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# EMG SIGNAL ANALYSIS USING IMPROVED WIGNER-VILLE DISTRIBUTION MODEL AND LONG SHORT- TERM MEMORY FOR AMYOTROPHIC LATERAL SCLEROSIS PREDICTION

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**Abstract -** *Amyotrophic Lateral Sclerosis (ALS) is a progressive neurodegenerative disease that severely impacts motor functions, necessitating early and accurate diagnosis for better patient management. This study proposes a hybrid approach combining the Improved Wigner-Ville Distribution (WVD) for feature extraction with Convolutional Neural Networks (CNNs) for spatial feature learning and Long Short-Term Memory (LSTM) networks for capturing temporal dependencies in Electromyography (EMG) data. The WVD enhances the time-frequency representation of the signals, while CNNs extract complex spatial patterns, and the LSTM network ensures robust classification by modeling sequential relationships in the data. This hybrid methodology demonstrates significant improvements in diagnostic accuracy over traditional methods, offering a non-invasive, efficient solution for ALS prediction with the potential for clinical implementation.*

***Keywords:*** *ALS, EMG signal analysis, Wigner-Ville Distribution, Convolutional Neural Networks, Long Short-Term Memory, neurodegenerative disease prediction, time-frequency analysis.*

## 1. INTRODUCTION

Amyotrophic Lateral Sclerosis (ALS) is a severe neurodegenerative disease characterized by the progressive loss of motor neurons, leading to muscle atrophy, paralysis, and eventually, respiratory failure [1]. ALS typically manifests in mid-to-late adulthood, with most patients surviving only 2 to 5 years post-diagnosis. Despite decades of research, the underlying causes remain largely unknown, making early diagnosis and intervention essential for improving patient outcomes and quality of life.

Electromyography (EMG) is a non-invasive diagnostic tool widely used to assess neuromuscular activity. However, the complex, non-stationary nature of EMG signals poses significant challenges for analysis and interpretation. Traditional methods often rely on simple frequency-domain features, which may fail to capture subtle temporal and frequency variations critical for detecting ALS at its early stages [2].

To address these challenges, this study proposes a hybrid methodology that integrates advanced time-frequency analysis with machine learning. The Improved Wigner-Ville Distribution (WVD) is employed for precise feature extraction, effectively resolving the intricate time-frequency characteristics of EMG signals. Complementing this, a Long Short-Term Memory (LSTM) network is used to model the temporal dependencies within the data, providing a robust framework for ALS prediction.

By leveraging these advanced techniques, the proposed approach aims to enhance the accuracy and reliability of ALS diagnosis. This method holds significant potential for non-invasive, scalable clinical applications, reducing diagnostic delays and supporting timely treatment planning.

### 1.1 Background of the Work

Amyotrophic Lateral Sclerosis (ALS) is a progressive neurodegenerative disease with severe consequences for patients, affecting motor neurons, leading to muscle weakness, atrophy, and respiratory failure. Early diagnosis is critical for better patient management, but current diagnostic methods are fraught with challenges. Traditional diagnostic techniques such as nerve conduction studies and clinical evaluations are invasive, time-consuming, and prone to human error. Moreover, these methods often result in a late-stage diagnosis when the disease has already progressed significantly.

### 1.2 Motivation and Scope of the Proposed Work

The rising prevalence of Amyotrophic Lateral Sclerosis (ALS) and the limitations of current invasive and delayed diagnostic methods underscore the need for advanced solutions. EMG signals, despite their complexity, offer a non-invasive avenue for early ALS detection when analyzed effectively. The side effects of delayed diagnosis are profound, as early intervention can improve patient outcomes and slow disease progression. Traditional methods fail to detect ALS in its early stages, which limits opportunities for timely treatment and symptom management. Patients may also experience increased anxiety and uncertainty while waiting for an accurate diagnosis, which can affect their quality of life. Furthermore, the inability to differentiate ALS from other neuromuscular disorders early on leads to misdiagnoses, further complicating treatment plans. There is an urgent need for non-invasive, rapid, and reliable diagnostic methods to address these challenges

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## 2. METHODOLOGY

The methodology of this project employs a hybrid approach that integrates advanced signal processing with machine learning for ALS prediction using EMG signals. Initially, raw EMG data is acquired and preprocessed to eliminate noise. The Improved Wigner-Ville Distribution (WVD) is applied to extract precise time-frequency features from the signals. These features are then input into a combination of Convolutional Neural Networks (CNNs) for spatial feature extraction and Long Short-Term Memory (LSTM) networks for capturing temporal dependencies in the data. The model is trained and validated on labeled datasets to ensure accurate classification of ALS. This integrated workflow combines the strengths of CNNs for feature learning and LSTMs for sequence modeling, providing a robust, non-invasive framework for early detection of ALS.

### 2.1 System Architecture

The architecture of the proposed system includes sensors for real-time acquisition of EMG signals, preprocessing units to filter and normalize the data, the Improved Wigner-Ville Distribution (WVD) for feature extraction, and an LSTM network for ALS classification. The system is designed to ensure continuous monitoring, with the EMG data being processed and analyzed in real-time. The extracted features are fed into the LSTM model for prediction, and the results are displayed on a user-friendly web interface. This structure allows for seamless flow of data from acquisition to prediction, enabling early detection of ALS and providing clinicians with actionable insights for timely intervention. The flow of data and processing steps is illustrated in Fig. 1.

### 2.2 Data Acquisition

The EMG signals used in this study were obtained from the EMGLAB dataset N2001, which includes clinical data recorded from normal controls, myopathy patients, and ALS patients. The data were recorded under standard conditions for motor unit action potential (MUAP) analysis, utilizing concentric needle electrodes and processed with appropriate filtering techniques (Nikolic, 2001) [4].

### 2.3 Wigner - Ville Distribution Model

The Wigner-Ville Distribution (WVD) is a time-frequency analysis method used to analyze non-stationary signals by providing a detailed representation of a signal's frequency content over time. It is particularly useful for EMG signal analysis, as it captures the instantaneous frequency and amplitude variations, essential for identifying patterns in ALS progression [4]. While WVD can suffer from cross-term interference in multi-component signals, various improvements have been proposed to mitigate these issues, making it a powerful tool for feature extraction in ALS prediction. By applying the WVD, we enhance the quality of EMG signals, allowing for more accurate classification and early ALS detection.

### 2.4 Hybrid LSTM-CNN Architecture

The hybrid LSTM-CNN architecture combines the strengths of both Convolutional Neural Networks (CNNs) and Long Short-Term Memory (LSTM) networks to enhance performance in tasks like ALS detection from EMG signals. CNNs are particularly effective at extracting spatial features from data, such as time-frequency representations of EMG signals generated by methods like the Wigner-Ville Distribution. These spatial features are essential for identifying patterns within the signals. On the other hand, LSTMs are designed to handle sequential data, learning the temporal dependencies inherent in the signal over time, making them ideal for capturing the progression of ALS in the dataset. By leveraging CNNs for feature extraction and LSTMs for sequence modeling, this hybrid architecture is able to effectively analyze both the spatial and temporal dimensions of EMG signals, leading to improved accuracy in ALS prediction [9].

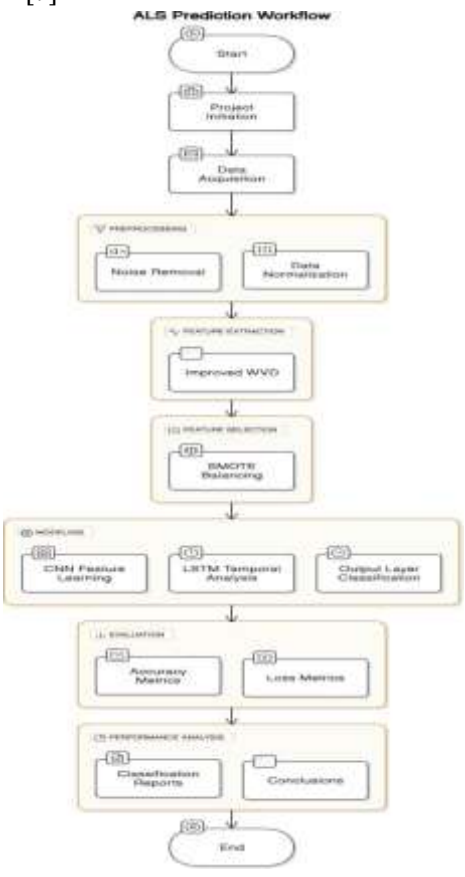


**Fig -1- Flowchart**

## 3. RESULTS AND DISCUSSION

The hybrid LSTM-CNN model demonstrated strong performance, achieving a test accuracy of 88.1%, precision of 0.92, sensitivity (recall) of 0.816, F1-score of 0.865, and a test loss of 0.417. The high accuracy indicates the model's

effective classification of ALS, with precision showing that 92% of ALS predictions were correct. Sensitivity indicates that the model successfully identified 81.6% of ALS cases, while the F1-score reflects a well-balanced performance between precision and recall. The test loss suggests minimal error in predictions, confirming the model's robustness in detecting ALS with high reliability.

Additionally, the model output, shown in Fig. 2, is visualized as a Kernel Density Estimate (KDE) plot. This plot illustrates the distribution of model output probabilities, which likely represent the confidence levels for ALS detection. The X-axis represents the probability values, ranging from 0 to 1, while the Y-axis shows the density of predictions in each probability range. The plot exhibits a bimodal distribution, with peaks around two distinct probability values, suggesting that the model frequently outputs moderately confident predictions for the two classes (ALS and non-ALS). This reflects the model's tendency to avoid extreme probabilities, likely indicating balanced classification between the two outcomes. The confusion matrix displayed in Fig. 3 further supports these findings, showing how well the model differentiates between ALS and non-ALS cases. These results confirm that the hybrid LSTM-CNN architecture is effective for ALS detection using EMG signals, aligning with similar studies that highlight the efficacy of such models in medical diagnostics.

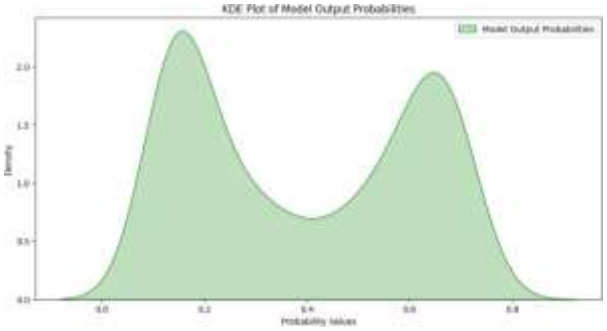


**Fig 2. Model Output Probabilities**

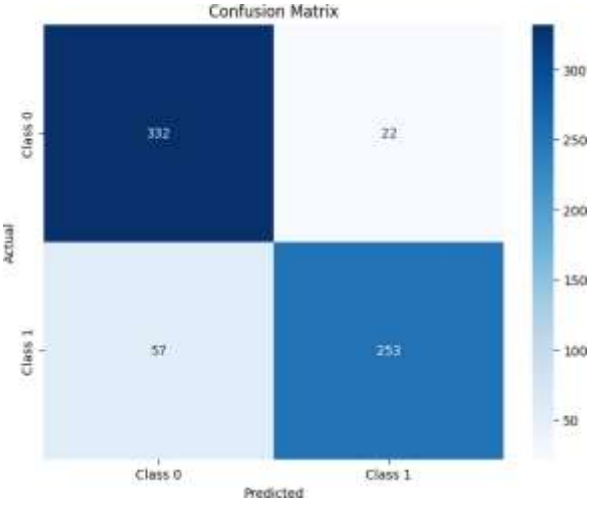


**Fig 3. Confusion Matrix**

## 4. CONCLUSION

This work presents a hybrid LSTM-CNN model for the prediction of ALS using EMG signals, achieving promising results. The combination of CNN's spatial feature extraction and LSTM's ability to model temporal dependencies allowed for improved classification accuracy, with a test accuracy of 88%. The model demonstrated high precision (0.92) and sensitivity (0.81), reflecting its effectiveness in detecting ALS and minimizing false positives. The F1-Score of 0.864 suggests a balanced performance, ensuring both reliable detection and reduced errors. These findings highlight the potential of deep learning techniques in the non-invasive diagnosis of ALS from EMG data. Future directions include refining the model through additional data and exploring its adaptability to other neuromuscular disorders.

### Suggestions for Future Work

Future research in ALS detection using EMG signals could benefit from several enhancements. First, expanding the dataset to include a more diverse range of ALS patients, as well as controls from varying demographics, could improve the model's generalization and robustness. Integrating additional biomarkers, such as muscle strength and neurophysiological parameters, might provide a more comprehensive understanding of ALS progression, thereby enhancing the accuracy of predictions. Moreover, incorporating advanced techniques like transfer learning could help optimize the model for different datasets, especially in real-time clinical applications. Exploring other deep learning models, such as attention mechanisms or transformers, may further improve the ability to capture complex patterns within the EMG data. Lastly, real-time implementation and continuous monitoring of ALS patients using wearable devices could facilitate early diagnosis and improve patient management, making this technology scalable for practical use in healthcare settings

## REFERENCES

[1] P. Kasi, L. Krivickas, E. Clancy, et al., "Characterization of motor unit behaviour in patients with amyotrophic lateral sclerosis," Int. IEEE/EMBS Conf. Neural Engineering, 23 Jun. 2009.

[2] A. Mokdad, S. Debbal, and F. Meziani, "Diagnosis of amyotrophic lateral sclerosis (ALS) disorders based on electromyogram (EMG) signal analysis and feature selection," Polish Journal of Medical Physics and Engineering, vol. 26, no. 3, pp. 55–65, Sep. 2020.

[3] C. M. Castro-Costa, R. B. Oriá, et al., "Amyotrophic lateral sclerosis: Clinical analysis of 78 cases from Fortaleza (Northeastern Brazil)," Arquivos de Neuro-Psiquiatria, vol. 57, no. 3B, pp. 784–789, Sep. 1999.

[4] M. Nikolic, Detailed Analysis of Clinical Electromyography Signals EMG Decomposition, Findings and Firing Pattern Analysis in Controls and Patients with Myopathy and Amyotrophic Lateral Sclerosis, PhD Thesis, Faculty of Health Science, University of Copenhagen, 2001. Available at: EMGLAB N2001 Dataset.

**5.** M. Khezri and M. Jahed, "An inventive quadratic time-frequency scheme based on Wigner-Ville distribution for classification of surface electromyography (sEMG) signals," in Proc. 6th Int. Special Topic Conf. Information Technology Applications in Biomedicine, Dec. 2007.

[5] A. B. Sonone, "DWT based Identification of Amyotrophic Lateral Sclerosis Using Surface EMG Signal," The Journal of Medical Research, Aug. 28, 2017.

[6] A. Nahon and B. Lerner, "Temporal modeling of ALS using longitudinal data and long-short term memory-based algorithm," in Proc. European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning (ESANN), 2018.

[7] M. Manap, A. Abdullah, M. Jopri, and M. A. Jamaluddin, "An improved smooth-windowed Wigner-Ville distribution analysis for voltage variation signal," Int. Journal of Electrical and Computer Engineering, vol. 10, no. 5, pp. 4982–4991, Oct. 2020.

[8] E. Amooei, A. Sharifi, and M. Manthouri, "Early diagnosis of neurodegenerative diseases using CNN-LSTM and wavelet transform," Journal of Healthcare Engineering, vol. 11, no. 2, pp. 123–135, Feb. 2023.

[9] S. Ouamri, M. Abed, A. Ould Ali, "Classification of intramuscular EMG signals using a separable compact support kernel-based time-frequency distribution and deep transfer learning," International Symposium on Biomedical Engineering, 13 Jul. 2023.