Journal of Advanced Research in Applied Sciences and Engineering Technology

SEMARAK ILMU PUBLISHING

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

Automated Seizure Detection in Neonatal EEG using Signal Processing Algorithms

Sandhyakumari Golla[1,*], Maloji Suman[1]

[1] Department of Electronics and communication Engineering, Koneru Lakshmaiah Education Foundation, Vijayawada, Andhra Pradesh, India

ARTICLE INFO

Article history:
Received 2 May 2023
Received in revised form 25 July 2023
Accepted 30 July 2023
Available online 15 August 2023

Keywords:
EEG; EDFBROWSER; EEG STUDIO; EOG; EKG; EMG; Machine learning

ABSTRACT

The crucial challenge of identifying seizures in newborn electroencephalogram (EEG) data is the subject of this research. (ElectroEncephaloGram) EEG analysis has traditionally been labor-intensive and subjective due to the heavy reliance on human inspection by skilled electrophysiologists and neurologists. The authors suggest a novel online automatic detection approach to get over these restrictions. This approach intends to open the door for effective and reliable early seizure detection, delivering a potential development in neonatal care and neurological research. It does this by utilising the capabilities of signal processing and brain-inspired modelling. The suggested machine-learning method makes effective use of real-time EEG signal processing methods. Its processing of incoming EEG data streams makes it appropriate for neonates to be closely tracked in critical care situations. Automation of the detection method minimises the need for manual inspection by highly specialised experts, allowing for more rapid responses and possibly increasing seizure management's overall results.Using metal electrodes, the electroencephalogram (EEG) analyses the electrical activity of the brain. European Data Format (EDF) BROWSER and EEG STUDIO are used to analyse EEG signals. Root Mean Square (RMS) and signal samples are performed by EDF BROWSER, as well as mean, frequency, and frequency from filtered output using a band-pass filter. The standard deviation and average frequency are examined by EEG STUDIO. Spike detection, frequency domain analysis, and nonlinear techniques are used in seizure prediction. EOG, EKG, and EMG artifacts produced by the eyes, the heart, and the muscles, respectively may be present in EEG readings.

1. Introduction

A neurological condition called epilepsy is characterised by unpredictably frequent episodes. Although it affects people of all ages, it is more widespread in small children and the elderly. It is one of the most prevalent neurological disorders. The hallmark of this disorder are epileptic seizures, which can take many different forms, from brief periods of loss of awareness to convulsions involving uncontrollable movements. Epilepsy, which is brought on by aberrant electrical activity in the brain, can significantly affect a person's quality of life, daily activities, and social interactions [1]. Epilepsy

*Corresponding author.
E-mail address: sandhyakumarigolla@gmail.com

https://doi.org/10.37934/araset.31.3.220227

has a wide range of underlying causes, including genetics, head trauma, infections, developmental problems, and structural abnormalities in the brain. Usually, epilepsy is diagnosed after a person has had two or more unprovoked seizures.

Numerous diagnostic procedures, such as electroencephalogram (EEG), brain imaging (MRI or CT scan), and clinical evaluations are carried out to confirm the diagnosis and choose the best course of treatment. Antiepileptic drugs are frequently used as part of epilepsy treatment to curb and lessen the frequency of seizures [2]. If the seizures are uncontrollable by medicine and have a precise focal location in the brain that may be safely removed, surgery may in some situations be an option. Living with epilepsy involves careful management and support, which includes following drug regimens, making lifestyle changes, and creating seizure response strategies [3]. Many people with epilepsy can have full lives and effectively manage their illness with the right medical care and assistance.

Epilepsy in infants presents unique challenges due to their rapidly developing brains and limited ability to communicate symptoms. Seizures in infants can be caused by a wide range of factors, including genetic conditions, brain malformations, birth injuries, metabolic disorders, infections, or other neurological abnormalities. Detecting epilepsy in infants can be particularly challenging because seizures may not always exhibit the classic convulsive movements seen in older children and adults. Instead, seizures in infants can manifest as subtle changes in behavior, altered responsiveness, repetitive movements, or even just brief staring spells. These atypical seizure presentations can be easily overlooked or misinterpreted as normal infant behavior, delaying the diagnosis and treatment.

Early diagnosis is critical, as prompt intervention can lead to better outcomes and minimize the potential impact of seizures on the developing brain. Pediatricians and parents play a crucial role in identifying possible seizure activity in infants [4]. If there are any concerns about unusual behaviors or suspected seizures, it is essential to seek medical evaluation promptly. Diagnosing epilepsy in infants often involves a combination of diagnostic tests. An electroencephalogram (EEG) is a valuable tool used to record and analyze the brain's electrical activity. It can help identify abnormal patterns indicative of seizures, even when there are no visible external signs. Brain imaging studies, such as magnetic resonance imaging (MRI) and computed tomography (CT) scans, may also be performed to assess the structure of the brain and identify any underlying causes.

Once a diagnosis of epilepsy is confirmed, the focus shifts to managing the condition effectively. Treatment options for infants with epilepsy may include antiepileptic medications, which must be carefully chosen based on the infant's age, weight, and specific seizure type. The medication's dosage needs to be closely monitored and adjusted as the infant grows to maintain optimal control of seizures. Living with epilepsy in infants can be emotionally challenging for parents and caregivers. It requires constant vigilance to recognize and respond appropriately to seizure activity. Parents may also need to learn how to perform rescue treatments in case of prolonged or severe seizures.

Early intervention services, such as physical therapy, occupational therapy, and speech therapy, may be beneficial for infants with epilepsy, particularly if there are developmental delays or concerns. These services can help support the infant's overall development and improve their quality of life [5]. Research and advancements in understanding and treating epilepsy in infants are ongoing, aiming to provide better outcomes and improved care. Support networks and resources for parents and caregivers are essential to help navigate the complexities of managing epilepsy in infants and ensure that they receive the best possible care and support for their unique needs.

2. Literature Survey

The literature on EEG studies focusing on infants covers a diverse array of research topics, each contributing valuable insights into the understanding of early brain development and neurological conditions. Neonatal EEG monitoring has emerged as a critical tool for assessing brain activity in premature infants and newborns, enabling the detection of potential abnormalities and the identification of early signs of neurological disorders. Researchers have explored the development of algorithms and methods for seizure detection and prediction in neonatal EEG recordings, tackling the challenges posed by the immature brain's complex patterns. Moreover, studies investigating brain maturation in infants shed light on the evolving neural networks and their role in cognitive processes.

Examining newborn sleep patterns and their consequences on neurological outcomes, as well as understanding the impacts of preterm and brain injuries on infant brain activity, have been major areas of focus. The neurological underpinnings of memory formation and language acquisition have been revealed by using EEG to study cognitive and language development in babies. Researchers have used EEG to find potential biomarkers and diagnostic aids for illnesses including autism spectrum disorder and attention deficit hyperactivity disorder in the context of neurodevelopmental disorders. Additionally, research on brain-computer interfaces for babies with motor deficits has showed promise, opening up new channels for interaction and communication.

As researchers delve into the effects of environmental factors and technological advancements in EEG, the literature continues to grow, revealing novel findings and offering prospects for improved clinical applications. Literature surveys play a crucial role in synthesizing the collective knowledge, providing a comprehensive overview of existing research, and paving the way for future investigations that will further enrich our understanding of the developing infant brain and its complexities. Ultimately, these studies contribute to enhancing early diagnosis, treatment, and intervention strategies, ensuring the well-being and healthy development of infants worldwide.

3. Methodology

EEG STUDIO and EDF BROWSER are powerful tools commonly used for EEG signal processing and analysis. They come equipped with default filtering options, including high-pass, low-pass, and notch filters, which are essential for reducing noise and unwanted artifacts in EEG recordings. EEG Studio is an advanced software designed for EEG data analysis and processing. It offers an intuitive interface that allows researchers and clinicians to visualize, annotate, and analyze EEG signals effectively. The software enables users to apply various data analysis techniques, such as filtering, spectral analysis, event-related potential (ERP) analysis, and connectivity analysis, to extract valuable insights from EEG recordings. On the other hand, EDF Browser specializes in viewing and examining EEG data stored in European Data Format (EDF) files. This lightweight and cross-platform tool ensures efficient loading and browsing of large EEG datasets encoded in the EDF format. The high-pass filter removes low-frequency components, such as baseline drift, while the low-pass filter attenuates high-frequency noise. Additionally, the notch filter specifically targets power line interference to further clean the EEG signals. After applying these filters, the software generates a filtered EEG output signal that is more suitable for analysis.

4. Dataset

The CHB-MIT (Children's Hospital Boston-Massachusetts Institute of Technology) database and PhysioNet database are two well-known and widely used repositories of physiological signal data, including EEG data, that are made available to the research community for various purposes, such as algorithm development, validation, and comparative studies. Figure 1 represents the block diagram of the model.

The CHB-MIT database is a collection of EEG recordings obtained from pediatric patients with epilepsy. It was created as a collaborative effort between Children's Hospital Boston and the Massachusetts Institute of Technology. The database contains long-term continuous EEG recordings captured from infants, children, and young adults with various forms of epilepsy. The recordings include both interictal (between seizures) and ictal (during seizures) segments, making it valuable for seizure detection and prediction research. Researchers often use the CHB-MIT database to develop and evaluate automated seizure detection algorithms and other techniques aimed at understanding epileptic brain activity in pediatric patients. The data is meticulously annotated, providing information about the seizure onset and offset times, making it a valuable resource for researchers in the field of pediatric epileptology.

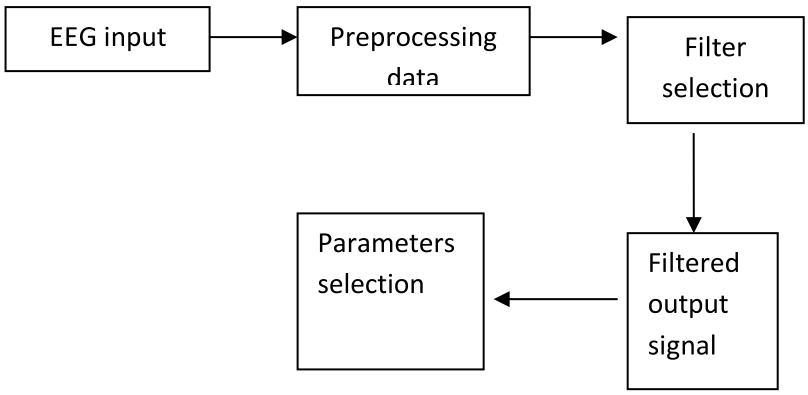

Fig. 1. Block diagram of the model

5. Related works

5.1 Wavelet packets

Wavelet packets are a powerful extension of wavelet analysis that allow for more detailed and versatile decomposition of signals. In standard wavelet analysis, a signal is decomposed into different frequency components using a single wavelet basis. However, wavelet packets take this decomposition further by enabling the exploration of multiple wavelet bases at each level of the decomposition tree [6]. The wavelet packet decomposition process involves splitting the signal into various frequency subbands, similar to wavelet analysis. However, instead of just two subbands (approximation and detail coefficients), wavelet packets allow for more flexibility by offering multiple subbands at each level [7]. This results in a richer representation of the signal, capturing a wider range of frequency information and providing better adaptability to different signal characteristics.

These are particularly useful when analyzing signals with complex or non-stationary frequency content. By allowing the decomposition to explore different wavelet bases, wavelet packets can identify and highlight specific frequency bands that are relevant to the analysis. The decomposition process starts with the original signal at the root of the wavelet packet tree. Then, at each level, the signal is split into different subbands using various wavelet bases. This process continues recursively until a desired level of decomposition is reached or specific subbands of interest are obtained [8]. It offers several advantages, such as improved signal representation, better time-frequency localization, and the ability to tailor the decomposition to the characteristics of the signal being analyzed. Figure 2 represents the Original Signal. Figure 3 represents the dual tree wavelet transformed signal.

However, it also increases the complexity of the analysis and requires careful selection of wavelet bases and decomposition levels to achieve meaningful results. The applications in various fields like including signal and image processing, audio compression, denoising, feature extraction, and pattern recognition. Researchers and engineers leverage wavelet packets to extract valuable information from signals with diverse and complex frequency structures, making it a valuable tool in modern signal processing and analysis.

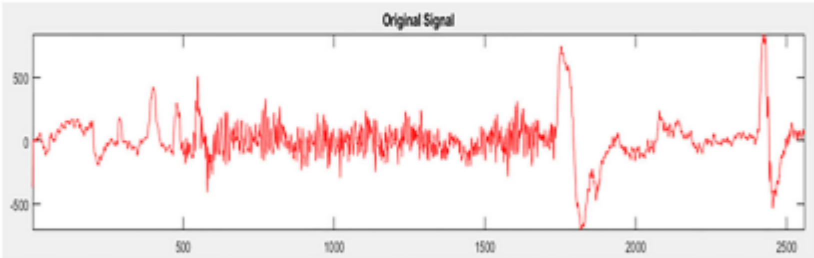

Fig. 2. Original Signal

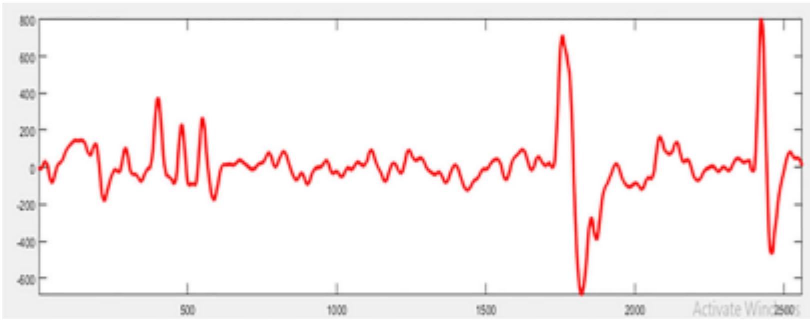

Fig. 3. Dual tree wavelet transforms technique

The Dual-Tree Wavelet Transform (DTWT) is an advanced extension of the conventional discrete wavelet transform (DWT) that overcomes some of its limitations and provides enhanced capabilities in various applications, particularly in image and signal processing. Unlike the DWT, which uses a single wavelet filter for analysis, the DTWT employs two separate sets of wavelet filters arranged in a dual-tree structure. This design enables improved shift-invariance and enhanced directional sensitivity, making it better suited for tasks involving feature detection, edge preservation, and complex structure analysis. The DTWT's advantages lie in its ability to efficiently handle image processing tasks, such as denoising, image fusion, and edge detection, while maintaining a reduction in aliasing artifacts [9,10]. Its unique characteristics have rendered it a valuable tool in modern image and signal processing, where high-quality representations and accurate feature extraction are essential [11]. The specific wavelet filters used in the DTWT can vary depending on the application and desired properties. The design of the filters plays a crucial role in achieving shift-invariance and directional selectivity. Typically, filters with near-orthogonal or biorthogonal properties are employed in the dual-tree structure to achieve these benefits. Figure 4 represents the comparison of EEG studio and EDF browser tool based on EEG mean without filter. Figure 5 represents the comparison of EEG studio and EDF browser tool based on EEG mean with filter.

In EEG Studio, researchers and clinicians can apply various types of filters, such as high-pass filters, low-pass filters, bandpass filters, and notch filters, to clean and preprocess the EEG signals. High-pass filters remove low-frequency drifts and baseline wander, while low-pass filters attenuate high-frequency noise. EDF Browser is designed for viewing and examining EEG data stored in European Data Format (EDF) files. Similar to EEG Studio, it doesn't provide filter design functionality. However, it allows users to visualize EEG signals from EDF files, which may have been preprocessed with filters using other software or tools. Before importing data into EDF Browser, researchers often preprocess EEG signals using specialized EEG data analysis software or programming libraries, where they can design and apply various filters based on their research objectives and the characteristics of the EEG data.

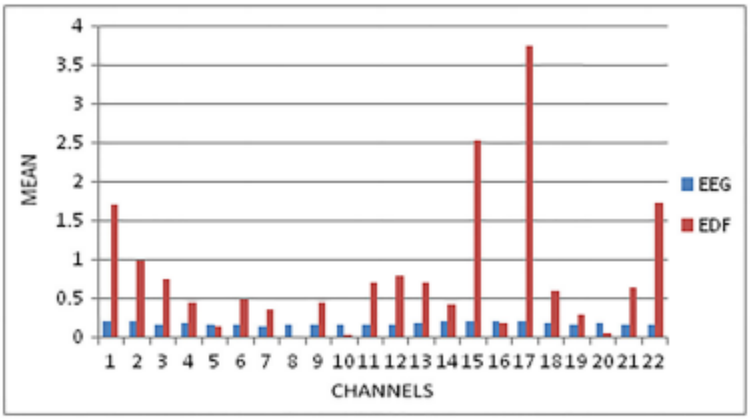

Fig. 4. Comparison of EEG studio and EDF browser tool based on EEG mean without filter

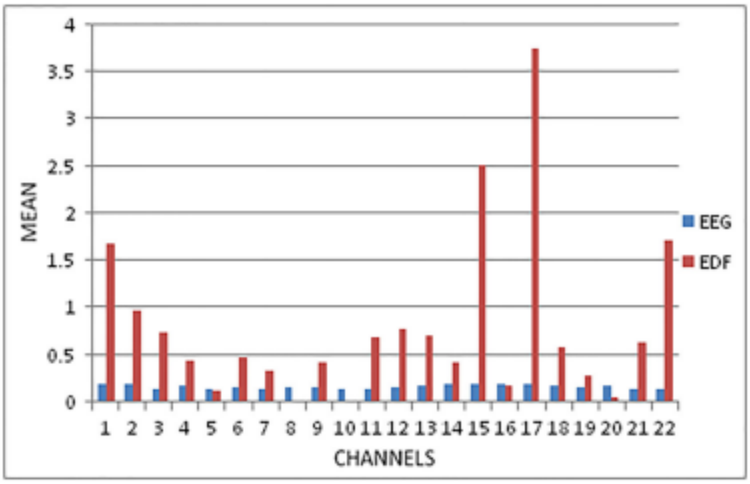

Fig. 5. Comparison of EEG studio and EDF browser tool based on EEG mean with filter

The Dual-Tree Wavelet Transform (DTWT) technique has been employed to filter the signals, providing improved shift-invariance and enhanced directional sensitivity compared to conventional wavelet transforms. The filtered signals are then subjected to analysis using two widely used EEG processing tools, EEG STUDIO and EDF BROWSER. The goal is to compare the results obtained from both tools, identify any discrepancies, and gain insights into the effectiveness of the DTWT filtering approach. Upon analyzing the EEG signals with EEG STUDIO and EDF BROWSER, a comparison table is generated to highlight the differences in the extracted features and measurements. The table includes various parameters such as mean values, frequency bands, and other relevant EEG characteristics. It provides an overview of how the signal's representation changes after being processed by each tool, both with and without the application of the DTWT filtering.

The comparison table may reveal variations between the two tools due to differences in their underlying algorithms, default settings, and signal processing methods [12]. For instance, the mean values and frequency band estimates might show slight discrepancies, which can be attributed to variations in the way each tool calculates these parameters. Additionally, the comparison might indicate that the DTWT filtering has a notable impact on the extracted features, such as enhancing the detection of certain frequency components or reducing noise artifacts. This would demonstrate the effectiveness of the DTWT technique in improving signal quality and analysis outcomes.

To visualize the differences more comprehensively, plots are generated for the EEG signals both with and without the application of the DTWT filter [13]. These plots illustrate how the signals are altered and highlight the changes introduced by the DTWT filtering [14]. The plots may showcase the effects of the filter on specific frequency components, the preservation of signal details, and the reduction of noise. Moreover, comparison plots can be generated to illustrate the spectral content of the signals before and after filtering. These spectral plots can help assess the impact of the DTWT filtering on different frequency bands and their distribution in the EEG signals.

The elaborate analysis, comparison tables, and plots allow researchers and clinicians to make informed decisions about the suitability of each tool and the advantages of using the DTWT filtering technique [15]. The evaluation of these results contributes to the refinement of signal processing approaches in EEG analysis and helps in selecting the most appropriate tools for specific research or clinical applications.

The Dual-Tree Complex Wavelet Transform (DT-CWT) is an extension of the traditional discrete wavelet transform (DWT) that offers several advantages, particularly in the field of signal and image processing. The DT-CWT provides improved directional sensitivity compared to the DWT, making it well-suited for analyzing signals and images with distinct directional features.

6. Conclusions

EEG processing tools, such as EEG STUDIO and EDF BROWSER, provide significant advantages over manual analysis when it comes to the parametric analysis of EEG signals. These tools automate various tasks, ensuring faster and more efficient analyses of EEG data without disturbances. By applying predefined algorithms and methods consistently, they enhance the objectivity and standardization of the analysis, resulting in reliable and reproducible measurements. Moreover, EEG processing tools excel in signal enhancement, employing advanced filtering techniques like the Dual-Tree Wavelet Transform (DTWT) to remove noise and artifacts, leading to clearer and more accurate results. The visualization capabilities of these tools aid in better understanding EEG data through intuitive plots and graphs, facilitating comprehensive data interpretation and streamlined reporting. Their ability to handle extensive datasets and customization options further empowers researchers and clinicians to conduct large-scale studies and adapt the analysis to their specific research or clinical needs. Overall, EEG processing tools play a pivotal role in advancing EEG analysis, providing researchers and clinicians with smoother, more objective, and disturbance-free parametric analyses of EEG signals.

References

[1] Wijayanto, Inung, Achmad Rizal, and Sugondo Hadiyoso. "Multilevel wavelet packet entropy and support vector machine for epileptic EEG classification." In *2018 4th International Conference on Science and Technology (ICST)*, pp. 1-6. IEEE, 2018. https://doi.org/10.1109/ICSTC.2018.8528634

[2] Deshmukh, Prashant, Rahul Ingle, Vikram Kehri, and R. N. Awale. "Epileptic seizure detection using discrete wavelet transform based support vector machine." In *2017 International Conference on Communication and Signal Processing (ICCSP)*, pp. 1933-1937. IEEE, 2017. https://doi.org/10.1109/ICCSP.2017.8286736

[3] Jun, Guo, and Kavallur Gopi Smitha. "EEG based stress level identification." In *2016 IEEE international conference on systems, man, and cybernetics (SMC)*, pp. 003270-003274. IEEE, 2016. https://doi.org/10.1109/SMC.2016.7844738

[4] Asakawa, Tetsuya, Takuto Hayashi, Eika Okamoto, and Yuko Mizuno-Matsumoto. "Visualization of the correlation and propagation of information between EEG electrodes." In *2010 World Automation Congress*, pp. 1-6. IEEE, 2010.

[5] Karakuş, Delal, Özlem Karabıber Cura, Bartu Yeşilkaya, and Aydın Akan. "Desıgn of Brain-Computer Interface for Controlling A Virtual Keyboard." In *2019 Medical Technologies Congress (TIPTEKNO)*, pp. 1-4. IEEE, 2019. https://doi.org/10.1109/TIPTEKNO.2019.8895133

[6] Harshini, D., M. Ranjitha, and Rushali Jadon. "A single electrode blink for text interface (BCI)." In *2020 IEEE International Conference for Innovation in Technology (INOCON)*, pp. 1-5. IEEE, 2020.

[7] Shi, Tianwei, Ling Ren, and Wenhua Cui. "Feature extraction of brain–computer interface electroencephalogram based on motor imagery." *IEEE Sensors Journal* 20, no. 20 (2019): 11787-11794. https://doi.org/10.1109/JSEN.2019.2939343

[8] Nisar, Humaira, Kee Wee Boon, Yeap Kim Ho, and Teoh Shen Khang. "Brain-Computer Interface: Feature Extraction and Classification of Motor Imagery-Based Cognitive Tasks." In *2022 IEEE International Conference on Automatic Control and Intelligent Systems (I2CACIS)*, pp. 42-47. IEEE, 2022. https://doi.org/10.1109/I2CACIS54679.2022.9815460

[9] Shen, Chia-Ping, Chih-Min Chan, Feng-Sheng Lin, Ming-Jang Chiu, Jeng-Wei Lin, Jui-Hung Kao, Chung-Ping Chen, and Feipei Lai. “Epileptic seizure detection for multichannel EEG signals with support vector machines.” In *2011 IEEE 11th International Conference on Bioinformatics and Bioengineering*, pp. 39-43. IEEE, 2011. https://doi.org/10.1109/BIBE.2011.13

[10] Lepkova, Kamila, Petr Nejedly, Vladimir Sladky, Filip Mivalt, Pavel Krsek, Martin Kudr, Matyas Ebel et al. "Electrophysiological Biomarkers of Epileptic Tissue in Human Brain Epilepsy." In *2022 E-Health and Bioengineering Conference (EHB)*, pp. 1-4. IEEE, 2022. https://doi.org/10.1109/EHB55594.2022.9991682

[11] Dian, Joshua A., Sinisa Colic, Yotin Chinvarun, Peter L. Carlen, and Berj L. Bardakjian. "Identification of brain regions of interest for epilepsy surgery planning using support vector machines." In *2015 37th annual international conference of the IEEE engineering in medicine and biology society (EMBC)*, pp. 6590-6593. IEEE, 2015. https://doi.org/10.1109/EMBC.2015.7319903

[12] Al-Bakri, Amir F., Mauricio F. Villamar, Chase Haddix, Meriem Bensalem-Owen, and Sridhar Sunderam. "Noninvasive seizure prediction using autonomic measurements in patients with refractory epilepsy." In *2018 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, pp. 2422-2425. IEEE, 2018. https://doi.org/10.1109/EMBC.2018.8512785

[13] Bao, Forrest Sheng, Jue-Ming Gao, Jing Hu, Donald YC Lie, Yuanlin Zhang, and K. J. Oommen. "Automated epilepsy diagnosis using interictal scalp EEG." In *2009 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, pp. 6603-6607. IEEE, 2009. https://doi.org/10.1109/IEMBS.2009.5332550

[14] Ossenblok, Pauly, Manfred Fuchs, Demetrios N. Velis, Ellen Veltman, Jan Pieter Pijn, and FH Lopes da Silva. "Source analysis of lesional frontal-lobe epilepsy." *IEEE engineering in medicine and biology magazine* 18, no. 3 (1999): 67-77. https://doi.org/10.1109/51.765191

[15] Misirlis, Yannis, Katerina D. Tzimourta, Pantelis Angelidis, Nikolaos Giannakeas, Alexandros T. Tzallas, and Markos G. Tsipouras. "Pediatric Epilepsy Assessment Based on EEG Analysis." In *2022 45th International Conference on Telecommunications and Signal Processing (TSP)*, pp. 377-380. IEEE, 2022. https://doi.org/10.1109/TSP55681.2022.9851298