Abstract

Seizure prediction is a well-studied problem within medicine as most of the danger of a seizure can be mitigated with successful predictions. While several other algorithms exist, they have limitations, such as short prediction timeframes, low sensitivities, or high false positive rates. We propose a model based on a combination of traditional convolutional and spiking neural networks. These spiking neural networks are newer and more closely model how the brain learns than traditional networks. By using a combination of traditional and spiking networks, we will be able to determine how effective spiking neural networks are at complicated tasks such as seizure prediction. We have so far tested our convolutional neural network model on a prediction timeframe of 10 minutes. Initial, incomplete results are promising, showing a very high sensitivity and accuracy, validating our data processing plan. Improving our confidence in this assertion will require more testing and a more complete model with the multi-spiking side included and controls for comparison.

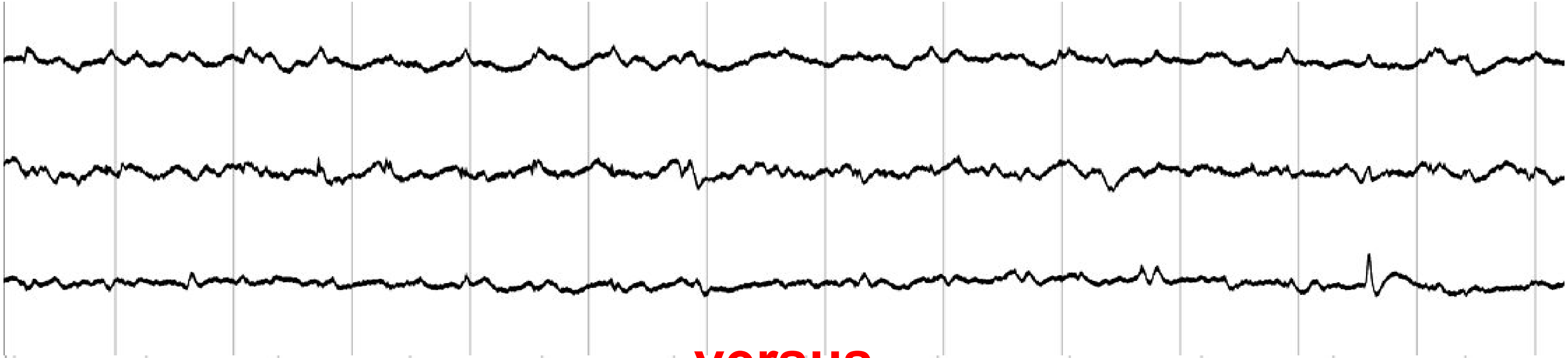
Predicting seizures with artificial spiking neural networks

Jeremy Angel, Matthew Wootten, Junwon Kim, and Jimin Chae

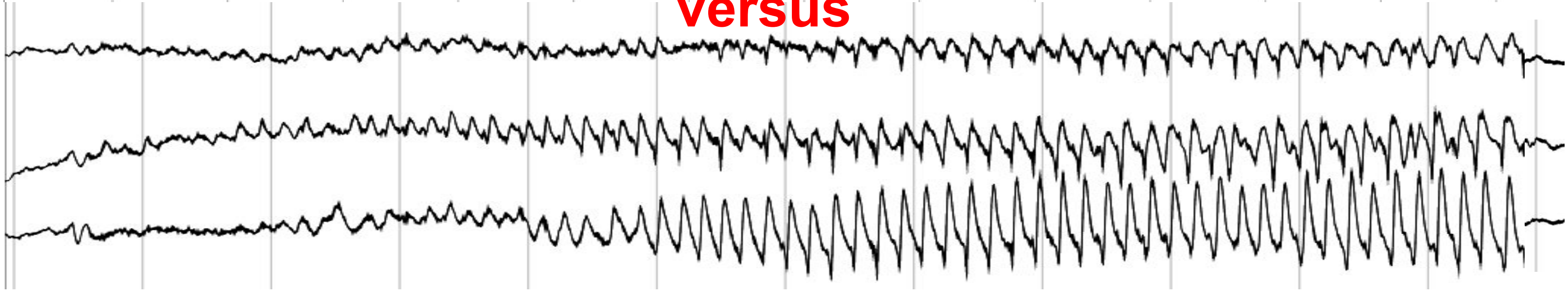
Motivation

- The unpredictability of seizures can be problematic
  - People with severe epilepsy are unable to drive, in case they have a seizure on the road
  - People with epilepsy report a significantly lower quality of life, due in part to the unpredictability of the condition (Camfield, 2010)

The effects of seizures are clearly visible on EEGs



versus



Some Existing EEG-based Solutions (not exhaustive)

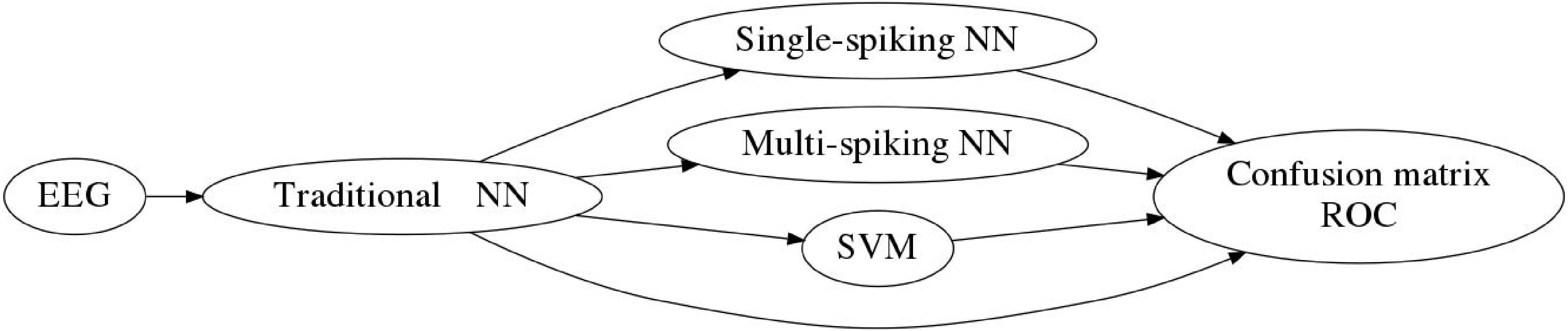
D'Alessandro et al. (2005)

- 10 minutes
- 100% sensitivity
- 1.1 false positives per hour

Netoff et al. (2009)

- 5 minutes
- 79% sensitivity
- 0.0 false positives per hour

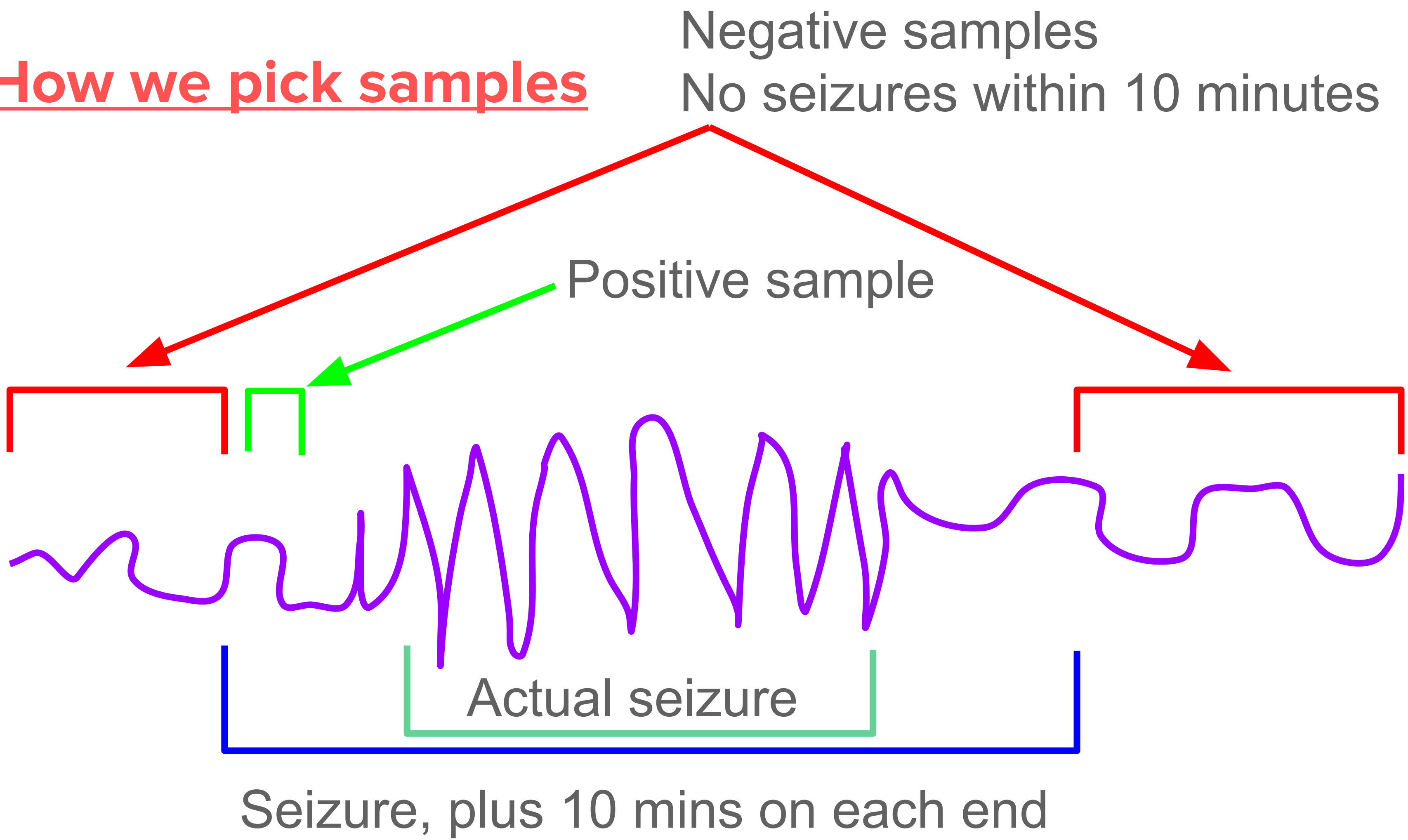
Korea only



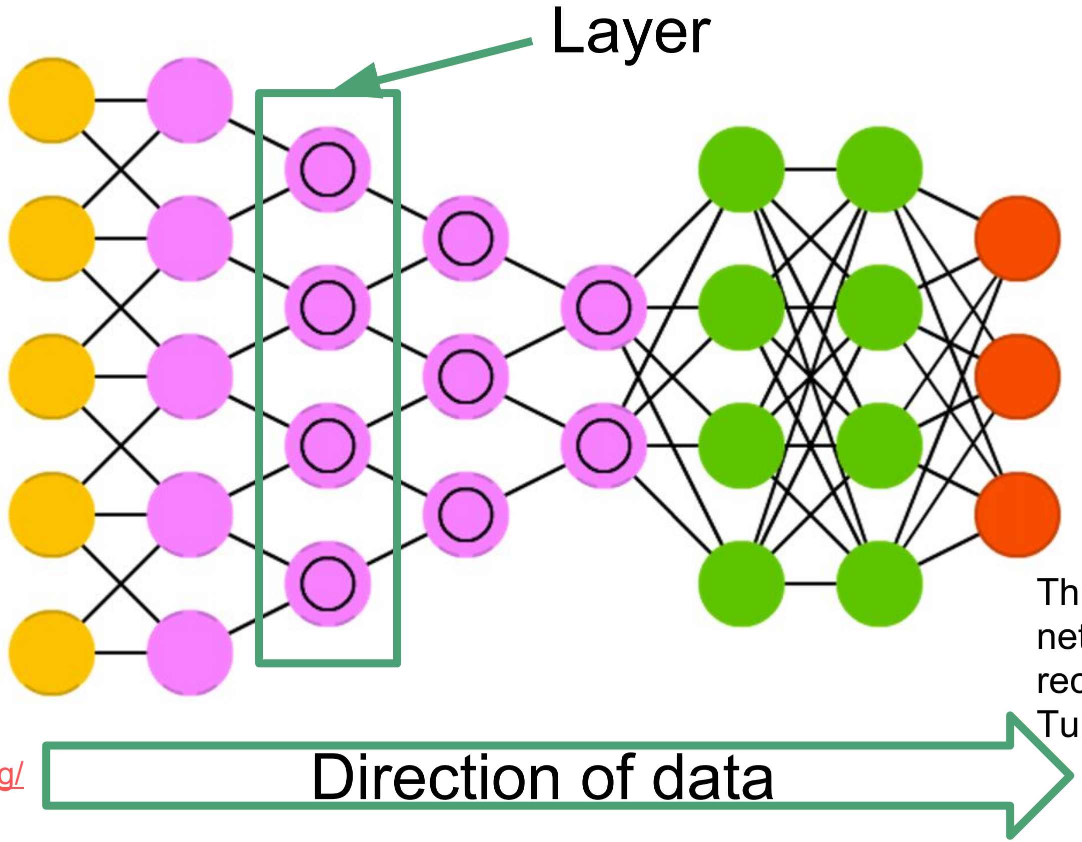
Hypothesis: The Spiking NN will have the highest prediction accuracy followed by the Traditional NN and SVM

Our data processing pipeline

How we pick samples



Traditional NN



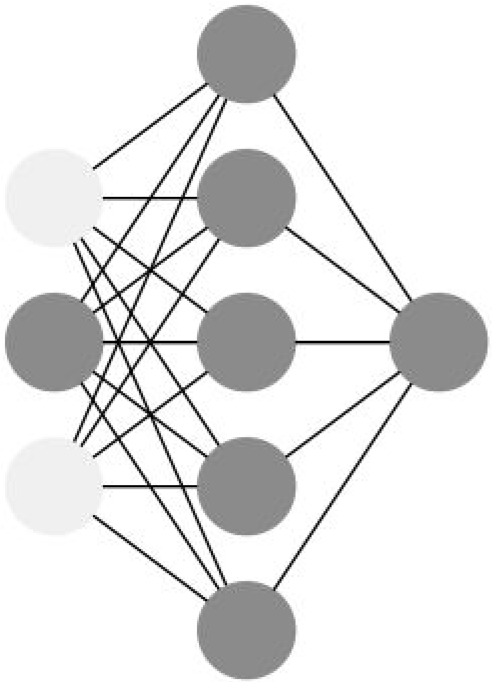
This use of traditional networks was recommended by Dr. Turaga at HHMI

http://www.asimovinstitute.org/neural-network-zoo/

Multi-spiking NN

- More closely models the brain
- Requires fewer neurons
- “Remembers” values

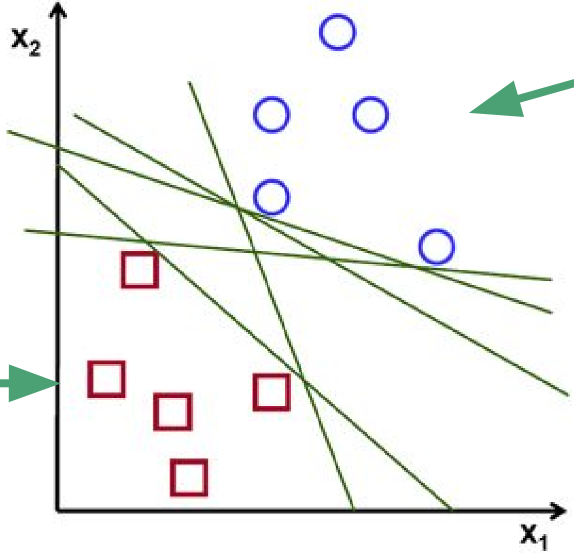
Currently, we have a Multi-Spiking NN in python coded without the use of libraries.



Support Vector Machines (SVMs)

Seizures

Not seizures



https://docs.opencv.org/2.4/_images/separating-lines.png

Axes: Traditional NN outputs

This control was recommended by Dr. Scheffer at HHMI.

EXAMPLE DATA

Analysis

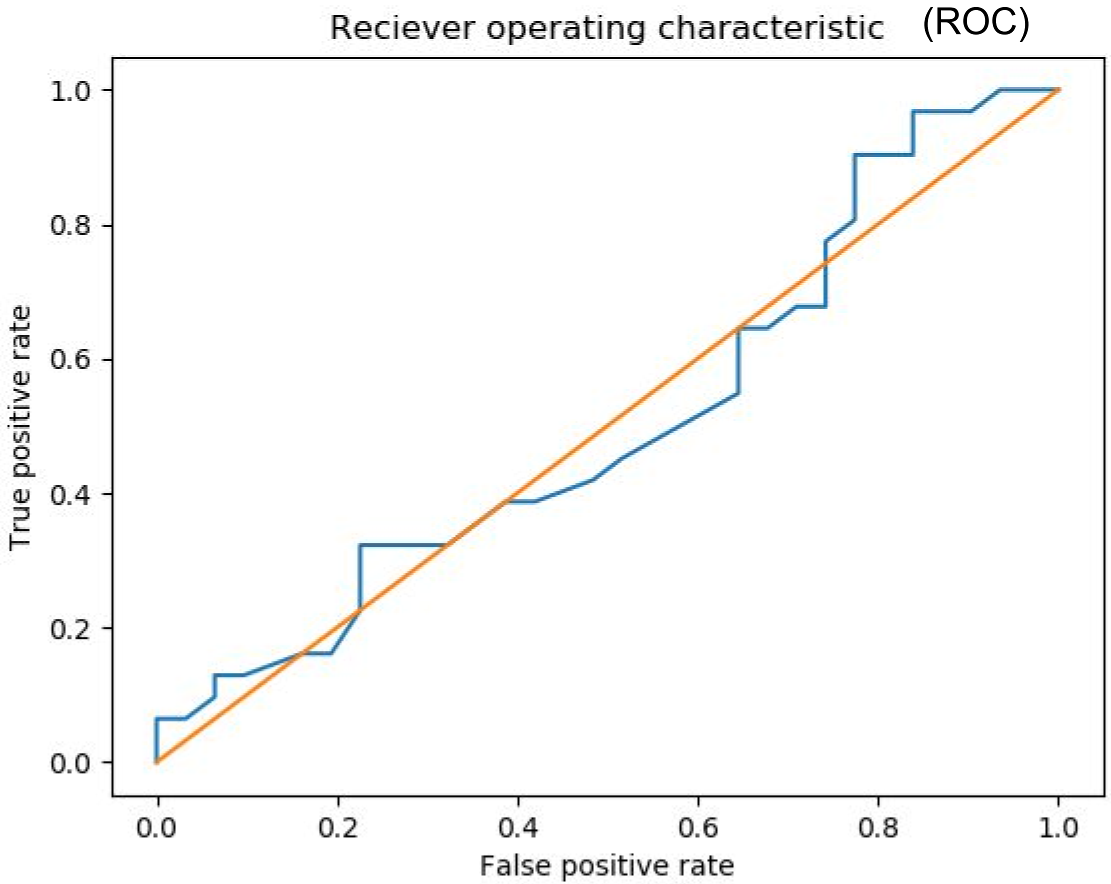
Collect the data into something that looks like this:

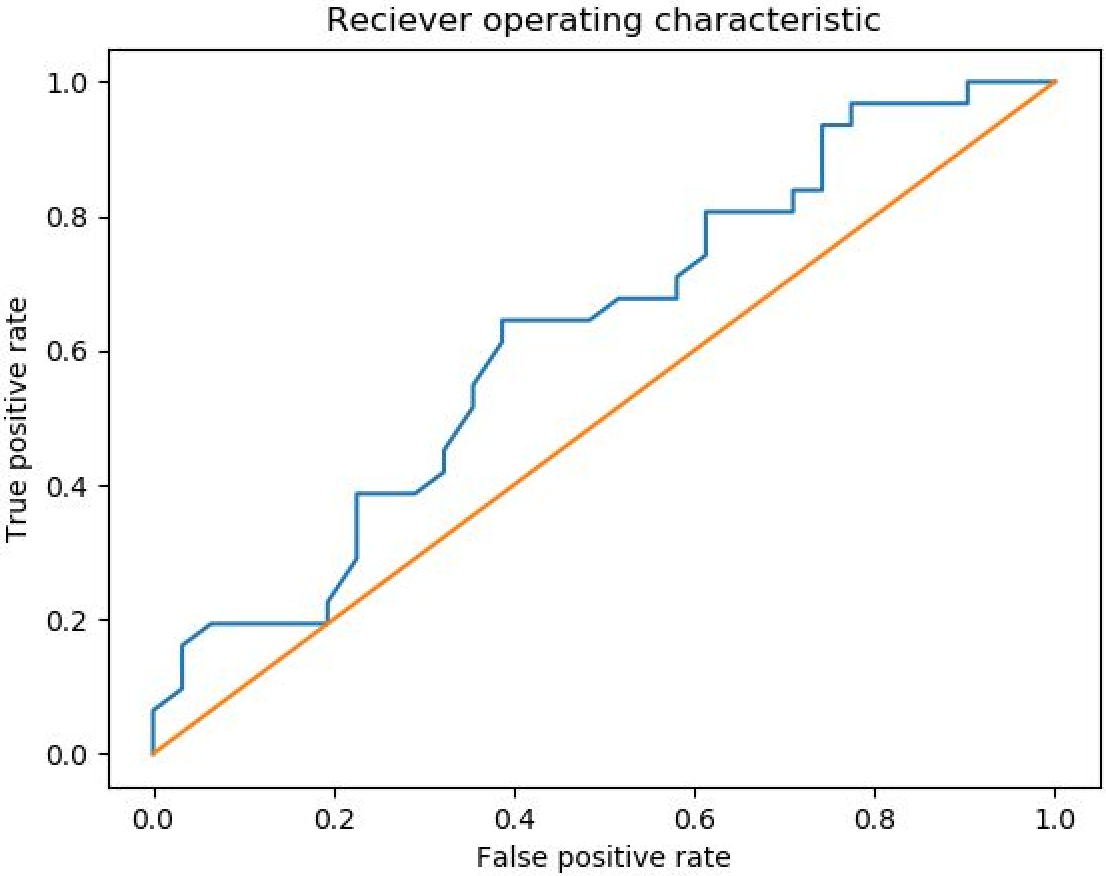
Confusion Matrix		Actual	
		Seizure	Not seizure
Predicted	Seizure	True pos.	False pos.
	Not seizure	False neg.	True neg.

Final metrics

- True positive rate (sensitivity): how often a seizure was **predicted** and **actually occurred**
- False positive rate: how often a seizure was **predicted** but **never occurred**
- There's a tradeoff between the two, so we need to pick a threshold
- What if we try all the thresholds at once? What does that look like?

These statistical metrics were recommended by Dr. Oguz at NIH


Reciever operating characteristic (ROC)
True positive rate
False positive rate
0.0
0.2
0.4
0.6
0.8
1.0



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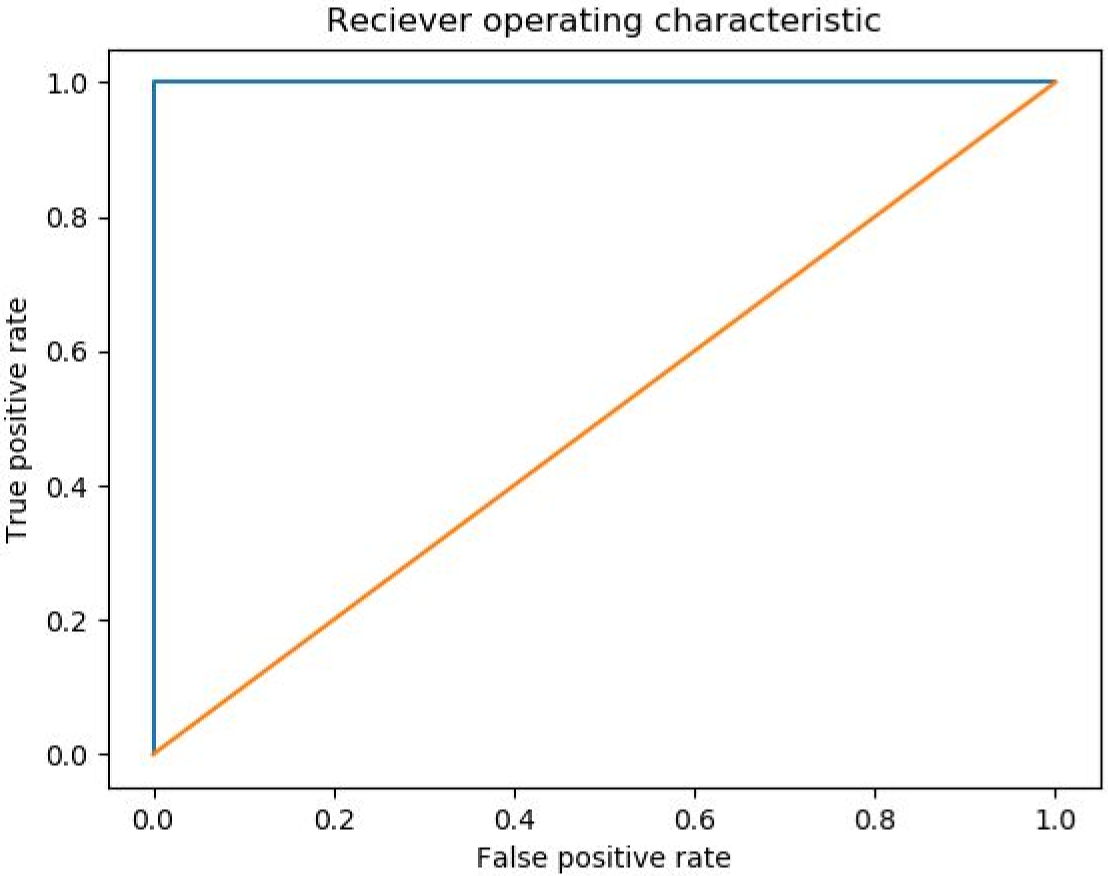

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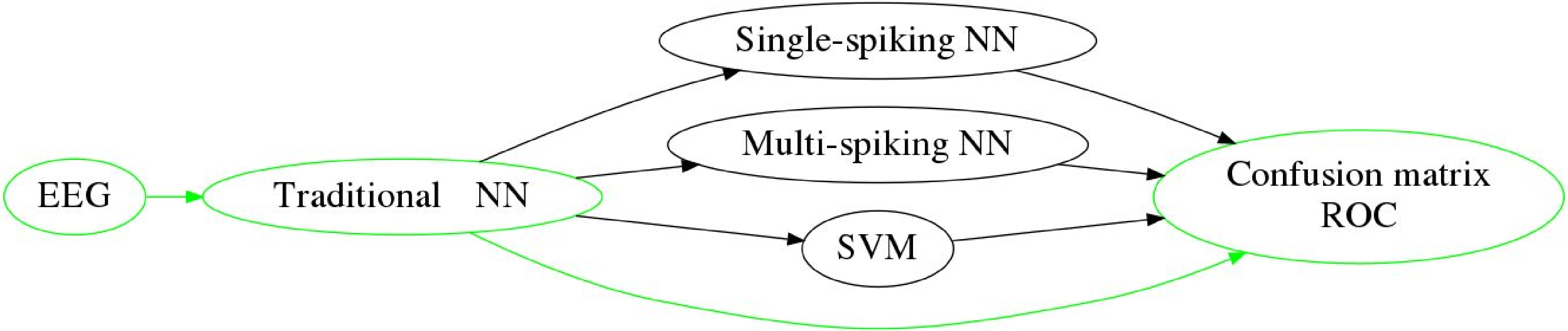
Progress



Single-spiking NN
Multi-spiking NN
EEG
Traditional NN
SVM
Confusion matrix
ROC

Immediate Future

- Find new, more effective step to go before the conventional neural network
- Work on an efficient implementation of the multi-spiking network
- Add an SVM

References

Camfield, P. & Camfield, C. Idiopathic generalized epilepsy with generalized tonic-clonic seizures (IGE-GTC): A population-based cohort with >20 year follow up for medical and social outcome Epilepsy & Behavior, Elsevier BV, 2010, 18, 61-63

D'Alessandro, M.; Vachtsevanos, G.; Esteller, R.; Echauz, J.; Cranstoun, S.; Worrell, G.; Parish, L. & Litt, B. A multi-feature and multi-channel univariate selection process for seizure prediction Clinical Neurophysiology, Elsevier BV, 2005, 116, 506-516

Netoff, T.; Park, Y. & Parhi, K. Seizure prediction using cost-sensitive support vector machine 2009 Annual International Conference of the IEEE Engineering in Medicine and Biology Society, IEEE, 2009

Important Works

Ghosh-Dastidar, S. & Adeli, H. A new supervised learning algorithm for multiple spiking neural networks with application in epilepsy and seizure detection Neural Networks, Elsevier BV, 2009, 22, 1419-1431

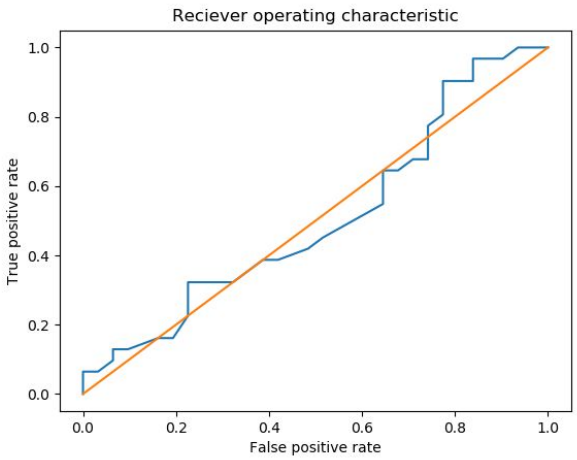
University of Pennsylvania and Mayo Clinic IEEG-Portal documentation: Collaborative research in the cloud 2014

Lee, J. H.; Delbruck, T. & Pfeiffer, M. Training Deep Spiking Neural Networks Using Backpropagation Frontiers in Neuroscience, Frontiers Media SA, 2016, 10, 508

THE END

Go back; there are a bunch of discarded slides

Data



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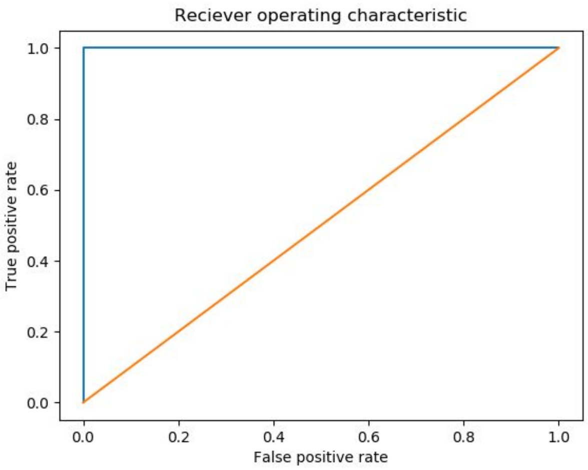

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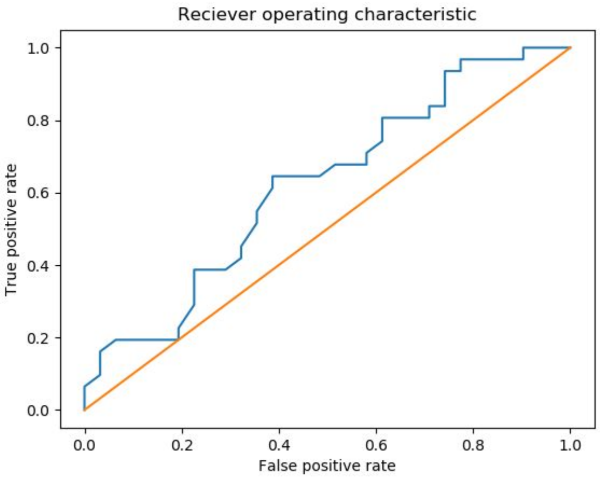

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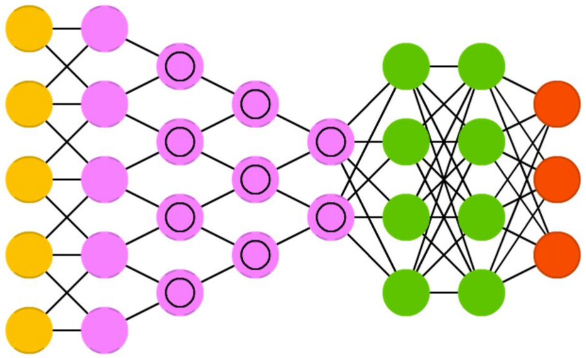
False positive rate

Traditional NN

- Data flows through the network
- Its inputs, on the left, each have a series of numbers
- Each layer, the data get a bit more organized
- The network makes a prediction and self-corrects
- Does more preprocessing
- Trains more quickly, so we can iterate faster
- Provides input for the subsequent steps



http://www.asimovinstitute.org/neural-network-zoo/

Progress up to Progress Report 1

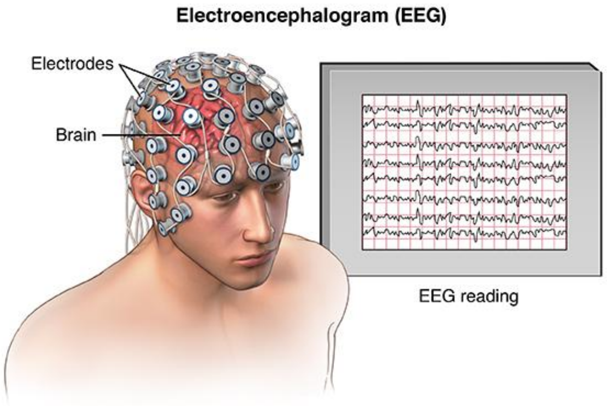
- We have a single multi-spiking neuron that can take inputs and receive outputs in isolation.
- We have an initial more advanced preprocessing step based on EEG signal steepness instead of signal height
- Discussion with Dr. Scheffer

Progress After Progress Report 1

- Multi-spiking neural network in python without the use of neural networking libraries
- Preliminary work on a slightly different mathematical formulation that *may* run faster (if it works)
- Convolutional neural network in python using PyTorch
- Some lightly preprocessed data for the convolutional network
- Discussions with Dr. Turuga and Dr. Oguz

EEG Preprocessing

- Reading the raw EEGs
- Picking positive and negative samples
- Picking out features we know will be important
- Combining channels into a single list of numbers



http://i.imgur.com/ZrmxJRu.jpg

More Preprocessing

COMING SOON...

(our current experiments with preprocessing have been unsuccessful --- making the prediction worse)