CS-GY 6673 COMPUTER VISION
Face Recognition Project

Team Members:

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Instructions:

1. The project Github is https://github.com/Vishwanath-Ayyappan/Computer-Vision-Project
2. The code is implemented and interactively explained in Google Colab https://colab.research.google.com/drive/1YPgt2cpaTIqJIwTwdE4r2BrMV3FAb66j?usp=sharing
3. All the steps implemented are explained with output at each step and with comments and observations.
4. After opening the colab, Run all the cells by selecting RunAll from Runtime option in the menu bar.
5. The mean face image, eigen faces, prediction output images are saved once the cell is run. The Github repository also contains a Output Images folder, which contains the output images run by us.
6. The Eigen co-efficients are saved as text files for both training and test images.
7. The following is a pdf version of the notebook with all implementations, explanations, outputs and images.

Cloning my repository

It contains the training and testing images

In [1]:
```
! git clone https://github.com/Vishwanath-Ayyappan/Computer-Vision-Project
```

```
Cloning into 'Computer-Vision-Project'...
remote: Enumerating objects: 24, done.
remote: Counting objects: 100% (24/24), done.
remote: Compressing objects: 100% (23/23), done.
remote: Total 24 (delta 0), reused 0 (delta 0), pack-reused 0
Unpacking objects: 100% (24/24), done.
```

In [3]:
```
%cd /content/Computer-Vision-Project
# Moving to current directory
```

```
/content/Computer-Vision-Project
```

Imports

In [4]:
```
import os
import numpy as np
from PIL import Image
import matplotlib.pyplot as plt
```

Reading Training Images

In [52]:
```
training_images = '/content/Computer-Vision-Project/Training'
image_size = [195,231]

"""
This function takes each training image and read it as a array and
appends it to a directory
"""
def read_images(path, default_size=image_size):
    images = []
    images_labels=[]
    image_dirs = [image for image in os.listdir(path) if not image.startswith('.')]
    res = [sub[: -4] for sub in image_dirs]
    for image_dir in image_dirs:
        dir_path = os.path.join(path, image_dir)
        image = Image.open (dir_path)
        image = image.convert ("L")
        if (default_size is not None ):
            image = image.resize (default_size , Image.ANTIALIAS )
        images.append(np.array (image , dtype =np. uint8 ))
        images_labels.append(image_dir)
    return [images,images_labels]
```

In [53]:
```
[X_train, y_train] = read_images(path=training_images)
```

In [54]:
```
# Printing Training Labels
print('Training Labels:')
y_train
```

```
Training Labels:
```

Out[54]:
```
['subject01.happy.jpg',
 'subject07.centerlight.jpg',
 'subject15.normal.jpg',
 'subject14.normal.jpg',
 'subject10.normal.jpg',
 'subject03.normal.jpg',
 'subject02.normal.jpg',
 'subject11.normal.jpg']
```

In [20]:
```
# Shape of one input training image
print('Training Image Shape',X_train[0].shape)
```

```
Training Image Shape (231, 195)
```

In [21]:
```
# Shape of the Training data
print('Training Data Shape',np.array(X_train).shape)
```

```
Training Data Shape (8, 231, 195)
```

Input Training image shape (NxN)= (231, 195)

Total Training data shape (MxNxN) = (8, 231, 195)

Mean Face

In [23]:
```
'''
This function stacks a NxN matrix into N^2x1 vector
'''
def stack (X):
    if len (X) == 0:
        return np.array([])
    vector = np.empty((0,X[0].size),dtype=X[0].dtype)
    for row in X:
        vector = np.vstack((vector,np.asarray(row).reshape(1,-1)))
    return vector
```

In [31]:
```
mean_matrix = np.reshape(stack(X_train).mean(axis=0), X_train[0].shape)
plt.imshow(mean_matrix, cmap=plt.cm.gray)
plt.title("Mean Face");
plt.savefig('Mean_Face.jpg')
```

In [25]:
```
print('Mean Face Shape:',mean_matrix.shape)
```

```
Mean Face Shape: (231, 195)
```

PCA

In [27]:
```
"""
The choose_num_components_function selects the top M components while preserving high va
"""
def choose_num_components(eigenvalues, variance=.95):
    for ii, eigen_value_cumsum in enumerate(np.cumsum(eigenvalues) / np.sum(eigenvalues)
        if eigen_value_cumsum > variance:
            return ii

"""
PCA is done and eigen vector and eigen values are retured
"""
def pca (X, y, num_components =0):
    [n,d] = X.shape
    if ( num_components <= 0) or ( num_components >n):
        num_components = n
        mu = X.mean( axis =0)
        X = X - mu
    if n>d:
        C = np.dot(X.T,X) # Covariance Matrix
        [ eigenvalues , eigenvectors ] = np.linalg.eigh(C)
    else :
        C = np.dot (X,X.T) # Covariance Matrix
        [ eigenvalues , eigenvectors ] = np.linalg.eigh(C)
        eigenvectors = np.dot(X.T, eigenvectors )
        for i in range (n):
            eigenvectors [:,i] = eigenvectors [:,i]/ np.linalg.norm( eigenvectors [:,i])
    # Selecting top M eigen vectors by sorting them in descending order.
    idx = np.argsort (- eigenvalues )
    eigenvalues = eigenvalues [idx ]
    eigenvectors = eigenvectors [:, idx ]
    num_components = choose_num_components(eigenvalues)
    eigenvalues = eigenvalues [0: num_components +3].copy ()
    eigenvectors = eigenvectors [: ,0: num_components+3 ].copy ()
    return [ eigenvalues , eigenvectors , mu]

[eigenvalues, eigenvectors, mean] = pca (stack(X_train), y_train)
```

In [28]:
```
print('Eigen Vectors Shape:',np.array(eigenvectors).shape)
print('Eigen Values Shape:',np.array(eigenvalues).shape)
```

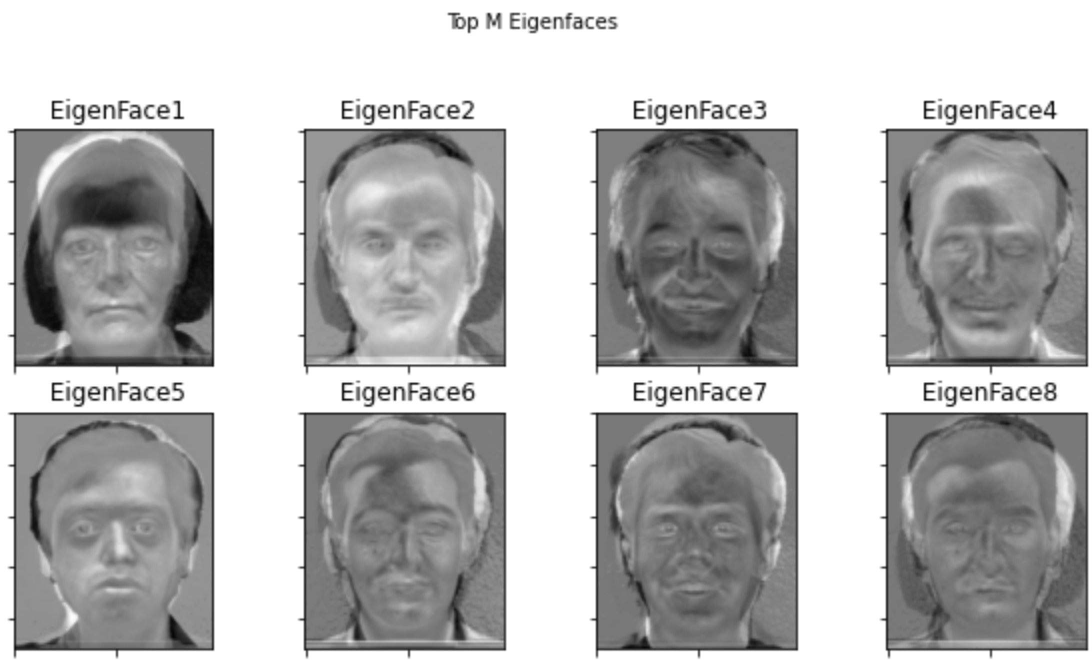
```
Eigen Vectors Shape: (45045, 8)
Eigen Values Shape: (8,)
```

```
Eigen vector shape(N^2xM) = (231x195,8)
M = Number of Training samples = 8
```

Plot Top M Eigenfaces

In [30]:
```
def subplot ( title , images , rows , cols , sptitle ="", sptitles =[] , colormap = plt.
    fig = plt.figure(figsize = figsize)
    # main title
    fig.text (.5 , .95 , title , horizontalalignment ="center")
    for i in range ( len ( images )):
        ax0 = fig.add_subplot( rows , cols ,( i +1))
        plt.setp ( ax0.get_xticklabels() , visible = False )
        plt.setp ( ax0.get_yticklabels() , visible = False )
        if len ( sptitles ) == len ( images ):
            plt.title("%EigenFace #%s" % ( sptitle , str ( sptitles [i ]) )  )
```

```
        else:
            plt.title("%s EigenFace%d" % ( sptitle , (i +1) )  )
        plt.imshow(np.asarray(images[i]) , cmap = colormap )
    if filename is None :
        plt.show()
    else:
        fig.savefig( filename )


E = []
number = eigenvectors.shape[1]
for i in range (min(number, 16)):
    e = eigenvectors[:,i].reshape(X_train[0].shape )
    E.append(np.asarray(e))
subplot ( title ="Top M Eigenfaces", images=E, rows =4, cols =4, colormap =plt.cm.gray ,
```



Eigen Co-efficients for Training Images

In [33]:
```
count=1
for i in X_train:
    R_i=i.reshape(45045,1) # Reshaping the matrix to vector
    eigen_coeff=np.matmul(eigenvectors.transpose(),R_i) # Projecting the training face i
    print('Eigen_Face_Co-efficient for training image for '+str(count)+':\n',eigen_coeff
    count=count+1
```

```
Eigen_Face_Co-efficient for training image for 1:
 [[-11455.31321183]
 [   575.61055704]
 [-21528.29417198]
 [  1400.79061033]
 [ -1376.09515463]
 [  5328.59564468]
 [  2863.95853702]
 [ -6571.22164446]]
Eigen_Face_Co-efficient for training image for 2:
 [[-10768.04901166]
 [ -8906.99948762]
 [ -9367.81626361]
 [ -3382.21863686]
 [ -5352.57444743]
 [  4887.76170677]
 [  3787.15142831]
```

```
 [ -3683.45008505]]
Eigen_Face_Co-efficient for training image for 3:
 [[-18578.27226476]
 [  4260.67922502]
 [-11129.68523645]
 [ -6652.79119894]
 [  -647.44033389]
 [  8850.30445809]
 [   -58.33109198]
 [  3085.84731527]]
Eigen_Face_Co-efficient for training image for 4:
 [[ -9084.34629059]
 [ -7603.48791243]
 [-16650.85053139]
 [ -3305.93369717]
 [ -3273.59914592]
 [  5620.7284802 ]
 [ -4680.08327893]
 [ -8585.32378332]]
Eigen_Face_Co-efficient for training image for 5:
 [[-10390.24178921]
 [ -7190.66584618]
 [-12888.31603189]
 [ -3918.16174562]
 [  6352.42549847]
 [  3487.06707173]
 [   955.53109616]
 [ -9234.24087406]]
Eigen_Face_Co-efficient for training image for 6:
 [[-14812.88263046]
 [  -644.37829276]
 [-17204.69656213]
 [ -9575.9201835 ]
 [ -2615.96553136]
 [  -996.30648375]
 [   823.46394578]
 [ -6400.71956119]]
Eigen_Face_Co-efficient for training image for 7:
 [[-14968.25916663]
 [  1809.3873253 ]
 [ -8938.05025608]
 [  2315.89231694]
 [ -1571.36487508]
 [   179.20009482]
 [ -1329.53175352]
 [ -3526.52777561]]
Eigen_Face_Co-efficient for training image for 8:
 [[  5225.6273209 ]
 [  3239.52265788]
 [-12127.94559438]
 [ -4848.48950128]
 [ -1355.94114256]
 [  3993.50480141]
 [   452.6729411 ]
 [  -577.47002834]]
```

In [36]:
```
eigen_coeff.shape
```

Out[36]:
```
(8, 1)
```

Each training face can then be projected onto the face space to obtain its eigenface coefficients
$\Omega i = U^{T}Ri$ for i=1to$M$

```
(MxN^2)X(N^2x1) =Mx1
Eigen Co-efficient shape for each training image = (8, 1)
```

In [34]:

```python
# Saving the eigen co-efficients into text file
with open('Eigen_Coeff_Training_images.txt', 'w') as f:
    count=1
    for i in X_train:
        R_i=i.reshape(45045,1) # Reshaping the matrix to vector
        eigen_coeff=np.matmul(eigenvectors.transpose(),R_i) # Projecting the training fa
        print('Eigen_Face_Co-efficient for training image for '+str(count)+':\n',eigen_c
        count=count+1
```

Reading Test Images

In [42]:

```python
test_images='/content/Computer-Vision-Project/Testing'
X_test,y_test=read_images(path=test_images)
```

In [44]:

```python
print('Test Dataset Shape: ',np.array(X_test).shape)
```

```
Test Dataset Shape:  (6, 231, 195)
```

Eigen Co-efficients for Test Images

In [46]:

```python
count=1
for i in X_test:
    R_i=i.reshape(45045,1) # Reshaping the matrix to vector
    eigen_coeff=np.matmul(eigenvectors.transpose(),R_i) # Projecting the test face image
    print('Eigen_Face_Co-efficient for test image for '+str(count)+':\n',eigen_coeff)
    count=count+1
```

```
Eigen_Face_Co-efficient for test image for 1:
 [[-16608.43742774]
 [ -1235.11344439]
 [ -9908.29975763]
 [ -5147.60189204]
 [ -3746.17723139]
 [  3313.2396691 ]
 [   477.96346739]
 [ -1485.40648523]]
Eigen_Face_Co-efficient for test image for 2:
 [[-15596.66958355]
 [ -3304.93320258]
 [-10859.97222317]
 [ -4119.47942364]
 [ -3113.98825305]
 [  4340.40472884]
 [  2081.4598034 ]
 [ -2567.22740275]]
Eigen_Face_Co-efficient for test image for 3:
 [[-10001.52392006]
 [ -6511.90803946]
 [-17194.35045692]
 [ -2982.9463799 ]
 [ -4001.66402628]
 [  5281.74503293]
 [ -1767.29822874]
 [ -7654.65601731]]
Eigen_Face_Co-efficient for test image for 4:
 [[-10004.80741523]
 [ -7189.44301695]
```

```
 [-15704.95681709]
 [ -3235.06745952]
 [ -3479.86964405]
 [  4399.47069493]
 [ -3144.1526114 ]
 [ -8169.40988952]]
Eigen_Face_Co-efficient for test image for 5:
 [[ -9777.59141506]
 [  -608.59477892]
 [-21511.06230793]
 [  -726.66711531]
 [ -1032.684361  ]
 [  5503.23314757]
 [   966.1935217 ]
 [ -7196.78059147]]
Eigen_Face_Co-efficient for test image for 6:
 [[  4397.17719666]
 [  3964.16952919]
 [-12401.37426196]
 [ -3895.92774228]
 [ -1575.76624797]
 [  3878.82894504]
 [  -278.93819796]
 [  -656.59012181]]
```

In [47]:

```
# Saving the eigen co-efficients into text file
with open('Eigen_Coeff_Test_images.txt', 'w') as f:
    count=1
    for i in X_test:
        R_i=i.reshape(45045,1) # Reshaping the matrix to vector
        eigen_coeff=np.matmul(eigenvectors.transpose(),R_i) # Projecting the test face i
        print('Eigen_Face_Co-efficient for test image for '+str(count)+':\n',eigen_coeff
        count=count+1
```

Recognition

Classification using 1-Nearest Neighbor

Euclidean Distance metric is used

In [48]:

```
def euclidean_dist(p,q):
    p = np.asarray(p).flatten()
    q = np.asarray (q).flatten()
    return np.sqrt (np.sum (np. power ((p-q) ,2)))
```

In [50]:

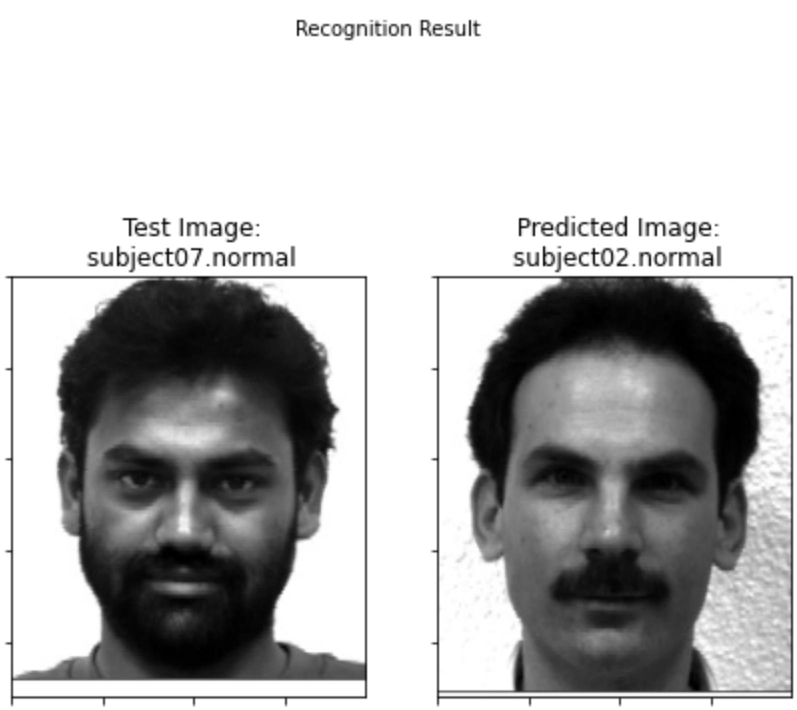
```
def project (W , X , mu):
    return np.dot (X - mu , W)
def predict (W, mu , projections, X):
    minDist = float("inf")
    minClass = -1
    Q = project (W, X.reshape (1 , -1) , mu)
    for i in range (len(projections)):
        dist = euclidean_dist( projections[i], Q)
        if dist < minDist:
            minDist = dist
            minClass = i
    return minClass

projections = []
```

```
for xi in X_train:
    projections.append(project (eigenvectors, xi.reshape(1 , -1) , mean))
```

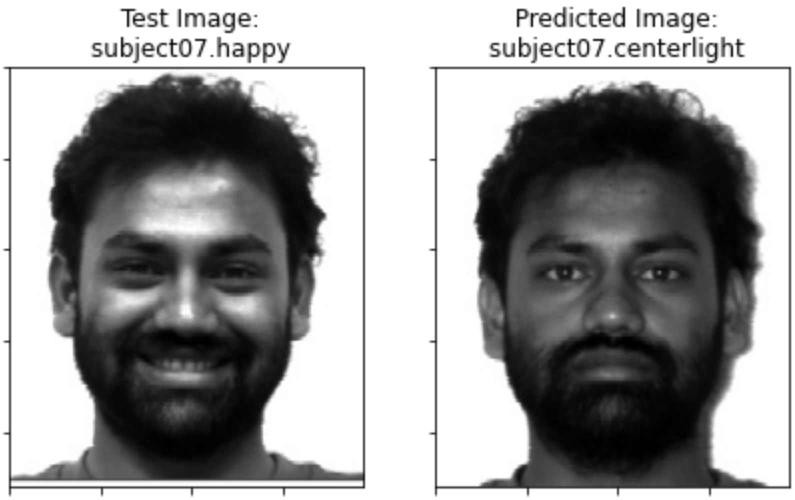
In [82]:
```
def subplot2 ( title , images , rows , cols , sptitle ="", sptitles =[] , colormap = plt
    fig = plt.figure(figsize = figsize)
    # main title
    fig.text (.5 , .95 , title , horizontalalignment ="center")
    for i in range ( len ( images )):
        ax0 = fig.add_subplot( rows , cols ,( i +1))
        plt.setp ( ax0.get_xticklabels() , visible = False )
        plt.setp ( ax0.get_yticklabels() , visible = False )
        if len ( sptitles ) == len ( images ):
            plt.title("%s %s" % ( sptitle , str ( sptitles [i ]) )  )
        else:
            plt.title("%s %d" % ( sptitle , (i +1) )  )
        plt.imshow(np.asarray(images[i]) , cmap = colormap )
    if filename is None :
        plt.show()
    else:
        fig.savefig( filename )
```

In [ ]:
```
def accuracy(X,y):
  if X[:9]==y[:9]:
```

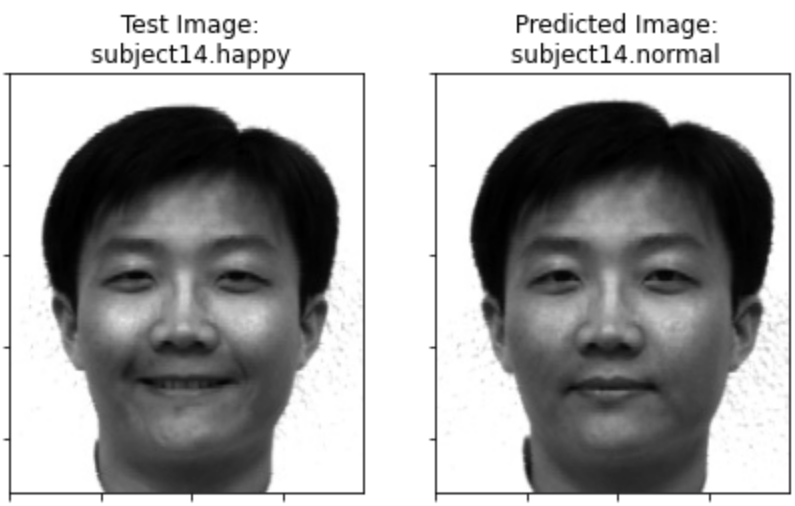
In [94]:
```
count=0
for i in os.listdir('/content/Computer-Vision-Project/Testing'):
  if i[-4:]=='.jpg':
    img='/content/Computer-Vision-Project/Testing/'+i
    image = Image.open(img)
    image = image.convert ("L")
    if (image_size is not None ):
        image = image.resize (image_size , Image.ANTIALIAS )
    test_image = np. asarray (image , dtype =np. uint8 )
    predicted = predict(eigenvectors, mean , projections, test_image)
    if i[:9]==y_train[predicted][:9]:
      count=count+1
    subplot2(title ="Recognition Result", images =[test_image, X_train[predicted]], rows
         sptitles = ["Test Image:\n {0}".format(i[:-4]), "Predicted Image:\n {0}".format
          filename=i[:-4]+'_output.jpg',figsize = (7,7))
```



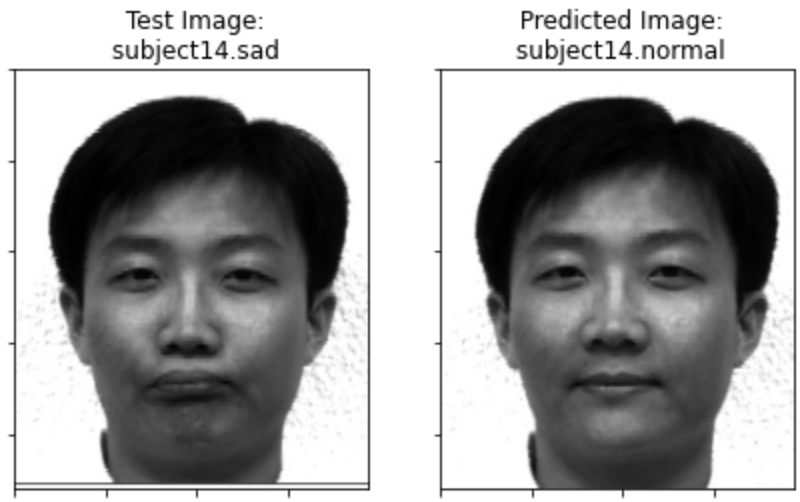
Recognition Result



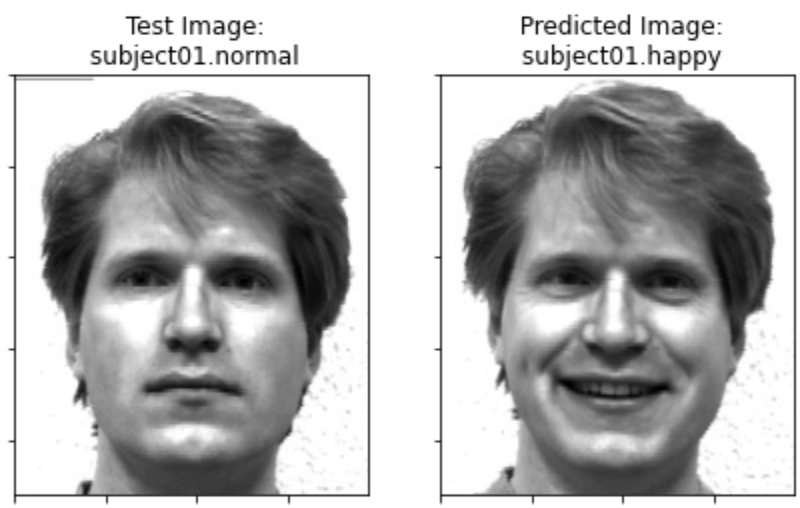
Recognition Result



Recognition Result



Recognition Result



Recognition Accuracy

In [93]:
```
print("Recognition Accuracy:"+str((count/6)*100)+'%')
```

```
Recognition Accuracy:83.33333333333334%
```