Predicting seizures with artificial spiking neural networks

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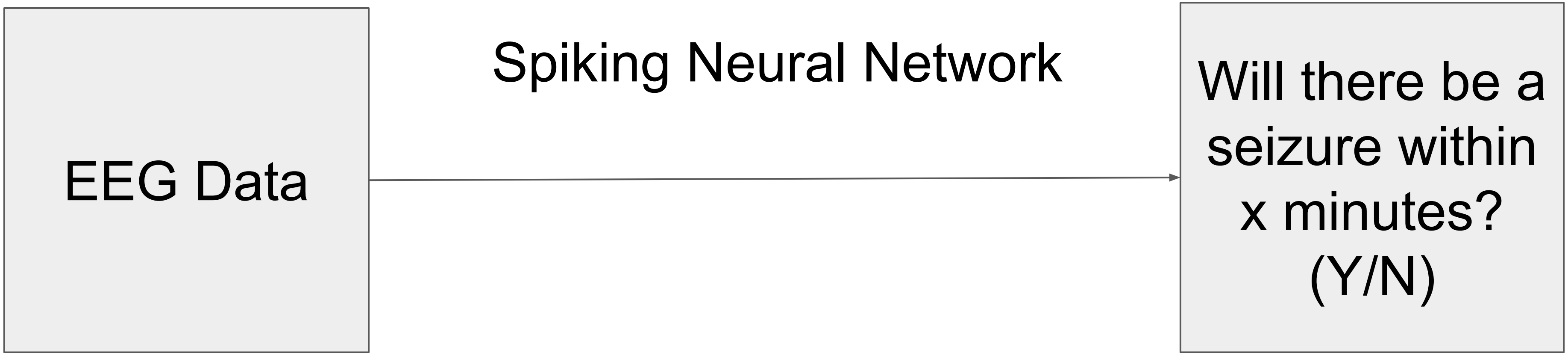
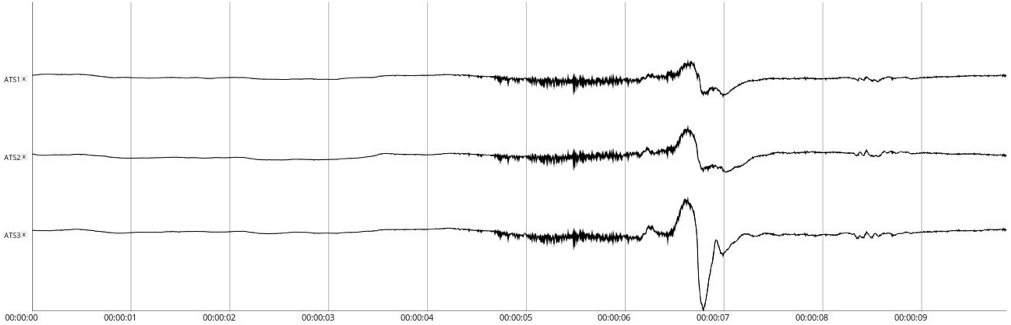
A view from above



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:



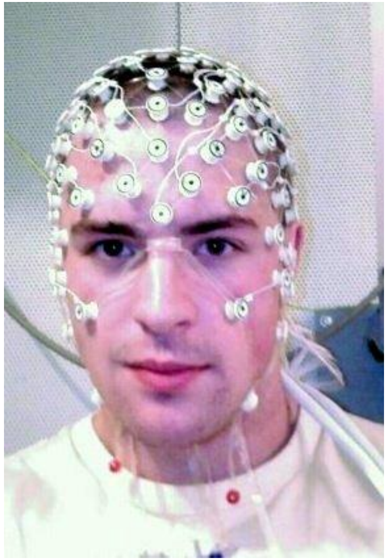
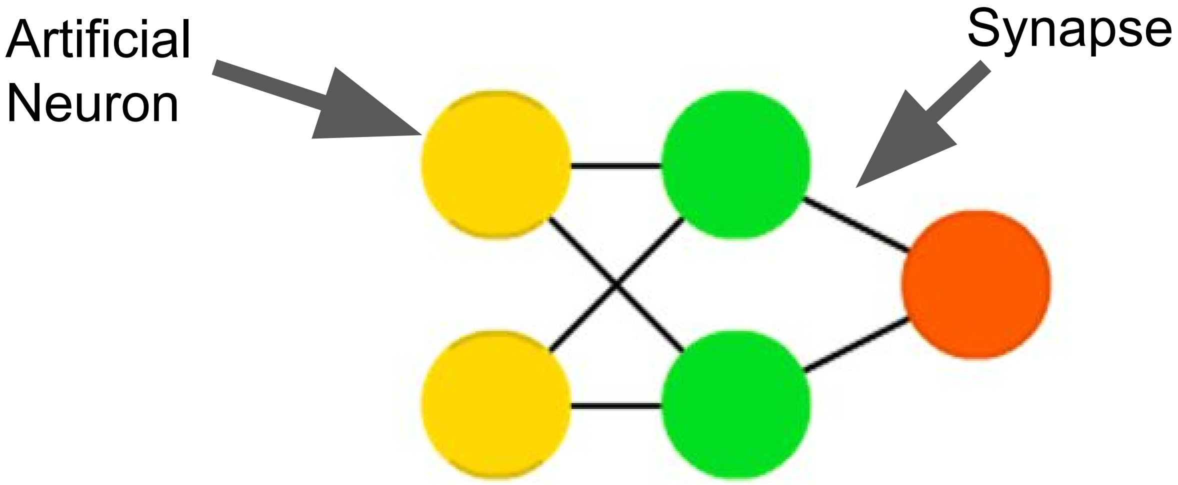


Image is by Douglas Myers

Seizures

- Seizures are electrical disruptions in the brain, and can cause serious symptoms, such as convulsions
- EEG signals have been used in the past to predict these several minutes before they occur.

Artificial neural networks (ANNs)



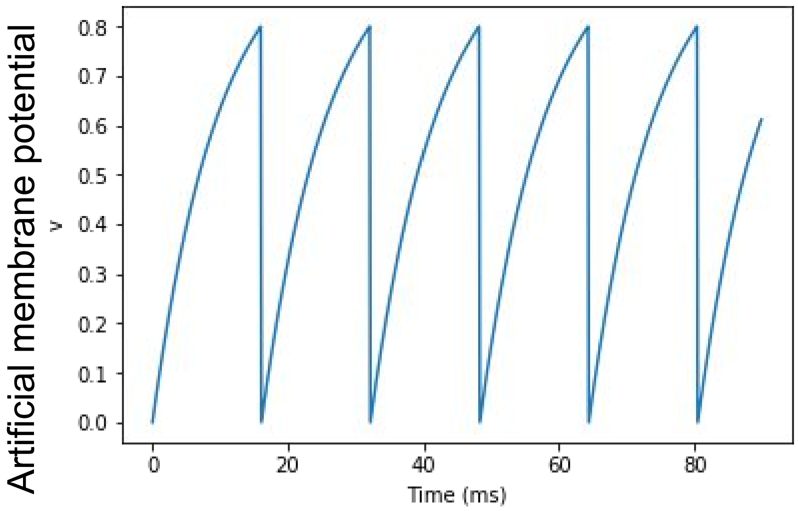
A very small feed-forward non-spiking neural network

This and all neural net diagrams by Fjodor van Veen

Spiking neural networks (SNNs)

- Traditional (non-spiking) networks have a single number associated with each “neuron”
- Spiking networks have an entire time-varying **function** associated with each “neuron”
  - This function is called an internal state or membrane potential (a term borrowed from biology)
- SNNs have more efficient execution time than traditional networks

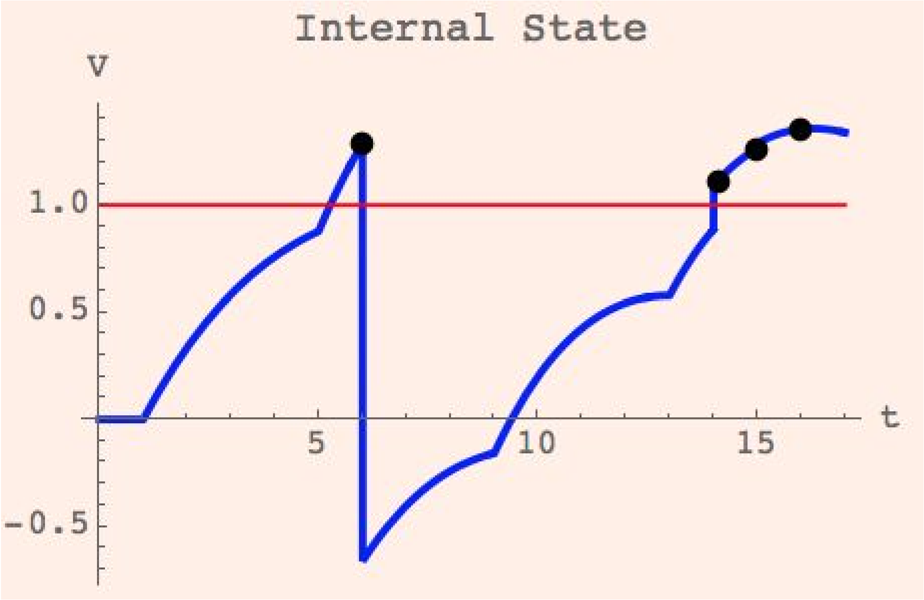
Single-spiking networks



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

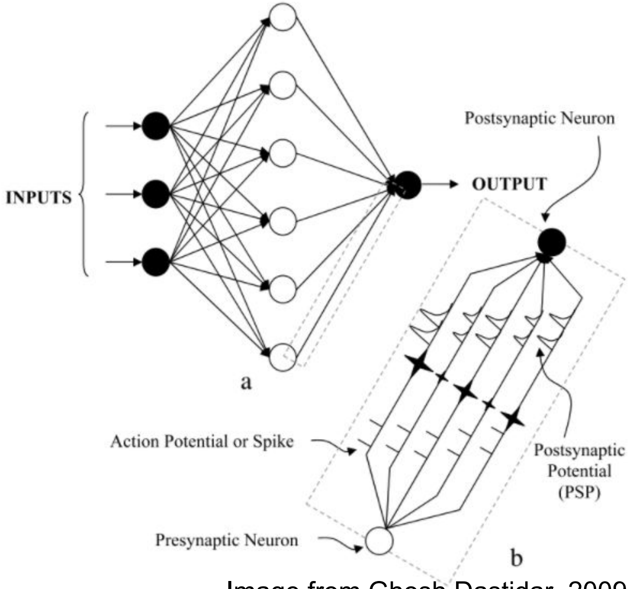


Image from Ghosh Dastidar, 2009

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

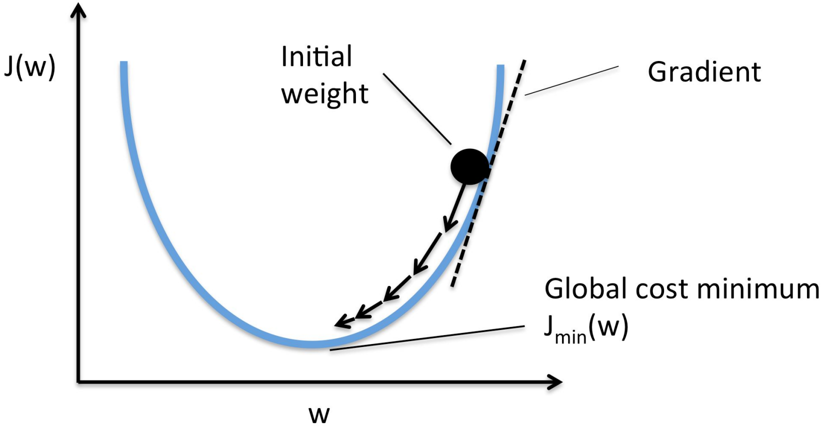
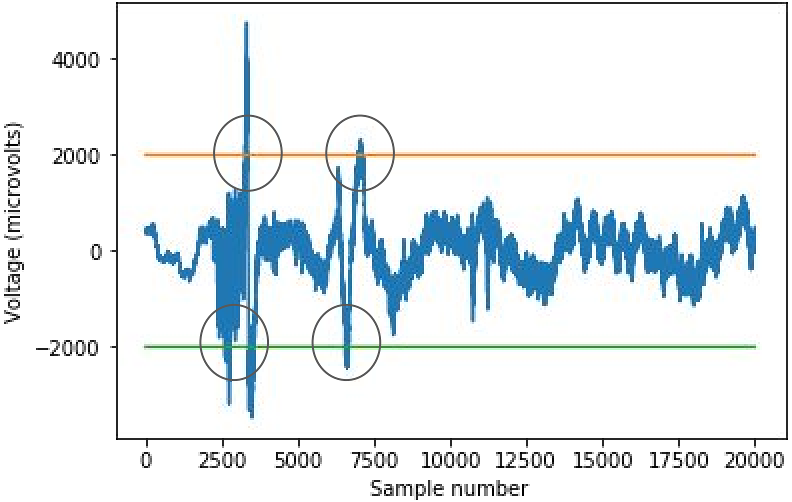


Image from: How to learn better way by using Backpropagation

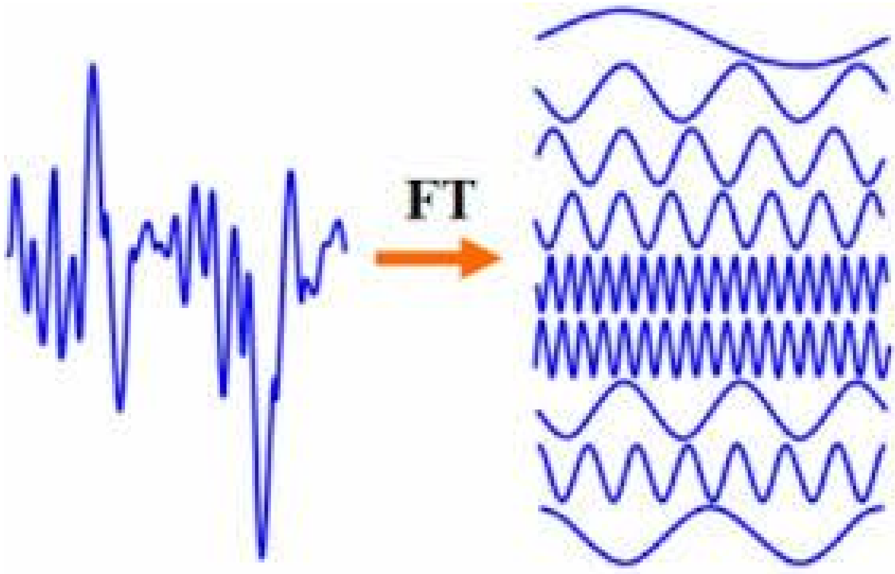
Preprocessing

- Preprocessing is processing done between the original data (EEG) and the input to the neural network.
- 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



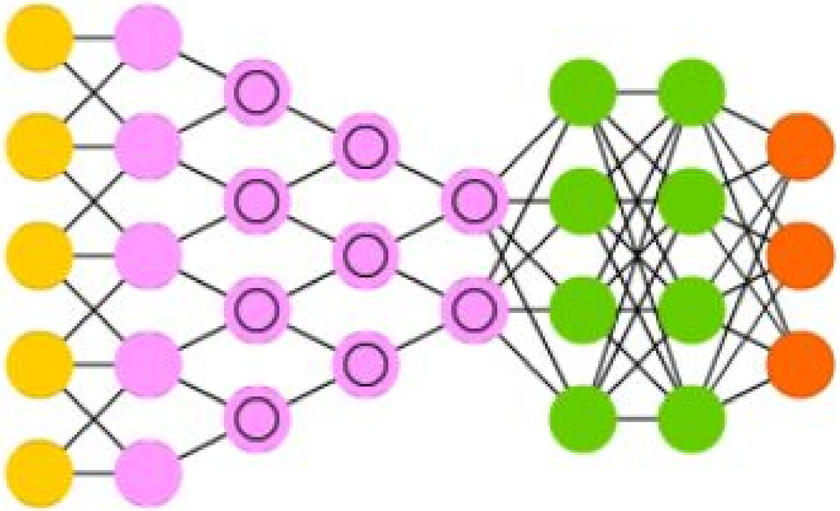
Fourier transform

- Represent a complicated function as a sum of sine waves
- Useful to pick out particular frequencies
- Different frequency oscillations in the brain have different effects, so we can pick out known important frequencies related to seizures



Fourier Transform

Convolutional neural network

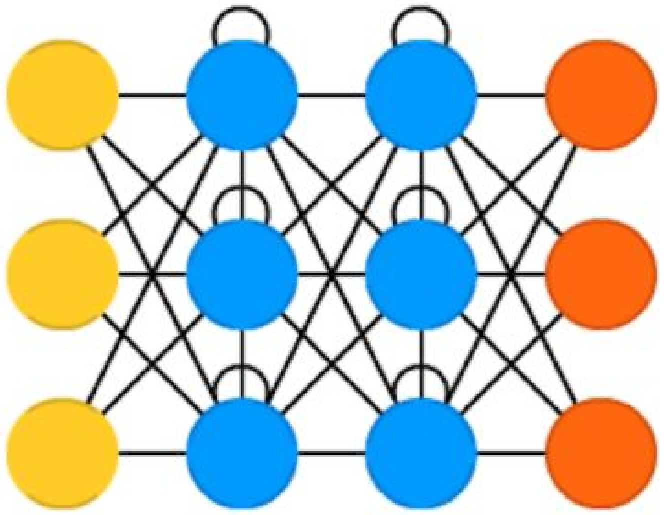


Convolution: multiplying smaller ‘mask’ matrix on the other matrix

Makes the multidimensional input data compact and representative

Apply fully connected NN afterwise

Recurrent neural network



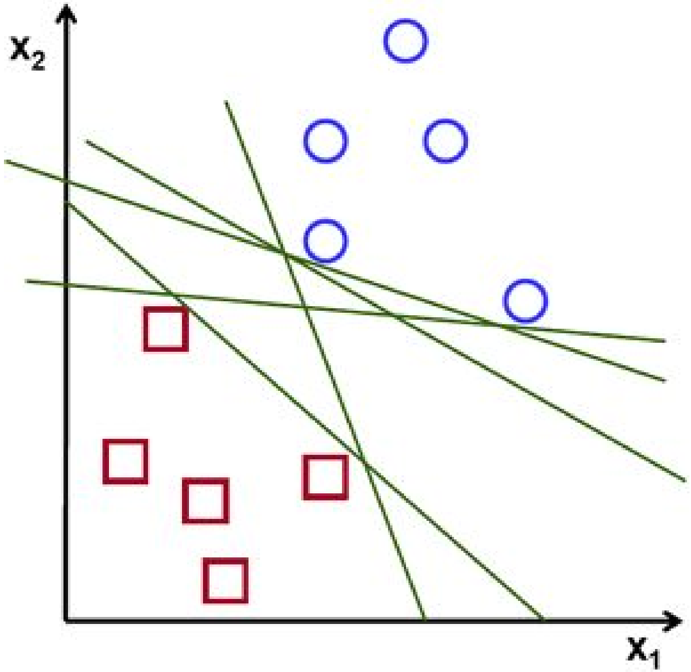
Get fed from previous layer and themselves

“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



Previous research

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 are doing

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

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

What we have now

- 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

What we are doing

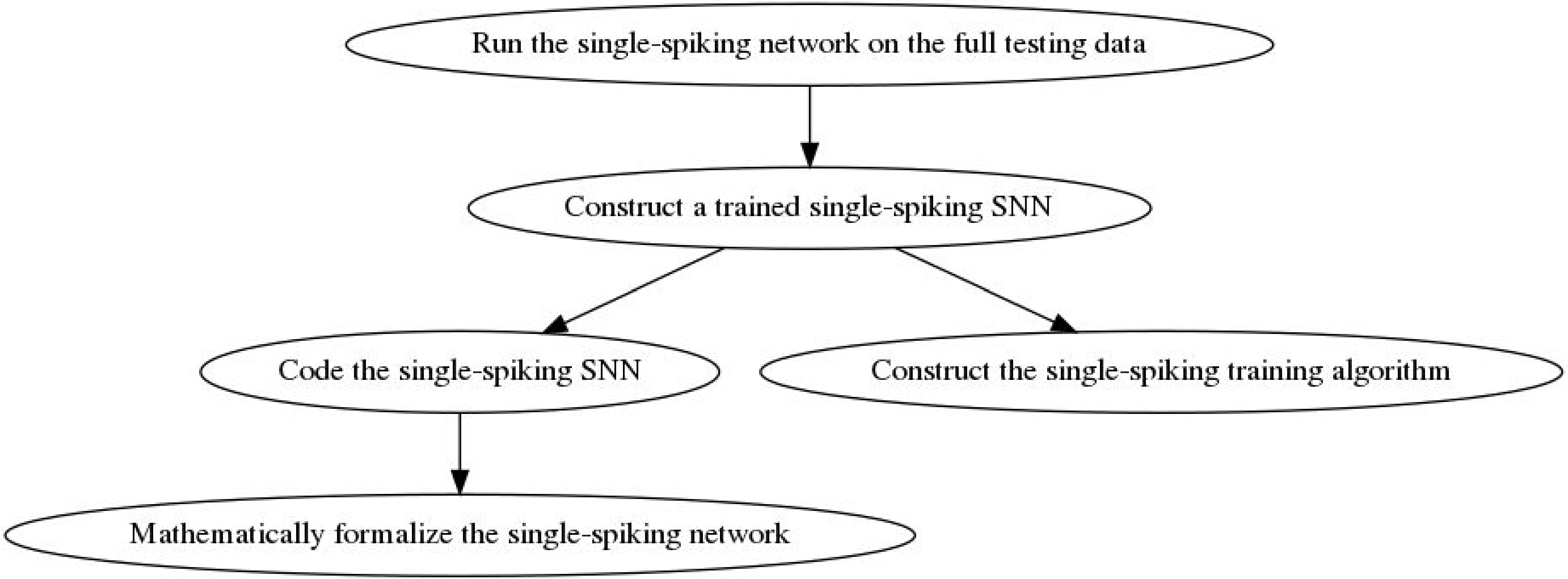
Coding:

- 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 we are doing



Immediate future

- Start on constructing multi-spiking neural network
- Depending on collaborator needs, possibly switch over to preprocessing

Most relevant sources

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