BIRZEIT UNIVERSITY

Faculty of Engineering and Technology
Electrical and Computer Engineering Department

Digital Signal Processing
ENCS4310
Task 1 & 2

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Task1: The Relationship Between Convolution & Correlation

Overview

Convolution

- Convolution is used to find the response of a system when an input signal is applied.
- Mathematically, the convolution of 2 signals (x[k] and h[k]) is represented as:

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

- In convolution, one of the signals is flipped before shifting it across the other signal. This flipping is essential for accurately modeling how an input signal interacts with a system's properties over time, and by flipping, we align the beginning of the impulse response with the current point in the input signal, ensuring that the earliest parts of the impulse response affect the input as we calculate the convolution.

Cross-Correlation

- Cross-correlation measures the similarity between two signals as one shifts over the other.
- The cross-correlation of 2 signals (x[n], y[n]) is given by:

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

- In correlation, no flipping is done. The signals are compared in their original orientations to find the best alignment, which is crucial for tasks like pattern matching or signal detection, as in the Alarm systems.

Output Meaning

Convolution

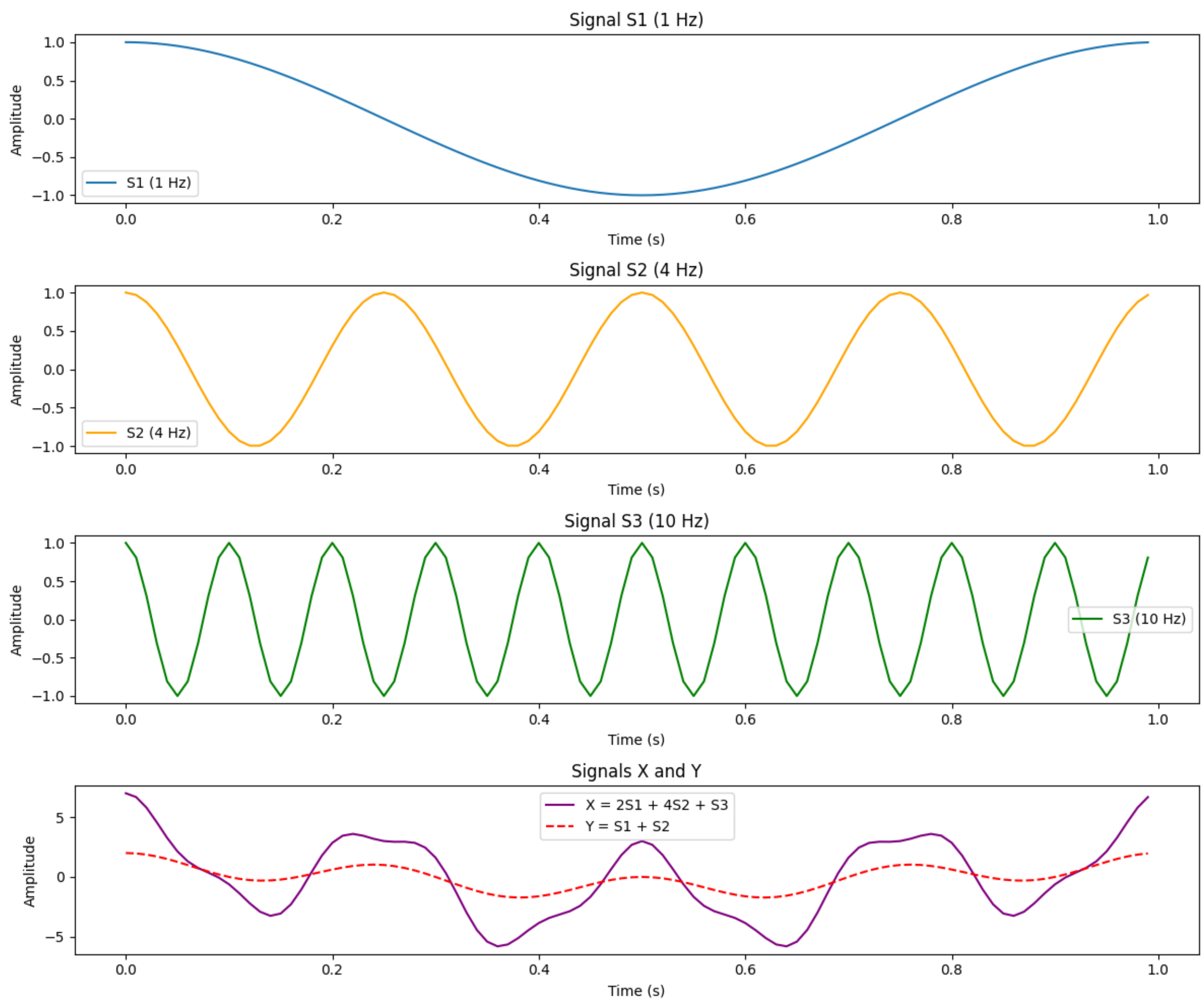
- In convolution, the output signal describes how the input signal is modified by the system, that means, the convolution output combines each point in the input signal with the system's impulse response and each sample in the resulting signal is a weighted sum that reflects how the system affects the input signal at that specific time.

Cross-correlation

- In cross-correlation, the output signal reflects the similarity between two signals at various time shifts, the maximum value in the cross-correlation result shows the shift where the signals are most similar, often referred to as the best match.
- If the cross-correlation has a high peak at k=0, it means the signals are most similar without any shift but, a high peak at k=10, for example, would mean the signals best align when one is shifted by 10 units relative to the other.

Task2: which is more beneficial to identify how strongly one signal is present in two different signals (Standard or Normalize) Correlation?

- The result by Calculating Zero-Lag Correlation



- Standard correlation of S1 in X: 99.99999999999997
- Standard correlation of S1 in Y: 50.00000000000001
- Normalized correlation of S1 in X: 0.43643578047198467
- Normalized correlation of S1 in Y: 0.7071067811865476

- The results show that normalized correlation works better than standard correlation for identifying how strongly one signal appears in another. Normalized correlation removes the effect of amplitude differences, giving a clearer and more reliable measure of similarity. This method shows that S1 is more strongly present in Y (with a similarity score of 0.71) than in X (similarity score of 0.44), demonstrating the practical advantage of normalized correlation for detecting signals within other signals. In addition, we saw that in the example provided in Task2 text.