CS474/674 Image Processing and Interpretation

Fall 2009 – Dr. George Bebis

Programming Assignment 3

Due Date: 10/15/2009

In this programming assignment, you will perform a number of experiments using the Discrete Fourier Transform (DFT). The objective is to get a better understanding of the DFT and its applications. In these experiments, you will need to write a program to compute the 2-D DFT of an image and the inverse 2-D DFT. The 2-D DFT implementation should be based on 1-D DFT based on the idea discussed in class (i.e., 1-D DFT on the rows, followed by 1-D DFT on the columns). An efficient 1-D FFT implementation in C can be downloaded from the course's webpage. The code comes from the book *"Numerical Recipes in C"* which is available on-line (i.e., there is a link to that book from the course's webpage). To find more about the 1-D FFT implementation, click on the "Numerical Recipes in C" link and download chapter 12.2. Please, note that the DFT definition in *"Numerical Recipes in C"* is slightly different from the definition given in our textbook; when you compute the 2-D DFT using 1-D DFTs, you will need to divide the column values by N and not multiply the row values by N as explained in class. Use the following function prototype for the 2-D DFT:

fft2D(N, M, real_Fuv, imag_Fuv, isign)

Important: Before you start any experiments, make sure that both the 1-D DFT and 2-D DFT work correctly. For example, take the 2-D DFT of an image, followed by the inverse 2-D DFT; if you don't get the original image back, then something is wrong!

Experiment 1

For this part you need to generate a 512 x 512 image which contains a 32 x 32 square placed at the center of the image (i.e., at (256,256)). Set the background to black (i.e., 0) and the interior of the square (and its boundary) to white (i.e. 255). The image should look like the one in Fig. 4.24 on page 246 of your textbook. Take the DFT of the image and display its magnitude without shifting it to the center of the frequency domain. Then, shift the magnitude to the center of the frequency domain and display it again. The shifting should be done as discussed in class;

that is, using property 4 on Table 4.3 (page 254 in your textbook). Your results should look similar to those shown in Fig. 4.24(d).

Note: In the following experiments, the magnitude should be displayed centered at the frequency domain.

Experiment 2

In this experiment, you will consider the effects of additive noise and the use of DFT to remove this kind of noise. The noisy image shown below (i.e., can be downloaded from the course's webpage) has been generated by adding noise in the form of a cosine function. If we denote the original image as $f(x,y)$, then the noisy image can be denoted as $f(x,y)+n(x,y)$ where $n(x,y)$ is a 2-D cosine function. Using the additive property of FT, the FT of the noisy image will be $F(u,v)+N(u,v)$ where $F(u,v)$ is the FT of $f(x,y)$ and $N(u,v)$ is the FT of $n(x,y)$. **Your goal is to remove the cosine interference.** This can be done as follows:

(1) Compute the DFT of the noisy image
(2) Compute the magnitude and find the frequencies (i.e., (u,v) locations) corresponding to the four largest values of the magnitude **(explain why!)** (do not consider the values of the magnitude close to its center)
(3) Replace each one of these values by the average of its 8 neighbors (i.e., average both for the real and imaginary parts).
(4) Take the inverse DFT transform and display the resulted image.

If all of the above steps have been carried out correctly, you should get the “boy” image without the cosine interference.

Experiment 3 – Graduate Students Only

In this experiment, you are going to examine the importance of magnitude and phase. For this, take the DFT of the *Lenna* image (available from the image database on the course's webpage). First, set the phase equal to zero, and take the inverse DFT (**hint:** the real part to the magnitude of the image and the imaginary part to zero). The resulting image should look nothing like the original. Can you explain why? Then, let the phase be the original one and set the magnitude equal to one and take the inverse FT (**hint:** to set the magnitude equal to one, set the real part to *cos(theta)* and the imaginary part to *sin(theta)* where $theta=tan^{-1}(imag/real)$ - **show why this should work**). Since the magnitude is set to such a small value in the Fourier domain, all the values in the spatial domain will be very small when you take the inverse DFT. To alleviate this problem, rescale the pixel values after the inverse FFT has been taken (i.e., values should be in [0, 255]). **Note:** to compute $\mathbf{tan^{-1}}$, use the function **atan2()**.

Laboratory Write-up

You are to turn in a brief report including a print-out of your source code. Your report should include the following: a description of the experiments, theoretical background (i.e., what the reader needs to know to understand the experiments), methodology (i.e., explanation of the methods used), results (i.e., include graphic output of your results), explanation of results (i.e., justify your results and answer the questions that might exist in the handout), and a brief summary of what you have learned.

The report is very important in determining your grade for the programming assignment. Be well organized, type your reports, and include figure captions with a brief description for all the figures included in your report. Motivation and initiative are greatly encouraged and will earn extra points!