Deep Learning for Computer Vision
Homework 1

National Taiwan University

Due: March 21st Wed 01:00 AM Total: 110 points

Homework policy

- Late policy: Up to 3 free late days in a semester. After that, late homework will be deducted 30% each day.
- Taking any unfair advantages over other class members (or letting anyone do so) is strictly prohibited. Violating university policy would result in F for this course.
- Students are encouraged to discuss the homework assignments, but you must complete the assignment by yourself. TA will compare the similarity of everyone's homework. Any form of cheating or plagiarism will not be tolerated, which will also result in F for students with such misconduct.

Problem 1: Bayes Decision Rule (30%)

For a 2-class problem based on a single feature $\mathbf{x}$, the class PDFs are defined as below:
$p(\mathbf{x}|\omega_1)$ = uniform over (0, 5)
$p(\mathbf{x}|\omega_2)$ = uniform over (3, 6).
Determine the minimum P_e decision scheme with $P(\omega_1) = 3/4$. Please state clearly what the decision regions R_1 and R_2 are. What is the resulting P_e?

Problem 2: Principal Component Analysis and k-Nearest Neighbors Classification (70%)

Download the file **hw1_dataset.zip (https://goo.gl/F7o9wz)**, which contains 56×46 pixel face images of 40 different subjects (classes), and 10 images available for each subject. Note that, **i_j.png** means $\mathbf{person}_i\_\mathbf{image}_j$. Now you have to split the dataset into two subsets (i.e., training and test sets). The first subset contains the first 6 images of each subject, while the second subset include the remaining images. Thus, a total of $6 \times 40 = 240$ images are in the training set, while 160 images in the test set. You will compute the eigenfaces of the training set, and face images from both training and test sets onto the same feature space with reduced dimension.

(a) (10%) Perform PCA on the training set. Plot the mean face and the first three eigenfaces.

(b) (25%) Take $\text{person}_1\_\text{image}_1$, and project it onto the above PCA eigenspace. Reconstruct this image using the first $n = 3, 50, 100, 239$ eigenfaces. For each n, compute the mean square error (MSE) between the reconstructed face image and $\text{person}_1\_\text{image}_1$. Please plot these reconstructed images, with the corresponding MSE values.

(c) (35%) To apply the k-nearest neighbors classifier to recognize test set images, please determine the best k and n values by 3-fold cross-validation. For simplicity, the choices for such hyperparameters are $k = \{1, 3, 5\}$ and $n = \{3, 50, 159\}$. Please show the cross-validation results and explain your choice for (k, n). Finally, use your hyperparameter choice to report the recognition rate on the test set.

(Bonus) Problem 3 (10%)

Given a $d \times d$ positive semi-definite symmetric matrix with d distinct eigenvalues (i.e., $\lambda_1 > \lambda_2 > ...$), explain how you can derive the first eigenvector *without* performing any eigenanalysis. In other words, how to determine the first eigenvector by simple matrix/vector operations. Can you see why we need to have the symmetric matrix to be positive semi-definite?(Hint: the eigenvectors of a symmetric matrix are orthonormal.)

Remarks

- When you plot eigenfaces, you should always start from the more dominant Eigenface to the least dominant one. Depending on what version of programming tools you are using, the eigenvalues returned are sorted in either ascending or descending order, so you need to be careful.
- When you display an image using imagesc, you will need to adjust the color scheme using the command "colormap grey".

Turn-in format

Please turn in your homework in PDF and submit it to Ceiba. Your file name should be **hw1_YourStudentID.pdf** (e.g., hw1_r06941111.pdf).