**Lab # 6 Linear convolution and Moving Averaging Filter**

**Objective:**

Understand and implement linear convolution and moving average filter

**Description**

**Linear Convolution**

* Convolution is a mathematical operation used to combine two signals, producing a third signal that represents how one signal modifies the other.
* For discrete signals, the linear convolution of two sequences
* X[n] and h[n] is defined as:

### **Step-by-Step Explanation of Convolution of x[n] with h[n]**

### Step 1: Define the Signals

* Let
* X[n] be the input signal of length N
* Let h[n] be the impulse response (or filter) of length
* M The output y[n] will have a length of N+M−1

Example:

x[n]=[1,2,3,4] length N=4

h[n]=[1,1,1] length M=3

### Step 2: Flip the Impulse Response

* Flip h[n] in time to get h[−n] .h[−n]. This is a key step in convolution.
* For h[n]=[1,1,1] the flipped version is h[−n]=[1,1,1] (since it is symmetric).

### Step 3: Slide the Flipped impulse response h[−n] over x[n]

### Slide the flipped impulse response h[−n] over the input signal x[n]. At each position n, multiply the overlapping samples of x[n] and h[−n] and sum the results.

### Step 4: Compute the Convolution at Each Step

For each position n, compute the sum of the products of overlapping samples

Detailed Calculation:

1. Position n=0

* Align h[−n] such that h[0] overlaps with x[0].
* Multiply and sum: y[0] = x[0]⋅h[0]=1⋅1=1

1. Position n=1:
   * Shift h[−n] by 1 sample to the right.
   * Multiply and sum: y[1]=x[0]⋅h[1]+x[1]⋅h[0]=1⋅1+2⋅1=1+2=3
2. Position n=2
   * + Shift h[−n] by 2 samples to the right.
     + Multiply and sum: y[2]=x[0]⋅h[2]+x[1]⋅h[1]+x[2]⋅h[0]=1⋅1+2⋅1+3⋅1=1+2+3=6
3. Position n=3
   * + Shift h[−n] by 3 samples to the right.
     + Multiply and sum y[3]=x[1]⋅h[2]+x[2]⋅h[1]+x[3]⋅h[0]=2⋅1+3⋅1+4⋅1=2+3+4=9
4. Position n=4
   * Shift h[−n] by 4 samples to the right.
   * Multiply and sum: y[4]=x[2]⋅h[2]+x[3]⋅h[1]=3⋅1+4⋅1=3+4=7
5. Position n=5
   * + Shift h[−n] by 5 samples to the right.
     + Multiply and sum: y[5]=x[3]⋅h[2]=4⋅1=4

### Step 5: Write the Convolution Result

The final convolved signal is y[n]=[1,3,6,9,7,4]

### **Moving Average Filter**

* A moving average filter is a simple low-pass filter used to smooth a signal by averaging a set of neighboring samples.
* The output of a moving average filter with window size M is given by

**Lab Task:**

1. Write a MATLAB function which takes two signals x[n] and h[n] as parameters and perform the convolution of the two signals.
2. Use MATLAB built-in function of convolution to perform the convolution of two same signals and compare the results with Lab Task # 01. The result of convolution should be same. MATLAB function for convolution is conv.
3. Generate a clean sinusoidal signal with a duration of 2 seconds and a sampling frequency of 1000 Hz. Then, create Gaussian noise with an amplitude of 0.5 and add it to the clean sinusoidal signal to produce a noisy signal
4. Create a MATLAB function to implement a moving average filter for the noisy signal generated in Task 2. Apply the moving average filter using different window sizes (e.g., 3, 5, 10) and compare the filtered signals. Analyze the trade-off between the level of smoothing achieved and the potential distortion of the original signal.