EEE 473/573 Medical Imaging – Fall 2021-2022
Homework 2
Due 7 November 2021, 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. For the part labeled as "MATLAB Question", you can choose to use MATLAB or other softwares (e.g., Python). Make sure to include the relevant codes at the end of the PDF file to be submitted. If your codes are missing, that question 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) Show that $\mathcal{H}\left\{rect\left(\frac{r}{a}\right)\right\} = a^2\text{jinc}(qa)$, where $\mathcal{H}\{\cdot\}$ denotes the Hankel transform. **Hint:** $\int_0^x J_0(\xi)\xi d\xi = xJ_1(x)$.

2) Consider the two LSI systems given below,

$$h_1(x,y) = e^{-\pi\left(\left(\frac{x}{2}\right)^2 + \left(\frac{y}{3}\right)^2\right)} \quad , \quad h_2(x,y) = \text{sinc}(4x,y)$$

a) Calculate the MTF associated with these systems, $MTF_1(u,v)$ and $MTF_2(u,v)$.
b) Sketch $MTF_1(u,0)$, $MTF_1(0,v)$, $MTF_2(u,0)$, and $MTF_2(0,v)$ as a function of frequency. For plotting purposes, clearly mark the points where the MTF functions are equal to 1/2.
c) An object $f(x,y) = 3 + 2\sin(2\pi(x+y))$ is imaged using each of these systems, separately. What is the modulation of this object? What is the modulation of the image generated by each system for this object?

3) Consider a 2D imaging system, which has two subsystems with PSFs $h_1(x,y)$ and $h_2(x,y)$ as given in Question 2 above.
a) Calculate the full-width half-maximum (FWHM) resolutions of each system along x- and y-directions.
b) Using the approximate relation for FWHM, calculate the FWHM of the entire system along x- and y-directions.

4) Imagine a new type of artificial neural network (ANN) assisted test is developed to determine if a person has breast cancer or not. In this test, researchers first extract tissue samples from the breast of a patient, then inject a special type of dye to paint the cells. Once the dye is injected into the tissue, under the electron microscope, the cancer cells have dark purple, whereas healthy cells have light pink color. If the ratio of the amount of dark purple cell to the light pink cells are above some set threshold, researchers conclude that the donor has breast cancer. The ANN helps with counting the number of dark purple cells and pink cells, and is compared to a "gold standard" test (i.e., lab technicians counting the cells by themselves) that gives 100% correct results.

a) The researchers set the threshold as 1/10. Below is the contingency table resulting from this threshold. Compute the prevalence of the breast cancer, and the sensitivity, specificity, PPV, and NPV for the test.

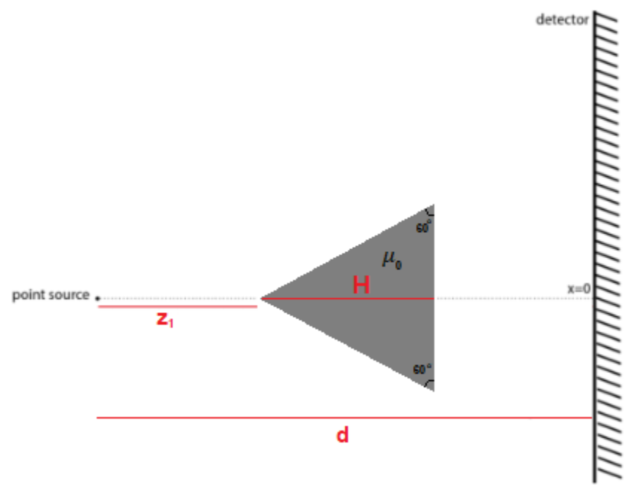
		Disease	
		+	-
Test	+	183	72
	-	320	7425

b) The researchers change their minds and set the ratio threshold as 1/8. 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 researcher working on this ANN. Which threshold ((a) or (b)) would you prefer, and why?

5) A cone with height $H = 10\ cm$ and constant linear attenuation coefficient $\mu_0 = 0.1\ cm^{-1}$, is imaged with a point source x-ray imaging system, $d = 1\ m$ away from the detector. The object is placed between the source and the detector (as shown on the right for a cross-sectional view in the x-z plane). Formulate the intensity on the detector along the x-axis (i.e., y=0), $I_d(x, 0)$, for two cases: $z_1 = 0.5\ m$ and $z_1 = 0.8\ m$. <u>Do not ignore obliquities.</u>



6) MATLAB Question: Include your MATLAB codes in your solution.

For Question 5, assume that the detector has a size of $30\ cm \times 30\ cm$ with 512×512 elements on it (i.e., it generates a 512×512 x-ray image). We place the object at the two locations indicated in Question 5 (i.e., $z_1 = 0.5\ m$ and $z_1 = 0.8\ m$) and take x-ray projection images separately for those two cases.

a) Plot the 1-D normalized intensity profiles (i.e., $I_d(x, 0)/I_0$) for the two cases.
b) Compare the two plots and comment on their differences.