BME 350: Signals & Systems for Bioengineers

MATLAB Project 2 (50 points)

Due Thursday, October 13 by 9AM

Objective: This project is intended to make you familiar with 2D convolution, LTI systems, and Fourier Series calculations.

Project Details: This project has been implemented in MATLAB version R2015a. However, this project can be run on legacy versions of MATLAB. The project prompt can be found in the 'MATLAB Assignments' folder on BlackBoard and consists of the assignment sheet and one MATLAB script entitled 'LastnameFirstname_Project2.m'.

Instructions:
1) All plots must be plotted with MATLAB and must contain clear labels. (Please label both axes and include a title.)
2) Clearly mention your ASU ID in the 'Initialization' section of the MATLAB script.
3) Rename the .m file with your last name and first name.
4) Ideally your submission to BlackBoard will include two files.
a. The completed and renamed .m script.
b. A correctly named PDF file with the plots and the small write up.
5) Submit your files by **Thursday, October 13 by 9AM**.

Deliverables:
1) Completed and renamed .m file containing the figure generating code.
2) Correctly named PDF file of the figures and write up.

Any questions on this assignment should be directed to:
Swathy or Subash : At the recitation sections - **Preferred**
Or:
Swathy: ssampat9@asu.edu or Subash: spadman9@asu.edu
Do not email the project reports to the professors or TAs; reports sent by email will be discarded.

NOTE: YOUR MODIFIED MATLAB FILE SHOULD RUN WITHOUT ERRORS, AND GENERATE ALL REQUIRED PLOTS (Correctly labeled and titled). **[5 points]**

Before starting the file, please assign the last digit of your ASU ID to the variable 'ASUID' in the initialization section.

Question 1 [10 points]: 2D Convolution

a. **[1 point]** Select any photo (e.g. that of your pet rock) and modify the filename to match the code. Show your chosen image and include it in your report.

b. **[1 point]** Run this code to blur your chosen image. Using the subplot command, show the original image, point spread function and blurred image and include in your report.

c. **[2 points]** Change the definition of the point-spread function to have a width of:

$$width = 15 - (ASUID/2)$$

Generate the corresponding blurred image. Use the subplot command to show the before and after effect, horizontally. Entitle the blurred image with your ASU ID number. Add the figure to your report.

d. **[2 points]** Restore the images with the functions deconvreg() and deconvblind(). Add the images to your report.

e. **[4 points]** Change the definition of the point-spread function to have inputs of:

$$width = 4$$
$$size = 20 + (ASUID \times 5)$$

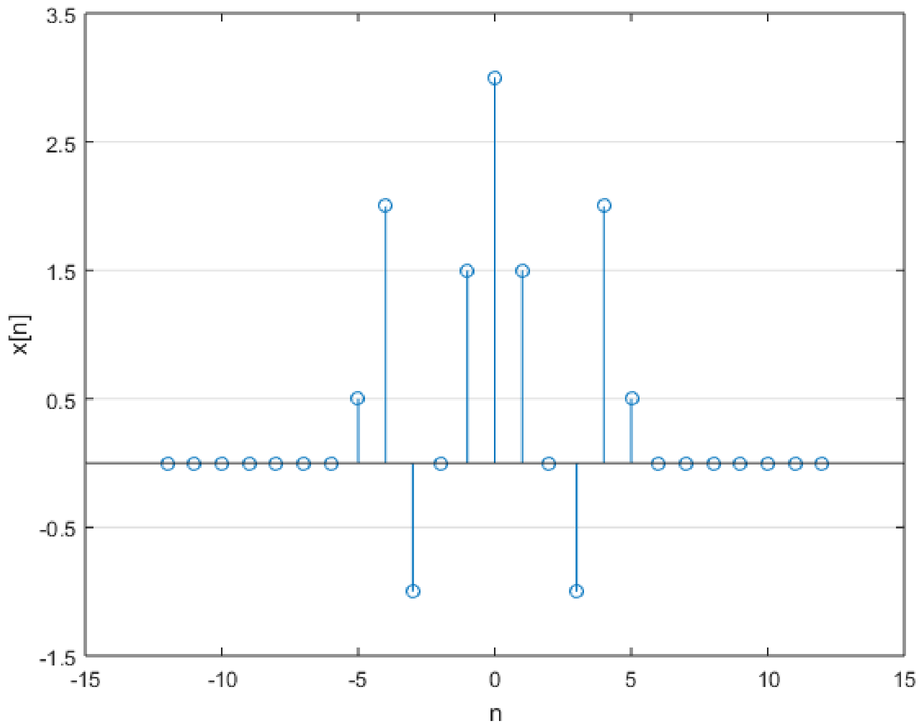
Generate the before and after images. Entitle the blurred image with your ASU ID number. Also, generate the restored images using the functions deconvreg() and dconvblind(). Add the images to your report.

Question 2 [10 points] LTI Systems

Consider the discrete-time LTI system initially at rest whose input, $x[n]$, and output, $y[n]$, are related by the following difference equation:

$$y[n] - \frac{3}{4}y[n-2] + \frac{1}{2}y[n-4] = 4x[n] + 2x[n-2] - \frac{7}{3}x[n-4] - \frac{1}{3}x[n+2]$$

Where $x[n]$ =



a. **[8 points]** Compute the response y$[n]$ of this system for the input $x[n]$. Use the following values for n:

$$-25 - ASUID \leq n \leq 45 - ASUID$$

b. **[2 points]** Is the above system causal? Justify your answer.

Question 3 [25 points] Fourier Series

The provided code plots a periodic function signal defined by:

$$x(t) = \frac{7t^2}{2T}, \qquad \frac{-T}{7} \leq t \leq \frac{T}{7}$$

a. **[2 points]** What is the fundamental period of x(t)? What is the signal amplitude? Include your answers in your report.

b. **[3 points]** Modify the signal x(t) in the MATLAB code to set the fundamental period to:

$$T = (ASUID/2) + 7$$

Plot the modified signal over **5 cycles** and name it $\mathbf{y(t)}$. Include this plot in your report.

c. **[2 points]** Find the a_0 coefficient for the signal y(t). Show your work and highlight the final expression for a_0.

d. **[3 points]** Modify the provided MATLAB code to compute the Fourier coefficients a_k of $y(t)$ for $-50 \leq k \leq 50$. Plot the Fourier series coefficients a_k, use the stem plot to plot both the real and imaginary components of the coefficients.

e. **[11 points]** Consider $y_N(t)$ to be the reconstructed signal from the Fourier coefficients, where –N and N are the limits of k.

$$y_N(t) = \sum_{k=-N}^{N} a_k e^{jkw_0 t}$$

Create code that will compute $y_{10}(t)$, $y_{25}(t)$, $y_{50}(t)$, $y_{100}(t)$, and $y_{200}(t)$ by implementing the synthesis equation for a finite number of k from –N to N. You will need to use/modify the code from part c to generate $a_k's$. Graph the reconstructed $y_N(t)$ in each case. Include the plots in the report (use subplots). What happens when you increase N? Explain in detail.

f. **[4 points]** The approximation for error is given by:

$$e_N(t) = y(t) - y_N(t)$$

And the mean-squared error (MSE) is defined as:

$$MSE_N = \int_T \left| e_N(t)^2 \right| dt$$

And the normalized MSE is defined as:

$$Normalized\ MSE = \frac{MSE}{\max(MSE)}$$

Modify the provided code so you can compute the MSE for the signals $y_{10}(t)$, $y_{25}(t)$, $y_{50}(t)$, $y_{100}(t)$, and $y_{200}(t)$. Plot the Normalized MSE vs number of coefficients. Include the plot in your report. What can be inferred about the convergence of the Fourier series?

A good approximation can be described as a reconstruction having 5% error or lower. How many coefficients will be enough to get a good approximation of y(t)?