

## CSE152 – Introduction to Computer Vision – Assignment 4 (SP15)

Instructor: Ben Ochoa

Maximum Points : 75, Maximum Bonus : 20

Deadline : 11:59 p.m., Friday, 05-Jun-2015

### Instructions:

- This assignment should be solved, and written up in groups of 3.
- Individual work is not allowed.
- There is no physical hand-in for this assignment.
- Coding for this assignment should be done in **MATLAB**
- All code developed for this assignment should be included in the appendix of the report.
- You may do problems on pen and paper; just scan and include it in the report.
- In general, **MATLAB** code does not have to be efficient. Focus on clarity, correctness and function here, and we can worry about speed in another course.
- Submit your assignment electronically by email to Akshat Dave [akdave@ucsd.edu] with the subject line **CSE152A-Assignment-4**. The email should contain one attached file named [CSE\_152A\_HW4\_<student1-id>\_<student2-id>\_<student3-id>.zip]. This zip file must contain the following two artifacts:
  1. A pdf file named [CSE\_152A\_HW4\_<student1-id>\_<student2-id>\_<student3-id>.pdf] containing your writeup. Please mention all the authors' full names and student identities in the report.
  2. A folder named [CSE\_152A\_HW4\_<student1-id>\_<student2-id>\_<student3-id>\_code] containing all your **MATLAB** code files

## The Yale Face Database

In this assignment, we will have a look at some simple techniques for object recognition, in particular, we will try to recognize faces. The face data that we will use is derived from the Yale Face Database. For more information, follow link : (YFDB-link). The database consists of 5760 images of 10 individuals, each under 9 poses and 64 different lighting conditions. The availability of such standardized databases is important for scientific research as they are useful for benchmarking different algorithms.

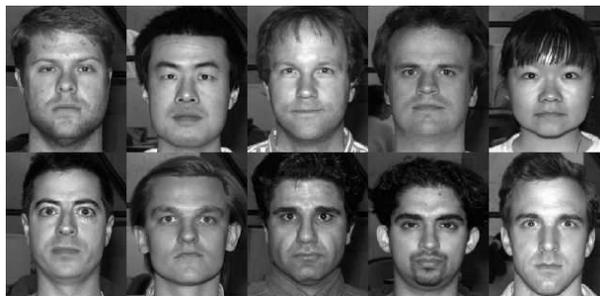


Figure 1: The Yale face database B.

In this assignment, we will only use 640 images corresponding to a frontal orientation of the face. These faces are included in the file `yaleBfaces.zip`. You will find the faces divided into five

different subsets. Subset 0 consists of images where the light source direction is almost frontal, so that almost all of the face is brightly illuminated. From subset 1 to 4, the light source is progressively moved toward the horizon, so that the effects of shadows increase and not all pixels are illuminated. The faces in subset 0 will be used as training images, and subsets 1 to 4 will be used as test images.

## 1 Naïve Recognition [15 points]

For this first problem, you will do face recognition by comparing the raw pixel values of the images. Let subset 0 be the train set, and report classification accuracy on test sets 1 to 4. Use the nearest neighbor classifier (1-NN) (Reference notes : Notes-link).

1. (5 points) Once you have classified all images in a test set, report the average test error (percentage of misclassified test images). Report the average accuracy for each test set, i.e. **4 numbers**.
2. (5 points) Comment on the performance, does it make sense? Is there any difference between the sets?
3. (5 points) show any two misclassified examples and explain why these might have been misclassified.

Notes:

- You can load a dataset by using e.g. `[trainset trainlabels]=loadSubset(0)`.
- You can use `drawFaces.m` to look at the images (e.g. `imshow(drawFaces(trainset, 10))`).

## 2 k-NN Recognition [10 points]

Instead of using a single nearest neighbour, sometimes it is useful to consider the consensus (majority vote) of  $k$ -nearest neighbours. Repeat Part 1 using  $k$ -nearest neighbor classifier (k-NN) (Reference notes : Notes-link).

1. (5 points) Test the performance for each test dataset using  $k = 3$  and  $k = 5$ .
2. (5 points) Compare the performance to the corresponding 1-NN performance, did it improve? Why/ why not?

## 3 Recognition Using Eigenfaces [50 points]

- (10 points) Write a function `[W,mu]=eigenTrain(trainset,k)` that takes as input a  $N \times d$  matrix `trainset` of vectorized images from subset 0, where  $N = 70$  is the number of training images and  $d = 2500$  is the number of pixels in each training image. Perform PCA on the data and compute the top  $k = 20$  eigenvectors. Return the  $k \times d$  matrix of eigenvectors  $W$ , and a  $d$  dimensional vector `mu` encoding the mean of the training images. You should use the matlab command `svds` to find the first  $k$  eigenvectors.
- (5 points) Rearrange each of the top 20 eigenvectors you obtained in the previous step into a 2D image of size  $50 \times 50$ . Display these images by appending them together into a  $500 \times 100$  image (a  $10 \times 2$  grid of images).
- (5 points) Explain the objective of performing PCA on the training images. What does this achieve?

- (5 points) Select one image per person from subset 0 (e.g., the 10 images `person01_01.png`, `person02_01.png`, ... `person10_01.png`). Show what each of these images would look like when using only the top  $k$  eigenvectors to reconstruct them, for  $k = 1, 2, 3, 4, 5, \dots, 10$ . This reconstruction procedure should project each image into a  $k$  dimensional space, project that  $k$  dimensional space back into a 2500 dimensional space, and finally resize that 2500 vector into a  $50 \times 50$  image.
- (15 points) Write a function called `testlabels=eigenTest(trainset,trainlabels,testset,W,mu,k)` that takes as input :
  - The same  $N \times d$  matrix `trainset` of vectorized images from subset 0
  - An  $N$  dimensional vector `trainlabels` that encodes the class label of each training image (e.g., 1 for person01, 2 for person02, etc.)
  - An  $M \times d$  matrix `testset` of  $M$  vectorized images from one of the test subsets (1-4)
  - The output of PCA i.e.  $W$  and  $\mu$ , and the number of eigenvectors to use  $k$ .

Project each image from `trainset` and `testset` onto the space spanned by the first  $k$  eigenvectors. For each test image, find the nearest neighbor (1-NN) in the training set using an  $L_2$  distance in this lower dimensional space and predict the class label as the class of the nearest training image. Your function should return an  $M$  dimensional vector `testlabels` encoding the predicted class label for each test example. Evaluate `eigenTest` on each test subset 1-4 separately for values  $k = 1 \dots 20$  (so it should be evaluated  $4 \times 20$  times). Plot the error rate (fraction of incorrect predicted class labels) of each subset as a function of  $k$  in the same plot, and use the matlab `legend` function to add a legend to your plot.

- (5 points) Repeat the experiment from the previous step, but throw out the first 4 eigenvectors. That is, use  $k$  eigenvectors starting with the 5<sup>th</sup> eigenvector. Produce a plot similar to the one in the previous step. How do you explain the difference in recognition performance from the previous part?
- (5 points) Explain any trends you observe in the variation of error rates as you move from subsets 1 to 4 and as you increase the number of eigenvectors. Use images from each subset to reinforce your claims.

## 4 BONUS : Recognition Using Fisherfaces [20 points]

- (10 points) Write a function called `[W,mu]=fisherTrain(trainset,trainlabels,c)` that takes as input the same  $N \times d$  matrix `trainset` of vectorized images from subset 0, the corresponding class labels `trainlabels`, and the number of classes  $c = 10$ . Your function should do the following :
  - Compute the mean  $\mu$  of the training data, and use PCA to compute the first  $N - c$  principal components. Let this be  $W_{PCA}$ .
  - Use  $W_{PCA}$  to project the training data into a space of dimension  $(N - c)$ .
  - Compute the between-class scatter matrix  $S_B$  and the within class scatter matrix  $S_W$  on the  $(N - c)$  dimensional space from the previous space.
  - Compute  $W_{FLD}$ , by solving for the generalized eigenvectors of the  $(c - 1)$  largest generalized eigenvalues for the problem  $S_B w_i = \lambda_i S_W w_i$ . You can use the matlab function `eig` to solve for the generalized eigenvalues of  $S_B$  and  $S_W$ .
  - The fisher bases will be a  $W = W_{FLD} W_{PCA}$ , where  $W$  is  $(c - 1) \times d$  dimensional,  $W_{FLD}$  is  $(c - 1) \times (N - c)$  dimensional, and  $W_{PCA}$  is  $(N - c) \times d$  dimensional.

- (5 points) As in the Eigenfaces exercise, rearrange the top 9 Fisher bases you obtained in the previous part into images of size  $50 \times 50$  and stack them into one big  $450 \times 50$  image.
- (5 points) As in the eigenfaces exercise, perform recognition on the testset with Fisherfaces. As before, use a nearest neighbor classifier (1-NN), and evaluate results separately for each test subset 1-4 for values  $k = 1 \dots 9$ . Plot the error rate of each subset as a function of  $k$  in the same plot, and use the matlab `legend` function to add a legend to your plot. Explain any trends you observe in the variation of error rates with different subsets and different values of  $k$ , and compare performance to the Eigenface method. (paper-link)