BioWaveNet

A Novel Multi-Scale Convolutional Neural Network for Generalized Bio-signal Applications

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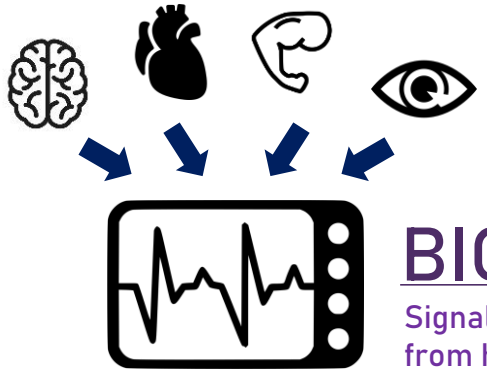
Background & Inspiration



BIO-Signal

Signal data collected from human organs

Difficulties

Require Clinical Expertise with **Substantial Medical Knowledge**

Automations

Feature engineering-based machine learning algorithm to aid clinicians

Limitations

Current feature engineering algorithms are **too rigid** and take **high-domain knowledge** to develop, while being **too specific on a single task**

How can we develop a bio-signal analysis idea/prototype to generalize on different signals?

Our tasks

BIO-Signals

Choose 2 signals that cover other signals characteristics

→ Electrical Signals (electrodes)

→ Non-electrical Signals (light, kinetics)

Choose important signals and tasks

1. Electroencephalography (EEG-Brain) + Seizure Detection
   - EEG = main measure for epilepsy
   - Over 100 million epilepsy patients worldwide
   - Help doctors screen hours of EEG recording
2. Photoplethysmography (PPG-Blood) + Respiratory Rate Estimation
   - PPG = easily collected from smartwatches
   - Respiratory rate can screen abnormal breathing on COVID-19

Datasets

EEG

Bonn dataset (n=5)

- 3 classes (can predict pre-seizure)

CHB-MIT (n=23)

- Medical cohort (most complete)

TUSZ (n=28)

- Many devices used (most varied)

PPG

Capnobase (n=42) and BIDMC (n=52) datasets

- ICU dataset (most complete)

WESAD Dataset (n=15)

- ICU dataset (realistic usage)

Our study covers a larger amount of datasets than others to show demonstrate our robustness

Experiment Protocols

(A) Subject Dependent : Trained and tested on the same patients

(B) Subject Independent : Tested on unknown patients (LOOCV)

(C) Transfer Learning : Weights are pre-trained among datasets

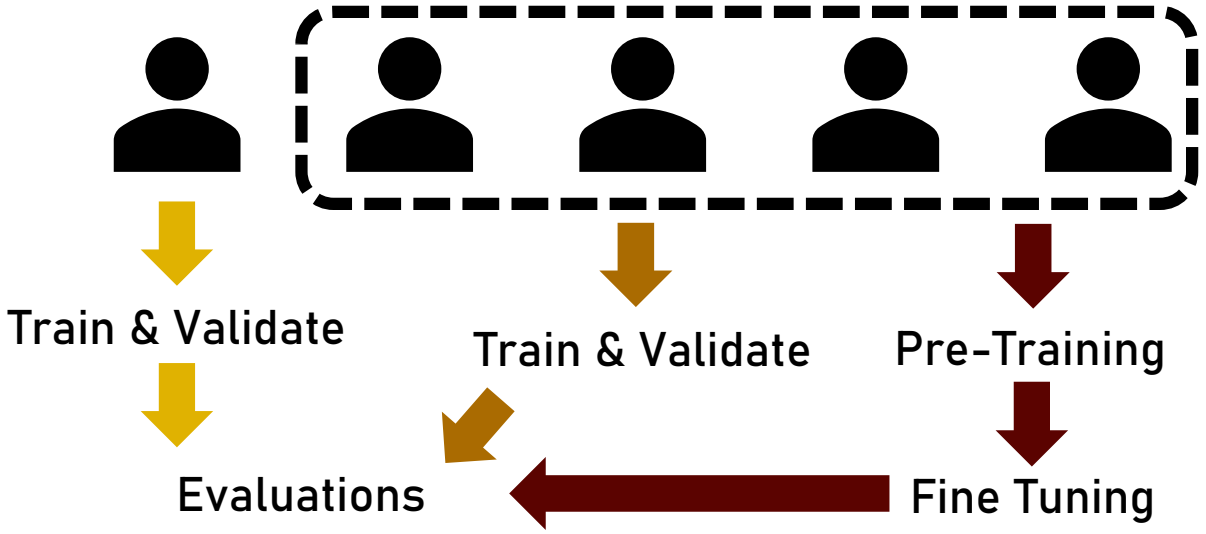
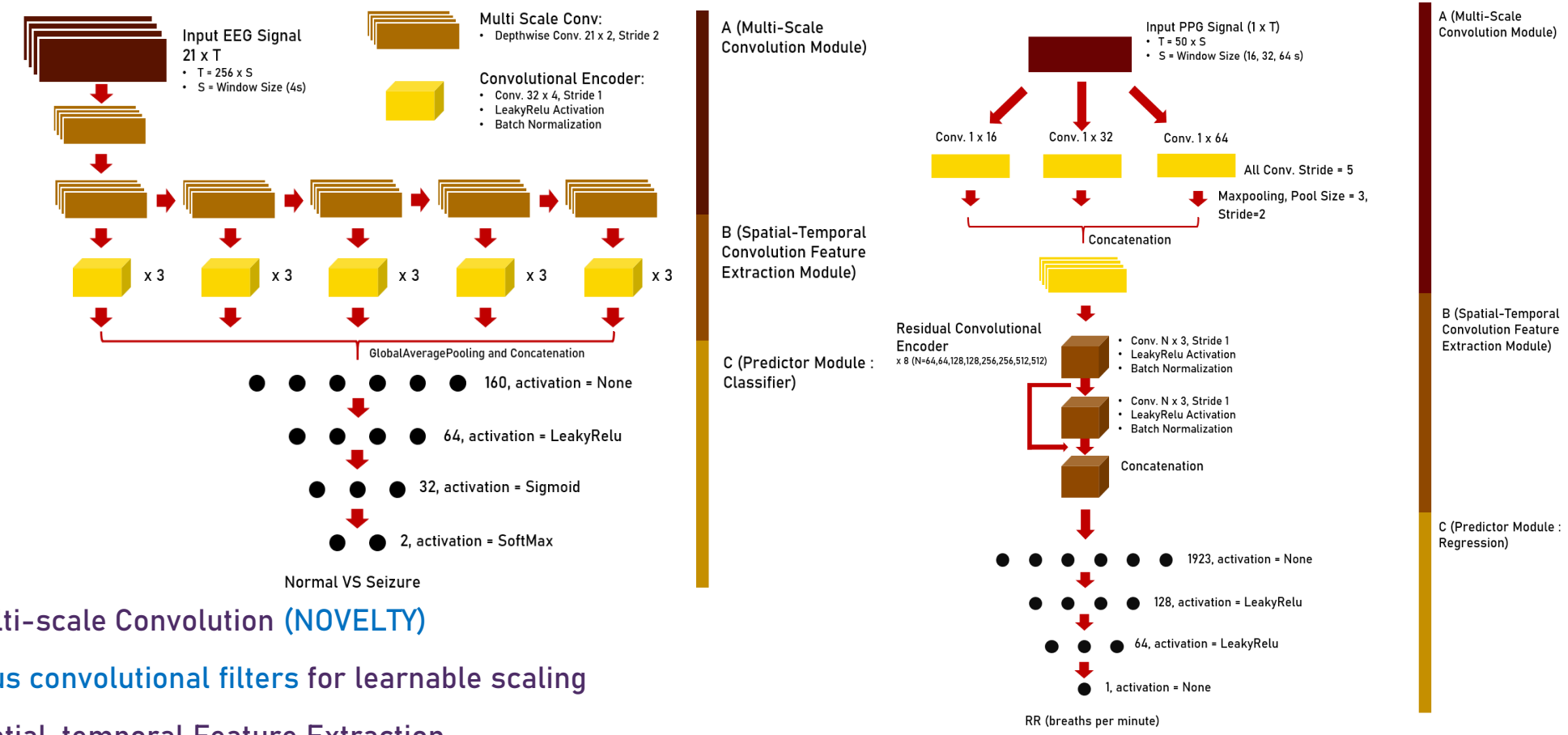


Figure 1 : Experimental Setups (all experiments used 5-fold cross validation)

BioWaveNet – EEG and PPG



(A) Multi-scale Convolution (NOVELTY)

: various convolutional filters for learnable scaling

(B) Spatial-temporal Feature Extraction

: CNN to analyze signal patterns from (A)

(C) Multilayer Perceptron

: Output Network

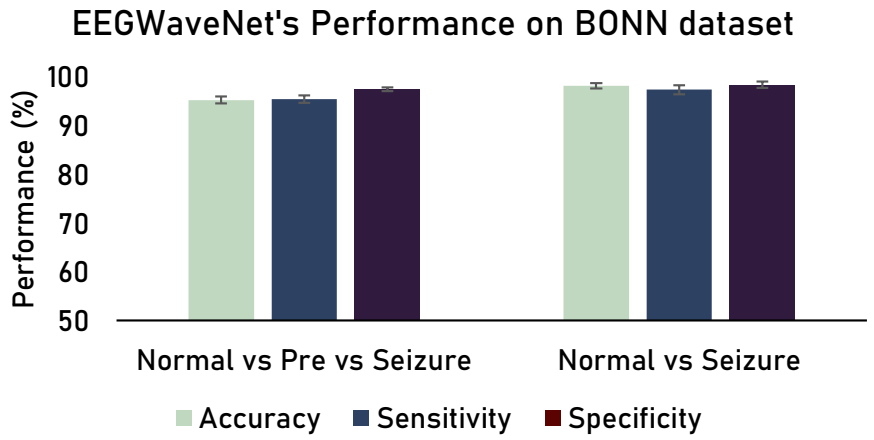
(i) Hyperband for hyperparameter tuning

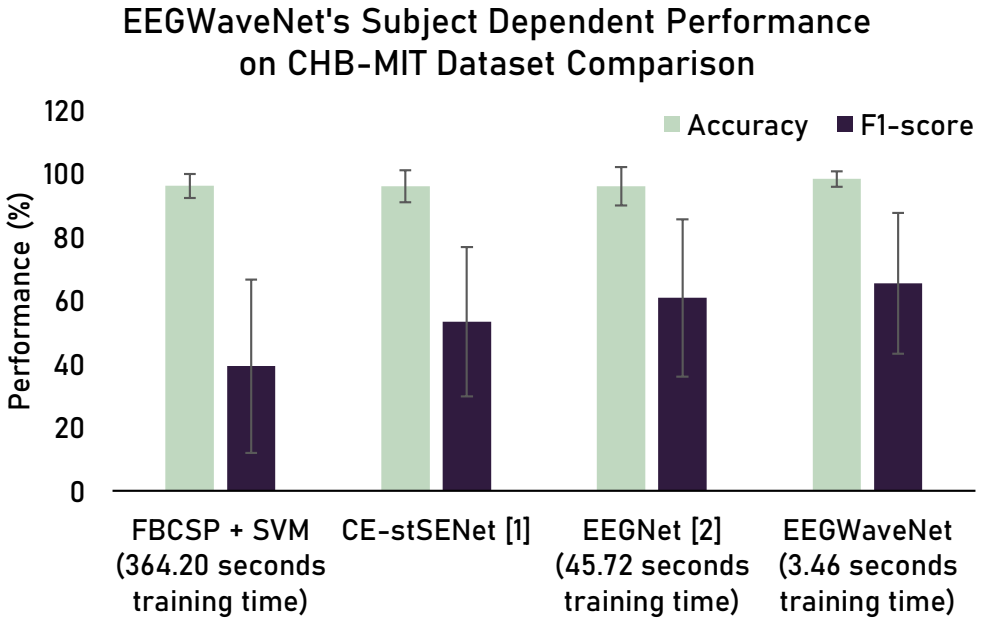
(ii) AdaBelief optimizer with 0.001 learning rate (0.25 decay – 5 patience)

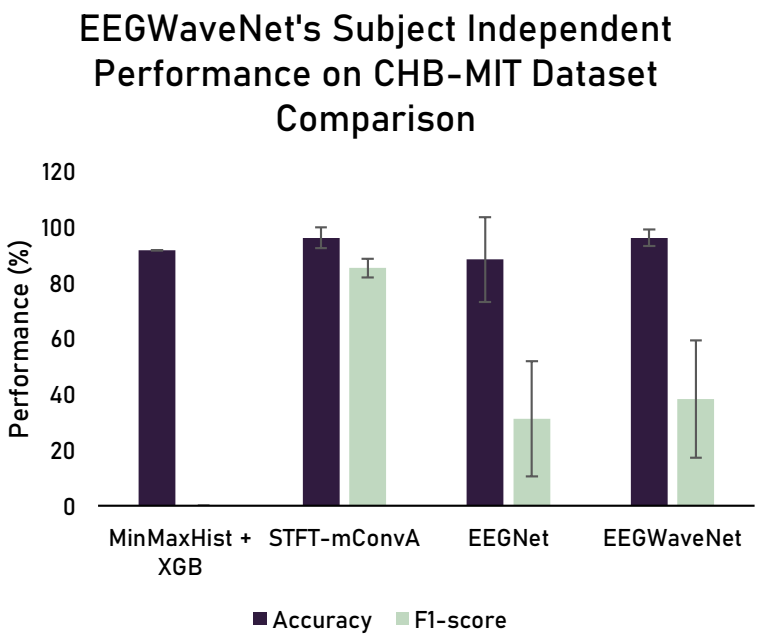
(iii) Earlystopping after 10 consecutive epochs

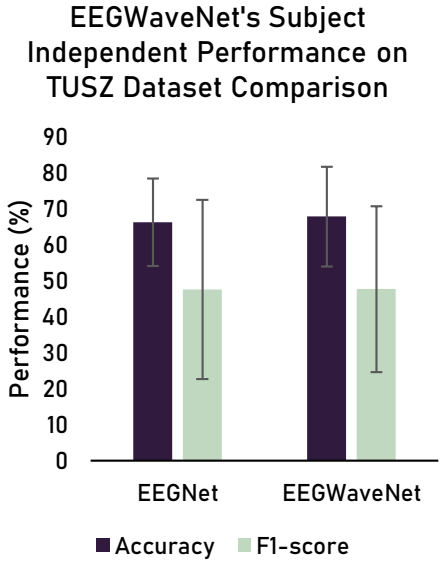
(iv) Cross Entropy (classification) and MSE (regression) loss

EEG Seizure Results





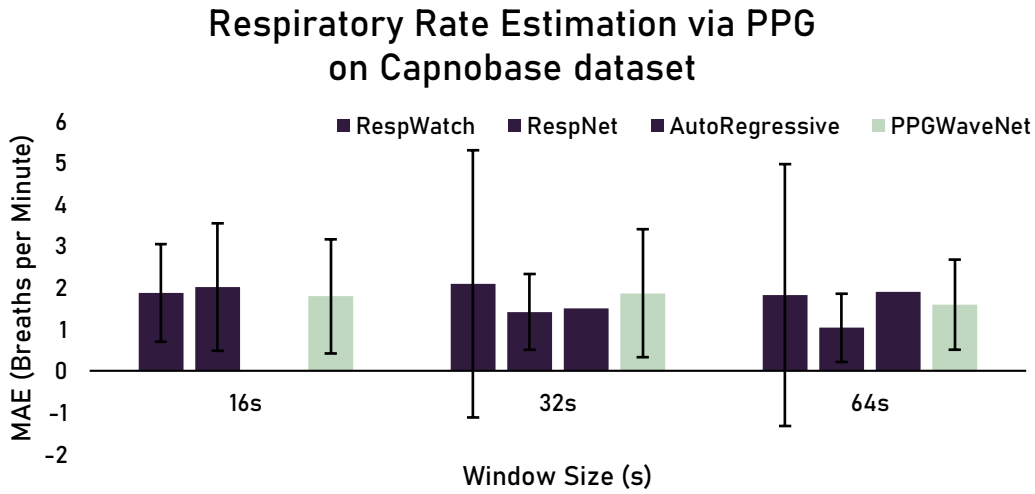


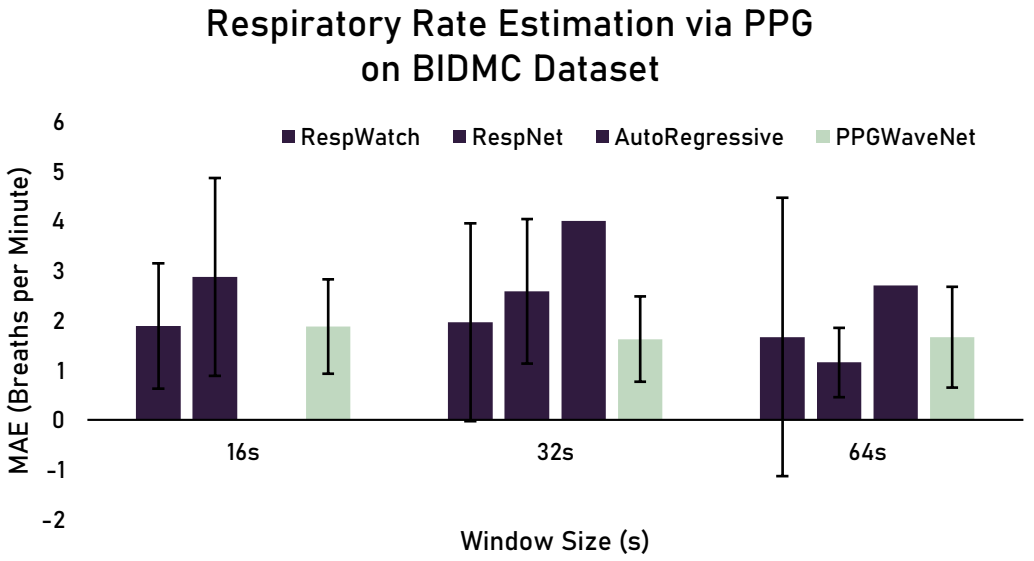


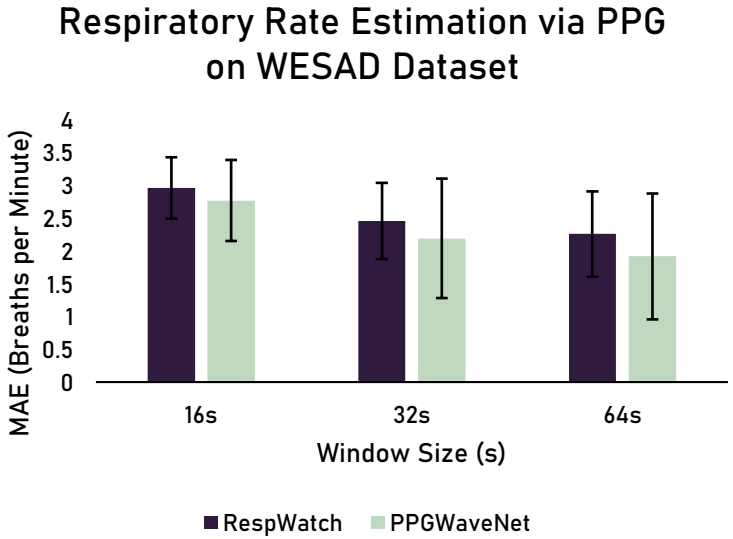
Findings (Dependent) : EEGWaveNet achieves the best performance while trains the fastest, due to faster fitting to minimal loss

Findings (Independent) : EEGWaveNet outperforms the SOTA (EEGNet) while achieving reasonable starting performance before transfer learning

PPG Respiratory Results



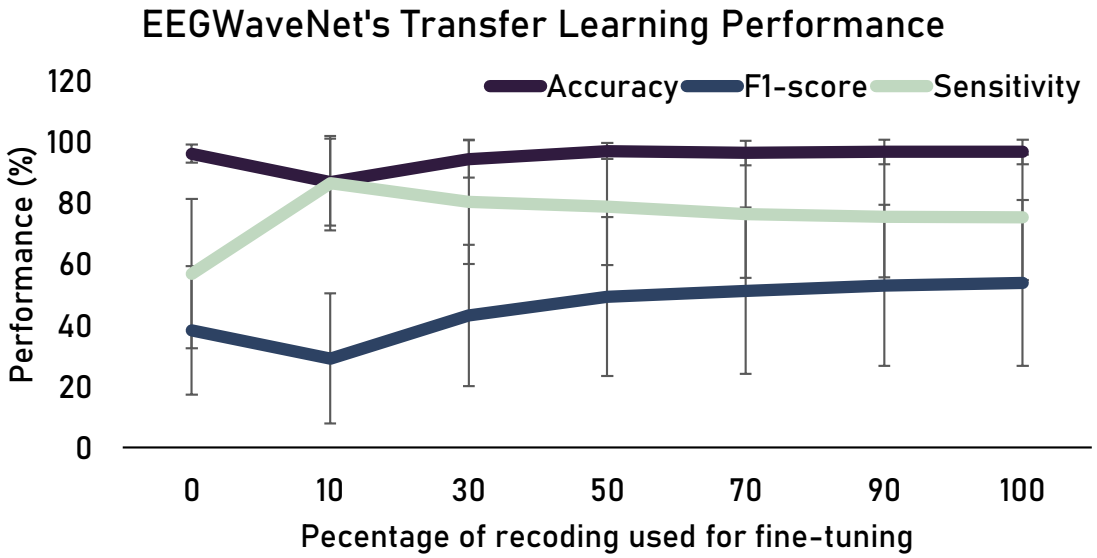


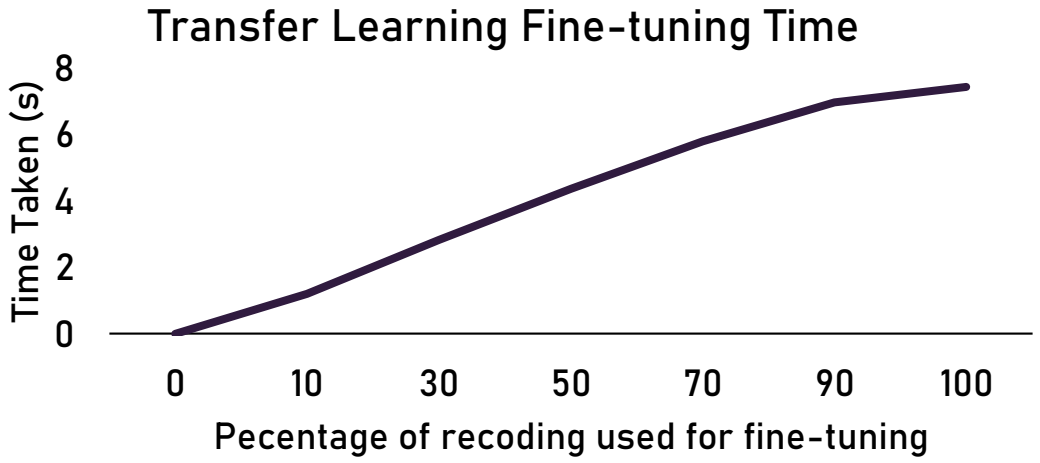


Findings (1) : PPGWaveNet achieves the best performance on 16 seconds – the smallest window size (model can infer up to 60 seconds after!)

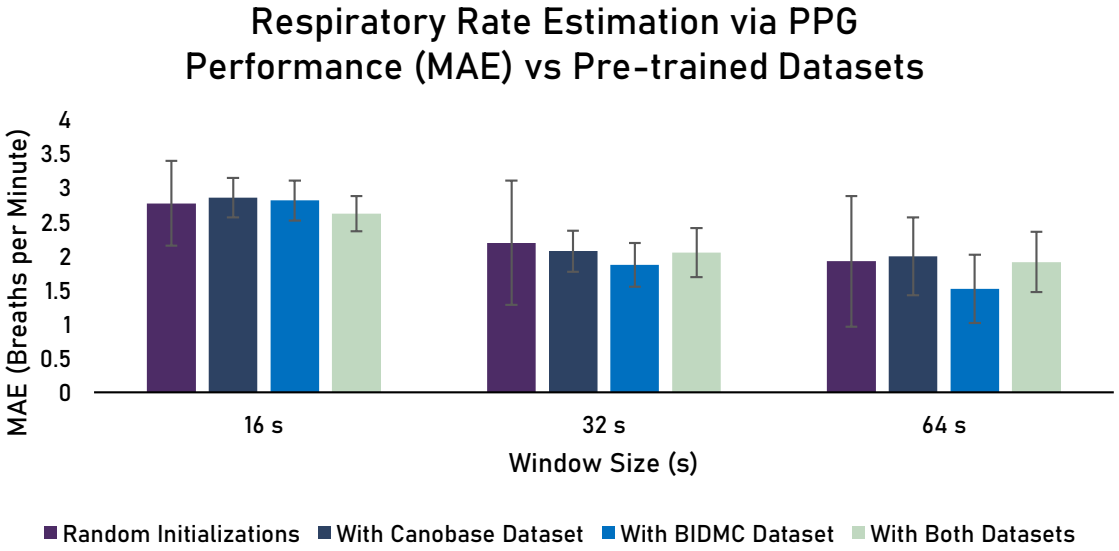
Findings (2) : When compared the model size, PPGWaveNet is the smallest and works on all dataset

Transfer Learning Results





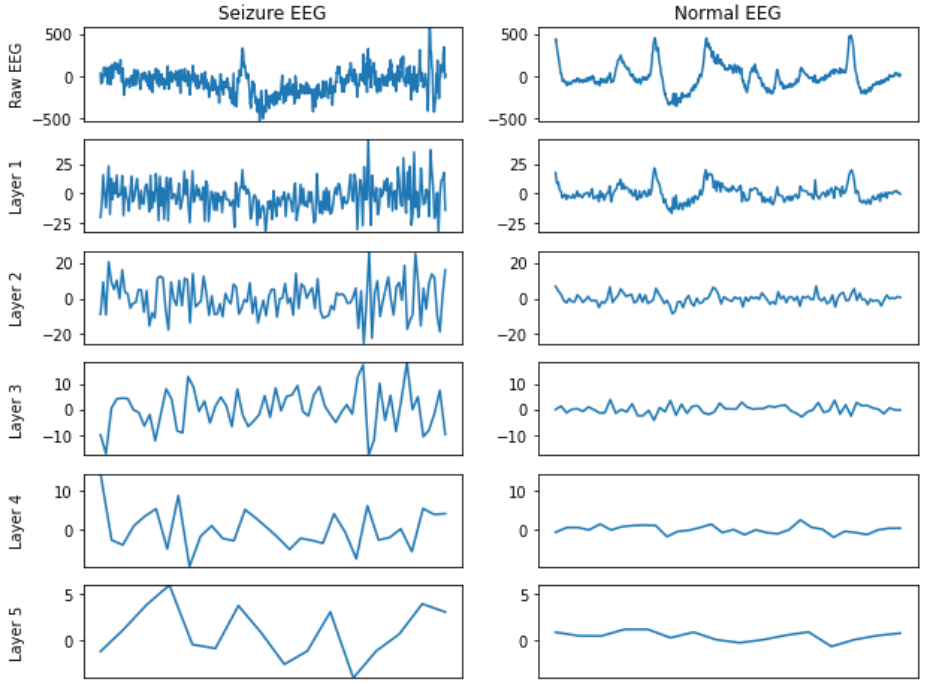
Findings (EEG) : Transfer learning with 1-hour fine-tuning data can adjust our performance boost within 10 seconds of fine-tuning.



Findings (PPG) : Transfer learning from an ICU dataset can reduce the error when trained again on the WESAD (wearable device) dataset

Discussions

EEGWaveNet's Generated Scales

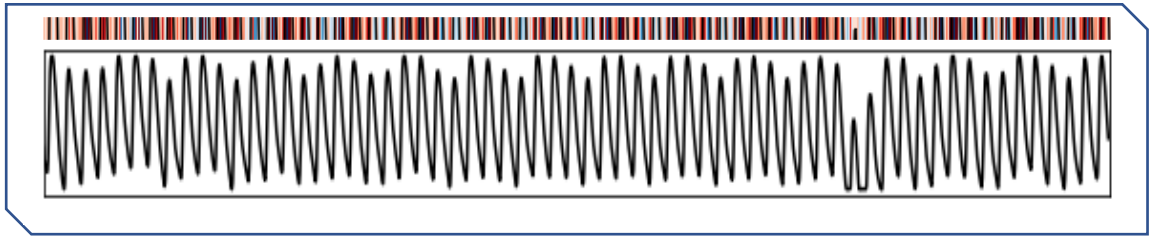


Findings (EEG) : Seizure (left) and normal (right) EEG are further discriminated when passed through the multi-scale module

Findings (PPG) : SHAP values are shown in P-peaks that corresponds medically to respiratory rate.

Findings (Overall) : Our multi-scale module allow for a smaller yet more effective model, while transfer learning boost performances.

PPGWaveNet's SHAP explanation



Impacts and Conclusions

Generalized Bio-signal Model
We successfully create a generalized system for bio-signal applications, and showcased on 2 tasks.

Transfer Learning Experimental Protocol
We proposed transfer learning protocols that deal with the lack of data, which can be applied in hospitals

EEG Seizure Detection
Our model can be developed into a screening application for seizure diagnosis, potentially saving 100 millions epilepsy patients

PPG Respiratory Rate Estimation
Our model can screen abnormal breathing remotely, potentially allowing telemedicine on COVID-19 patients through a smartwatch.

References

UNDER CONSTRUCTION, WILL BE REVISED AND DONE IN THE NEXT DRAFT!!!!