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Detecting epileptic seizures by analyzing brain waves with Long Short-Term Memory networks

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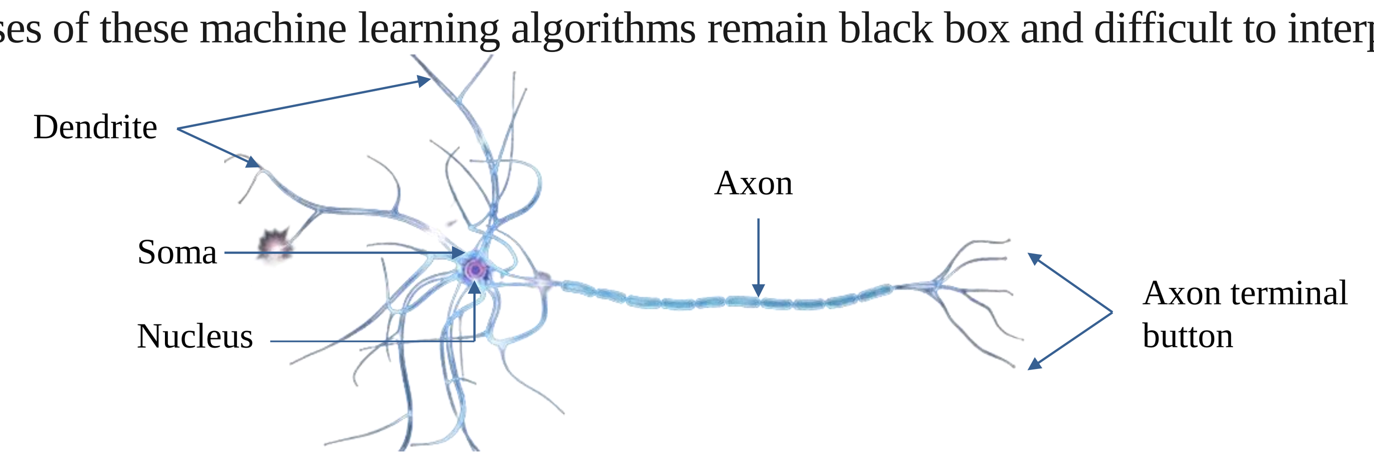
INTRODUCTION & AIM

Epilepsy is a neurological disorder characterized by recurrent, unprovoked seizures affecting around 50 million people worldwide. It involves abnormal electrical activity in the brain, leading to various symptoms such as convulsions, loss of consciousness, and sensory disturbances.

The Electroencephalogram (EEG) is a non-invasive method used to diagnose brain illnesses. While EEG recordings are essential for diagnosing epilepsy, manually detecting seizures is a lengthy process. Automated techniques are required to expedite this task; however, despite the existence of several successful methods, the decision-making processes of these machine learning algorithms remain black box and difficult to interpret.



METHOD

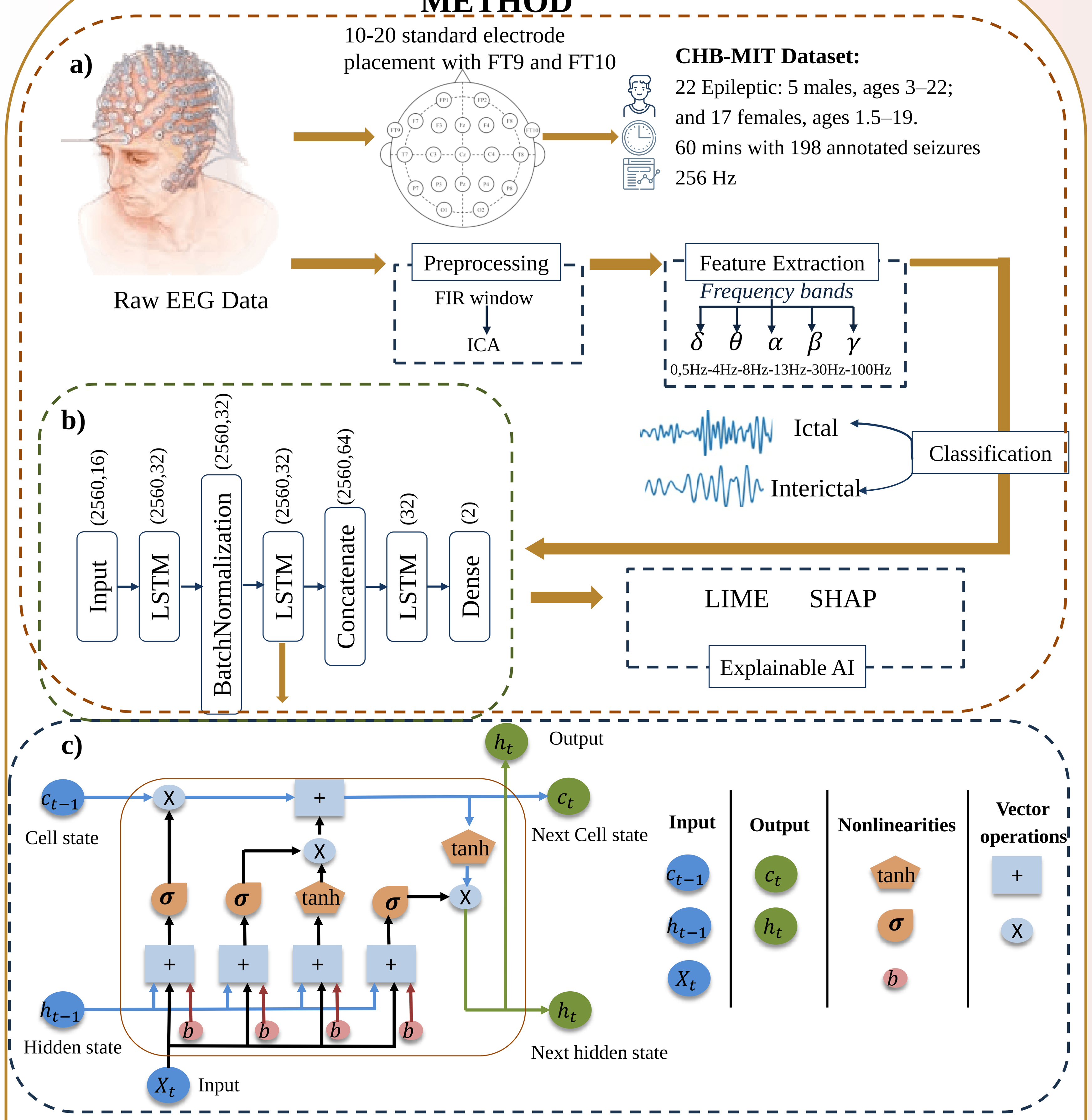
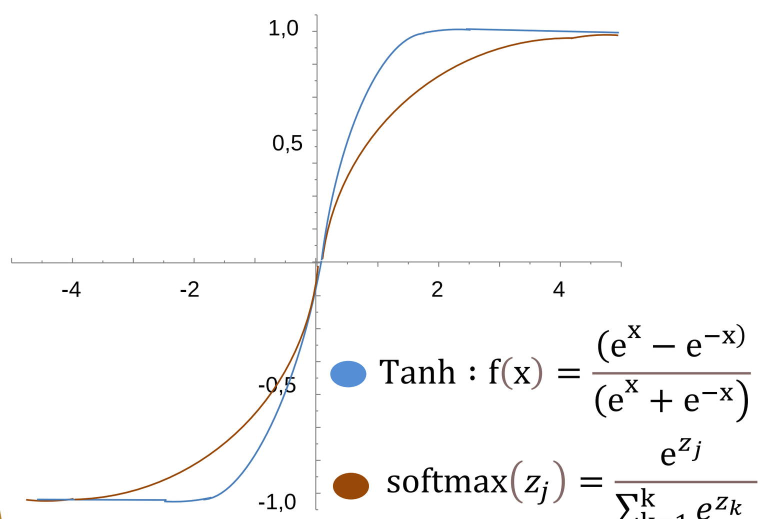


Figure.1 Proposed model. a) Block diagram of an EEG-based diagnostic system b) Long Short Term Memory (LSTM) neural network. Values in parentheses are as follows: (/number of features, number of filters). c) LSTM architecture diagram



$$\text{Tanh}: f(x) = \frac{(e^{x} - e^{-x})}{(e^{x} + e^{-x})}$$

$$\text{softmax}(z_j) = \frac{e^{z_j}}{\sum_{k=1}^{k} e^{z_k}} \quad for\ j = 1, \ldots, k$$

Figure.2 Activation Function: Tanh for LSTM layers & Softmax for dense layer

- We decomposed the preprocessed EEG signal into subbands corresponding to brain activities (alpha, beta, gamma, theta, and delta) to analyze the spatial and temporal independencies of the signal.
- We classified the decomposed output into ictal and interictal classes using our LSTM model, which effectively addressed the vanishing gradient problem.
- The main objective of this work is to evaluate the utility of explanations generated by XAI techniques, such as SHAP and Local Interpretable Model-Agnostic Explanations (LIME), in identifying epileptiform patterns in EEG signals.

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3, Bouallegue G, Djemal R. EEG person identification using Facenet, LSTM-RNN and SVM. In2020 17th International Multi-Conference on Systems, Signals & Devices (SSD) 2020 Jul 20 (pp. 22-28). IEEE.

RESULTS & DISCUSSION

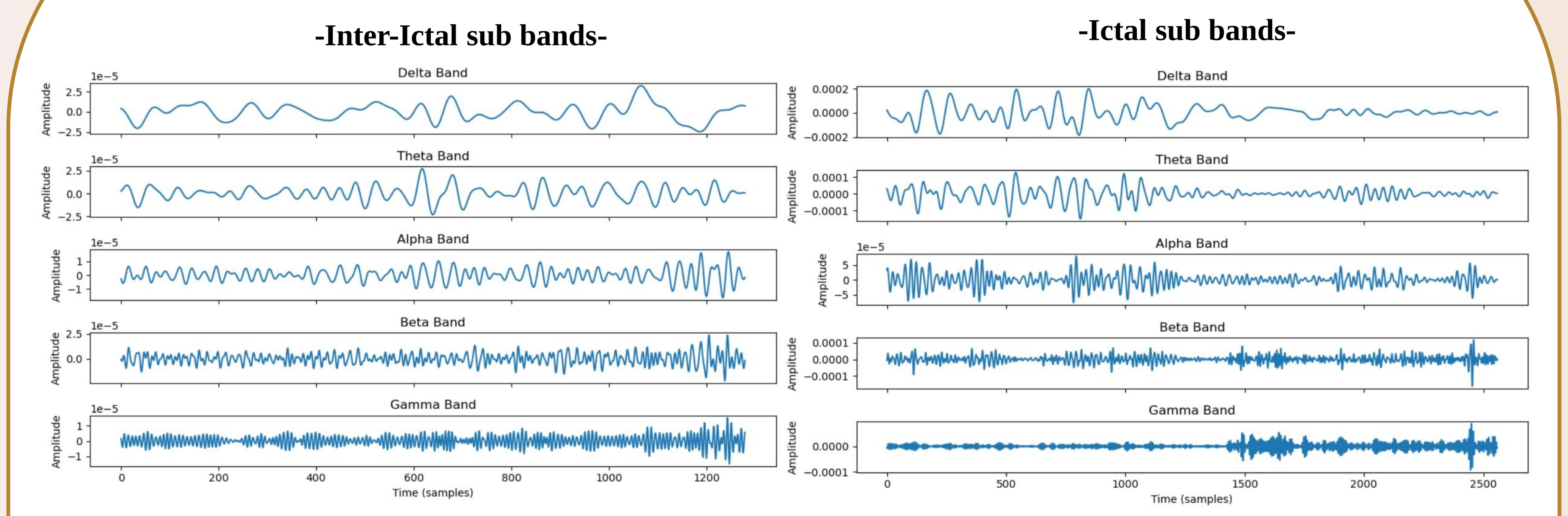

Figure. Brain Wave Decomposition: Comparison between Inter-ictal and ictal state

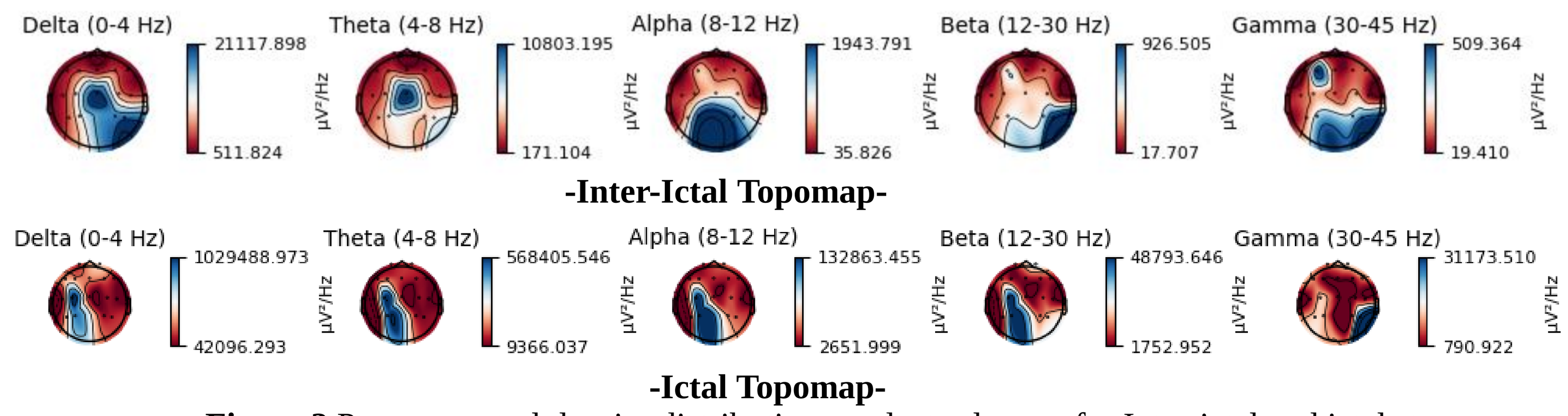

Figure.3 Power spectral density distribution on electrode map for Inter-ictal and ictal states

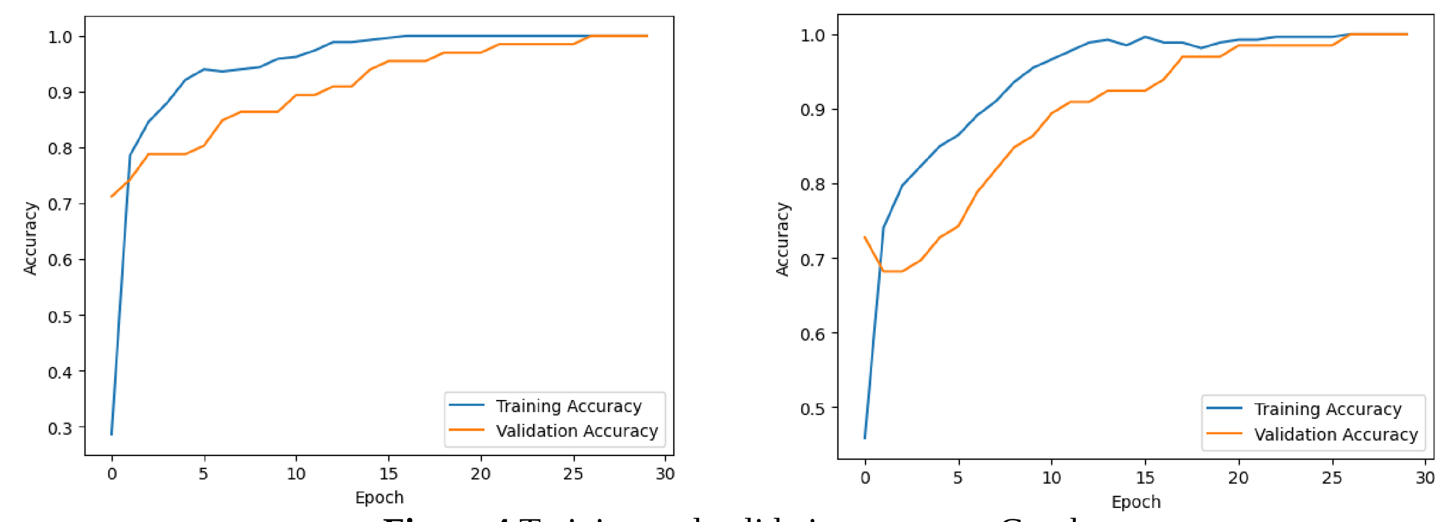

Figure.4 Training and validation accuracy Graph

Table I. Mean performance of the classification model LSTM.

Brain Activity	Accuracy	Precision	F1 Score	Recall
First Fold				
Delta δ	0,9253	1	0,96378426	0,9301
Theta θ	0,9885	1	0,98877541	0,9778
Alpha α	0,9886	1	0,98984797	0,9799
Beta β	0,9899	1	0,98989899	0,98
Second Fold				
Delta δ	0,9788	1	0,9796439	0,9601
Theta θ	0,9966	1	0,99345747	0,987
Alpha α	1	1	0,99381194	0,9877
Beta β	1	1	0,98590407	0,9722
Third Fold				
Delta δ	0,9701	1	0,97729597	0,9556
Theta θ	0,9883	1	0,98877541	0,9778
Alpha α	0,9859	1	0,98984797	0,9799
Beta β	0,9937	1	0,98995	0,9801

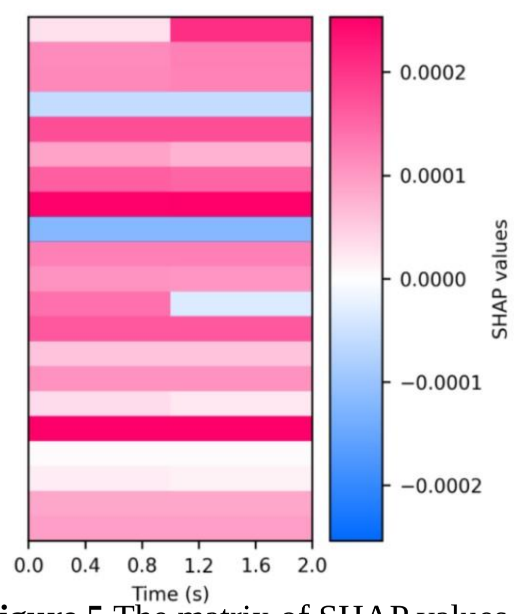

Figure.5 The matrix of SHAP values

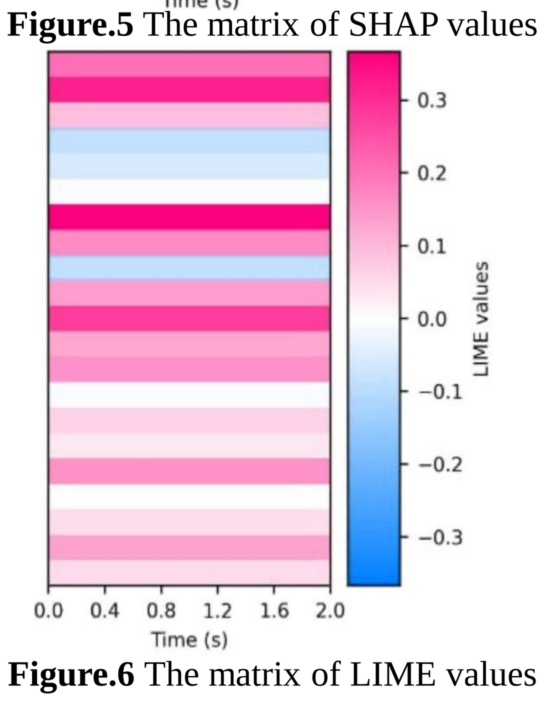

Figure.6 The matrix of LIME values

CONCLUSION

- we propose an active learning method for seizure detection for epileptic patients
- This paper evaluates the techniques of XAI in interpreting and clearing the selection of features in a black box model,

FUTURE WORK

- Incorporate an additional dataset that includes seizure subtypes to enhance the interpretation and training of our model.
- Investigate which EEG channels provide the highest accuracy in pinpointing the brain regions most affected by seizures.