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Real-time preictal detection through the application of machine learning to Electroencephalogram signals.

Final Major Project

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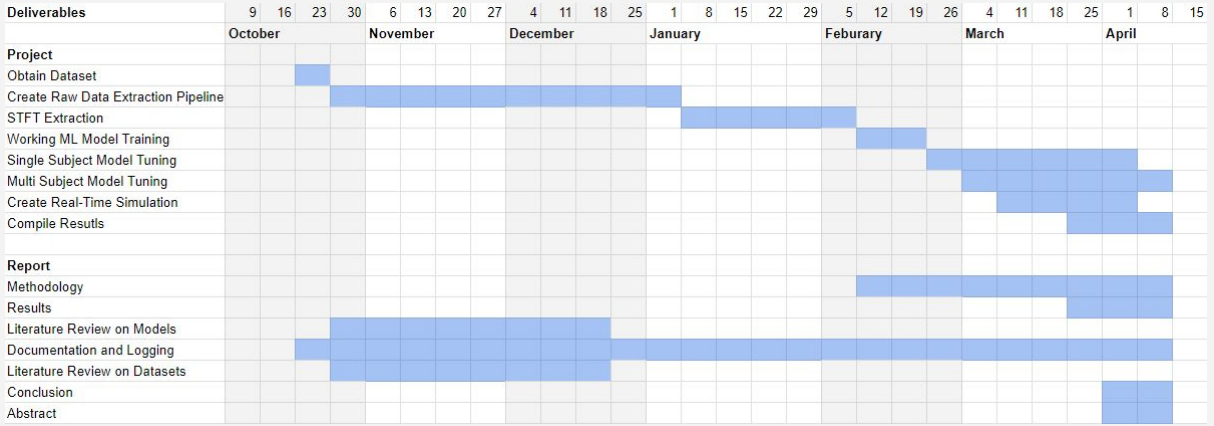
Contents

Epilepsy

- “Epilepsy is one of the most common serious brain conditions, affecting over 70 million people worldwide.” - Thijs, R.D., Surges, R., O'Brien, T.J. and Sander, J.W., 2019. Epilepsy in adults. The Lancet, 393(10172), pp.689-701.
- “One third of people with epilepsy will not have adequate seizure control with the current medications [available Antiepileptic Drugs (AEDs)]. For these patients the situation has improved very little in the last few decades” - Galanopoulou, A.S., Buckmaster, P.S., Staley, K.J., Moshé, S.L., Perucca, E., Engel Jr, J., Löscher, W., Noebels, J.L., Pitkänen, A., Stables, J. and White, H.S., 2012. Identification of new epilepsy treatments: issues in preclinical methodology. Epilepsia, 53(3), pp.571-582.
- “Of those treated with AEDs, 35% become resistant to medication” - Moghim, N. and Corne, D.W., 2014. Predicting epileptic seizures in advance. PloS one, 9(6), p.e99334.
- “There is an urgent need for more effective and better-tolerated treatments to control drug-resistant seizures, as well as for innovative therapies to prevent, stop, or reverse the development of epilepsy and epilepsy-related comorbidities” - Löscher, W. and Schmidt, D., 2011. Modern antiepileptic drug development has failed to deliver: ways out of the current dilemma. Epilepsia, 52(4), pp.657-678.

Order of Work

- Emphasis on literature review findings instead of personal experiments.
- Increased the time allocated for hyper-parameter tuning due to the training times for a single model.
- Added time to allow for further developments, such as subject agnostic model training or node configuration tuning.



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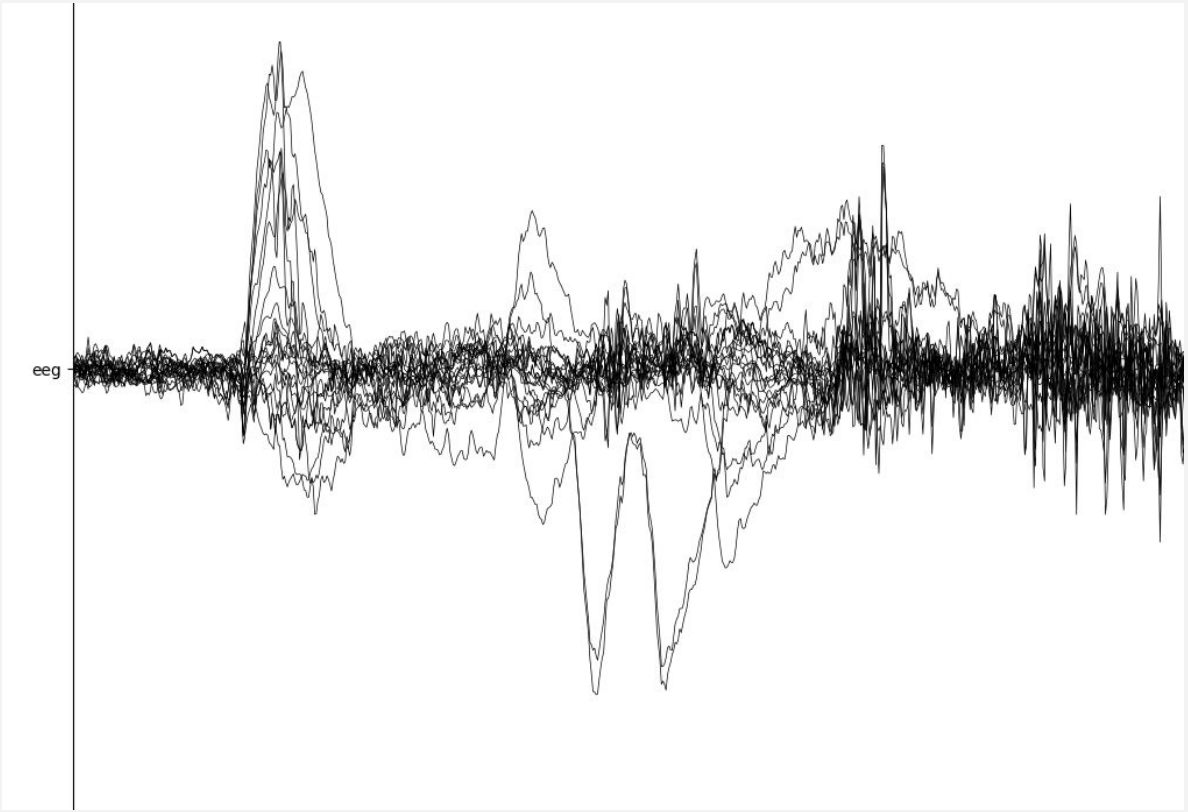
The Solution

CHB-MIT EEG

- 23 unique subjects.
- 10-20 International System for Scalp EEG.
- 17 common channels between all subjects.
- Continuous recordings with labeled seizure times.
- Open source; hosted through Google Cloud.



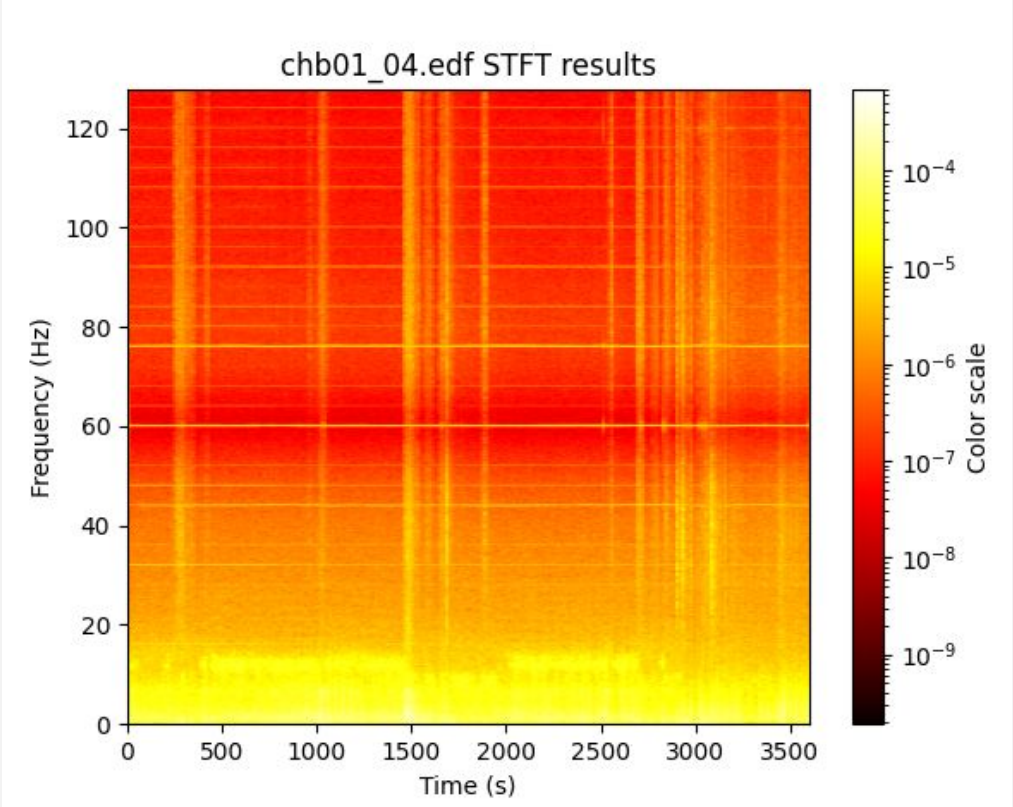
A Butterfly representation of subject 1's EEG recording.
https://github.com/N3utra1/COMP6013_Dissertation.git

Boston Children's Hospital
Until every child is well™

Preprocessing

- Short-time Fourier transform.
- Band Pass Filter.
- Class balancing.
- Approach influenced by “Convolutional neural networks for seizure prediction and scalp electroencephalogram”.

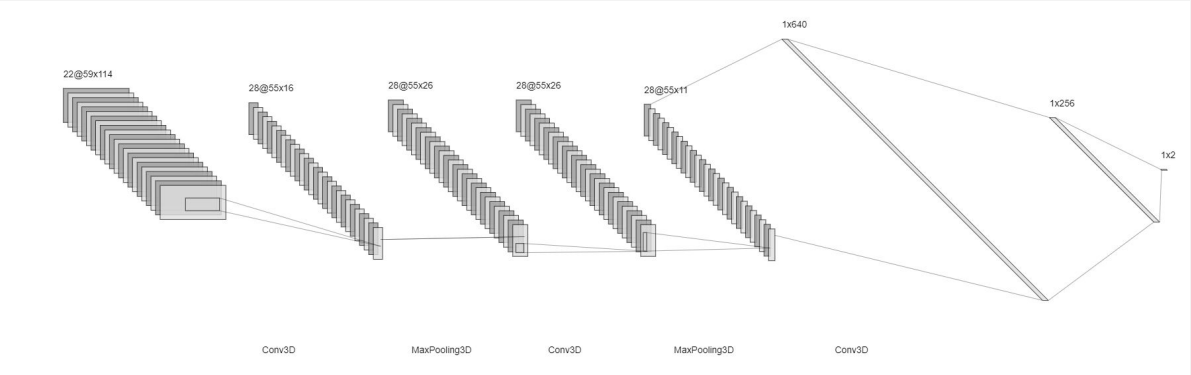
Truong, N.D., Nguyen, A.D., Kuhlmann, L., Bonyadi, M.R., Yang, J., Ippolito, S. and Kavehei, O., 2018. Convolutional neural networks for seizure prediction using intracranial and scalp electroencephalogram. Neural Networks, 105, pp.104-111.



Heat map of a Short-time Fourier transform result. Seizure between 1467-1494 seconds..
https://github.com/N3utra1/COMP6013_Dissertation.git

The Convolution Neural Network

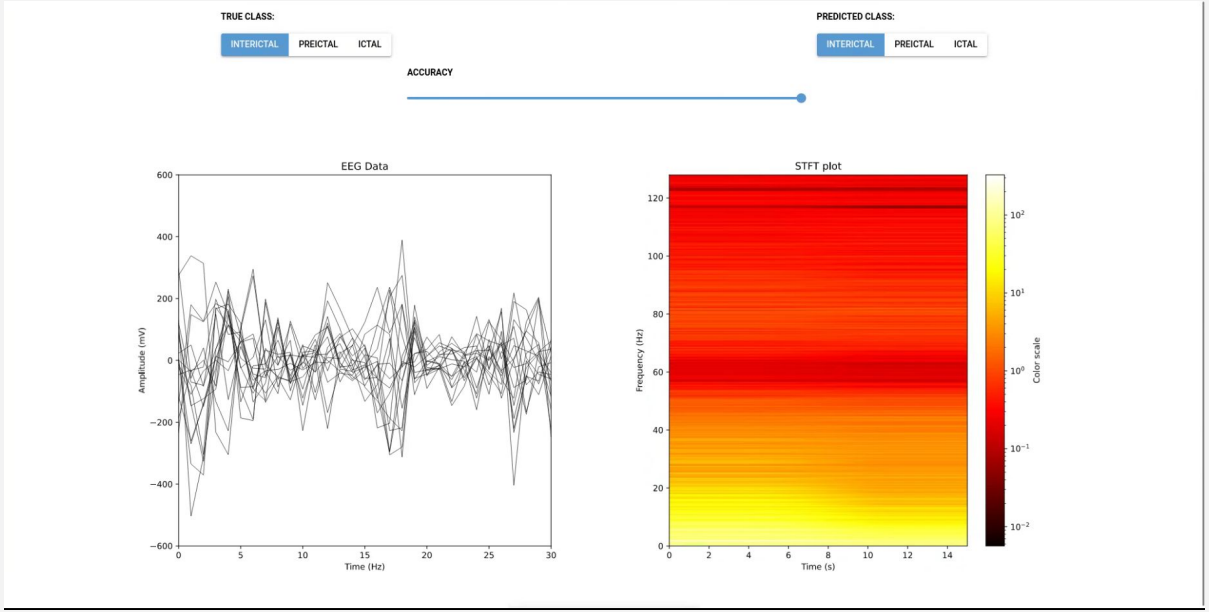
- The CNN is created using Python 3 along with the TensorFlow and Keras.
- The solution is an image recognition approach to the problem.
- CNN model architecture has been tuned, along with the hyper-parameters.



Representation of an model architecture. Created using https://alexlenail.me/NN-SVG/LeNet.html

Real Time Simulation

- Shows the preprocessing pipeline's ability to run in real-time.
- User selects an class in the top left and the model shows it's prediction in the top right.
- The plot on the left shows the last 30 seconds of raw EEG data. 256 new data points for each EEG node arrive each second.
- The right plot is the STFT spectrogram image being inputted into the ML model.



Model Results

- Models trained against a single subject's data, allowing the CNN to pick up on their characteristics.
- The models were tested against 20% of the dataset (unseen).
- 14 models were perfect models with 100% accuracy against the test dataset.
- This shows the potential this approach has for real-time preictal prediction.

Model	Training Accuracy	Training Loss
2.4.128/16.1	0.9832265377044678	0.8224268555641174
2.4.128/16.32	0.9993602503091097	0.02814496521023102
2.4.128/16.8	0.9976428672671318	0.11281578045975693
2.4.128/32.1	0.975464940071106	1.4378010034561157
2.4.128/32.32	0.9989679381251335	0.04745509265126133
2.4.128/32.8	0.9962754622101784	0.18717686411091886
2.4.128/48.1	0.9669219255447388	2.318654775619507
2.4.128/48.8	0.9958652406930923	0.2898520281258925
2.4.64/16.1	0.9799447655677795	0.6853911876678467
2.4.64/16.32	0.9992593247443438	0.024666143968849415
2.4.64/16.8	0.9969331100583076	0.08956567873635081
2.4.64/32.1	0.9619211554527283	1.725386619567871
2.4.64/32.32	0.9987660832703114	0.05414362490514908
2.4.64/32.8	0.9953247904777527	0.21542102738881397
2.4.64/48.1	0.9655154347419739	2.379462718963623
2.4.64/48.32	0.9989125896245241	0.07438817310655671
2.4.64/48.8	0.994374118745327	0.31704871635884047

Table 24: Accuracy and Loss metrics (average across epochs) during model training.

Results table taken from report.

Model key: [convolution block count].[dense layer count].[dense layer size]/[batch size].[epochs]

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Wrapping up

Future Advancements

- Tuning STFT parameters.
- Further tuning of model architecture.
- Testing different EEG node configurations.
- “From a large number of recent studies, it is clear that BCI is an up-and-coming research area.” - Zabcikova, M., Koudelkova, Z., Jasek, R. and Lorenzo Navarro, J.J., 2022. Recent advances and current trends in brain‐computer interface research and their applications. International Journal of Developmental Neuroscience, 82(2), pp.107-123.