EXG-based gesture classification

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Abstract - This study focused on classifying eye gestures using electroencephalography (EEG), electrooculography (EOG), and electromyography (EMG) data. Artifacts like noise and low-frequency drifts were removed using digital filters, and Short-Time Fourier Transform (STFT) was applied to differentiate between gestures such as horizontal (HEM) and vertical movements (VEM), eye blinks (EB), and closed-eye alpha activity (CE). The goal was to classify gestures based on their frequency characteristics, revealing an order of CE, HEM, EB, HEM, VEM, VEM, EMG, EB, CE, EMG. These results highlight the effectiveness of digital filters and STFT for improving gesture classification in EEG-based systems, with potential applications in brain-computer interfaces (BCIs).

I. INTRODUCTION

Alpha activity refers to brainwaves in the 8-13 Hz range, associated with relaxation and wakefulness. Their likely function is to enable the brain to filter out task-irrelevant information [1]. These waves are measured through EEG, which records electrical activity in the brain. Alpha waves increase when the eyes are closed due to reduced visual input, allowing the brain to shift from processing external stimuli to a more relaxed, internally focused state. This shift is accompanied by a decrease in beta activity and a rise in alpha waves, reflecting a restful and wakeful state.

II. METHODS

The experiment utilized the BCI2000 software in conjunction with an amplifier and electrodes to record EEG data from the subject. The subject wore an EEG cap with 4 electrode placements with channels 5-7 measuring EEG activity at O1, POz, and O2 and Cz was used as a reference electrode. Additionally, 4 electrodes were placed around the subject's eyes with channels 1-2 capturing horizontal eye movements (HEOG) and channels 3-4 recording vertical eye movements (VEOG). A ground electrode was placed on the ear lobe. Before data collection, we prepared the electrodes by applying gel and ensuring that the impedance between the scalp and electrodes was below 40k ohms. The sampling frequency was 256Hz. During the experiment, we measured alpha activity while the subject closed their eyes, which is known to increase alpha waves.

For signal processing, MATLAB was used to analyze the data. Each signal's mean was subtracted to remove DC offsets, and a notch filter was applied to eliminate 60 Hz noise. A high-pass filter set at 0.5 Hz was used to remove low-frequency artifacts. The data was then processed using the Short-Time Fourier Transform (STFT) with a 5-second window and 50% overlap. Power spectra derived from the STFT revealed key energy distributions, aiding in gesture characterization [2]. Eye movements and gestures were identified by their specific frequency characteristics: HEOG and VEOG (0.1-5 Hz), eye blinks (1-4 Hz), EMG noise (30-300 Hz), and closed-eye alpha activity (8-13 Hz) at O1, O2, and POz.

III. RESULTS

The order of gestures determined was CE, HEM, EB, HEM, VEM, VEM, EMG, EB, CE, EMG.

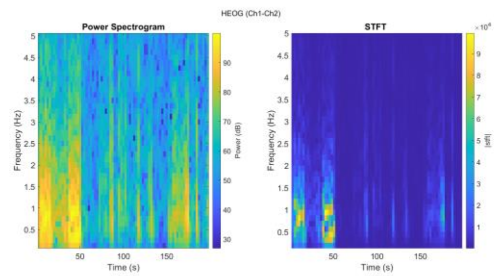

Figure 1 HEOG Power & STFT Spectrograms, .1-5Hz

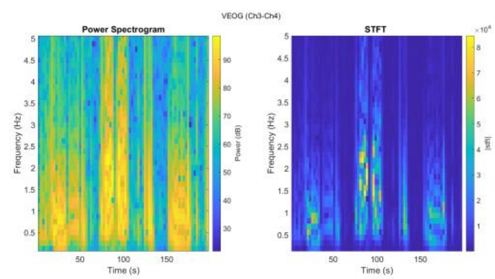

Figure 2 VEOG Power & STFT Spectrograms, .1-5Hz

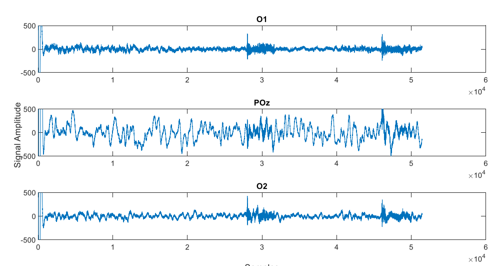

Figure 3 EEG Signals O1, POz, O2

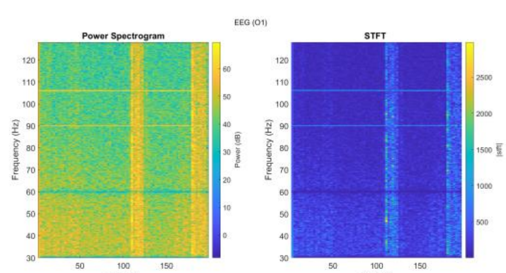

Figure 4 O1 Power & STFT Spectrograms, 30-300Hz

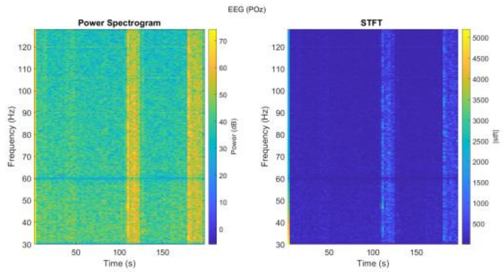

Figure 5 POz Power & STFT Spectrograms, 30-300Hz

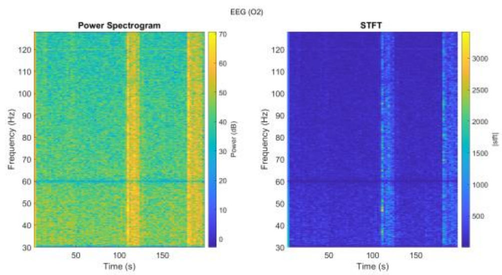

Figure 6 O2 Power & STFT Spectrograms, 30-300Hz

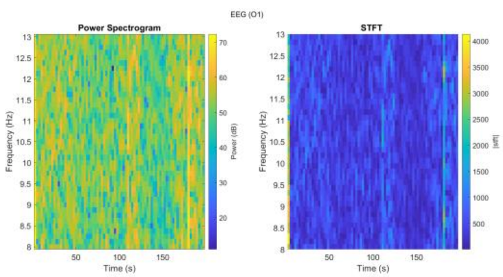

Figure 7 O1 Power & STFT Spectrograms, 8-13Hz

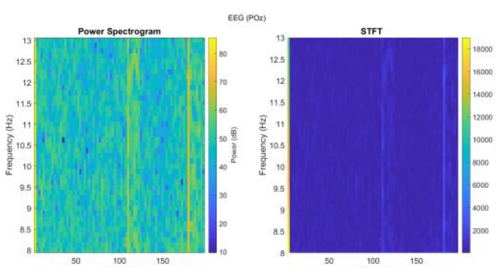

Figure 8 POz Power & STFT Spectrograms, 8-13Hz

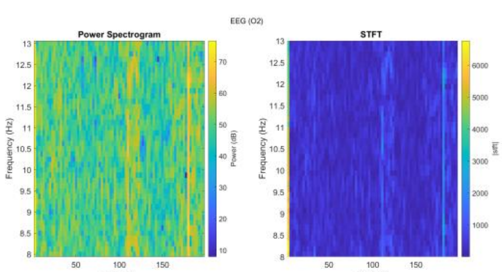

Figure 9 O2 Power & STFT Spectrograms, 8-13Hz

IV. DISCUSSION

HEOG: Fig. 1 reveals significant power in STFT during 0-20s and 35-50s, aligning with HEOG activity at low frequencies (0.1-5 Hz).

VEOG: Fig. 2 shows peak STFT power between 70-110s, marking periods of vertical eye movement, also within 0.1-5 Hz.

EB: STFT of HEOG and VEOG (Figs. 1 and 2) show significant power around 25s and 160s in 1-4Hz range, corresponding to eye blinks.

EMG: Fig. 3 shows high-frequency noise (30-300 Hz) peaks at 117s and 186s (30,000 and 47,500 samples), indicating EMG activity. Figs. 4-6 also reveal high power in the 30-300Hz range across all channels.

CE: Figs. 7-9 show notable power in the 8-13 Hz range at the start and around 180s, indicating alpha activity during closed eyes, with some overlap with EMG frequencies complicating distinct classifications.

The ability to classify eye movements and differentiate between alpha activity and EMG signals has potential for epilepsy research. Improved precision in EEG analysis can help distinguish seizure-related activity from normal brain rhythms and artifacts like EMG, enhancing the accuracy of seizure detection and patient monitoring. The use of machine learning techniques such as RNNs and BiLSTMs, which have shown promise in epilepsy studies, could further refine signal classification and improve diagnostic outcomes [3].

V. REFERENCES

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3. Abdel Samee N, Mahmoud NF, Aldhahri EA, Rafiq A, Muthanna MSA, Ahmad I. RNN and BiLSTM Fusion for Accurate Automatic Epileptic Seizure Diagnosis Using EEG Signals. PMCID: PMC9784456, PMID: 36556313.