SMLab
Weekly Presentation
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Spiking Neural Network

An Introduction

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Neuromorphic Computing

Bio-plausiblility

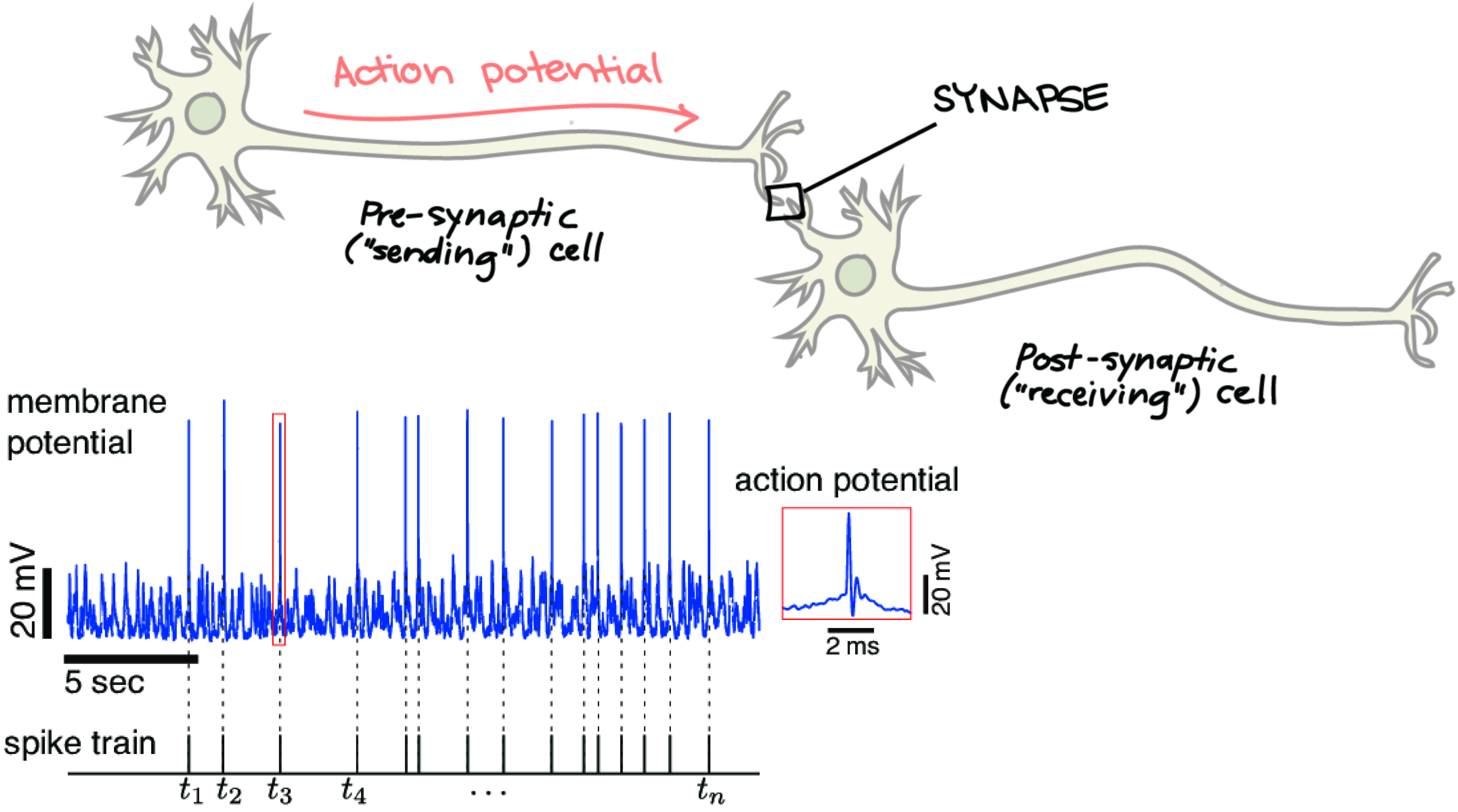
Spiking Neural Networks

Neuromorphic Computing

Bio-plausiblility

$\boxed{\text{Spiking Neural Networks}}$

We take cues from how brain works?



A simple model: the leaky integrate-and-fire (LIF) neuron

Membrane potential V evolves according to a differential equation

$$\tau \frac{\mathrm{d}V}{\mathrm{d}t} = -V$$

Leak

When a neuron receives a spike, V increases by synaptic weight w:

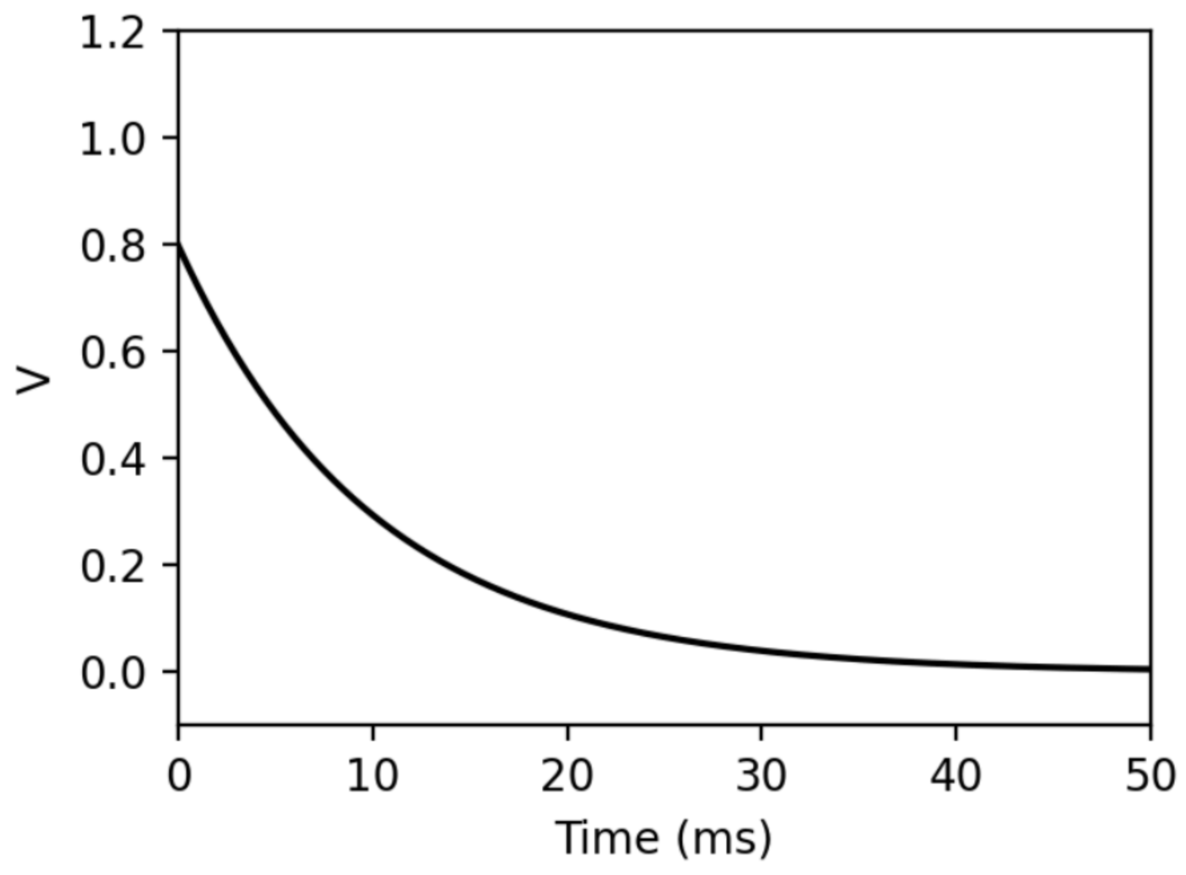
$$V \leftarrow V + w$$

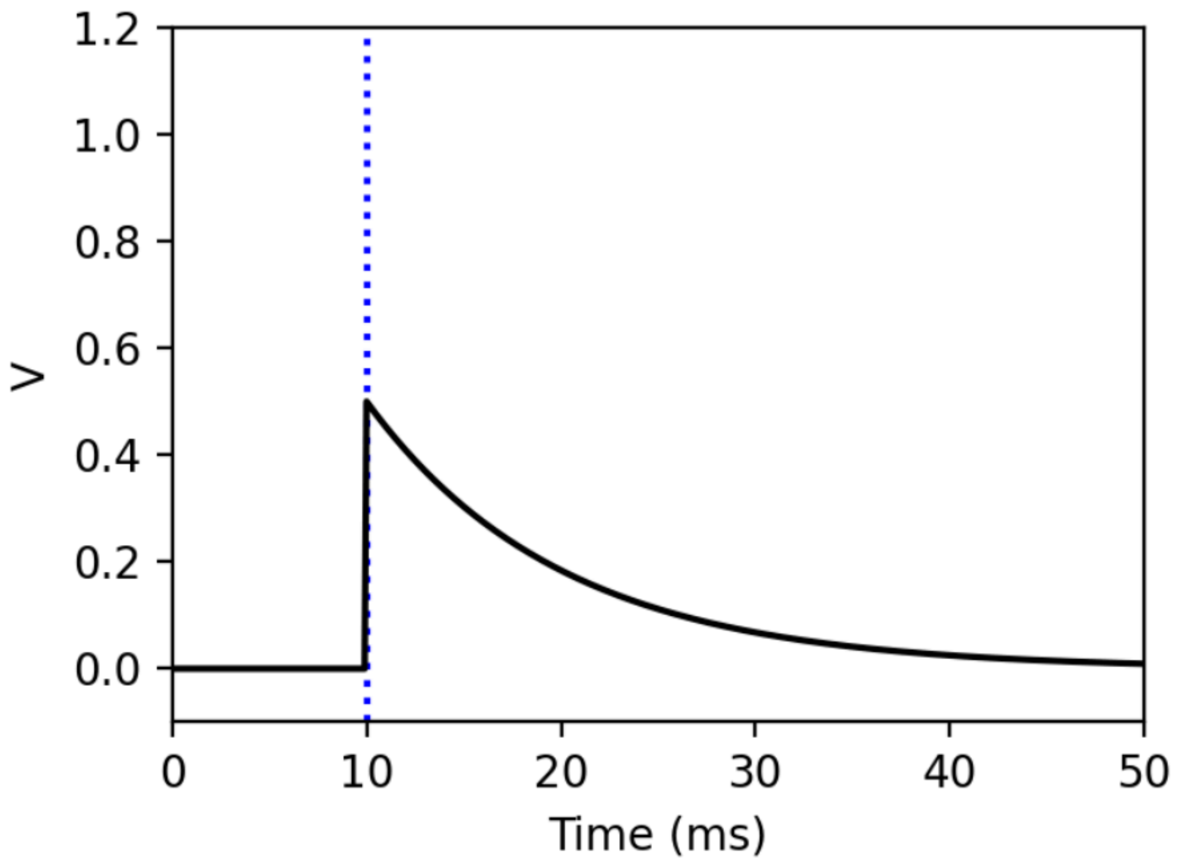
Integrate

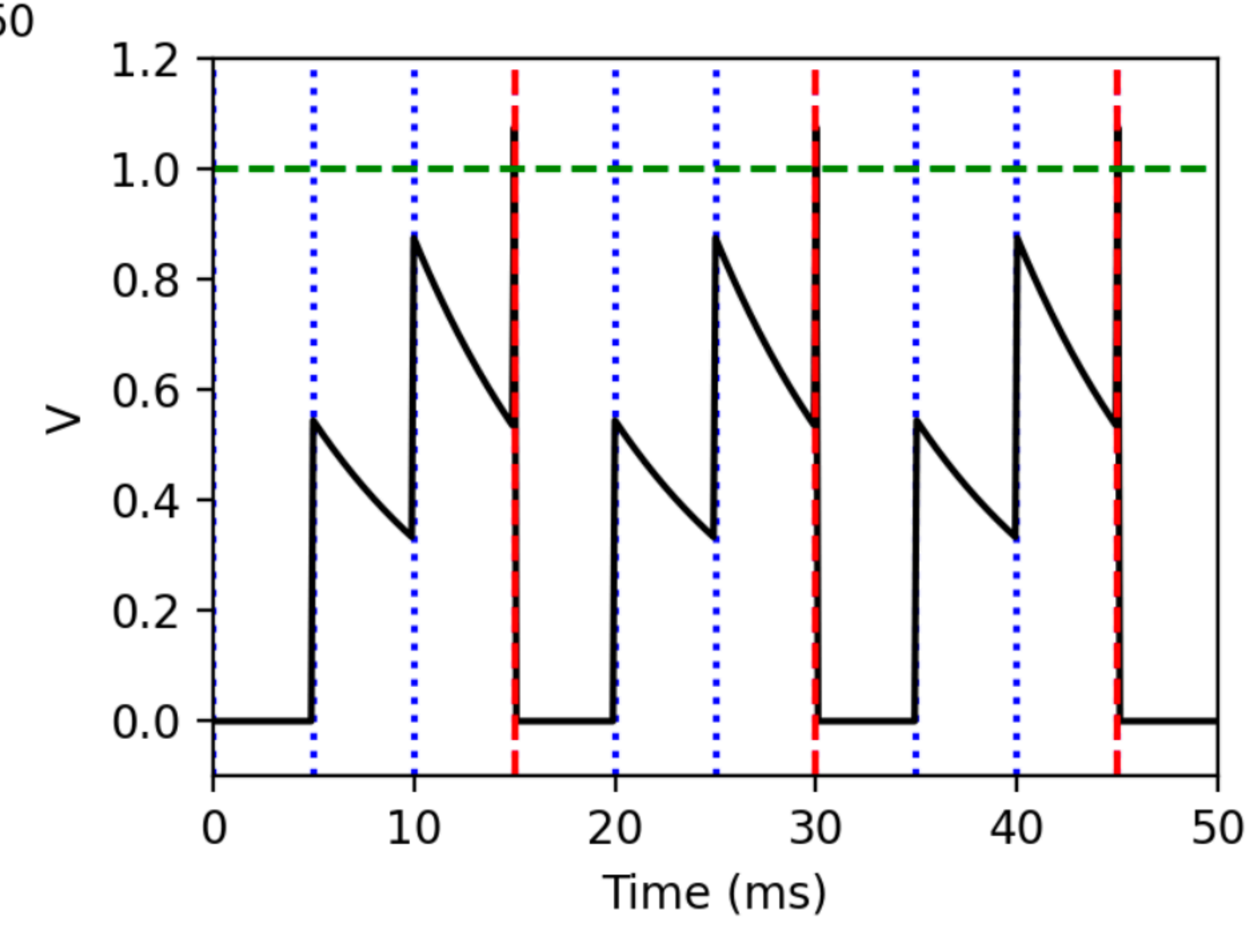
When $V > V_t$ the neuron "fires a spike" and resets:

$$V \leftarrow 0$$

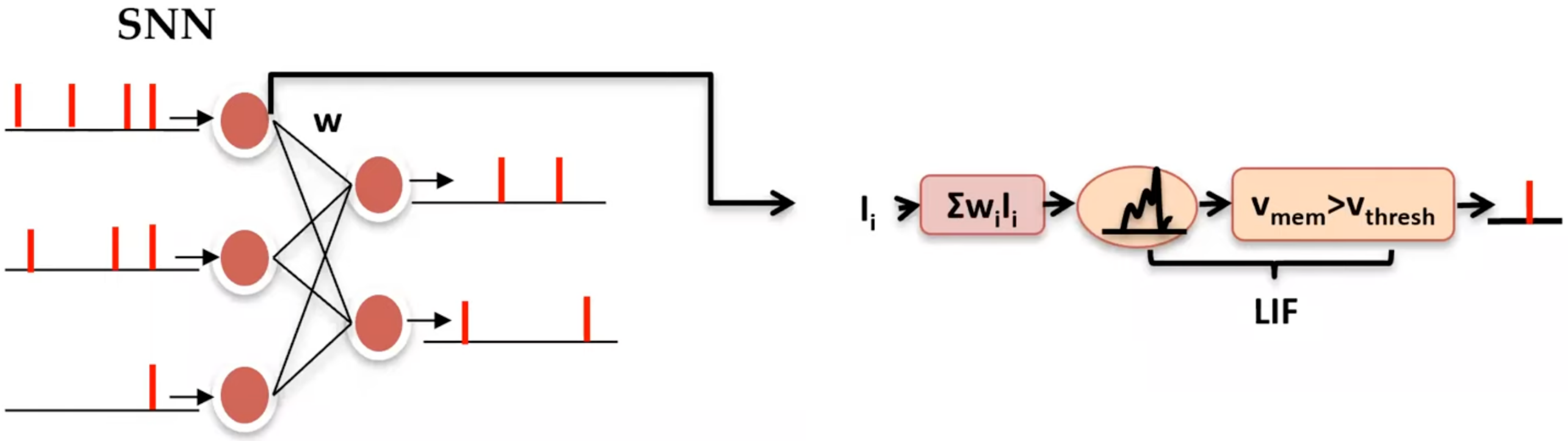
Nonlinear, discontinuous dynamics!

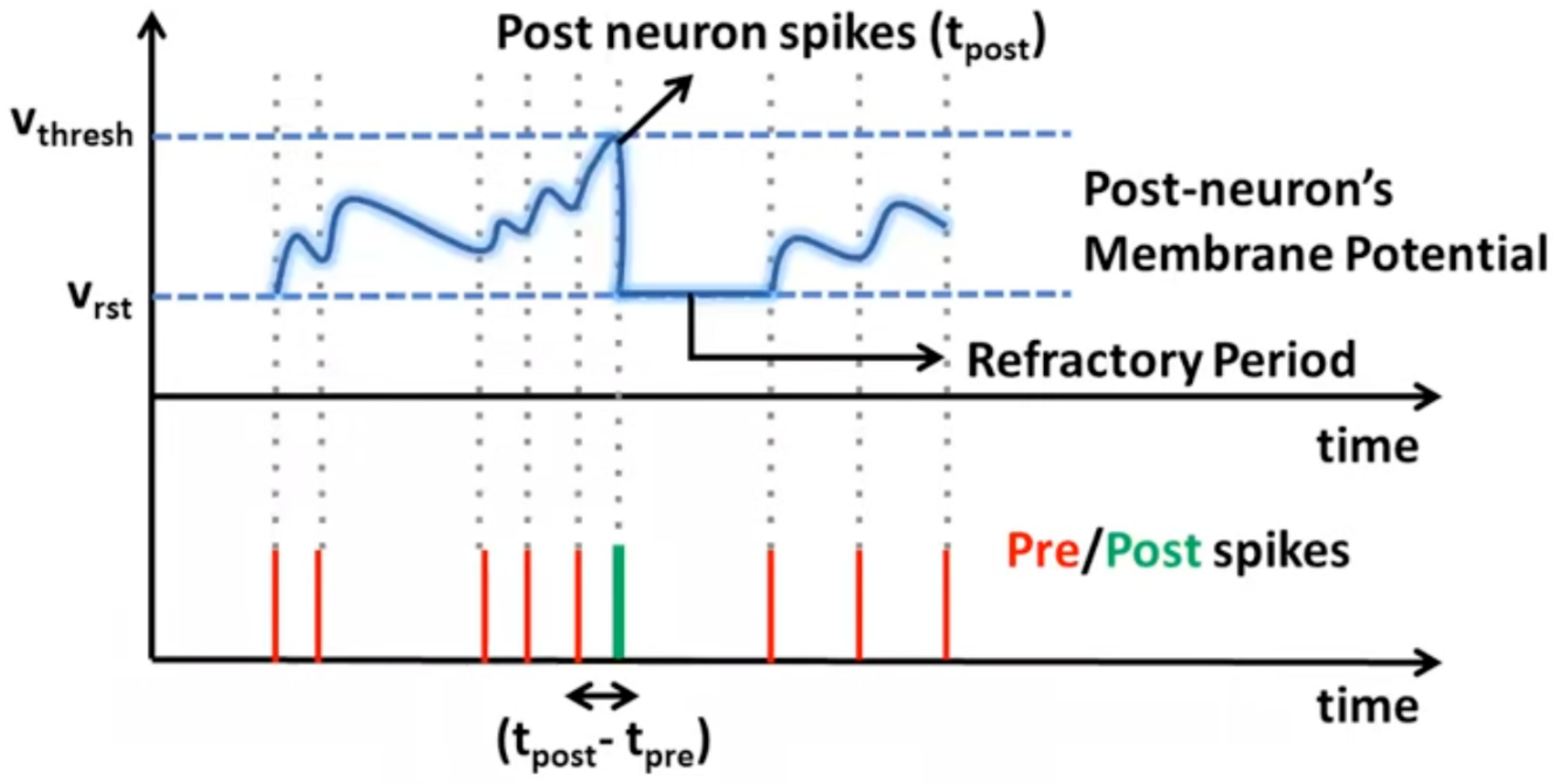




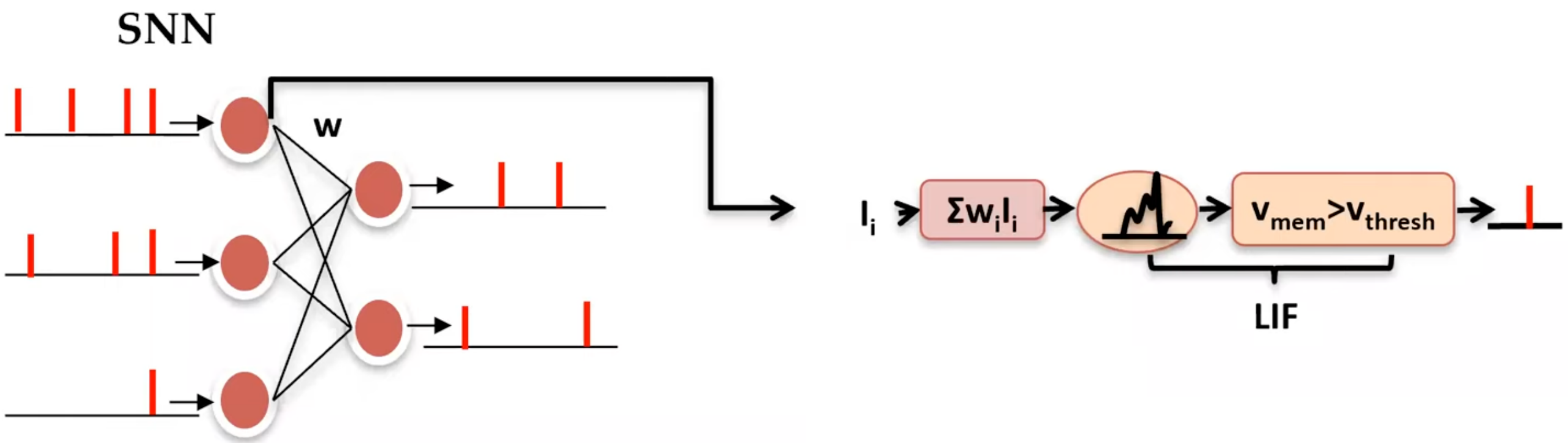


Spiking Neural Networks

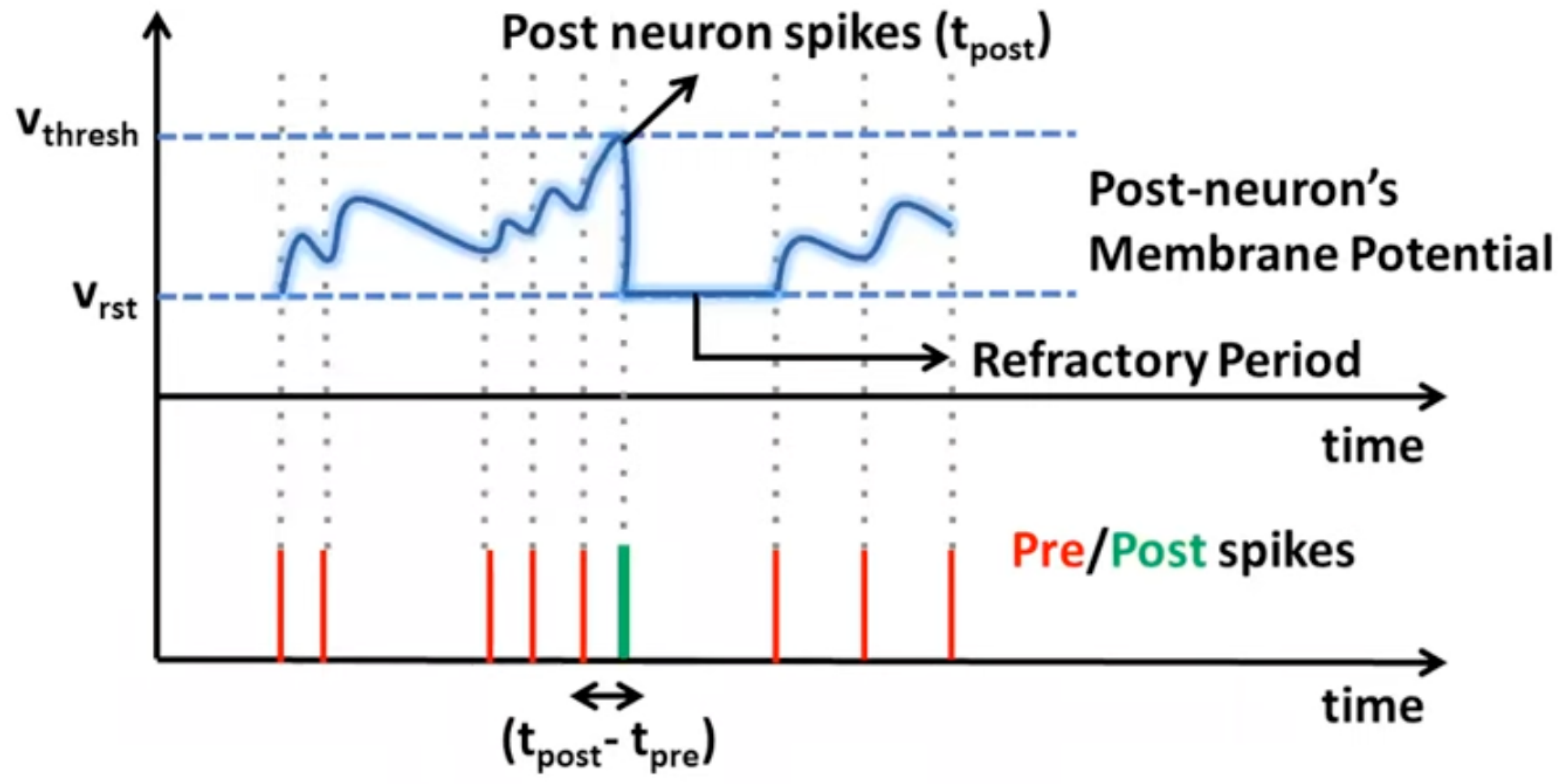




Spiking Neural Networks



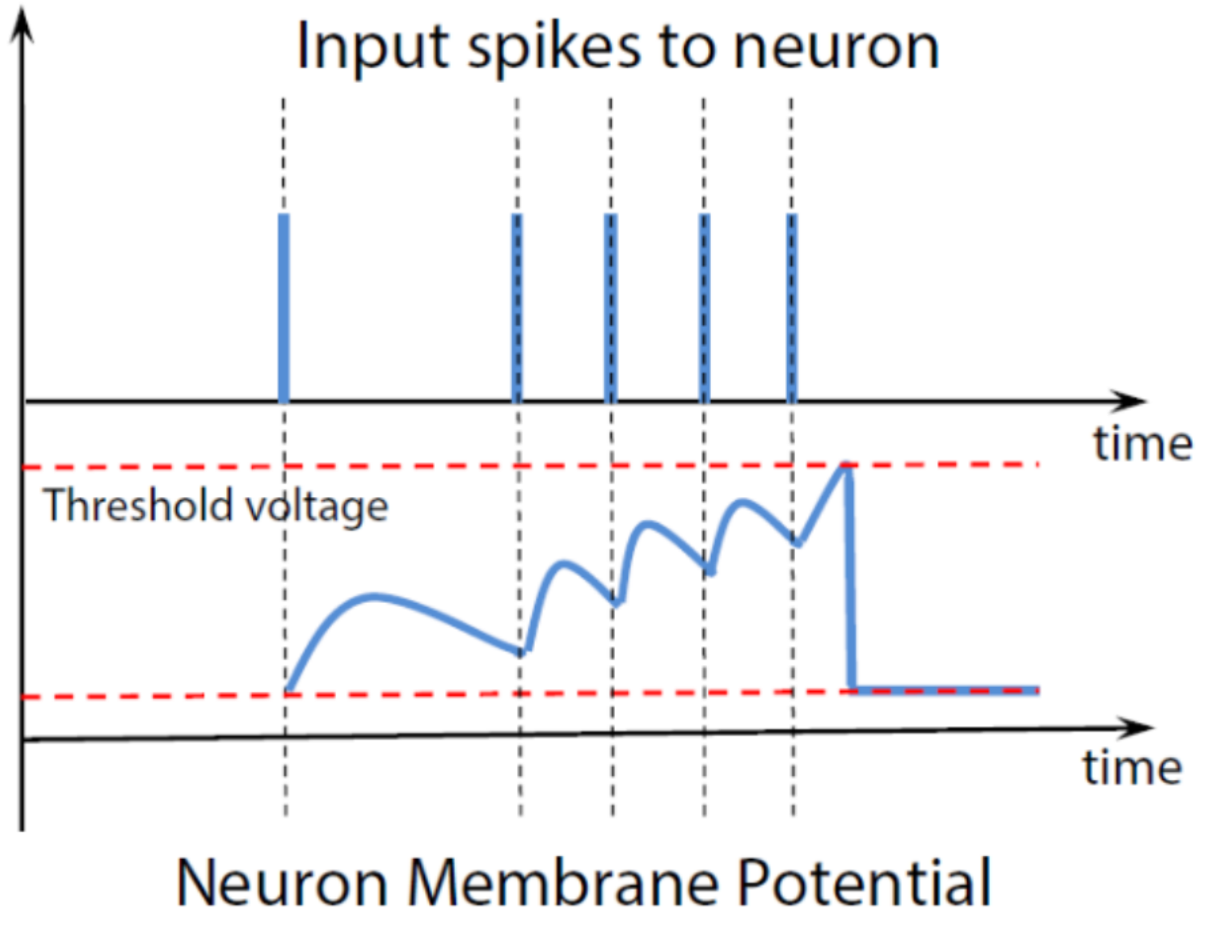
How to train it though? Backpropagation?

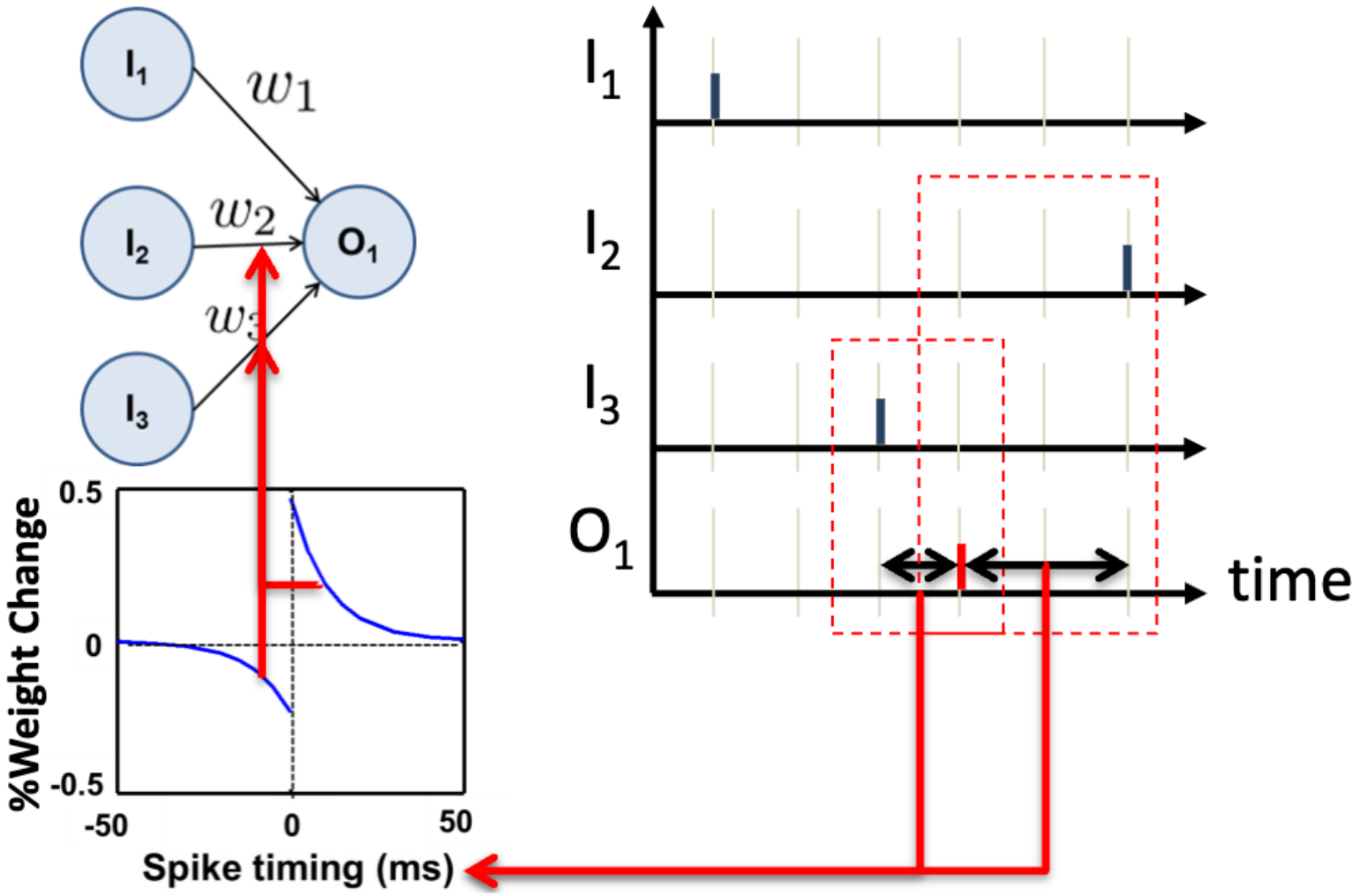


Spike timing dependent plasticity (Local) Learning

LIF Equation:

$$C\frac{dV}{dt} = -\frac{V}{R} + \sum_j w_j I_{post,j}$$





Weight Update Equations

$$w_i^{new} = w_i^{old} + \Delta w(t_i) \times w_{max} \qquad i = 1, 2, 3$$

Strength of the synapse should increase (decrease) as post and pre neurons appear to be temporally correlated (uncorrelated)

Can we train deep SNNs efficiently?

STDP Learning

Pros: Unsupervised local learning

Cons: Limited accuracy and shallow networks

Reference	MNIST Accuracy
Cook *et al.* Frontiers 2015 (ETH Zurich)	95.00%
Masquelier *et al.* Neural Networks 2017	98.40%
Lee *et al.* TCDS 2018	91.10%

ANN-SNN Conv

Pros: Takes advantage of standard ANN training

Cons: Conversion limited by constraints

Reference	MNIST Accuracy
Pfeiffer *et al.* IJCNN 2015 (ETH Zurich)	99.10%
Eliasmith *et al.* arXiv 2016 (U Waterloo)	99.12%
Liu *et al.* Frontiers 2017 (ETH Zurich)	99.44%

Backprop in SNN

Pros: Higher accuracy

Cons: Limited scalability, Discontinuous spike activities

Reference	MNIST Accuracy
Pfeiffer *et al.* Frontiers 2016 (ETH Zurich)	99.31%
Shi *et al.* Frontiers 2018 (Tsinghua)	99.42%
Zhang *et al.* arXiv 2018 (TAMU)	99.49%

Stochastic STDP

Pros: Unsupervised local learning with binary synaptic weights

Cons: Limited accuracy

Reference	MNIST Accuracy
Gamrat *et al.* Proceedings of the IEEE '15	60.00%
Yousefzadeh *et al.* Frontiers 2018	95.70%
Roy *et al.* (Frontiers, 2019)	98.54%

Panda, Roy et al. Frontiers 2019

Roy et al. Frontiers 2019