4.2 Intrinsic plasticity

(Video 4.2) Experiments have shown that neurons have multiple strategies for maintaining healthy firing rates. Some types of plasticity can regulate the neuron's output spiking without acting on the input synapses. We call these "Intrinsic Plasticity" (IP) mechanisms [**?**]. Instead of changing the structure and protein content of the synapses, IP acts upon the ion channels in the neuron membrane, making the neuron less responsive to a single input if the strength of the inputs increases. The IP can therefore implement a homeostatic effect, nudging the spiking threshold of the neuron down or up depending on its recent history of activity. The time scale of IP is typically on the order of hours or even days. In a model neuron, we do not necessarily employ such a long timescale directly, but as with synaptic normalisation, it should be a slower dynamic compared to STDP. In the LIF neuron, IP can be directly implemented with a moving threshold V_{thresh}, and a target firing rate for the neuron, R_{target}. First, create an online spike counter that records the neuron's output spikes, and determine the online firing rate in Hz every second as R_{count}. Set the neuron to change its V_{thresh} by an amount $\eta_{\text{IP}} = 0.1$ mV every second. Reset R_{count} right after every change to V_{thresh}. When the spike counter produces a value that deviates from the target firing rate,

$$V_{\text{thresh},t+1} = V_{\text{thresh},t} + \eta_{\text{IP}}(R_{\text{count},t} - R_{\text{target}}) \tag{1}$$

For instance, V_{thresh} is shifted upwards when the firing rate is too high, and as a consequence the neuron responds less to the same inputs. This is then an opposite effect to for instance, growing synaptic weights from excitatory inputs. Leave out STDP and normalisation in this exercise. Test the IP in a neuron receiving 10 excitatory spike trains with frequency 3 Hz, and a target postsynaptic firing rate of 3 Hz. Set the initial w_{e} to 0.35. Add STDP with $A_{\text{LTP}} = 0.001$ and $A_{\text{LTD}} = =$ -0.0005. Add also 10 inhibitory Poisson inputs of 10 Hz with $w_{\text{i}} = 1.0$. To see the effect best, remove the synaptic normalisation included before. Are the excitatory weights increasing? Does the neuron maintain its firing rate over time? Does the change in firing rate affect the weight evolution?

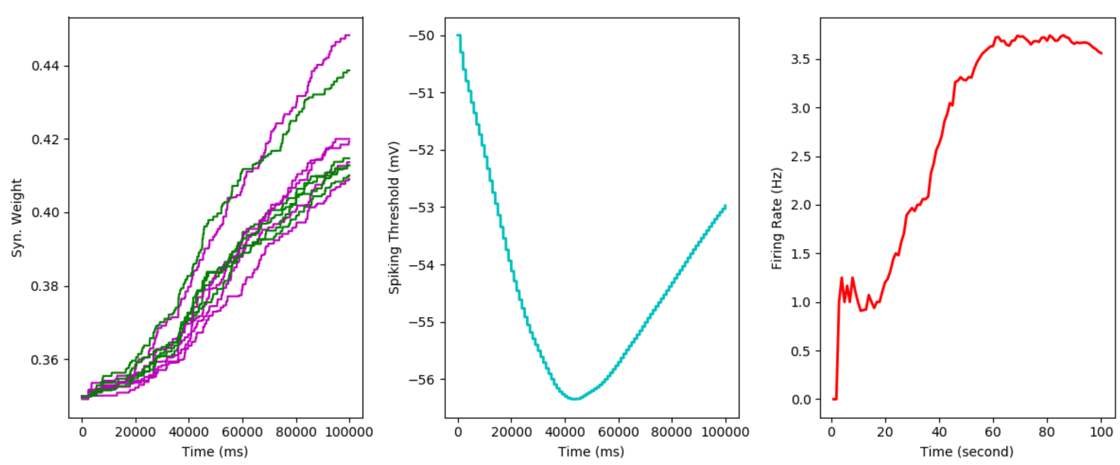

Figure 1: A LIF neuron with an adapable spiking threshold (intrinsic plasticity) and Poisson spiking inputs with STDP. Left: The synaptic weights from the two excitatory input groups increase over time due to STDP. Middle: The spiking threshold first decreases to meet the target firing rate, then increases to compensate for the strong synaptic inputs at the end of the simulation. Right: The output firing rate becomes stable over time.