SleepZzNet: Sleep Stage Classification Using Single-Channel EEG Based on CNN and Transformer

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I. INTRODUCTION

Sleep stage classification is one of the most important methods to diagnose narcolepsy and sleep disorders. By analyzing the polysomnogram, which includes bioelectrical signals such as EEG and ECG, the whole night's sleep is divided into 30-second epochs, each belonging to five sleep stages: Wake, N1, N2, N3, and REM stages, according to the AASM guidelines.

As deep learning has made breakthroughs in various fields in recent years, automatic sleep stages classification tasks are also undergoing a revolution from traditional methods to deep learning methods. Currently, models combining convolutional neural networks and recurrent neural networks (e.g., LSTM) achieve state-of-the-art performance on many benchmark datasets.

II.METHODS

This paper proposes an effective deep learning model called SleepZzNet for processing end-to-end single-channel EEG signals for automatic sleep stages classification. The main contributions of this paper are as follows:

1. We propose a convolutional neural network as a feature extractor for extracting time-invariant features within epochs. This CNN network is a one-dimensional convolutional neural network that combines the advantages of ResNet and SENet.

2. We introduce the Transformer to extract temporal features over long sleep periods. Features of multiple epochs output by CNN are concatenated in temporal dimension as input to Transformer. In addition, since the Transformer uses a parallel structure, it is necessary to encode the positional relationships of epochs in the input sequence.

3. To solve the problem of unbalanced sleep stages data classes, we introduced Focal Loss as the loss function. It gives larger weights to the classes with fewer samples and focuses more on the difficult samples (e.g., N1 sleep stage) during training.

IV. DISCUSSION & CONCLUSION

In this study, we propose a new end-to-end automatic sleep stage classification deep learning model. The model takes a single-channel EEG signal as input and uses a modified ResNet-18 and SENet to extract sleep-related features during time periods, and then learns long-time sleep transition rules by Transformer. The results show that the model achieves comparable performance to other state-of-the-art results on benchmark datasets.

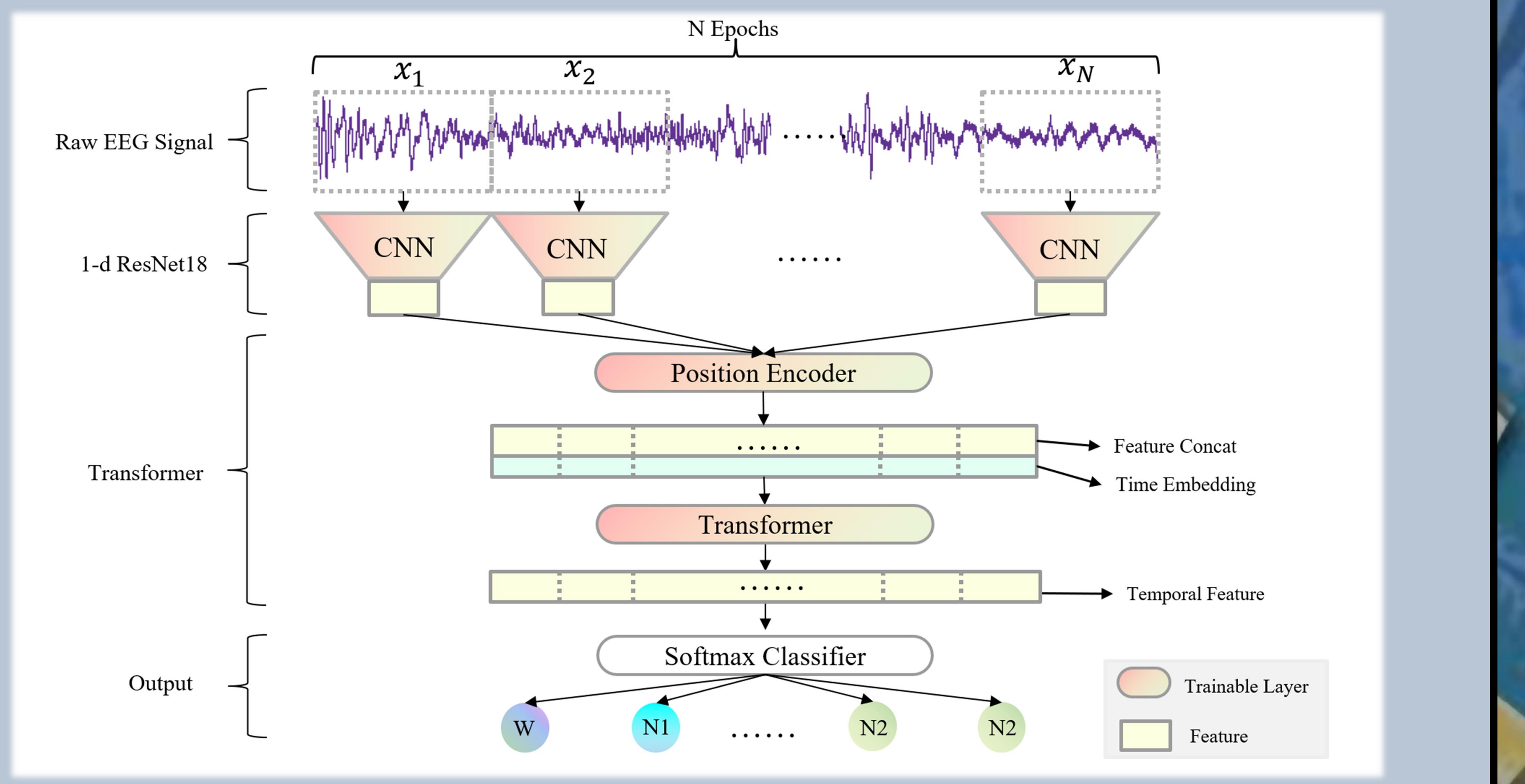

Figure 1. The architecture of SleepZzNet. Rounded rectangles indicate one or more layers in the model. Yellow rectangles indicate data features and blue rectangles indicate epochs location-encoded features. Arrows indicate the flow of data from raw single-channel EEG to the sleep stage

III. RESULTS

We used Sleep-EDF as the benchmark dataset, with data recorded from 20 healthy subjects. Table 1 shows the performance of SleepZzNet compared with other models. We only selected methods that extract features from the raw EEG signal using deep learning models.

Overall, we get an accuracy of 86.1% on the Sleep-EDF dataset and F1 scores on each class that achieves performance similar to that of state-of-the-art methods. In particular, the performance of the N1 classes has been improved.

Table I. Performance Comparison Between SleepZznet(our Methods) And Other Methods For Sleepedf Dataset Across Overall Accuracy(acc), Macro F1-score(mf1), Cohen's Kappa, And Per-class F1-score.

Methods	Overall Metrics			Per-class F1-Score				
	Acc	MF1	Kappa	W	N1	N2	N3	REM
TinySleepNet	85.4	80.5	0.8	90.1	51.4	88.5	88.3	84.3
IITNET	83.9	77.7	0.78	87.7	43.4	87.7	86.7	82.5
SleepEEGNet	84.3	79.7	0.79	89.2	52.2	86.8	85.1	85
DeepSleepNet	82	76.9	0.76	84.7	46.6	89.8	84.8	82.4
Our Methods	86.1	81	0.79	90.2	52.8	89.6	81.3	89.1