Exercises: Spike-timing dependent plasticity

It is recommended to work through Part 3 of *Introduction to PyNEST* before starting.

To complete these exercises, start from the provided template `exercises_stdp.py`. As the exercises build on one another, do them in order.

1) Parameters

a) Read through the script and understand the network set-up. Make yourself familiar with unknown models by looking them up in the documentation. Sketch the network structure on a piece of paper including stimulating devices, (types of) neurons, (types of) connections, weights, delays, rates and show this to a tutor to check that you are going to create the right network.

b) Which parameter defines the weight dependence of the STDP synapses?

c) Determine the equilibrium firing rate of the `neuron` for the case that all synapses are static (average firing rate over $100\,\mathrm{s}$ after an equilibration period of $100\,\mathrm{s}$).

d) Find (empirically) a value for the asymmetry parameter α that results in a comparable equilibrium firing rate for plastic synapses using the additive and the multiplicative STDP update rules.

2) Uncorrelated input

You can use the NEST command `GetConnections` to access the synapses of given pre-synaptic neurons and with the help of `GetStatus` you can extract the synaptic properties such as `weight` and `delay`. To record the synaptic weights you will have to make a loop which in each iteration calls `Simulate()` for a given recording interval and then queries the weights. For consistency the recording interval needs to be a multiple of the minimum delay in the network. Here, you should simulate the network for $200\,\mathrm{s}$ in total, and record the weights of the connections from the `inputs` to the `neuron` in recording intervals of $1\,\mathrm{s}$.

a) Plot the development of the weight of the first synapse and the development of the mean synaptic weight for both the additive and the multiplicative rules.

b) Plot the equilibrium weight distribution (histogram of all weights recorded in the final $100\,\mathrm{s}$) for the additive and the multiplicative rule. Weights should be normalized to the interval $[0, 1]$. Calculate the mean equilibrium weight for both rules (average over the recordings of the final $100\,\mathrm{s}$).

c) Determine (approximately) the critical value of the weight-dependence parameter: below the critical value a bi-modal equilibrium weight distribution is obtained, above the critical value a unimodal equilibrium weight distribution is obtained. Illustrate your results in an appropriate plot (e.g. see Fig. 4A in Guetig et al., 2003).

Hint: each iteration should store the heights of the histogram in a list, which gets appended to a master list. Thus, after all the iterations you have a list of lists, which you can then cast into a `numpy.array`. To illustrate, try `pcolor` from `matplotlib` (or `pylab` if you prefer).

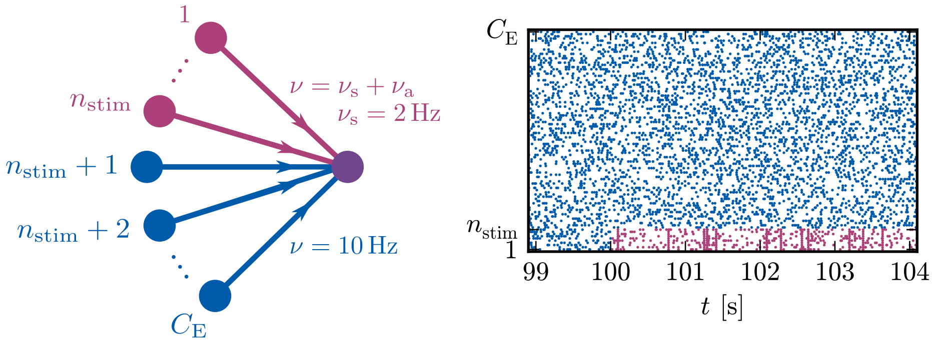

Figure 1: Left: Schematic of input structure to the neuron. The first n_{stim} inputs should have an asynchronous fitting rate of 8 spikes/s and a synchronous firing rate of 2 spikes/s; the rest of the inputs hould have an asynchronous fitting rate of 10 spikes/s. Right: Dot display of input activity. Before 100 s, all inputs are asynchronous at 10 spikes/s, after 100 s the first n_{stim} inputs are partially synchronous.

3) Synchronous stimulus

Adapt the simulation such that after an equilibration period of 100 s the first `n_stim inputs` start to fire synchronously at a rate of 2 Hz. Their asynchronous firing rate should be reduced by 2 Hz to compensate. Simulate for 300 s and record the weights of the connections from the `n_stim=10` synchronous `inputs` to the `neuron` and from the asynchronous `inputs` to the `neuron` every 1 s.
Hint: Devices can be set to turn on and off at specified times, see Part 2, Sec. 6.

a) Plot the development of the mean synaptic weights of the 'asynchronous' and of the 'synchronous synapses' for the additive and the multiplicative rule.

b) Plot the equilibrium weight distributions of the 'asynchronous' and of the 'synchronous' for the multiplicative rule (i.e. mean histogram over the last 100 recordings). Weights should be normalized to the interval $[0, 1]$. Calculate the mean equilibrium weight of the 'asynchronous' and of the 'synchronous synapses'.

c) Perform the simulation for a range of `n_stim` (e.g. from 5 to 55 in steps of 5) for the multiplicative rule. Plot the mean equilibrium weight of the 'asynchronous' and of the 'synchronous synapses' in dependence of the number of synchronous `inputs` (`n_stim`).

d) Include a simple mechanism for dendritic homeostasis: After the first 100 s (no stimulus during that period) calculate the total weight of the incoming STDP synapses of `neuron`. During the following 200 s scale the weights of the STDP synapses every 1 s such that the previously determined total synaptic weight is reobtained. Perform the simulation for a range of `n_stim` for the multiplicative rule and plot the mean equilibrium weight of the 'asynchronous' and of the 'synchronous synapses' in dependence of `n_stim`.