NAME:	Anish Gade
UID:	2021700022
BRANCH:	T.Y. CSE Data Science
BATCH:	B
SUBJECT:	FOSIP
EXP. NO.:	2
DATE:	23/09/23

AIM: - To study mathematical operation Correlation and measure degree of similarity between two signals.

OBJECTIVES:

1. Write a function to find Correlation Operation
2. Write a function to find Correlation Operation

INPUT SPECIFICATIONS:

1. Length of first Signal L and signal values.
2. Length of second Signal M and signal values

PROBLEM DEFINITION:

1. Find auto correlation of input signal and find the significance of value of output signal at n=0.
   Let y[n] = x[n] O x[n]
   Classify the resultant signal (Even / Odd). Calculate the energy of the signal.
   Q. What is the significance of value of y [0]?
2. Find auto correlation of delayed input signal.
   Let p[n]= x[n-1] O x[n-1].
   Compare the resultant signal p[n] with y[n]. Give your conclusion.
3. Find cross correlation of input signal and delayed input signal
   q[n] = x[n] 0 x[n-1].
   Compare the resultant signal q[n] with p[n] and y[n]
   Give your conclusion.
4. Find cross correlation of input signal and
   scaled input signal.
   Let s[n] = x[n] O a x[n-2].
   Compare the resultant signals.
   Give your conclusion.
5. Authenticate the user by measuring the degree of similarity between stored audio Password and Test Audio Password

WRITE UP ON CORRELATION:

- **What is Correlation?**
  The correlation of two functions or signals or waveforms is defined as the measure of similarity between those signals.
- **Types of Correlations:**
  - **Cross Correlation:**
    - The cross-correlation between two different signals or functions or waveforms is defined as the measure of similarity or coherence between one signal and the time-delayed version of another signal. The cross-correlation between two different signals indicates the degree of relatedness between one signal and the time-delayed version of another signal.
    - The cross-correlation of energy (or aperiodic) signals and power (or periodic) signals is defined separately.

  - **Auto Correlation:**
    - The autocorrelation function is defined as the measure of similarity or coherence between a signal and its time delayed version. Therefore, the autocorrelation is the correlation of a signal with itself.
    - Like cross-correlation, autocorrelation is also defined separately for energy (or aperiodic) signals and power (periodic) signals.

The correlation of two real-valued and time-dependent signals $x(t)$ and $y(t)$ is defined as

$$r_{xy}(\tau) = \int_{-\infty}^{\infty} x(t) \cdot y(t-\tau) \mathrm{d}t$$

- **Applications of Correlation:**
  - **Signal Detection and Recognition:** Correlation is used to detect and recognize signals in noisy environments. Cross-correlation helps in finding similarities between a received signal and a reference signal, making it useful in applications like speech recognition, radar target detection, and wireless communication.
  - **Filtering and Equalization:** Auto-correlation and cross-correlation functions are used to design filters and equalizers. For instance, in adaptive filtering, the Wiener-Hopf equations involve cross-correlation to adapt filter coefficients and cancel interference or noise.
  - **Time-Delay Estimation:** Cross-correlation can be employed to estimate time delays between signals. This is valuable in various applications, such as time-of-arrival estimation in GPS, sonar, and echo-location systems.
  - **Spectral Analysis:** Auto-correlation is used in estimating power spectral density. The Fourier Transform of the auto-correlation function gives the power spectral density of a signal, which is useful in understanding the frequency content of a signal.
  - **Channel Estimation:** Cross-correlation can be used to estimate channel characteristics in wireless communication systems. By correlating transmitted and received signals, the channel's impulse response can be determined, aiding in equalization and error correction.
  - **Pattern Matching:** Cross-correlation is used in pattern matching applications. For instance, in image processing, template matching involves sliding a template over an image and computing cross-correlations to find the best match.
  - **Speech Processing:** In speech processing, auto-correlation functions are used to estimate pitch periods and speech formants, which are crucial for speech recognition and synthesis.

SOLUTIONS TO PROBLEM DEFINITIONS:
(The Codes for all problem Definitions have been uploaded to Moodle)

Problem Definition 1:

Input:

```
x[n] =  [3, 4, 5, 6]
```

Output:

1. y[n] = x[n] o x[n]

```
Y[n] =  [18 39 62 86 62 39 18]
```

2. Classify the Signal

```
Y[n] is even
```

3. Calculate Energy

```
Energy =  86
```

4. Significance of y [0]
   a. We can see that y [0] is 86 which is nothing but the energy of x[n]

Problem Definition 2:

Input:

```
x[n-1] =  [0 3 4 5 6]
```

Output:

1. p[n] = x[n-1] o x[n-1]

```
p[n] =  [ 0 18 39 62 86 62 39 18  0]
```

2. Compare p[n] and y[n]
   a. As we can see p[n] as one leading as well as trailing 0 we can also write it as [18 39 62 86 62 39 18] which is exactly y[n]. So, we can say that p[n] = y[n] i.e., the autocorrelations of delayed and original signal are the same.

Problem Definition 3:

Input:

```
Modify x to correlate with x[n-1] =  [3 4 5 6 0]
x[n-1] =  [0 3 4 5 6]
```

Output:

1. q[n] = x[n] o x[n-1]

```
The correlation of x[n] and x[n-1] i.e q[n]:  [18 39 62 86 62 39 18  0  0]
```

2. Compare p[n], y[n] and q[n]
   a. p[n] = y[n] as proved earlier and we can see here that q[n] is advanced by y[n] with 1 sample. So, q[n] = y[n+1] = p[n+1]

Problem Definition 4:

Input:

```
2*x[n-2] =  [ 0  0  6  8 10 12]
```

```
Modify x to correlate with x[n-2] =  [3 4 5 6 0 0]
```

Output:

1. s[n] = x[n] o a*x[n-2] where a = 2

```
The correlation of x[n] and 2*x[n-2] i.e s[n]:  [ 36  78 124 172 124  78  36   0   0   0   0]
```

2. Compare s[n] and y[n]
   a. s[n] = 2*y[n+2]

Problem Statement 5:

Output:

```
Correlation between original and matching password:  0.9999999999999476
```

```
Correlation between original and not matching password:  0.02041615759123469
```

CONCLUSIONS:

1. The auto-correlation of a signal and the auto-correlation of the same signal delayed are equal.
2. The cross correlation of a signal with its delayed signal is advanced than auto-correlation of that signal but equal.
3. Multiplying the amplitude of signal also multiples the correlation.
4. Correlation can be applied in voice recognition which I successfully applied in this experiment.