Apnea Event Classification Using Deep Learning

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Abstract

This report presents the work on classifying apnea and non-apnea events using deep learning techniques. The project utilizes the ISRUC-Sleep dataset, which contains polysomnographic (PSG) signals from healthy individuals and those with sleep disorders. The goal is to develop an automated system for detecting apnea events from respiratory signals.

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1 Introduction

1.1 Background

Sleep apnea is a severe sleep disorder characterized by interruptions in breathing during sleep. Polysomnography (PSG) is the gold standard for diagnosing sleep apnea. This report explores deep learning, specifically Temporal Convolutional Networks (TCNs), to automate the detection of apnea events from PSG data.

1.2 Problem Statement

This project aims to classify apnea and non-apnea events from PSG signals, facilitating an automated and accurate diagnostic tool. The computerized classification system aims to provide quicker, scalable solutions to identify sleep apnea. Also, the goal is to check the minimum number of channels required to classify events with high accuracy within AASM guidelines for non-intrusive or less intrusive classification.

1.3 Objectives

This project aims to:

- Preprocess the ISRUC-Sleep dataset for model training.
- Implement a Deep Learning model for apnea event classification.
- Evaluate the model's performance.

2 Literature Review

2.1 Overview of Sleep Apnea Detection

Sleep apnea detection traditionally involves the manual scoring of PSG signals. Recent advancements have focused on automating this process using various signal processing and machine learning techniques.

2.2 Deep Learning in Medical Signal Processing

Deep learning models, especially Bi-Directional Long Short Term Memory Networks (LSTMs) and Temporal Convolutional Networks (TCNs), have shown promise in processing time-series data like PSG signals. These models can automatically learn relevant features from raw data, eliminating the need for manual feature extraction.

2.3 Previous Work on Apnea Detection

Several studies have utilized machine learning and deep learning methods for detecting sleep apnea, particularly through features such as oxygen saturation (SpO2) and airflow. Notable works include:

- *Towards automatic home-based sleep apnea estimation using deep learning* [1]

- *Deep learning for obstructive sleep apnea diagnosis based on single channel oximetry* [2]

3 Methodology

3.1 Dataset

The ISRUC-Sleep dataset contains PSG recordings from healthy subjects and those with sleep disorders. The dataset includes respiratory signals such as SpO2 and abdominal and nasal airflow, which are essential for apnea event detection.

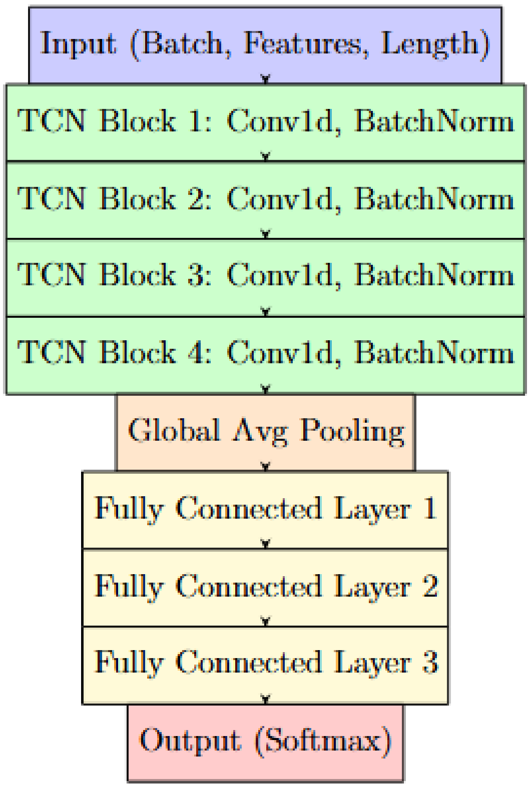
3.2 Data Preprocessing

The preprocessing steps include:

- Cleaning: The annotations files had contaminated columns which were cleaned using regex and string matching. And later used for segmentation.
- Filtering: A bandpass filter (Respiration and Airflow Signals: 0.1 Hz - 0.5 Hz; SaO2: 0.05 Hz-2.0 Hz) is applied to remove noise and retain relevant respiratory frequencies.
- Signal Extraction: Relevant signals like SaO2 and abdominal, thoracic, and nasal airflow are extracted from the raw data.
- Segmentation: The data is divided into windows corresponding to apnea and non-apnea events of 30 seconds as done by the expert annotators.
- Normalization: Data is normalized to ensure consistency across subjects.

3.3 Model Architecture

The Temporal Convolutional Network [3] (TCN) is used for this project. TCNs are chosen due to their ability to handle sequential data, making them well-suited for time-series classification tasks such as apnea detection.



3.4 Training and Evaluation

The model is trained using a training set and evaluated using a validation set. Performance metrics such as accuracy, precision, recall, and F1 score are used to assess the model's effectiveness.

4 Results

4.1 Model Performance

The TCN model achieves an accuracy of 90.89% on the validation set. The confusion matrix and other performance metrics are presented below:

4.2 Challenges and Limitations

Key challenges include handling missing or noisy data and ensuring consistency across the dataset due to different signal lengths and qualities. Also, the human-level annotation is bound to have some errors; thus, ensuring high-quality labels was another challenge. Limiting the number of examples to high-quality input would mean less number of examples, which affects the model training.

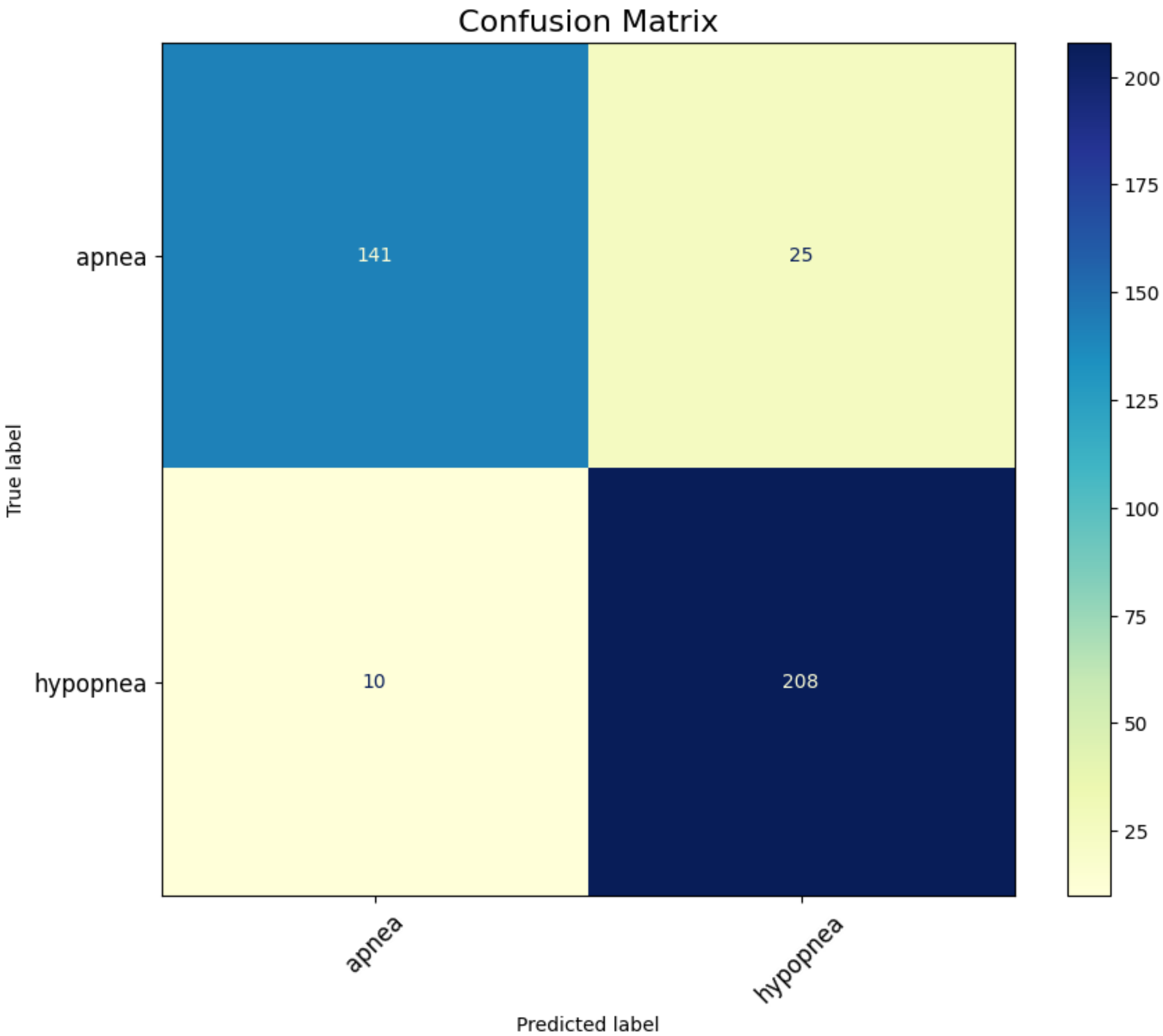


Figure 1: Confusion Matrix for Model Evaluation

5 Discussion

5.1 Interpretation of Results

The TCN model demonstrates significant promise in automating the classification of apnea events. The results suggest deep learning methods can effectively apply to PSG signal analysis.

5.2 Future Work

Future work will focus on refining the model, using a combination of metadata and signal features to improve the accuracy. Also, machine learning models were experimented with to build on the prediction of the TCNs for further classification into specific types of apnea(s).

Using this knowledge to predict Sleep Stages and eventually build a model that can do this in real time.

6 Conclusion

This project successfully demonstrates deep learning techniques, specifically Temporal Convolutional Networks, for classifying apnea events from PSG data. The results indicate the potential of automated systems in aiding the diagnosis of sleep apnea.

7 References

References

[1] Retamales, G., Gavidia, M.E., Bausch, B. et al., *Towards automatic home-based sleep apnea estimation using deep learning.*, Nature Medicine, 2024, link.

[2] Levy, J., Álvarez, D., Del Campo, F. et al., *Deep learning for obstructive sleep apnea diagnosis based on single channel oximetry.*, Nature Communications, 2023, link.

[3] Colin Lea, Rene Vidal, Austin Reiter, Gregory D. Hager, *Temporal Convolutional Networks: A Unified Approach to Action Segmentation*, arXiv:1608.08242, 2016, link.