5 Short-term plasticity (STP)

5.1 Short-term facilitation (STF)

(video 5.1) Short-term plasticity (STP) is a transient change in synaptic efficacy caused by the recent activity in the synapse. STP consists of short-term depression (STD) and short-term facilitation (STF). The STD is the result of temporary neurotransmitter depletion, and STF of temporary increase in neurotransmitter release probability due to calcium influx after a spike is generated in the presynaptic neuron. As the name implies, STP does not lead to any lasting memory trace but is nevertheless important for certain dynamics. The best known model of STP is from [**?**]. It is a simplification of the true processes of STP, but captures the phenomenon qualitatively and is widely used in neuronal and network models. The STF is represented by the variable u:

$$\frac{du}{dt} = -\frac{u}{\tau_f} + U(1-u^-)\delta(t-t_{\text{sp}}) \tag{1}$$

where u is analogous to the fraction of readily available neurotransmitter. The time of the incoming presynaptic spike at the synapse is referred to as t_{sp}. The parameters U and τ_f are constants. At every spike, u is increased by the amount U by the calcium influx in the presynaptic terminal, after which a fraction of u is consumed to produce the postsynaptic current. u^- is the value u just before the spike, and u^+ the value just after the spike. Between spikes u then decays back to 0.

The synaptic efficacy at any time is the product of a fixed maximum weight w_{fixed}, and the facilitation variable u:

$$w_{\text{e}} = w_{\text{fixed}} u^+ \tag{2}$$

Note that the weight in this model does not depend on any post-synaptic behaviour such as whether the postsynaptic neuron spikes or not. Now implement STF in a single excitatory input in the neuron model. Leave out the STDP, normalisation and intrinsic plasticity, so that you can see what the effect of STP will be. Use a Poisson spike train with firing rate 10 Hz. Set $w_{\text{fixed}} = 1.0$, $U = 0.2$, and for τ_f try 50 ms and 750 ms. Plot the change in u, w_{e} and the postsynaptic firing rate over time. What happens to the weight w_{e} and the output firing rate of the neuron?

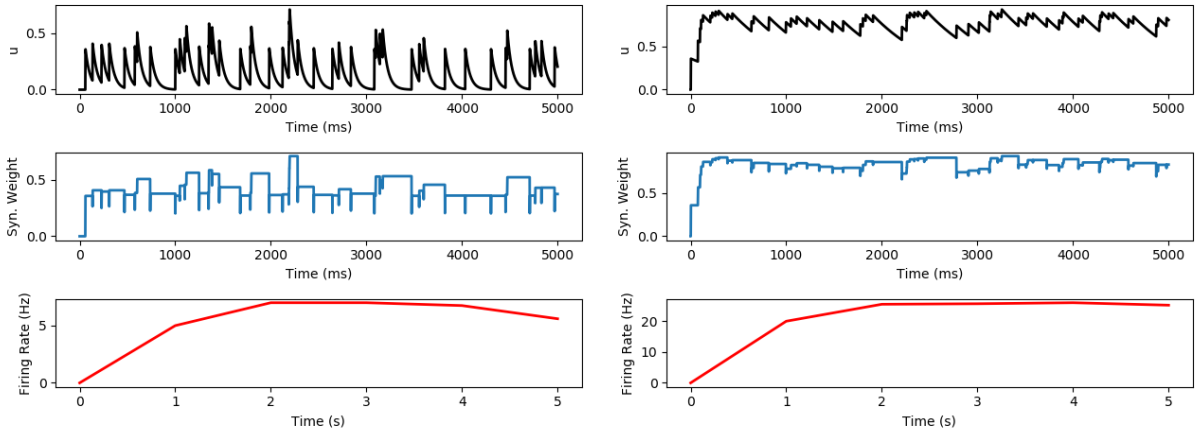

Figure 1: A LIF neuron with excitatory inputs and short-term facilitation in the input synapses, with $\tau_f =$ 50 ms (left three figures) and $\tau_f = 750$ ms (right three figures), causing respectively a quickly decaying effect or longer lastig effect of facilitation. Here $U = 0.2$. Top: The fraction of facilitated neurotransmitter in the presynaptic terminal. Middle: The change in the effective synaptic weight. Bottom: The change in output firing rate over time.