Brain Inspired Computing (SS 19): Exercise sheet 4

Hand in on 23.05.2019, 14:15

Name(s): Group:

Question:	1	2	3	Total
Points:	40	15	45	100
Score:				

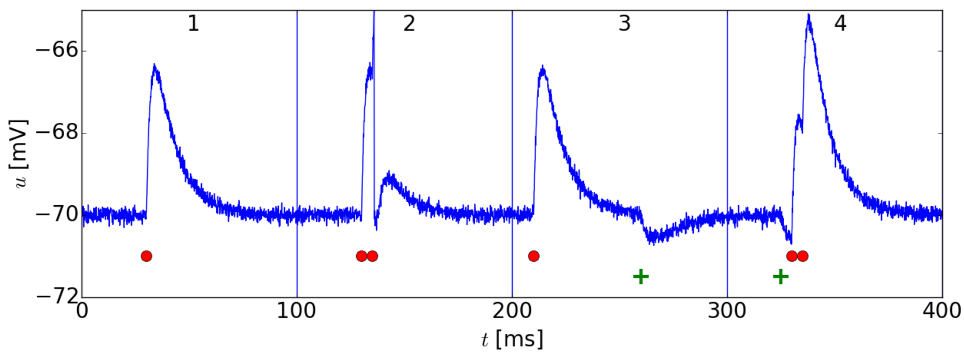
Exercise 1: Conductance-based synapses (40 points)

Consider the LIF neuron model with COBA exponential synapse kernels, as given in the lecture.

a) Show that you can reformulate the COBA LIF ODE as follows. Give expressions for τ_{eff} and U_{eff}.

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

b) Consider the following (simulated) voltage data from a COBA LIF neuron which receives input from an excitatory and an inhibitory presynaptic neuron. For the purpose of the discussion, the experiment has been partitioned into 4 sections.



The excitatory (inhibitory) reversal potential is 20 mV (−80 mV), and the exc. (inh.) neuron's spikes are indicated by red dots (green crosses). Synaptic transmission delays are negligible. A single EPSP (Sec. 1) almost drives the neuron over the threshold (at −65 mV), and two of them (Sec. 2) easily elicit a spike at 136 ms. However, despite a single IPSP being much smaller in amplitude (Sec. 3), it can prevent the neuron from firing (Sec. 4).

Explain this phenomenon based on a model of conductance-based synapses. Base your argumentation on a). Could such a phenomenon even occur if the inhibitory reversal potential was above the resting potential?

Exercise 2: COBA membrane trace analysis (15 points)

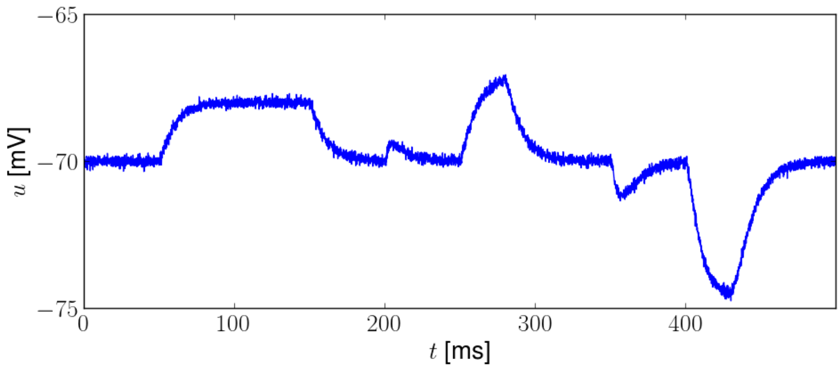
You are given three membrane potential datasets of a COBA LIF neuron (see Moodle, use `numpy.load()`, sampling rate 10 kHz). The neuron has been exposed to different types of so-called synaptic background stimuli (random spike times) of balanced excitation and inhibition. In each dataset, the background stimulus has a different strength. In addition, the neuron has been stimulated with regular "probe" spikes which arrive via another synapse at times $t_s \in \{20\,\mathrm{ms}, 40\,\mathrm{ms}, \ldots, 200\,\mathrm{ms}\}$.

Indentify and discuss the influence of the different background stimuli on the membrane by proceeding along the following steps:

1) Extract the (noisy) PSPs induced by the probe spikes from the membrane potential.
2) Average them by temporal alignment at the spike times t_s (for each dataset).
3) Plot the averaged PSPs from all three datasets into one plot.
4) Compare the PSPs qualitatively with respect to amplitude and time constant and discuss the result.

Exercise 3: Parameter estimation for a COBA LIF neuron (45 points)

You are given access to membrane potential data (sampled at 10 kHz) from a COBA LIF neuron with exponential synaptic kernels stimulated by two presynaptic neurons: an excitatory and an inhibitory one (see moodle for membrane voltage data and spike times (`data_4.2.npy`). Use `numpy.load()`):



The weak noise on the membrane potential trace is inherent to the hypothetical measurement apparatus and can be neglected in the following.

A similar membrane potential dataset can been generated by a NEST simulation that you can find in `bic_4_2_template.ipynb` on moodle. There you will also find installation instructions for Google Colab.
The provided script contains wrong neuron and synapse parameters. Your task is to estimate the correct parameters from the membrane potential data and enter them into the NEST simulation for verification.

Between 50 and 150 ms, the neuron is stimulated by an external DC pulse. The spike times of the excitatory presynaptic neuron occur at 200, 250, 253, 256, 259, 262, 265, 268, 271, 274 and 277 ms. The inhibitory presynaptic neuron has the same spike pattern, only 150 ms later. From a previous measurement, you know that the membrane capacitance is 1 nF and that the synaptic reversal potentials are 20 mV and −80 mV, respectively.

a) Estimate the leak conductance g_l and the synaptic weights w_e, w_i and synaptic time constants τ_{syn}^e, τ_{syn}^i from the given voltage trace. (Hint: Use the simulator to define a fit curve for the synaptic time constants and weights)

b) Perform the NEST simulation using your estimated parameters, and plot your simulated membrane potential data alongside the given one in one figure (with different colors).