Face Recognition Project 2 Report

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I. Aim of the Project

A facial recognition system is a system capable of matching a human face from a digital image or a video frame against a database of faces. Such a system is typically employed to authenticate users through ID verification services and works by pinpointing and measuring facial features from a given image. The aim of this project is to use the Eigenface method taught to us in class and implement the same on the test images and training images provided to us. We use the image and implement the 1-NN (nearest neighbor) classifier. We aim to identify our input faces as one of the faces provided to us in the training set. We begin by computing the Euclidean distances between the Eigenface coefficients of the input image and the Eigenface coefficients of the training images. The input face is then recognized as the face in the training images with the smallest Euclidean distance.

What does a Facial recognition system do:

- Detects faces in an image
- Compute the face features to represent the face
- Classify face features for the person into different classes

Two types of face recognition problems:

- Face Identification (1-to-N matching)-Match input faces with faces in a database to identify the person.
- Face Verification(1-to-1 matching)-Match input face with the face of a particular person(or the individual itself)

One of the earliest face recognition methods. Faces are represented by a set of eigenface coefficients (eigenvalues.) Matching is done by computing distances between eigenface coefficients. A set of face training images is used to obtain the eigenfaces that form the eigenface space. An unknown face image is then projected onto the eigenface space for matching.

We display the Eigen coefficients values and the resultant image after performing 1-NN Classifier over the test images. Since the classifier runs on the testing images only and we build our method over the images, we conclude the project by predicting the overall accuracy of the classifier.

II. Results

The following outputs show how the Face recognition method was implemented and how we reached the desired outputs.We were given 14 images to work with. images are given for Training and 6 images are for testing.The next step was to convert the image values into a human face. The images with their coefficient values are presented below.

1. The following images represent the Eigen face images of the original image

Fig. 1. Eigenfaces

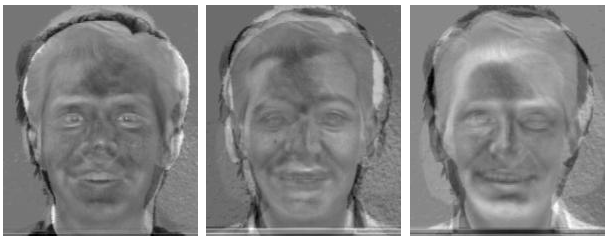

Fig. 2. Eigenfaces

Fig. 3. Eigenfaces

2. Eigenface coefficient and Recognition Result We perform the classifier in order to receive a predictive accuracy score for the testing images.

Test Image Name	Recognition Result
Subject 1 (subject01.normal.jpg)	Subject 1 (subject01.happy.jpg)
Subject 7 (subject07.happy.jpg)	Subject 2 (subject02.normal.jpg)
Subject 7 (subject07.normal.jpg)	Subject 2 (subject02.normal.jpg)
Subject 11 (subject11.normal.jpg)	Subject 11 (subject11.normal.jpg)
Subject 14 (subject14.happy.jpg)	Subject 14 (subject14.normal.jpg)
Subject 14 (subject14.sad.jpg)	Subject 14 (subject14.normal.jpg)

3.Acccuracy

The Accuracy of the program is 4 / 6 = 0.67 = 67%

```
Predicted Label: Subject 1 subject01.happy.jpg , True Label: Subject 1 subject01.normal.jpg
Eigenface coefficient:  [ 2.80339894e+07  2.34648126e+06  4.09184704e-09  8.25440772e+06
  4.34601543e+07  3.37021797e+07 -7.52727547e+07 -8.02856834e+06]

Predicted Label: Subject 2 subject02.normal.jpg , True Label: Subject 7 subject07.happy.jpg
Eigenface coefficient:  [-9.82359865e+07 -1.17310191e+07 -4.40800287e-08  1.14994467e+07
 -2.18686836e+06 -8.12372616e+06  2.60480030e+07 -1.32135051e+07]

Predicted Label: Subject 2 subject02.normal.jpg , True Label: Subject 7 subject07.normal.jpg
Eigenface coefficient:  [-1.16771406e+08  1.94535475e+07 -4.54533514e-08  2.00202560e+05
 -9.36449714e+06 -1.90152265e+07  2.74435806e+07 -1.97650518e+07]

Predicted Label: Subject 11 subject11.normal.jpg , True Label: Subject 11 subject11.happy.jpg
Eigenface coefficient:  [ 2.82605165e+08  6.92765475e+07  1.32574981e-07 -6.87873720e+06
 -2.04464233e+07 -6.01062509e+06  3.58215407e+07  3.16020984e+06]

Predicted Label: Subject 14 subject14.normal.jpg , True Label: Subject 14 subject14.happy.jpg
Eigenface coefficient:  [ 1.24208640e+07 -7.17008884e+07 -2.58943412e-08 -1.29282516e+07
  2.23758718e+07  6.94887484e+06 -1.82530628e+07 -2.64451272e+07]

Predicted Label: Subject 14 subject14.normal.jpg , True Label: Subject 14 subject14.sad.jpg
Eigenface coefficient:  [ 9.35369274e+06 -7.83302545e+07 -2.62314283e-08 -2.34432094e+07
  8.98022539e+06  3.38877745e+06 -5.36607090e+06 -2.05361412e+07]
```

Fig. 4. EigenFace coefficient of testing images

4. Eigenface coefficient of Training Images

```
File: subject01.happy.jpg
Label: Subject 1
Eigneface coefficients: [-2.14549134e+06  2.01164312e+07  2.15986910e-09  2.16175558e+07
  4.49520053e+07  5.59150315e+07 -7.94095481e+07 -1.21272021e+07]

File: subject02.normal.jpg
Label: Subject 2
Eigneface coefficients: [-8.58839316e+07  6.25290432e+07 -5.13809824e-09 -1.38566611e+07
 -3.86553463e+07  5.77694777e+07  2.73940076e+07 -2.91768462e+06]

File: subject03.normal.jpg
Label: Subject 3
Eigneface coefficients: [-7.30419026e+07  1.42032113e+07  1.89565605e-08  4.16444445e+06
 -1.46174372e+07 -5.94636676e+07 -6.27227395e+07 -2.60065258e+07]

File: subject07.centerlight.jpg
Label: Subject 7
Eigneface coefficients: [-1.52701331e+07 -9.07974642e+07 -1.90703695e-08  2.13296843e+07
 -1.50417719e+07 -2.63347435e+06  6.73765860e+07 -2.62575437e+07]

File: subject10.normal.jpg
Label: Subject 10
Eigneface coefficients: [-2.62652584e+06 -7.26417303e+07 -2.44289677e-09  2.47981000e+06
 -1.84775840e+07 -5.08986833e+06  4.65216344e+06  6.93117119e+07]

File: subject11.normal.jpg
Label: Subject 11
Eigneface coefficients: [ 2.97027078e+08  5.90039620e+07  1.39547439e-07 -2.18591789e+06
 -2.28644246e+07 -1.61694741e+07  4.11749680e+07  6.18624067e+06]

File: subject14.normal.jpg
Label: Subject 14
Eigneface coefficients: [ 2.77061609e+07 -8.66026495e+07 -3.62172287e-08 -3.33266598e+07
  2.09564237e+07  3.07885629e+06 -9.61832486e+06 -1.82199671e+07]

File: subject15.normal.jpg
Label: Subject 15
Eigneface coefficients: [-1.45765254e+08  9.41891961e+07 -9.77952750e-08 -2.22255716e+05
  4.37481350e+07 -3.34068812e+07  1.11528875e+07  1.00309707e+07]
```

Fig. 5. EigenFace coefficient for training Images

5. The image represents the mean face generated(Fig 6)

Fig. 6. Mean faces

III. How to run the program

The dependencies used for this project are as follows:

- Numpy
- Matplotlib (pyplot)
- PIL (In order to save the images)

The program is in the form of an IPython Notebook (.ipynb). In order to run this program on your local computer the images should be in the same folder as the program and have all the listed dependent libraries installed. Alternatively, the program can be run on Google Colab (url mentioned in the footnote), by uploading all the pictures. The entire notebook, with all the cells, needs to be run. The program will display the Eigenface coefficients of testing and training images, the Eigenfaces of training images along with the Mean face. It will also store the images in the same folder as the program, with the filenames being prepended with "eigenface_", followed by the corresponding file name.

[1]s

[1]https://colab.research.google.com/drive/1Ju3wfbZin1Fm1_b-gr_Uvw_9JdbZpEc_?usp=sharing

Project 2

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In [1]:
```
#importing libraries
import matplotlib.image as mpimg
import matplotlib.pyplot as plt
import numpy as np
from PIL import Image
from IPython.display import display
```

Inputting the Train and Test filenames and initializing the corresponding Labels

In [2]:
```
#storing the images and labels in corresponding lists
train_images = ["subject01.happy.jpg", "subject02.normal.jpg", "subject03.normal.jpg", "subject07.centerlight.jpg",
                "subject10.normal.jpg", "subject11.normal.jpg", "subject14.normal.jpg", "subject15.normal.jpg"]
pred_label = ["Subject 1", "Subject 2", "Subject 3", "Subject 7", "Subject 10", "Subject 11", "Subject 14", "Subject 15"]

test_images = ["subject01.normal.jpg", "subject07.happy.jpg", "subject07.normal.jpg", "subject11.happy.jpg", "subject14.happy.jpg",
               "subject14.sad.jpg"]
true_label = ["Subject 1", "Subject 7", "Subject 7", "Subject 11", "Subject 14", "Subject 14"]
```

m Training faces and tl Testing faces, each of size n1 x n2

In [3]:
```
m = len(train_images)     #number of training images
tl = len(test_images)     #number of testing images
n1, n2 = mpimg.imread(train_images[0]).shape      #getting the dimensions of the images
```

Reading m Training images and for each image i, the rows are stacked together to form a column vector ri, stored together in a matrix r

In [4]:
```
r = []
for i in range(m):
    ri = mpimg.imread(train_images[i])      #reading images into numpy arrays
    ri = ri.reshape(n1 * n2, )      #reshaping the numpy arrays to column vectors
    r.append(ri)
r = np.asarray(r)
```

Mean face mn is computed by taking average over the m faces using matrix r

In [5]:
```
mn = r.mean(axis=0)     #calculating mean face
```

Plotting mean face mn and saving the image into a jpg

In [6]:
```
plt.axis('off')
plt.imshow(mn.reshape(n1, n2), cmap='gray')
plt.savefig('meanface.jpg', bbox_inches='tight', pad_inches=0)
plt.tick_params(labelleft='off', labelbottom='off', bottom='off',top='off',right='off',left='off', which='both')
#resizing plotted image to original image size and saving as .jpg
Image.open('meanface.jpg').resize((n2, n1), Image.LANCZOS).save('meanface.jpg')
plt.show()
```

Subtracting mean face mn from each training face stored in r and updating r using $\vec{R_i} = R_i - m$

In [7]:
```
r = np.subtract(r,mn)
```

Putting all the training faces into a single matrix a of dimentions (n1 x n2) x m

In [8]:
```
a = r.transpose()
```

Calculating covariance matrix $L = A^T . A$, with dimensions M x M because $C = A . A^T$, with dimensions (n1 x n2) x (n1 x n2) is beyond our computation capabilities

In [9]:
```
l = np.cov(a.transpose())
```

Calculating eigen vectors of l into a single matrix v

In [10]:
```
eigen_values, v = np.linalg.eig(l)
```

Calculating m largest eigenvectors of c to u, which then contains m eigenfaces and has dimensions (n1 x n2) x m, using formula $U = A \times V$ and transpose of u as ut

In [11]:
```
u = a.dot(v)
ut = u.transpose()
```

For each training face from 0 to m - 1, obtaining its eigenface coefficients, using formula $\Omega_i = U^T \times \vec{R_i}$ for i = 1 to M

In [12]:
```
o = []
for i in range(0, m):
  ox = np.dot(ut, r[i])
  o.append(ox)
o = np.asarray(o)
```

Printing Eigenface coefficients of Training images

In [13]:
```
for i in range(0, m):
  print("File:", train_images[i])
  print("Label:", pred_label[i])
  print("Eigneface coefficients:", o[i])
  print("")
```

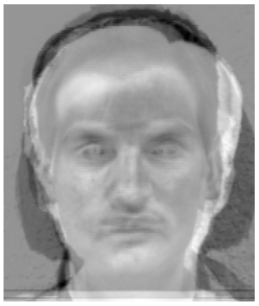
```
File: subject01.happy.jpg
Label: Subject 1
Eigneface coefficients: [-2.14549134e+06  2.01164312e+07  2.15986910e-09  2.16175558e+07
  4.49520053e+07  5.59150315e+07 -7.94095481e+07 -1.21272021e+07]

File: subject02.normal.jpg
Label: Subject 2
Eigneface coefficients: [-8.58839316e+07  6.25290432e+07 -5.13809824e-09 -1.38566611e+07
 -3.86553463e+07  5.77694777e+07  2.73940076e+07 -2.91768462e+06]

File: subject03.normal.jpg
Label: Subject 3
Eigneface coefficients: [-7.30419026e+07  1.42032113e+07  1.89565605e-08  4.16444445e+06
 -1.46174372e+07 -5.94636676e+07 -6.27227395e+07 -2.60065258e+07]

File: subject07.centerlight.jpg
Label: Subject 7
Eigneface coefficients: [-1.52701331e+07 -9.07974642e+07 -1.90703695e-08  2.13296843e+07
 -1.50417719e+07 -2.63347435e+06  6.73765860e+07 -2.62575437e+07]

File: subject10.normal.jpg
Label: Subject 10
Eigneface coefficients: [-2.62652584e+06 -7.26417303e+07 -2.44289677e-09  2.47981000e+06
 -1.84775840e+07 -5.08986833e+06  4.65216344e+06  6.93117119e+07]

File: subject11.normal.jpg
Label: Subject 11
Eigneface coefficients: [ 2.97027078e+08  5.90039620e+07  1.39547439e-07 -2.18591789e+06
 -2.28644246e+07 -1.61694741e+07  4.11749680e+07  6.18624067e+06]

File: subject14.normal.jpg
Label: Subject 14
Eigneface coefficients: [ 2.77061609e+07 -8.66026495e+07 -3.62172287e-08 -3.33266598e+07
  2.09564237e+07  3.07885629e+06 -9.61832486e+06 -1.82199671e+07]

File: subject15.normal.jpg
Label: Subject 15
Eigneface coefficients: [-1.45765254e+08  9.41891961e+07 -9.77952750e-08 -2.22255716e+05
  4.37481350e+07 -3.34068812e+07  1.11528875e+07  1.00309707e+07]
```

Plotting the m eigenfaces of the training images and saving them into jpg

In [14]:
```
for i in range(m):
    plt.axis('off')
    plt.imshow(ut[i].reshape(n1,n2), cmap='gray')
    plt.savefig('eigenface_' + train_images[i], bbox_inches='tight', pad_inches=0)
    plt.tick_params(labelleft='off', labelbottom='off', bottom='off',top='off',right='off',left='off', which='both')
    #resizing plotted image to original image size (using LANCZOS anti-aliasing) and saving as .jpg
```

```
    Image.open('eigenface_' + train_images[i]).resize((n2, n1), Image.LANCZOS).save('eigenface_' + train_images[i])
    plt.show()
    print(train_images[i], pred_label[i])
```

subject01.happy.jpg Subject 1



subject02.normal.jpg Subject 2

subject03.normal.jpg Subject 3

subject07.centerlight.jpg Subject 7

subject10.normal.jpg Subject 10

subject11.normal.jpg Subject 11

subject14.normal.jpg Subject 14

subject15.normal.jpg Subject 15

Reading tl Testing images of faces and reshaping their grayscale matrixes into the same order as Training images

In [15]:
```
t = []
for i in test_images:
  ti = mpimg.imread(i)      #reading the testing images to numpy array
  ti = ti.reshape(n1 * n2,)     #reshaping the numpy array to column vector
  t.append(ti)
t = np.asarray(t)     #storing all the column vectors into a single numpy array t
```

Subtracting mean face mn from input faces in t using $\vec{I} = I - m$

In [16]:
```
t = np.subtract(t, mn)
```

Computing the eigenface coefficients oi of Testing faces using $\Omega_I = U^T \vec{I}$

In [17]:
```
oi = []
for i in range(0, tl):
  oix = np.dot(ut,t[i])
  oi.append(oix)
oi = np.asarray(oi)
```

Printing Eigenface coefficients of Testing images

In [18]:
```
for i in range(0, tl):
  print("File:", test_images[i])
  print("Label:", true_label[i])
  print("Eigneface coefficients:", oi[i])
  print("")
```

```
File: subject01.normal.jpg
Label: Subject 1
Eigneface coefficients: [ 2.80339894e+07  2.34648126e+06  4.09184704e-09  8.25440772e+06
  4.34601543e+07  3.37021797e+07 -7.52727547e+07 -8.02856834e+06]

File: subject07.happy.jpg
Label: Subject 7
Eigneface coefficients: [-9.82359865e+07 -1.17310191e+07 -4.40800287e-08  1.14994467e+07
 -2.18686836e+06 -8.12372616e+06  2.60480030e+07 -1.32135051e+07]

File: subject07.normal.jpg
Label: Subject 7
Eigneface coefficients: [-1.16771406e+08  1.94535475e+07 -4.54533514e-08  2.00202560e+05
 -9.36449714e+06 -1.90152265e+07  2.74435806e+07 -1.97650518e+07]

File: subject11.happy.jpg
Label: Subject 11
Eigneface coefficients: [ 2.82605165e+08  6.92765475e+07  1.32574981e-07 -6.87873720e+06
 -2.04464233e+07 -6.01062509e+06  3.58215407e+07  3.16020984e+06]

File: subject14.happy.jpg
Label: Subject 14
Eigneface coefficients: [ 1.24208640e+07 -7.17008884e+07 -2.58943412e-08 -1.29282516e+07
  2.23758718e+07  6.94887484e+06 -1.82530628e+07 -2.64451272e+07]

File: subject14.sad.jpg
Label: Subject 14
Eigneface coefficients: [ 9.35369274e+06 -7.83302545e+07 -2.62314283e-08 -2.34432094e+07
  8.98022539e+06  3.38877745e+06 -5.36607090e+06 -2.05361412e+07]
```

Computing distance between input faces and training images using Euclidean distance $d_i = dist(\Omega_I, \Omega_i)$ for i = 1 to M and finding the index of the face with the least d_i as predicted face pf.

In [19]:
```
pf = []
for i in range(tl):
  dj = np.linalg.norm(oi[i] - o, axis=1)
  j = np.argmin(dj)
  pf.append(j)
```

Displaying the Predicted Label (& corresponding Training file name) and True Label (& corresponding Testing file name), with its Eigenface coefficients.

In [20]:
```
tp = 0
k = 0
for i in pf:
  print("Predicted Label:", pred_label[i], train_images[i], ", True Label:", true_label[k], test_images[k])
  Image.open(test_images[k]).show()
  print("Eigenface coefficient: ", oi[k])
  print("")
  if (pred_label[i] == true_label[k]):
    tp += 1
  k += 1
```

```
Predicted Label: Subject 1 subject01.happy.jpg , True Label: Subject 1 subject01.normal.jpg
Eigenface coefficient:  [ 2.80339894e+07  2.34648126e+06  4.09184704e-09  8.25440772e+06
  4.34601543e+07  3.37021797e+07 -7.52727547e+07 -8.02856834e+06]

Predicted Label: Subject 2 subject02.normal.jpg , True Label: Subject 7 subject07.happy.jpg
Eigenface coefficient:  [-9.82359865e+07 -1.17310191e+07 -4.40800287e-08  1.14994467e+07
 -2.18686836e+06 -8.12372616e+06  2.60480030e+07 -1.32135051e+07]

Predicted Label: Subject 2 subject02.normal.jpg , True Label: Subject 7 subject07.normal.jpg
Eigenface coefficient:  [-1.16771406e+08  1.94535475e+07 -4.54533514e-08  2.00202560e+05
 -9.36449714e+06 -1.90152265e+07  2.74435806e+07 -1.97650518e+07]

Predicted Label: Subject 11 subject11.normal.jpg , True Label: Subject 11 subject11.happy.jpg
Eigenface coefficient:  [ 2.82605165e+08  6.92765475e+07  1.32574981e-07 -6.87873720e+06
 -2.04464233e+07 -6.01062509e+06  3.58215407e+07  3.16020984e+06]

Predicted Label: Subject 14 subject14.normal.jpg , True Label: Subject 14 subject14.happy.jpg
Eigenface coefficient:  [ 1.24208640e+07 -7.17008884e+07 -2.58943412e-08 -1.29282516e+07
  2.23758718e+07  6.94887484e+06 -1.82530628e+07 -2.64451272e+07]

Predicted Label: Subject 14 subject14.normal.jpg , True Label: Subject 14 subject14.sad.jpg
Eigenface coefficient:  [ 9.35369274e+06 -7.83302545e+07 -2.62314283e-08 -2.34432094e+07
  8.98022539e+06  3.38877745e+06 -5.36607090e+06 -2.05361412e+07]
```

Calculating Accuracy as (Correct Predictions / Total Observations) x 100%

In [21]:
```
accuracy = (tp / tl) * 100
print("Accuracy:", accuracy, "%")
```

```
Accuracy: 66.66666666666666 %
```

In [21]: