Introduction:

Face recognition is a method of identifying or verifying the identity of an individual using their face. There are various algorithms that can do face recognition but their accuracy might vary. Here I am going to describe how we do face recognition using deep learning in this project. It is a technology in computer vision. In Face recognition / detection we locate and visualize the human faces in any digital image. A facial recognition system uses biometrics to map facial features from a photograph or video. It compares the information with a database of known faces to find a match.

Methodology:

Face recognition ml model is a statistical approach used for reducing the number of variables in face recognition. In Face recognition model, every image in the training set is represented as a linear combination of weighted eigenvectors called Eigen faces. These eigenvectors are obtained from covariance matrix of a training image set

- Standardize the data.
- Compute the covariance matrix of the features from the dataset.
- Perform eigen decomposition on the covariance matrix.
- Order the eigenvectors in decreasing order based on the magnitude of their corresponding eigen values.
- Determine k, the number of top principal components to select.
- Construct the projection matrix from the chosen number of top principal components.
- Compute the new k-dimensional feature space.

Screenshot Of Model:

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Import Libraries

First, we need to import matplotlib libraries as well as numpy library.

```
[1] from matplotlib import pyplot as plt
    from matplotlib.image import imread
    import numpy as np
    import os
```

Data loading

```
[2] TRAIN_IMG_FOLDER = (r"/content/sample_data/Training images")
    TEST_IMG_FOLDER =  (r"/content/sample_data/TEST")

    train_set_files = os.listdir(TRAIN_IMG_FOLDER)
    test_set_files = os.listdir(TEST_IMG_FOLDER)

    width  = 128
    height = 128
```

Check: All data from 'train' is included in 'test'?

```
[3] train_id_file = set([f.split('_')[0] for f in train_set_files])
    test_id_file = set([f.split('_')[0] for f in train_set_files])
```

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```
[3] test_id_file = set([f.split('_')[0] for f in train_set_files])
    print(train_id_file <= test_id_file)
```

```
True
```

```
[4] print('Train Images:')

    train_image_names = os.listdir(TRAIN_IMG_FOLDER)
    training_tensor   = np.ndarray(shape=(len(train_image_names), height*width), dtype=np.float64)

    for i in range(len(train_image_names)):
        img = plt.imread(os.path.join(TRAIN_IMG_FOLDER, train_image_names[i]))
        training_tensor[i,:] = np.array(img, dtype='float64').flatten()
        plt.subplot(5,5,1+i)
        plt.imshow(img, cmap='gray')
        plt.tick_params(labelleft='off', labelbottom='off', bottom='off',top='off',right='off',left='off', which='both')
    plt.show()

    print('Test Images:')
    test_image_names = os.listdir(TEST_IMG_FOLDER)#[i for i in dataset_dir if i not in train_image_names]
    testing_tensor   = np.ndarray(shape=(len(test_image_names), height*width), dtype=np.float64)

    for i in range(len(test_image_names)):
        img = imread(os.path.join(TEST_IMG_FOLDER, test_image_names[i]))
        testing_tensor[i,:] = np.array(img, dtype='float64').flatten()
        plt.subplot(8,5,1+i)
        plt.imshow(img, cmap='gray')
        plt.subplots_adjust(right=1.2, top=1.2)
        plt.tick_params(labelleft='off', labelbottom='off', bottom='off',top='off',right='off',left='off', which='both')
    plt.show()
```

```
Train Images:
```

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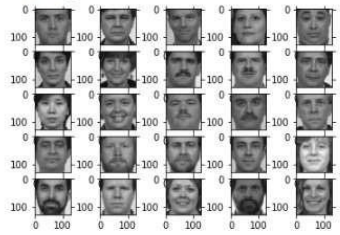
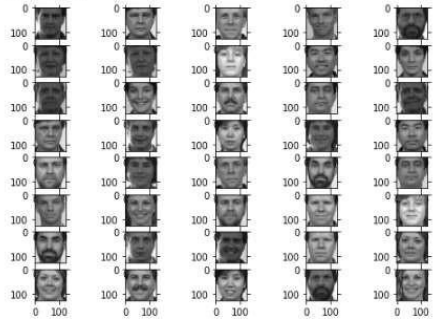
[4]

Train Images:



Test Images:



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Calculate the mean face

The mean is just the sum of all of the pictures divided by the number of pictures. As a result, we will have an "average" face.

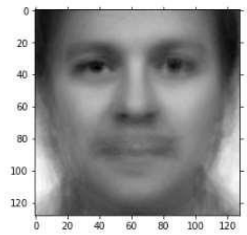
[5]

```
mean_face = np.zeros((1,height*width))

for i in training_tensor:
    mean_face = np.add(mean_face,i)

mean_face = np.divide(mean_face,float(len(train_image_names))).flatten()

plt.imshow(mean_face.reshape(height, width), cmap='gray')
plt.tick_params(labelleft='off', labelbottom='off', bottom='off',top='off',right='off',left='off', which='both')
plt.show()
```



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From the covariance we can extract the eigenvectors. Fortunately, there is a function that helps us in this step. There is plenty of information in the internet about eigenvectors but the general idea is that eigenvectors are the vectors of the covariance that describe the direction of the data.

```
[9]  #eigenvalues and eigenvectors
     eigenvalues, eigenvectors, = np.linalg.eig(cov_matrix)
     print('eigenvalues.shape: {} eigenvectors.shape: {}'.format(eigenvalues.shape, eigenvectors.shape))
```

```
eigenvalues.shape: (25,) eigenvectors.shape: (25, 25)
```

```
[10] eig_pairs = [(eigenvalues[index], eigenvectors[:,index]) for index in range(len(eigenvalues))]

     # Sort the eigen pairs in descending order:
     eig_pairs.sort(reverse=True)
     eigvalues_sort  = [eig_pairs[index][0] for index in range(len(eigenvalues))]
     eigvectors_sort = [eig_pairs[index][1] for index in range(len(eigenvalues))]

     sorted_ind = sorted(range(eigenvalues.shape[0]), key=lambda k: eigenvalues[k], reverse=True)

     eigvalues_sort = eigenvalues[sorted_ind]
     eigvectors_sort = eigenvectors[sorted_ind]
     train_set_files_sort = np.array(train_set_files)[sorted_ind]
```

Find cumulative variance of each principle component

```
[11] var_comp_sum = np.cumsum(eigvalues_sort)/sum(eigvalues_sort)

     # Show cumulative proportion of varaince with respect to components
```

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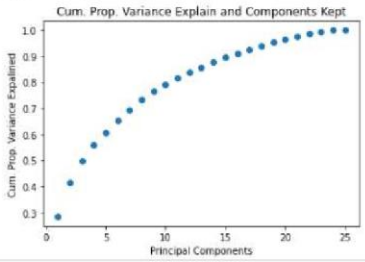
```
[11] var_comp_sum = np.cumsum(eigvalues_sort)/sum(eigvalues_sort)

     # Show cumulative proportion of varaince with respect to components
     print("Cumulative proportion of variance explained vector: \n%s" %var_comp_sum)

     # x-axis for number of principal components kept
     num_comp = range(1,len(eigvalues_sort)+1)
     plt.title('Cum. Prop. Variance Explain and Components Kept')
     plt.xlabel('Principal Components')
     plt.ylabel('Cum. Prop. Variance Expalined')

     plt.scatter(num_comp, var_comp_sum)
     plt.show()
```

```
Cumulative proportion of variance explained vector:
[0.28481989 0.41576165 0.49714907 0.55777059 0.60785024 0.65427472
 0.69489721 0.73168527 0.7641529  0.7916646  0.81546473 0.83669985
 0.85752859 0.87642433 0.89418977 0.91069532 0.92659352 0.94017913
 0.95309028 0.96500642 0.97612862 0.98491526 0.99275274 1.
 1.         ]
```



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Choose the necessary of principal components:

```
[12] reduced_data = np.array(eigvectors_sort[:25]).transpose()
     reduced_data.shape
```

```
(25, 25)
```

```
[13] print(training_tensor.transpose().shape, reduced_data.shape)
```

```
(16384, 25) (25, 25)
```

Calculate eigenfaces

Each eigenvector is multiplied by the whole normalized training set matrix and as a result, we will have the same amount of eigenfaces as images in our training set.

```
[14] proj_data = np.dot(training_tensor.transpose(),reduced_data)
     proj_data = proj_data.transpose()
     proj_data.shape
```

```
(25, 16384)
```

Plot eigen faces

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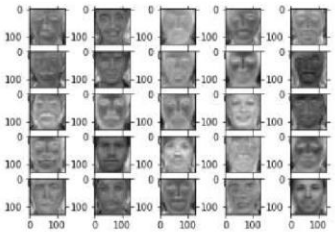
```
[15] for i in range(proj_data.shape[0]):
         img = proj_data[i].reshape(height,width)
         plt.subplot(5,5,1+i)
         plt.imshow(img, cmap='gray')
         plt.tick_params(labelleft='off', labelbottom='off', bottom='off',top='off',right='off',left='off', which='both')
     plt.show()
```



Finding weights for each traning image

Each normalized face in the training set multiplies each eigenface. Consequently, there will be N set of weights with M elements (N = amount of pictures in the training set, M = number of eigenfaces).

```
[16] w = np.array([np.dot(proj_data,i) for i in normalised_training_tensor])
     print(w.shape)
```

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```
(25, 25)
```

Reconizing all test images

```
[17] def recogniser(test_image_names, train_image_names,proj_data,w, t0=2e8, prn=False):

        count       = 0
        num_images  = 0
        correct_pred = 0

        result = []
        wts = []

        #False match rate (FMR)
        FMR_count = 0

        #False non-match rate (FNMR)
        FNMR_count = 0


        test_image_names2 = sorted(test_image_names)

        for img in test_image_names2:
            #img = imread(os.path.join(TEST_IMG_FOLDER, test_image_names[i]))
            unknown_face = plt.imread(os.path.join(TEST_IMG_FOLDER, img))
            num_images += 1

            unknown_face_vector = np.array(unknown_face, dtype='float64').flatten()
            normalised_uface_vector = np.subtract(unknown_face_vector,mean_face)

            w_unknown = np.dot(proj_data, normalised_uface_vector)
```

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```
[17]        w_unknown = np.dot(proj_data, normalised_uface_vector)
            diff  = w - w_unknown
            norms = np.linalg.norm(diff, axis=1)
            index = np.argmin(norms)

            wts.append([count, norms[index]])

            if prn: print('Input:'+'.'.join(img.split('.')[:2]), end='\t')
            count+=1

            match = img.split('_')[0] == train_image_names[index].split('_')[0]
            if norms[index] < t0: # It's a face
                if match:
                    if prn: print('Matched:' + train_image_names[index], end = '\t')
                    correct_pred += 1
                    result.append(1)
                else:
                    if prn: print('F/Matched:'+train_image_names[index], end = '\t')
                    result.append(0)
                    FMR_count += 1
            else:
                if match:
                    if prn: print('Unknown face!'+train_image_names[index], end = '\t')
                    FNMR_count +=1

                else:
                    pass
                    correct_pred += 1



            if prn: print(norms[index], end=' ')
            if prn: print()
```

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```
[17]    FMR = FMR_count/num_images
        FNMR = FNMR_count/num_images


        print('Correct predictions: {}/{} = {} \t\t'.format(correct_pred, num_images, correct_pred/num_images), end=' ')
        print('FMR: {} \t'.format(FMR), end=' ')
        print('FNMR: {} \t'.format(FNMR))



        return wts, result, correct_pred, num_images, FMR, FNMR


wts, result, correct_pred, num_images, FMR, FNMR =recogniser(test_image_names, train_image_names,proj_data,w, t0=2e8, prn=True)
```

```
Input:00770_960530_fa.jpg       Matched:00770_960530_fa.jpg     0.0
Input:00770_960530_fa_a.jpg     F/Matched:00744_941201_fa.jpg   40443667.467302494
Input:00771_941205_fa.jpg       Matched:00771_941205_fa.jpg     0.0
Input:00771_941205_fb.jpg       Matched:00771_941205_fa.jpg     12411902.37011687
Input:00772_941201_fa.jpg       Matched:00772_941201_fa.jpg     0.0
Input:00772_941201_fb.jpg       F/Matched:00763_941201_fa.jpg   21167349.767040696
Input:00773_941201_fa.jpg       Matched:00773_941201_fa.jpg     0.0
Input:00773_941201_fb.jpg       Matched:00773_941201_fa.jpg     21385298.893085312
Input:00775_941205_fa.jpg       Matched:00775_941205_fa.jpg     0.0
Input:00775_941205_fb.jpg       Matched:00775_941205_fa.jpg     9590985.449027378
Input:00779_941205_fa.jpg       Matched:00779_941205_fa.jpg     0.0
Input:00779_941205_fb.jpg       Matched:00779_941205_fa.jpg     38922068.407121904
Input:00781_941205_fa.jpg       Matched:00781_941205_fa.jpg     0.0
Input:00781_941205_fb.jpg       F/Matched:00804_941205_fa.jpg   14277462.667984799
Input:00787_941205_fa.jpg       Matched:00787_941205_fa.jpg     0.0
Input:00787_941205_fb.jpg       F/Matched:00744_941201_fa.jpg   32827038.49216738
Input:00794_941205_fa.jpg       Matched:00794_941205_fa.jpg     0.0
Input:00794_941205_fb.jpg       F/Matched:00775_941205_fa.jpg   13696831.306772245
Input:00797_941205_fa.jpg       Matched:00797_941205_fa.jpg     0.0
Input:00797_941205_fb.jpg       Matched:00797_941205_fa.jpg     22738402.814766508
Input:00804_941205_fa.jpg       Matched:00804_941205_fa.jpg     0.0
```

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[17]

```
Input:00772_941201_fb.jpg       F/Matched:00763_941201_fa.jpg   21167349.767040696
Input:00773_941201_fa.jpg       Matched:00773_941201_fa.jpg     0.0
Input:00773_941201_fb.jpg       Matched:00773_941201_fa.jpg     21385298.893085312
Input:00775_941205_fa.jpg       Matched:00775_941205_fa.jpg     0.0
Input:00775_941205_fb.jpg       Matched:00775_941205_fa.jpg     9590985.449027378
Input:00779_941205_fa.jpg       Matched:00779_941205_fa.jpg     0.0
Input:00779_941205_fb.jpg       Matched:00779_941205_fa.jpg     38922068.407121904
Input:00781_941205_fa.jpg       Matched:00781_941205_fa.jpg     0.0
Input:00781_941205_fb.jpg       F/Matched:00804_941205_fa.jpg   14277462.667984799
Input:00787_941205_fa.jpg       Matched:00787_941205_fa.jpg     0.0
Input:00787_941205_fb.jpg       F/Matched:00744_941201_fa.jpg   32827038.49216738
Input:00794_941205_fa.jpg       Matched:00794_941205_fa.jpg     0.0
Input:00794_941205_fb.jpg       F/Matched:00775_941205_fa.jpg   13696831.306772245
Input:00797_941205_fa.jpg       Matched:00797_941205_fa.jpg     0.0
Input:00797_941205_fb.jpg       Matched:00797_941205_fa.jpg     22738402.814766508
Input:00804_941205_fa.jpg       Matched:00804_941205_fa.jpg     0.0
Input:00804_941205_fb.jpg       Matched:00804_941205_fa.jpg     23695586.065497693
Input:00806_941205_fa.jpg       Matched:00806_941205_fa.jpg     0.0
Input:00806_941205_fb.jpg       Matched:00806_941205_fa.jpg     22783423.946304042
Input:00807_941205_fa.jpg       Matched:00807_941205_fa.jpg     0.0
Input:00807_941205_fb.jpg       Matched:00807_941205_fa.jpg     19176199.70993461
Input:00809_941205_fa.jpg       F/Matched:00761_941201_fa.jpg   13086008.769753503
Input:00809_941205_fb.jpg       F/Matched:00761_941201_fa.jpg   22463983.150025778
Input:00816_941205_fa.jpg       F/Matched:00766_941201_fa.jpg   16977907.094736833
Input:00816_941205_fb.jpg       F/Matched:00794_941205_fa.jpg   10808932.965668682
Input:00876_960530_fa.jpg       F/Matched:00744_941201_fa.jpg   55433907.515527114
Input:00876_960530_fb.jpg       F/Matched:00744_941201_fa.jpg   44354768.59399727
Input:00879_960530_fa.jpg       F/Matched:00797_941205_fa.jpg   44897093.13547301
Input:00879_960530_fb.jpg       F/Matched:00797_941205_fa.jpg   42228054.24150416
Input:00894_960530_fa.jpg       F/Matched:00781_941205_fa.jpg   40255117.39147155
Input:00894_960530_fb.jpg       F/Matched:00781_941205_fa.jpg   37625178.90044492
Input:00900_960530_fa.jpg       F/Matched:00745_941201_fa.jpg   55566607.45522714
Input:00900_960530_fb.jpg       F/Matched:00745_941201_fa.jpg   50361147.60444721
Input:00903_960530_fa.jpg       F/Matched:00745_941201_fa.jpg   91323857.85102612
Input:00903_960530_fb.jpg       F/Matched:00745_941201_fa.jpg   54705102.14316325
Correct predictions: 21/40 = 0.525              FMR: 0.475      FNMR: 0.0
```

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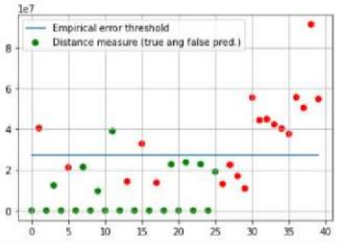
```
[18] def rg(r):
         if r: return 'g'
         else: return 'r'
     cl = [rg(r) for r in result]

     x=[x[0] for x in wts]
     y=[y[1] for y in wts]
     plt.scatter(x,y, color=cl, label = 'Distance measure (true ang false pred.)')

     x2=[x[0] for x in wts]
     y2=[2.7e7 for y in wts]

     plt.plot(x2,y2, label = 'Empirical error threshold')
     plt.legend()
     plt.grid()

     plt.show()
```



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```
[19] CPR_list, t0_list, FMR_list, FNMR_list = [], [] , [] , []
     for t0 in np.linspace(start=0, stop=1e8, num=20):
         print('{:e}'.format(t0), end=' ')
         wts, result, correct_pred, num_images, FMR, FNMR = recogniser(test_image_names, train_image_names,proj_data,w, t0)

         CPR_list.append(correct_pred/num_images)
         t0_list.append(t0)
         FMR_list.append(FMR)
         FNMR_list.append(FNMR)
```

```
0.000000e+00 Correct predictions: 19/40 = 0.475              FMR: 0.0        FNMR: 0.525
5.263158e+06 Correct predictions: 32/40 = 0.8          FMR: 0.0        FNMR: 0.2
1.052632e+07 Correct predictions: 33/40 = 0.825              FMR: 0.0        FNMR: 0.175
1.578947e+07 Correct predictions: 30/40 = 0.75         FMR: 0.1        FNMR: 0.15
2.105263e+07 Correct predictions: 30/40 = 0.75         FMR: 0.125      FNMR: 0.125
2.631579e+07 Correct predictions: 32/40 = 0.8          FMR: 0.175      FNMR: 0.025
3.157895e+07 Correct predictions: 32/40 = 0.8          FMR: 0.175      FNMR: 0.025
3.684211e+07 Correct predictions: 31/40 = 0.775              FMR: 0.2        FNMR: 0.025
4.210526e+07 Correct predictions: 29/40 = 0.725              FMR: 0.275      FNMR: 0.0
4.736842e+07 Correct predictions: 26/40 = 0.65         FMR: 0.35       FNMR: 0.0
5.263158e+07 Correct predictions: 25/40 = 0.625              FMR: 0.375      FNMR: 0.0
5.789474e+07 Correct predictions: 22/40 = 0.55         FMR: 0.45       FNMR: 0.0
6.315789e+07 Correct predictions: 22/40 = 0.55         FMR: 0.45       FNMR: 0.0
6.842105e+07 Correct predictions: 22/40 = 0.55         FMR: 0.45       FNMR: 0.0
7.368421e+07 Correct predictions: 22/40 = 0.55         FMR: 0.45       FNMR: 0.0
7.894737e+07 Correct predictions: 22/40 = 0.55         FMR: 0.45       FNMR: 0.0
8.421053e+07 Correct predictions: 22/40 = 0.55         FMR: 0.45       FNMR: 0.0
8.947368e+07 Correct predictions: 22/40 = 0.55         FMR: 0.45       FNMR: 0.0
9.473684e+07 Correct predictions: 21/40 = 0.525              FMR: 0.475      FNMR: 0.0
1.000000e+08 Correct predictions: 21/40 = 0.525              FMR: 0.475      FNMR: 0.0
```

```
[20] x1=t0_list
     y1=FMR_list
```

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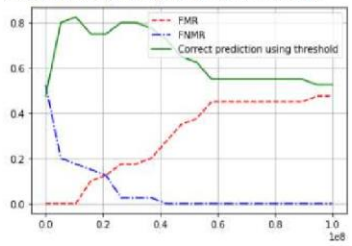
```
[20] x1=t0_list
     y1=FMR_list

     x2=t0_list
     y2=FNMR_list

     x3=t0_list
     y3=CPR_list

     plt.plot(x1,y1, ls='--', color='r', label='FMR',)
     plt.plot(x2,y2, ls='-.', color='b', label='FNMR')
     plt.plot(x3,y3, color='g', label='Correct prediction using threshold')

     plt.grid()
     plt.legend()
```

```
<matplotlib.legend.Legend at 0x7fbec23ae7d0>
```



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Visualization of prediction result on all test images

```
count       = 0
num_images  = 0
correct_pred = 0
def Visualization(img, train_image_names,proj_data,w, t0):
    global count,highest_min,num_images,correct_pred
    unknown_face         = plt.imread(os.path.join(TEST_IMG_FOLDER, img))
    num_images           += 1
    unknown_face_vector = np.array(unknown_face, dtype='float64').flatten()
    normalised_uface_vector = np.subtract(unknown_face_vector,mean_face)

    plt.subplot(40,2,1+count)
    plt.imshow(unknown_face, cmap='gray')
    plt.title('Input:'+'.'.join(img.split('.')[:2]))
    plt.tick_params(labelleft='off', labelbottom='off', bottom='off',top='off',right='off',left='off', which='both')
    count+=1

    w_unknown = np.dot(proj_data, normalised_uface_vector)
    diff  = w - w_unknown
    norms = np.linalg.norm(diff, axis=1)
    index = np.argmin(norms)



    plt.subplot(40,2,1+count)
    if norms[index] < t0: # It's a face

        match = img.split('_')[0] == train_image_names[index].split('_')[0]
        #if img.split('.')[0] == train_image_names[index].split('.')[0]:
        if match:
```

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```
    if norms[index] < t0: # It's a face

        match = img.split('_')[0] == train_image_names[index].split('_')[0]
        #if img.split('.')[0] == train_image_names[index].split('.')[0]:
        if match:
            #plt.title('Matched:'+'.'.join(train_image_names[index].split('.')[:2]), color='g')
            plt.title('Matched:', color='g')
            plt.imshow(imread(os.path.join(TRAIN_IMG_FOLDER, train_image_names[index])), cmap='gray')
             #img = plt.imread(os.path.join(TRAIN_IMG_FOLDER, train_image_names[i]))
            correct_pred += 1
        else:
            #plt.title('Matched:'+'.'.join(train_image_names[index].split('.')[:2]), color='r')
            plt.title('False matched:', color='r')
            plt.imshow(imread(os.path.join(TRAIN_IMG_FOLDER, train_image_names[index])), cmap='gray')
    else:
        #if img.split('.')[0] not in [i.split('.')[0] for i in train_image_names] and img.split('.')[0] != 'apple':
        if img.split('_')[0] not in [i.split('_')[0] for i in train_image_names]:
            plt.title('Unknown face', color='g')
            correct_pred += 1
        else:
            plt.title('Unknown face', color='r')

    plt.tick_params(labelleft='off', labelbottom='off', bottom='off',top='off',right='off',left='off', which='both')
    plt.subplots_adjust(right=1.2, top=2.5)

    count+=1


fig = plt.figure(figsize=(5, 30))

test_image_names2 = sorted(test_image_names)
for i in range(len(test_image_names2)):
    Visualization(test_image_names2[i], train_image_names,proj_data,w, t0=2.7e7)
```

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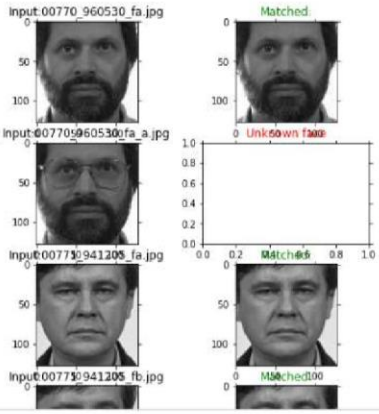
```
    count+=1


fig = plt.figure(figsize=(5, 30))

test_image_names2 = sorted(test_image_names)
for i in range(len(test_image_names2)):
    Visualization(test_image_names2[i], train_image_names,proj_data,w, t0=2.7e7)

plt.show()
```



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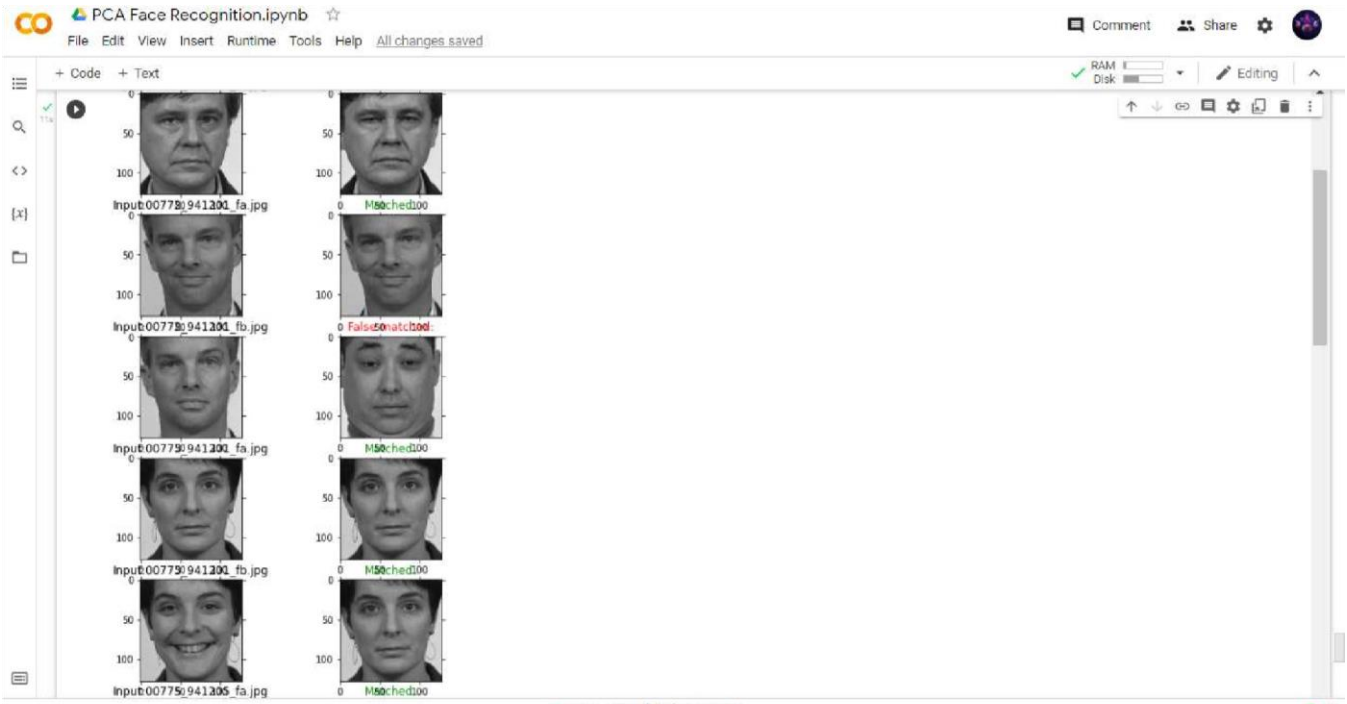
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File Edit View Insert Runtime Tools Help All changes saved
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Editing
Input:00775_941201_fa.jpg
Matched:100
Input:00775_941201_fb.jpg
False match!!
Input:00775_941205_fa.jpg
Input:00775_941205_fb.jpg
11s completed at 5:36 PM


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Disk
Editing
Input:00775_941205_fa.jpg
Input:00775_941205_fb.jpg
Unknown face
Input:00783_941205_fa.jpg
Matched
11s completed at 5:36 PM


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Editing
Input 00781_941205_fb.jpg
False match!!
Input 00785_941205_fa.jpg
Matched
Input 00785_941205_fb.jpg
Unknown face
Input 00798_941205_fa.jpg
Matched
Input 00798_941205_fb.jpg
False match!!
11s completed at 5:36 PM


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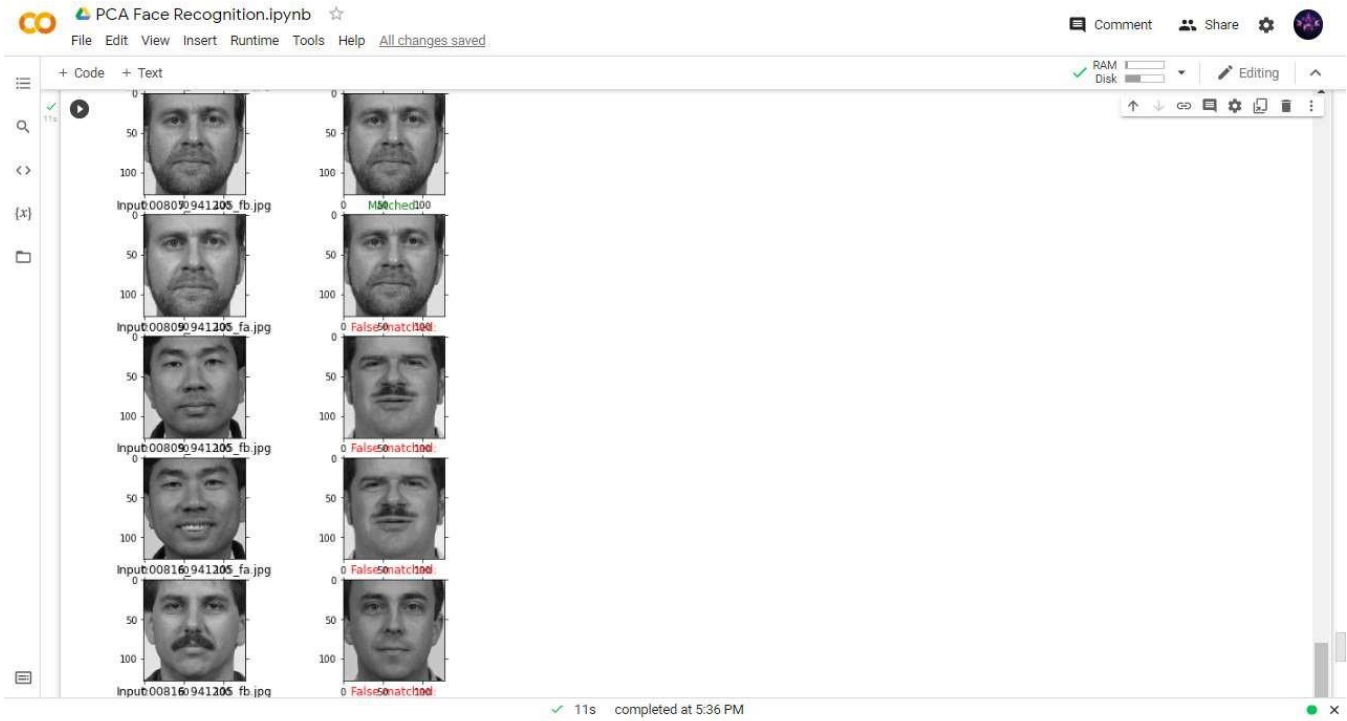
RAM Disk
Editing
Input 00799_941205_fa.jpg
Matched
Input 00799_941205_fb.jpg
Matched
Input 00808_941205_fa.jpg
Matched
Input 00808_941205_fb.jpg
Matched
Input 00806_941205_fa.jpg
Matched
11s completed at 5:36 PM


PCA Face Recognition.ipynb
File Edit View Insert Runtime Tools Help All changes saved
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RAM Disk
Editing
Input 00809_941205_fb.jpg
Matched
Input 00809_941205_fa.jpg
False match
Input 00809_941205_fb.jpg
False match
Input 00816_941205_fa.jpg
False match
Input 00816_941205_fb.jpg
False match
11s completed at 5:36 PM


PCA Face Recognition.ipynb
File Edit View Insert Runtime Tools Help All changes saved
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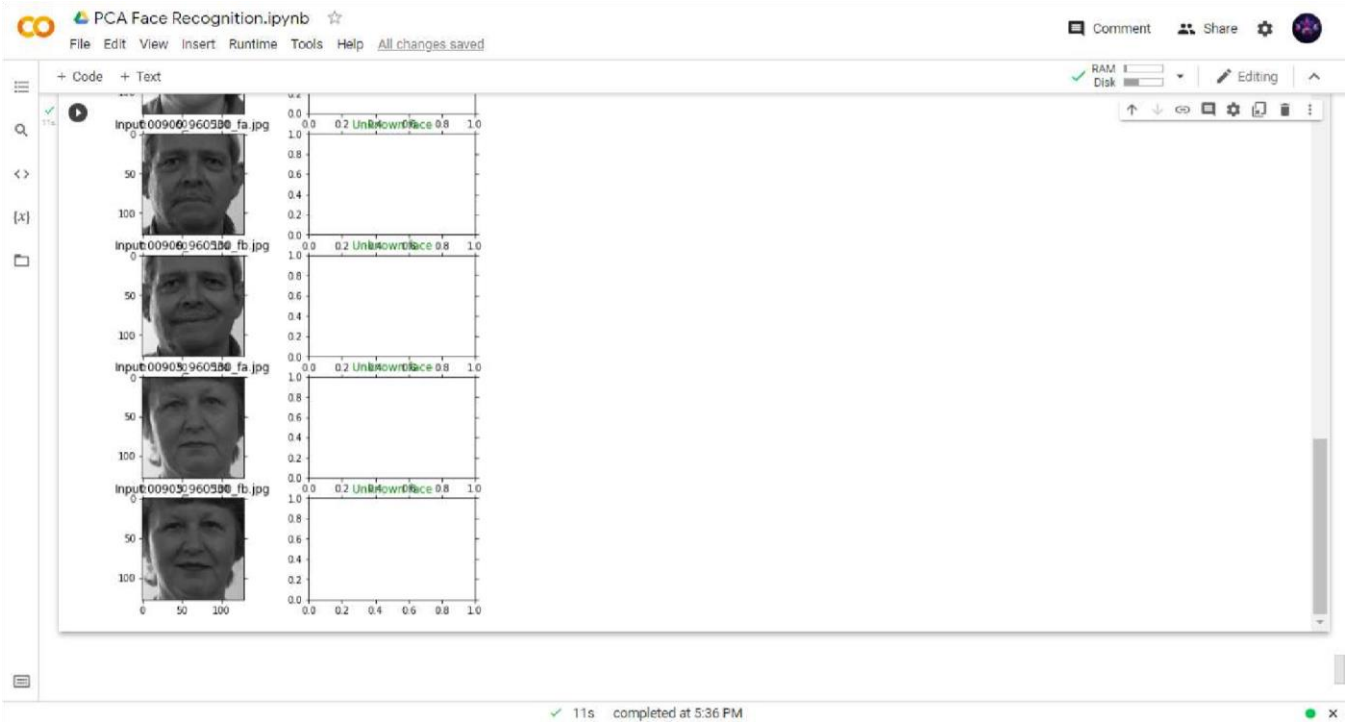
RAM Disk
Editing
Input 00816_941205_fb.jpg
False match
Input 00876_960530_fa.jpg
Unknown face
Input 00876_960530_fb.jpg
Unknown face
Input 00879_960530_fa.jpg
Unknown face
Input 00879_960530_fb.jpg
11s completed at 5:36 PM



Code:

```
from matplotlib import pyplot as plt from
matplotlib.image import imread import numpy as np
import os


TRAIN_IMG_FOLDER = (r"/content/sample_data/Training images")
TEST_IMG_FOLDER =  (r"/content/sample_data/TEST")

train_set_files = os.listdir(TRAIN_IMG_FOLDER) test_set_files =
os.listdir(TEST_IMG_FOLDER)
 width       =    128
height = 128


train_id_file = set([f.split('_')[0] for f in train_set_files]) test_id_file = set([f.split('_')[0] for f in train_set_files])
print(train_id_file <= test_id_file)


print('Train Images:')
 train_image_names = os.listdir(TRAIN_IMG_FOLDER)
training_tensor   = np.ndarray(shape=(len( train_image_names), height*width), dtype = np.float64)
 for i in range(len(train_image_names)):
    img = plt.imread(os.path.join(TRAIN_IMG_FOLDER, train_image_names[i]))     training_tensor[i,:] = np.array(img,
dtype='float64').flatten()
```

```
    plt.subplot(5,5,1+i)     plt.imshow(img, cmap='gray')     plt.tick_params(labelleft='off', labelbottom='off',
bottom='off',top='off',righ t='off',left='off', which='both') plt.show()
 print('Test Images:') test_image_names = os.listdir(TEST_IMG_FOLDER)#[i for i in dataset_dir if i not in
train_image_names] testing_tensor   = np.ndarray(shape=(len( test_image_names), height*width), dtype=np .float64)  for i
in range(len(test_image_names)):
    img = imread(os.path.join(TEST_IMG_FOLDER, test_image_names[i]))     testing_tensor[i,:] =
np.array(img, dtype='float64').flatten()     plt.subplot(8,5,1+i)     plt.imshow(img, cmap='gray')
plt.subplots_adjust(right=1.2, top=1.2)
    plt.tick_params(labelleft='off', labelbottom='off', bottom='off',top='off',righ t='off',left='off', which='both') plt.show()



mean_face = np.zeros((1,height*width))
 for i in training_tensor:
    mean_face = np.add(mean_face,i)
 mean_face = np.divide(mean_face,float(len(train_image_names))).flatten()

plt.imshow(mean_face.reshape(height, width), cmap='gray') plt.tick_params(labelleft='off', labelbottom='off',
bottom='off',top='off',right='o ff',left='off', which='both') plt.show()



normalised_training_tensor = np.ndarray(shape=(len( train_image_names), height*width
))  for i in range(len(train_image_names)):
    normalised_training_tensor[i] = np.subtract(training_tensor[i],mean_face)



for i in range(len(train_image_names)):
    img = normalised_training_tensor[i].reshape(height,width)     plt.subplot(5,5,1+i)     plt.imshow(img, cmap='gray')
plt.tick_params(labelleft='off', labelbottom='off', bottom='off',top='off',righ t='off',left='off', which='both') plt.show()



cov_matrix=np.cov(normalised_training_tensor) cov_matrix =
np.divide(cov_matrix,25.0) print('Covariance Matrix Shape:', cov_matrix.shape)
#print('Covariance matrix of X: \n%s' %cov_matrix)



#eigenvalues and eigenvectors eigenvalues, eigenvectors, =
np.linalg.eig(cov_matrix)
print('eigenvalues.shape: {} eigenvectors.shape: {}'.format( eigenvalues.shape, eige nvectors.shape))

eig_pairs = [(eigenvalues[index], eigenvectors[:,index]) for index in range(len( eig envalues))]

# Sort the eigen pairs in descending order: eig_pairs.sort(reverse=True)
eigvalues_sort  = [eig_pairs[index][0] for index in range(len(eigenvalues))] eigvectors_sort = [eig_pairs[index][1] for
index in range(len(eigenvalues))]
```

```
sorted_ind = sorted(range(eigenvalues.shape[0]), key=lambda k: eigenvalues[k], reve rse=True)  eigvalues_sort =
eigenvalues[sorted_ind] eigvectors_sort = eigenvectors[sorted_ind]
train_set_files_sort = np.array(train_set_files)[sorted_ind]


var_comp_sum = np.cumsum(eigvalues_sort)/sum(eigvalues_sort)


# Show cumulative proportion of varaince with respect to components print("Cumulative proportion of variance
explained vector: \n%s" %var_comp_sum)
# x-axis for number of principal components kept num_comp =
range(1,len(eigvalues_sort)+1) plt.title('Cum. Prop. Variance Explain and Components
Kept') plt.xlabel('Principal Components') plt.ylabel('Cum. Prop. Variance Expalined')
 plt.scatter(num_comp, var_comp_sum) plt.show()



reduced_data = np.array(eigvectors_sort[:25]).transpose() reduced_data.shape


print(training_tensor.transpose().shape, reduced_data.shape)


proj_data = np.dot(training_tensor.transpose(),reduced_data) proj_data =
proj_data.transpose() proj_data.shape



for i in range(proj_data.shape[0]):
   img = proj_data[i].reshape(height,width)     plt.subplot(5,5,1+i)     plt.imshow(img, cmap='gray')
plt.tick_params(labelleft='off', labelbottom='off', bottom='off',top='off',righ t='off',left='off', which='both')
plt.show()



w = np.array([np.dot(proj_data,i) for i in normalised_training_tensor]) print(w.shape)


def recogniser(test_image_names, train_image_names,proj_data,w, t0=2e8, prn=False):
    count        = 0
num_images   = 0
correct_pred = 0
       result = []     wts
= []


   #False match rate (FMR)
   FMR_count = 0


   #False non-match rate (FNMR)
   FNMR_count = 0
        test_image_names2 = sorted(test_image_names)
    for img in test_image_names2:
      #img = imread(os.path.join(TEST_IMG_FOLDER, test_image_names[i]))         unknown_face =
plt.imread(os.path.join(TEST_IMG_FOLDER, img))         num_images += 1
```

```
            unknown_face_vector = np.array(unknown_face, dtype='float64').flatten()        normalised_uface_vector =
np.subtract(unknown_face_vector,mean_face)
        w_unknown = np.dot(proj_data, normalised_uface_vector)        diff  = w - w_unknown
norms = np.linalg.norm(diff, axis=1)        index = np.argmin(norms)


      wts.append([count, norms[index]])


      if prn: print('Input:'+'.'.join(img.split('.')[:2]), end='\t')        count+=1                match = img.split('_')[0] ==
train_image_names[index].split('_')[0]        if norms[index] < t0: # It's a face            if match:
            if prn: print('Matched:' + train_image_names[index], end = '\t')                correct_pred += 1
result.append(1)            else:
            if prn: print('F/Matched:'+train_image_names[index], end = '\t')                result.append(0)
FMR_count += 1        else:            if match:
            if prn: print('Unknown face!'+train_image_names[index], end = '\t')
            FNMR_count +=1
                    else:                pass
correct_pred += 1


      if prn: print(norms[index], end=' ')        if prn: print()



   FMR = FMR_count/num_images
   FNMR = FNMR_count/num_images
          print('Correct predictions: {}/{} = {} \t\t'.format( correct_pred, num_images, c orrect_pred/num_images), end=' ')
print('FMR: {} \t'.format(FMR), end=' ')     print('FNMR: {} \t'.format(FNMR))


          return wts, result, correct_pred, num_images, FMR, FNMR
     wts, result, correct_pred, num_images, FMR, FNMR =recogniser(test_image_names, trai n_image_names,proj_data,w,
t0=2e8, prn=True)


def rg(r):
   if r: return 'g'     else: return 'r' cl = [rg(r)
for r in result]

x=[x[0] for x in wts] y=[y[1] for y in wts] plt.scatter(x,y, color=cl, label = 'Distance measure (true ang false pred.)')

x2=[x[0] for x in wts] y2=[2.7e7 for y in wts]
 plt.plot(x2,y2, label = 'Empirical error threshold') plt.legend() plt.grid()
 plt.show()


CPR_list, t0_list, FMR_list, FNMR_list = [], [] , [] , [] for t0 in np.linspace(start=0, stop=1e8,
num=20):
```

```
    print('{:e}'.format(t0), end=' ')
    wts, result, correct_pred, num_images, FMR, FNMR = recogniser(test_image_names,  train_image_names,proj_data,w,
t0)


    CPR_list.append(correct_pred/num_images)
t0_list.append(t0)     FMR_list.append(FMR)
    FNMR_list.append(FNMR)



x1=t0_list y1=FMR_list
 x2=t0_list
y2=FNMR_list
 x3=t0_list
y3=CPR_list
 plt.plot(x1,y1, ls='--', color='r', label='FMR',) plt.plot(x2,y2, ls='-.',
color='b', label='FNMR')
plt.plot(x3,y3, color='g', label='Correct prediction using threshold')
 plt.grid()
plt.legend()



count       = 0 num_images   = 0 correct_pred = 0 def Visualization(img,
train_image_names,proj_data,w, t0):
    global count,highest_min,num_images,correct_pred     unknown_face       =
plt.imread(os.path.join(TEST_IMG_FOLDER, img))     num_images         += 1     unknown_face_vector =
np.array(unknown_face, dtype='float64').flatten()     normalised_uface_vector =
np.subtract(unknown_face_vector,mean_face)
        plt.subplot(40,2,1+count)     plt.imshow(unknown_face, cmap='gray')     plt.title('Input:'+'.'.join(img.split('.')[:2]))
plt.tick_params(labelleft='off', labelbottom='off', bottom='off',top='off',righ t='off',left='off', which='both')     count+=1
w_unknown = np.dot(proj_data, normalised_uface_vector)     diff  = w - w_unknown     norms = np.linalg.norm(diff,
axis=1)     index = np.argmin(norms)



        plt.subplot(40,2,1+count)     if norms[index] < t0: #
It's a face         match = img.split('_')[0] ==
train_image_names[index].split('_')[0]
       #if img.split('.')[0] == train_image_names[index].split('.')[0]:         if match:
          #plt.title('Matched:'+'.'.join(train_image_names[index].split('.')[:2])
, color='g')
          plt.title('Matched:', color='g')           plt.imshow(imread(os.path.join(TRAIN_IMG_FOLDER,
train_image_names[inde x])), cmap='gray')
           #img = plt.imread(os.path.join(TRAIN_IMG_FOLDER, train_image_names[i])
)              correct_pred += 1         else:
          #plt.title('Matched:'+'.'.join(train_image_names[index].split('.')[:2])
, color='r')              plt.title('False matched:', color='r')              plt.imshow(imread(os.path.join(TRAIN_IMG_FOLDER,
train_image_names[inde x])), cmap='gray')     else:
       #if img.split('.')[0] not in [i.split('.')[0] for i in train_image_names] a nd img.split('.')[0] != 'apple':
       if img.split('_')[0] not in [i.split('_')[0] for i in train_image_names]:
```

```
        plt.title('Unknown face', color='g')            correct_pred += 1
else:           plt.title('Unknown face', color='r')
                plt.tick_params(labelleft='off', labelbottom='off', bottom='off',top='off',righ t='off',left='off', which='both')
plt.subplots_adjust(right=1.2, top=2.5)
      count+=1
    fig = plt.figure(figsize=(5, 30))


test_image_names2 = sorted(test_image_names) for i in
range(len(test_image_names2)):
   Visualization(test_image_names2[i], train_image_names,proj_data,w, t0=2.7e7)


plt.show()
```

Conclusion:

Conclusion for this Face recognition ml model is that with the help of this project we learn Artificial intelligence and coding of face recognition in python.