Decoding Life Signals Lab: EEG Signal Analysis

Overview

In this lab exercise, you will analyze EEG (Electroencephalogram) recordings from the instructor that contain different mental states and a hidden message encoded using eye blinks. You'll explore how different cognitive activities affect brain waves and learn to decode patterns from frontal and occipital electrodes.

Part 1: Loading the EEG Recording

Opening the Pre-recorded Data

1. Download the "EEG_sample recording.txt" file from the course website
2. Launch the OpenBCI GUI application
3. In the System Control Panel (left side of the screen), select "PLAYBACK (from file)" from the DATA SOURCE options
4. In the PLAYBACK FILE section, click the text field to browse and select the EEG file
5. Click "START SESSION" at the bottom of the System Control Panel to load the recording

Configuring the Display

1. After starting the session, focus on the three active EEG channels:
    - Channel 1: Fp1 (Left frontal pole - above left eyebrow)
    - Channel 2: Fp2 (Right frontal pole - above right eyebrow)
    - Channel 8: O1 (Left occipital - back of the head, left side)
2. In each widget, use the "Channels" dropdown to select only these three channels
3. Adjust the vertical scale to 100 μV initially
4. Set the time window to display 5 seconds at a time

Part 2: Understanding the Recording

Recording Structure

The EEG recording contains two main sections:

Section 1: Mental State Detection (approximately first 3 minutes)

The instructor alternated between three different cognitive states, each lasting about 1 minute:

1. Eyes closed relaxation
2. Mental arithmetic (solving multiplication problems)
3. Reading text

Section 2: Blink Morse Code (latter portion of recording)

The instructor blinked in a pattern that encodes a hidden word.

The Morse code pattern includes:

- Short blinks (dots) lasting about 0.5 seconds
- Long blinks (dashes) lasting about 1.5 seconds
- Pauses between each dot/dash (about 1 second)
- Longer pauses between letters (about 3-5 seconds)

Part 3: Analysis Using Different Widgets

1. Time Series Widget

- Look for distinct patterns in each channel during different mental states
- In Fp1 and Fp2 channels, identify eye blink artifacts (large positive deflections)
- In O1 channel, look for alpha rhythms (8-13 Hz waves) especially during eyes closed relaxation

2. FFT Plot

Configure the FFT Plot widget:

- Set Max Freq to 40 Hz
- Use Log scale for better visualization
- Adjust smoothing to 0.9
- Compare the frequency distributions between:
  - Different mental states (relaxation vs. arithmetic vs. reading)
  - Different electrode locations (frontal vs. occipital)
- Look for prominent frequency bands:
  - Delta (1-4 Hz)
  - Theta (4-8 Hz)
  - Alpha (8-13 Hz)
  - Beta (13-30 Hz)
  - Gamma (30-60 Hz)

3. Spectrogram

Configure the Spectrogram widget:

- Set Max Freq to 40 Hz
- Set Window to 3 Min to see transitions between activities
- Use Log scale
- Look for:
  - Changes in frequency patterns over time

    - Clear transitions between mental states
    - Alpha wave activity (8-13 Hz) during relaxation
    - Increased beta activity (13-30 Hz) during cognitive tasks

4. Band Power Widget

Add the Band Power widget:

- This widget separates brain activity into traditional EEG frequency bands
- Compare the relative power of each band across different mental states
- Pay particular attention to:
    - Alpha power during eyes closed relaxation (should be higher)
    - Beta power during mental arithmetic (should increase)
    - Theta power during different cognitive states

Part 4: Decoding Tasks

Mental State Analysis

1. Determine which segments of the recording correspond to each mental state:
    - Identify the timestamp ranges for relaxation, arithmetic, and reading
    - Note the characteristic patterns in each frequency band for each activity
2. Using the FFT plot and Band Power widget:
    - Compare the alpha/beta ratio during each mental state
    - Identify which frequency bands show the most significant differences between states

Morse Code Decoding

1. Locate the section of the recording containing blink patterns
2. In the Time Series Widget, focus on Fp1 or Fp2 channels
3. Identify short blinks (dots) and long blinks (dashes)
4. Note the pattern of dots and dashes, with spaces between letters
5. Use the Morse code reference to decode the message

Questions to Answer

EEG Pattern Analysis:

1. Which mental state showed the highest alpha wave activity? In which channel was this most prominent?
2. How did the beta wave activity differ between relaxation and mental arithmetic?
3. What changes did you observe in the theta band during different cognitive tasks?
4. How did the occipital (O1) channel activity differ from the frontal (Fp1/Fp2) channels?

Signal Characteristics:

1. What was the approximate frequency range of the most dominant activity during eyes-closed relaxation?
2. Did you observe any artifacts in the signal? How did they appear across different channels?
3. Which visualization (Time Series, FFT, Spectrogram, or Band Power) was most useful for identifying different mental states? Why?

Morse Code Challenge:

1. What is the hidden message encoded in the blink patterns?
2. How did you distinguish between short and long blinks in the EEG signal?
3. What challenges did you encounter when trying to decode the Morse code message?

Submission Guidelines

1. Document which segments of the recording corresponded to each mental state
2. Provide screenshots of the FFT, Spectrogram, and Band Power widgets during each mental state
3. Draw or describe the blink pattern you identified and your decoded message
4. Answer the questions based on your analysis
5. Summarize what you learned about how different mental activities affect brain wave patterns

Good luck with your EEG signal analysis!