EEE 473/573 Medical Imaging – Fall 2020-2021
Homework 2
Due 25 October 2020, Sunday at 23:59

GUIDELINES FOR HOMEWORK SUBMISSION

1. NO submission via E-MAIL (all email submissions will be discarded).
2. Submit a PDF file. Other file types will not be accepted. If there are any handwritten parts, you can scan them (make sure they are legible) and insert into the PDF file. Unclear presentation of results will be penalized heavily. No partial credits to unjustified answers.
3. If your Matlab codes are not included at the end of the PDF file, your Matlab questions will NOT be graded.
4. This is a Turnitin submission. The Turnitin system requires the submitted file to contain at least 20 words in it. If you are submitting a Word file with scanned pages only, the file will be rejected by the system. You can type your name multiple times at the beginning of the file to overcome this problem.
5. Submission system will remain open for 1 day after the deadline. No points will be lost if you submit your assignment within 12 hours of the deadline. There will be a 50% penalty if you submit after 12 hours but within 24 hours past the deadline. No submissions beyond 24 hours past the deadline.

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1) Consider an LSI medical imaging system with PSF

$$h(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+4y^2}{2\sigma^2}} \quad with \quad \sigma = 4$$

a) Calculate the MTF associated with this system and plot $MTF(u,0)$ and $MTF(0,v)$ as a function of frequency.

b) An object $f(x,y) = 3 + 2\sin\left(\frac{2\pi x}{10}\right)$ is imaged using this system. What is the modulation of this object? What is the modulation of the image generated by the system?

c) An object $f(x,y) = 3 + 2\sin\left(\frac{2\pi y}{10}\right)$ is imaged using this system. What is the modulation of this object? What is the modulation of the image generated by the system?

d) An object $f(x,y) = 3 + 2\sin\left(\frac{2\pi(x+y)}{10}\right)$ is imaged using this system. What is the modulation of this object? What is the modulation of the image generated by the system?

2) Consider the following 1D medical imaging systems, with PSFs given by

$$h_1(x) = tri(4x) \qquad h_2(x) = e^{-8\pi x^2}$$

where $tri(x)$ is the triangle function extending from -1 to 1 with a peak value of 1.

a) Calculate the full with half maximum (FWHM) of each system. Which of these two systems have better spatial resolution?

b) If you want to image $f(x) = \sin(8\pi x)$, which system should you use? Hint: You should not have to calculate any convolution integrals.

3) Imagine a new type of pandemic has emerged due to a virus found in piranha fish in Brazil. In order to develop a proper test for the piranha virus disease (PIRAD-20), researchers try to set a threshold in their test kits for the amount of Na+ ions found in blood. Once they set the threshold, everyone scoring above this level will be classified as having PIRAD-20. Let's assume that these results are compared to a "gold standard" test that gives 100% correct results.

a) The researchers set the threshold Na+ ion level as 145 mmol/L. Below is the contingency table resulting from this threshold. Compute the prevalence of the disease, and the sensitivity, specificity, PPV, and NPV for the test.

		Disease	
		+	-
Test	+	183	72
	-	320	7425

b) The researchers change their minds and set the threshold Na+ ion level as 185 mmol/L. Below is the contingency table resulting from this threshold. Compute the prevalence of the disease, and the sensitivity, specificity, PPV, and NPV for the test. How did these numbers change?

		Disease	
		+	-
Test	+	143	39
	-	360	7458

c) Imagine that you are a patient being screened with the test, and the doctor tells you the result (either positive or negative). Which test ((a) or (b)) would you prefer, and why?

4) MATLAB QUESTION: Let's say we developed a new type of iron oxide nanoparticle tracer for magnetic particle imaging (MPI). We now want to characterize its response with imaging experiments. Since there is no "gold standard" tracer in MPI, we decide to compare our new tracer with two different commercially available tracers for MPI, namely Perimag and Resovist. You prepared a phantom with point sources of these three tracers (i.e., new tracer and two commercial tracers) that are separated 5-mm apart from each other's center. The tracers are placed in the following order from left to right: Perimag, new tracer, and Resovist. To have a fair comparison, all of the tracers have the same iron concentration level.

a) Load the experiment data ("MPI_data.mat") into your workspace and display the MPI image. The image has a physical x-axis and y-axis ranging from $-45 \text{ mm} < x \leq 45 \text{ mm}$ and $-15 \text{ mm} < y \leq 15 \text{ mm}$ (i.e., 500 x 1500 pixels corresponding a physical extent of 30mm x 90 mm). Put the ticks and labels to the x-axis and y-axis properly.

b) Measure the approximate FWHM of these three tracers. Note that the tracer responses are circularly symmetric.

c) Calculate the SNR of each tracer in the image, using the amplitude SNR metric (i.e., the peak pixel intensity level for a tracer divided by the standard deviation (STD) of noise). **Note:** For measuring STD for noise, first choose a rectangular region in the background where there is negligible tracer signal. Then compute the STD in that region using the built-in *std* function.

d) Load the vessel imaging data ("vessel.mat") into your workspace and display the vessel phantom ("vessel_phantom"). Here, three different imaging experiments were conducted by filling this vessel phantom with one of the three tracers each time ("vessel_image_#"). Display these images. The researchers forgot to label which tracer was used in each experiment. Find out which image corresponds to which tracer. Explain your reasoning.