Assignment 4

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I. Introduction:

This assignment required taking a set of 'fa' face images and fiducial grids from two different ethnic groups, and trying to compare their grouping in the eigen image space. The second part required assessing if the set of corresponding 'fb' face images lie close to the 'fa' image points in the eigen image space, and thereby performing facial recognition.

The steps in implementation followed the Homework aid document closely.

II. Data:

The implementation is tested on two ethnic groups 'AsianFemale' and 'WhiteMale'. These can be found in the 'data' folder.

III. Image Transformations:

In this section the processing of Facial Images for obtaining required outputs are described using Image Transformation Operators.

1. Average Faces: To create an average face, the faces are warped to the average fiducial grid (G) and the resulting images are averaged. In the operator notation:

$$\mathbf{G} = \frac{1}{P}\sum_{i}^{P}\mathbf{F}_i \qquad \text{(Average Fiducial Grid: G)}$$

$$\mathbf{b}[\overrightarrow{x}] = \frac{1}{N}\sum_{i} W_G \mathbf{a_i}[\overrightarrow{x}]$$

2. Eigen Images and Facial Recognition:

1. For the set of images $(\mathbf{a}_i[\overrightarrow{x}], \mathbf{F}_i; i = 1, 2, ..., N)$, we form the average fiducial grid (G), and warp each of the images to this grid

$$\mathbf{c}_i[\overrightarrow{x}] = \mathbf{W}_G \mathbf{a}_i[\overrightarrow{x}]$$

$$d_{i<5}[\overrightarrow{x}] = T_5\mathbf{c}_i[\overrightarrow{x}], \forall i.$$

These images are then compared in the eigen space.

IV. Running the Code:

There are Multiple Outputs for this assignment as listed below:

1. Output and Comparision for Face Recognition
2. Images of Average Faces
3. Images of Eigen Images for each grouping
4. Plots for Seperation of Ethnic Groups
5. Plots for comparing FA and FB images in Each Group

Method to obtain each of the above outputs from beginning is mentioned below sequentially.

The code should be run initially by calling the 'python running_code.py' file from terminal.

```
#python running_code.py
```

1. Output and Comparision for Face Recognition:

The code displays a menu asking for input to view the output for Face Recognition (this is “5.Output and Comparision of Face Recognition” mentioned above).

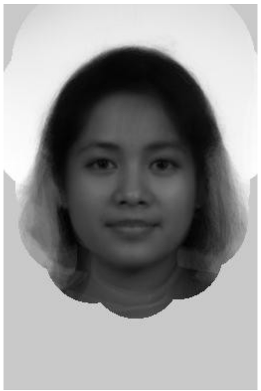
The menu can be explored interactively and displays the Warped FA Image and its Closest Matching Image. For example: Choosing 1 and 1 in the menu gives:

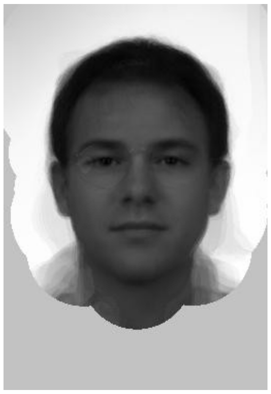
It also prints out a list of images in decreasing order of similarity to the choosen image, and prints their file names in the terminal:

```
Enter Image # (from 1 to 10): 1

data/AsianFemale/00130_931230_fa.txt

[0, 2, 4, 1, 3, 9, 7, 8, 5, 6]

The closest match is:

 data/AsianFemale/00130_931230_fb.txt
```

2. Images of Average Faces:

Images of Average Faces can be found in 'output/' directory with the names “AsianFemale.jpg” and “WhiteMale.jpg”. They are shown below:





3. Images of Eigen Images for Each Group:

Each of the 5 Eigen Images , generated for both groups is placed in the 'output/' directory. An Example is shown in the “Results” section.

4. Plot for Seperation of Ethnic Groups:

The plot can be generated using GNUPlot from command line using the following command:

```
# gnuplot plotaf.txt
```

This generates a “diff_in_groups.png” file in the directory that shows the seperation of both groups.

5. Plots for comparing FA and FB Images in Each Group:

Plot for comparing FA and FB images in “AsianFemale” Group can be obtained as:

```
#gnuplot plotAsianFemale_fa_fb.txt
```

The output for AsianFemale is in file “Asian_Femalefa_fb.png”

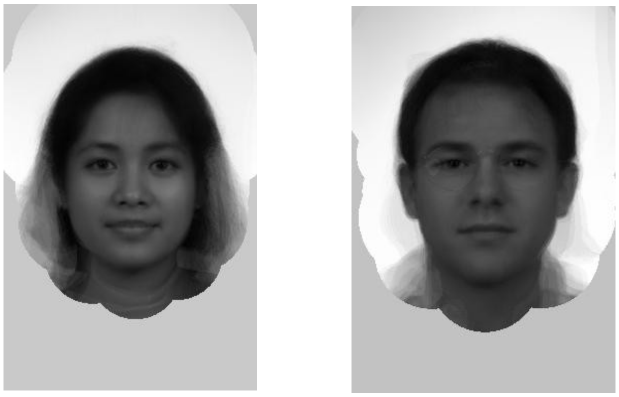
Plot for comparing FA and FB images in “WhiteMale” Group can be obtained as:

```
#gnuplot plotWhiteMale_fa_fb.txt
```

The output for WhiteMale is in file “White_Malefa_fb.png”

V. Results:

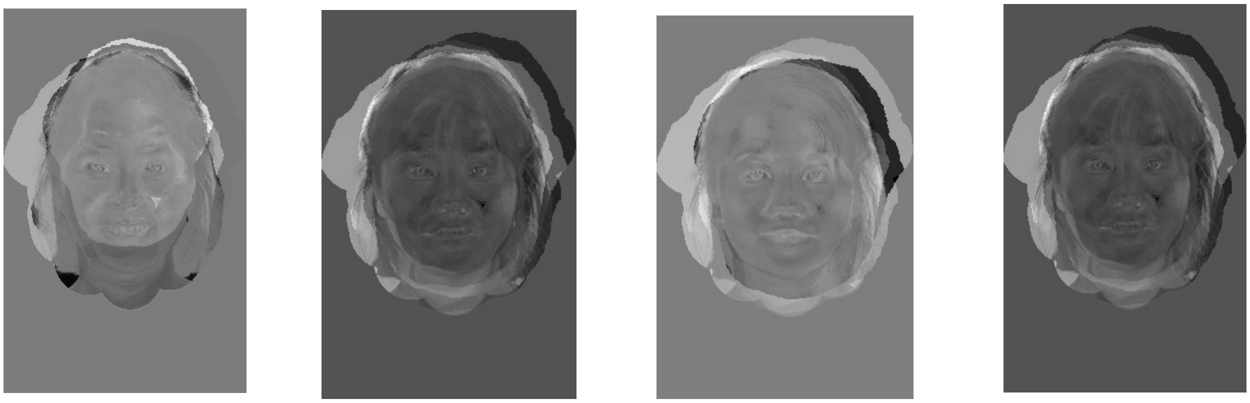
1. Average Faces: The average faces for each of the ethnic groups were calculated by averaging the fiducial grids, warping the images to the average fiducial grid and averaging the warped faces. The resulting average faces were as follows:



The Eigen image space was constructed from 'fa' group of images in each group after applying a mask (created manually using GIMP), and 5 vectors corresponding to the largest eigenvalues were retained to map the eigen space.

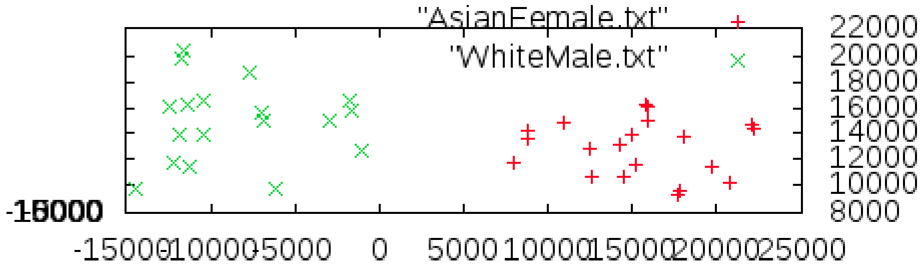
2. Eigen Images: Eigen Images/vectors for Each of the group sorted according to their eigen values showed decreasing number of common features. This was computed only using masked 'fa' images and the result obtained was as expected.

The eigen images for “AsianFemale” are shown below:

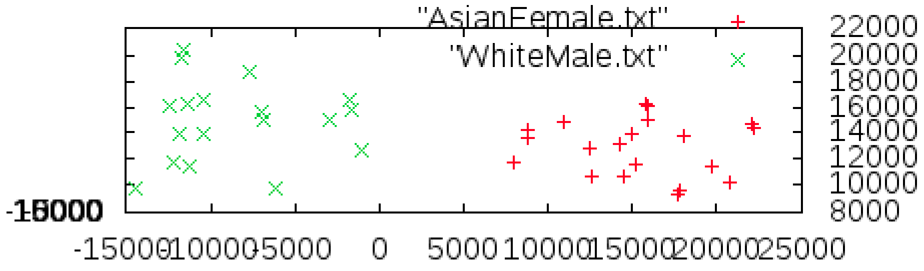


3. Seperation of Ethnic Groups: All images ('fa' and 'fb') in each ethnic group were applied with the mask, warped to the average grid and then mapped into the eigen space using the ProjectEigen function:

The resulting vectors were sorted according to their eigenvalues and the vectors corresponding the the 3 largest eigenvalues were mapped and plotted using Gnuplot to see if they form distinct groups when plotted in eigen image space. The result was as follows in the x-y 2d plane:

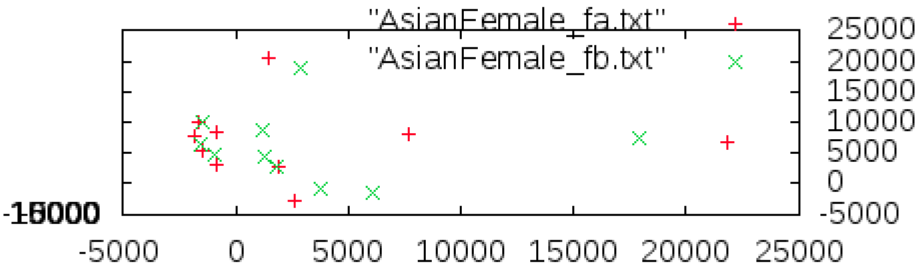


Here we can see both the groups seperate very clearly.

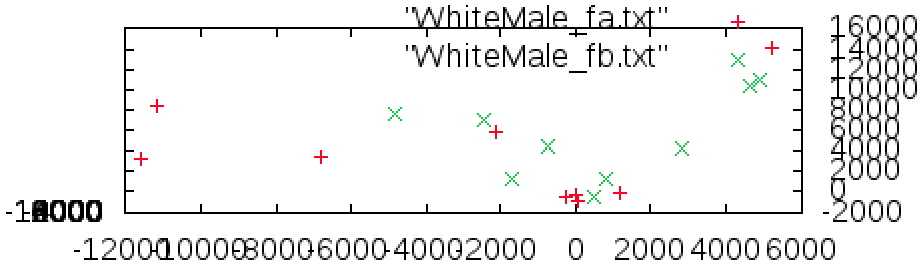


4. Similarity in FA and FB Images:

To compare the similarity of 'fa' and 'fb' images in one ethnic group, the images were seperately mapped to the eigen image space and plotted. The result obtained for ' ' was as follows:



For the 'AsianFemale' Ethnic group the plot for Fa and Fb images were close. This is shown in the plot below:For the 'WhiteMale' Ethnic group the plot for Fa and Fb images were not as close as expected, with many outliers, as shown in the plot below:



The fa and fb are more closely matched in AsianFemale group than in WhiteMale group.

5. Euclidean distance in Eigen Space and Recognition:

The recognition by mapping fa and fb images into eigen image space showed good results for most of the images in 'AsianFemale' group and did exceptionally well in the 'WhiteMale' group.

Example:

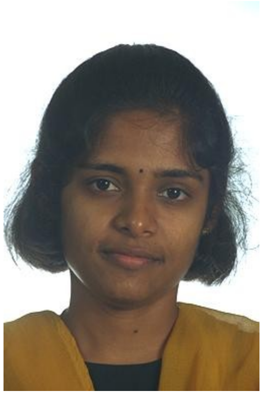
The code calculates the eigen distance of each fa image to each of the fb images.

It then displays the closest match array of fb images to the given fa image. A sample output of this is shown below:

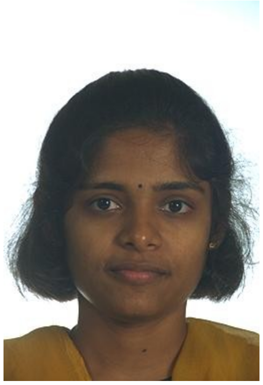
Output:

```
Enter Image # (from 1 to 10): 1

data/AsianFemale/00130_931230_fa.txt

[0, 2, 4, 1, 3, 9, 7, 8, 5, 6]

The closest match is:

 data/AsianFemale/00130_931230_fb.txt
```

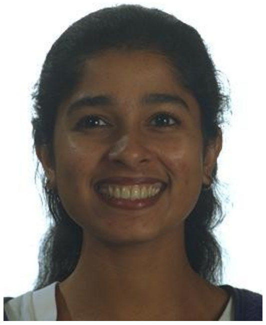
Some of the images, however, were matched to other images. This mismatch was probably due to using only 5 eigen images instead of 7 or more, and also possibly due to the mask removing some features in some of the images. As for Image #8 in Asian Female Ethnic Group:



FA Image



Expected Match



Best Match