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

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Introduction

"A seizure is a burst of uncontrolled electrical activity… that causes temporary abnormalities in muscle tone or movements, behaviors, sensations or states of awareness." (Medicine n.d.). "Persistent seizures constitute a considerable burden on healthcare resources." (Assi, Nguyen, Rihana & Sawan 2017). Therefore "An automated accurate prediction of seizures will significantly improve the quality of life of patients and reduce the burden on caregivers" (Acharya, Hagiwara & Adeli 2018). As uncontrolled electrical activity causes seizures, a method has been devised that applies image recognition through the use of machine learning to images generated from EEG data. This method can be run in real-time, outputting a prediction each second, with the ability to predict seizures up to 20 minutes before onset.

Literature

10 datasets, 6 models, and 10 preprocessing pipelines were evaluated. Results varied with a preprocessing pipeline using "Distribution of Wavelet Coherence" along with a CNN (Mirowski et al. 2009) obtaining some of the highest results.

Another approach was using a pre-processing pipeline with Short Time Fourier Transforms (Truong, Nguyen, Kuhlmann, Bonyadi, Yang, Ippolito & Kavehei 2018). This achieved respectable results of 81.4% sensitivity and 0.06 false positives/hour.

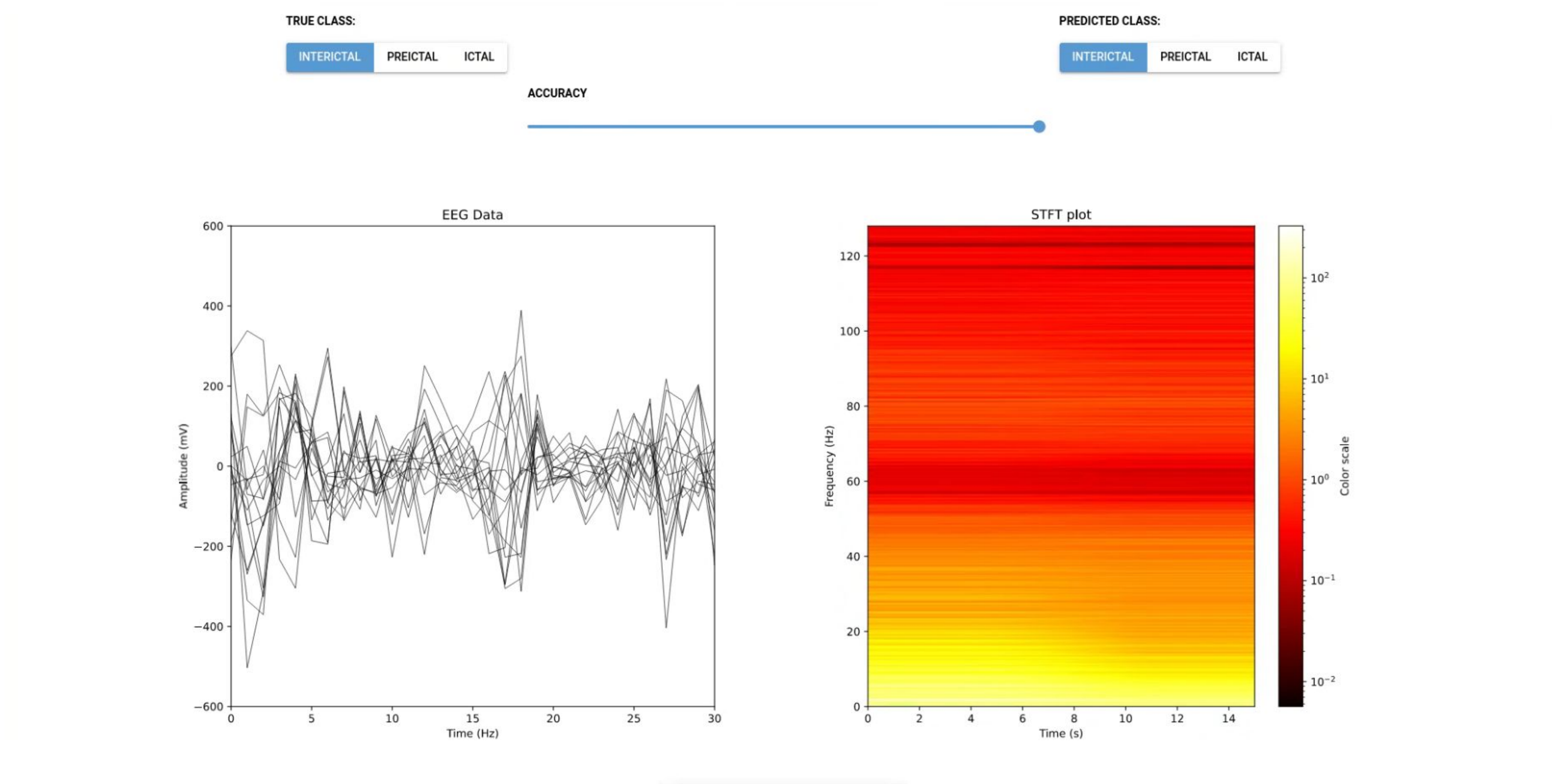
Ethical Issues

As this project is only training ML models ethical issues are very small, however, if this is embedded in a seizure prediction system the false positive rate will have to be very low; if the system alerts the user and is incorrect, it will cause a large amount of unneeded stress for the end user as they prepare for a seizure which has been incorrectly predicted.

Methodology

This project used a Short-Time Fourier-Transform which creates an image from the electrical signals in the brain, recorded with an EEG. Interference is then removed by using a notch filter. For training the machine learning models, data was synthesized by using a sliding window method to balance the dataset, however, for prediction, the images can be directly fed into a model which classifies the results.

The project was programmed in Python 3 and used TensorFlow and MNE as the main libraries.



Real Time Simulation. EEG data left, Spectrogram (STFT) image right. Model's predicted class top right.

Results

This project has trained over 15 models which obtained 100% accuracy during testing. These models are trained against an individual, allowing the neural network to pick up on their specific characteristics. Any of these models can then be used in conjunction with the real-time simulation which has also been developed.
The real-time simulation displays the model's ability to classify the current state of the subject each second, alerting the subject if a seizure is imminent. This shows the potential this project has to greatly alleviate stress for people suffering from seizures.

Conclusions

This project was able to achieve its objectives, developing a model with an accuracy >90%, along with a preprocessing pipeline that can process the raw data in under a second. The research and development done allows for many future advancements;

- Tuning STFT window parameters directly changes the properties of the model's input images.
- Implementing online learning, such that the model is trained against a subject at all times, further reduces false positives and inaccurate predictions.
- EEG Node configurations should also be tested, possibly showing that the same results can be obtained by using fewer EEG nodes.

With hindsight and more time, other preprocessing pipelines and ML model types would have been integrated into the solution. As the code is open source, structuring the code such that anyone could integrate the future advancements discussed above would allow for many different variable configurations to be tested against many different model types and preprocessing approaches.

References

https://drive.google.com/file/d/1VGSPdRVlAAZp02pls3qw4FANiYk2peBG/view?usp=sharing

https://github.com/N3utra1/COMP6013_Dissertation