PAF - Karachi Institute of Economics and Technology
Numerical Computing - 107931

Project Report

Project Name: PCA Face Recognition

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Faculty: Sir Waqas Pasha

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:

PCA is a statistical approach used for reducing the number of variables in face recognition. In PCA, every image in the training set is represented as a linear combination of weighted eigenvectors called eigenfaces. 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.

UI:

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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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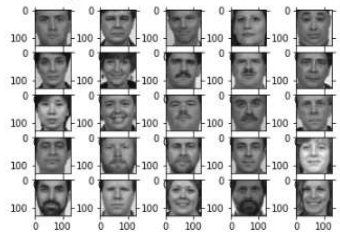
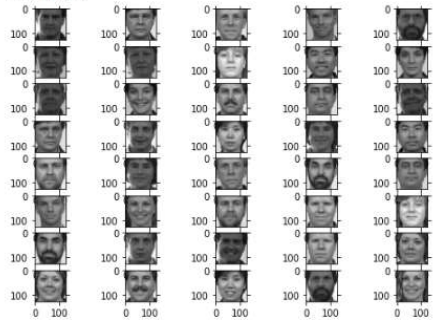
[4]

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.

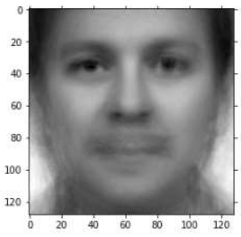
[5]

```
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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Calculation of difference between training vector and mean vector

To normalize the training set, we just simply need to subtract for each picture in the training set the mean that was calculated in the previous step.

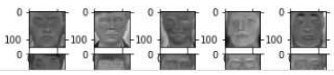
The reason why this is necessary is because we want to create a system that is able to represent any face. Therefore, we calculated the elements that all faces have in common (the mean). If we extract this average from the pictures, the features that distinguish each picture from the rest of the set are visible.

```
[6] 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)
```

Display normalised faces

```
[7] 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',right='off',left='off', which='both')
    plt.show()
```



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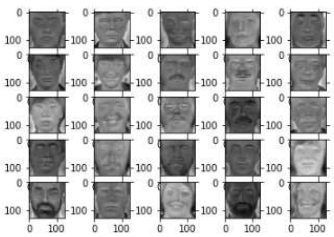
```
[7]
```



Converience Matrix

The covariance represents how two variables change together. After the previous step, we have a set of images that have different features, so now we want to see how these features for each individual picture change in relation to the rest of the pictures.

```
[8] 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)

    Covariance Matrix Shape: (25, 25)
```

Eigenvector of covariance

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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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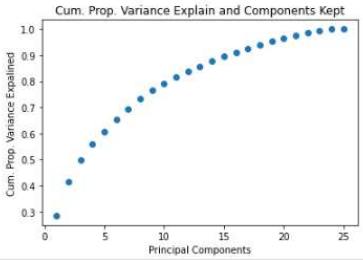
```
[11] var_comp_sum = np.cumsum(eigvalues_sort)/sum(eigvalues_sort)
     # Show cumulative proportion of varaince with respect to components
     print("Cumulative proportion of variance explained vector: \n%s" %var_comp_sum)

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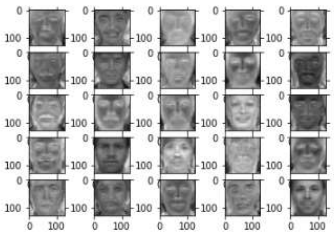
```
[15] for i in range(proj_data.shape[0]):
         img = proj_data[i].reshape(height,width)
         plt.subplot(5,5,1+i)
         plt.imshow(img, cmap='gray')
         plt.tick_params(labelleft='off', labelbottom='off', bottom='off',top='off',right='off',left='off', which='both')
     plt.show()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



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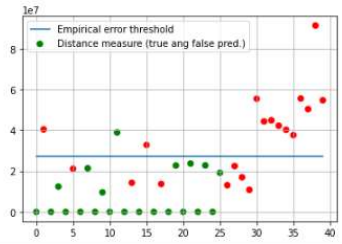
```
[18] def rg(r):
         if r: return 'g'
         else: return 'r'
     cl = [rg(r) for r in result]

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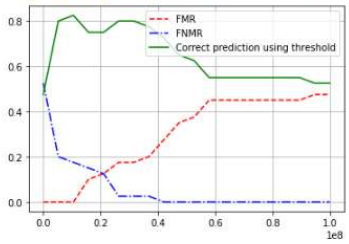
```
[20] x1=t0_list
     y1=FMR_list

     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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RAM Disk Editing

```
    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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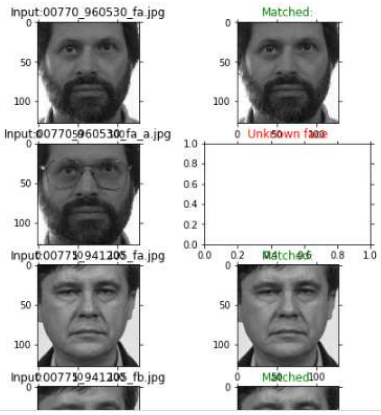
```
    count+=1


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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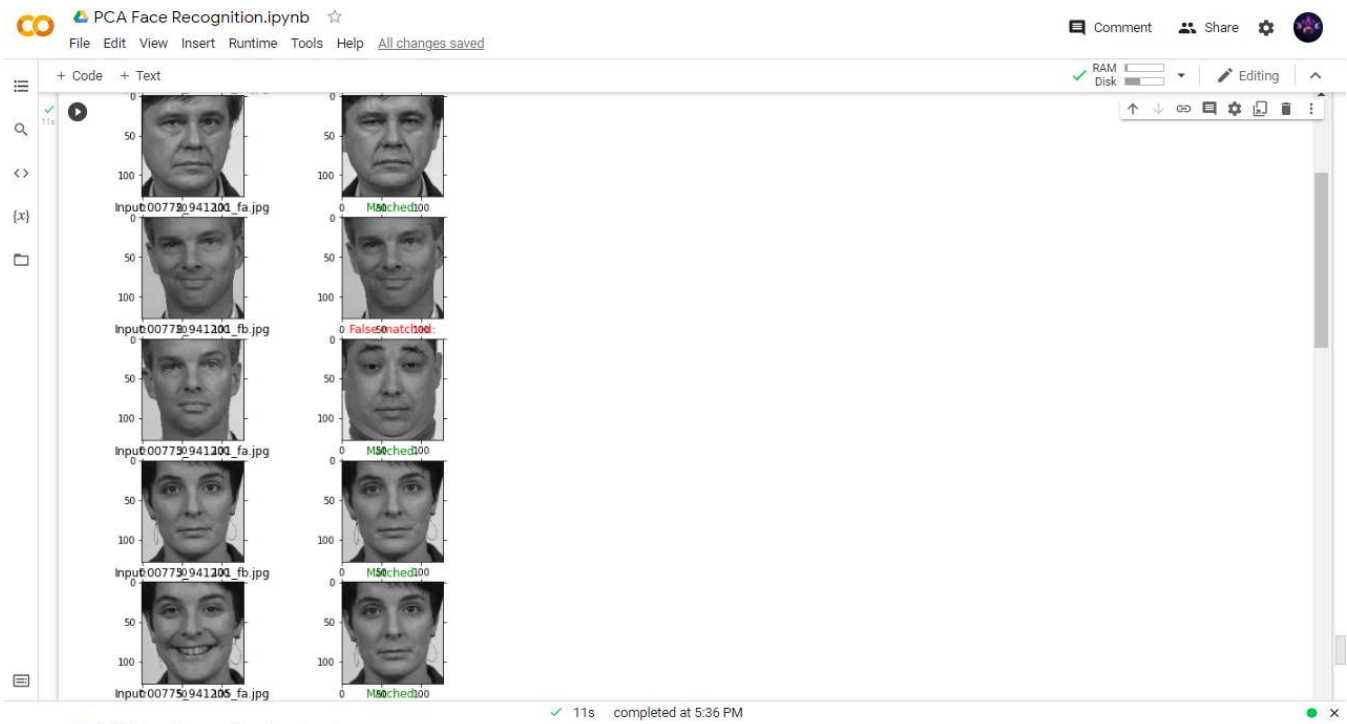
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Editing
Input: 00775_941201_fa.jpg
Matched
Input: 00775_941201_fb.jpg
False match
Input: 00775_941205_fa.jpg
Matched
Input: 00775_941205_fb.jpg
Matched
11s completed at 5:36 PM


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Editing
Input: 00775_941205_fb.jpg
Matched
Input: 00775_941205_fa.jpg
Matched
Input: 00775_941205_fb.jpg
Unknown face
Input: 00781_941205_fa.jpg
Matched
11s completed at 5:36 PM

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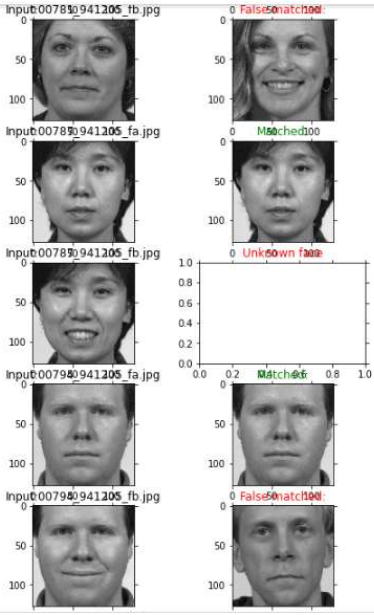

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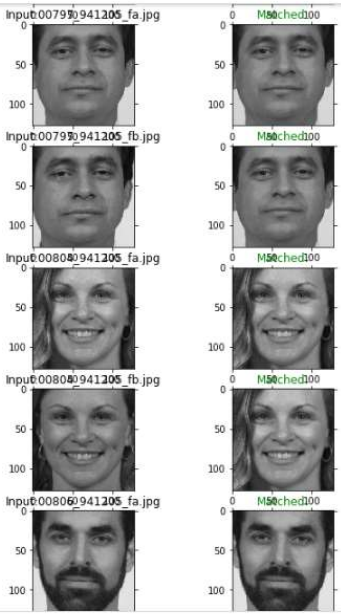
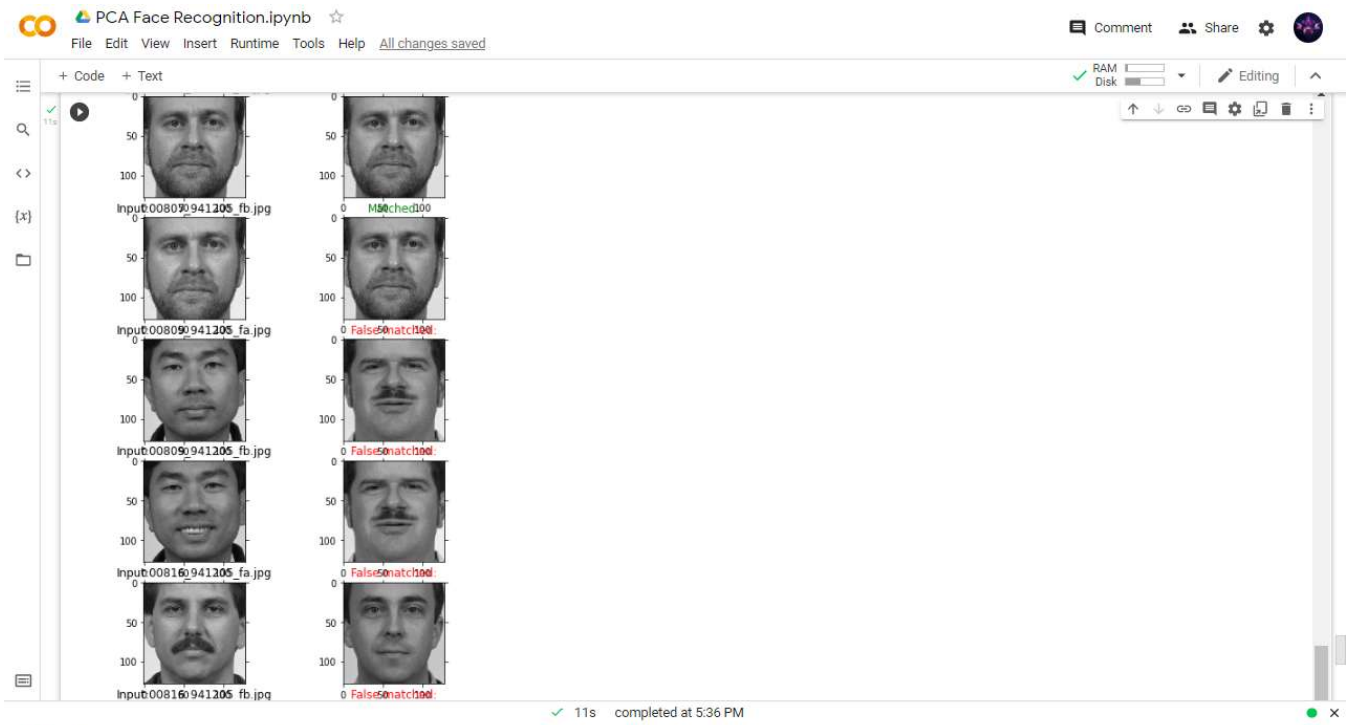


11s completed at 5:36 PM


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


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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_960380_fa.jpg
Unknown face
Input 00876_960380_fb.jpg
Unknown face
Input 00879_960380_fa.jpg
Unknown face
Input 00879_960380_fb.jpg
Unknown face
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 project is that with the help of this project we learn Artificial intelligence and coding of face recognition in python. The best part is that we've learned a lot by creating this face application.