Lab 4: PCA-based Face Recognition

Submission : Blackboard, by 2:30PM on Wednesday, 26 September, 2018

Dataset

We will use the ORL database, available to download on AT&T's web site. This database contains photographs showing the faces of 40 people. Each one of them was photographed 10 times. These photos are stored as grayscale images with 112×92 pixels.

In our example, we construct a catalog called `orlfaces`, comprised of people named $s_1, s_2, ..., s_{40}$, each one of them containing 10 photographs of the person. The data has already been split into a training

```
clear
close all
% dir = 'orl_faces/Train/s10/%d.pgm'
% figure
% for i =1:9
%     subplot(1,9,i)
%     imshow(sprintf(dir,i));
% end
```

and testing split, where for each person, we use the first 9 photographs for training and the last photograph for test.

1. Load the training data

```
% Your code goes here
train_directory = 'orl_faces/Train/s%d/%d.pgm';
train_data = zeros(40,9,112,92);
for i = 1:40
    for j = 1:9
        image_name = sprintf(train_directory, i, j);
        train_data(i,j,:,:) = imread(image_name);
%          disp(image_name);
    end
end
size(train_data(1,1,:,:))
```

```
ans =
     1     1   112    92
```

2. Change each $(d_1, d_2) = (112, 92)$ photograph into a vector

```
% Your code goes here
image_size = size(train_data,3)*size(train_data,4);
train_reshape = reshape(train_data, [40, 9, image_size]);

size(train_reshape)
```

```
ans =
          40           9       10304
```

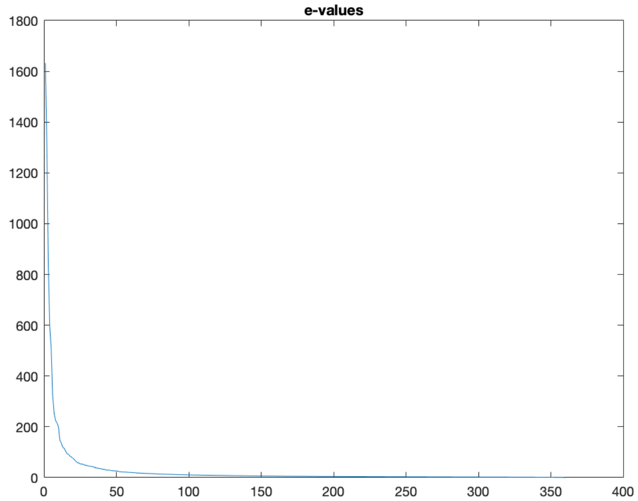
3. Using all the training photographs for the N people in the training dataset, construct a subspace $H$with dimensionality less than or equal to Nsuch that this subspace has the maximum dispersion for the N projections. To extract this subspace, use Principal Component Analysis, as described below -

- Center the data
- Compute the correlation matrix
- Use either the SVD or `eig` functions to perform SVD and get the eigenvectors and eigenvalues for the correlation matrix.
- Normalize the eigenvectors by the corresponding eigenvalues.

```
% Your code goes here
typical_face = mean(mean(train_reshape, 1), 2);
train_difference_face  = zeros(40,9,10304);
for i = 1:40
    for j = 1:9
        train_difference_face(i,j,:) = (train_reshape(i,j,:) - typical_face);
    end
end
train_center = double(reshape(train_difference_face, [], 10304));


corr_matrix = corr(train_center);
[e_vector, e_values] = eigs(corr_matrix, 360);

e_vector = real(e_vector);
e_values = abs(e_values);

disp('for easy calculation, use 360 for output')
```

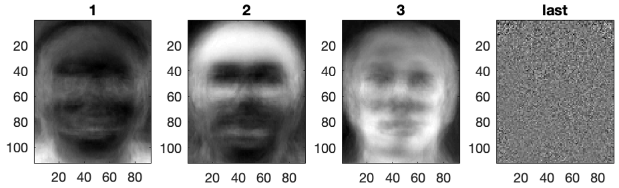
4. Plot the eigenvalues

```
% Your code goes here
figure(1)
plot(diag(e_values)), title('e-values');
```



5. Plot the first 3 eigenfaces and the last eigenface (these will be the correctly reshaped eigenvectors)

```
% Your code goes here
figure(2)
subplot(1,4,1); imagesc(reshape(e_vector(:,1), 112,92)), title('1'),axis image, colormap gray; %imshow(mat2gray(reshape(e_ve
subplot(1,4,2); imagesc(reshape(e_vector(:,2), 112,92)), title('2'),axis image, colormap gray;
subplot(1,4,3); imagesc(reshape(e_vector(:,3), 112,92)), title('3'),axis image, colormap gray;
subplot(1,4,4); imagesc(reshape(e_vector(:,end), 112,92)), title('last'),axis image, colormap gray;
```



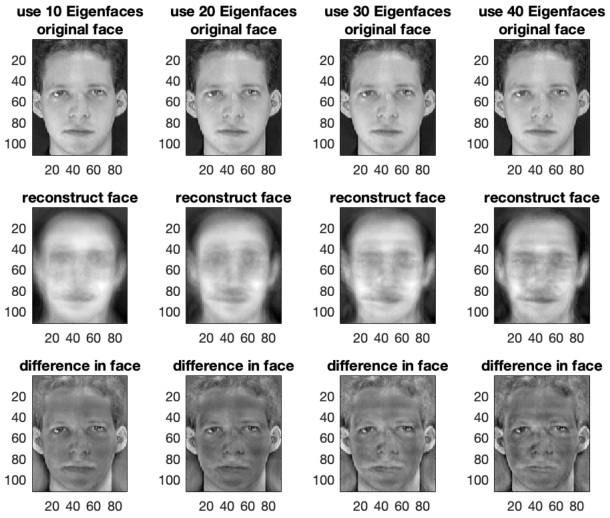
6. Pick a face and reconstruct it using $k = 10, 20, 30, 40$ eigenvectors. Plot all of these reconstructions and compare them. For each value of k, plot the original image, reconstructed image, and the difference b/w the original image and reconstruction in each case. Write your observations.

```
size(train_data)
```

```
ans =
    40     9   112    92
```

```
% Your code goes here
figure(3);
K_values = [10,20,30,40];
for i = 1:4
    B = e_vector(:,1:K_values(i));
    W = pinv(B) * double(reshape(train_difference_face(1,1,:),10304,1));
    image_approx = B * W;
    image_approx_rehape = reshape(image_approx, 112,92);
    typical_face_reshape = reshape(typical_face, 112,92);
    image_approx_face = image_approx_rehape + typical_face_reshape;
    image_approx_difference = reshape(train_data(1,1,:), 112,92) - image_approx_face;
    %plot
    subplot(3,4,i)
    imagesc(reshape(train_data(1,1,:), 112,92)), axis image, colormap gray, title({[sprintf('use %d Eigenfaces',K_values(i))
    subplot(3,4,i+4)
    imagesc(image_approx_face), axis image, colormap gray, title('reconstruct face');
    subplot(3,4,i+8)
    imagesc(image_approx_difference), axis image, colormap gray, title('difference in face');
```

```
end
```



```
disp('as the k increases, the reconstruct face become much more clear, the difference become less')
```

```
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```

7. Load the testing data, and reshape it similar to the training data.

```
% Your code goes here
test_directory = 'orl_faces/Test/s%d/%d.pgm';
test_data = zeros(40,1,112,92);
for i = 1:40
        image_name = sprintf(test_directory, i, 10);
        test_data(i,1,:,:) = imread(image_name);
end
```

```
test_reshape = reshape(test_data, [40, 1, image_size]);

size(test_reshape)
```

```
ans =

        40           1       10304
```

```
% Your code goes here
typical_face = mean(mean(train_reshape, 1), 2);
test_difference_face  = zeros(40,1,10304);
for i = 1:40
      test_difference_face(i,1,:) = (test_reshape(i,1,:) - typical_face);

end
test_center = double(reshape(test_difference_face, [], 10304));
```

8. For each photograph in the testing dataset, you will implement a classifier to predict the identity of the person. To do this, follow these steps -

- Determine the projection of each test photo onto H with different dimensionalities $d = 10, 20, 30, 40$
- Compare the distance of this projection to the projections of all images in the training data.
- For each test photo's projection, find the closest category of projection in the training data.

```
% Your code goes here
figure(4)

d_values = [10,20,30,360];

p_test = zeros(40,4,10304);

for i = 1:4
    for j = 1:40
         B1 = e_vector(:,1:d_values(i));
         W1 = pinv(B1) * double(reshape(test_difference_face(j,1,:),10304,1));
         image_approx1 = B1 * W1;
         p_test(j,i,:) = image_approx1;
    end
end
```

```
p_train = zeros(360,4,10304);

K_values = [10,20,30,360];

train_difference_face2  = zeros(360,1,10304);
k360=1;
for i = 1:40
```

```
    for j = 1:9
         train_difference_face2(k360,1,:) = train_difference_face(i,j,:);
         k360 = k360+1;
    end
end

for i = 1:4
    for j = 1:360
        B2 = e_vector(:,1:K_values(i));
        W2 = pinv(B2) * double(reshape(train_difference_face2(j,1,:),10304,1));
        image_approx2 = B2 * W2;
        p_train(j,i,:) = image_approx2;
    end
end
```

```
disp('distance is save in the error_result matrix')
```

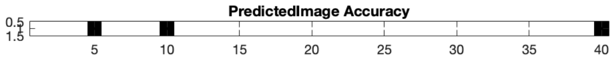
```
distance is save in the error_result matrix
```

```

error_result=zeros(40,360,1);
for i = 1:40
    for j = 1:360

    error = bsxfun(@minus, p_test(i,4,:), p_train(j,4,:));
    error = sqrt(error.^2);
    error_result(i,j,1) = sum(error,3);

    end
end

results = [];
for i = 1:40
    [minval, index] = min(error_result(i,:,1));
    results = [results, index];
end
```

```
results
```

```
results =
     5    16    27    32   356    49    58    66    77    66    91   108   113   123   128   138   151  ···
```

```


for i = 1:40
    lower_end = (i-1)*9;
    upper_end = i*9;
    index_result = results(i);
    if index_result <= upper_end
        if index_result > lower_end
            results_plot(i) = true;
            %disp('1')
        else
            results_plot(i) = false;
            %disp('2')
        end
    else
        esults_plot(i) = false;
        %disp('3')
    end
end
figure(10);
imagesc(results_plot), axis image, colormap gray, title("PredictedImage Accuracy");
```



```
disp('the results matrix save the most similiar photo number to each test photo')
```

```
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```

```
disp('for the results_plot, it save whether the prediction is correct or not')
```

```
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```

```
disp('in here I use 360 for dimensionality, which can give a better prediction')
```

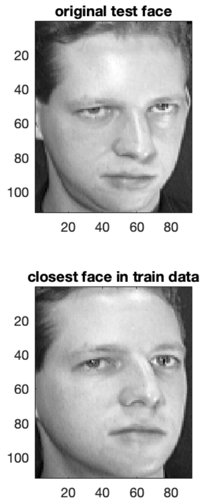
```
in here I use 360 for dimensionality, which can give a better prediction
```

```
disp('in the picture, white means prediction is correct, black is false.')
```

```
in the picture, white means prediction is correct, black is false.
```

9. Show the closest image in the training dataset for the s_1 test example.

```
% Your code goes here
figure(9)
subplot(2,1,1)
imagesc(reshape(test_data(1,1,:), 112,92)), axis image, colormap gray, title(['original test face']);
subplot(2,1,2)
imagesc(reshape(train_data(1,results(1,1),:), 112,92)), axis image, colormap gray, title(['closest face in train data']);
```



```
disp('this is the closest face in train to the test')
```

```
this is the closest face in train to the test
```