BMEN 509 Introduction to Biomedical Imaging

Assignment 2 Imaging Basics

1. (10 pts) Show mathematically that for a Gaussian line spread function the Full Width at Half Maximum can be approximated to

$$FWHM \approx 2.36\sigma$$

Explain in your own words why a Gaussian line is often an adequate representation of a system‘s PSF.

2. (40 pts) For the following spatial functions:

$$f(x,y) = 20\sin(1000\pi x)$$

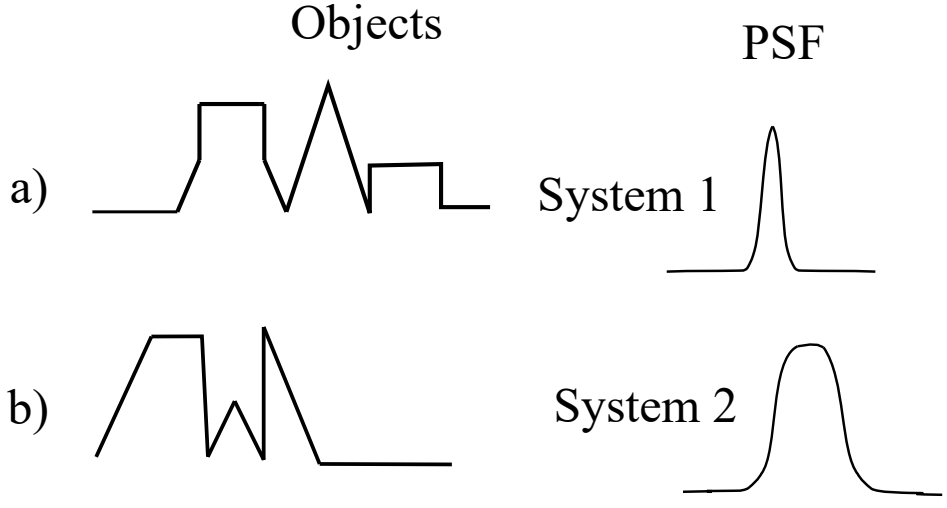
$$f(x,y) = 20\sin^2(2000\pi x)$$

$$f(x,y) = \exp - \left[\left(\frac{(x-1)^2}{2} + \frac{(y-5)^2}{2}\right)\right]$$

$$f(x,y) = \begin{cases} 0 & -10 < x < 10; -10 < y < 10 \\ 1 & otherwise \end{cases}$$

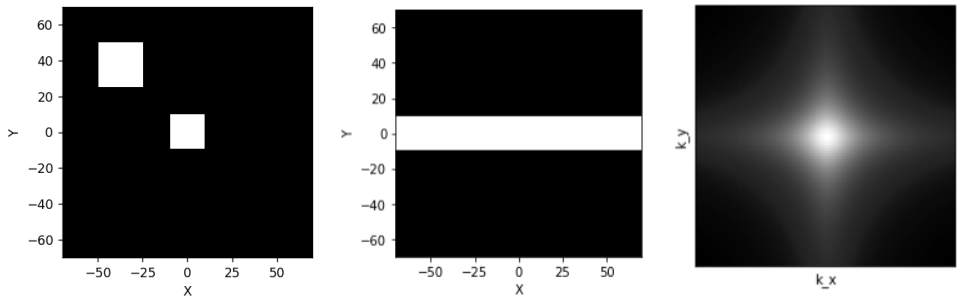
1) Obtain the image corresponding to the equation
2) Obtain the histogram for each image
3) Obtain the frequency spectrum for each image
Note: you should use Python to obtain the image, and you can either draft the histograms and spectra by hand or also use Python for this. Submit a link to your code in a Jupyter notebook on your GitHub repository.
4) Explain in your own words how at least two features of each equation can be observed in the image (i.e. amplitude, frequency, width, etc.)
5) What would be the advantage of learning how an equation is “observed” in an image for you as an engineer? (i.e. what will learning this may help you understand when working with “real” images)

3. (10 pts) For the 1D objects shown below (a-b) consider that we imaged them using two different systems with the point spread functions (PSF) on the right.
a) Sketch the resulting 1D images obtained for each object using each system
b) Explain the effect that the PSF has on the resolution of the image
c) This is a 1D object, how would having those PSFs will translate into a 2D image? (i.e. would the signal, contrast, resolution, etc. be impacted and how?)

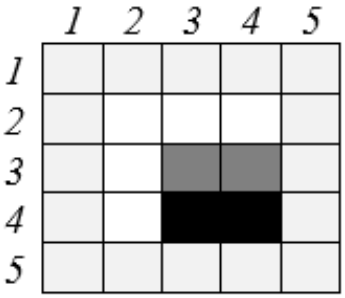


4. (5 pts) Calculate the minimum FWHM that a system needs on its PSF if we will image a field of view of 30 cm and the image has 1024x1024 pixels. If the system proved to have a larger PWHM to what you calculated, what would be the expected result on this image? (i.e. would the FOV and/or the size of the image need to be changed? why?)

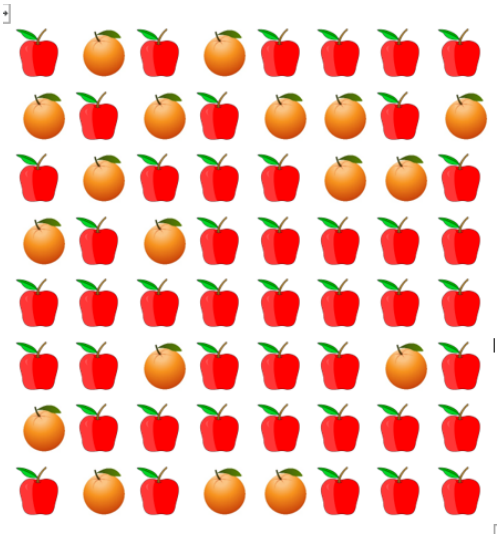
5. (10 pts) Sketch the histograms for the images below. Explain what the histogram tells about the image in your own words.



6. (10 pts) Calculate the SNR and CNR (between [1,1] and [3,3]) in the following image assuming you have 2 bits (values between 0 and 3) to encode the colours. Explain what would happen to those SNR and CNR values if you were to encode using 3 bits instead.



7. (15 pts) Two automatic diagnostic systems have been created to detect "apples" and it is tested with the "real" data in the following image.



It is then observed that **system 1** provides the following results:

yes	no	yes	no	no	yes	no	yes
yes	yes	no	yes	no	yes	yes	no
yes	no	yes	no	no	no	no	yes
no	yes	no	yes	yes	yes	no	yes
yes	yes	yes	no	yes	yes	yes	yes
yes	yes	yes	yes	yes	yes	no	no
no	no	yes	yes	yes	yes	yes	yes
yes	no	yes	no	yes	yes	yes	yes

And **system 2** provides the following results:

yes	no	yes	no	yes	yes	no	yes
yes	yes	no	yes	no	yes	yes	no
yes	no	yes	yes	no	no	no	yes
no	yes	yes	yes	yes	yes	yes	yes
yes	yes	yes	no	yes	yes	yes	yes
yes	yes	yes	yes	yes	yes	yes	yes
yes	yes	yes	yes	yes	yes	yes	yes
yes	no	yes	no	yes	yes	yes	yes

a) Provide a table showing which are the false positive, false negative, true positive and true negative results for each system
b) Calculate the sensitivity for both systems
c) Calculate the specificity for both systems
d) Draft a receiving operating curve for both systems (together)
e) Which system provides the best diagnostic? Explain why.
f) Imagine that instead of apples and oranges when the system detects an "apple" a malignancy is diagnosed. How would you explain to a patient the sensitivity and specificity of this system? (use words that a Grade 8 student will understand)

Total 100 pts