“Heaven’s Light is Our Guide”

Rajshahi University of Engineering & Technology

Department of Computer Science & Engineering

Assignment

Course Code : CSE 3209

Course Title : Digital Signal Processing

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Introduction:

Electroencephalography (EEG) records electrical activity of the brain using electrodes placed on the scalp. The signal is rich in neural information, encompassing multiple frequency bands such as delta, theta, alpha, and beta waves. This assignment focuses on analyzing an EEG signal by applying the Discrete Fourier Transform (DFT) to identify and reconstruct brainwave activity in the frequency domain, especially targeting the alpha (8–12 Hz) and beta (13–30 Hz) bands.

Motivation:

EEG analysis is a cornerstone of modern neuroscience and neurology. It helps diagnose disorders such as epilepsy, sleep disorders, and brain injuries. By applying DFT, we can analyze the frequency composition of EEG signals, identify brain activity patterns, and potentially detect abnormalities. This motivated the use of DFT for understanding the underlying dynamics of EEG signals.

Background Study:

EEG signals are typically non-stationary and complex. In the time domain, they are hard to interpret due to overlapping frequencies. Transforming the signal to the frequency domain using DFT allows for easier interpretation of its constituent frequencies. Frequency-domain analysis helps isolate specific brainwave bands for further study.

Social and Economic Impact:

Improved EEG analysis enhances the accuracy of diagnosing neurological conditions, potentially reducing the burden on healthcare systems. It can aid in early detection of diseases, lower diagnostic costs, and open up possibilities in brain computer interfaces and mental health monitoring, contributing to societal well-being and economic growth.

Related Mathematical Studies:

The Discrete Fourier Transform (DFT) of a sequence:

$$X[k] = \sum_{n=0}^{N-1} x[n] \cdot e^{-j2\pi kn/N}$$

The Inverse DFT (IDFT) is given by:

$$x[n] = \frac{1}{N} \sum_{k=0}^{N-1} x[k] \cdot e^{j2\pi kn/N}$$

These transforms convert the signal between 5me and frequency domains, enabling the decomposi5on and reconstruc5on of signals based on frequency components.

Theory:

The DFT decomposes a discrete signal into its sinusoidal components. EEG signals contain various frequency bands corresponding to different cognitive or neurological states:

- **Alpha (8–12 Hz):** Relaxed, awake state
- **Beta (13–30 Hz):** Active thinking, attention
- **Theta/Delta:** Sleep or deep meditation

By analyzing these bands, we can isolate and study specific aspects of brain function.

Implementation:

Tools Used:

- **Python libraries:** pandas, numpy, matplotlib, scipy.fft

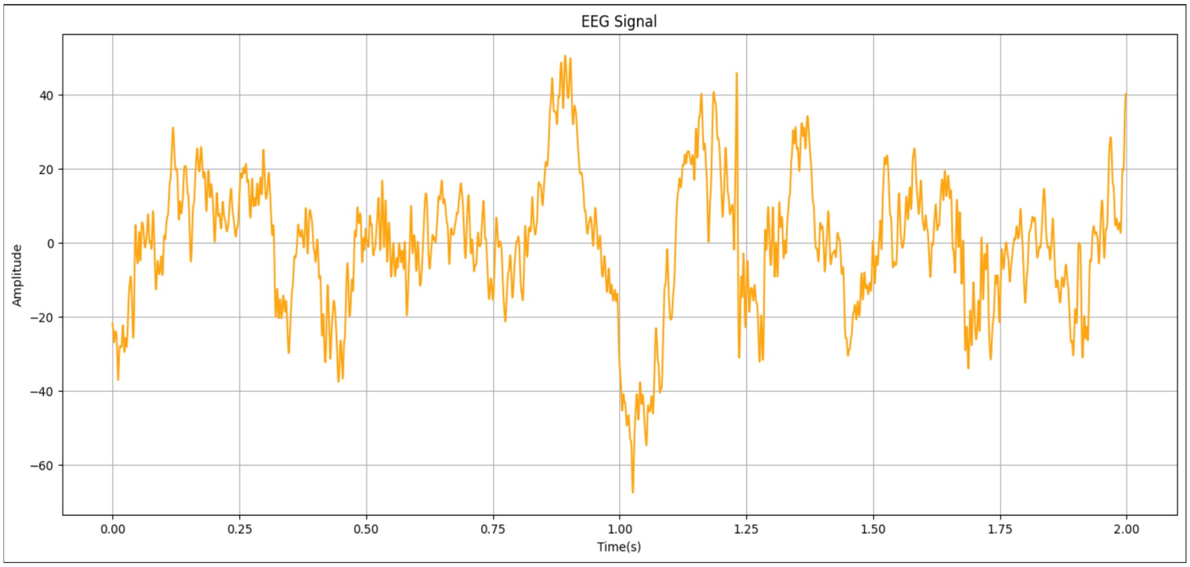
Steps:

1. Load EEG signal from a CSV file.
2. Visualize the signal in the time domain.
3. Compute the DFT using a custom DFT function.
4. Plot the frequency spectrum and identify alpha and beta ranges.
5. Apply a band-pass filter in the frequency domain to isolate alpha and beta components.
6. Reconstruct the filtered signal using the Inverse FFT.
7. Visualize the reconstructed signal.

Original EEG Signal Code Segment:

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from scipy.fft import fft, ifft, fftfreq

df = pd.read_csv("EEG.csv")
data = df.values

EEG = data[:4096] if data.ndim == 1 else data[:4096, 0]
sampling_rate = 2048  # sampling rate

# EEG Signal
time = np.arange(len(EEG)) / sampling_rate
plt.figure(figsize=(17, 7))
plt.plot(time, EEG,color='orange')
plt.title("EEG Signal")
plt.xlabel("Time(s)")
plt.ylabel("Amplitude")
plt.grid()
plt.show()

# DFT
def DFT(signal):
    N = len(signal)
    dft_result = np.zeros(N, dtype=complex)
    for k in range(N):
        for n in range(N):
            dft_result[k] += signal[n] * np.exp(-2j *
np.pi * k * n / N)
    return dft_result

# DFT Frequencies
def Frequencies(N, sampling_rate):
    return np.fft.fftfreq(N, d=1/sampling_rate)

# DFT values
values = DFT(EEG)
frequencies = Frequencies(len(EEG), sampling_rate
```

Original EEG Signal Output:

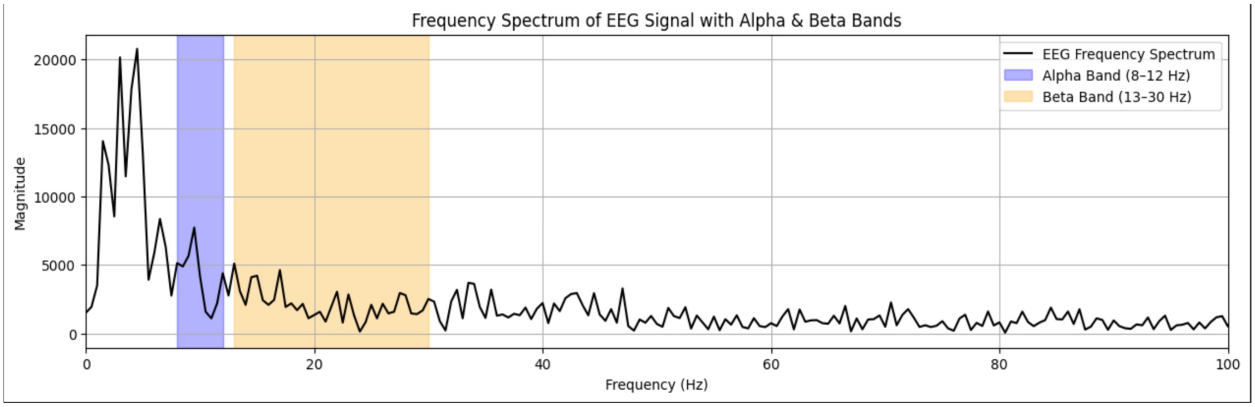


Frequency Spectrum Code Segment:

```
# Magnitude Spectrum
n = len(EEG)
magnitude = np.abs(values[:n // 2])
freqs = frequencies[:n // 2]

plt.figure(figsize=(15, 4))
plt.plot(freqs, magnitude, label="EEG Frequency
Spectrum", color='black')

# Alpha Wave (8-12 Hz)
plt.axvspan(8, 12, color='blue', alpha=0.3,
label='Alpha Band (8-12 Hz)')

# Beta Wave (13-30 Hz)
plt.axvspan(13, 30, color='orange', alpha=0.3,
label='Beta Band (13-30 Hz)')

plt.title("Frequency Spectrum of EEG Signal with Alpha
& Beta Bands")
plt.xlabel("Frequency (Hz)")
plt.ylabel("Magnitude")
plt.xlim(0, 100)
plt.grid()
```

```
plt.legend()
plt.show()
```

Frequency Spectrum Output:

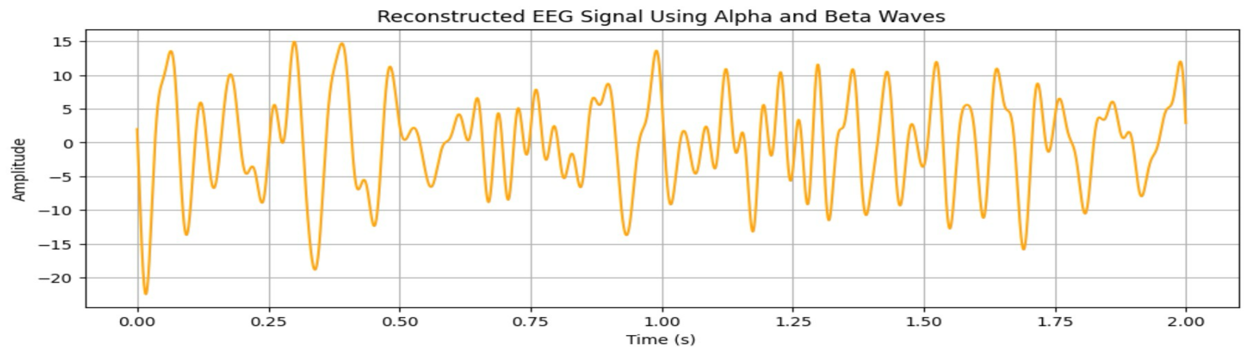


Reconstruction of EEG Signal Using Alpha, Beta Code:

```
# Band-Pass Filter
def band_filter(values, frequencies, f_low, f_high):
    fft = np.copy(values)
    for i in range(len(frequencies)):
        freq = abs(frequencies[i])
        if not (f_low <= freq <= f_high):
            fft[i] = 0
    return fft

alpha_fft = band_filter(values, frequencies, 8, 12)
alpha_signal = ifft(alpha_fft).real

beta_fft = band_filter(values, frequencies, 13, 30)
beta_signal = ifft(beta_fft).real

combined_fft = band_filter(values, frequencies, 8, 30)
reconstructed_signal = ifft(combined_fft).real

# Reconstruct the signal
plt.figure(figsize=(12, 4))
plt.plot(time, reconstructed_signal, color='orange')
plt.title("Reconstructed EEG Signal Using Alpha and
Beta Waves")
plt.xlabel("Time (s)")
```

```
plt.ylabel("Amplitude")
plt.grid()
plt.show()
```

Reconstruction of EEG Signal Using Alpha, Beta Output:



Results:

Original EEG Signal:

A plot of the EEG signal over time shows a fluctuating waveform typical of neural activity.

Frequency Spectrum:

The DFT reveals the presence of frequency components with noticeable magnitude peaks in the alpha and beta ranges.

Alpha & Beta Band Highlighting:

The bands are highlighted on the frequency spectrum plot for clear visualization.

Reconstructed EEG Signal:

- After filtering out the alpha and beta bands and reconstructing the signal:

- The new signal is smoother.
- It emphasizes oscillations relevant to the selected frequency bands.
- Demonstrates successful frequency isolation and signal reconstruction.

Conclusion:

This assignment successfully demonstrated the application of DFT to EEG signals. The process enabled:

- Frequency decomposition of complex EEG data.
- Isolation of brainwave bands (alpha and beta).
- Reconstruction of filtered signals for further analysis.

The project highlights how frequency-domain analysis is instrumental in interpreting biological signals and lays a foundation for advanced applications in neuroscience, medical diagnostics, and cognitive technology.