

A forecast-based biologically-plausible STDP learning rule

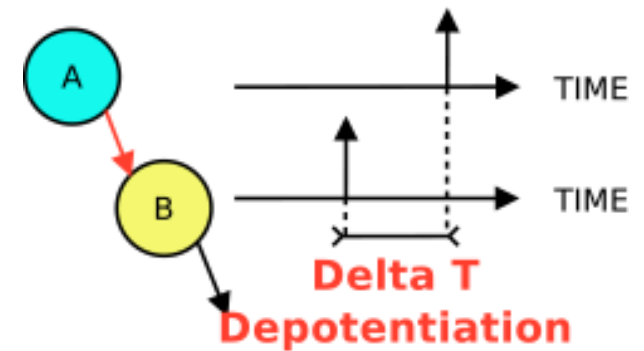
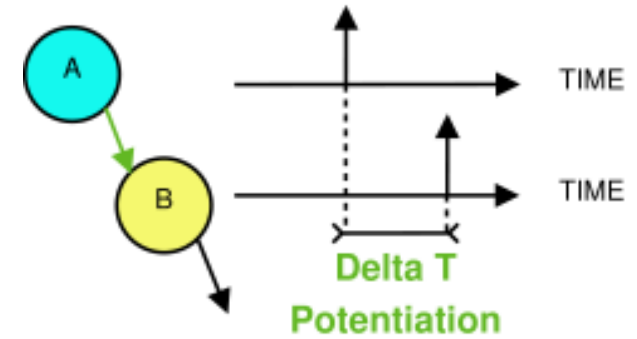
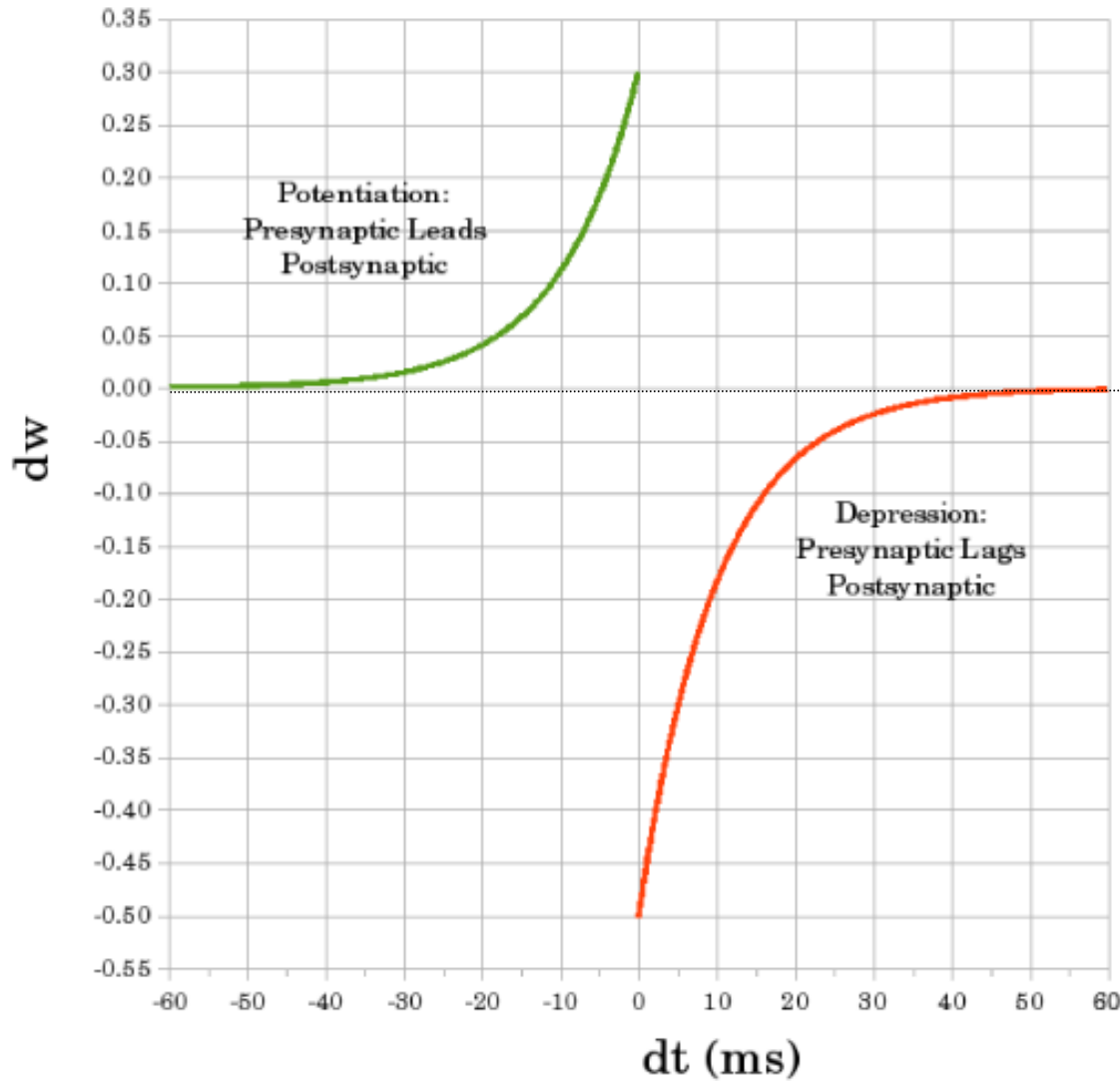
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APT group
The University of Manchester

Overview of topics

- Standard STDP learning rule
- Description of the new approach
- Statistical details involved
- The STDP-TTS
- Test environment
- Learning features

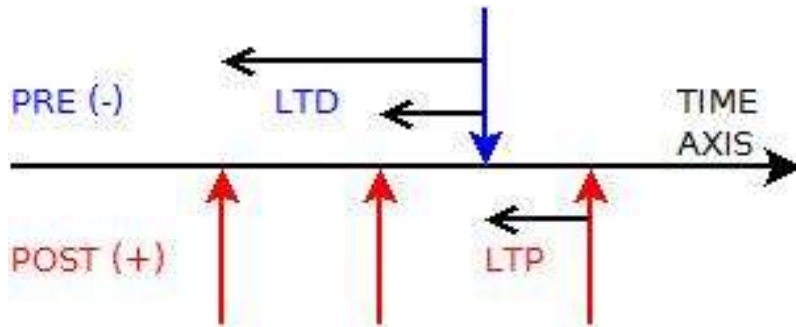
Spike Timing Dependent Plasticity



Implementation

Triggering the STDP algorithm

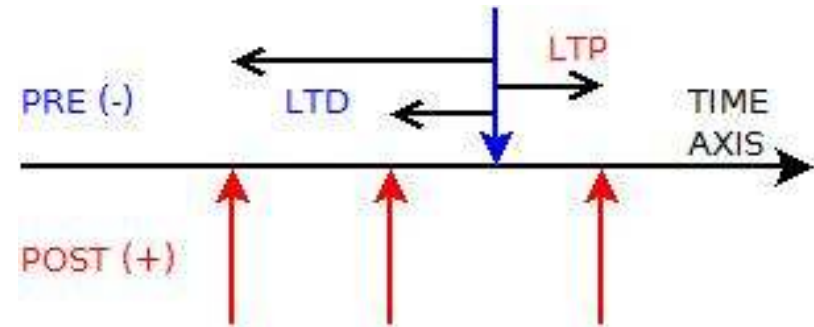
The usual way:



STDP is triggered on:

- Pre-synaptic spike arrival (LTD)
- Post-synaptic spike emission (LTP)

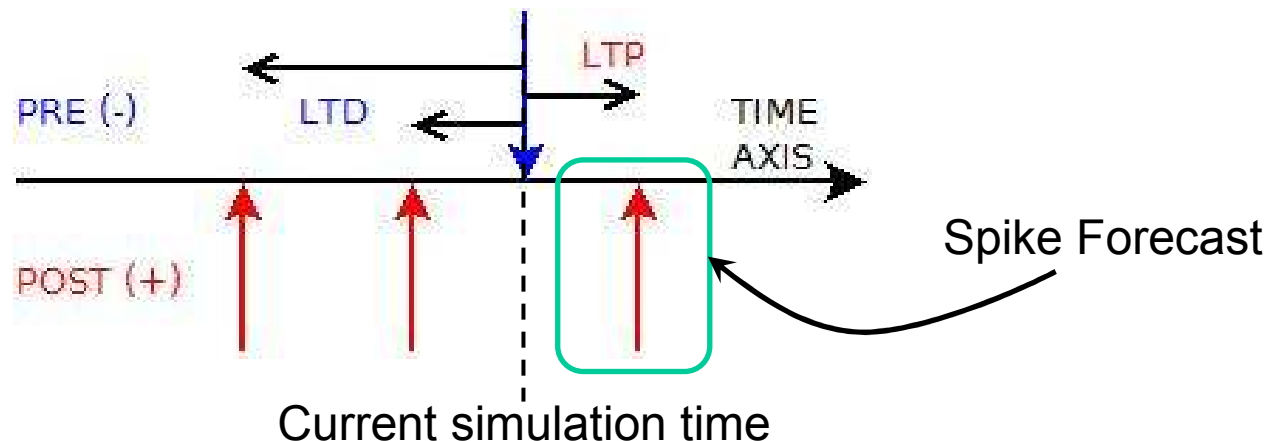
The SpiNNaker way:



- STDP is triggered only on pre-synaptic spike arrival (LTD and LTP)
- Weights are available only at pre-synaptic spike arrival.
- Since LTP needs future information, the algorithm needs to be deferred until the time window is filled

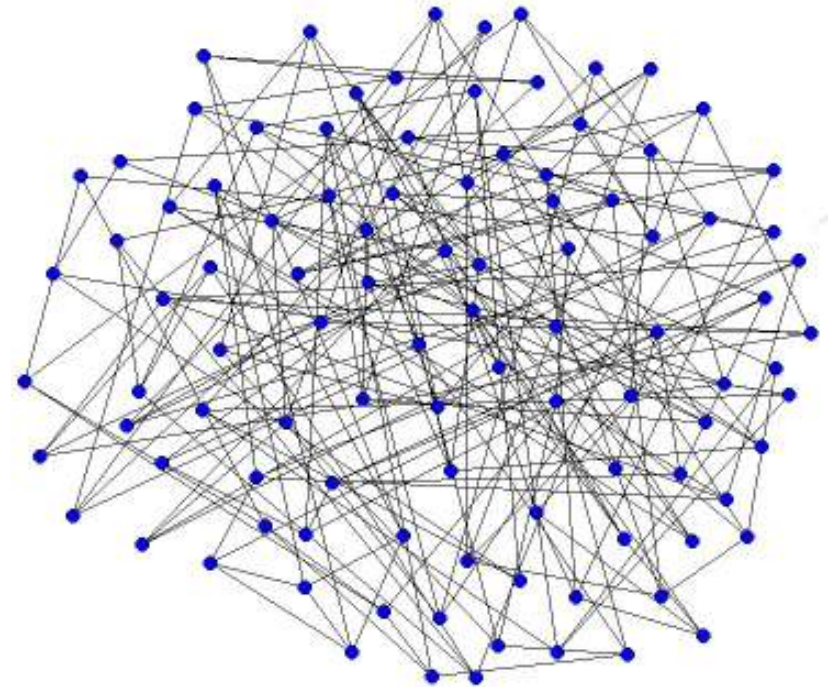
New approach

- Is it possible to simplify the STDP model so that its implementation on SpiNNaker is more performant (from both memory and computational points of view)?
- To avoid the Deferred Event Model, we need to have statistics that tell us when a neuron is going to fire in the future (at least with some probability).



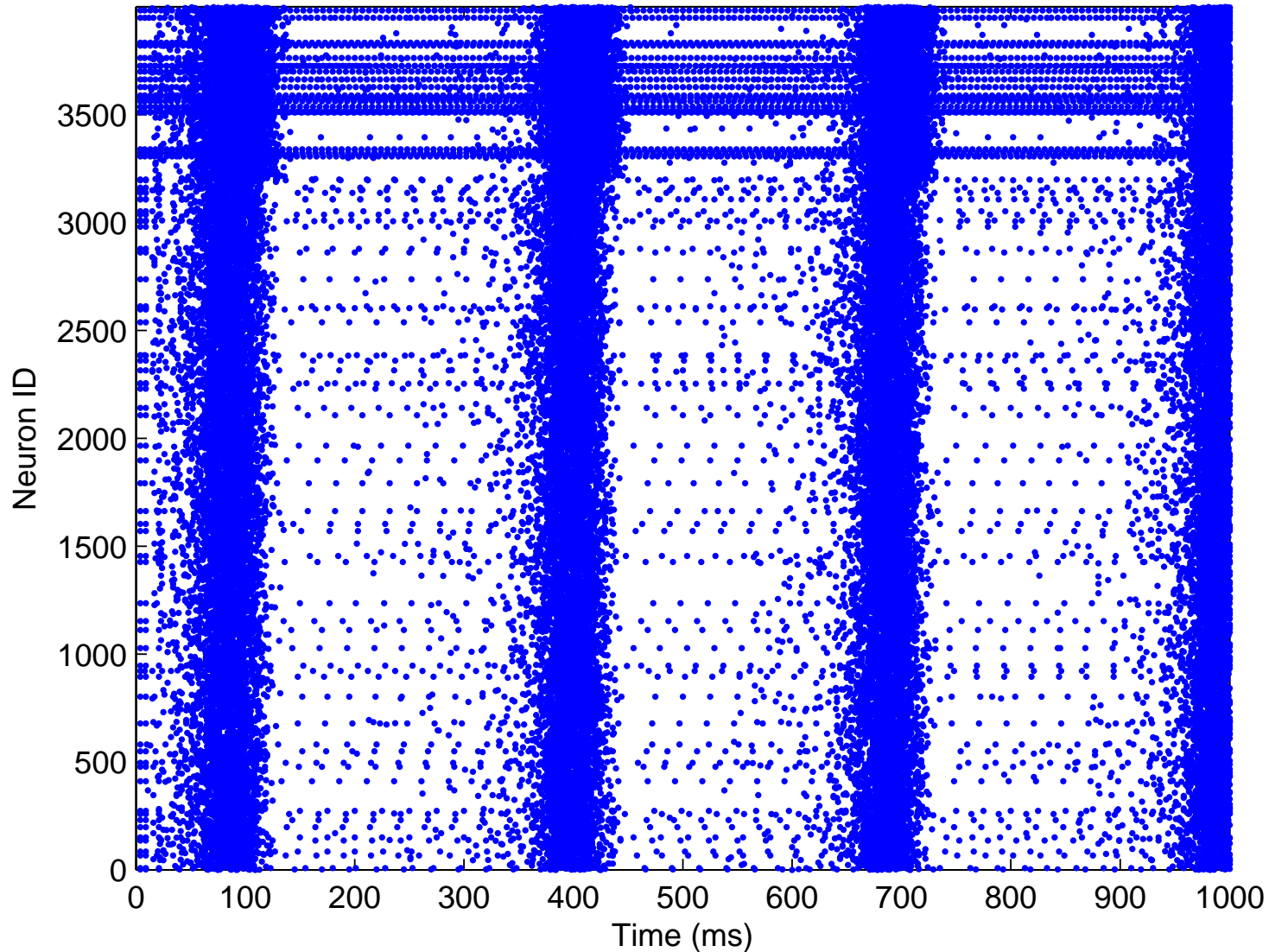
Statistical approach - 1

- The idea is: the higher the membrane potential of a neuron (that receives a spike), the sooner it is likely to emit an action potential.
- Starting with a random network of Izhikevich neurons, fed with input to random neurons with random delays;
- We store all the activity in the network (especially membrane potential evolution).



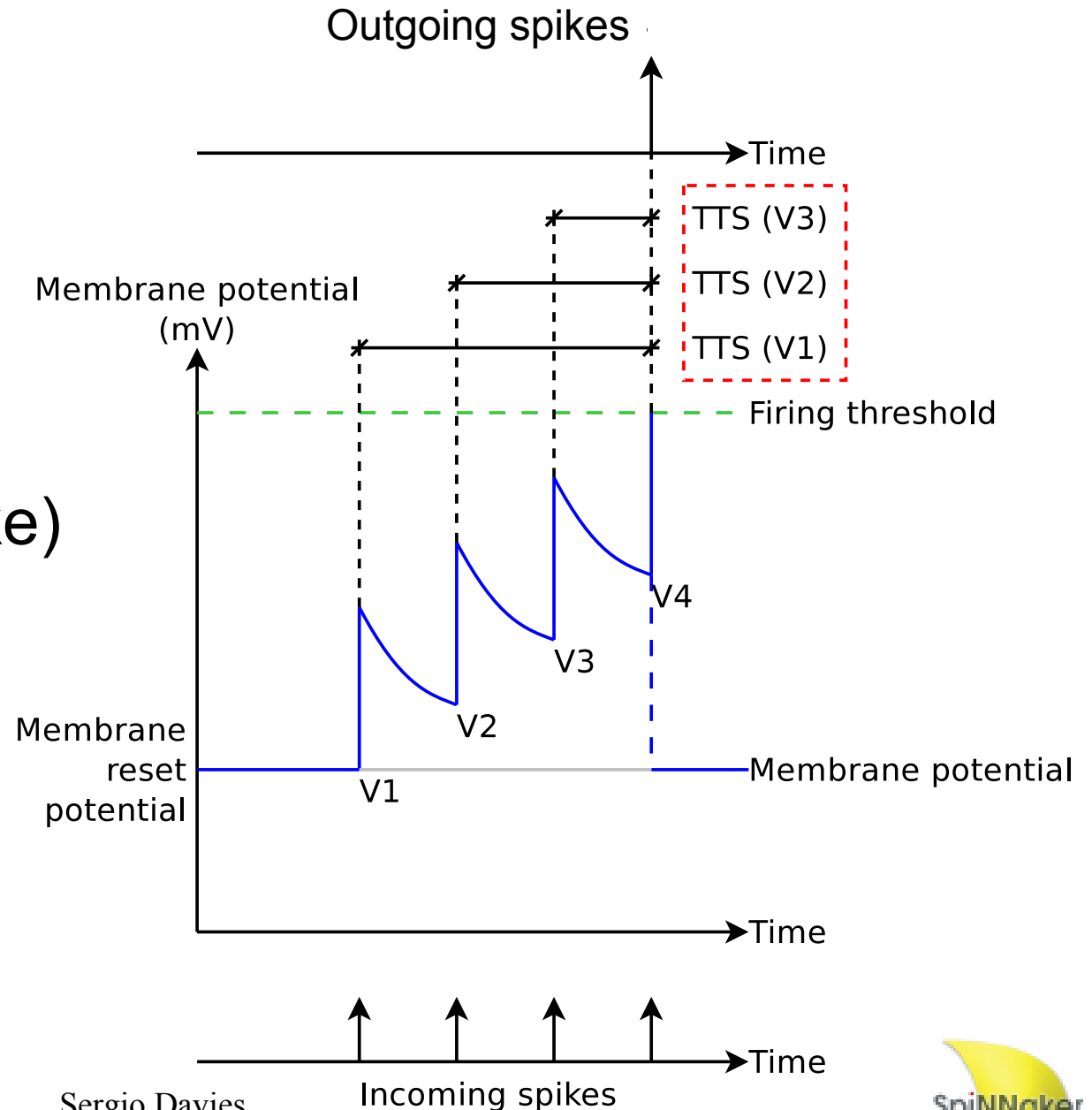
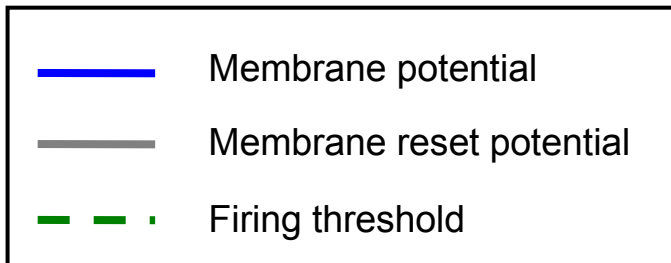
Statistical approach - 2

Raster plot in Matlab (fixed-point)



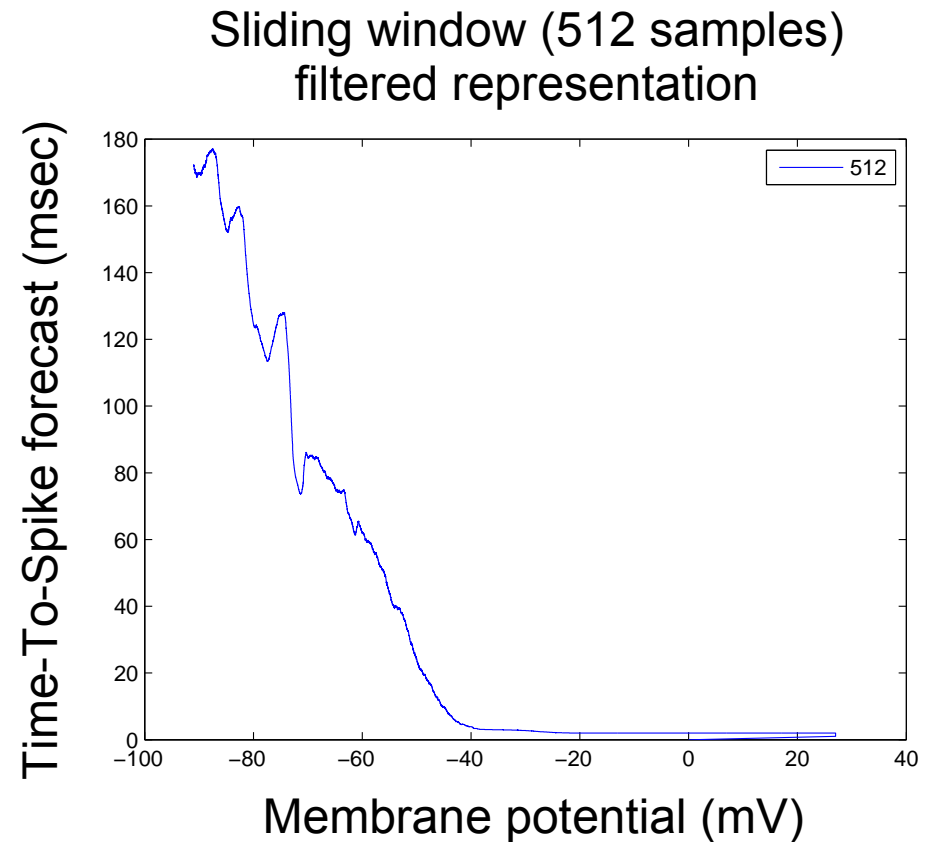
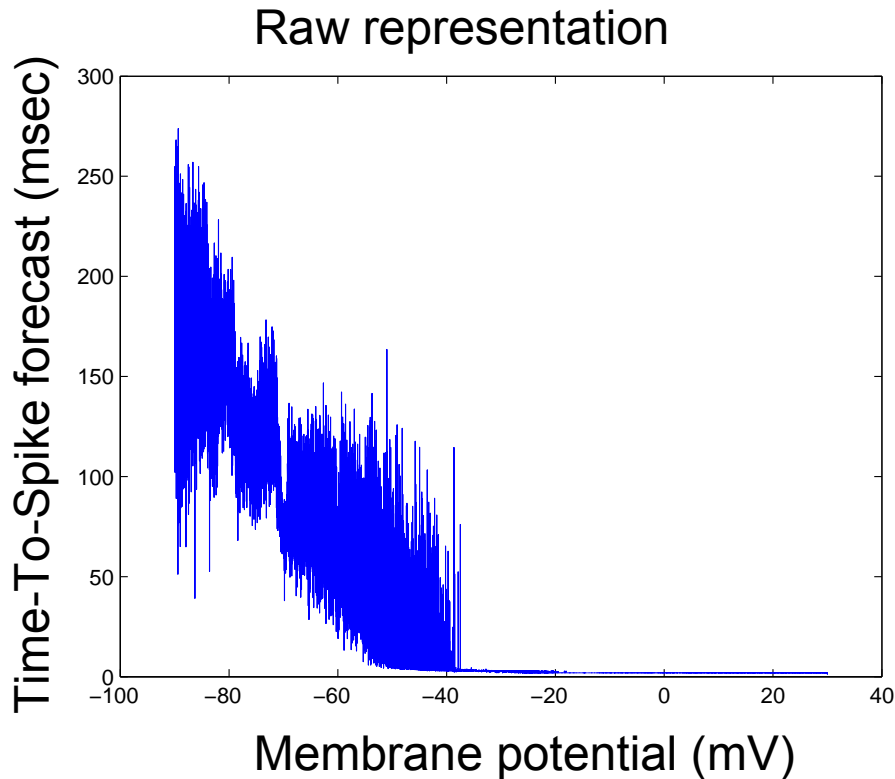
Statistical approach - 3

- We evaluate all the couples (membrane potential; time-to-spike)



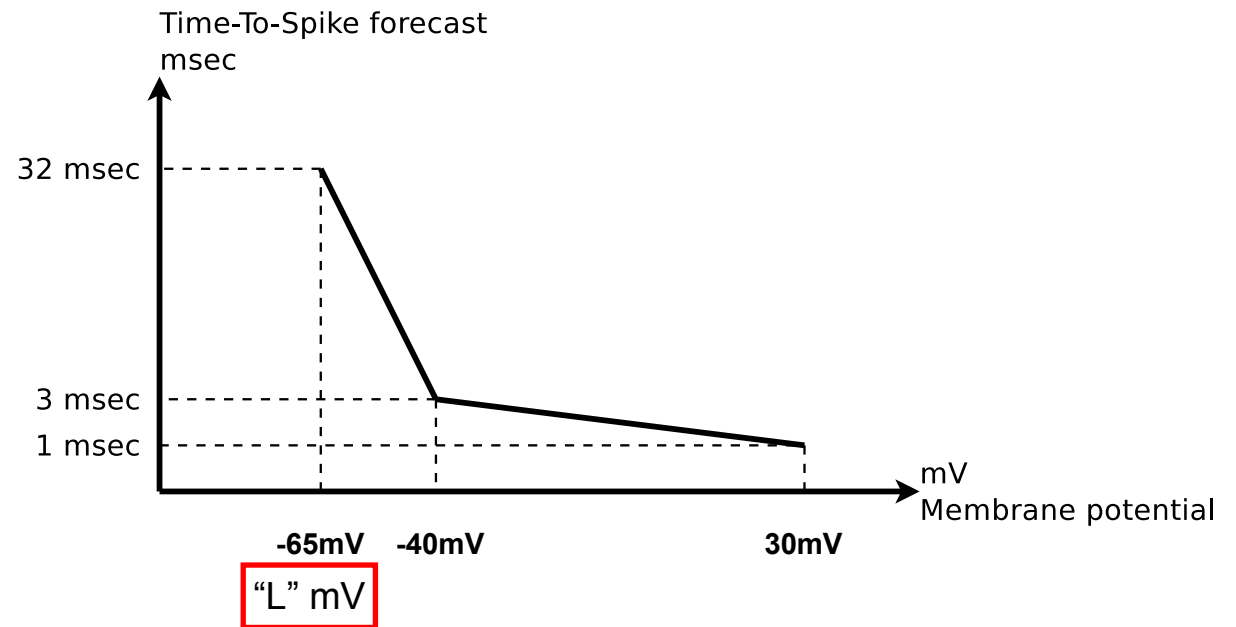
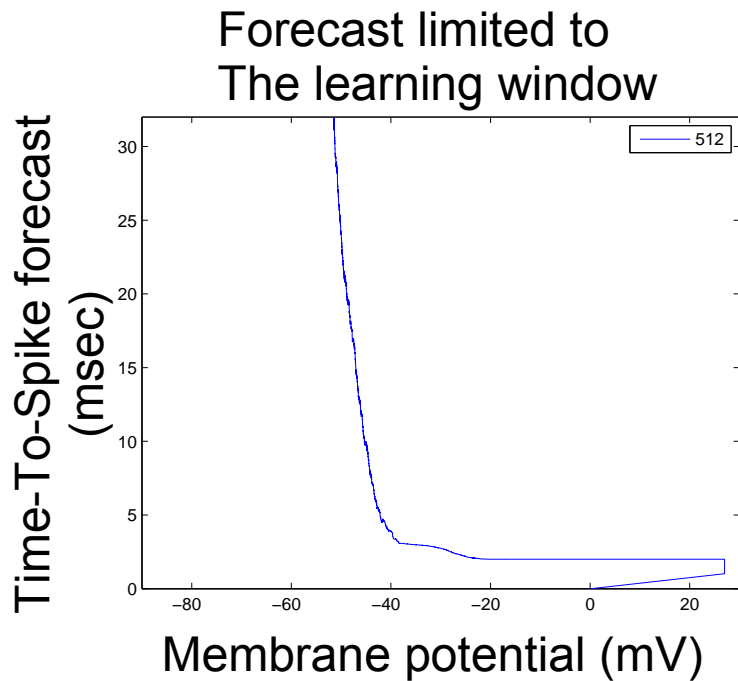
Results of the statistical approach

- Representation of all the couples computed before



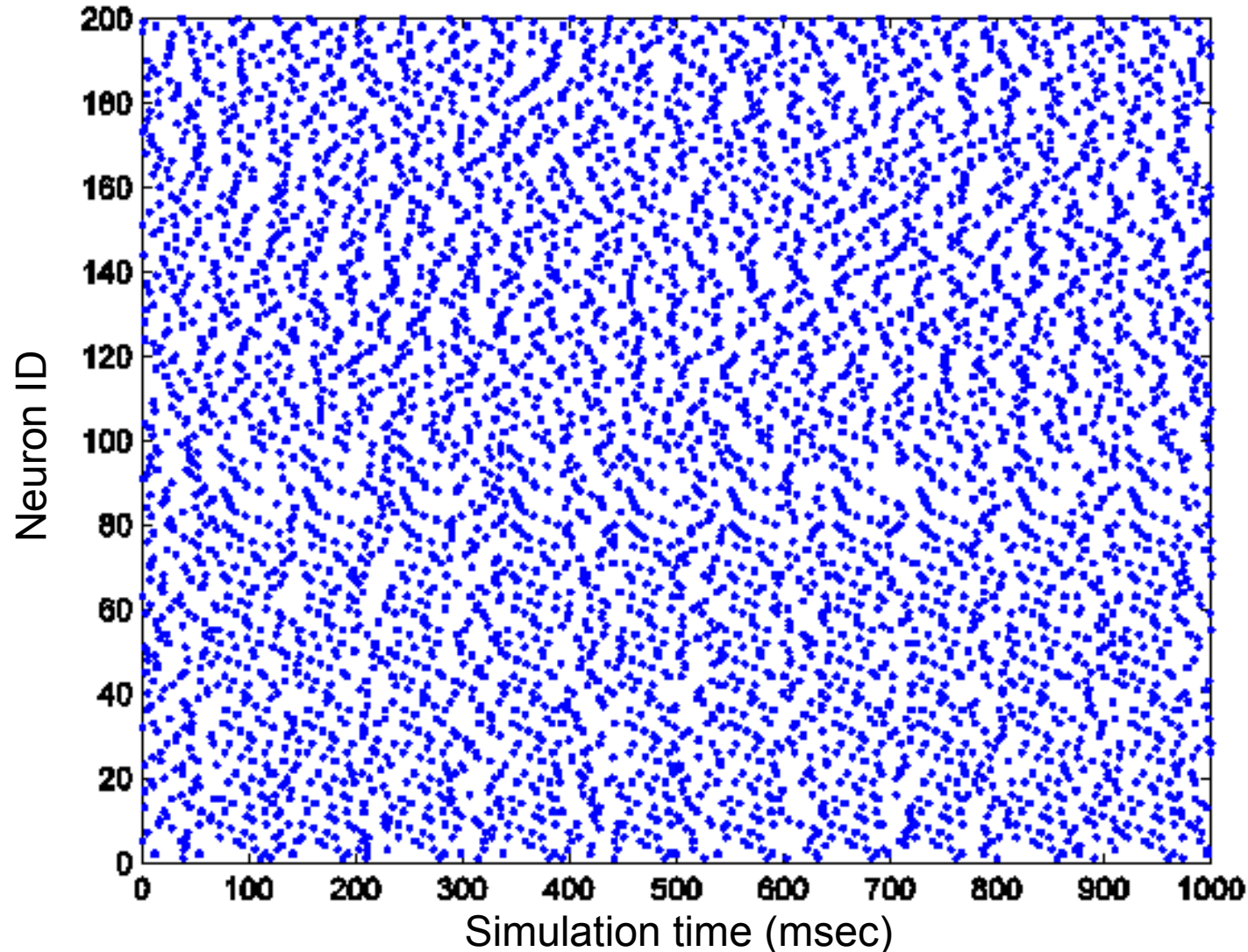
The STDP-TTS

- The wider the STDP time window, the greater the uncertainty of the forecast of the time-to-spike. We limit the STDP time window to 32 msec.



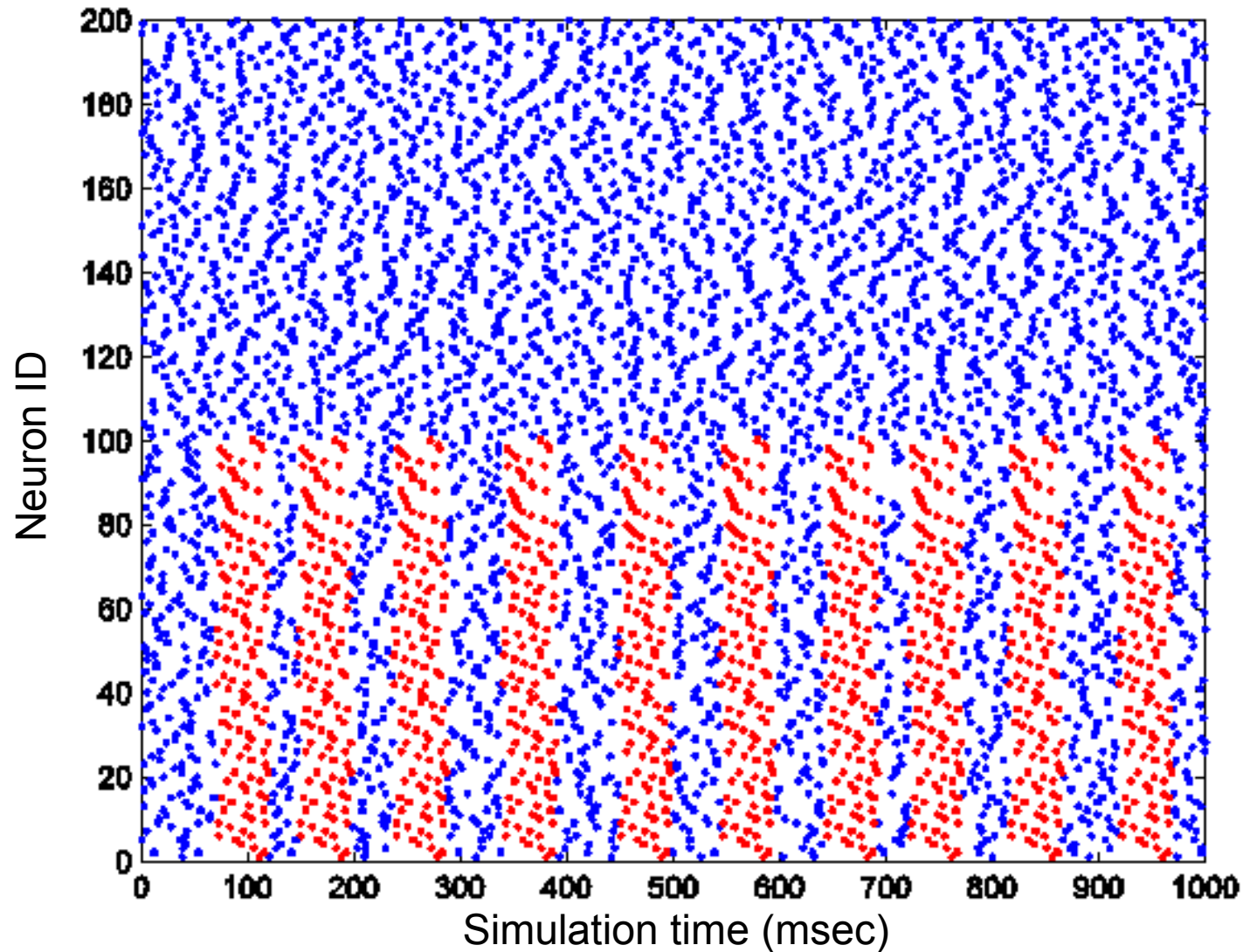
Input provided

Can you identify any pattern in this raster plot?



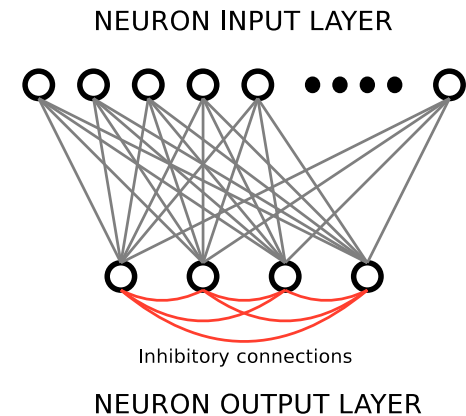
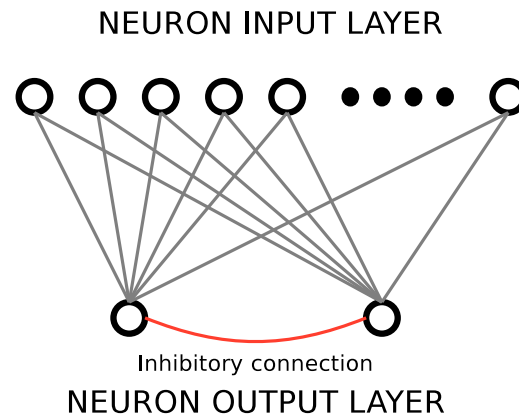
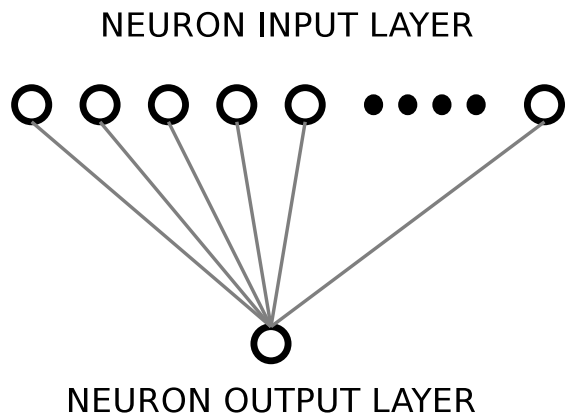
Input provided

Solution: in red the pattern



Testing the features

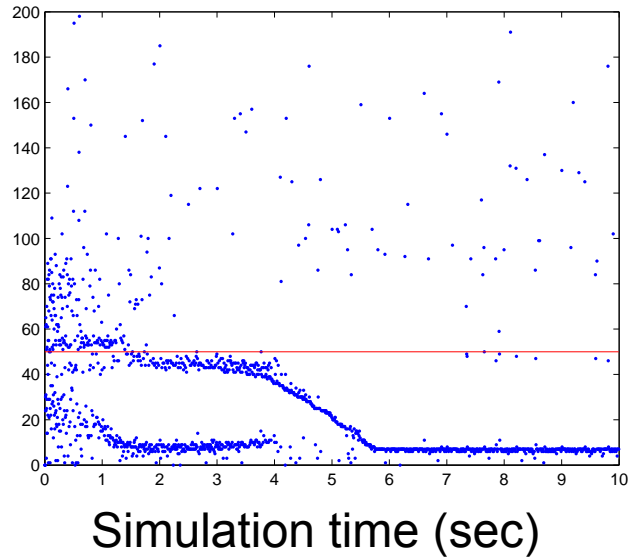
- To test this forecast learning rule we use as a benchmark the tests ran by Masquelier et al. in 2008 and 2009.



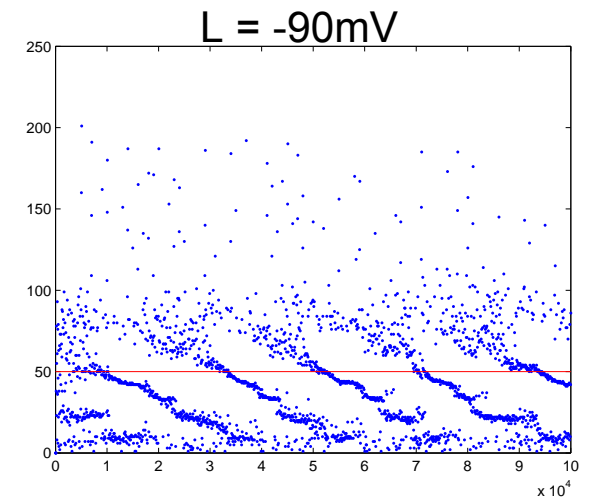
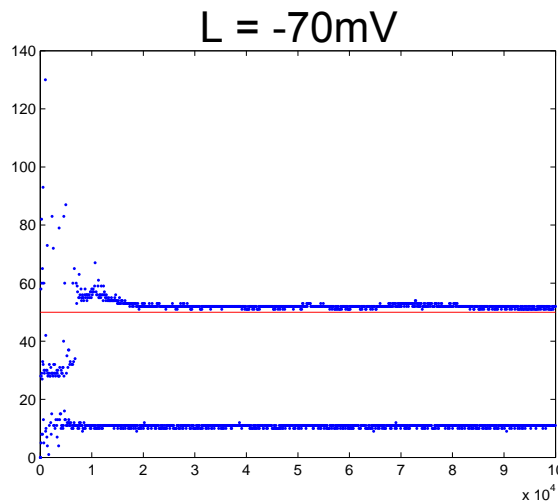
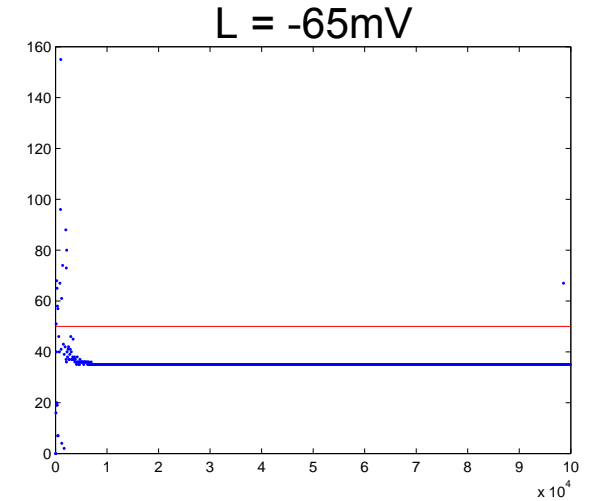
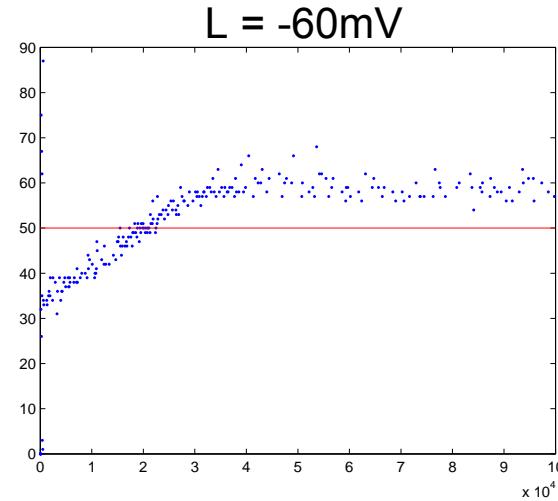
Results of the tests - 1

Standard STDP

Delay after pattern input (msec)



STDP-TTS (with forecast)

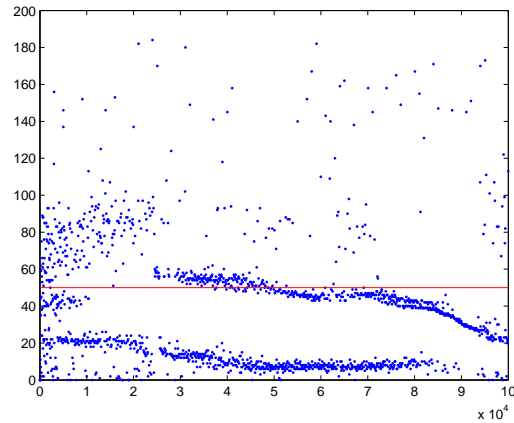


Results of the tests - 2

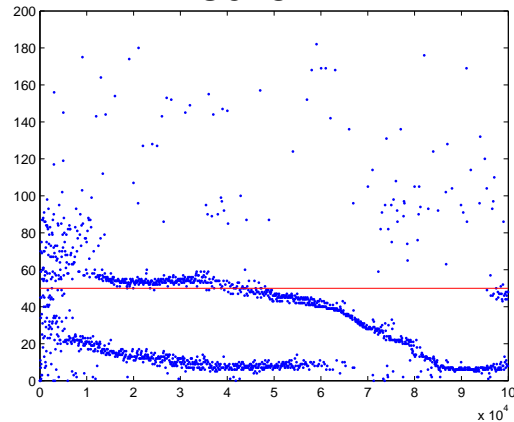
Two output neurons – one input pattern

Standard STDP

Neuron 1

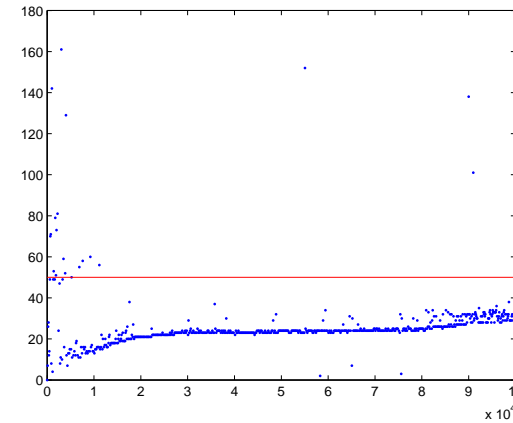


Neuron 2

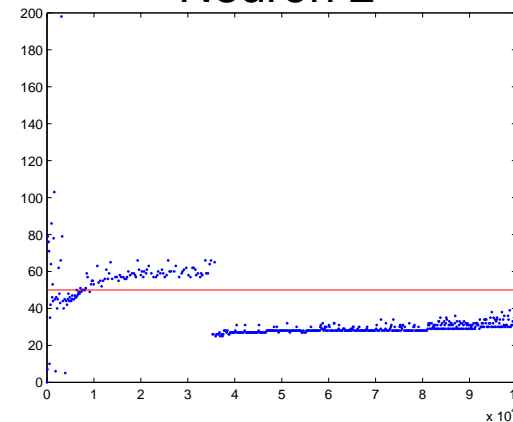


STDP with forecast

Neuron 1



Neuron 2



Results of the tests - 3

Four output neurons – two input patterns
standard STDP

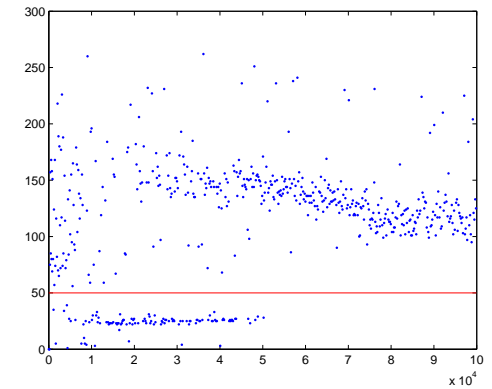
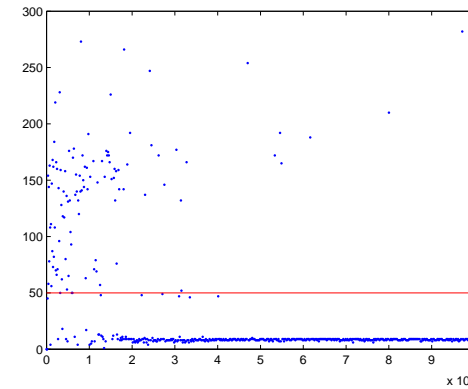
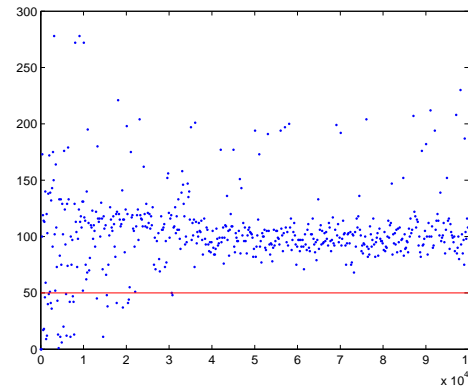
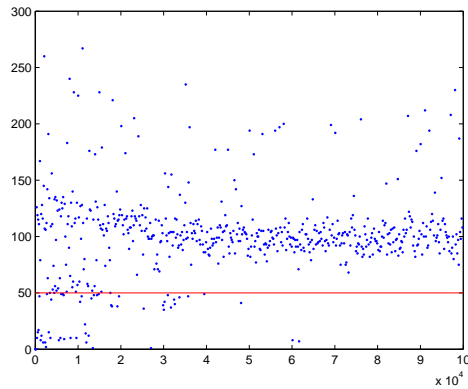
Neuron 1

Neuron 2

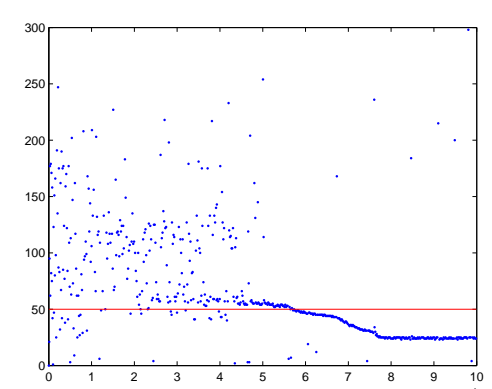
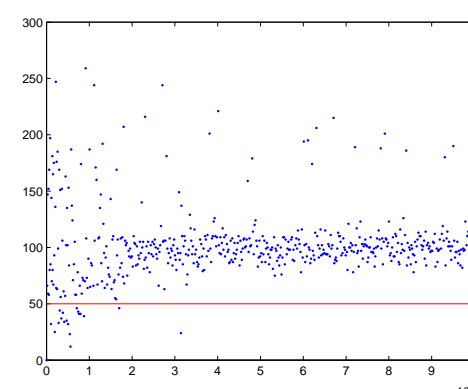
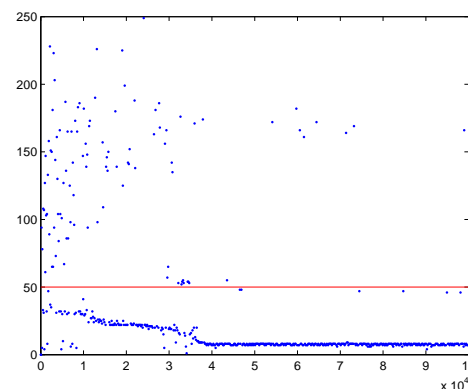
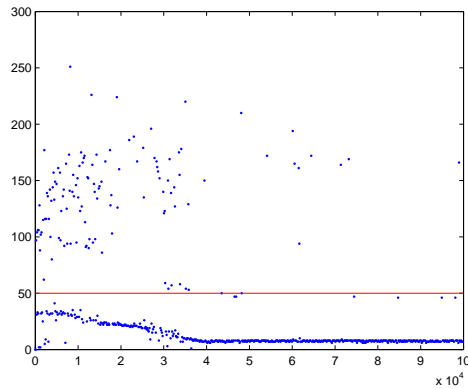
Neuron 3

Neuron 4

Pattern 1



Pattern 2



Results of the tests - 4

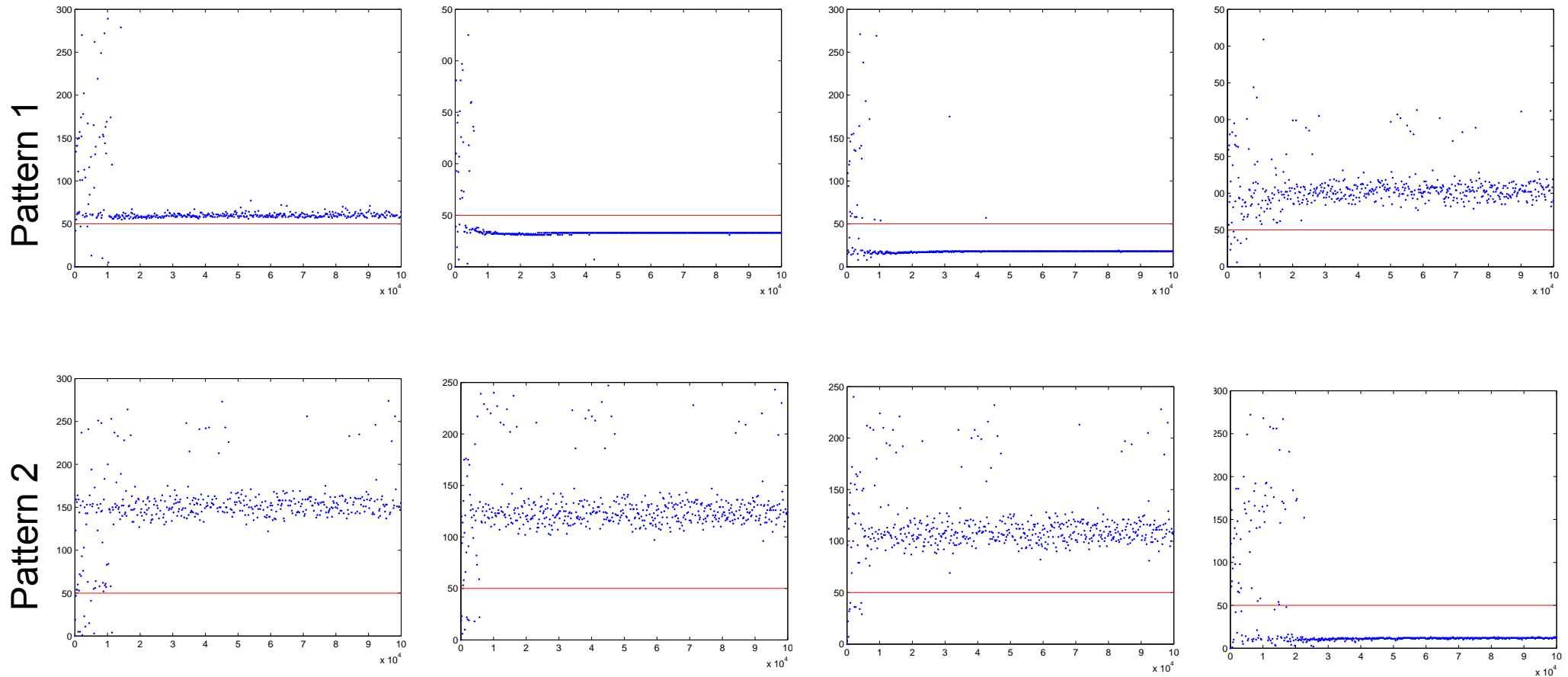
Four output neurons – two input patterns
STDP with forecast

Neuron 1

Neuron 2

Neuron 3

Neuron 4

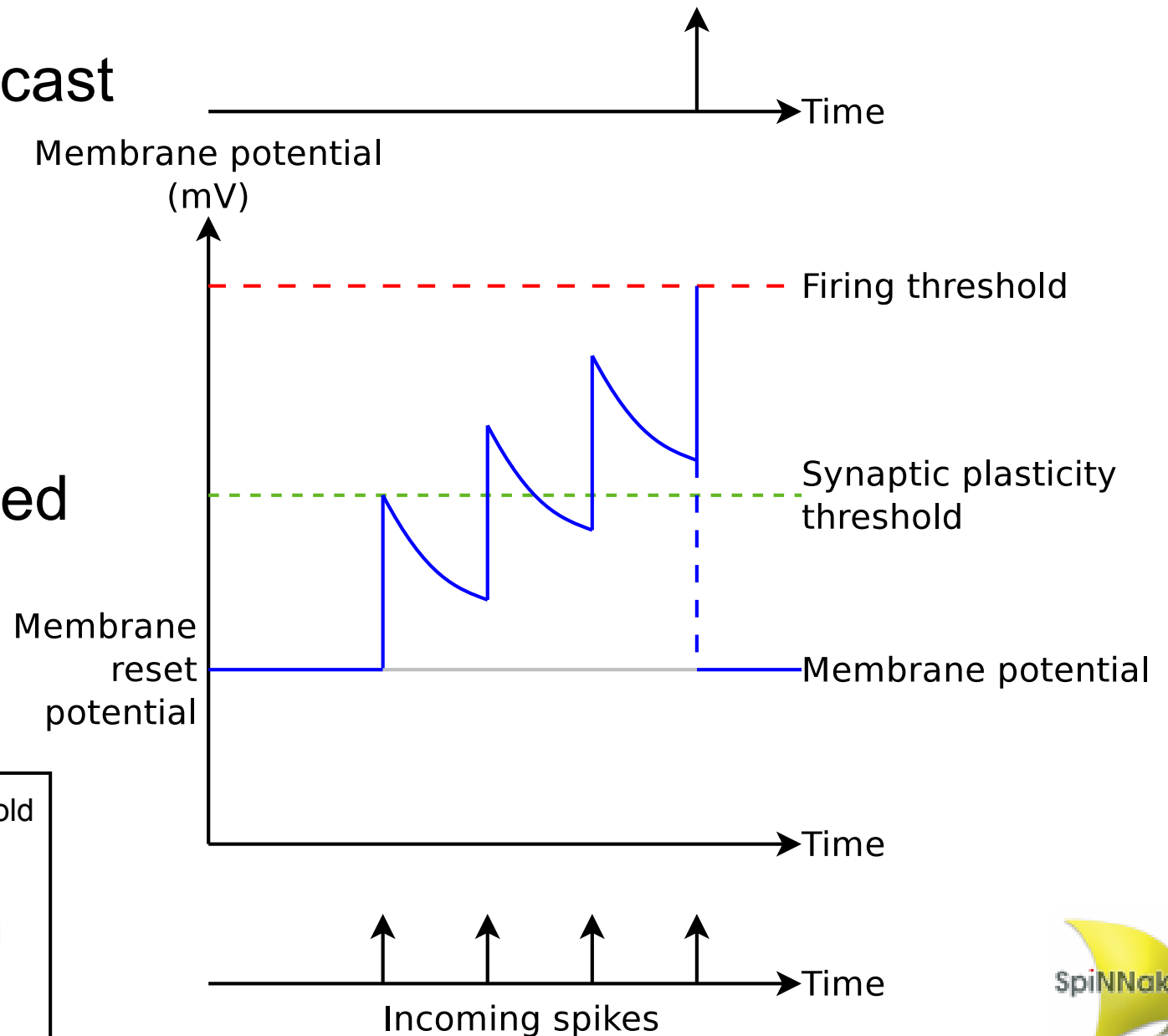


Backup slides

Limitations of the new rule

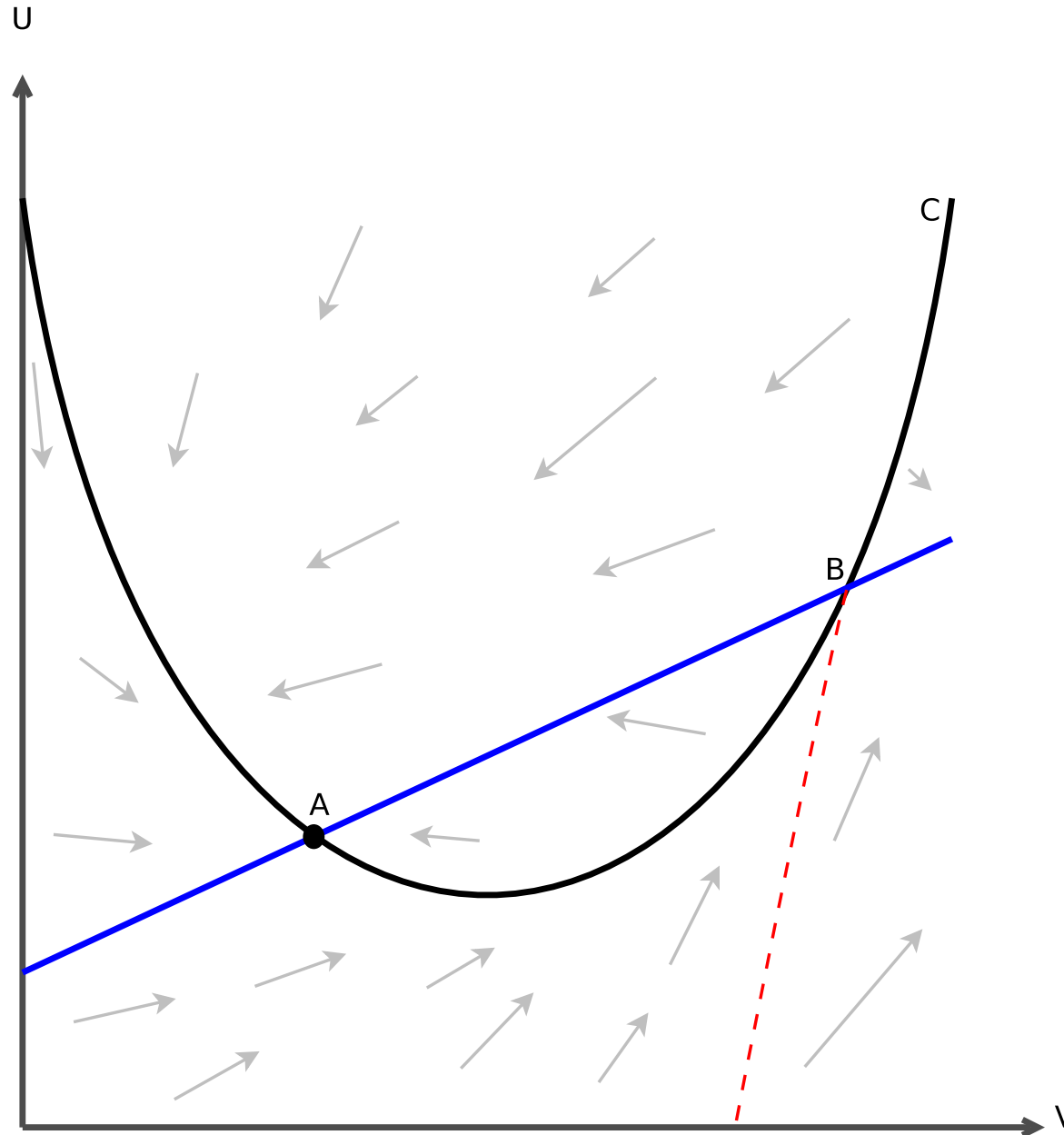
- STDP with forecast cannot tune to the earliest spikes
- The forecast function is related to the type of Izhikevich neuron

Outgoing spikes

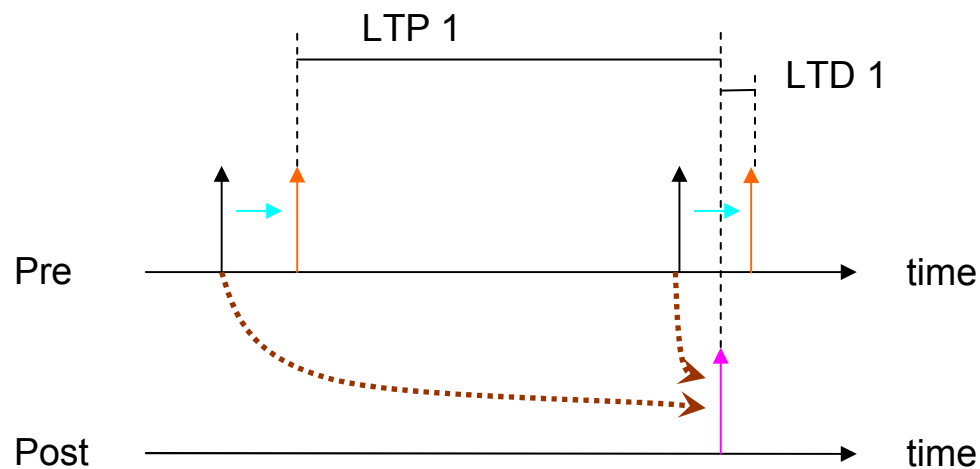
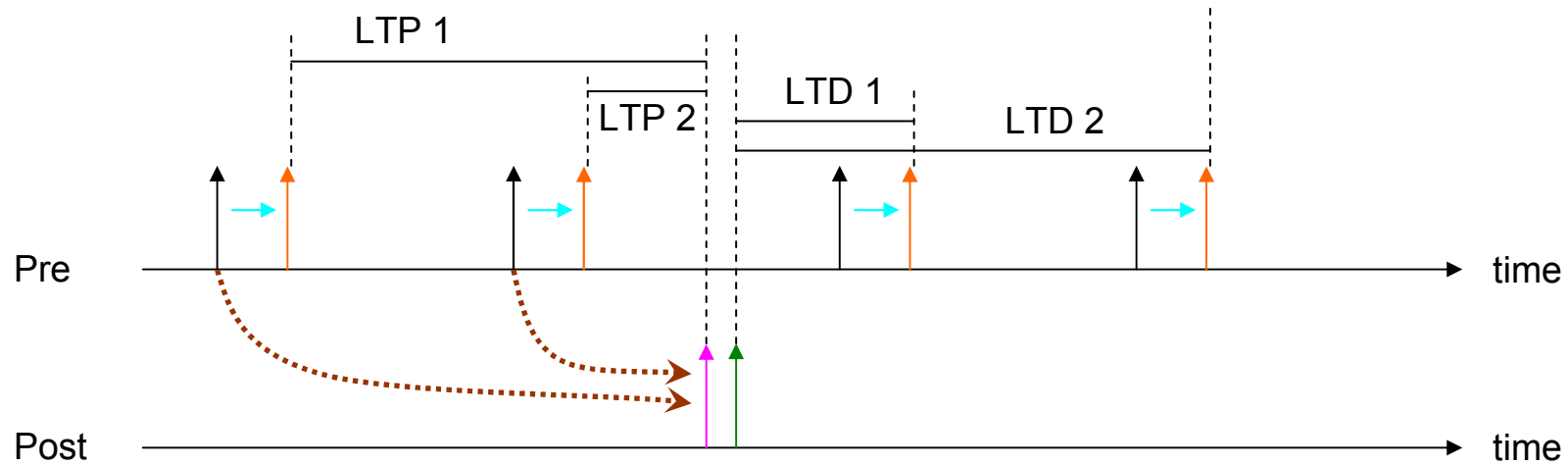


- Synaptic plasticity threshold
- Membrane potential
- Membrane reset potential
- - - Firing threshold

The Izhikevich phase space



Implementation on SpiNNaker



- ▶ Incoming spike
- ▶ Incoming spike delayed by synapse
- ▶ Synaptic delay
- ▶ Forecast based on the current neuron membrane potential
- ▶ Forecasted spike
- ▶ Real outgoing spike