ECE3230 - Practicum IV

Convolution

Reporting Requirements: Follow report instructions for Practicum I.

Objective: To gain hands on experience with convolution and its application on simulated and real signals.

Procedures: Before the lab session, Procedure 1(a) should be completed and the example in Appendix 1 for the convolution of $x[n]=p_6[n-5]$ and $h[n]=0.9^{n-5}p_{16}[n-5]$ should be studied.

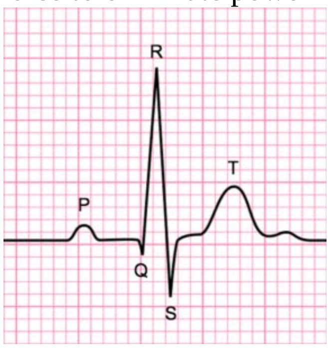
1. Convolution sum for finite duration DT signals:
(a) By hand, compute and plot the convolution of the signals $x_1[n] = p_{20}[n]$ and $h_1[n] = p_{10}[n]$.
(b) Now use Matlab to compute and plot the convolution of these two signals. Specifically, do this twice, using the two methods illustrated in the attached Appendix 1:

1) by using the Matlab conv command; and
2) by programming the convolution operation, yourself. For both methods, plot the result for $n = 0, 1, 2, \cdots, 27, 28$.

(c) Let q be the number of contiguous nonzero elements of h[n] (i.e. the length of h[n]). Let p be the length of x[n]. Generalizing the results observed above, what is the length of $y[n] = x[n] * h[n]$?

2. Convolution operation on a real recording

Now that you have tested and verified different ways to perform convolution operation in Matlab you will proceed to use any one of those convolution codes of your choice to eliminate power line interference on a real electrocardiogram (ECG) recording. An ECG signal represents the electrical activity of the heart and usually consists of repeated heart beat signals, called PQRST complexes as shown in the figure.



ECG recordings can get corrupted by various noise sources, one of them being the power line noise (a sinusoidal signal oscillating at 60Hz). In this part you will work on the noisy electrocardiogram (ECG) recording within ‘ECG_p4.mat’ given in the course website which is sampled at sampling frequency, fs=200Hz.

a) Load and plot ECG signal vs time in seconds (You can use plot command here). In this ECG recording, in addition to the repeating PQRST complexes notice the oscillating signal at 60Hz. Plot the spectrogram of this signal using the command line spectrogram(ECG,256,250,512,fs,'yaxis'). Note that, you have to define fs=200Hz in your code before calling spectrogram function. Notice the frequency component at 60Hz.
b) Suppose that this noisy ECG signal passes through the given finite impulse response (FIR) system with difference equation where input is x[n] and output y[n] is defined as:

$y[n]=0.25\ (0.25x[n+3]+0.5x[n+2]+ 0.75x[n+1]+x[n]+0.75x[n-1]+0.5x[n-2] +0.25x[n-3])$

Find and plot the impulse response, h[n] of this system vs n (Use stem command).

c) When the input to the given FIR system is the noisy ECG signal, using convolution operation, plot the output of the system vs. time in seconds for the time period, the same as the original ECG signal (Use the plot command). Compare the output of the FIR system with the noisy ECG, were you able to suppress the power line noise using this simple FIR system?

Hints: Here, you can implement any convolution calculation you have tested in part 1. Note that due to the convolution operation the length of the signal as the output of the given FIR system will be longer than the original ECG, to plot the output for the corresponding time the same as the original ECG you have to make some adjustments to the signal length (for samples corresponding to n=0,1,…,N-1 where N is the original noisy ECG signal's sample size).

d) Plot the spectrogram of the output of the given FIR system found in part 2.c. Compare the spectrogram of the FIR system output with the spectrogram of the original, noisy ECG signal and comment on your observations.

Appendix 1

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% Practicum III, Appendix 1, The convolution sum
%
% Example x[n]=p6[n-5] and h[n]=(0.9)^(n-5)p16[n-5] given as
% x[n] = u[n-5] – u[n-11]
% h[n] = (.9)^(n-5) (u[n-5] – u[n-21])
%
% To illustrate one way of handling delayed signals in Matlab we load zeros into the data arrays
% so that the first element of each array corresponds to time n=0. However, using the
% convolution delay property (to keep track of what time the array elements correspond to),
% there is really no need to prepend or append zeros to the input arrays in Matlab's conv.m
% function.
%
clear
clear functions
clf
pause
x=ones(1,6); % Generate 6 samples of x[n] for n=5,..,10
k=1:16; % Generate 16 samples of h[n] for n=5,..,20
h(k)=(.9).^(k-1);
pause
y=conv(x,h); % Using the MATLAB conv command to convolve h and x and form the output y
pause
%
y1(1:40)=zeros(1,40); % Plot 40 samples of y[n] for n=0,1,...,39
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y1(11:31)=y;
n=0:1:39;
subplot(211)
stem(n,y1,'*'),xlabel('n'),ylabel('y(n)'),
title('1-st Convolution Result'),
pause
%
% Now let's do it again without using the MATLAB conv command.
% We'll do it ourselves.
clear
x=zeros(1,11); % Generate 11 samples of x[n] for n=0,..,10
x(6:11)=ones(1,6); %
h=zeros(1,21); % Generate 21 samples of h[n] for n=0,..,20
k=0:1:15; %
h(6:21)=(.9).^k; %
pause
%
x(12:40)=zeros(1,29); % Directly convolve h and x --> output y
h(22:40)=zeros(1,19);
for n=1:40;
	y(n)=0.;
	for k=1:n;
		y(n)=y(n)+x(k)*h(n+1-k);
	end
end
pause
%
clear n
n=0:1:39;
subplot(212)
stem(n,y),xlabel('n'),ylabel('y(n)')
title('2-nd Convolution Result')
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Practicum IV

Instructor/TA Sign Off Sheet

Student's Name: ____

1. Pract. IV, Procedure 1(a): computation and plot_________________________________

2. Pract. IV, Procedure 1(b): convolution plots_________________________________

3. Pract. IV, answer for Procedure 1(c): _______________________(a function of p and q)

4. Pract. IV, Procedure 2(a): time domain and spectrogram plots for noisy ECG__________

5. Pract. IV, Procedure 2(b): impulse response of the FIR system, h[n] vs n______________

6. Pract. IV, Procedure 2(c,d): time domain and spectrogram plots of FIR system output with noisy ECG input _______________________

   Answers to the comments