EEE 473/573 Medical Imaging – Fall 2018
Homework 1
28 October 2018, Sunday at 23:59

GUIDELINES FOR HOMEWORK SUBMISSION

1. NO submission via E-MAIL (all emails will be discarded).
2. Submit a Word or 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 Word 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) Find one image from each of the following medical imaging modalities: x-ray, CT, PET, ultrasound, and MRI. Clearly label the image type and indicate which body part is shown in the image (e.g., head, torso, heart, kidneys, etc.). For reference, include the URLs of the source webpages under each image.

2) For each system with the following input-output equation, determine whether the system is linear and determine whether it is shift-invariant:

a) $g(x,y) = f(x_0 - x, y_0)$

b) $g(x,y) = \begin{cases} f(x,y) - f(x-1,y-1), & f(x,y) \geq 0 \\ 0, & otherwise \end{cases}$

3) Given a continuous signal, $f(x,y) = 4x^2 + 2xy$, evaluate the following:

a) $f(x,y)\delta(x+4,y-3)$

b) $f(x,y) * \delta(x+4,y-3)$

c) $\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \delta(x+4,y-3) f(x,0)\, dx\, dy$

d) $f(x-4,y-3) * \delta(x+4,y-3)$

4) Find the 2D Fourier transforms of the following 2D continuous signals.

a) $g(x,y) = \delta(x+1)$

b) $g(x,y) = \delta(2x+2,-y)$

c) $g(x,y) = rect(x-1,2y)$

d) $g(x,y) = sinc(2x,y)\delta(x)e^{j2\pi y}$

e) $g(x,y) = rect(2x,y-1) * cos(2\pi x + \pi y)$

f) $g(x,y) = e^{-2\pi(x^2+y^2)} * e^{j2\pi(x+y)}$

g) $g(x,y) = rect\left(\frac{x-y}{\sqrt{2}}\right) rect\left(\frac{x+y}{\sqrt{2}}\right)$

h) $g(x,y) = sinc(x-y)sinc(x+y)$

<u>PREPARATION 1)</u> Centered FFT: In medical imaging, the preferred way to display the image and the Fourier domain data is such that the origin is at the center of the image or data array. The usual convention for the FFT in MATLAB, however, is that the origin is at the beginning of the array, or the upper left corner of a 2D array. To do a centered FFT, you want to do fftshift/ifftshift before/after the FFT. To do this, define the following functions in MATLAB:

```
function d = fft2c(im)
% d = fft2c(im)
%
% fft2c performs a centered fft2
im = fftshift(fft2(ifftshift(im)));
end

function im = ifft2c(d)
% im = fft2c(d)
%
% ifft2c performs a centered ifft2
im = fftshift(ifft2(ifftshift(d)));
end
```

When you type 'help fft2c' in Matlab, you will now see the commented text that gives the function usage. Pay attention to including "help" sections when you create your own functions/scripts.

You may also want the corresponding one dimensional versions fftc and ifftc. Note that fftshift and ifftshift give exactly the same result when the array size is even-valued, but are different otherwise.

<u>PREPARATION 2)</u> Displaying the magnitude spectrum: To display the magnitude spectrum as an image, we typically do the following:

```
>> imshow(log(abs(F)+1),[])
```

where F is the 2D Fourier transform of an image. In Fourier domain, the value at DC (i.e., at the origin of Fourier domain) is much larger than the values elsewhere. The "log" operation brings these values closer together, so that we can display the entire magnitude spectrum more easily. The addition of 1 is to avoid the log(0) problem.

5) MATLAB QUESTION: Generate a "phantom" image in MATLAB using the following command:

```
P = phantom('Modified Shepp-Logan',512);
```

This digital phantom presents an axial crosscut of a human body, showing the lungs, the heart, and a few blood vessels. Assume that this is our object of interest, with its physical x-axis and y-axis ranging from -32 cm $< x \leq 32$ cm and -32 cm $< y \leq 32$ cm (i.e., 512 pixels corresponding a physical extent of 64 cm). "P" is our "ideal" image.

Assume the point spread function (PSF) of a medical imaging system is given as the following 2-D Gaussian function:

$$h(x, y) = \frac{1}{2\pi\sigma_x\sigma_y} e^{\frac{-x^2}{2\sigma_x^2}+\frac{-y^2}{2\sigma_y^2}}$$

a) Display the "ideal" image P and its magnitude spectrum.

b) For three different values σ_x and σ_y:

i. $\sigma_x = 0.1\ cm$ and $\sigma_y = 0.1\ cm$

ii. $\sigma_x = 0.5\ cm$ and $\sigma_y = 0.1\ cm$

iii. $\sigma_x = 0.6\ cm$ and $\sigma_y = 0.6\ cm$

Do the following: Display each PSF and the image resulting from the medical imaging system. Also, display the magnitude spectrum of each resulting image.

c) Explain what you see in the images and the resulting magnitude spectrums, and how they change with different σ_x and σ_y values.