Epileptic Seizure Detection Using EEG Signals

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***Abstract*—The detection of seizures, particularly elliptical seizures characterized by their complex and non-linear patterns, is crucial for effective diagnosis and treatment of neurological disorders such as epilepsy. Electroencephalography (EEG) signals provide valuable insights into brain activity, but their analysis requires sophisticated techniques due to their noisy and intricate nature. This paper explores the application of digital signal processing (DSP) concepts, including the Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT), and various filtering methods, for the detection of elliptical seizures using EEG signals. We discuss the theoretical foundations of these techniques and their practical implementation in preprocessing EEG data to enhance signal clarity and remove artifacts. By transforming EEG signals into the frequency domain and employing appropriate filters, subtle changes indicative of seizures can be discerned with greater accuracy. Our research aims to contribute to the development of reliable and efficient methods for seizure detection, ultimately improving the management and quality of life for individuals with epilepsy.**

***Index Terms*—Digital Signal Processing(DSP),**

I. Introduction

The detection and diagnosis of neurological disorders such as epilepsy present significant challenges in the medical field. Among these challenges, identifying seizures accurately and efficiently remains a crucial aspect for effective treatment and management. Electroencephalography (EEG) has emerged as a vital tool in this endeavor, offering real-time insights into brain activity through the measurement of electrical signals generated by neuronal activity. In particular, the detection of elliptical seizures, characterized by their non-linear and complex patterns, demands sophisticated analytical techniques.

This paper explores the application of digital signal processing (DSP) concepts in the detection of elliptical seizures using EEG signals. DSP techniques leverage mathematical algorithms to manipulate signals, enabling the extraction of meaningful information from noisy and complex data. Fundamental to this approach are concepts such as the Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT), and various filtering methods.

The DFT and its efficient variant, the FFT, play pivotal roles in analyzing EEG signals by transforming them from the time domain to the frequency domain. This transformation facilitates the identification of spectral components associated with different brain activities, including epileptic events. By decomposing the EEG signal into its frequency components, subtle changes indicative of seizures, especially in the higher frequency bands, can be discerned with greater clarity.

Furthermore, the application of various filters within the DSP framework is indispensable for preprocessing EEG data. Filters such as high-pass, low-pass, band-pass, and notch filters are utilized to remove noise, artifacts, and unwanted frequencies from the EEG recordings. These filters not only enhance the signal-to-noise ratio but also mitigate the interference that could obscure the detection of elliptical seizure patterns.

In this paper, we delve into the theoretical underpinnings of DFT, FFT, and filtering techniques, elucidating their significance in the context of elliptical seizure detection from EEG signals. Additionally, we discuss practical implementation strategies and challenges encountered in real-world applications. Through the integration of DSP methodologies, this research aims to contribute to the advancement of reliable and efficient techniques for diagnosing and managing epilepsy, ultimately improving the quality of life for individuals affected by this neurological disorder.

II. Literature Review

A survey of six papers have been made to get exact information of the procedure to be carried out. Many frequency response techniques have been used by researchers. [1] uses Discrete wavelet transform and LS-SVM methodology which has higher accuracy in classifying preictal and interictal EEG signals but its dependent on a particular dataset and the gaps in this paper include consideration of real-time applicability of the seizure prediction system. [2] includes Fast Fourier Transform (FFT) and Hilbert-Huang Transform (HHT) methodology and in this Detailed comparison of the performance of FFT and HHT and implementing the algorithm in real-world scenarios would be more complex and there are also limitations of implementing the algorithm in clinical settings. [3] has Discrete Wavelet Transform (DWT) and SMOTE and K-NN for classification methodology and has Addresses imbalanced data class distribution but further validation and testing on larger datasets will be difficult and there is Absence of a discussion on the resource requirements for practical implementation [4] uses Empirical Wavelet Transform based Hilbert Marginal Spectrum and RF classifier methodology which is Potential for Patient-Specific Detection and improved accuracy but is has Limited Experimental Validation and Lack of Clinical Application and the paper has a limited dataset. [5] includes MRBF-MPSO-based TVAR modeling scheme as its methodology and provides more accuracy than most of the papers' methodology referred in this paper but it can be improved for further analysis to achieve more accuracy. The paper does not explicitly address areas for future research. [6] has (tv-gPDC) method Hjorth parameter as its methodology and it has efficient artifact handling, improvement of signal-to-noise ratio but computing the Gabor transform is an intensive task and it can be found that there is a need for improvement in artifact removal through the hybridization of transform.

III. Methodology

The steps used to reach to get the final results are listed below in the subtopics. The different phases of this project are data collection, data analysis, applying DFT and FFT to EEG signals, data selection and filter selection. This is further represented in the below flow diagram in Fig.1

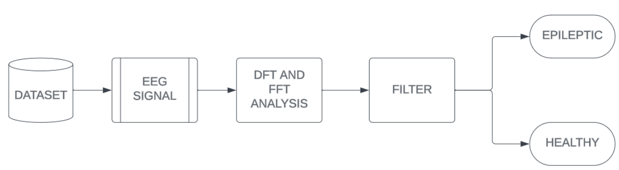

Fig. 1. Flow Chart of project

A. Data collection

The EEG dataset are widely available on various platforms related to the bio-medical signal processing, the data used in this case is the UKB EEG dataset, it consists of five sets (donated A-E) where each set consists of 100 single channel EEG segments of duration 23.6sec. The sampling rate of the dataset is 173.61Hz.

B. Data analysis

The data analysis involves understanding the data, processing the data, converting the data, if necessary, format where the necessary features can be understood and extracted. In this case the methodology consists of the following steps:

- Initially, the EEG signals will be in time domain, so Discrete Fourier Transform was applied to the EEG signals in order to convert them to frequency domain and further analyse the frequency components of the EEG signals and also tells us about the various activities of the brain. When the DFT coefficients are squared, the power spectral density can be obtained, which precisely represents power distribution across the various frequencies, through which the identification of the frequency bands associated with various neurological disorders can be done. Despite these merits DFT has limited time resolution i.e., there is not much sufficient time to capture and analyse the rapid changes of the EEG signals and also the computational time of the DFT is a bit more than the FFT. So, in the next step the FFT analysis os the EEG signals is done. The formulae for the DFT is described below with the equation in Eq. (1)

$$X[k] = \sum x(n)e^{-j2\pi kn/N} \tag{1}$$

- FFT is basically a faster algorithm to compute the DFT of any signal, so applying FFT to an EEG signal mainly reduces the computational time enabling wide range of analyses of the EEG signals. Apart from the power spectral density applying FFT to the EEG signals can help identify the domnamt frequency bands associated with the EEG signals delta (0.5-4 Hz), theta (4-8 Hz), alpha (8-13 Hz), beta (13-30 Hz), and gamma (more than30 Hz) waves and also compute the peak frequencies.The original signal in time domain of the epileptic signal is in Fig.2. The Matplot FFT of epileptic signal is shown in Fig.3. FFT is effective in identifying sharp, spike waves

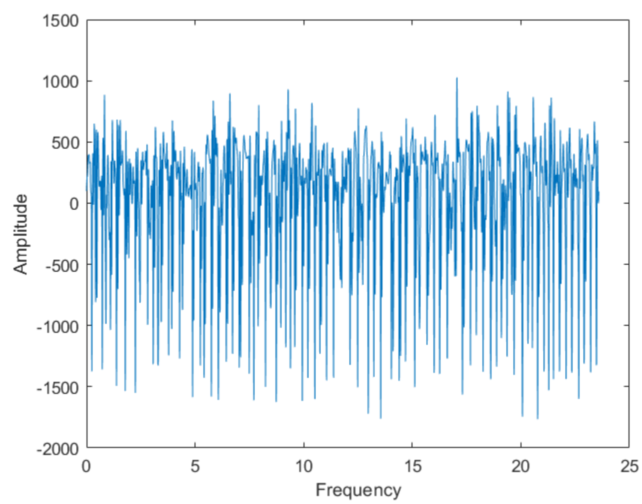

Fig. 2. Time series of EEG signal

and the abnormal patterns associated with the epilepsy disorder. Apart from identify the componets related to the disorder, FFT analysis is also helpful in monitoring the treatment response i.e., the changes before and after treatment can be precisely identified. Constantly monitoring the changes in the power and frequency distribution is helpful for efficient treatment of the Epilepsy disorders.

C. Filter Selection

The relevant data required for the epileptic seizure prediction can be obtained by applying the IIR (Infinite Impulse Response) and FIR (Finite Impulse Response) filters to the

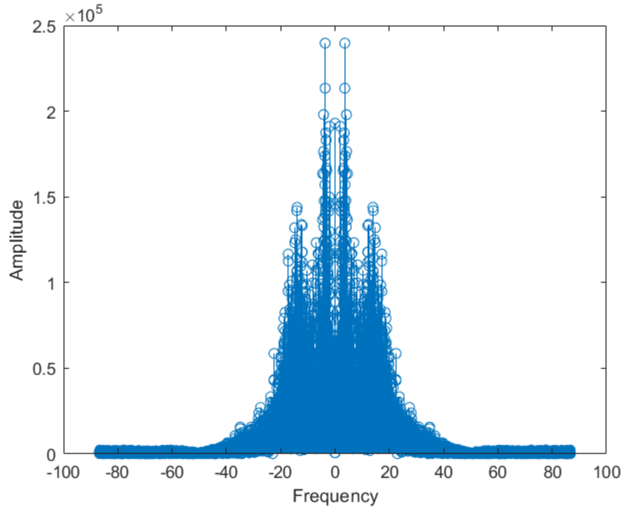

Fig. 3. FFT of EEG signal

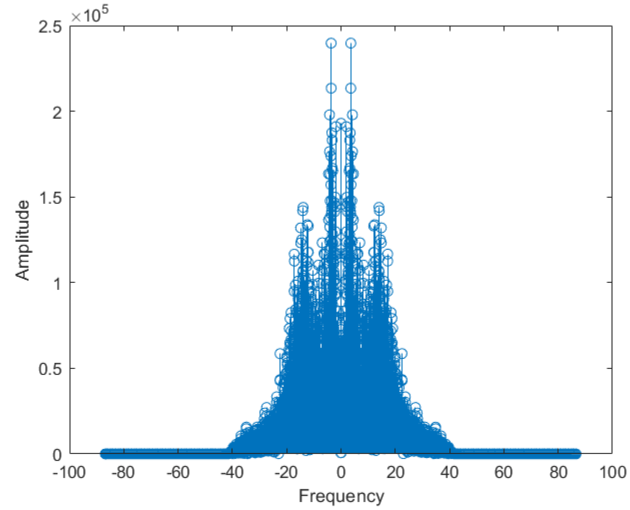

Fig. 4. Filtered of EEG signal

EEG signals. Each of these filters have their own merits and demerits. For EEG signals, to detect epileptic seizures we neeed to consider frequency range of 0-40Hz. Since the dataset contains EEG signals with frequency range 0-85Hz we need to filter it out using Low Pass filter of cutoff frequency 40Hz. We have used multiple filters to compare and find the appropriate filter for our case. The FIR windows used in our case are Hamming, Hanning, Rectangular, Triangular, Blackmann and the IIR filters used are Butterworth and Chebyshev. All the filters were tested with their appropriate orders and on comparison the best results were [provided the hamming window. The order of the hamming window is 100. The main purpose of using the filters and the obtained output are the EEG signals with a frequency range between 0-40Hz. The equation of the considered filter window i.e., Hamming window is given below in Eq. (2)

$$\omega(n) = 0.54 - 046 \times cos(2\pi n)/(N-1) \qquad (2)$$

Fig.4 shows the filtered output of EEG signal within the range of 0-40Hz neglecting the 50Hz electrical signal and the noise beyond 40Hz.

IV. Results

After designing the hamming window for the EEG signals among the 7 filters, we were successful in predicting the epileptic seizures and differentiate the subjects as healthy and epileptic. Many test cases were used to check the accuracy from the testing data. For comparison Matlab plots were used. Usually from basic view the healthy signals had less spikes or sharp edges than the epileptic seizure signals. The fast Fourier transform was used to realize the frequency domain of the signals, as to check whether the signals was filtered up to 40Hz. The comparison is direct where the epileptic and healthy graphs are plotted in the same plot. The comparison is plotted for both time series and frequency domain. The time domain representation of the signal is shown in Fig.5.

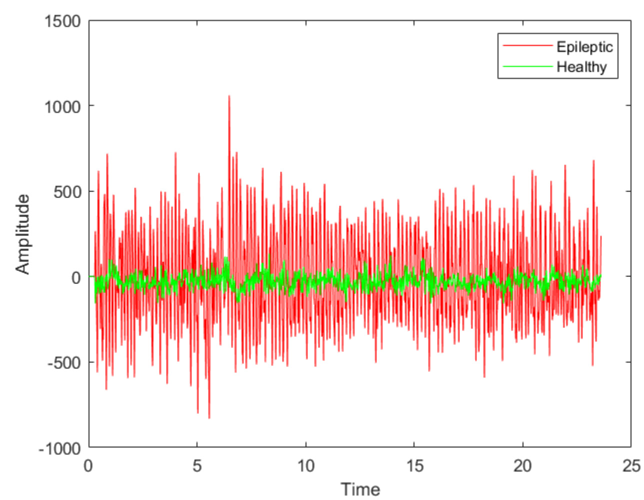

Fig. 5. Comparison of Time series signals

The frequency domain representation of the signal in shown in Fig.6.

V. Conclusion

In conclusion, our investigation into elliptical seizure detection using EEG signals and digital signal processing techniques, including DFT, FFT, and various filters, has led us to employ a low-pass filter with a FIR Hamming window technique. With a cutoff frequency of 40Hz, this filter effectively isolates EEG signals necessary for distinguishing between healthy individuals and those experiencing elliptical seizures. By refining our approach, we aim to enhance the accuracy and efficiency of seizure detection, offering promising avenues for improved diagnosis and treatment of neurological disorders such as epilepsy

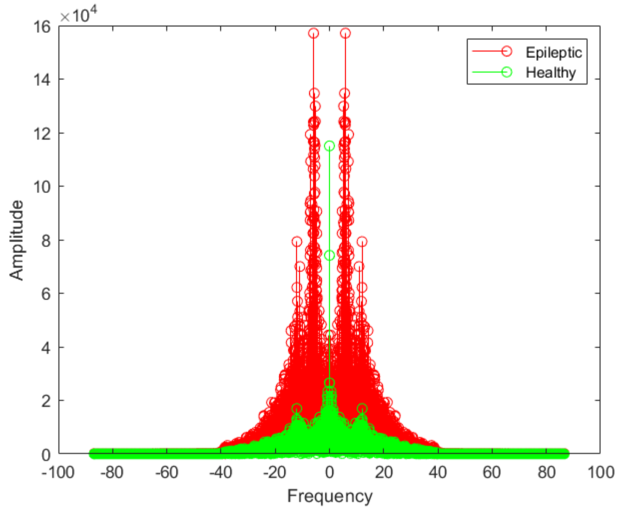

Fig. 6. Comparison of Frequency domain signals

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REFERENCES

[1] M. Z. Parvez and M. Paul, "EEG signal classification using frequency band analysis towards epileptic seizure prediction," 16th Int'l Conf. Computer and Information Technology, Khulna, Bangladesh, 2014, pp. 126-130, doi: 10.1109/ICCITechn.2014.6997315.

[2] Y. Li, Y. -L. Hsin and W. Liu, "Comparison study of seizure detection using stationary and nonstationary methods," 2014 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Chicago, IL, USA, 2014, pp. 3272-3275, doi: 10.1109/EMBC.2014.6944321.

[3] D. Romaissa, M. E. Habib and M. A. Chikh, "Epileptic Seizure Detection from Imbalanced EEG signal," 2019 International Conference on Advanced Electrical Engineering (ICAEE), Algiers, Algeria, 2019, pp. 1-6, doi: 10.1109/ICAEE47123.2019.9015113.

[4] A. Bhattacharyya, V. Gupta and R. B. Pachori, "Automated identification of epileptic seizure EEG signals using empirical wavelet transform based Hilbert marginal spectrum," 2017 22nd International Conference on Digital Signal Processing (DSP), London, UK, 2017, pp. 1-5, doi: 10.1109/ICDSP.2017.8096122.

[5] Li Y, Wang XD, Luo ML, Li K, Yang XF, Guo Q. Epileptic Seizure Classification of EEGs Using Time-Frequency Analysis Based Multiscale Radial Basis Functions. IEEE J Biomed Health Inform. 2018 Mar;22(2):386-397. doi: 10.1109/JBHI.2017.2654479. Epub 2017 Mar 10. PMID: 28362595.

[6] V. K. Harpale and V. K. Bairagi, "Time and frequency domain analysis of EEG signals for seizure detection: A review," 2016 International Conference on Microelectronics, Computing and Communications (MicroCom), Durgapur, India, 2016, pp. 1-6, doi: 10.1109/MicroCom.2016.7522581.