Experiment No.-2: Analysis of LTI systems

1. Overview

In this lab we will study convolution, properties of convolution and analysis of LTI systems using MATLAB.

2. Linear Time-Invariant Systems

In discrete time, linearity provides the ability to completely characterize a system in terms of its response $h_k[n]$ to signals of the form $\delta[n-k]$ for all k. If a linear system is also time-invariant, then the responses $h_k[n]$ satisfy $h_k[n] = h[n-k]$. The combination of linearity and time-invariance therefore allows a system to be completely described by its impulse response $h[n]$ since the output of the system $y[n]$ is related to the input $x[n]$ through the convolution sum.

$$y[n] = \sum_{n=-\infty}^{n=\infty} h[n-m]x[m] \tag{1}$$

The MATLAB function `conv` computes the convolution sum in (1) assuming that $x[n]$ and $h[n]$ are finite length sequences. If $x[n]$ is non zero only on the interval $n_x \le n \le n_x+N_x-1$ and $h[n]$ is non-zero only on the interval $n_h \le n \le n_h+N_h-1$, then $y[n]$ is non-zero in $n_x + n_h \le n \le n_x + n_h + N_x + N_h - 2$ meaning that `conv` computes $N_x + N_h - 1$ samples. Consider the finite length signal

$$x[n] = \begin{cases} 1, & 0 \le n \le 5 \\ 0, & \text{otherwise,} \end{cases}$$

Use `conv` to compute $y[n] = x[n] * x[n]$. Store the result in `y`. Plot `y` using `stem` command. Note `conv` does not return an index vector. Index vector `ny` must be constructed such that `ny(i)` $= y$[`nyi`]. `ny(1)` must be $n_x + n_y$.

3. Exercise

1. Plot the response of a LTI system described by an impulse response $h(n) = 3\delta(n) - \delta(n-1) - 2\delta(n-2) + 3\delta(n-3) + \delta(n-4)$ for input $x(n) = \cos(n)$, $n = 0{:}\,2$. [Without using inbuilt function].

2. Two LTI systems described by impulse responses $h_1(n) = 3\delta(n) - \delta(n-1) - 2\delta(n-2)$ and $h_2(n) = 3\delta(n-3) + \delta(n-4)$ are connected in series. Find the overall impulse response of the system. Plot the response of system for input $x(n)$. [Using inbuilt function].

3. Two LTI systems described by impulse responses $h_1(n) = 3\delta(n) - \delta(n-1) - 2\delta(n-2)$ and $h_2(n) = 3\delta(n-3) + \delta(n-4)$ are connected in parallel. Find the overall impulse response of the system. Plot the response of system for input $x(n)$. [Using inbuilt function].

Source: https://web.stanford.edu/~kairouzp/teaching/ece311/secure/lab3/lab3.pdf