Seizure Detection in Epilepsy Patients using Machine Learning Algorithms

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ABSTRACT

Epilepsy is a neurological condition that makes individuals more prone to suffer from seizures. There are over 50 million people who suffer from this condition today[1], making it the fourth most common neurological disorder[2]. Seizures, the primary feature of this disease, start with abnormal electrical activity in the brain and can manifest themselves through lapses in attention and memory, sensory hallucinations, or whole-body convulsions. Electroencephalography (EEG) is a test that measures the electrical activity in the brain and has been extensively used in the field of seizure onset detection. The primary focus of this project is to develop a patient-specific machine learning algorithm that, given a set of EEG data, can classify whether or not an event is a seizure in the shortest amount of time. This will be accomplished through the utilization of MATLAB and Simulink for feature extraction and MATLAB's Linear Support Vector Machine classifier. At the end of the project, an algorithm was created which had a seizure accuracy rate of 69%, a non-seizure accuracy rate of 98%, and a latency period of 0.48 seconds when tested on an hour of EEG data.

BACKGROUND

- The processing of EEG data (Figure 1) follows a general outline of preprocessing, feature extraction and selection, and classification
  - These steps aim to make it easier for researchers to draw trends from the noisy EEG waveforms (Figure 2)
- Preprocessing aims to refining and ordering raw EEG data
  - This is done with band stop filters which remove high frequency noise
- Feature extraction and selection highlights the imperceptible information in the still chaotic wave forms
  - EEG data is filtered into their respective frequency bands[3]: delta (1-4 Hz), theta (4-8 Hz), alpha (8-13 Hz), beta (13-35 Hz), and gamma (35-100 Hz)
  - Each of these frequencies outline different types of brain activity
  - The power level of these frequency bands change rapidly during a seizure
- With these features, one can apply statistics to show trends in the data
- A machine learning classification algorithm, which can make predictions based on the features given to it, can be created

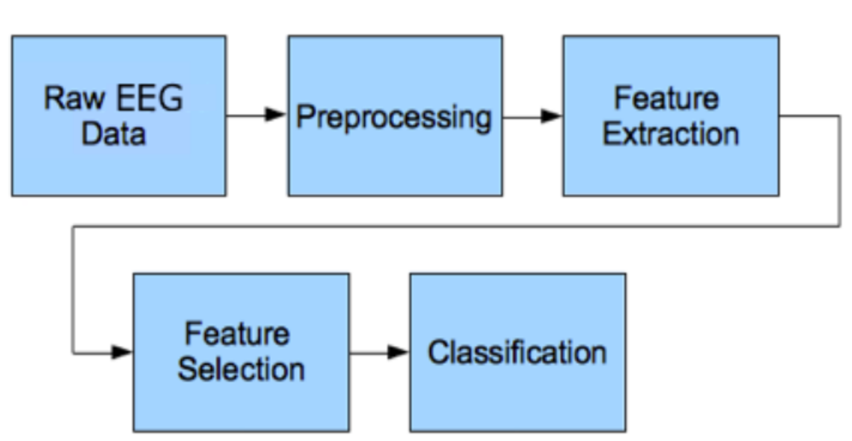
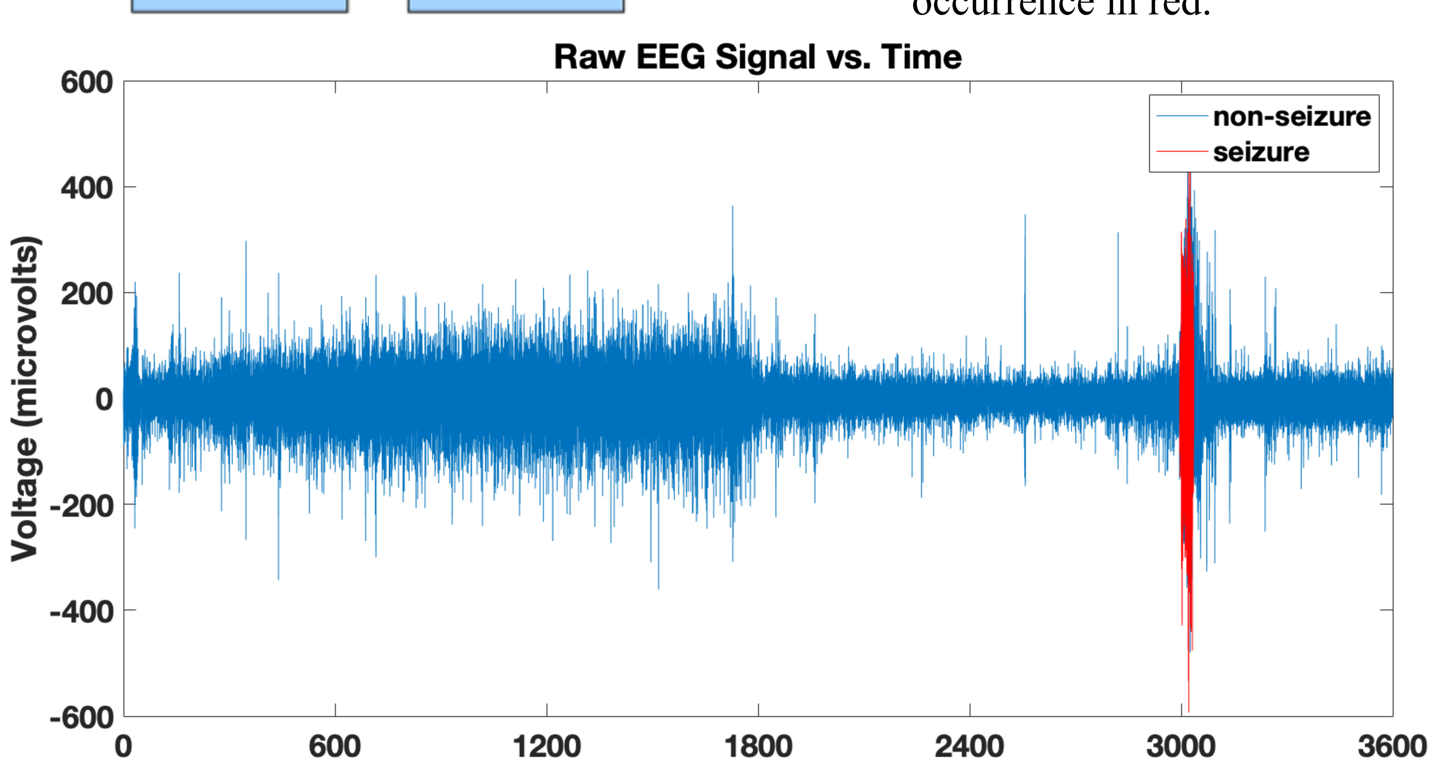


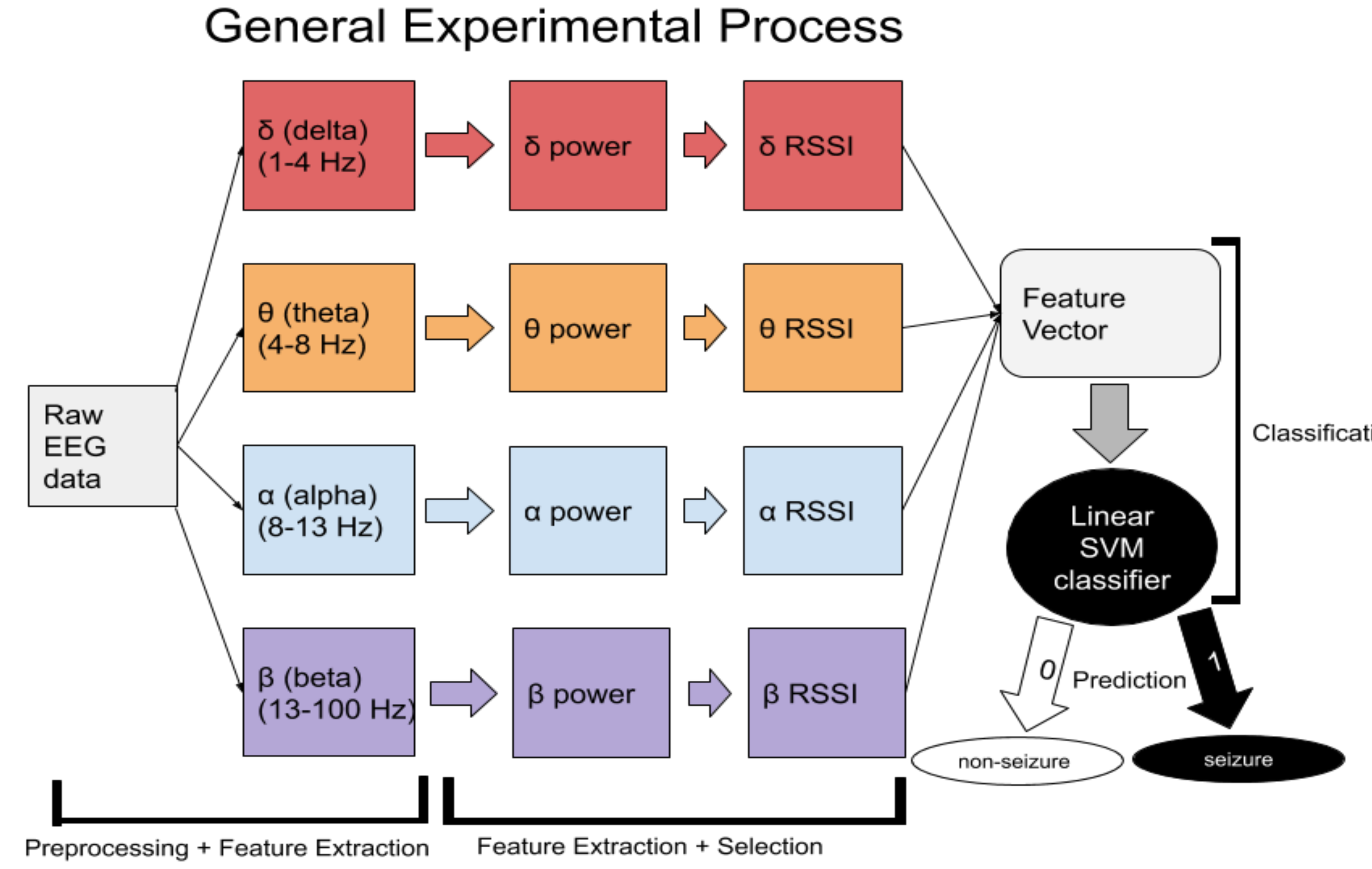
Figure 1 (left): General outline of EEG data processing.

Figure 2 (below): A graph of a raw EEG signal with the seizure occurrence in red.



EXPERIMENTAL METHODS

General Experimental Process



*For the sake of simplicity the γ (gamma) frequency (35-100 Hz) has been included in the beta frequency domain.

1. Filter raw EEG data into different frequency bands and convert into power (watts) (Figure 3)

2. Convert power from watts into dBm and then use RSSI to get mapped voltage (Figure 4)

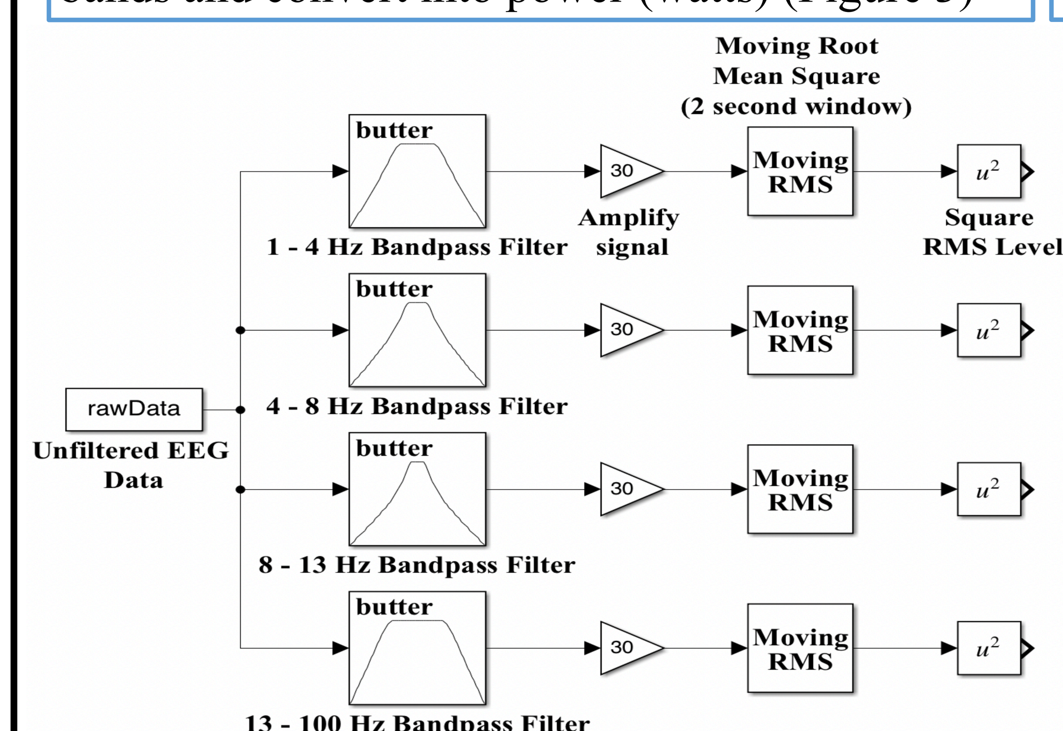
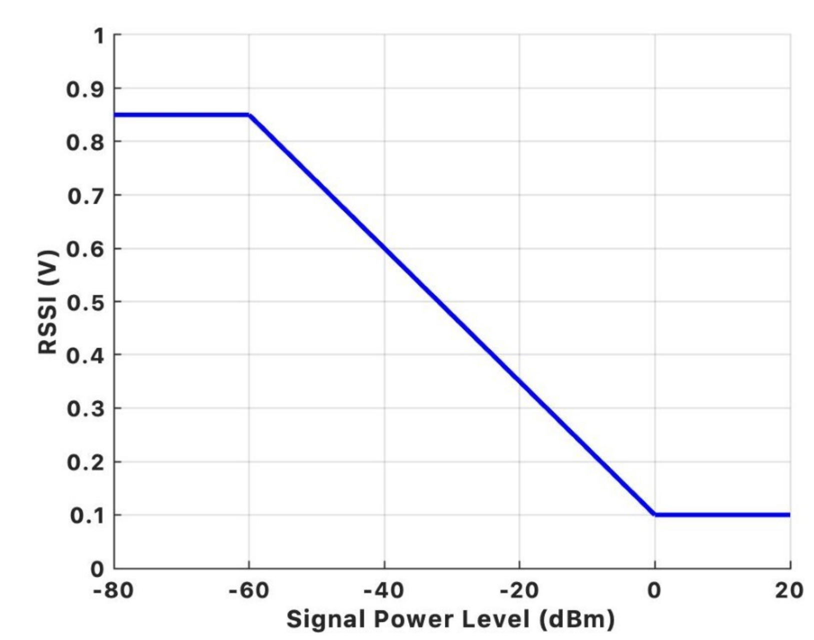


Figure 3: Block diagram created in Simulink to calculate power of each frequency.



3. Create 92 column feature vector from the 23 channels- each with their 4 frequency bands- and label it with an additional column with 0 (non-seizure) and 1 (seizure) (Figure 5)

4. Train and test linear Support Vector Machine (SVM) to classify the points in feature vector as either a seizure or non-seizure event (Figure 6)

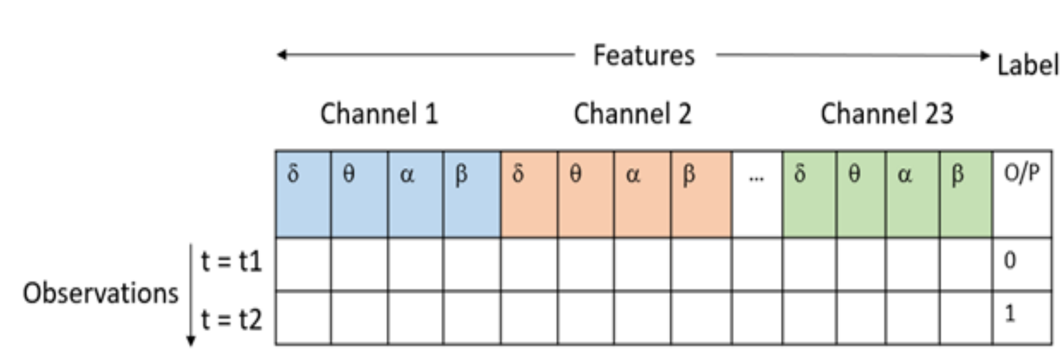


Figure 5: A general diagram of the final labeled 93-column feature vector.

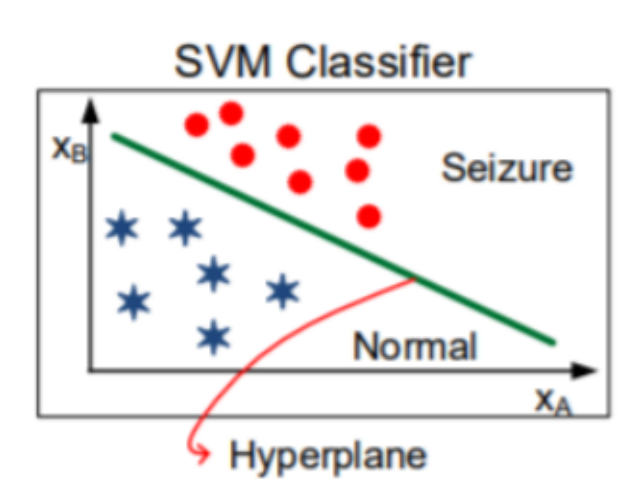


Figure 6: A diagram of an SVM using a hyperplane to classify data points into seizure or non-seizure.

RESULTS

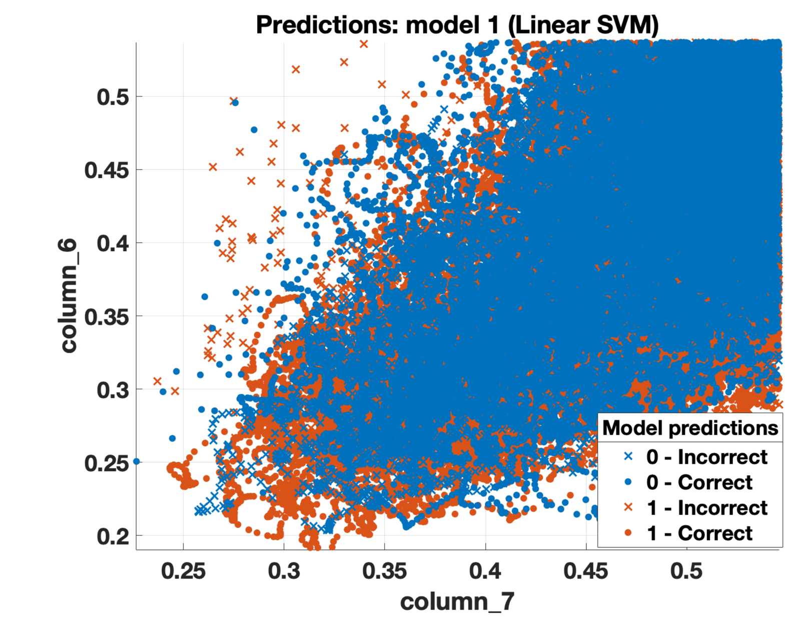
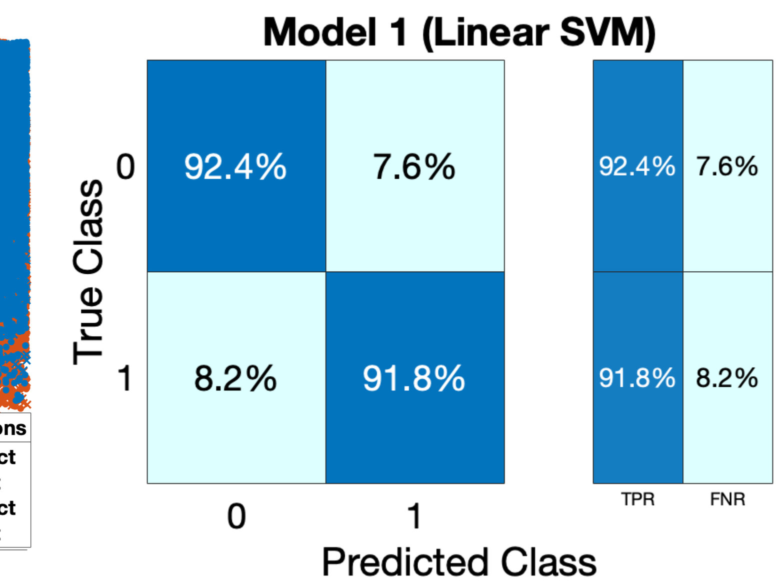


Figure 7 (above): A scatter plot of the predictions from the linear SVM. Although the points seem random when graphed on a 2D scatter plot, they are separated and classified by a 91-dimensional hyperplane.



Figures 8 (above): A confusion matrix of the predictions from the linear SVM. The matrix describes how accurate the system was with training.

Figure 9 (below**)**: The prediction accuracy and latency of our trained SVM model on an hour of EEG data after being trained with 41 hours of EEG data.

	Non-Seizure	Seizure	Non-Seizure and Seizure
Correct	97.87%	69.16%	97.54%
Incorrect	2.13%	30.84%	2.46%
Seizure Detection Latency	0.48 seconds		

CONCLUSION

- Seizure accuracy was lower than expected, while non-seizure accuracy was adequate (Figure 9)
- Seizure detection latency was shorter than expected (Figure 9)
- Seizure classification accuracy can be improved by:
  - Training the algorithm with more EEG data
  - Adding temporal data as a feature
- Implement algorithm into an implantable onset seizure detection device (Figure 10)
- Create algorithm to predict rather than detect seizures

Figure 10: A prototype of the onset seizure detection device.

ACKNOWLEDGEMENTS

Department of Electrical and Computer Engineering
Yuqing Zhang, *Research Mentor*
Tiancheng Yang, *Research Mentor*
Nikita Mirchandani, *Research Mentor*
Aatmesh Shrivastava, *Professor*

Center for STEM Education
Claire Duggan, *Director of Programs and Operations*
Salima Amiji , *YSP Coordinator*
Natasha Zaarour, *YSP Coordinator*
Nicolas Fuchs, *Project Implementation Coordinator*

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Young Scholar's Program at Northeastern University
Claire Duggan, Program Director

This work was supported by the National Science Foundation
Grant #1812588