Experiment No   : 03
Experiment Name: Auto-Correlation and Cross-Correlation in MATLAB

Objective:
The objective of this experiment is to know about Autocorrelation and Cross-Correlation

Theory:
Autocorrelation is a mathematical operation that measures the similarity between a signal and a time-delayed version of itself. It gives details on any periodicity or recurring patterns in a signal. Numerous applications, including audio processing, voice recognition, image processing, and communication systems, frequently use autocorrelation.

Mathematically, the autocorrelation function of a discrete-time signal x(n) is defined as:

$R_{xx}(m) = \Sigma [x(n) * x(n - m)]$

where $R_{xx}(m)$ represents the autocorrelation value at lag m, x(n) is the input signal.

The autocorrelation function has several properties that are useful in analyzing signals:

1. Symmetry: For real-valued signals, the autocorrelation function is symmetric, i.e., $R_{xx}(m) = R_{xx}(-m)$. This property indicates that positive and negative lags yield the same autocorrelation value.
2. Peak value: When the lag is zero ($R_{xx}(0)$), the autocorrelation function is at its highest value. The signal's energy or power is represented by this number.
3. Width of peaks: The length of the signal or the distance between repeating patterns can be determined from the breadth of the autocorrelation peaks. Wider peaks denote less periodicity, while narrower peaks signify a highly periodic signal.
4. Side lobes: On either side of the primary peak, the autocorrelation function may have side lobes or secondary peaks. These side lobes might reveal whether there are any competing signals or background noise.

Cross-correlation is a mathematical operation that measures the similarity between two signals as a function of the time lag between them. It is a helpful tool for looking for similarities, delays, or synchronization between various signals as well as other interactions between them. Applications for Cross-correlation include pattern identification, image processing, audio and speech processing, and communications.

Mathematically, the cross-correlation function is given by:

$Rxy(m) = \Sigma [x(n) * y(n - m)]$

where Rxy(m) represents the cross-correlation value at lag m, x(n) and y(n) are the two input signals, and the summation is performed over the appropriate range of n.

Some properties of the cross-correlation function include:

1. Symmetry: For real-valued signals, the cross-correlation function is symmetric, i.e., Rxy(m) = Ryx(-m). This property implies that the cross-correlation is unaffected by swapping the order of the signals.
2. Peak value: The cross-correlation function's maximum value (Rxy(m)) denotes the highest degree of alignment or similarity between the two signals. It displays the correlation's strength at the relevant time lag.
3. Lag interpretation: The time lag between the signals is shown by the lag at which the cross-correlation function peaks. Positive lags show a delay between y(n) and x(n), whereas negative lags show the opposite.
4. Cross-correlation coefficients: The cross-correlation function can be divided by the sum of the standard deviations of the two signals to produce normalized cross-correlation coefficients. The range of this normalization is -1 to 1, with values closer to 1 indicating a strong correlation and values closer to -1 indicating a strong correlation. Values close to 0 indicate no significant correlation.

Code: (Auto-correlation)

```
1. clc
2. clear all
3. %x = input('Enter x: ')
4. x=[1 2 3 4];
5. y = fliplr(x);
6. N1 = length(x);
7. N2 = length(y);
8. n = N1+N2-1
9.
10. R_man= zeros(1,n);
11.
12. for i=0: n
13.    for j=0: n
14.       if((i-j+1)>0 && (i-j+1)<=N2 && (j+1)<=N1)
15.          R_man(i+1)=R_man(i+1)+x(j+1)*y(i-j+1);
16.       end
17.    end
18. end
19.
20. R_man
21. R_fun = xcorr(x,x)
22.
23. subplot(3,1,1); stem(x); title('');
24. subplot(3,1,2); stem(R_man); title('R_{manual}');
25. subplot(3,1,3); stem(R_fun); title('R_{function}');
```

Output: (Auto-correlation)
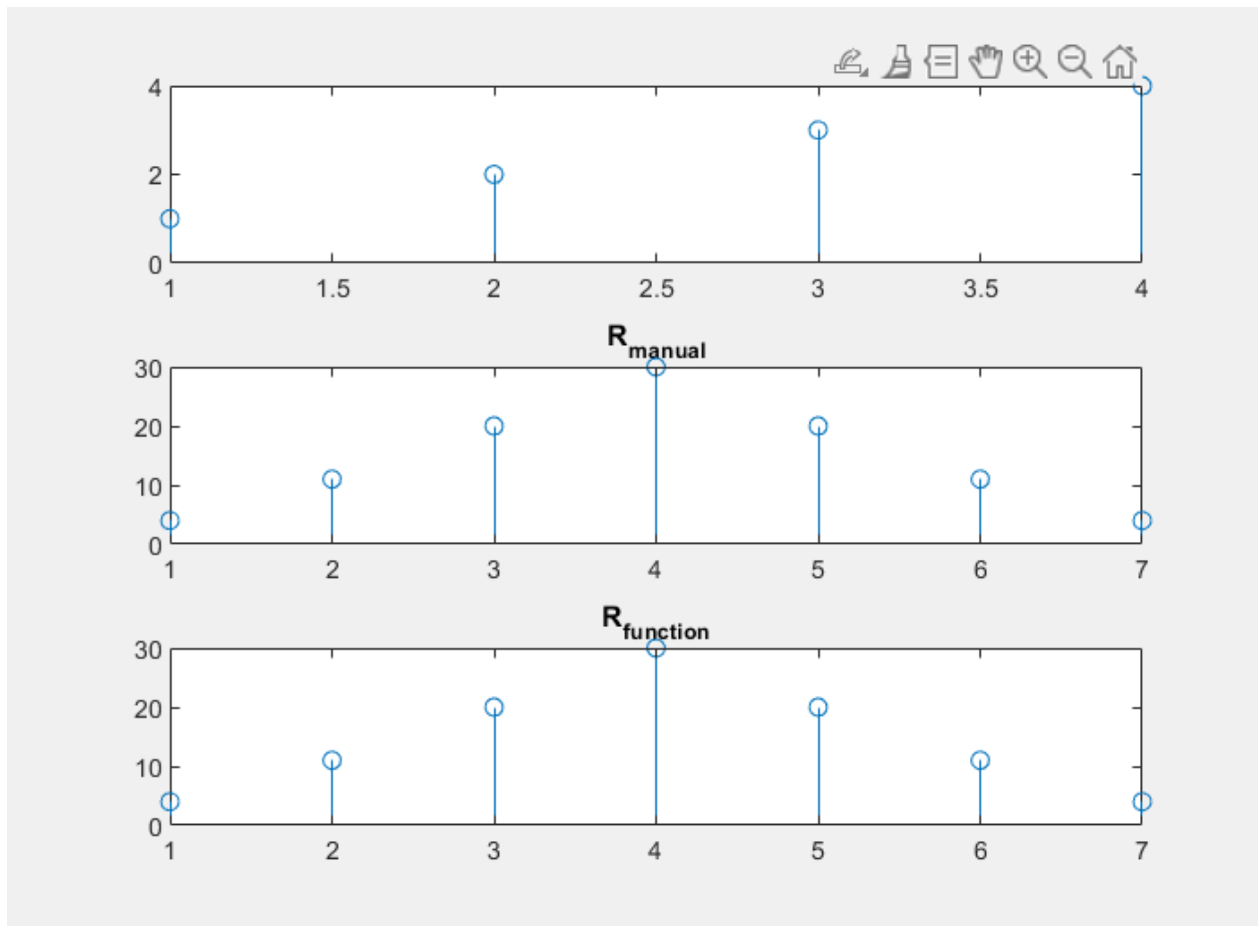
Code: (Cross-correlation)

```
1. clc
2. clear all
3. x = input('Enter x: ')
4. y = input('Enter y: ')
5. R_fun = xcorr(x,y);
6. y = fliplr(y);
7. N1 = length(x);
8. N2 = length(y);
9.
10. n = N1+N2-1;
11. R_man = zeros(1,n);
12.
13.  for i=0: n
14.    for j=0: n
15.      if((i-j+1)>0 && (i-j+1)<=N2 && (j+1)<=N1)
16.        R_man(i+1)=R_man(i+1)+x(j+1)*y(i-j+1);
17.    end
18.  end
19. end
```

20. %p=[1 2 3]
21. %p'
22. %p(1)
23. %p=fliplr(p)
24. %p(1)
25. R_man
26. R_fun
27. subplot(4,1,1); stem(x); title('X');
28. subplot(4,1,2); stem(y); title('Y');
29. subplot(4,1,3); stem(R_man); title('R_{manual}');
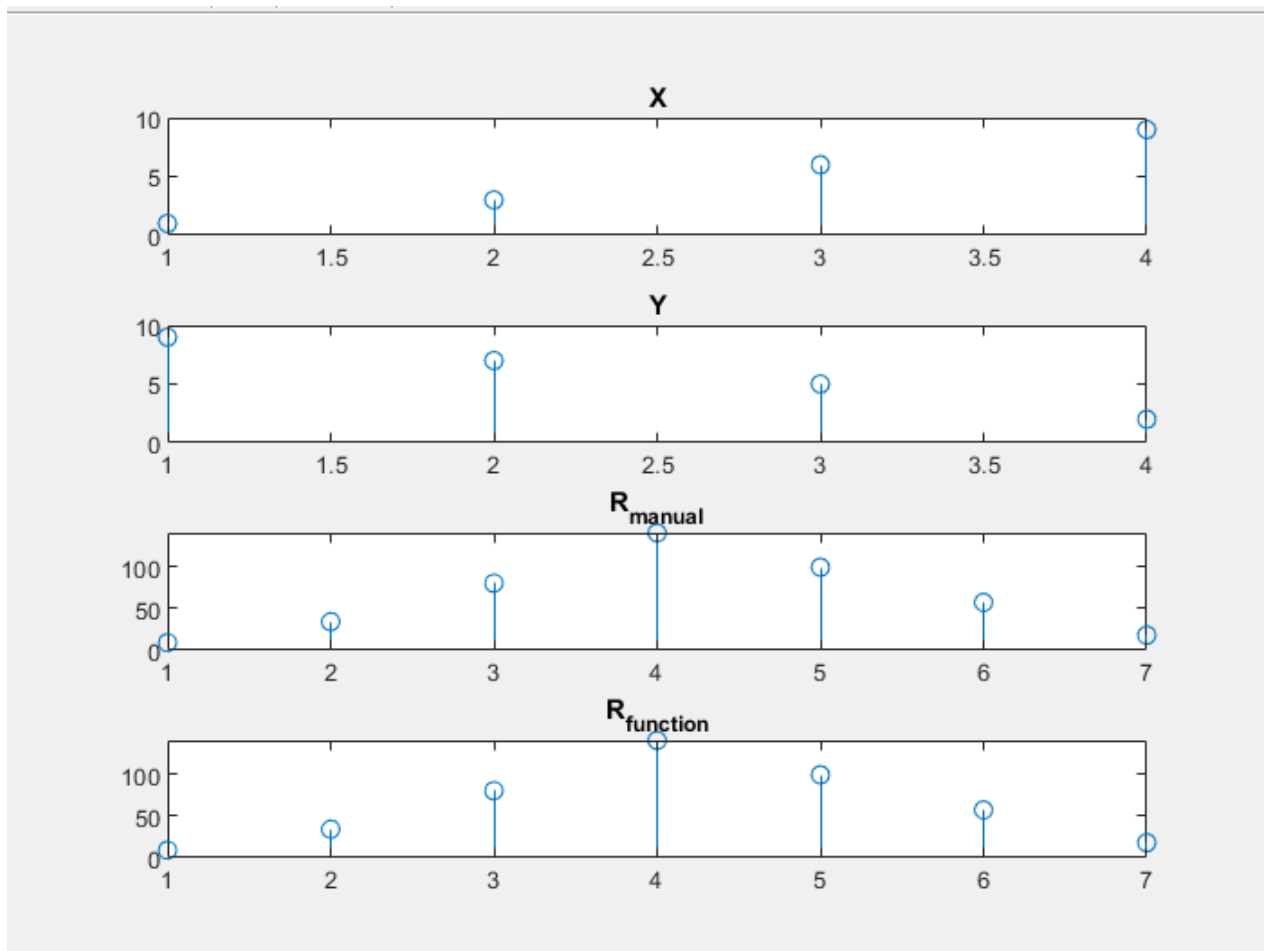30. subplot(4,1,4); stem(R_fun); title('R_{function}');

Input:

Enter X : [1 3 6 9]
Enter Y : [2 5 7 9]

Output: (Cross-correlation)

Conclusion:
In this experiment, Outcome of Correlation signal as it is as Theory. So, we can say that the experiment was done correctly.