IBEHS 3A03 – Biomedical Signals and Systems (2024)

Assignment #2: LTI System Responses and Convolution

Submission deadline: 11:59pm on Monday, October 28th.

Submission requirements: Please see the document **IBEHS3A03 - Assignments - General Instructions** on Avenue.

Motivation:

In lectures and tutorials, we have looked at: i) the mathematical relationships between the impulse and step responses of LTI systems and ii) how the output of an LTI system can be obtained by convolving the system's impulse response with any input signal. In this assignment, you will be carrying out testing of these theories for three different "black-box" discrete-time LTI systems in MATLAB.

Instructions:

Posted on Avenue in the content section **Assignments** and subsection *Assignment 2* are three MATLAB p-code function files named `ltisystemA.p`, `ltisystemB.p`, and `ltisystemC.p`, along with .mat files for two example physiological signals `ECG_assignment2.mat` and `respiration_assignment2.mat`.

These functions all operate in the same fashion as the .p files from the first assignment (i.e., `y = ltisystemN(n,x)` where `n` is a time-step index vector and `x` is an input signal vector), but they all implement *linear*, *time-invariant* systems. Note that all of these functions assume zero initial conditions, i.e., $x[n] = 0$ and $y[n] = 0$ for all values of n before the first time-step value in your supplied input array `n`, and that $x[n] = 0$ for all values of n after the last time-step value in your supplied input array `n`.

Download these files, and develop a MATLAB script (i.e., .m file) that for each of these systems A–C:

I. computes the system output when the input is the unit impulse function $\delta[n]$,

II. computes the system output when the input is the unit step function $u[n]$,

III. demonstrates that the unit step function output is equal to the cumulative sum of the unit impulse response (hint: MATLAB has a built-in function `cumsum`),

IV. demonstrates that the unit impulse function output is equal to the first difference of the unit step function response (hint: MATLAB has a built-in function `diff`),

V. directly computes the system output when the input is the provided example ECG signal `ECG_assignment2.mat`,

VI. directly computes the system output when the input is the provided example respiration signal `respiration_assignment2.mat`,

VII. demonstrates that the outputs for the ECG and respiration signals are equal to convolution of those input signals with the impulse response $h[n]$ of the system computed in part I above (hint: MATLAB has a built-in function `conv`).

Note that the output array `y` from each of these functions is only as long as your input array `x`, so you will need to make sure that your input array is long enough (i.e., has enough time steps) to capture the bulk of the impulse and step responses in parts I and II.

In your report, you should: i) show the plots from your code for parts I to VII, ii) state for each of the three systems whether it appears to be a finite impulse response (FIR) or an infinite impulse response (IIR) system, and iii) comment on where the demonstrations that you performed in parts III, IV and VII do or do not match the theory. Note that for this main part of the assignment is sufficient for the demonstrations in part III, IV and VII to be based on visual comparisons. In any case where your results do not (entirely) match the theory, give an explanation of why.

Bonus 1:

Write MATLAB code that performs a formal logical test for parts III, IV and VII. Note that you may need to take into account MATLAB's finite precision mathematics when implementing logical tests. In your report, give a brief explanation of how you have implemented these formal logical tests.

Bonus 2:

Write MATLAB code that analyzes systems A–C and determines whether each of them is a low-pass filter, a high-pass filter, or a band-pass filter. In your report, give an explanation of how you have tested the filtering properties of the systems and how you have arrived at your conclusions. Include any plots that your tests have generated.

Grading Scheme:

Completing all components listed under **Instructions** above.	60
Following requirements listed in the document **IBEHS3A03 - Assignments - General Instructions** on Avenue.	40
Bonus 1	5
Bonus 2	10