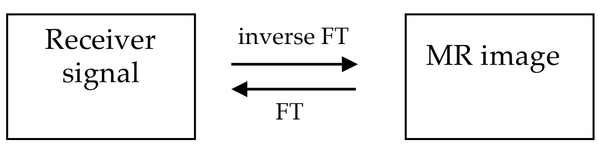
BME 6401/ECE 6961 Medical Imaging Systems
Homework #1
Due Monday, September 9, 2019

Submit a hardcopy of your solutions, which should include both the exact Matlab commands issued and the outputs. For displaying images, make sure the pixels have square aspect ratio. When printing, make each image no bigger than 1/4 page (to save toner and paper).

1. The purpose of this problem is to familiarize oneself with the conventions used by Matlab for representing and displaying images:
   a. To start, on paper, draw a square box with 256-long (arbitrary length unit) sides, and in it draw an equilateral triangle with 160-long sides. The triangle should point up, have its bottom side parallel to the horizontal axis, and have its centroid located at the center of the box. Using the coordinate convention in the imaging field where (a) the origin is located at the top left corner of the image and (b) the first data dimension corresponds to the horizontal axis, determine the coordinates of the triangle vertices and its centroid.
   b. Determine the equations of the lines that connect each two of the triangle vertices. Use inequality relationships to specify the condition(s) when a coordinate location is within the triangle.
   c. Create a 256 x 256 Matlab matrix of zeros to represent the box image. Assign ones to the pixels inside the triangle and zeros otherwise. Display the matrix using, for example, the `imagesc` command. Use appropriate commands including `axis` settings to make the image appear exactly as drawn above.

For Problems 2—5, consider that the signal received by the MRI receiver is the summation of magnetization vectors precessing at negative frequencies proportional to their spatial position. As such, the detected signal is the Fourier-domain equivalence of the associated MR image.



2. Use binary input/output commands to read the file `Prob2.raw` (144 × 192 complex, big-endian floating point matrix) into MATLAB, calling it `raw_signal`:
   a. Graph the *magnitude* of `raw_signal`, plotting the values as height along the z-axis using, for example, the MATLAB `mesh` or `surf` command. You may use the log function to compress the range of the matrix values.
   b. Visualize the same matrix but represent its values as black-and-white (i.e., grayscale) intensity levels using, for example, the MATLAB `pcolor` or `imagesc` command.
   c. Reconstruct the MR image. Perform magnitude computation and shift the low "frequency" component to the image center. Display the image in grayscale.
   d. What are the two consequences when forward instead of inverse Fourier transform is used for the reconstruction?

3. In MRI, a commonly used definition of signal-to-noise ratio (SNR) is the average intensity value over a region-of-interest (ROI) divided by the standard deviation of the noise field (e.g., the background). For the image obtained in Problem 2c, determine the SNR in at least 3 areas of the brain white matter, and compute the average SNR. To ascertain that the locations of the ROIs are correct, show the ROIs and background region selected as black or white-out regions on a copy of the image.

4. Obtain a sub-sampled version of `raw_signal` from Problem 2 by cropping and keeping the center 50% of the rows and columns of the matrix. Moreover, obtained another sub-sampled signal by extracting every other row and column of the original. (Each sub-sampled data should have 72×96 matrix size.) Reconstruct and show the MR images. Describe what you see and <u>explain</u> why via Fourier transform and sampling theories.

5. The goal of this Problem is to obtain the convolution of the result of Problem 2c and each of the convolution kernel (or mask) below. First, examine each kernel and explain what it does to an image. Next, use Matlab's or your own convolution function to obtain the results, and discuss whether they agree with your expectation. Pay attention to the orientation of the kernels and how they are represented in Matlab.

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

(a)

1	1	1
0	0	0
-1	-1	-1

(b)

-1	0	1
-1	0	1
-1	0	1

(c)