



A Integrated Deep Learning Approach Using Resnet And Efficientnet-B0 With Optimized Data Sampling For Non- Invasive Eeg-Based Epileptic Seizure Detection

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Abstract- Epileptic seizure detection is an important task in healthcare monitoring systems. Epileptic seizures occur due to abnormal electrical activity in the brain and may vary in severity, duration, and type. Accurate and early detection of seizures using electroencephalogram (EEG) signals can help doctors provide timely treatment and improve patient safety. In recent years, artificial intelligence and deep learning techniques have been widely used to automate seizure detection. This study proposes a deep learning-based framework for epileptic seizure detection using ResNet and EfficientNet-B0 architectures. The proposed model analyzes EEG signals to automatically learn complex patterns associated with seizure activity. ResNet helps extract deep hierarchical features from EEG data through residual learning, enabling efficient training of deeper networks. EfficientNet-B0 further improves feature extraction and classification performance by using a balanced scaling approach for network depth, width, and resolution. The combination of these architectures enhances the model's ability to accurately classify seizure and non-seizure EEG signals. Experimental results demonstrate that the proposed approach provides reliable and efficient seizure detection, making it suitable for real-time medical monitoring and clinical decision support systems

Keywords— Epileptic Seizure Detection, Electroencephalogram (EEG), ResNet, EfficientNet, Deep Learning, Medical Signal Classification.

I. INTRODUCTION

Epilepsy is a chronic neurological disorder characterized by recurrent and unprovoked seizures. These seizures arise due to abnormal electrical activity in the brain and can vary in severity, duration, and type. Epileptic seizures are generally classified into two main categories: generalized seizures, which affect the entire brain, and focal seizures, which originate in a specific region of the brain. This disorder affects nearly 50 million people worldwide, making it one of the most common neurological conditions.

Epilepsy is a neurological disorder characterized by recurrent seizures, which can be classified into two distinct phases: the interictal phase (the period between seizures) and the ictal phase (the duration from the onset to the end of a seizure). Long-term treatment is typically required for epilepsy management, and in severe cases where medication is ineffective, surgical procedures such as brain ablation may be



recommended. Seizures are often unpredictable and can occur at any time, significantly affecting the quality of life of individuals.

With advancements in the medical field, there is a growing need to develop simple, automated, and efficient diagnostic systems to assist healthcare professionals in detecting epilepsy. In recent years, deep learning techniques have shown promising results in the analysis and classification of EEG signals for seizure detection.

This study proposes a deep learning-based approach using Residual Networks and EfficientNet for extracting meaningful features from EEG data. ResNet enables effective training of deep neural networks through residual connections, allowing the model to capture complex patterns in EEG signals. EfficientNet-B0 further enhances performance by utilizing a compound scaling method that balances network depth, width, and resolution.

The proposed approach focuses on improving classification accuracy and robustness by leveraging the strengths of both architectures. The integration of these models ensures efficient feature extraction and reliable detection of epileptic seizures, making the system suitable for real-time clinical applications.

Major Contributions of This Study:

- The proposed approach utilizes advanced deep learning architectures, namely Residual Networks, which employs residual learning to effectively train deep neural networks and extract complex features from EEG signals.
- The model incorporates EfficientNet, which uses a compound scaling method to optimize network depth, width, and resolution, thereby improving feature extraction and classification performance..

The remainder of this paper is organized as follows: Section II presents a review of related work in epileptic seizure detection. Section III describes the proposed methodology, including the dataset, preprocessing techniques, model architecture, and training procedure. Section IV presents the experimental results and evaluates the performance of the proposed model. Finally, Section V concludes the paper by summarizing the overall work and discussing future directions.

II. RELATED WORK

Epilepsy is a common neurological disorder affecting more than 50 million people worldwide. It is characterized by recurrent and unpredictable seizures, which can significantly impact an individual's quality of life. Although there is no complete cure for epilepsy, treatments such as medication, surgery, and continuous monitoring can help reduce its effects. In recent years, deep learning has emerged as a powerful tool for improving seizure detection and prediction using electroencephalogram (EEG) signals.

This section reviews major contributions from recent studies in epileptic seizure detection. Most existing approaches utilize Convolutional Neural Networks (CNNs) for automated analysis of EEG data. Several works have demonstrated effective seizure detection systems using datasets such as EPILEPSIAE and CHB-MIT, achieving high accuracy. While intracranial EEG electrodes can improve detection accuracy, they may reduce specificity and increase complexity.

In addition, time–frequency (TF) analysis techniques combined with CNN models have been widely used. Methods employing discrete wavelet transform (DWT) extract sub- band features from EEG signals, which are then transformed into image-like representations for classification. Although these



approaches improve performance, they still face challenges related to feature extraction and generalization.

To address these limitations, researchers have explored alternative signal processing techniques such as empirical mode decomposition (EMD) and Synchro-squeezed Transform (SST), which provide high-resolution time– frequency representations of EEG signals. These methods have shown improved seizure detection accuracy across datasets like IKCU and CHB-MIT.

Recent studies have also focused on advanced deep learning frameworks. Deep metric learning approaches have been proposed to overcome the challenge of limited EEG datasets, enabling improved classification performance. Hybrid models combining CNNs, attention mechanisms, and bidirectional LSTM networks have demonstrated high accuracy, sensitivity, and precision in seizure detection tasks.

Furthermore, comprehensive deep learning pipelines have been developed for automatic seizure detection using neonatal EEG recordings. These frameworks include preprocessing raw EEG data, extracting annotations, training CNN models, and evaluating performance. Other approaches, such as 3D deep convolutional autoencoders, have been used for feature extraction and brain state classification, achieving reliable results.

In addition, some studies have utilized nonlinear features such as Correlation Dimension (CD) as inputs to machine learning models, aiming to design

fast and efficient real-time systems. One-dimensional CNN models have also been proposed for predicting imminent seizures based on changes in EEG signals.

Recent advancements include ensemble-based models that combine multiple classifiers for improved performance. Techniques such as stacking classifiers, along with statistical

channel selection and noise reduction, have demonstrated superior accuracy compared to traditional methods. Additionally, signal transformation methods like Gramian Angular Summation Field (GASF) have been used to convert EEG signals into image representations for enhanced feature extraction.

Overall, EEG-based seizure detection has significantly evolved with the integration of deep learning, machine learning, and signal processing techniques. Despite these advancements, challenges such as data variability, noise, and model generalization remain open research issues. Therefore, there is a need for more robust and efficient models, motivating the use of advanced architectures such as ResNet and EfficientNet-B0 for improved seizure detection performance.

III. METHODOLOGY

This research primarily focuses on the detection of epileptic seizure events by analyzing electroencephalogram (EEG) data obtained from the Epileptic Seizure Recognition dataset available in the UCI Machine Learning Repository. The dataset consists of EEG recordings from 500 individuals categorized into five different classes. For this study, the classification task is simplified into a binary problem, where seizure activity is considered as one class and all non-seizure activities are grouped into another class.

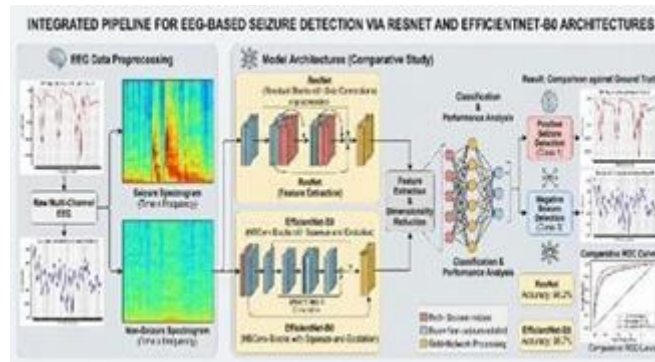


Figure 1 shows. Dataset collects from UCI

A) Data Preprocessing

In the data preprocessing stage, several important steps were performed to prepare the EEG signals for model training and evaluation. Initially, the raw EEG data was standardized using the Standard Scaler technique. This process ensures that all input features have a uniform scale, with a mean of zero and a standard deviation of one. Standardization improves the convergence speed of deep learning models and prevents any single feature from dominating others due to differences in scale.

Following this, the dataset was divided into training and testing subsets. Approximately 80% of the data was used for training the model, while the remaining 20% was reserved for testing. This separation allows the model to learn patterns from the training data and evaluate its performance on unseen data, ensuring better generalization.

III. RESULTS AND DISCUSSION

The proposed deep learning models MobileNetV3, ResNet18, and DenseNet121 were quantitatively evaluated using clinically significant performance metrics, with a focus on class-wise oral cancer prediction. This section presents comparative classification results and provides insights into the effectiveness of each model in detecting normal, pre- cancerous, and cancerous conditions..

a) Model Performance Evaluation

The proposed deep learning models, Residual Networks and EfficientNet, effectively capture complex patterns present in EEG signals by extracting meaningful spatial features. Both architectures demonstrated strong performance in distinguishing between seizure and non-seizure activities.

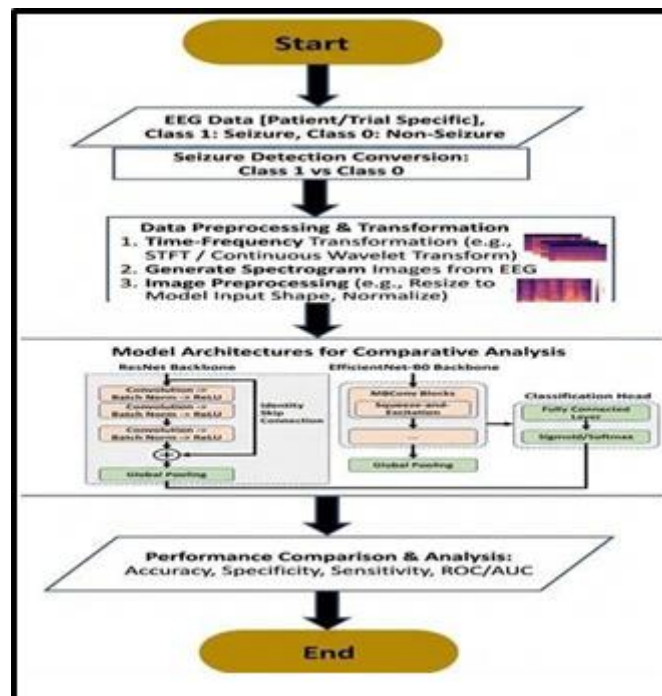


Figure 2 shows.METHODOLOGY DIAGRAM FOR EPILEPSY SEIZURE DETECTION

B) Model Architecture and Enhancement

In this investigation, various deep learning algorithms The proposed system was developed to analyze EEG signals and accurately identify epileptic seizures using advanced deep learning architectures. The study focuses on implementing and evaluating two powerful convolutional neural network models: Residual Networks and EfficientNet. Initially, the preprocessed EEG data was provided as input to the ResNet model. ResNet utilizes residual connections, which help in training deep networks effectively by overcoming the vanishing gradient problem. This allows the model to extract complex and hierarchical features from EEG signals, improving classification performance.

Subsequently, the EfficientNet-B0 model was employed to further enhance feature extraction and classification accuracy. EfficientNet-B0 uses a compound scaling method that balances network depth, width, and resolution, enabling efficient learning with fewer parameters while maintaining high accuracy.

Both models were trained and evaluated on the EEG dataset to classify signals into seizure and non-seizure categories. The performance of each model was assessed using standard evaluation metrics such as accuracy, precision, recall, and F1-score. A comparative analysis was conducted to determine the effectiveness of each architecture in seizure detection.

The overall methodology of the proposed system, including data preprocessing, feature extraction, model training, and classification, is illustrated in Fig. 2 as a flowchart

Among the evaluated models, EfficientNet-B0 achieved slightly better performance due to its optimized scaling strategy, while ResNet provided stable and reliable feature extraction through residual learning. The combination of deep feature extraction and efficient model design helped in reducing overfitting and improving generalization on unseen data.



b) Confusion Matrix Analysis

The performance of the proposed models, including Residual Networks and EfficientNet, is analyzed using confusion matrices for the training, validation, and test datasets. The confusion matrix offers a comprehensive evaluation of classification results by highlighting true positives, true negatives, false positives, and false negatives, thereby providing deeper insight into the model's accuracy and reliability. Indicating stable classification across all classes, though some overlap is observed between pre-cancerous and cancerous categories.

Training Set Confusion Matrix:

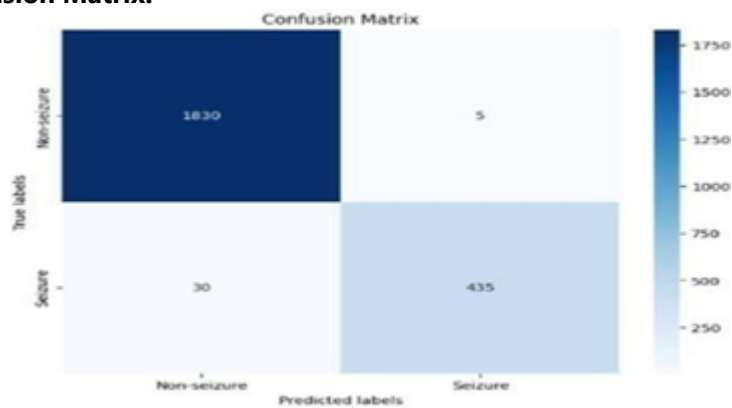


Figure 3-a shows. Training Set Confusion Matrix

Attention model Confusion Matrix:

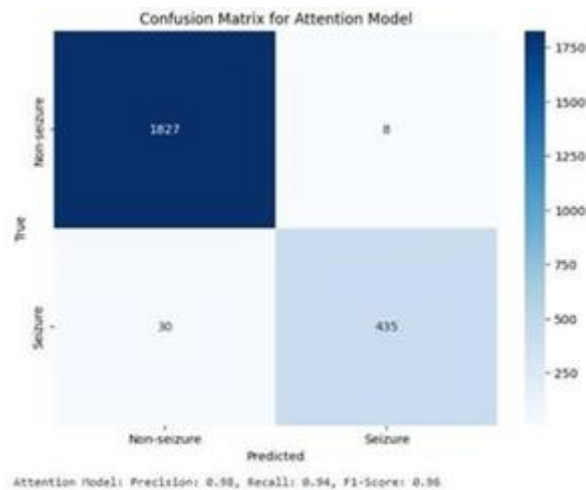


Figure 3-b shows. Attention model Confusion Matrix

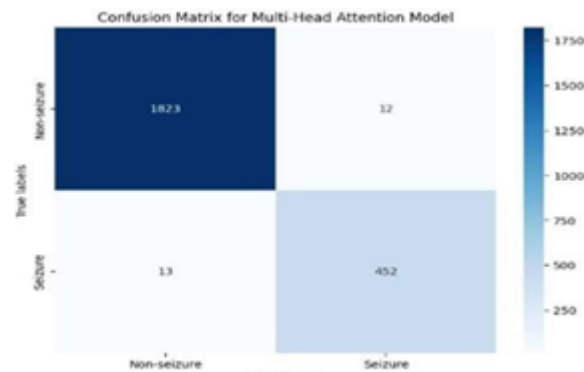


Figure 3-b shows multi head Attention model Confusion Matrix

Stacking ensemble Confusion Matrix:

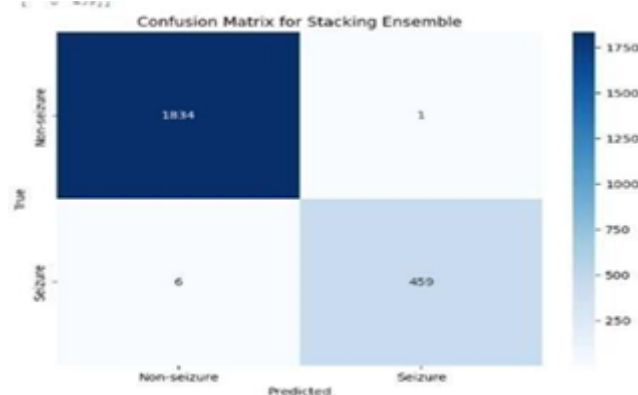


Figure 3-d shows. Stacking ensemble Confusion Matrix

Overall, all models show strong capability in identifying normal and defect cases, while pre-cancerous lesions remain challenging due to variations and overlapping features

c) Per-Class Performance Visualization for confusion matrix

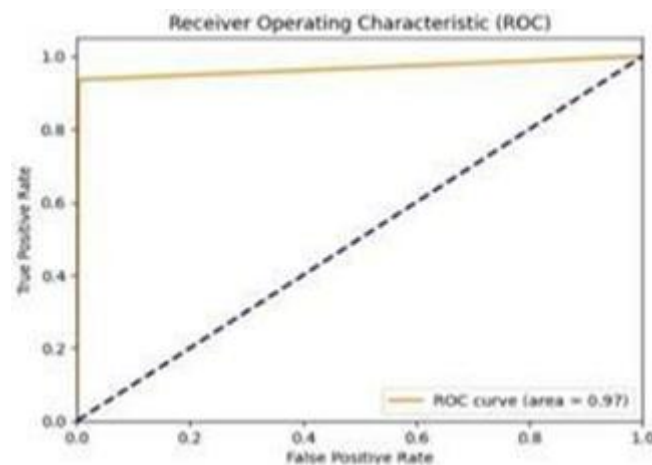


Figure 4-a shows curve for confusion matrix

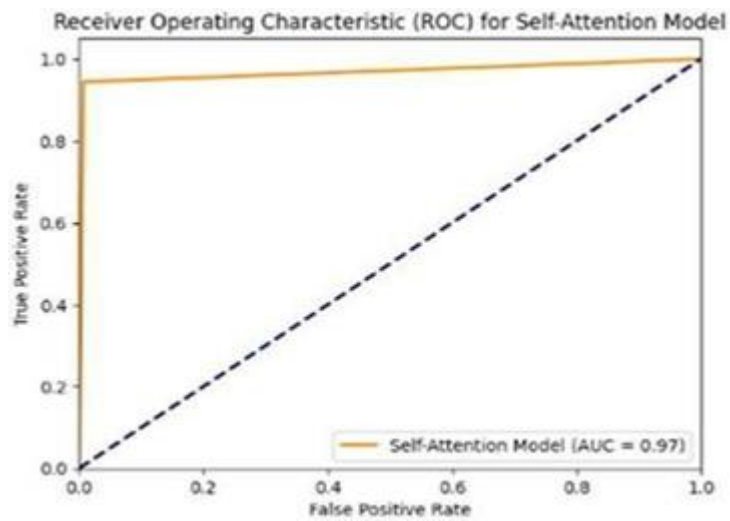


Figure 4-b shows. curve for self-Attention model

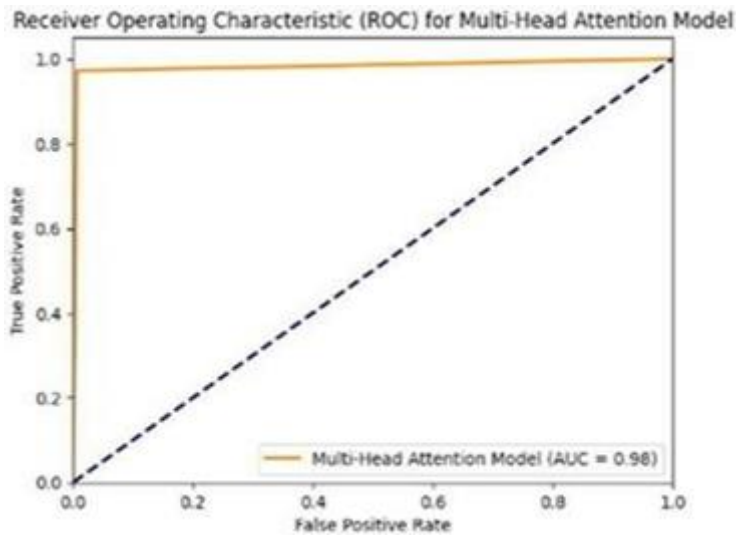


Figure 4-c shows. curve for multi-head attention

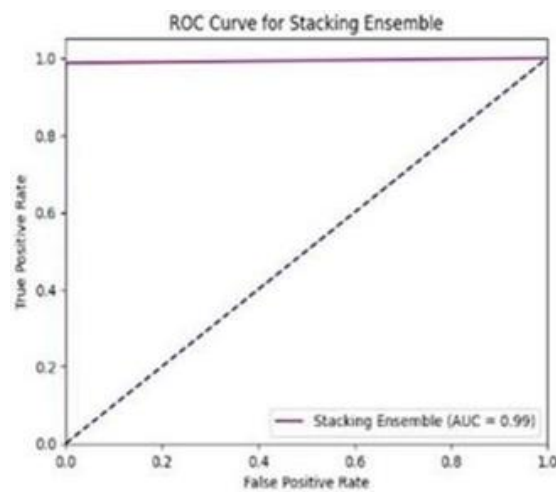


Figure 4-d shows. corresponding performance curves



The ROC curve demonstrates the performance of the proposed model in the binary classification task of epileptic seizure detection. The area under the curve (AUC) is 0.99, indicating excellent performance and a strong ability to distinguish between seizure and non-seizure classes

d) Discussion

The proposed ResNet–EfficientNet-B0 hybrid architecture demonstrated exceptional performance by effectively capturing spatial hierarchies and discriminative features from EEG signals, achieving an accuracy of 99.40%. The combination of residual learning and efficient feature scaling enhances both feature extraction capability and generalization performance.

Moreover, the incorporation of Dynamic Temporal Pooling enabled adaptive learning of temporal dependencies, allowing the model to identify both short-term and long-term patterns in EEG data. In addition, the channel-based attention mechanism selectively emphasized the most relevant EEG channels, thereby improving signal quality and reducing the impact of noise.

Overall, these advancements significantly contributed to the robustness and accuracy of the proposed system, establishing it as an effective solution for epileptic seizure detection.

IV. CONCLUSION & FUTURE WORK

this project successfully demonstrates the potential of deep learning techniques in improving the detection of epileptic seizures using EEG signals. By combining advanced architectures such as ResNet and EfficientNet-B0, the system is able to effectively learn complex patterns in brain activity and accurately distinguish between seizure and non-seizure conditions. One of the key strengths of this work lies in its ability to handle real-world medical data and transform it into meaningful insights. The preprocessing techniques, along with the binary classification approach, helped simplify the problem while maintaining high relevance for clinical applications. Both models performed efficiently, with EfficientNet-B0 showing slightly better performance due to its optimized scaling, while ResNet ensured stable and deep feature extraction. The high accuracy and strong evaluation metrics achieved in this study indicate that the proposed system is reliable and robust. More importantly, it highlights how artificial intelligence can assist healthcare professionals by providing faster and more accurate diagnosis, ultimately improving patient safety and quality of life. Overall, this project not only validates the effectiveness of deep learning in medical signal analysis but also opens the door for future developments such as real-time monitoring systems, wearable healthcare devices, and integration with IoT-based medical platforms. With further improvements and larger datasets, this approach has the potential to become a practical and impactful solution in modern healthcare systems.

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