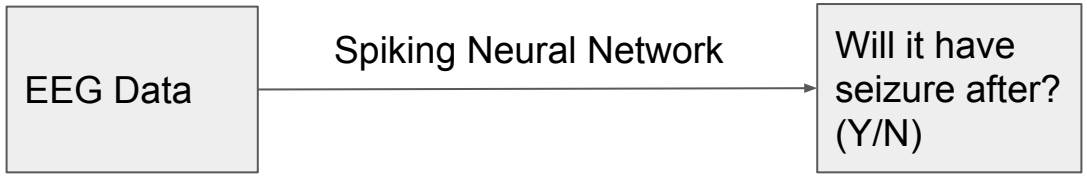
Predicting seizures with artificial spiking neural networks

Matthew Wootten, Jeremy Angel,
Junwon Kim, Jimin Chae

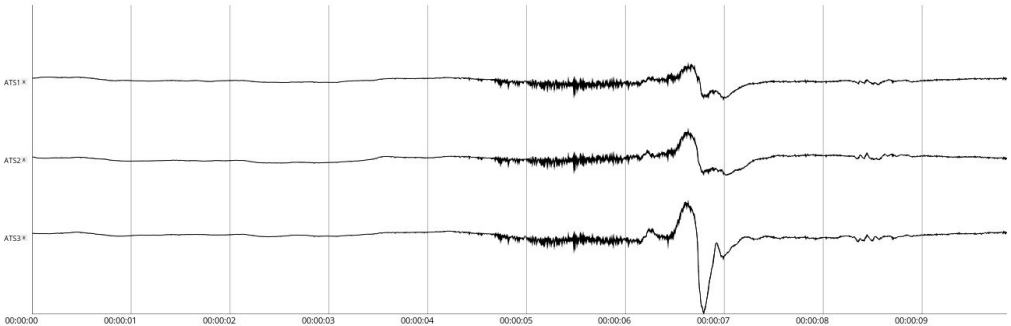
Objective - Predicting Seizures with NN

- Spiking neural network
  - Single spiking
  - Multi spiking
- Preprocessing data; Making data learnable
  - Simple method: Taking mean value
  - Fourier transform
  - Convolution



Background: EEGs

- EEG - Electroencephalogram
- EEGs are measurements of brain electrical activity
  - Specifically, this is the voltage between each pair of electrodes
  - These different measurements are called **channels**
  - A typical EEG has a few dozen channels
  - They look like this:



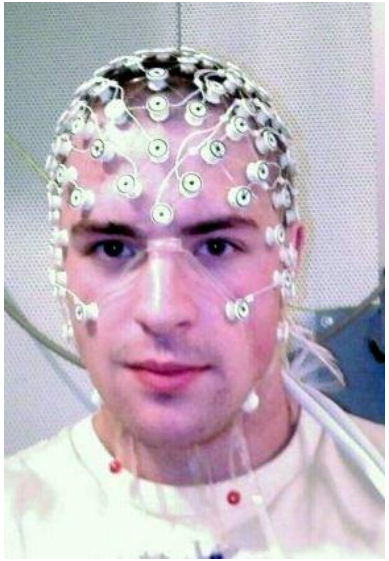
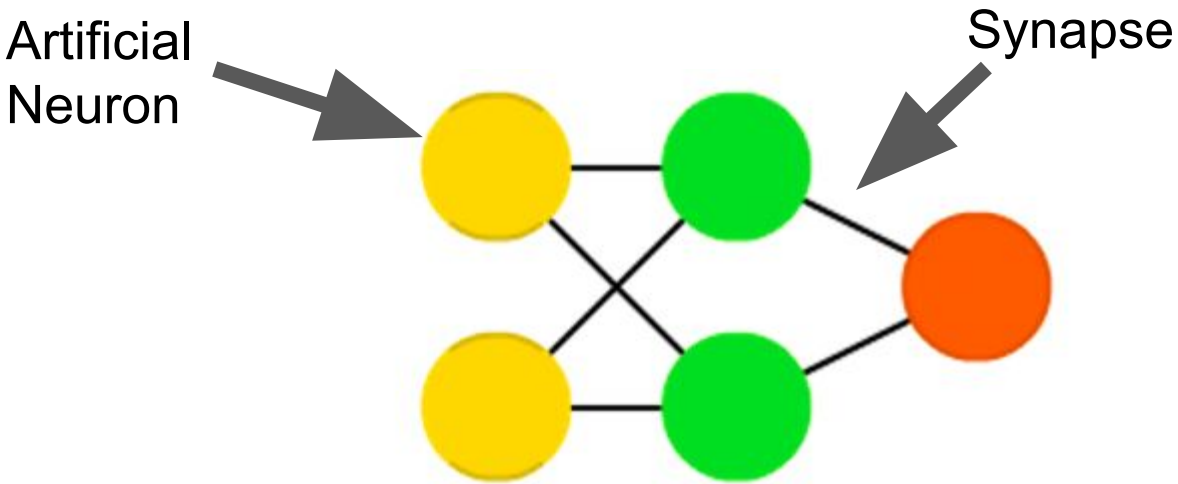


Image is by Douglas Myers

Background - Artificial Neural Networks (ANNs)



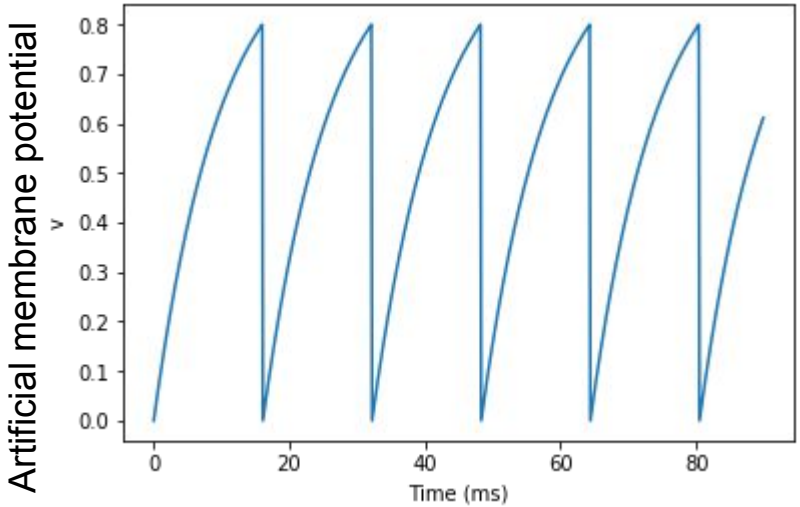
A very small feed-forward non-spiking neural network

This and all neural net diagrams by Fjodor van Veen

Background - Spiking Neural Networks

- Traditional networks
  - Forward, once
- Spiking networks
  - Forward, with a series of time values
    : constructor of an internal state/membrane potential function
    - The internal state/membrane potential function determines when the neuron outputs and varies based on inputs.
- Closer to how the brain does it

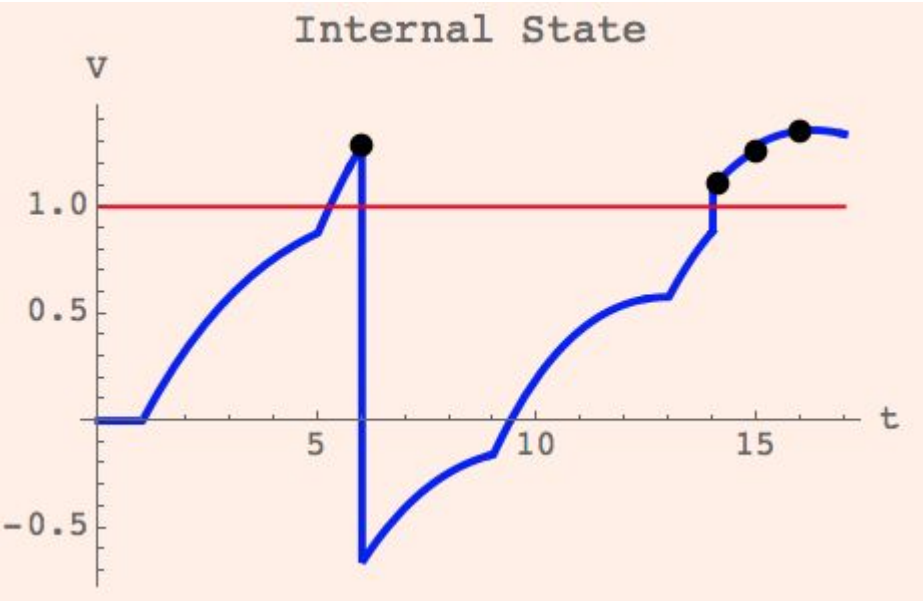
Single-Spiking Networks



In a single-spiking neural network, an artificial neuron transmits output spikes

A neuron in this model can fire at most once per input transmission, and every transmission is at most one spike.

Multi-spiking networks



In a multi-spiking neural network, a neuron can transmit output spikes more than once per input transmission from previous neuron.

Multi-spiking neurons

Also, each connection between neurons is made up of multiple synapses.

Each of those is with different ‘delays’, which cover the whole simulation time

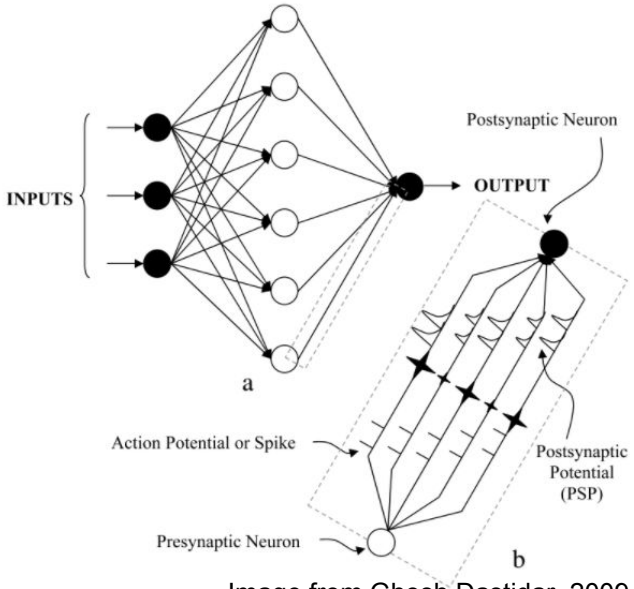
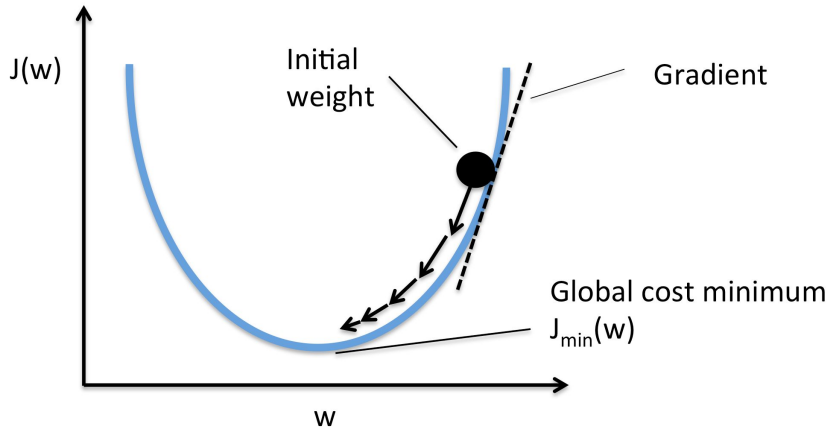


Image from Ghosh Dastidar, 2009

How to learn - Backpropagation

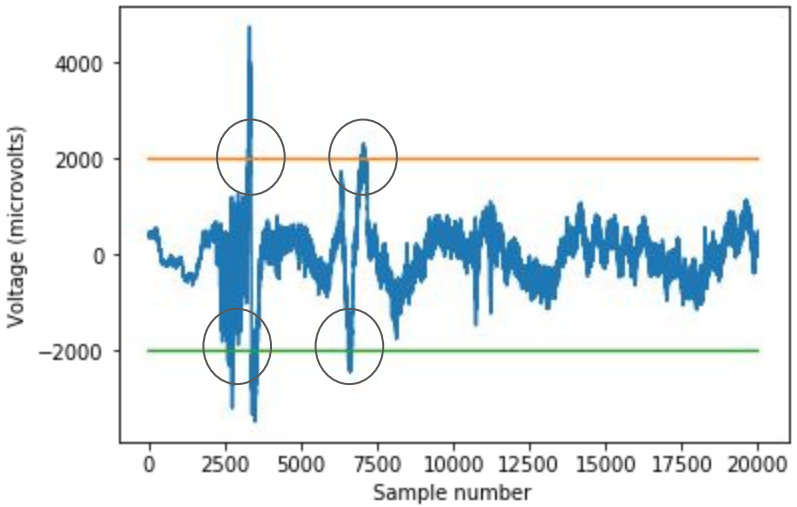
- Method to train ANN
  - Training - giving examples to a neural network so that it can predict the outcome
- We want to minimize the error of the network, given the weights as inputs
  - Minimize an almost-continuous function using partial derivative



How to learn better way
by using Backpropagation

Preprocessing

- Both neural networks take timings of spikes as their input
- Our original data is a huge list of the voltage across the electrodes near the brain at different times
- We can divide this into two steps:
  - Merge some channels together
  - Convert the signal into a series of spike times



Fourier Transform

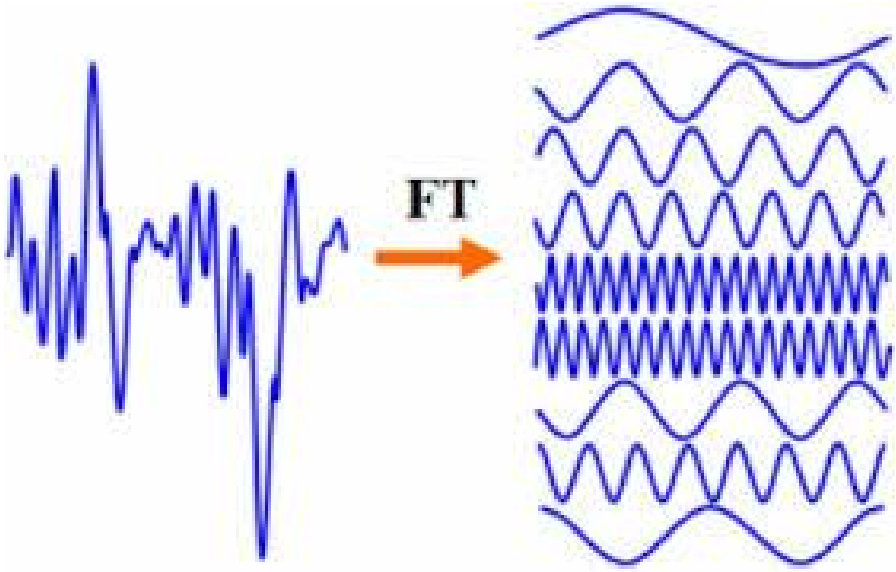
Function to sum of trigonometric function

Uses a key value rather than a function

Similar function has similar key value

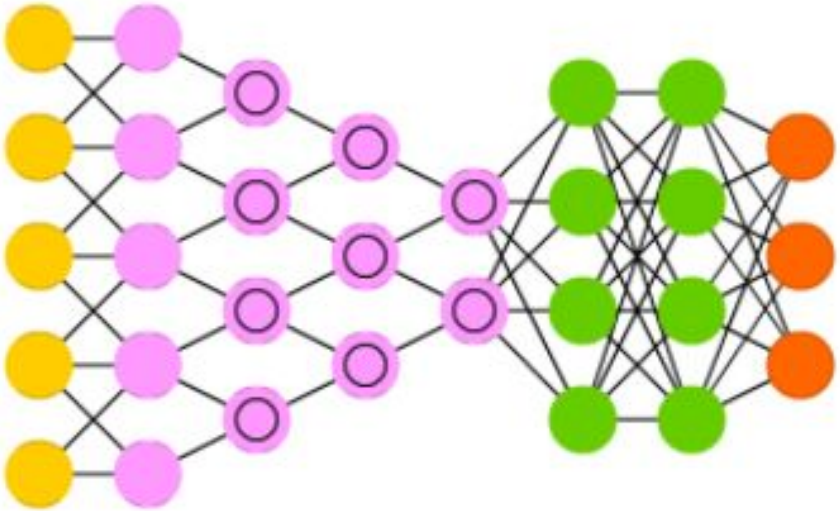
Can take derivative easily

Have O(n log(n)) algorithm -> fast!



Fourier Transform

Convolutional Neural Network

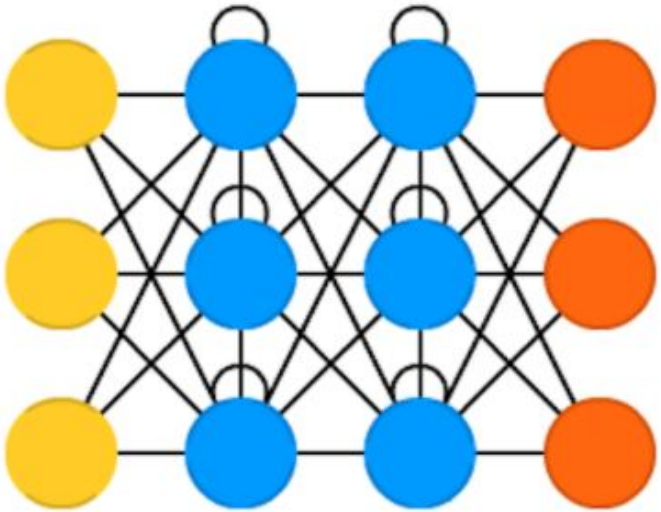


Convolution: multiplying smaller ‘mask’ matrix on the other matrix

Makes the input data compact and representative

Apply fully connected NN afterwise

Recurrent Neural Network



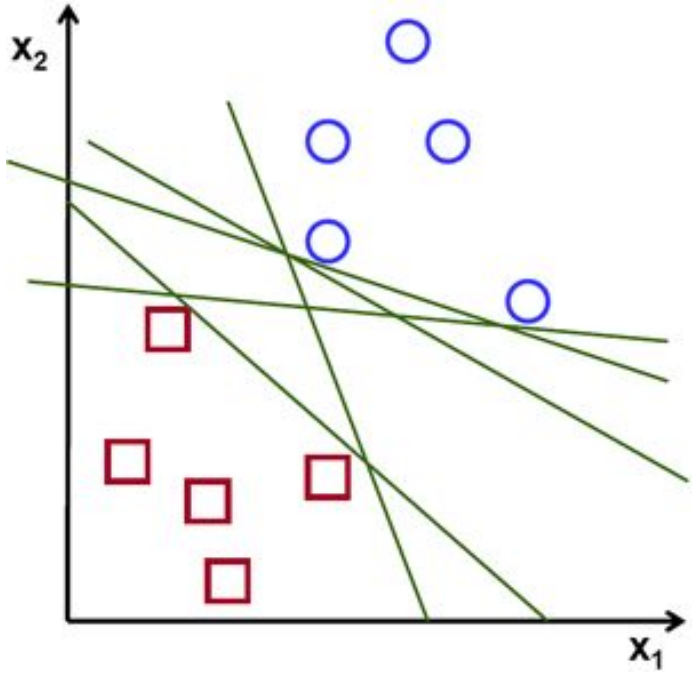
Get fed from previous layer and themselves

“Remembers” the previous input, which makes better performance in sequential input data

Long-Short Term Memory (LSTM)

Control

- SVM (Support Vector Machine)
- Using metrics from preprocessing as dimensions
- Looking for relationship between metrics and seizures using a hyperplane
- Seeing if neural networks are improvements on seizure prediction methods



What's Been Done

Paper	**Algorithm**	**Use**
Lee, Delbruck, & Pfeiffer (2016)	Single Spiking +Feed Forward Backpropagation	Recognizing handwritten digits
Ghosh-Dastidar, Adeli (2009)	Multiple Spiking + Feed Forward Backpropagation	Multiple applications including seizure detection

What We're Doing

Team	Algorithm	Use
DSHS	Single Spiking +Feed Forward Backpropagation	Seizure prediction
AOS	Multiple Spiking + Feed Forward Backpropagation	

What To Do

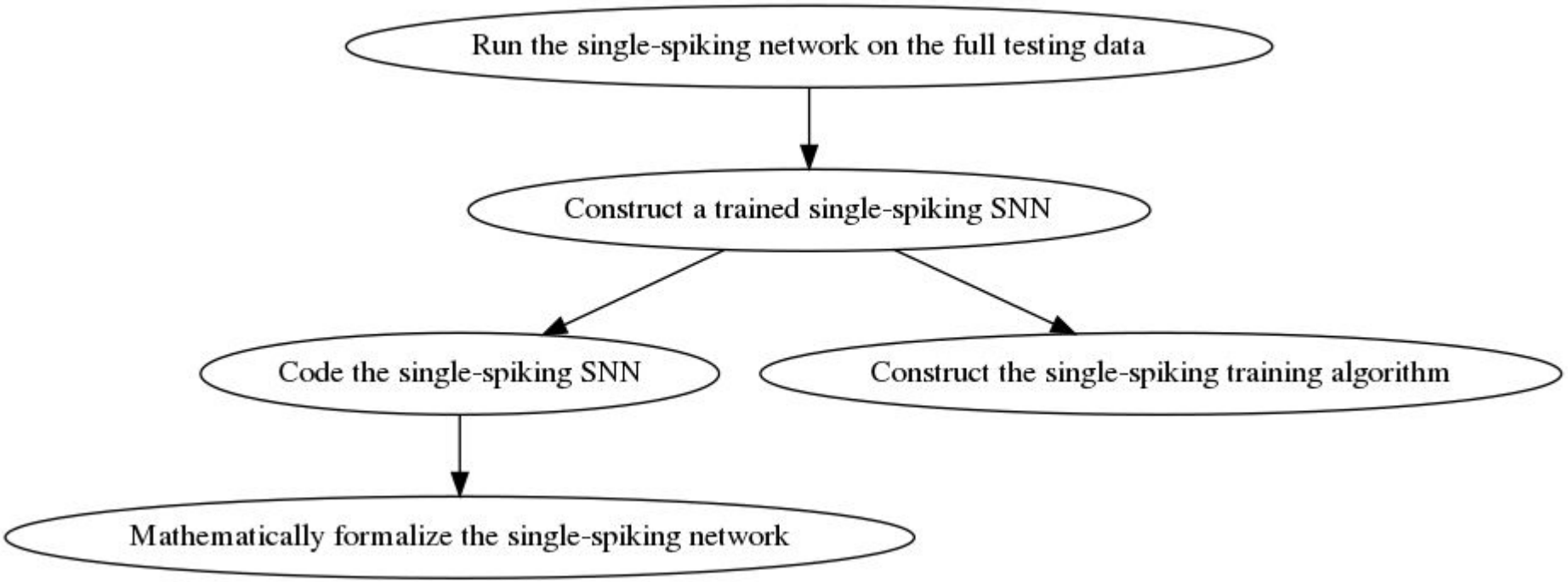
Coding:

- Single-spiking neural network
- Multi-spiking neural network
- Translation from EEG into spikes (preprocessing)

Designing:

- Topology of the neural network: comparison with SNNs applied

What To Do


Run the single-spiking network on the full testing data
Construct a trained single-spiking SNN
Code the single-spiking SNN
Construct the single-spiking training algorithm
Mathematically formalize the single-spiking network

What we have now

- We have an example of a single-neuron network running based on the XOR problem
- We have code for a trivial preprocessing technique that currently can turn an EEG channel into a sequence of spikes
  - Our final preprocessing will probably be more advanced, but what we have now fills the immediate need, so we can start on other tasks

Bibliography

Lee, J. H., Delbruck, T., and Pfeiffer, M. (2016). Training deep spiked neural networks using backpropagation. Frontiers in Neuroscience, 10:508. doi:10.3389/fnins.2016.00508

Ghosh-Dastidar, S., & Adeli, H. (2009). A new supervised learning algorithm for multiple spiking neural networks with application in epilepsy and seizure detection. Neural Networks, 22(10), 1419–1431. doi:10.1016/j.neunet.2009.04.003