Face Recognition: Project Report

Contents :

1. **Source Code (Please see attached file FaceRecognition.py)**

```
import numpy as np
from PIL import Image
import os

# Load Images
def load(image_list):
    image_mat_array =[]
    for image in image_list:
        img = Image.open(image).convert("L")
        arr = np.array(img)
        image_mat_array.append(arr)

    return image_mat_array

# Save a numpy array to an image
def save_image(image_obj,filename):
    if not os.path.exists(os.path.dirname(filename)):
        try:
            os.makedirs(os.path.dirname(filename))
        except OSError as exc: # Guard against race
condition
            if exc.errno != errno.EEXIST:
                raise

    height, width = image_obj.shape
    grayLevelImage = Image.new("L",(width,height))
    for i in range(0,width):
        for j in range(0,height):
```

```
grayLevelImage.putpixel((i,j),int(image_obj[j][i]))
    grayLevelImage.save(filename+".png")


#Load Training images
training_images_list = ["subject01.normal",
"subject02.normal", "subject03.normal",
                  "subject07.normal", "subject10.normal",
"subject11.normal",
                  "subject14.normal", "subject15.normal"]
training_images = ["Face dataset/"+ x+".jpg" for x in
training_images_list]
training_images_matrices = load(training_images)



# Stacking row in each matrix to form a column vaector
def form_column_vectors(training_images_matrices):
    training_column_vectors = [x.flatten() for x in
training_images_matrices]
    return training_column_vectors


# Forming M Face vectors
training_faces =
form_column_vectors(training_images_matrices)
# create a Matrix
training_faces  = np.vstack(training_faces)


training_faces = np.transpose(training_faces)
```

```
# Calculating the mean face, taking mean across column
mean_face = training_faces.mean(1)
size=training_images_matrices[0].shape
mean_face_image = mean_face.reshape(size)
save_image(mean_face_image,"Mean Face/mean_face")


# Function to subtract mean face from each face
def subtract_mean_from_each_face(mean_face, faces):
    size = faces.shape[1]
    new_faces = np.zeros(faces.shape)
    for i in range(0,size):
        new_faces[:,i] = np.subtract(faces[:,i], mean_face)
    return new_faces


adjusted_training_faces =
subtract_mean_from_each_face(mean_face, training_faces)


## -------------Eigenfaces:
Training------------------------

# calculating eigenfaces of the covariance matrix C= A.A^T
# going by alternate method of Singular Value decomposition
# Find eigenvalues of L = Transpose(A).A

A = adjusted_training_faces
A_t = np.transpose(A)
L  = np.dot(A_t,A)
L.shape
```

```
L_eig_vals, L_eig_vecs = np.linalg.eig(L)
V=L_eig_vecs
eigen_face_space = np.dot(A,V)


print("Eigen values:")
print(L_eig_vals)


# Projecting each training face to Eigen_face_space
eigen_face_space_t= np.transpose(eigen_face_space)
projected_training_faces =
np.dot(eigen_face_space_t,adjusted_training_faces)

#Load test images
from os import listdir
from os.path import isfile, join
testImagesList =
['subject01.centerlight.jpg','subject01.happy.jpg',

'subject01.normal.jpg','subject02.normal.jpg','subject03.no
rmal.jpg',

'subject07.centerlight.jpg','subject07.happy.jpg','subject0
7.normal.jpg',

'subject10.normal.jpg','subject11.centerlight.jpg','subject
11.happy.jpg',

'subject11.normal.jpg','subject12.normal.jpg','subject14.ha
ppy.jpg',
```

```
'subject14.normal.jpg','subject14.sad.jpg','subject15.norma
l.jpg','apple1_gray.jpg']



test_images_list = testImagesList
test_images = ["Face dataset/"+ x for x in
test_images_list]

test_images_matrices = load(test_images)
# Forming M Face vectors
test_faces = form_column_vectors(test_images_matrices)
# create a Matrix
test_faces  = np.vstack(test_faces)
test_faces = test_faces.T


# Saving Eigen Faces Images
for i in range(0,eigen_face_space.shape[1]):
    x=eigen_face_space[:,i]
    image_obj =x.reshape(test_images_matrices[0].shape)
    save_image(image_obj,"Eigen
Faces/eigenface{}".format(i))


#Recognition of test images in training images
# 1. Subtract mean face from the test images
adjusted_test_faces =
subtract_mean_from_each_face(mean_face, test_faces)


# Subtract mean face from each test face
```

```
for i in range(0,adjusted_test_faces.shape[1]):
    x=adjusted_test_faces[:,i]
    image_obj = x.reshape(test_images_matrices[0].shape)
    save_image(image_obj,"Mean Subtracted Test
Faces/"+testImagesList[i])


# Transpose(U).test_faces for calculating projection of
test faces onto face space
eigen_face_space_t = np.transpose(eigen_face_space)
projected_test_faces =
np.dot(eigen_face_space_t,adjusted_test_faces)


print("\nPCA Coefficents for Test Images:\n")
for i in range(0,projected_test_faces.shape[1]):
    print("\nPCA Coeffivents for {}
:".format(test_images_list[i]))
    print(projected_test_faces[:,i])
    print("\n")


print("\nPCA Coefficents for Training Images:\n")
for i in range(0,projected_training_faces.shape[1]):
    print("\nPCA Coeffivents for {}
:".format(training_images_list[i]))
    print(projected_training_faces[:,i])
    print("\n")


# Reconstruct input face image from eigenfaces
reconstructed_test_faces =
```

```
np.dot(eigen_face_space,projected_test_faces)


# Save reconstructed test images
for i in range(0,reconstructed_test_faces.shape[1]):
    x=reconstructed_test_faces[:,i]
    image_obj = x.reshape(test_images_matrices[0].shape)

save_image(image_obj,"reconstructed_test_faces/{}".format(t
est_images_list[i]))


from numpy import  linalg as LA
# Compute distance between input face and training images
in the face space
temp_projected_test_faces = projected_test_faces.T
temp_projected_training_faces = projected_training_faces.T
min_distance_list=[]
distance_mat = np.zeros(projected_test_faces.shape)
for i in range(0,temp_projected_test_faces.shape[0]):
    distances
=[LA.norm(np.subtract(temp_projected_test_faces[i], x)) for
x in temp_projected_training_faces]
    distance_mat[:,i] = distances
    min_dist = min(distances)
    min_index = distances.index(min_dist)
    min_distance_list.append([min_dist,min_index])


# Computing Distance Between the Test Image and it's
reconstructed image in the Face Space
face_space_dist_list=[]
```

```
for i in range(0,reconstructed_test_faces.shape[1]):
    distance = LA.norm(reconstructed_test_faces[:,i] -
adjusted_test_faces[:,i])
    face_space_dist_list.append(distance)

# Threshold to classif the test image as an Identical or
Unknown Face
min_distance_threshold = 8.6e+7
# Print Distance of each test face from each training face
in face face
# Print closest training face to the projected test face
# Classify the  Face. as Identical or Unknown
for i in range(0,distance_mat.shape[1]):
    print("\nTest Face: {}".format(test_images_list[i]))
    print("Training Face\t\t\t Distance")

print("_____________________________________________")
    for j in range(0,distance_mat.shape[0]):

print(training_images_list[j],"\t\t",distance_mat[j][i])
#     print("Test Face {}- {} has minimum distance with:
Face {}: {}, distance:  {}".format(i+1,testImagesList[i],
#
min_distance_list[i][1]+1,
#
training_images[min_distance_list[i][1]],
#
min_distance_list[i][0]))
    if(min_distance_list[i][0] < min_distance_threshold):
        print("Identity of Face:
{}".format(training_images_list[min_distance_list[i][1]]))
    else:
```

```
        print("Unknown Face")


# Print the distance Between the Test Image and it's
reconstructed image in the Face Space
# Classify the test image as  a Face or Non Face Image
based on the threshold set
print("Test Face\t\tDistance From Face Space\t\t\t Face
classification")
print("_____________________________________________________
_____________________________")
# Threshold to distinguish between a Face and non face
image
threshold = 7e+12
for i in range(0,len(face_space_dist_list)):
        if(face_space_dist_list[i]>threshold):
            face_class ="Non Face "
        else:
            face_class ="Face"


print(test_images_list[i],"\t\t\t",face_space_dist_list[i],
"\t\t\t", face_class)
```

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2. **Instructions on how to compile and run :** There is no need to compile the program. Just make sure that the Face dataset directory containing all the test images and the script are in the same folder. To run the script , type the

following command:

python FaceRecognition.py >> output.txt

Output. Py captures the following output generated by the script:

1. PCA coefficients,
2. eigenvalues
3. classification of Images as Identical Face or Unknown Face,
4. Classification as face or Non face Image

It will create following 4 folders:

1. Eigen Faces
2. Mean Face
3. Mean Subtracted Test Faces
4. Reconstructed_test_images

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3. Thresholds

- For classifying the image as an identical or unknown image,

  T_1= 8.6e+7 (which is 86000000.0)

- For classifying the image as a Face or Non Face image,

  T_0 = 7e+12 (which is 7000000000000.0)

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4. Mean Face:

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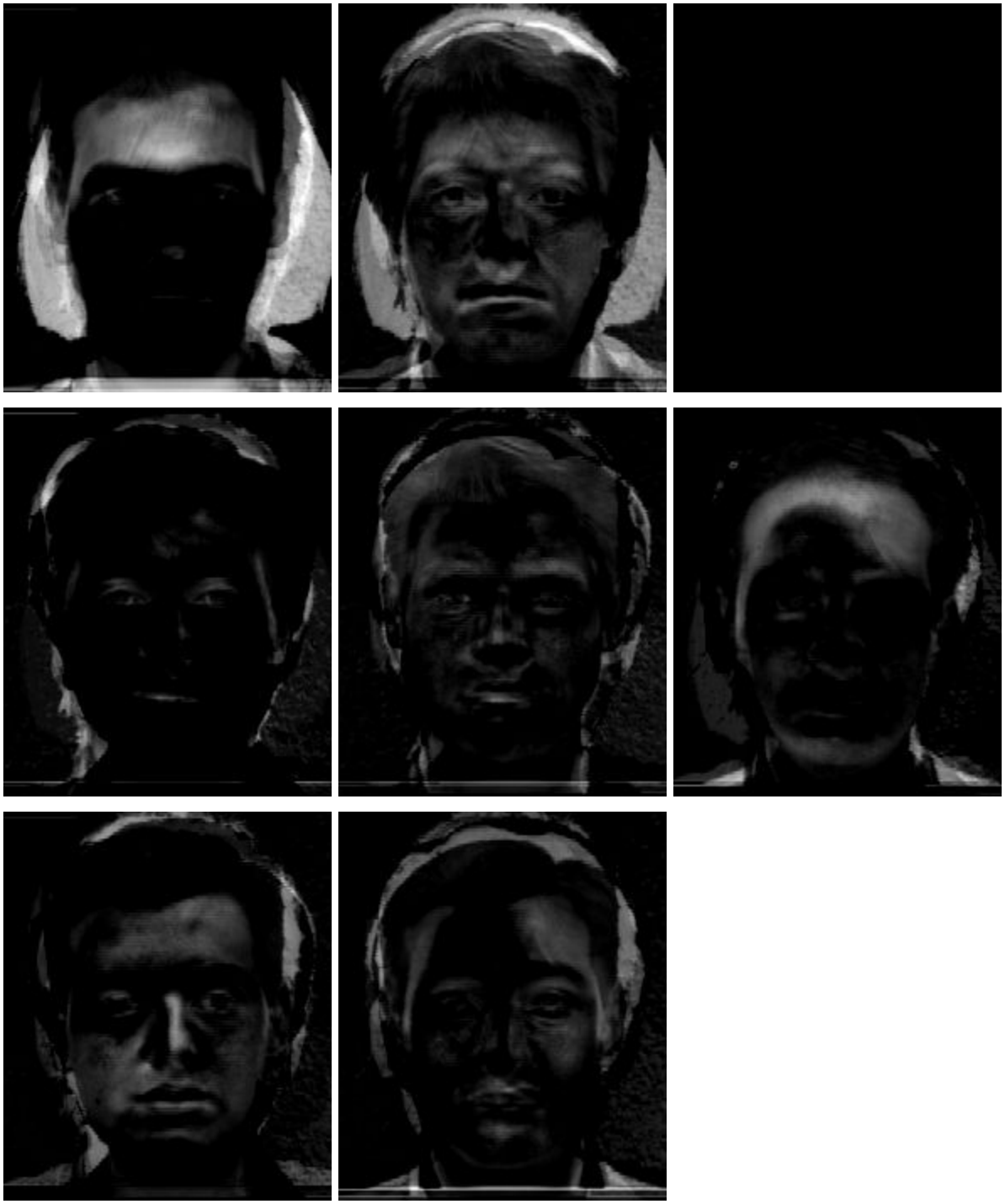
5. Eigen Faces:



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6. PCA Coefficients for Training Images:

PCA Coefficient for subject01.normal :
[-7.58393182e+07 9.86591897e+07 8.92059302e-09 -7.35308451e+07
  2.03390545e+07 2.09059360e+07 -1.34689494e+07 4.95663886e+06]

PCA Coefficient for subject02.normal :
[8.55914694e+07 -5.32769258e+07 -5.69868670e-09 -4.35819945e+04
 -1.02912808e+07 7.27564771e+07 -2.36191334e+07 -2.56112293e+07]

PCA Coefficient for subject03.normal :
[6.79094869e+07 2.86096157e+07 2.00918010e-08 -2.11976451e+07
 -9.00930120e+06 -6.14469992e+07 3.38368115e+06 -4.32998677e+07]

PCA Coefficient for subject07.normal :
[1.59365384e+08 -5.98976188e+07 -2.57703407e-08 3.62392288e+07
  2.39421030e+07 -2.99666082e+07 -3.11659201e+07 1.50158366e+07]

PCA Coefficient for subject10.normal :
[-2.57010807e+07 5.31036358e+07 -5.08184474e-08 7.67395071e+07
  1.13657321e+07 2.13665227e+07 4.79155988e+07 -8.39149947e+06]

PCA Coefficient for subject11.normal :
[-3.09965508e+08 -1.01569225e+08 5.30136190e-08 -7.23282904e+06
  3.43527729e+05 -1.38164759e+07 4.01893283e+06 6.69097274e+05]

PCA Coefficient for subject14.normal :
[-5.48035678e+07 7.56177219e+07 -1.44194261e-08 4.07897743e+07
 -2.52009615e+07 -9.97235825e+06 -2.99136079e+07 2.68289508e+07]

PCA Coefficient for subject15.normal :
[1.53443135e+08 -4.12463935e+07 1.46808878e-08 -5.17636090e+07
 -1.14888738e+07 1.73505791e+05 4.28493981e+07 2.98320729e+07]

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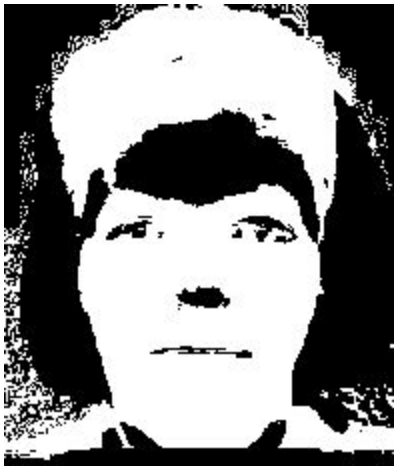
7. Results For Test Images

1. subject01.centerlight.jpg

Mean Subtracted Test Image

Reconstructed Test Image:



- **PCA Coefficient for subject01.centerlight.jpg :**
  [-4.19265944e+07 9.33435765e+06 4.97426790e-09 -1.96894052e+07
  3.51175100e+06 2.33364673e+07 -4.53879945e+06 -2.45326164e+06]

- **Distances From Training Images:**

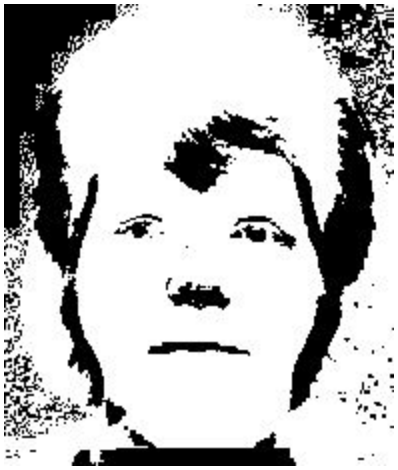
Training Face	Distance
subject01.normal	111586822.418
subject02.normal	155242389.34
subject03.normal	146676511.366
subject07.normal	229591657.824
subject10.normal	119707328.133
subject11.normal	292870266.507
subject14.normal	107945627.816
subject15.normal	214023418.315

- **Clasiification:**
  Identity of Face: Unknown Face

2. subject01.happy.jpg

Mean Subtracted Test Image:

Reconstructed Test Image:



- **PCA Coefficients for subject01.happy.jpg :**
  [-2.84226819e+07 6.21657618e+07 5.84770206e-09 -5.58402336e+07
  1.39551196e+07 2.39919521e+07 -1.56038461e+07 -4.88745009e+05]

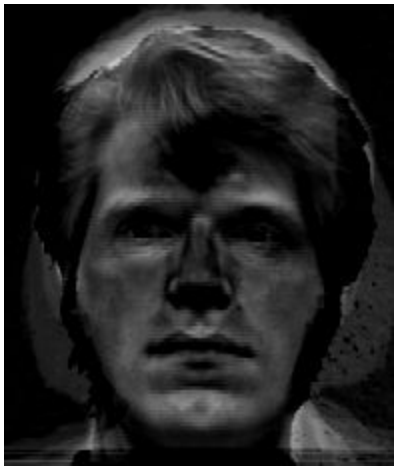
- **Distances from training faces:**

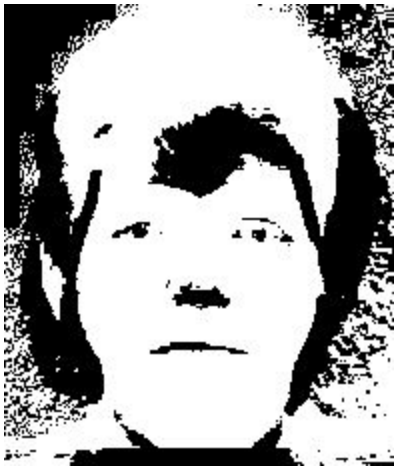
Training Face	Distance
subject01.normal	63067848.625
subject02.normal	181936137.178
subject03.normal	147059539.161
subject07.normal	249271519.075
subject10.normal	147572653.644
subject11.normal	332324142.182
subject14.normal	117694790.263
subject15.normal	222118699.969

- **Classification**
  Identity of Face: subject01.normal

3. subject01.normal.jpg

Mean Subtracted Test Image: **Reconstructed Test Image:**





- **PCA Coefficients for subject01.normal.jpg :**
  [-7.58393182e+07 9.86591897e+07 8.92059302e-09 -7.35308451e+07
  2.03390545e+07 2.09059360e+07 -1.34689494e+07 4.95663886e+06]

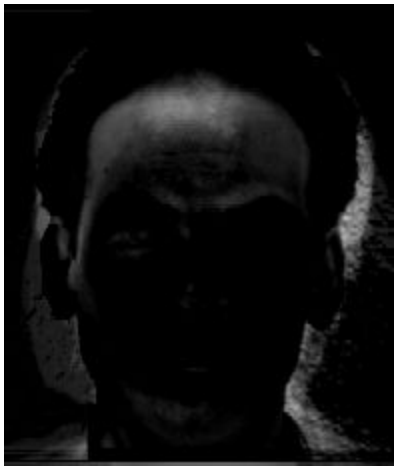
- **Distances from training faces:**
  Test Face: subject01.normal.jpg

Training Face	Distance
subject01.normal	0.0
subject02.normal	243328948.302
subject03.normal	196380903.102
subject07.normal	309073374.025
subject10.normal	176627569.523
subject11.normal	318169127.804
subject14.normal	133487089.229
subject15.normal	279018318.621

- **Classification**
  Identity of Face: subject01.normal

4. Subject02.normal.jpg

Mean Subtracted Test Image: **Reconstructed Test Image**



PCA Coefficient for subject02.normal.jpg :
[8.55914694e+07 -5.32769258e+07 -5.69868670e-09 -4.35819945e+04
-1.02912808e+07 7.27564771e+07 -2.36191334e+07 -2.56112293e+07]

- **Distances from training images:**
  Test Face: subject02.normal.jpg

Training Face	Distance
subject01.normal	243328948.302
subject02.normal	0.0
subject03.normal	162849037.561
subject07.normal	142247445.345
subject10.normal	195249043.536
subject11.normal	409770237.603
subject14.normal	218741654.313
subject15.normal	142074947.716

- **Classification:**
  Identity of Face: subject02.normal

5 subject03.normal.jpg

Mean Subtracted Test Image:

Reconstructed Test Image:

- **PCA Coefficient for subject03.normal.jpg :**
  [6.79094869e+07 2.86096157e+07 2.00918010e-08 -2.11976451e+07
  -9.00930120e+06 -6.14469992e+07 3.38368115e+06 -4.32998677e+07]

- **Distance from training faces:**
  Test Face: subject03.normal.jpg

Training Face	Distance
subject01.normal	196380903.102
subject02.normal	162849037.561
subject03.normal	0.0
subject07.normal	161764991.664
subject10.normal	171550250.39
subject11.normal	405241747.8
subject14.normal	173347238.682
subject15.normal	154399493.307

- **Classification**:
  Identity of Face: subject03.normal

6. subject07.centerlight.jpg :

Mean Subtracted Test Image:

Reconstructed Test Image

- **PCA Coefficient for subject07.centerlight.jpg :**
  [5.94280720e+06 1.09073119e+07 -2.93655309e-08 6.44391875e+07
  -4.06118038e+06 -1.88646091e+06 -1.60012838e+07 1.25351205e+07]

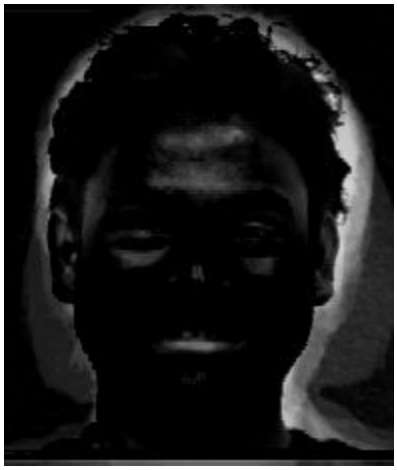
- **Distances from Training Images:**
  Test Face: subject07.centerlight.jpg

Training Face	Distance
subject01.normal	186019216.483
subject02.normal	147462236.853
subject03.normal	136206359.704
subject07.normal	176510231.04
subject10.normal	90747702.0619
subject11.normal	343932044.681
subject14.normal	96679844.911
subject15.normal	204454021.453

- **Classification:** Unknown Face

7. subject07.happy.jpg :

Mean Subtracted Test Image:



Reconstructed Test Image:

- **PCA Coefficient for subject07.happy.jpg :**
  [1.03893380e+08 -9.15597753e+06 -1.88353249e-08 2.31395182e+07
  9.78874352e+05 -3.10262255e+06 -4.00701970e+06 6.01476791e+06]

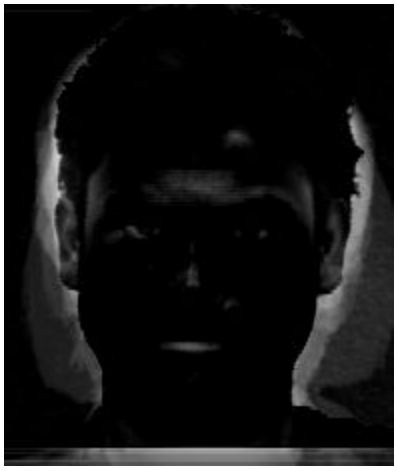
- **Distances from Training Images:**
  Test Face: subject07.happy.jpg

Training Face	Distance
subject01.normal	233055760.24
subject02.normal	100426750.645
subject03.normal	103330781.054
subject07.normal	88831686.4948
subject10.normal	164784911.904
subject11.normal	425382239.24
subject14.normal	185795025.334
subject15.normal	

- **Classification: Unknown Face**

8. subject07.normal.jpg :

Mean Subtracted Test Image:



Reconstructed Test Image:

- **PCA Coefficient for subject07.normal.jpg :**
  [1.59365384e+08 -5.98976188e+07 -2.57703407e-08 3.62392288e+07
  2.39421030e+07 -2.99666082e+07 -3.11659201e+07 1.50158366e+07]

- **Distances from Training Images:**
  Test Face: subject07.normal.jpg

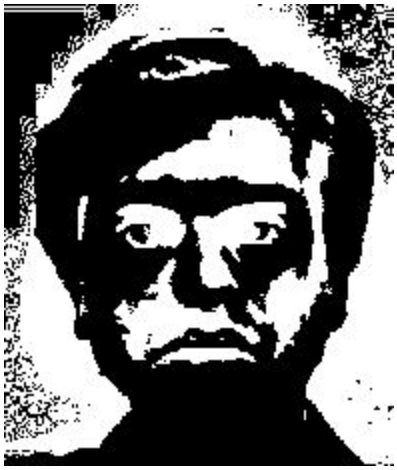
Training Face	Distance
subject01.normal	309073374.025
subject02.normal	142247445.345
subject03.normal	161764991.664
subject07.normal	0.0
subject10.normal	241359064.247
subject11.normal	475562142.495
subject14.normal	259247726.572
subject15.normal	126447654.975

  Identity of Face: subject07.normal

- **Classification**:
  Identity of Face: subject07.normal

9. subject10.normal.jpg :

Mean Subtracted Test Image: **Reconstructed Test Image:**



- **PCA Coefficient for subject10.normal.jpg :**
  [-2.57010807e+07 5.31036358e+07 -5.08184474e-08 7.67395071e+07
  1.13657321e+07 2.13665227e+07 4.79155988e+07 -8.39149947e+06]

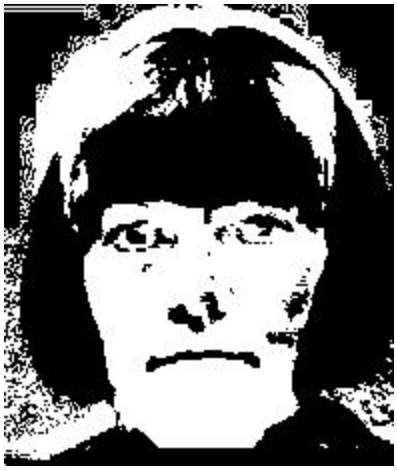
- **Distances from Training Images:**
  Test Face: subject10.normal.jpg

Training Face	Distance
subject01.normal	176627569.523
subject02.normal	195249043.536
subject03.normal	171550250.39
subject07.normal	241359064.247
subject10.normal	1.75721591936e-08
subject11.normal	339337083.098
subject14.normal	110739948.506
subject15.normal	244879181.662

- **Classification:** Identity of Face: subject10.normal

10. subject11.centerlight.jpg :

Mean Subtracted Test Image: **Reconstructed Test Image:**



- **PCA Coefficient for subject11.centerlight.jpg :**
  [-1.84458324e+08 -1.27514264e+08 4.30947028e-08 -3.94098492e+06
  -4.82546087e+06 6.57524499e+06 -1.18073793e+07 -4.07760603e+06]

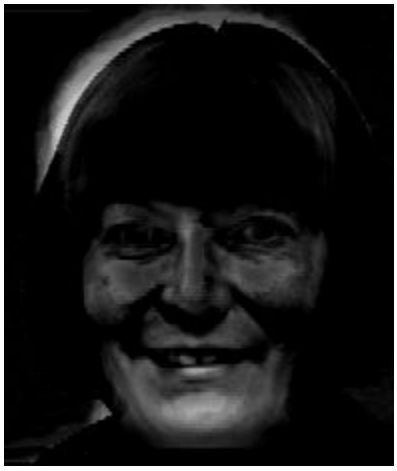
- **Distances from Training Images:**
  Test Face: subject11.centerlight.jpg

Training Face	Distance
subject01.normal	262141694.81
subject02.normal	288905361.763
subject03.normal	307856548.306
subject07.normal	356796012.795
subject10.normal	261538544.375
subject11.normal	130964036.022
subject14.normal	249090014.327
subject15.normal	357951333.858

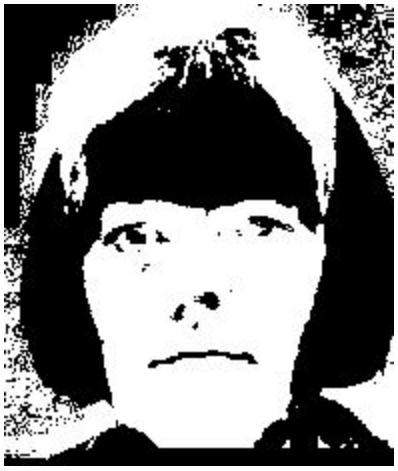
- **Classification:** Unknown Face

11. subject11.happy.jpg :

Mean Subtracted Test Image:



Reconstructed Test Image:



- **PCA Coefficient for subject11.happy.jpg :**
  [-2.91280480e+08 -1.07981032e+08 5.34113925e-08 -8.07984970e+06
  -3.16856693e+06 -8.84253231e+06 -2.77433359e+06 1.23549801e+06]

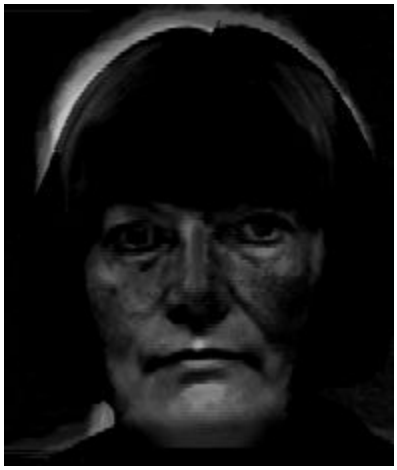
- **Distances from Training Images:**
  Test Face: subject11.happy.jpg

Training Face	Distance
subject01.normal	308163446.499
subject02.normal	391093302.164
subject03.normal	390729034.105
subject07.normal	457750024.724
subject10.normal	327812434.44
subject11.normal	21783094.3634
subject14.normal	306425098.006
subject15.normal	455182031.455

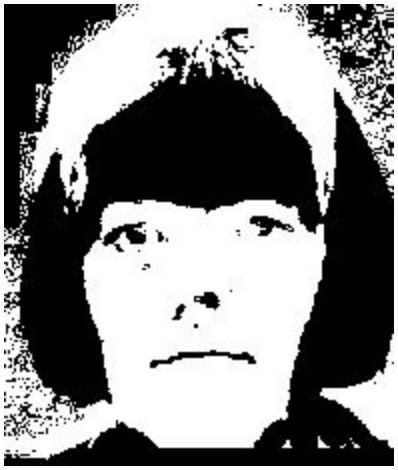
- **Classification:** Identity of Face: subject11.normal

12. subject11.normal.jpg :

Mean Subtracted Test Image:



Reconstructed Test Image:



- **PCA Coefficient for subject11.normal.jpg :**
  [-3.09965508e+08 -1.01569225e+08 5.30136190e-08 -7.23282904e+06
  3.43527729e+05 -1.38164759e+07 4.01893283e+06 6.69097274e+05]

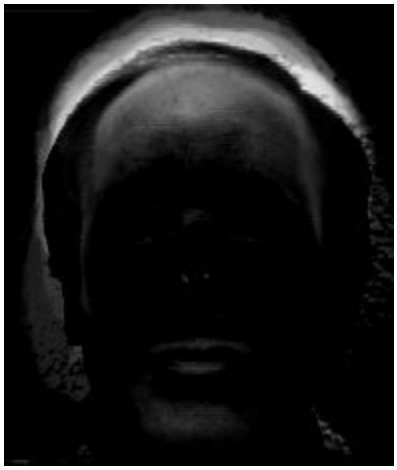
- **Distances from Training Images:**
  Test Face: subject11.normal.jpg

Training Face	Distance
subject01.normal	318169127.804
subject02.normal	409770237.603
subject03.normal	405241747.8
subject07.normal	475562142.495
subject10.normal	339337083.098
subject11.normal	0.0
subject14.normal	318295544.793
subject15.normal	472295896.835

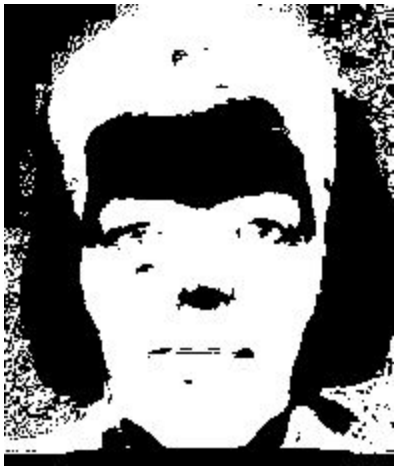
- **Classification:** Identity of Face: subject11.normal

13. subject12.normal.jpg :

Mean Subtracted Test Image:



Reconstructed Test Image:



- **PCA Coefficient for subject12.normal.jpg :**
  [-8.48151488e+07 2.39983394e+07 -7.94939199e-09 9.24693940e+06
  1.09479841e+06 3.03539436e+07 -1.06420075e+07 1.14064585e+07]

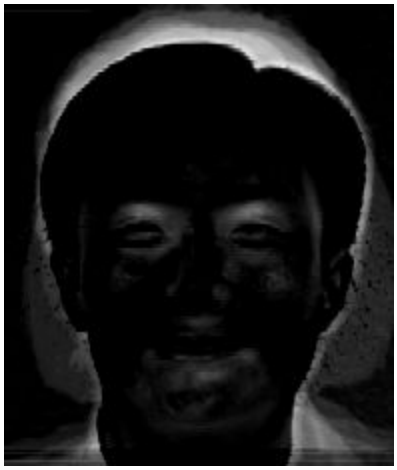
- **Distances from Training Images:**

Training Face	Distance
subject01.normal	114088420.684
subject02.normal	196373441.628
subject03.normal	189715468.363
subject07.normal	268302208.33
subject10.normal	113596022.111
subject11.normal	262703834.786
subject14.normal	86528212.3859
subject15.normal	262709370.184

- **Classification:**Unknown Face

14. subject14.happy.jpg :

Mean Subtracted Test Image:



Reconstructed Test Image:

- **PCA Coefficient for subject14.happy.jpg :**
  [-3.72003742e+07 7.23552596e+07 -1.15433914e-08 2.01072900e+07
  -1.10391535e+07 -1.16749219e+07 -3.12504845e+07 1.93984877e+07]

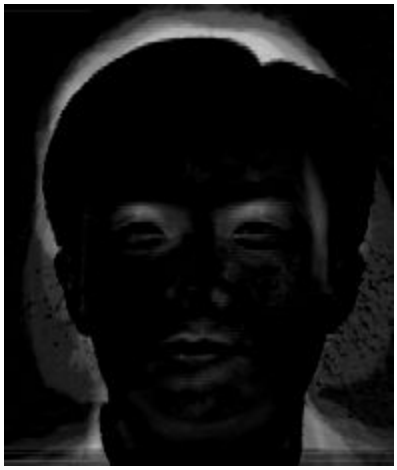
- **Distances from Training Images:**

Training Face	Distance
subject01.normal	116291957.183
subject02.normal	201198094.2
subject03.normal	149264366.459
subject07.normal	240762641.378
subject10.normal	111100562.015
subject11.normal	327302460.046
subject14.normal	31760601.2445
subject15.normal	245267097.181

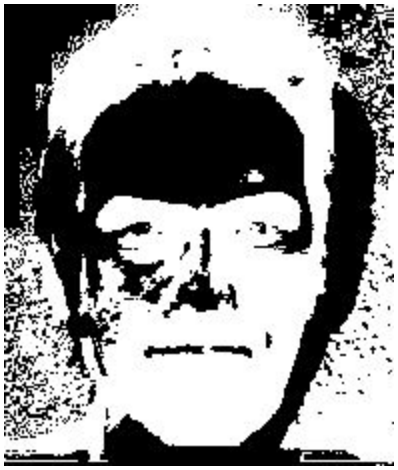
- **Classification:Identity of Face: subject14.normal**

15. subject14.normal.jpg :

Mean Subtracted Test Image:



Reconstructed Test Image:



- **PCA Coefficient for subject14.normal.jpg :**
  [-5.48035678e+07 7.56177219e+07 -1.44194261e-08 4.07897743e+07
  -2.52009615e+07 -9.97235825e+06 -2.99136079e+07 2.68289508e+07]

- **Distances from Training Images:**
  Test Face: subject14.normal.jpg

Training Face	Distance
subject01.normal	133487089.229
subject02.normal	218741654.313
subject03.normal	173347238.682
subject07.normal	259247726.572
subject10.normal	110739948.506
subject11.normal	318295544.793
subject14.normal	0.0
subject15.normal	266804184.747

- **Classification:** Identity of Face: subject14.normal

16. subject14.sad.jpg :

Mean Subtracted Test Image:

Reconstructed Test Image:

- **PCA Coefficient for subject14.sad.jpg :**
  [-3.09557722e+07 6.21419290e+07 -1.61496412e-08 4.11282105e+07
  -1.89530184e+07 -9.12193903e+06 -3.02355547e+07 1.57609187e+07]

- **Distances from Training Images:**
  Test Face: subject14.sad.jpg

Training Face	Distance
subject01.normal	139061618.925
subject02.normal	192702933.17
subject03.normal	149125741.228
subject07.normal	231118169.491
subject10.normal	99585049.0715
subject11.normal	329821305.091
subject14.normal	30212478.884
subject15.normal	242904340.548

  Unknown Fa**ce**

- **Classification:** Identity of Face: subject14.normal

17. subject15.normal.jpg :

Mean Subtracted Test Image:

Reconstructed Test Image:

- **PCA Coefficient for subject15.normal.jpg :**
  [1.53443135e+08 -4.12463935e+07 1.46808878e-08 -5.17636090e+07
  -1.14888738e+07 1.73505791e+05 4.28493981e+07 2.98320729e+07]

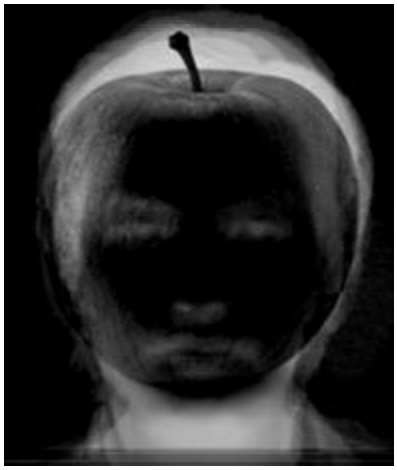
- **Distances from Training Images:**
  Test Face: subject15.normal.jpg

Training Face	Distance
subject01.normal	279018318.621
subject02.normal	142074947.716
subject03.normal	154399493.307
subject07.normal	126447654.975
subject10.normal	244879181.662
subject11.normal	472295896.835
subject14.normal	266804184.747
subject15.normal	0.0

- **Classification:** Identity of Face: subject15.normal

18. apple1_gray.jpg :

Mean Subtracted Test Image:



Reconstructed Test Image:

- **PCA Coefficient for apple1_gray.jpg :**
  [-2.40683176e+07 2.33966524e+07 1.42829988e-08 -5.18978138e+07
  1.54361939e+07 -2.59415798e+06 -3.62456870e+07 1.56605404e+07]

- **Distances from Training Images:**
  Test Face: apple1_gray.jpg

Training Face	Distance
subject01.normal	100111536.845
subject02.normal	169692008.721
subject03.normal	136153029.877
subject07.normal	221814828.114
subject10.normal	160265519.129
subject11.normal	318666513.742
subject14.normal	118883680.688
subject15.normal	207071343.061

- **Classification:** Unknown Face

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