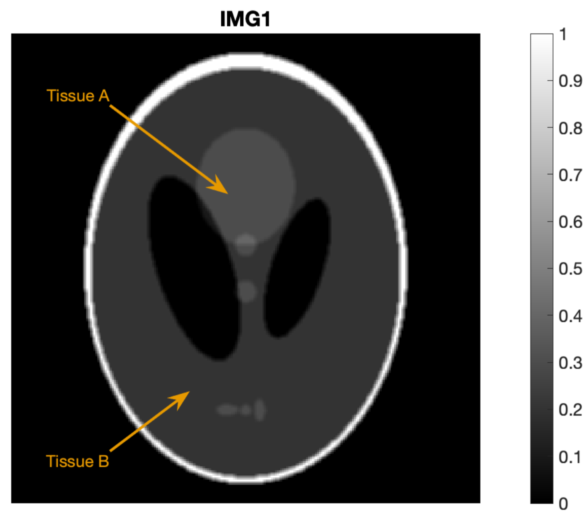
BME 4400/5400 Spring 2022
Assignment #1
Due: August 31, 2022 9:00 PM

Objectives: perform simple analysis of images in MATLAB, compute and observe 2D Fourier transforms, compute and observe 2D convolutions.



1. Load file *A1images.mat* in MATLAB. The object, IMG1N, contains 15 versions of an image (like the one to the right, without the tissue labels) produced by a hypothetical imaging system, with varying levels of added noise.

   a. Use the MATLAB function *roipoly* to measure the contrast-to-noise ratio (CNR) between Tissue A and B for each of the 12 noisy images. Define CNR ≡ Mean signal difference between tissues divided by the standard deviation of the signal in Tissue A. Make sure the regions-of-interest (ROIs) that you draw encompass at least 30 image pixels. Use the same two ROIs (Tissue A and B) for all 12 noisy images.

   b. From the calculations in part a, what is the minimal CNR at which you can confidently distinguish *all* structures by eye. How does this result depend on the size of the structure you are trying to identify? Discuss your observations in terms of the frequency response (i.e., modulation transfer function) of the hypothetical imaging system.

2. Load *A1images.mat.* Using IMG2 as the input, compute the outputs of linear and shift-invariant

$h_1 =$

1/16	1/8	1/16
1/8	1/4	1/8
1/16	1/8	1/16

$h_2 =$

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

$h_3 =$

0	-1	0
-1	5	-1
0	-1	0

systems with point spread functions of h_1, h_2 and h_3. Look at the <u>magnitude</u> (i.e., use *abs* function) of each image using the MATLAB function *imagesc*.

   a. Qualitatively, how has each of these three systems affected the image?

   b. Compute the 2D magnitude Fourier spectrum of each point spread function and describe how the spectral characteristics explain the qualitative observations in part a. Suggestions: zero-pad the *fft2* calculations to the size of the input image, display magnitude spectra using log scaling — $\log\left(1+\left|H\left(k_x,k_y\right)\right|\right)$, and use pseudocolor and the same scale for display of each magnitude spectrum to make comparison easier.

c. Construct an "identity" point-spread function, i.e., one which maps an input signal to an identical output signal. Use MATLAB to prove that it has this property. Explain intuitively why this particular point-spread function works this way.

d. Look at the 2D Fourier transform of this identity PSF. Does it have an expected shape, considering this is a transfer function? Explain this intuitively as well.

3. Assuming a pixel size of 2 mm, create 3x3 pixel point-spread functions that generate:

   a. the integral of the 3x3 area

   b. the approximate first derivative in the x direction, calculated as

   $$\frac{\partial I}{\partial x} \approx \frac{I\,(x + \Delta x) - I\,(x - \Delta x)}{2\Delta x}$$

   c. the cross derivative, $\frac{\partial^2 I}{\partial x \partial y}$. (Hint: evaluate $\frac{\partial I}{\partial x}$ using the result from part b, and then use a similar approach to evaluate $\frac{\partial I}{\partial y}$.)

   d. Look at the Fourier transforms of these filter/point-spread functions in parts a-c. Do they make intuitive sense? What does this tell you about the frequency information of a derivative or integral?