CS598 SP25 Project Proposal – Recreation of “Bringing At-home Pediatric Sleep Apnea Testing Closer to Reality: A Multi-modal Transformer Approach” (Fayyaz et al. 2023)

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Introduction

The goal of this project is to utilize a Large Language Model (LLM) to reproduce a research paper focused on computational healthcare. The target paper, “ Bringing At-home Pediatric Sleep Apnea Testing Closer to Reality: A Multi-modal Transformer Approach” (Fayyaz et al.. 2023), aimed to explore potential computational tools for use in the diagnosis of pediatric obstructive sleep apnea/hypo-apnea syndrome (OSAHS).

Pediatric obstructive sleep apnea is a sleep-related disorder in which periods of intermittent obstruction of the upper airway occur during a child’s sleep, which can lead to significant adverse health effects. (Gupta et al . 2024). This disorder can affect ~ 1-5% of children between ages 5 and 8. The authors of the original paper identified a gap in studies performed on pediatric OSAHS, despite a significant amount of literature on adult sleep apnea. The aim of the original method was to continue to expand the efficacy and potential for diagnostic methods for pediatric OSAHS, increasing the availability of accessible diagnostic methods for providers to help children with this condition.

Methodology

The study uses a transformer-based architecture with five components including: data sources, segmentor, tokenizer, transformer, and multi-layer perceptron head. The data sources will include signals such as ECG and SpO2. The segmentor will divide the signals into smaller fixed-length epochs. The tokenizer converts the segmented data into a set of time series that can be processed by the transformer. The transformer has a multi-head attention module and a position-wise fully connected network. The multi-head attention module computes attention scores between tokens which the position-wise fully connected network will apply non-linear transformations. The multi-layer perceptron head is the final layer which is a two-layer fully connected layer that will output a probability score for likelihood of apnea-hypopnea event. The baselines are from four studies on adult apnea detection: CNN, Fusion, CNN+LSTM, and Hybrid Transformer. They used 2 evaluation metrics: F1-score and AUROC. First, using both data sources they compared F1-score and AUROC of the baselines to their model. Second, the F1-score and AUROC of subsets of 1 and 2 PSG signals is compared to when all 6 signals is used. Finally, using NCH dataset the AUROC scores of the baselines is compared to their model across different age brackets from ages 0 to 18.

The paper proposes a multi-modal transformer based transformer based architecture designed for pediatric patients since current detection systems are specifically designed for adults and are less effective on children. Another thing it addresses is the feasibility of this test to be done at-home instead of in a clinic.

Their main hypothesis is by using a transformer-based architecture, we can use the combination of ECG and SpO2 signals and have comparable sleep apnea event detection in children to fully lab-based PSG testing in adults. Their method is better than baselines because the transformer model's attention module handle temporal context and interaction between modalities better. The multi-modal approach is more resilient to noise and variability to PSG. Additional data such as comorbidities associated with sleep apnea or audio recordings might improve outcomes. Their hypothesis seems legitimate as the AUROC and F1-score of their model outperforms baseline models on the two data sources used. Also, the combination of ECG and SpO2, which are easier to collect at home, have comparable results to a full PSG test.

Data Access and Implementation Details

The original paper utilized two datasets, the Nationwide Children's Hospital Sleep DataBank (NCH), and the Childhood Adenotonsillectomy Trial (CHAT) datasets. These datasets supply the necessary polysomnography data as well as additional characteristic data for children aged 0-6 years. Access to this data is requested through the governing bodies which manage the datasets (National Sleep Research Resource [NSRR] and BioLINCC respectively). The authors also maintained a repository for the developed codebase[3] which will be used to aid in the recreation in this project. This repository contains all code used to generate the model used in the paper, which will be used to recreate the results. Additionally, the code used to preprocess the datasets will be identical in this recreation to maintain the same conditions of the original computations.

As shown in the original report, there are approximately 4000 patients on which sleep studies were performed. With the modalities of data collected (EEG, EOG, ECG, SpO_2, $ETCO_2$), there is a significant amount of data for which to process. Every attempt will be made to utilize the same portion of the dataset as the original paper, though a subset of the data will be taken if necessary to mitigate extensive computation time.

REFERENCES

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