Computer Vision
Project 2 - Face Recogonition
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Project description. Design a face recognition system using the eigenface method you have learned in class. You will be given a set of M training images and another set of test images. Use the training images to produce a set of eigenfaces. Then recognize the face in the input image using the eigenface method. Use Euclidean distance as distance measure for computing d_i, for i=0 to M. You can manually choose the thresholds $T0$ and $T1$ that produce the best results.

I use C++ to build this project.
Way to build and run this project:
- Have to install make version 3.9.4
- Go to the dir with CMakeLists.txt
- run cmake .
- run make
- Then, g++ will compile the FaceDetection.cpp and generate executable application FaceDetection
- ./FaceDetection

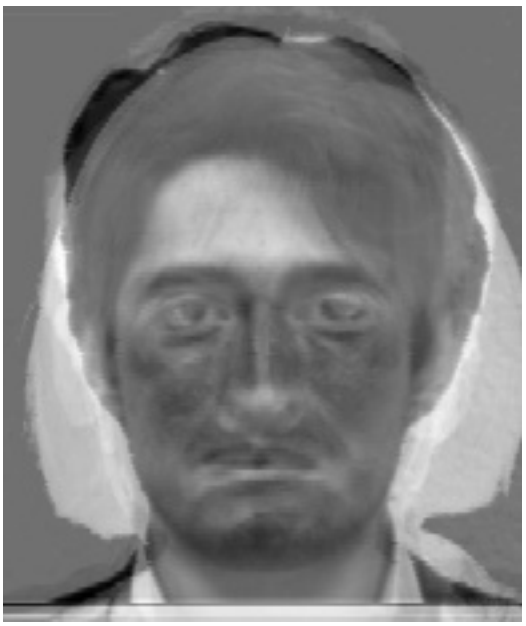
(1) The manually chosen thresholds $T0$ *and* $T1$,
T0 = 1.7+16 (because I cannot filter the apple so I choose the threshold with more accurate results)
T1 = 1.7+16
(2) the mean face m

(3) the M eigenfaces. The eigenfaces are contained in the matrix U, with each column represents an eigenface. You can output each eigenface as an $N \times N$ image.

Eigen Face 1

Eigen Face 2

Eigen Face 3



Eigen Face 4

Eigen Face 5

Eigen Face 6

Eigen Face 7

Eigen Face 8

(4) The PCA coefficients ($\vec{\Omega}\, i$) for each training image.

```
Omega0:
 2.19487e+16
-1.02413e+16
-2.49697e+15
-2.03056e+16
 1.53648e+15
  1.3686e+16
 8.43218e+15
-1.25595e+16
subject01.normal.jpg : It belongs to Eigen Face 1.
Omega1:
 6.15665e+15
-2.25323e+15
-3.53752e+15
 -8.4649e+15
 4.03932e+14
  1.1849e+16
 1.94918e+15
-6.10313e+15
subject01.centerlight.jpg : It belongs to Eigen Face 7.
Omega2:
 1.33879e+16
-3.75929e+15
-5.99545e+14
-1.01827e+16
-3.25762e+14
 2.51008e+15
  3.8435e+15
-4.87425e+15
subject01.happy.jpg : It belongs to Eigen Face 7.
Omega3:
-1.02413e+16
 1.67775e+16
 9.40258e+14
 1.47548e+16
-4.51156e+15
-2.22396e+16
-9.16797e+15
 1.36879e+16
```

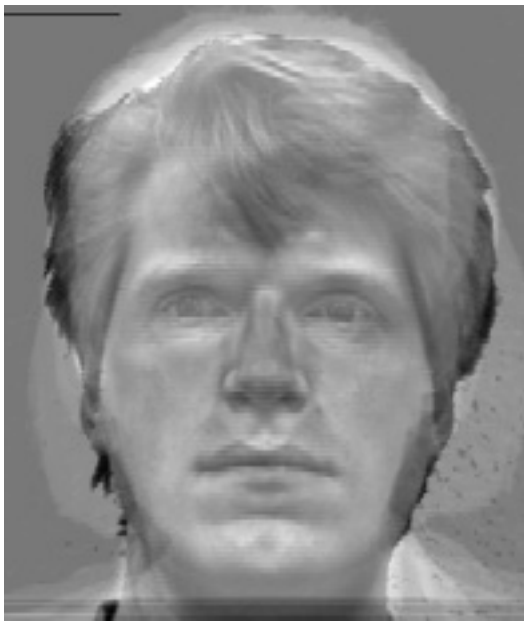
```
Omega4:
-2.49697e+15
 9.40258e+14
 1.16228e+16
  9.2106e+15
-2.74259e+15
-2.29716e+16
-2.84603e+15
 9.28358e+15
subject03.normal.jpg : It belongs to Eigen Face 3.
Omega5:
-2.03056e+16
 1.47548e+16
  9.2106e+15
 3.29663e+16
-6.48317e+15
-4.32691e+16
-1.07543e+16
 2.38805e+16
subject07.normal.jpg : It belongs to Eigen Face 4.
Omega6:
-3.95725e+15
-1.13824e+14
-1.09474e+15
  3.2752e+15
 4.41315e+15
-3.44724e+15
 4.06368e+15
-3.13897e+15
subject07.centerlight.jpg : It belongs to Eigen Face 5.
Omega7:
-1.04452e+16
 9.08397e+15
 6.21072e+15
 1.82756e+16
-1.67831e+15
-3.14096e+16
-5.15472e+15
 1.51175e+16
subject07.happy.jpg : It belongs to Eigen Face 2.
Omega8:
 1.53648e+15
-4.51156e+15
-2.74259e+15
-6.48317e+15
 1.23215e+16
```

```
Omega9:
  1.3686e+16
-2.22396e+16
-2.29716e+16
-4.32691e+16
 1.91336e+15
 1.06655e+17
 9.03861e+15
-4.28125e+16
subject11.normal.jpg : It belongs to Eigen Face 6.
Omega10:
 1.87666e+15
-8.08295e+15
 -1.6315e+16
-2.19071e+16
-2.77902e+15
 7.00131e+16
 6.05723e+14
-2.34114e+16
subject11.centerlight.jpg : Unknown face.
Omega11:
 1.18255e+16
-1.97547e+16
-2.21897e+16
-3.99509e+16
 7.63745e+14
 1.01424e+17
 7.75252e+15
-3.98701e+16
subject11.happy.jpg : It belongs to Eigen Face 6.
Omega12:
 8.97676e+15
-6.38201e+15
-7.67411e+15
-1.49994e+16
 4.21921e+15
 2.33313e+16
 7.13413e+15
-1.46058e+16
subject12.normal.jpg : It belongs to Eigen Face 7.
Omega13:
 8.43218e+15
-9.16797e+15
-2.84603e+15
-1.07543e+16
 6.39631e+15
```

```
Omega14:
 8.52972e+15
-7.53431e+15
-1.01128e+15
 -8.1829e+15
 4.30635e+15
 4.08123e+15
 1.01801e+16
-1.03689e+16
subject14.happy.jpg : It belongs to Eigen Face 7.
Omega15:
 5.36352e+15
-6.12022e+15
-1.24964e+15
-6.16642e+15
 5.26039e+15
 2.99459e+15
 9.96903e+15
-1.00513e+16
subject14.sad.jpg : It belongs to Eigen Face 5.
Omega16:
-1.25595e+16
 1.36879e+16
 9.28358e+15
 2.38805e+16
-8.43036e+15
-4.28125e+16
-1.38332e+16
 3.07836e+16
subject15.normal.jpg : It belongs to Eigen Face 8.
Omega17:
 8.77525e+15
-3.19688e+15
-6.45396e+14
 -5.3057e+15
-3.86972e+15
 5.36529e+15
 2.11259e+15
-3.23544e+15
apple1_gray.jpg : It belongs to Eigen Face 5.
```

(5) For each test image: the image after subtracting the mean face (I),

Sub_avgFace_subject01.normal.jpg



Sub_avgFace_subject01.happy.jpg

Sub_avgFace_subject01.centerlight.jpg

Sub_avgFace_subject02.normal.jpg

Sub_avgFace_subject03.normal.jpg

Sub_avgFace_subject07.normal.jpg

Sub_avgFace_subject07.happy.jpg

Sub_avgFace_subject07.centerlight.jpg

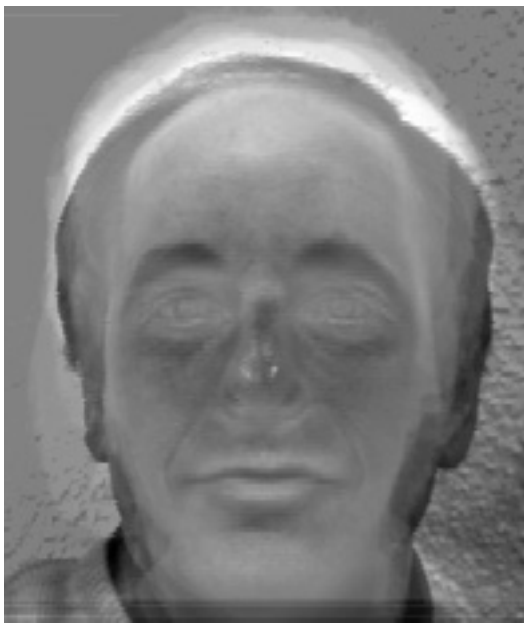
Sub_avgFace_subject10.normal.jpg

Sub_avgFace_subject11.normal.jpg

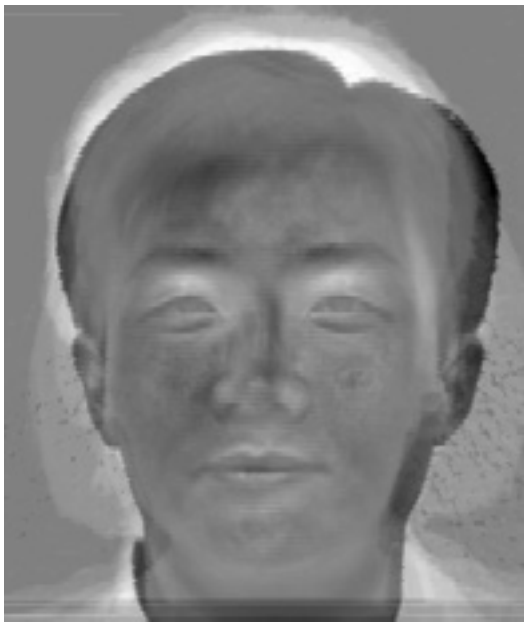
Sub_avgFace_subject11.happy.jpg

Sub_avgFace_subject11.centerlight.jpg

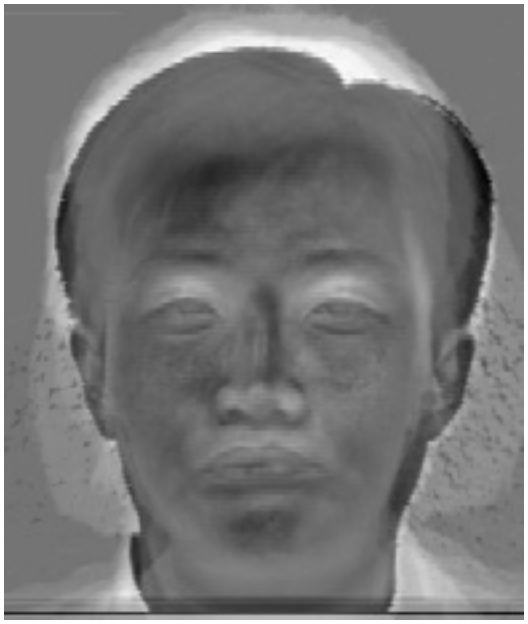
Sub_avgFace_subject12.normal.jpg



Sub_avgFace_subject14.normal.jpg



Sub_avgFace_subject14.sad.jpg



Sub_avgFace_subject15.normal.jpg

Sub_avgFace_apple1_gray.jpg

(6) its PCA coefficients (ΩI), the reconstructed face image ($I\ R$),

Reconstruct_subject01.normal.jpg

Reconstruct_subject01.happy.jpg

Reconstruct_subject01.centerlight.jpg

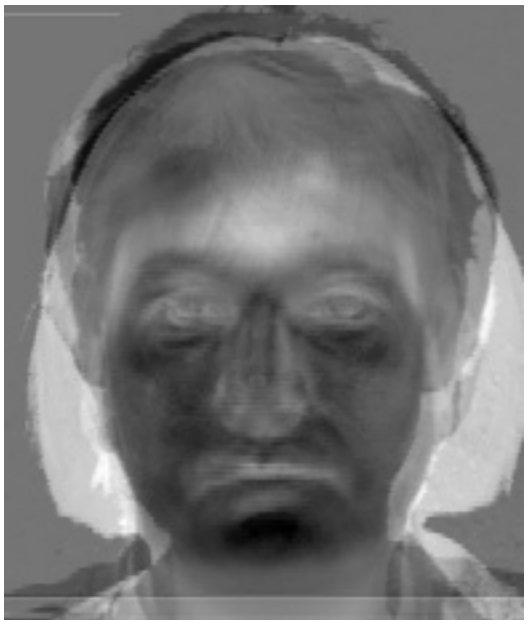
Reconstruct_subject02.normal.jpg

Reconstruct_subject03.normal.jpg

Reconstruct_subject07.normal.jpg

Reconstruct_subject07.happy.jpg

Reconstruct_subject07.centerlight.jpg



Reconstruct_subject10.normal.jpg

Reconstruct_subject11.normal.jpg

Reconstruct_subject11.happy.jpg

Reconstruct_subject11.centerlight.jpg

Reconstruct_subject12.normal.jpg

Reconstruct_subject14.normal.jpg

Reconstruct_subject14.happy.jpg

Reconstruct_subject14.sad.jpg

Reconstruct_subject15.normal.jpg

Reconstruct_apple1_gray.jpg

(7) distances *di* for *i*=0 *to M*, and classification result (non-face, unknown face, or identify of face.)

```
charson[~/NYU_courses/Computer_Vision/Project2_FaceRecogonition]$ ./FaceDetection
Eigen Space:
Eigen Face 1: subject01.normal.jpg
Eigen Face 2: subject02.normal.jpg
Eigen Face 3: subject03.normal.jpg
Eigen Face 4: subject07.normal.jpg
Eigen Face 5: subject10.normal.jpg
Eigen Face 6: subject11.normal.jpg
Eigen Face 7: subject14.normal.jpg
Eigen Face 8: subject15.normal.jpg

Result:
subject01.normal.jpg :  dist 0 -> It belongs to Eigen Face 1.
subject01.centerlight.jpg :  dist 1.66911e+16 -> It belongs to Eigen Face 7.
subject01.happy.jpg :  dist 1.75016e+16 -> It belongs to Eigen Face 7.
subject02.normal.jpg :  dist 0 -> It belongs to Eigen Face 2.
subject03.normal.jpg :  dist 0 -> It belongs to Eigen Face 3.
subject07.normal.jpg :  dist 0 -> It belongs to Eigen Face 4.
subject07.centerlight.jpg :  dist 1.64979e+16 -> It belongs to Eigen Face 5.
subject07.happy.jpg :  dist 1.44801e+16 -> It belongs to Eigen Face 2.
subject10.normal.jpg :  dist 0 -> It belongs to Eigen Face 5.
subject11.normal.jpg :  dist 0 -> It belongs to Eigen Face 6.
subject11.centerlight.jpg :  dist 5.15041e+16 -> Unknown face.
subject11.happy.jpg :  dist 7.76253e+15 -> It belongs to Eigen Face 6.
subject12.normal.jpg :  dist 1.70402e+16 -> It belongs to Eigen Face 7.
subject14.normal.jpg :  dist 0 -> It belongs to Eigen Face 7.
subject14.happy.jpg :  dist 7.75412e+15 -> It belongs to Eigen Face 7.
subject14.sad.jpg :  dist 9.27274e+15 -> It belongs to Eigen Face 5.
subject15.normal.jpg :  dist 0 -> It belongs to Eigen Face 8.
apple1_gray.jpg :  dist 1.94762e+16 -> It belongs to Eigen Face 5.
```