Homework #3

Special Topics in Signals & Systems: Biomedical Imaging

ECEn 682R, Section 3

Due: Thursday 10/1/2009 by midnight in the box outside Dr. Bangerter's office.

Homework help sessions: I will be holding a homework help session (in addition to my regularly scheduled office hours) for each homework assignment. For Homework #3, the help session will be Tuesday 9/29 from 5-6pm in 490 CB. If you need help and cannot make the help session, please see me during office hours or contact me to arrange an alternate time.

Problems from Prince & Links:

3.2

3.5

3.8

3.10

3.15

MATLAB Exercises:

Note: I will not be providing exact MATLAB code for most of this and future assignments. If you need additional MATLAB help to complete the assignment, please come to the homework help session. I am also willing to support a MATLAB homework help session if needed.

Only print out the results that are explicitly called for to be included with your homework set. I ask you to display a number of things that I don't want you to print out.

Problem 1: Effect of PSF on Image Quality

In this problem, you will explore the degrading effects on an ideal image from imaging systems with various PSFs.

(1) Load the Shepp-Logan phantom (file "shepp256.png" at the website). You will probably want to convert it from a uint8 (which only allows integer values from 0 to 255) to a double prior to manipulating the image, as shown below.

```
f1 = imread('shepp256.png');
f1 = double(f1);
imshow(abs(f1),[]);
```

(2) Load the various PSFs that I have provided on the web site (files "h1.png", "h2.png", and "h3.png"). NOTE: You should cast each of the PSFs to a double as you did with f1 above, since they may load as uint8.

a. Generate versions of the Shepp-Logan phantom showing how imaging systems with each of these PSFs would affect image quality. Note that this is most easily done by multiplying in the Fourier domain.
b. Generate a version of the Shepp-Logan phantom corresponding to sending the image through a cascade of three systems with PSFs h1, h2, and h3 respectively (from the files).
c. Print each of the final Shepp-Logan phantom images and include with your homework set. Explain your results.

(3) The PSF h1 that you loaded above is isotropic. How could you generate the 1-dimensional Modulation Transfer Function MTF(u) for the system from h1?

(4) In MRI, we often experience exponential decay in the signal in the Fourier domain in one direction. This can be modeled with the Transfer function H4 found in the file 'H4.png'. Note that this is a Transfer function (already in the Fourier domain), and not the PSF (which would be the inverse Fourier Transform of the Transfer function).
a. Load and display the Transfer function H4. Do you see why this would put an exponential decay weighting on the spatial frequency data? (NOTE: You may need to convert H4 to doubles.)
b. Produce the PSF h4 corresponding to the Transfer function H4. Display it. What effect do you expect a system with this PSF to have on image quality?
c. Produce a version of the Shepp-Logan phantom sent through a system with the transfer function H4. Print and include with your homework set. Explain your results.

Problem 2: Measuring SNR and CNR

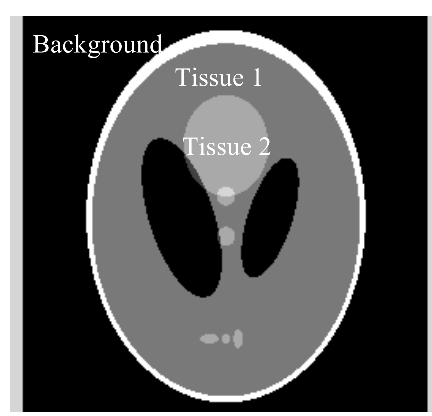
In this problem, we will add noise of various types to the Shepp-Logan phantom image and then measure SNR and CNR for various tissues in the phantom.

(1) Load the Shepp-Logan phantom (cast to double) and add Poisson distributed noise with parameter a=80 to the image. (Recall from the reading and lecture that a Poisson with a=80 has both mean and variance of 80). You can generate a 256x256 array of Poisson distributed random noise with a=80 with the command:

```
n1 = poissrnd(80, 256, 256);
```

Verify that your noise image n1 does indeed have a mean of about 80 and a variance of about 80. The 'mean' and 'var' commands in MATLAB will be helpful here. You can also quickly "flatten" a 2D array into a 1D vector by using the notation n1(:).

(2) Compute the SNR of Tissue 1 (as shown in the image below) by measuring the average signal value across a region in Tissue 1 and dividing by the standard deviation of the signal in a region of the background. Provide the measured SNR with your homework. NOTE: It is easiest to simply choose a rectangular region in each tissue across which to measure average values and standard deviation. Make sure you measure a large enough region in both the tissue and the background to get good statistics. For example, make sure you use at least a 15x15 pixel area (225 pixels) in the background for the standard deviation. The matlab command 'std' will give a standard deviation.



(3) Compute the CNR between Tissue 1 and Tissue 2 in your image, and provide the measured CNR with your homework. (Recall that CNR is defined as the difference in average signal between Tissue 1 and Tissue 2 divided by the standard deviation of the noise in the background. The book calls this "Differential SNR".) As stated in problem 2, it is easiest to simply choose small (e.g., 15x15 pixel) rectangular regions in each tissue across which to compute average signal levels.

Extra Credit: Problem 3 (Not mandatory!)

(1) Load the Shepp-Logan phantom and cast to a double.
(2) Transform the Shepp-Logan phantom into the Fourier domain.
(3) Our Fourier-domain image is complex-valued. In MRI, we find Gaussian noise on both the real and imaginary channels in the Fourier domain. Create zero-mean Gaussian noise with standard deviation of 5000 on both the real and imaginary channels with the following commands:

```
n3 = normrnd(0, 5000, 256, 256) + j*normrnd(0, 5000, 256, 256);
```

(4) Add this noise to the Fourier domain data of the Shepp-Logan phantom that you created in step (2).
(5) Inverse Fourier transform the noisy Fourier-domain data back into image space, and display the absolute value of the image.
(6) Repeat the SNR and CNR measurements from the previous problem on the **absolute value** of the new noisy image, and hand in the values you measure with your homework.