

# EE5301 ASSIGNMENT 1

SHANTANU YADAV

## 1 PROBLEM

Implement basic signal processing algorithms such as convolution, correlation, downsampling and upsampling

For a discrete time causal LTI system

$$h[n] = 0 \quad \text{for } k < 0$$

$$y[n] = \sum_{k=0}^{\infty} h[k]x[n-k]$$

## 2 C CODE IMPLEMENTATION

The C code solution code is available at

[https://github.com/Shantanu2508/mtech/tree/master/C/CSP\\_LAB/1](https://github.com/Shantanu2508/mtech/tree/master/C/CSP_LAB/1)

## 3 THEORY

### 3.1 Convolution

The complete characterization of a LTI system can be done by its impulse response. Mathematically,

$$x[n] = \delta[n]$$

$$y[n] = h[n]$$

According to the **shifting property**, any signal can be produced as combination of weighted and shifted impulses; that is

$$\begin{aligned} x[n] &= \sum_{k=-\infty}^{\infty} x[k]\delta[n-k] \\ \Rightarrow y[n] &= \sum_{k=-\infty}^{\infty} x[k]T\{\delta[n-k]\} \\ y[n] &= \sum_{k=-\infty}^{\infty} x[k]h[n-k] \end{aligned}$$

The operation can be symbolically as

$$y[n] = x[n] * h[n]$$

For a causal LTI system the output depends upon past and present values.

### 3.2 Correlation

Signal correlation can be considered as a measure of similarity of two signals. In signal processing systems, when a signal is corrupted by another undesirable signal (noise) signal estimation is performed by finding the correlation between the corrupted signal and the original signal.

Given two discrete-time real signals (sequences)  $x[k]$  and  $y[k]$  cross-correlation is defined as

$$R_{xy}[k] = \sum_{n=-\infty}^{\infty} x[n]y[n-k]$$

where the parameter  $k$  is any integer  $-\infty \leq k \leq \infty$ . Correlation can also be evaluated using the discrete-time convolution as follows

$$R_{xy}[k] = x[k] * y[-k]$$

**3.2.1 Properties of correlation:** 1. Signal cross-correlation can be also considered as a measure of similarity of two signals.

2. Signal autocorrelation indicates how the signal energy (power) is distributed within the signal, and as such is used to measure the signal power.

$$3. R_{xx}[0] = E_x^x$$

$$4. R_{xx}[k] \leq R_{xx}[0]$$

$$5. R_{xy}[k] = R_{yx}[-k]$$

### 3.3 Up/Down sampling

**3.3.1 Upsampling:** In upsampling the sampling rate is increased by inserting additional sample points of weight 0 between successive samples.

$$y[n] = x\left[\frac{n}{L}\right]$$

*3.3.2 Down sampling:* In down sampling the sampling rate is decreased by selecting every alternate  $M$  samples.

$$y[n] = x[Mn]$$