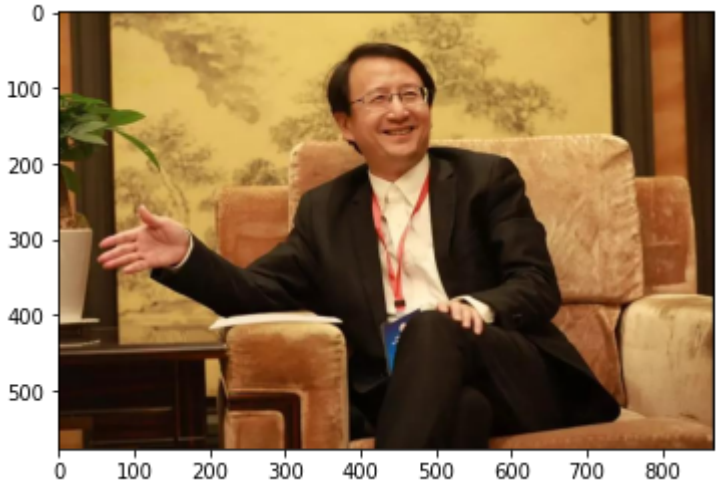
```
(533, 799, 3)
```

```
<matplotlib.image.AxesImage at 0x1a020d9fd30>
```

```
img_wu_3 = read_image("./images/wu_4.jpg")
plt.imshow(img_wu_3, norm=no_norm)
```

```
(577, 868, 3)
```

```
<matplotlib.image.AxesImage at 0x1a020c5f4c0>
```




```
# On line 3 we load the sift algorithm.
# On lines 4 and 5 we find the keypoints and descriptors of the original
image
# and of the image to compare.
sift = cv2.xfeatures2d.SIFT_create()
kp_1, desc_1 = sift.detectAndCompute(img_wu_2, None)
kp_2, desc_2 = sift.detectAndCompute(img_wu_3, None)
# On lines 10, 11 and 12 we load `FlannBasedMatcher` which is
# the method used to find the matches between the descriptors of the 2
images.
# On line 13 we find the matches between the 2 images.
# We're storing the matches in the array 'matches'.
index_params = dict(algorithm=0, trees=5)
search_params = dict()
flann = cv2.FlannBasedMatcher(index_params, search_params)
matches = flann.knnMatch(desc_1, desc_2, k=2)
print("Number of matches ->", len(matches))
```

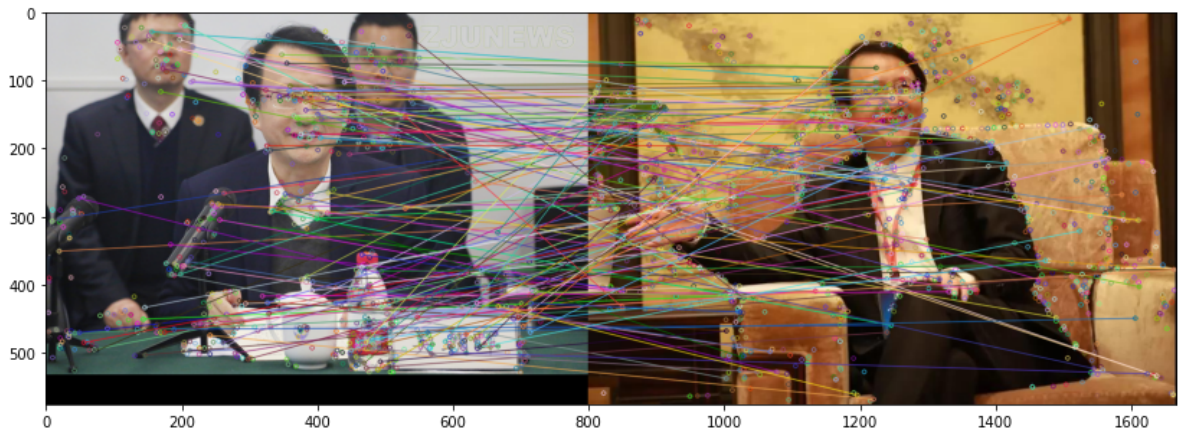
```
Number of matches -> 886
```

```
# In this part we apply the ratio test to select only the good matches.
# The quality of a match is define by the distance.
# The distance is a number, and the lower this number is,
# the more similar the features are.
good_points = []
ratio = 0.88
for m, n in matches:
    if m.distance < ratio * n.distance:
        good_points.append(m)
print("Number of good_points ->", len(good_points))
img_wu_res = cv2.drawMatches(img_wu_2, kp_1, img_wu_3, kp_2, good_points,
None)
```

```
Number of good_points -> 146
```

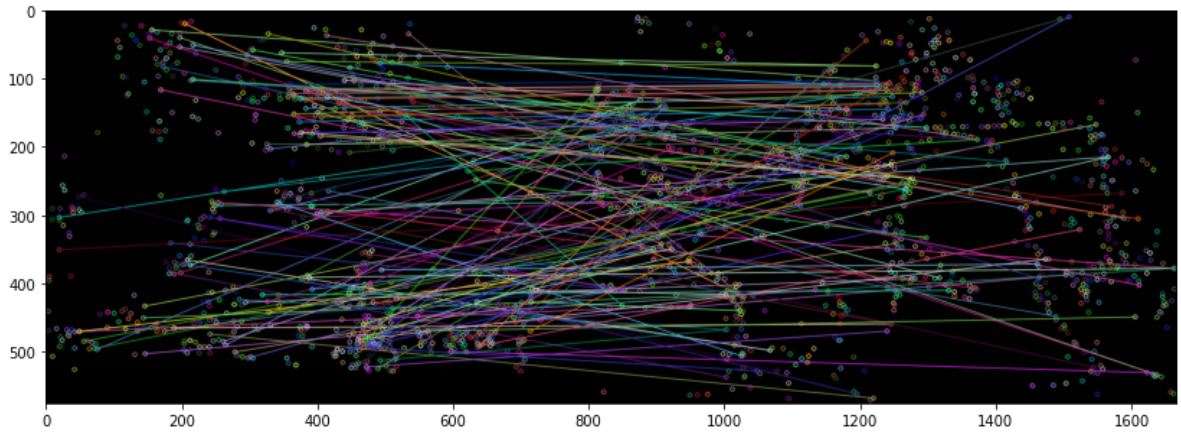
```
plt.figure(figsize=(16, 5))
plt.imshow(img_wu_res, norm=no_norm)
```

```
<matplotlib.image.AxesImage at 0x1a020a08640>
```



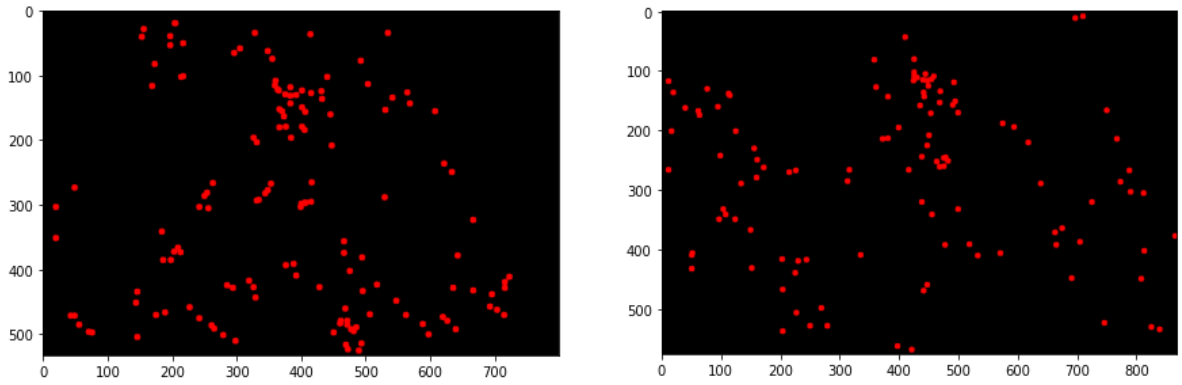
```
img_wu_res_ones = cv2.drawMatches(np.ones(img_wu_2.shape, dtype=np.uint8),
kp_1,
                                  np.ones(img_wu_3.shape, dtype=np.uint8),
kp_2,
                                  good_points, None)
plt.figure(figsize=(16, 5))
plt.imshow(img_wu_res_ones, norm=no_norm)
```

```
<matplotlib.image.AxesImage at 0x1a020ac2280>
```

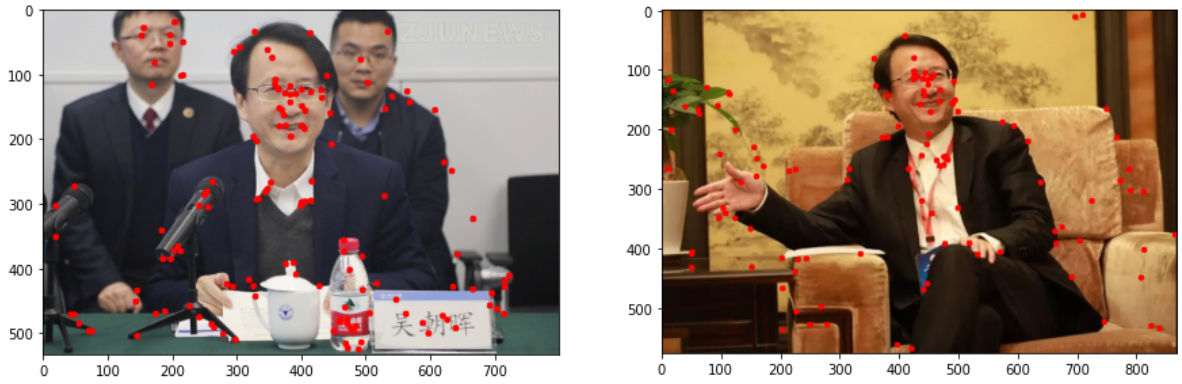



```
def draw_key_pts(good_points, img_2, img_3):
    list_kp_1 = [kp_1[mat.queryIdx].pt for mat in good_points]
    list_kp_2 = [kp_2[mat.trainIdx].pt for mat in good_points]
    for pt in list_kp_1:
        pt = (round(pt[0]), round(pt[1]))
        img_2 = cv2.circle(img_2, pt, 5, (255, 0, 0), -1)
    for pt in list_kp_2:
        pt = (round(pt[0]), round(pt[1]))
        img_3 = cv2.circle(img_3, pt, 5, (255, 0, 0), -1)
    return img_2, img_3

def show_img_den(img_2, img_3, group=None):
    plt.figure(figsize=(15, 5))
    plt.subplot(1, 2, 1)
    plt.imshow(img_2, group, norm=no_norm) if group is not None else
plt.imshow(img_2, norm=no_norm)
    plt.subplot(1, 2, 2)
    plt.imshow(img_3, group, norm=no_norm) if group is not None else
plt.imshow(img_3, norm=no_norm)
```

```
img_wu_den_2, img_wu_den_3 = draw_key_pts(good_points,
                                          img_2=np.zeros(img_wu_2.shape,
dtype=np.uint8),
                                          img_3=np.zeros(img_wu_3.shape,
dtype=np.uint8))
show_img_den(img_wu_den_2, img_wu_den_3)
```



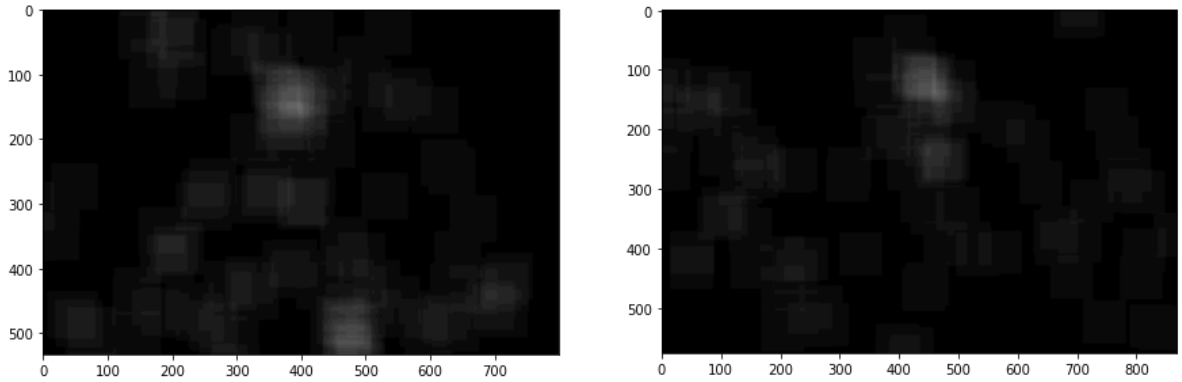
```
img_wu_den_2, img_wu_den_3 = draw_key_pts(good_points,
                                          np.copy(img_wu_2),
np.copy(img_wu_3))
show_img_den(img_wu_den_2, img_wu_den_3)
```



```
def filter_process(good_points, img_2_shape, img_3_shape, radius=2,
                   kernel_size=75, lightness_rate=1.0):
    list_kp_1 = [kp_1[mat.queryIdx].pt for mat in good_points]
    list_kp_2 = [kp_2[mat.trainIdx].pt for mat in good_points]
    def filter_process_single(list_kp, img, radius=radius,
                              kernel_size=kernel_size,
lightness_rate=lightness_rate):
        for pt in list_kp:
            pt = (round(pt[0]), round(pt[1]))
            img = cv2.circle(img, pt, radius, (255, 255, 255), -1)
```

```
        img = cv2.boxFilter(img, -1, (kernel_size, kernel_size),
normalize=True)
        for i in range(img.shape[0]):
            for j in range(img.shape[1]):
                pixel_value = min(round((img[i][j] - 0) * lightness_rate),
255)
                img[i][j] = pixel_value
        return img
    img_2 = filter_process_single(list_kp_1, np.zeros(img_2_shape,
dtype=np.uint8))
    img_3 = filter_process_single(list_kp_2, np.zeros(img_3_shape,
dtype=np.uint8))
    return img_2, img_3
```

```
img_wu_den_2, img_wu_den_3 = filter_process(good_points,
img_wu_2.shape[:2],
                                            img_wu_3.shape[:2],
lightness_rate=9.0)
show_img_den(img_wu_den_2, img_wu_den_3, group="gray")
```




```
def detect_process(img_wu_den, img_ori, radius_rate=1.0):
    min_val, max_val, min_loc, max_loc = cv2.minMaxLoc(img_wu_den)
    radius = max(round(max_val * radius_rate), 100)
    print(min_val, max_val, min_loc, max_loc, radius)
    img_wu_detect = cv2.circle(np.copy(img_ori), max_loc, radius, (255, 0,
0), 5)
    return img_wu_detect
```

```
img_wu_detect_2 = detect_process(img_wu_den_2, np.copy(img_wu_2))
img_wu_detect_3 = detect_process(img_wu_den_3, np.copy(img_wu_3))
show_img_den(img_wu_detect_2, img_wu_detect_3)
```

```
0.0 108.0 (0, 0) (395, 143) 108
0.0 99.0 (0, 0) (457, 123) 100
```

`cvzone` and `mediapipe`

- mediapipe link
- cvzone link
- mediapipe github
- cvzone github

The End

2022.4