4. Exercise Sheet – Brain-Inspired Computing (WS 15/16)

Due date 9.11.16.

Name(s): Group: Points: ___/___/___/___

4.1 The high-conductance state in LIF neurons (50 Points)

Consider the Leaky Integrate-and-Fire neuron model with exponential synapse kernels, as given in the lecture.

The neuron parameters are as follows:

$$\begin{aligned} E_{\text{leak/rest}} &= -50\,\text{mV} && \text{(leak potential)},\\ C_m &= 1\,\text{nF} && \text{(membrane capacitance)},\\ \vartheta &= -40\,\text{mV} && \text{(spike threshold)},\\ \varrho &= -50\,\text{mV} && \text{(reset potential)},\\ \tau_{\text{syn}} &= 5\,\text{ms} && \text{(synaptic time constant)}, \end{aligned}$$

CUBA	COBA	
$\tau_m^{\text{curr}} = 1\,\text{ms}$	$\tau_m^{\text{cond}} = 20\,\text{ms}$	(membrane time constant),
$w_{\text{syn}}^{\text{curr}} = 0.01\,\mu\text{A}$	$w_{\text{syn}}^{\text{cond}} = 0.1\,\text{nS}$	(synaptic weight),
	$E_{\text{rev}}^{\text{inh}} = -100\,\text{mV}$	(inhibitory reversal potential),
	$E_{\text{rev}}^{\text{exc}} = 0\,\text{mV}$	(excitatory reversal potential).

a) Show that you can reformulate the COBA LIF ODE as

$$\tau_{\text{eff}}\dot{u} = U_{\text{eff}} - u \quad .$$

Provide expressions for τ_{eff} and U_{eff}.

b) The effective time constant calculated in a) depends on the total membrane conductance g^{syn}, which is, in general, a function of time. However, in the limit of large Poisson input firing rates, it can be replaced by its average value $< g^{\text{syn}} >= \nu_{\text{input}} \int_0^\infty \varepsilon(t)dt$, where ε represents the synaptic kernel.

Assume that the neuron receives synaptic input with inhibitory and excitatory rate $\nu = \nu_{\text{inh}} = \nu_{\text{exc}}$.

Given the parameters above, what is the input rate ν_{HC} needed for the conductance-based model to reach the same (effective) membrane time constant as the current-based one?

c) Simulate a COBA neuron with the above parameters and the Poisson stimulus rates calculated in b) and plot the distribution of

- its free membrane potential (no spiking, i.e. $\vartheta \to \infty$),
- its total synaptic conductance.

Fit a Gaussian to the two histograms. Compare the simulated $< g^{\text{syn}} >$ to the one you found in b). Why is a Gaussian fit appropriate? And why is $< u >= E_{\text{l}}$?

4.2 ***f*-*I* curves** (50 Points)

The solution of the LIF equations and the resulting activation function were given in the lecture. The firing rate of a neuron as a function of its input – in this case I^{ext} – is also called an f-I curve.

a) Find the asymptotic behavior of $\nu(I^{\text{ext}})$ as $I^{\text{ext}} \to \infty$ in the limit of $\tau_{\text{ref}} \to 0$.

b) Plot the f-I curves for $\tau_{\text{ref}} = 5\,\text{ms}$ and $\tau_{\text{ref}} = 0\,\text{ms}$, as well as their associated asymptotes. Verify your results with PyNN simulations. Use the parameters from Ex.1.