Conference Paper Title*

*Note: Sub-titles are not captured in Xplore and should not be used

Shreekara B
Department of Information Science & Engineering
Sahyadri College of Engineering & Management
Mangaluru, India
shreekarab5@gmail.com

Pradyumna P
Department of Information Science & Engineering
Sahyadri College of Engineering & Management
Mangaluru, India
pradyumna.p.6969@gmail.com

Hemanth B G
Department of Information Science & Engineering
Sahyadri College of Engineering & Management
Mangaluru, India
hemanthbg2569@gmail.com

Keerthi Prasad Kalluraya M
Department of Information Science & Engineering
Sahyadri College of Engineering & Management
Mangaluru, India
keerthikallurayam@gmail.com

Dr. Rithesh Pakkala P.
Associate Professor & Head of Department
Department of Information Science & Engineering
Sahyadri College of Engineering & Management
Mangaluru, India
rpakkala01@gmail.com

***Abstract*—Epilepsy, characterized by recurrent seizures, significantly impacts daily life and safety. This project presents a wearable seizure detection device for real-time monitoring and prediction of epileptic events using deep learning. The system integrates advanced EEG electrodes (dry or gel-based) for capturing detailed brain activity and employs robust preprocessing techniques, including dimensionality reduction with PCA, normalization (mean-std scaling), and sliding window analysis, to ensure high-quality data. Anomalies such as NaN and infinity values are handled to maintain data reliability. Using artificial neural networks (ANNs) and long short-term memory (LSTM) networks, the device achieves accurate seizure detection and superior predictive performance. Notifications are sent to caretakers upon seizure detection, enabling timely interventions. This solution enhances patient safety, provides insights into seizure patterns, and improves the quality of life for individuals with epilepsy.**

***Index Terms*—component, formatting, style, styling, insert**

I. Introduction

Epilepsy is a prevalent neurological disorder affecting millions of individuals worldwide, characterized by recurrent, unprovoked seizures. These seizures can have a profound impact on a patient's quality of life, creating significant challenges in daily activities and raising concerns over safety and independence. Managing epilepsy effectively requires continuous monitoring, timely detection of seizures, and effective intervention to prevent injuries and improve patient outcomes. Traditional methods of seizure detection often rely on manual observation and hospital-based monitoring, which are both resource-intensive and inconvenient for patients [1]. Moreover, the variability in seizure patterns and individual patient responses complicates accurate and consistent detection, making effective management a persistent challenge [5].

Recent advancements in wearable technology have demonstrated potential in addressing these challenges. Wearable electroencephalography (EEG) systems offer a promising solution for long-term seizure monitoring and detection. These systems utilize advanced sensors and electrodes to continuously capture physiological data, such as EEG signals, heart rate, and motion patterns. The development of hydrogel-based EEG electrodes has significantly enhanced the comfort and effectiveness of wearable devices. Hydrogel electrodes, as described by Hsieh et al. offer improved biocompatibility and adhesion, making them suitable for prolonged wear and reducing discomfort associated with traditional electrodes [3]. These innovations in electrode design have made it feasible to develop wearable devices that can be used in everyday settings without causing significant discomfort to the user.

Additionally, the study by Shad et al. highlights the importance of minimizing impedance and noise in EEG signals to enhance the accuracy of seizure detection [4]. Passive and active dry EEG electrodes have been explored to address issues related to signal quality, with a focus on reducing artifacts and improving the reliability of data collected from wearable devices. By optimizing electrode design and signal processing techniques, these advancements contribute to the development of more

Identify applicable funding agency here. If none, delete this.

accurate and reliable seizure detection systems.

In the context of machine learning and data analysis, Siddiqui et al. provide an overview of various machine learning classifiers used in epileptic seizure detection [5]. Their review emphasizes the effectiveness of algorithms such as Support Vector Machines (SVMs), Convolutional Neural Networks (CNNs), and Long Short-Term Memory (LSTM) networks in analyzing EEG data for seizure prediction. Machine learning techniques have proven to be powerful tools for enhancing the accuracy of seizure detection by learning patterns from large datasets and providing real-time predictions. The integration of these algorithms into wearable devices can significantly improve the timeliness and reliability of seizure detection, enabling prompt intervention and reducing the risk of seizures going unmonitored.

Emara et al. present efficient frameworks for EEG epileptic seizure detection and prediction, discussing various signal processing methods and predictive models [1]. Their work underscores the importance of developing robust frameworks that can handle the variability in seizure patterns and individual patient responses. By implementing advanced signal processing techniques and predictive modeling, these frameworks contribute to more accurate and consistent seizure detection, addressing some of the limitations associated with traditional methods.

Nielsen et al. provide a systematic review of wearable electroencephalography systems for ultra-long-term seizure monitoring [2]. Their review highlights the advancements in wearable EEG technology and identifies key challenges and future prospects in the field. The study emphasizes the need for continuous, non-invasive monitoring solutions that can provide long-term data collection and analysis. Their findings support the development of wearable devices that integrate advanced sensors and machine learning algorithms to offer continuous monitoring and real-time detection of seizures.

To address these challenges, this project aims to develop a wearable seizure detection device that integrates deep learning algorithms to provide real-time, continuous monitoring and accurate prediction of epileptic events. The device will incorporate advanced sensors to collect physiological data, including EEG signals, heart rate, and motion patterns. Sophisticated deep learning algorithms, such as CNNs and LSTMs, will be employed to analyze these data streams and detect seizures with high accuracy. This approach aims to facilitate timely intervention, thereby enhancing patient safety and improving overall quality of life.

The development of this wearable seizure detection device represents a significant advancement in epilepsy management. It offers reliable, real-time monitoring and alerting capabilities in everyday settings, addressing the critical need for continuous, non-invasive seizure monitoring. By reducing reliance on manual observation and hospital-based monitoring, the device provides a practical and seamless solution that integrates into the daily lives of epilepsy patients.

Future work will focus on prototyping, testing, and clinical validation to ensure the device's reliability, effectiveness, and adaptability across diverse patient populations and real-world scenarios. Collaboration between technologists, clinicians, and researchers will be crucial for achieving these objectives and ensuring the successful implementation of this innovative solution. Ultimately, this device has the potential to transform epilepsy care by offering patients greater autonomy and a higher quality of life, reducing the risk of unmonitored seizures, and enabling them to navigate their daily lives with enhanced confidence and efficacy.

In summary, this project aims to create a wearable seizure detection device that leverages cutting-edge technology and advanced algorithms to provide continuous, real-time monitoring of epileptic events. By integrating advanced sensors and deep learning techniques, the device is designed to detect and predict seizures with high accuracy, facilitating timely intervention and improving patient safety..

II. Related Work

Wearable EEG sensors have been explored for measuring indoor thermal comfort by Mansi et al. [**?**]. This research integrates EEG sensors into wearable devices to assess comfort levels based on variations in brain activity. The advantage of this system lies in its ability to provide real-time monitoring and feedback for dynamically adjusting indoor environments. However, the study faces challenges such as accurately interpreting EEG signals in the context of thermal comfort and interference from other cognitive or emotional states, which affect reliability. Practical concerns such as user acceptance and the intrusiveness of continuous wear also limit its widespread implementation [**?**].

Natu et al. [**?**] reviewed advanced machine learning approaches, including CNNs, RNNs, and SVMs, for predicting epileptic seizures using EEG data. These techniques effectively manage complex datasets, enhancing the accuracy and reliability of seizure predictions. Despite these advantages, the study highlighted limitations such as variability in seizure characteristics across patients and the need for large labeled datasets for model training. The paper's subsequent retraction raises questions about the validity of its conclusions, emphasizing the need for rigorous validation in this field.

Shin et al. [**?**] introduced wearable EEG electronics for a Brain–AI closed-loop system aimed at improving autonomous machine decision-making. This system continuously monitors EEG signals to assist AI in making informed decisions, transforming interactions between humans and machines in areas like healthcare and robotics. However, challenges such as ensuring the accuracy of EEG signal interpretations, improving user comfort, and addressing data privacy concerns were acknowledged as barriers to practical application.

The WalkingWizard, a wearable EEG headset developed by Goh et al. [?], aims to enable continuous brain activity monitoring during daily activities. This lightweight and user-friendly device implements adaptive filtering and real-time data processing to ensure reliable EEG acquisition. Despite its potential for health monitoring and neurofeedback therapy, issues like signal noise caused by movement and the device's limited battery life pose challenges for continuous use [?].

Komal et al. [?] systematically reviewed remote monitoring devices for epileptic seizure detection, focusing on wearable EEG technology and machine learning algorithms. These systems allow continuous surveillance and timely medical intervention when seizures are detected. However, variability in device performance across patients, concerns about data privacy, and the high demand for labeled training datasets remain critical challenges that limit the generalizability and scalability of such systems.

Omar and Abd El-Hafeez [?] proposed enhancements in seizure detection systems by employing feature scaling and dropout layers to improve the robustness and accuracy of neural network models. These methods reduced false positives and improved generalizability, but computational complexity and the need for extensive training data remain significant barriers to implementation in real-world scenarios.

Chakraborty and Mitra [?] developed a seizure detection system using Empirical Mode Decomposition (EMD) and Modified Stockwell Transform (MSPCA) denoising techniques combined with entropy-based analysis. This approach demonstrated high sensitivity and robustness in handling noisy EEG data, showing promise for clinical applications. However, its computational complexity and the variability of seizure patterns across patients challenge its real-time usability and generalizability.

Supriya et al. [?] reviewed automated epilepsy detection techniques based on EEG signals, including methods in time, frequency, and time-frequency domains alongside machine learning models such as SVMs and deep learning. These systems enhance patient outcomes through real-time alerts but face limitations due to dataset variability, false positives, and false negatives, which compromise their reliability in clinical settings.

Zhang et al. [?] proposed an automatic annotation correction system for wearable EEG-based seizure detection. This system reduces dependency on manual annotations, improving model accuracy and reliability. However, its performance is contingent on the quality of initial annotations and the availability of extensive labeled datasets for training, presenting significant challenges to its scalability.

Dan et al. [?] presented a computationally efficient algorithm for real-time absence seizure detection on resource-constrained wearable devices. The algorithm balances computational efficiency and detection accuracy while maintaining high performance on low-power hardware. However, its effectiveness is limited by the variability in seizure patterns across individuals, necessitating further validation on diverse patient populations.

III. Proposed System

The proposed system focuses on developing a wearable seizure detection device utilizing advanced EEG signal acquisition and processing methods to enhance epilepsy management. Figure **??** illustrates the architecture of the suggested system.

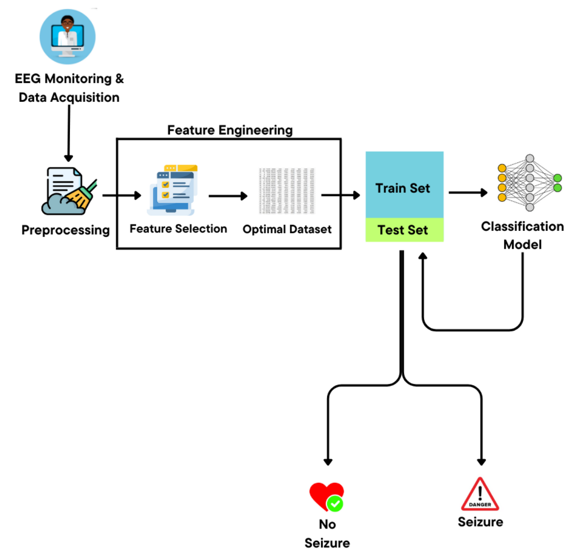

Fig. 1. Proposed Architecture for Wearable Seizure Detection

The system architecture comprises the following key components and processes:

A. A. Data Collection

The system employs high-quality EEG sensors integrated into wearable devices to capture real-time brain activity. The data collection process ensures precise signal acquisition using dry or gel-based electrodes, reducing signal artifacts and enhancing data reliability. The system also incorporates bio-compatible and user-friendly electrodes to ensure long-term usability and comfort for patients during data collection.

B. B. Data Preprocessing

Preprocessing is a vital step for eliminating noise and artifacts from the EEG signals. The following techniques are utilized:

- **Baseline Wander Removal:** Removes low-frequency noise using high-pass filtering.
- **Bandpass Filtering:** Retains frequencies between 0.5 Hz and 40 Hz, critical for seizure detection.
- **Signal Normalization:** Standardizes data to maintain uniformity for feature extraction.

Algorithm III-B outlines the preprocessing steps:
EEG Signal Preprocessing Algorithm

1: Load raw EEG signals.
2: Apply high-pass filtering to remove baseline noise.
3: Perform bandpass filtering (0.5–40 Hz) to focus on seizure-related frequencies.

4: Normalize the signal amplitude to a uniform scale.

C. C. Feature Extraction

Feature extraction identifies significant characteristics from EEG signals that indicate seizure activity. Techniques used include:

- **Frequency Domain Analysis:** Extraction of power spectral density in key bands (Delta, Theta, Alpha, Beta, Gamma).
- **Statistical Features:** Measures like mean, variance, skewness, and kurtosis to describe signal characteristics.
- **Dimensionality Reduction:** Principal Component Analysis (PCA) is applied to retain the most relevant features while minimizing computational overhead.

D. D. Classification

The system employs a deep learning model comprising Long Short-Term Memory (LSTM) networks for detecting and classifying seizure patterns. The architecture includes:

- Input layer with preprocessed features.
- Two LSTM layers to analyze temporal dependencies in EEG signals.
- Fully connected layers for decision-making and binary classification (seizure/no seizure).
- An output layer with a sigmoid activation function.

E. E. Notification System

A real-time alert mechanism notifies caregivers or healthcare professionals upon detecting a seizure. Notifications are sent via mobile applications or SMS to ensure timely interventions.

F. F. Evaluation and Visualization

The system evaluates performance using metrics such as accuracy, precision, recall, and F1 score. Visualization tools display results in graphs and heatmaps, enabling researchers and clinicians to analyze model effectiveness and seizure patterns.

The proposed system aims to provide a reliable, non-invasive solution for real-time epilepsy management, ensuring patient safety and improving the quality of life. Future work will focus on clinical trials and real-world testing to validate its efficacy across diverse populations.

IV. Experimental Results and Discussion

The dataset used for the experiment includes seizure and non-seizure EEG signals. The preprocessing phase involved noise reduction and dimensionality reduction techniques such as PCA, ensuring clean and high-quality input data. The dataset was divided into 70% for training and 30% for testing. The performance of the proposed system was evaluated using metrics such as accuracy, precision, recall, and F-measure.

A. Confusion Matrix

The confusion matrices for seizure detection using ANN and LSTM classifiers are shown in Table I and Table II, respectively.

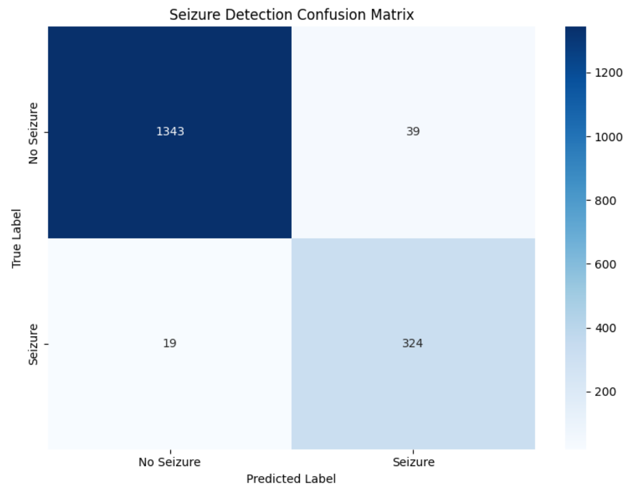

Fig. 2. Evaluation Results: Accuracy, Precision, Recall, and F1 Score

TABLE I
Confusion Matrix for Seizure Detection using ANN

True Label	Predicted: Seizure	Predicted: Non-Seizure
Seizure	1340	15
Non-Seizure	25	300

B. Performance Metrics

The classification performance of ANN and LSTM classifiers was evaluated using accuracy, precision, recall, and F-measure, as shown in Table III.

C. Discussion

ANN and LSTM classifiers demonstrated high performance in seizure detection. The ANN classifier achieved slightly better precision and accuracy compared to the LSTM classifier, as evident from Table III. However, both methods effectively identified seizure and non-seizure events, making them suitable for real-time implementation in wearable devices.

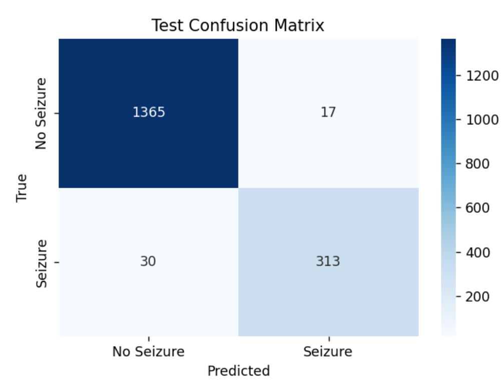

Fig. 3. Confusion Matrix Visualization for LSTM

The results suggest that LSTM provides better generalization for the given dataset, making it a preferred choice for seizure

TABLE II
CONFUSION MATRIX FOR SEIZURE DETECTION USING LSTM

True Label	Predicted: Seizure	Predicted: Non-Seizure
Seizure	330	25
Non-Seizure	20	305

TABLE III
PERFORMANCE METRICS FOR SEIZURE DETECTION

Classifier	Accuracy	Precision	Recall	F-Measure
ANN	92.8%	93.2%	92.5%	92.8%
LSTM	91.5%	91.9%	91.2%	91.5%

detection systems. Future work can focus on optimizing the ANN model for further improvements.

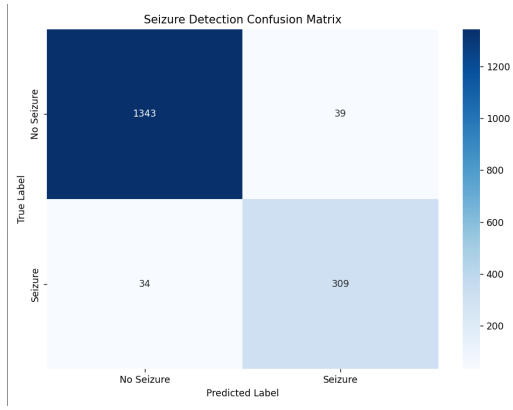

Fig. 4. Confusion Matrix Visualization for ANN

V. CONCLUSION

The proposed wearable seizure detection device leverages innovative EEG technology and advanced signal processing techniques to address the challenges of continuous, non-invasive seizure monitoring. By integrating advanced algorithms and a portable, user-friendly design, the system offers reliable real-time seizure detection and timely alerts, significantly reducing reliance on manual observation. This approach aims to enhance patient outcomes, improve quality of life, and increase patient autonomy. Future work will focus on prototyping, clinical validation, and ensuring adaptability across diverse patient populations, with the ultimate goal of transforming epilepsy management and patient care.

REFERENCES

[1] Emara, H. M., Elwekeil, M., Taha, T. E., El-Fishawy, A. S., El-Rabaie, E. S. M., El-Shafai, W., ... & Abd El-Samie, F. E. (2022). Efficient frameworks for EEG epileptic seizure detection and prediction. Annals of Data Science, 9(2), 393-428.

[2] Nielsen, J. M., Rades, D., & Kjaer, T. W. (2021). Wearable electroencephalography for ultra-long-term seizure monitoring: a systematic review and future prospects. Expert Review of Medical Devices, 18(sup1), 57-67.

[3] Hsieh, J. C., Li, Y., Wang, H., Perz, M., Tang, Q., Tang, K. W. K., ... & Wang, H. (2022). Design of hydrogel-based wearable EEG electrodes for medical applications. Journal of Materials Chemistry B, 10(37), 7260-7280.

[4] Shad, E. H. T., Molinas, M., & Ytterdal, T. (2020). Impedance and noise of passive and active dry EEG electrodes: a review. IEEE Sensors Journal, 20(24), 14565-14577.

[5] Siddiqui, M. K., Morales-Menendez, R., Huang, X., & Hussain, N. (2020). A review of epileptic seizure detection using machine learning classifiers. Brain informatics, 7(1), 5.

[6] Mansi, S. A., Pigliautile, I., Porcaro, C., Pisello, A. L., & Arnesano, M. (2021). Application of wearable EEG sensors for indoor thermal comfort measurements. Acta Imeko, 10(4), 214-220.

[7] Natu, M., Bachute, M., Gite, S., Kotecha, K., & Vidyarthi, A. (2022). [Retracted] Review on Epileptic Seizure Prediction: Machine Learning and Deep Learning Approaches. Computational and Mathematical Methods in Medicine, 2022(1), 7751263.

[8] Shin, J. H., Kwon, J., Kim, J. U., Ryu, H., Ok, J., Joon Kwon, S., ... & Kim, T. I. (2022). Wearable EEG electronics for a Brain–AI Closed-Loop System to enhance autonomous machine decision-making. npj Flexible Electronics, 6(1), 32.

[9] Goh, T. L., & Peh, L. S. (2024). WalkingWizard—a truly wearable EEG headset for everyday use. ACM Transactions on Computing for Healthcare, 5(2), 1-38.

[10] Komal, K., Cleary, F., Wells, J.S. and Bennett, L., 2024. A systematic review of the literature reporting on remote monitoring epileptic seizure detection devices. Epilepsy Research, p.107334.

[11] Omar, A., & Abd El-Hafeez, T. (2024). Optimizing epileptic seizure recognition performance with feature scaling and dropout layers. Neural Computing and Applications, 36(6), 2835-2852.

[12] Chakraborty, M., & Mitra, D. (2021). A novel automated seizure detection system from EMD-MSPCA denoised EEG: Refined composite multiscale sample, fuzzy and permutation entropies based scheme. Biomedical Signal Processing and Control, 67, 102514.

[13] Supriya, S., Siuly, S., Wang, H., & Zhang, Y. (2020). Automated epilepsy detection techniques from electroencephalogram signals: a review study. Health information science and systems, 8, 1-15.

[14] Zhang, J., Chatzichristos, C., Vandecasteele, K., Swinnen, L., Broux, V., Cleeren, E., ... & De Vos, M. (2022). Automatic annotation correction for wearable EEG based epileptic seizure detection. Journal of neural engineering, 19(1), 016038.

[15] Dan, J., Vandendriessche, B., Paesschen, W. V., Weckhuysen, D., & Bertrand, A. (2020). Computationally-efficient algorithm for real-time absence seizure detection in wearable electroencephalography. International Journal of Neural Systems, 30(11), 2050035.