Experiment No. 6

Convolution of Discrete Time Signals

Objectives

This experiment is designed to familiarize the students with the basic concept of basic operations on systems with respect to discrete time signals. The main feature of the experiment includes:

1. Convolution of discrete-time signals

Equipment

1. PC
2. Installed MATLAB

Introduction to Convolution

Convolution is a mathematical tool to combining two signals to form a third signal. Therefore, in signals and systems, the convolution is very important because it relates the input signal and the impulse response of the system to produce the output signal from the system. In other words, the convolution is used to express the input and output relationship of an LTI system.

Discrete Time Convolution

Discrete time convolution is an operation on two discrete time signals defined by the expression:

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

For all x and h defined on $\mathbb{Z}$, it is important to note that the operation of convolution is commutative, meaning that:

$$x * h = h * x$$

Thus, the convolution operation could have been just as easily stated using the equivalent definition:

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

There are two basic principles that should be considered when commutating the convolution between two discrete-time signals $x[n]\ and\ h[n]$.

The Two Principles of Convolution:

1. Suppose that the length of vector x is N and the length of vector h is M. The outcome of the command $y = conv(x, h)$ is a vector y of length $M + N - 1$. In other words, $length(y) = length(x) + length(y) - 1$.

2. If the nonzero values of $x[n]$ are in the interval $[a_x, b_x]$ and the nonzero values of h[n] are in the interval $[a_h, b_h]$ then the nonzero values of the output $y[n]$ are in the interval $[a_x + a_h, b_x + b_h]$.

In this section, an example is designed in order to understand how to computing the convolution between two discrete-time signals by using $for\ loop$ and then comparing the result by using the command $conv$.

Activity-1: A discrete-time system is described by the impulse response:

$$\boldsymbol{h[n] = [-1, -2, 8, -2, -1\ ]}$$

Without using $conv$ command compute the response of the system to an input signal:

$$\boldsymbol{x[n] = sin\ (n)}$$

```
clear
close all
n = -10:0.5:10;
x = sin(n);
h = [-1 -2 8 -2 -1];
N = length(x);
M = length(h);
Ny = N + M -1;
y = zeros(1,Ny);
for i = 1:N
 for k = 1:M
 y(i+k-1) = y(i+k-1) + h(k)*x(i);
 end
end
n_y= 0: Ny-1;
% Input/Output Plot
subplot(221);stem(n,x,'linewidth',2);grid;
a = title('x(n)=sin(n)');set(a,'fontsize',14);
a = ylabel('y(n)');set(a,'Fontsize',14);
a = xlabel('n');set(a,'Fontsize',14);
subplot(222);stem(h,'linewidth',2,'color','m');grid;
a = title('h(n)=[-1 -2  8 -2 -1]');
set(a,'fontsize',14);
```

```
a = ylabel('y(n)');set(a,'Fontsize',14);

a = xlabel('n');set(a,'Fontsize',14);

subplot(223);stem(n_y,y,'linewidth',2,'color','b');grid;

a = title('Output without using "conv"
comamnd');set(a,'fontsize',14);

a = ylabel('y(n)');set(a,'Fontsize',14);

a = xlabel('n');set(a,'Fontsize',14);

% Using MATLAB built-in function (you get the same results)

y2 = conv(x,h);

subplot(224);stem(n_y,y2,'linewidth',2,'color','r');grid;

a = title('Output y(n) using "conv"
comamnd');set(a,'fontsize',14);

a = ylabel('y(n)');set(a,'Fontsize',14);

a = xlabel('n ');set(a,'Fontsize',14);
```

Activity-2: Using "*conv*" command, compute the response of a discrete-time system with user defined input $\boldsymbol{x}[\boldsymbol{n}]$ and impulse response $\boldsymbol{h}[\boldsymbol{n}]$.

```
clear

close all

x=input('Enter x:    ')

h=input('Enter h:    ')

N = length(x);

M = length(h);

Ny = N + M -1;

y = zeros(1,Ny);

for i = 1:N

 for k = 1:M

 y(i+k-1) = y(i+k-1) + h(k)*x(i);

 end

end

n_y= 0: Ny-1;
```

```
subplot(121);stem(n_y,y,'linewidth',2,'color','b');grid;

a = title('Output without using "conv"
comamnd');set(a,'fontsize',14);

a = ylabel('y(n)');set(a,'Fontsize',14);

a = xlabel('n');set(a,'Fontsize',14);

% Using MATLAB built-in function (you get the same results)

y2 = conv(x,h);

subplot(122);stem(n_y,y2,'linewidth',2,'color','r');grid;

a = title('Output y(n) using "conv"
comamnd');set(a,'fontsize',14);

a = ylabel('y(n)');set(a,'Fontsize',14);

a = xlabel('n ');set(a,'Fontsize',14);
```

Lab Tasks (Psychomotor)

1. A discrete-time system is described by the impulse response:

$$\boldsymbol{h[n] = [2 \quad 1 \quad 2 \quad 1]}$$

Without using "*conv*" command, compute the response of the system to the input signal given below and compare the results using "*conv*" command

$$\boldsymbol{x[n] = [1 \quad 2 \quad 3]}$$

2. A discrete-time system is described by the impulse response:

$$\boldsymbol{h[n] = [3 \quad 11 \quad 7 \quad 0 \quad -1 \quad 4 \quad 2]}$$

Without using "*conv*" command, compute the response of the system to the input signal given below and compare the results using "*conv*" command

$$\boldsymbol{x[n] = [2 \quad 3 \quad 0 \quad -5 \quad 2 \quad 1]}$$

Lab Tasks (Cognitive)

Q. No.	Cognitive Assessment Question	Marks
1	For x[n]=[1,2,3] and h[n]=[2,1,2,1], determine the first two samples of y[n] using the convolution-sum definition.	2
2	For the same sequences, determine the length of y[n] before calculating its individual samples.	2
3	Given x[n]=[1,2] and h[n]=[3,4], apply the convolution-sum definition to determine y[0], y[1], and y[2].	2
4	Explain why the length of the linear convolution of sequences of lengths N and M is N+M−1.	2
5	For the second sequence pair in the manual, explain what happens to the output length when the input and impulse-response sequence lengths are increased.	2

Lab Exercise and Summary

Summary should cover Introduction, Procedure, Data Analysis and Evaluation.

Student's Signature: _____ **Date: _____**

LABORATORY SKILLS ASSESSMENT (Cognitive)

Obtained Marks	/10

Instructor's Signature: _____ Date: _____

LABORATORY SKILLS ASSESSMENT (Psychomotor)

Psychomotor Activity 1 — Experimental Setup

S. No	Criteria	Performance	Description	Marks
1	**MATLAB & Sequence Setup (4)**	Level 4	Correctly prepares MATLAB and defines the assigned discrete-time input and impulse-response sequences.	4
		Level 3	Prepares MATLAB with minor errors or assistance.	3
		Level 2	Partially prepares the required environment and requires considerable assistance.	2
		Level 1	Shows limited ability to prepare MATLAB and requires substantial assistance.	1
2	**Manual Convolution File Setup (4)**	Level 4	Correctly organizes the script/nested loops for convolution without using the conv command.	4
		Level 3	Completes the file setup with minor errors or assistance.	3
		Level 2	Partially completes the file setup and requires considerable assistance.	2
		Level 1	File setup is largely incomplete and requires substantial assistance.	1
3	**Index & Sequence Parameters (2)**	Level 2	Correctly defines sequence indices, lengths and output length N+M-1.	2
		Level 1	Defines sequence indices, lengths and output length N+M-1 with minor errors or assistance.	1
Total Obtained				/10

If a student is absent:

Criteria	Description	Marks
Absent	Student is absent from the laboratory activity.	**0**

Psychomotor Activity 2 — Implementation + Results

S. No	Criteria	Performance	Description	Marks
1	**Discrete Convolution Implementation & Safe Working Practice (4)**	Level 4	Correctly implements the nested-loop discrete convolution without conv independently and follows proper laboratory practices.	**4**
		Level 3	Implements the assigned work with minor errors or assistance and generally follows proper laboratory practices.	**3**
		Level 2	Partially implements the assigned work and requires considerable assistance or repeated guidance.	**2**
		Level 1	Implementation is largely incomplete, requires substantial assistance, or shows poor adherence to proper laboratory practices.	**1**
2	**Execution & Comparison (2)**	Level 2	Correctly executes both the manual and MATLAB conv procedures.	**2**
		Level 1	Executes both the manual and MATLAB conv procedures with minor errors or assistance.	**1**
3	**Sequence Results & Verification (4)**	Level 4	Produces correct output sequences and verifies agreement using stem plots/comparison.	**4**
		Level 3	Produces mostly correct output sequences and verifies agreement using stem plots/comparison with minor errors or omissions.	**3**
		Level 2	Produces partially correct output sequences and verifies agreement using stem plots/comparison with noticeable errors or omissions.	**2**
		Level 1	Produces largely incomplete output sequences and verifies agreement using stem plots/comparison with noticeable errors or omissions.	**1**
	Total Obtained			/10

If a student is absent:

Criteria	Description	Marks
Absent	Student is absent from the laboratory activity.	**0**

Instructor's Signature: _____ **Date: _____**

LABORATORY SKILLS ASSESSMENT (Affective)

Affective Activity — Lab Report + Viva Voce

S. No	Criteria	Performance	Description	Marks
1	**Lab Report Completeness & Organization (4)**	Level 4	Report is complete, well-organized, properly presented, and demonstrates responsible completion of the assigned Signals and Systems laboratory work.	**4**
		Level 3	Report is complete with minor omissions or organizational issues and demonstrates satisfactory responsibility for the assigned work.	**3**
		Level 2	Report is partially complete with several omissions and demonstrates limited responsibility for the assigned work.	**2**
		Level 1	Report has major omissions or poor organization and demonstrates minimal responsibility for the assigned work.	**1**
2	**Code, Results & Conclusion (2)**	Level 2	MATLAB code, results/plots, and conclusion are correctly presented and discussed, demonstrating ownership of the assigned work.	**2**
		Level 1	MATLAB code, results/plots, or conclusion are presented with minor errors or omissions.	**1**
3	**Viva Voce (4)**	Level 4	Clearly explains the assigned MATLAB code, signal/system concepts, analysis, results, and plots, demonstrating individual responsibility, participation, and effective communication.	**4**
		Level 3	Explains most of the assigned work and results correctly, with minor difficulty, and demonstrates good individual participation.	**3**
		Level 2	Explains basic aspects of the assigned work with some prompting and demonstrates basic participation.	**2**
		Level 1	Demonstrates limited understanding or involvement and requires substantial prompting to explain the assigned work.	**1**
	Total Obtained			/10

The student has not submitted the report and has not appeared in the Viva Voce.

Criteria	Description	Marks
Lab Report and Results Not Submitted	Student has not submitted the report and results file.	**0**
Absent in Viva Voce	Student is absent from the viva voce.	**0**

Instructor's Signature: _____ **Date:** _____