Deep Learning-based EEG Analysis for Sleep Apnea Detection

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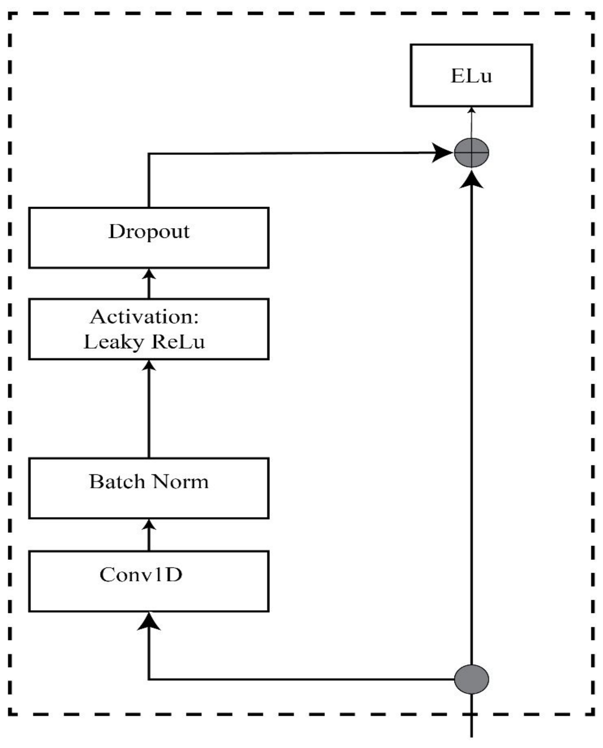
Introduction

Sleep apnea, a disorder marked by recurrent breathing interruptions during sleep, manifests in two primary forms: Obstructive Sleep Apnea (OSA) caused by physical blockage of the airway, and Central Sleep Apnea (CSA) resulting from brain signal failures. This condition significantly impacts sleep quality and overall health, necessitating accurate diagnosis by a medical professional primarily through polysomnography (PSG), an overnight procedure. However, the demand for PSG far exceeds available resources, leading to extensive wait times for diagnoses on recordings, ranging from two months to five years (Flemons et al.). This extended delay underscores the pressing need for the development of more efficient and less cumbersome diagnostic techniques to address this public health concern, ultimately improving patient outcomes and reducing healthcare burdens.

Methodology

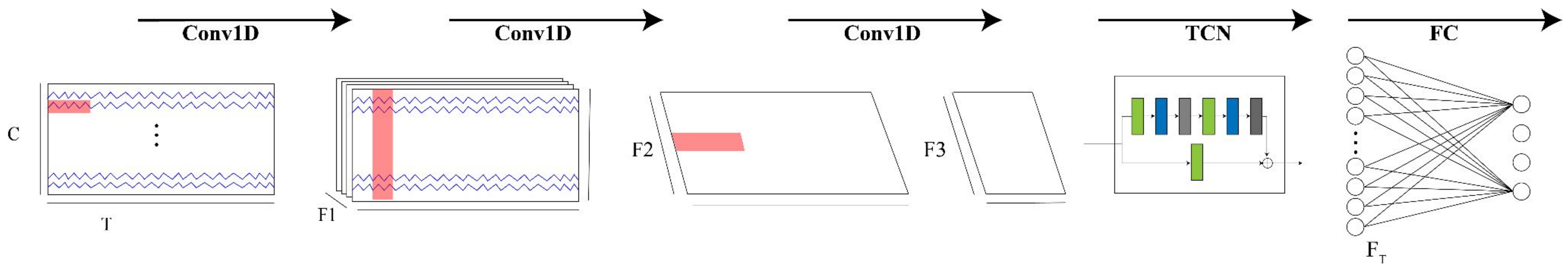
In our study, we approach the classification of sleep apnea events as a Sequence Modeling task using Temporal Convolutional Neural Networks (TCNNs). These networks excel in managing time series data by ensuring outputs for a given sequence only depend on current and previous inputs. This methodological choice aligns with our need to capture temporal patterns and dependencies inherent in EEG signals, where each interval of data we observe might contain or lack indications of apnea.

Our model architecture is carefully crafted for effective temporal data processing. It starts with several convolutional layers, learning time-dependent features, followed by our TCNN made up of residual blocks. The final fully connected layer is activated by a softmax function to transform this learning into actionable insights.



Residual Blocks

Residual blocks form the backbone of our TCNN architecture, employing a Dilated Convolutional Layer for expansive context, fortified with Batch Normalization and ELu activation, while fostering generalization through Dropout. By adding the result back to the input, our model learns weight adjustments that refine the original data directly, bypassing the need for complex linear transformations.

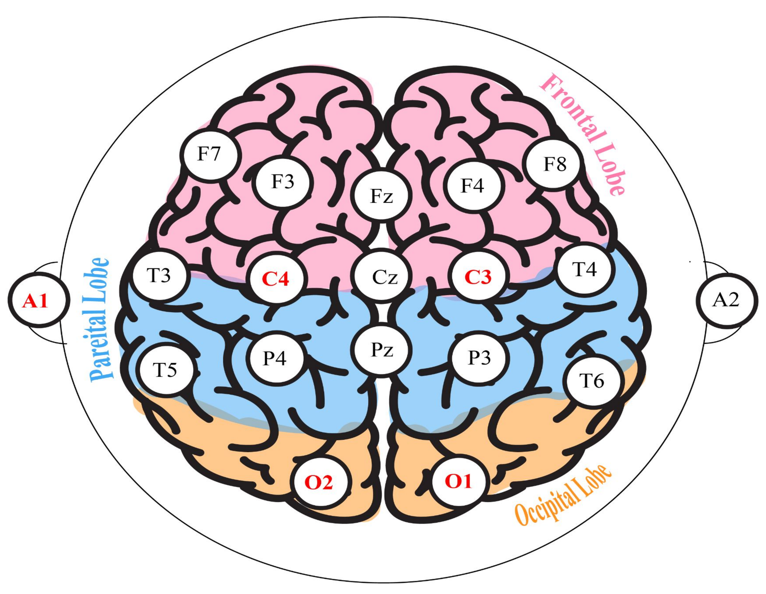


Utilizing the power of deep neural networks, an EEG-based sleep apnea detection system could help to not only reduce the costs of diagnoses but also potentially deliver them in a less invasive manner. Ultimately, we envision a future where the detection of sleep apnea is not only accurate and efficient but widely accessible, thereby enhancing patient outcomes and reducing the healthcare burden posed by this prevalent condition.

Data Summary

- **Source:** MIT-BIH Polysomnographic Database
- **Patient Information:** 16 males, 32-56 years old
- **EEG Signals Used:** C3-O1, C4-A1, O2-A1

80+ hours of EEG data divided across 18 recordings were generated through a sleep study researching Obstructive Sleep Apnea (OSA) and treatment with CPAP Machines.

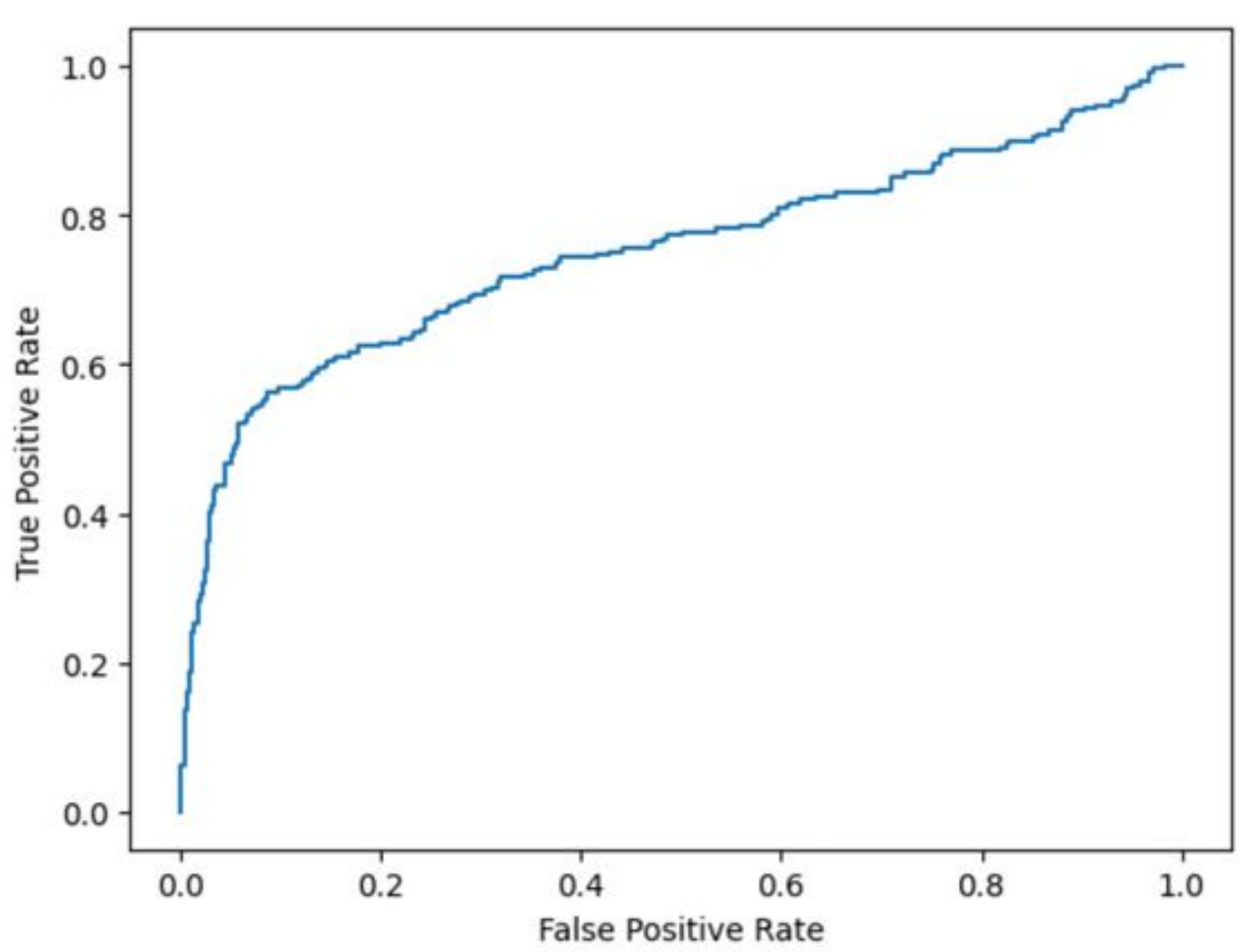


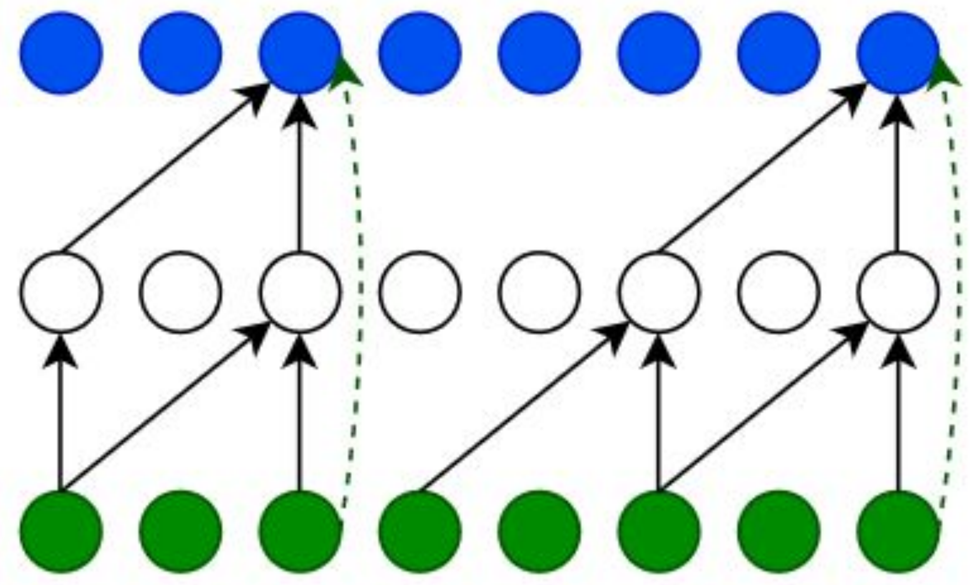
Results

After an intensive tuning process, our model produced the following results on our test patients (patient 11 and 17):

The model achieved an AUC of 0.75 and an accuracy of 85%. The below confusion matrix was generated using a cutoff threshold of 0.47.

		Predicted	
		Non-Apnea	Apnea
True	Non-Apnea	903	87
	Apnea	102	127





Dilated Casual Convolutions

Dilated convolutions act like peering through multiple lenses of varying focus, allowing deep neural networks to capture broader context while preserving computational efficiency. By strategically spacing the receptive field, dilated convolutions empower models to perceive distant relationships in data, enhancing their ability to understand complex patterns.

References

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