Statistical Digital Signal Processing Midterm Assignment

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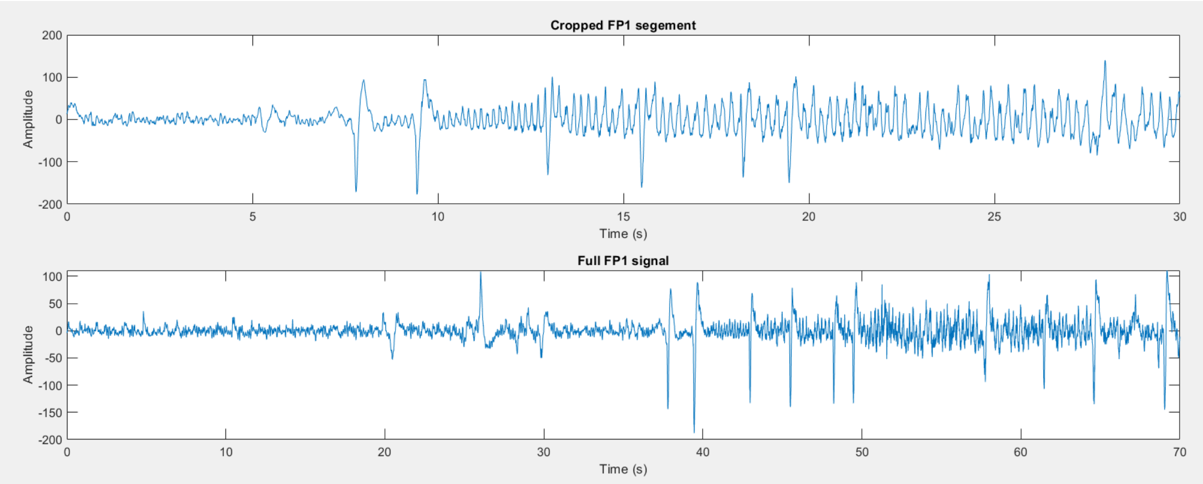
Introduction

The aim of this report is to understand how to model EEG signals especially for the case of epileptic seizure activity. To tackle the given tasks, a brief literature study was done to identify methods and challenges to do the same. The data set provided contains a segment of the electrical activity in channel FP1 in which the seizure starts. It is to be noted that the data is corrupted by eye blinks at particular time instances. So, to start the analysis the noise needs to be filtered out.



Tasks

1. Show that it is non stationary

Since EEG represents a sum of localised electrical activity of neurons in the brain it cannot be considered stationary in time since a human being performs different activities. It is visible just by looking at the signal and can also be proved by sectioning the signal and analysing its statistical characteristics. But if we section it using a very small window size, it can be shown that EEG is stationary a given person doing a particular activity.

2. Segment the signal

The choice of window size to segment can significantly impact the results and there is no one-size-fits-all protocol because the optimal window size depends on the specific goals of the analysis and the characteristics of the EEG data. Since the goal here is to detect epileptic seizures an appropriate window size must be selected that aligns with the duration of the start of the seizure attack. The International Federation of Clinical Neurophysiology (IFCN) Guidelines suggest a window size of 200-600ms to detect spikes, but a longer duration (1-2s) can be used to capture the context also.

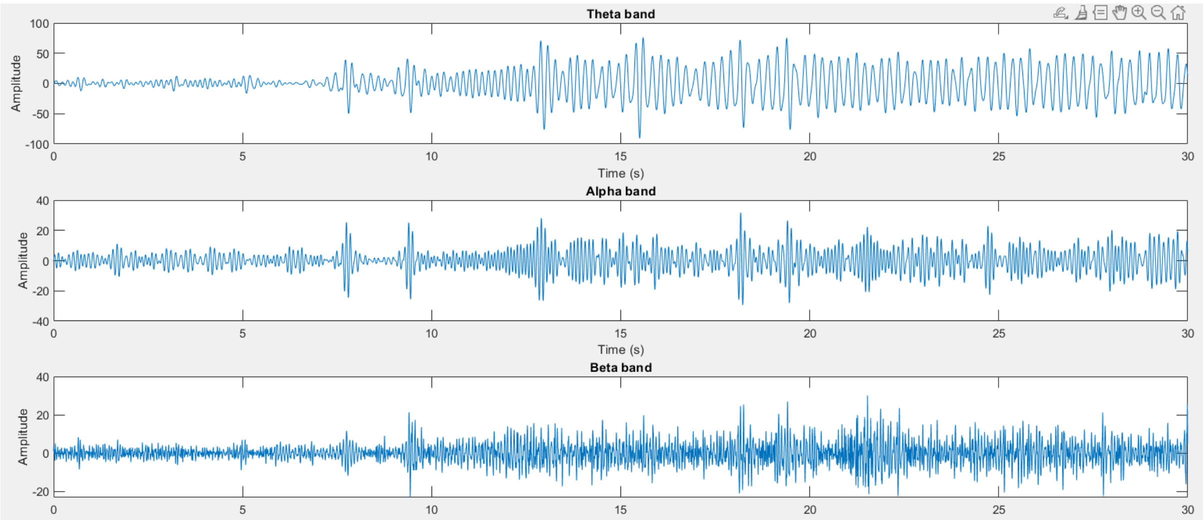
3. Model the signal

Modelling of EEG can be done in multiple ways but the choice depends on the usage and need. As suggested in [1], the two main types of modelling are time domain analysis and frequency domain analysis to characterize EEG signal properties. For this project a combination of time and frequency approach will be taken. By analysing the characteristics of the different frequency bands of the EEG signal (delta, theta, alpha, beta, and gamma) by using short time Fourier transform (STFT) like in [2] which uses the Fourier transforms of windowed sequences. To compute the STFT for a given input signal x_n and a fixed window w_m is given by:

$$STFT = X(m, \omega) = \sum_{n=-\infty}^{\infty} x(n)w(n-m)e^{-j\omega n}$$

4. Extract features that characterize the signal

For feature extraction, functions like the spectral power in each of the frequency bands can be used by summing the squared magnitudes of the STFT coefficients within each band. Other features like statistical features (e.g., mean, variance, skewness) of the STFT coefficients can be calculated across different frequency bands and time segments which can provide more insight about each windowed section. An example of the different frequency bands is given below.



5. **Where does the seizure start?**
   To determine where the seizure starts the parametric changes between each windowed section can be analysed. It is evident that the segment with seizure activity will have more energy than the normal activity segment. So, to detect the onset of the seizure the energy in the segment can be carefully analysed to predict it. The other statistical parameters can also provide additional information about the same.

Conclusion

During this project, all these tasks will be fulfilled and the EEG signal will be successfully modelled. If time permits, this can be done across all the 22 electrodes to add another spatial dimension into our features.

References:

1. T. N. Alotaiby, S. A. Alshebeili, T. Alshawi, I. Ahmad, and F. E. A. El-Samie, "EEG seizure detection and prediction algorithms: a survey," EURASIP Journal on Advances in Signal Processing, vol. 2014, no. 1, p. 183, 2014.
2. Wang Z, Mengoni P. "Seizure classification with selected frequency bands and EEG montages: a Natural Language Processing approach." Brain Inform. 2022 May 27;9(1):11.