CS 663 : Digital Image Processing : Assignment 3

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Due Date : 3rd Oct 2014, Tuesday, 11:55 pm

Instructions for submission are at `www.cse.iitb.ac.in/~suyash/cs663/submissionStyle.pdf`

5 points are reserved for submission in the described format.

1. (45 points) Fourier Analysis.

   Download the image
   `http://www.cse.iitb.ac.in/~suyash/cs663/Assignment3/boat.mat`

   Assume the pixel dimensions to be equal along both axes, i.e., assume an aspect ratio of 1:1 for the axes.

   Corrupt the image with independent and identically-distributed additive zero-mean Gaussian noise with standard deviation set to 10% of the intensity range. Note: in Matlab, randn() gives random numbers drawn independently from a Gaussian with mean 0 and standard deviation 1.

   Write code for Butterworth filtering in the frequency domain. Use a Butterworth filter with $n = 2$ (see slides for the equation).

   Define the root-mean-squared difference (RMSD) as the square root of the average, over all pixels, of the squared difference between a pixel intensity in the original image and the intensity of the corresponding pixel in the filtered image, i.e., given 2 images A and B with N pixels each, RMSD$(A, B) := \sqrt{(1/N)\sum_p (A(p) - B(p))^2}$, where $A(p)$ is the intensity of pixel p in image A.

   Apply the Butterworth filter to smooth the image. Tune the frequency parameter D_0 to minimize the RMSD between the filtered and the original image.

• Show the Butterworth filter, in the frequency domain, as an image.

• Show the original, corrupted, and filtered versions side by side, using the same (gray) colormap.

• Report the optimal parameter values found, say D_0^* along with the optimal RMSD.

• Report RMSD values for filtered images obtained with (i) $0.95D_0^*$ and (ii) $1.05D_0^*$.

• Consider a circular / disk mask around the pixel in the Fourier-transform image that corresponds to the zero-frequency in the centered image (i.e., after applying fftshift() in Matlab). Report the indices of this center pixel (containing the so-called "DC" offset). Let the radius of the circle be R pixels. Report radii R such that the sum, over pixels inside the mask, of the squared magnitudes of the Fourier transform is closest to (i) 88%, (ii) 91%, (iii) 94%, (iv) 97%, and (v) 99% of the total energy of the Fourier spectrum. Apply each of these masks to the Fourier transform, compute the inverse Fourier transform, take the magnitude of the resulting image values, and report the RMSDs between the resulting images and the original image.

2. In this part, you will implement a mini face recognition system. Download the ORL face database from `http://www.cl.cam.ac.uk/Research/DTG/attarchive/pub/data/att_faces.zip`. It contains 40 sub-folders, one for each of the 40 subjects/persons. For each person, there are ten images in the appropriate folder. The images are of size 92 by 110 each. Each image is in the pgm format. You can view the images in this format, either through MATLAB or through image viewers like IrfanView on Windows, or xv/display/gimp on Unix. Though the face images are in different poses, expressions and facial accessories, they are all roughly aligned (the eyes are in roughly similar locations in all images). For the first part of the assignment, you will work with the images of the first 35 people. For each person, you will include the first five images in the training set and the remaining 5 images in the testing set (note: there are 10 images per person labeled 1.pgm to 10.pgm). You should create an eigen-space from the training set as described during the lectures <u>without</u> explicitly computing the covariance matrix (note, in this case, you do have $N \ll d$ where $d = 92 \times 110$ is the size of the image, and $N = 35 \times 5$ is the number of images in the training set). Record the recognition rate while testing on all the images in the test set, for $k \in \{1, 2, 3, 5, 10, 20, 30, 50, 75, 100, 125, 150, 170\}$. Mention the

rates in your report. Repeat the same experiment on a small subset of the Yale Face database from `http://www.cse.iitb.ac.in/~ajitvr/CS663_Fall2014/HW3/`. The subset provided here contains five images each of 38 individuals (labeled from 1 to 39, with number 14 missing). Each image is in pgm format and has size 192 by 168. The provided images are taken under slightly different lighting conditions but in the same pose. Take two images each of every person for training and test on the remaining three images. State in your report the recognition rates for $k \in \{1, 2, 3, 5, 10, 20, 30, 50, 60, 65, 75\}$. [30 points]

3. Display the reconstruction of any one face image from the ORL database using $k \in \{2, 10, 20, 50, 75, 100, 125, 150, 175\}$ values. State what you observe. Plot the 25 eigenvectors (eigenfaces) corresponding to the 25 largest eigenvalues using the subplot or subimage commands in MATLAB. Also, display the Fourier transform magnitude of the top 25 eigenfaces using the log scale (i.e. you should plot $\log(1 + |F(\mu)|)$). What do you observe? Explain in your report. [10 points]

4. What will happen if you test your system on images of people which were not part of the training set? (i.e. the last 5 people from the ORL database). What mechanism will you use to report the fact that there is no matching identity? Work this out carefully and explain briefly in your report. Test whatever you propose on all the 50 remaining images (i.e. 5 people times 10 images per person), as also the entire test set containing 5 images each of the first 35 people. How many false positives/negatives did you get? [10 points]