Computational Neuroscience
Assignment 2

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Problem 1

I implemented a integrate and fire (IF) model with excitatory synapse by using the following equation:

$$c_m \frac{dV}{dt} = -\bar{g}_L(V - E_L) - g_{\text{ex}}(V - E_{\text{ex}}) \tag{1}$$

The code of the model implementation can be found in the Python script 'LIF_synapse_exc.ipynb'. As we observe from Figure 1, when we trigger the presynaptic action potential at a defined time, we have an increase in inward current into the neuron that causes membrane depolarization. If the presynaptic action potentials are not too far apart in time, this causes a higher membrane depolarization that leads to a spike triggered (at around 400 ms as seen in figure 1).

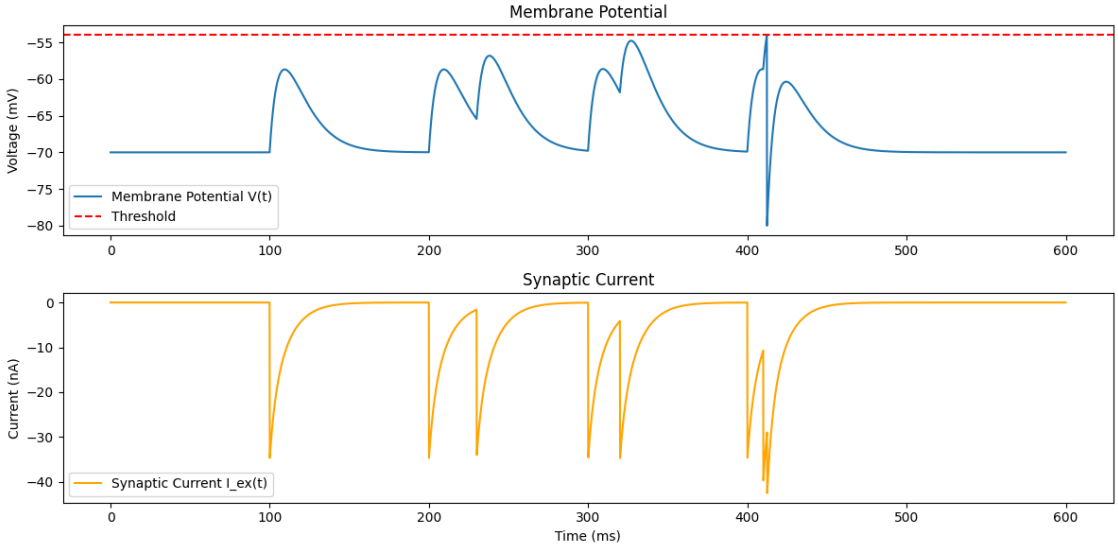

Figure 1: Membrane potential of the neuron from the IF model (blue) and current of the excitatory synapse (orange)

Problem 2

I simulated an IF model using the following differential equation for computing the membrane potential $V(t)$:

$$\tau_m \frac{dV}{dt} = -V + E_{\text{eff}},$$

where E_{eff} is:

$$E_{\text{eff}} = -56.0 + \sigma_V \sqrt{\frac{2\tau_m}{\Delta t}} \cdot \text{randn}(t),$$

The model can be found in the file 'noisy_LIF.ipynb'.I changed the noise values by modifying σ_V values and computed the standard deviation of the membrane potential, with the spike generation mechanism disabled by setting the spike threshold to a very large value. The result can be seen in figure 2. The plot shows that σ_V and $std(V)$ have a linear relationship.

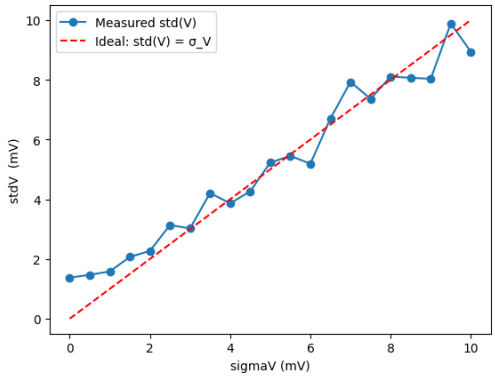

Figure 2: Linear relation between noise amplitude (σ_V) and standard deviation of the membrane potential.

Then, the spiking mechanism was enabled and the average firing rate was computed as seen in figure 3. The firing rate increases nonlinearly with σ_V. For low values, spikes are rare or absent. As σ_V increases, the firing rate increases and then saturates. In last week's assignment, the firing rate curve showed no response for low input current and then a roughly linear increase.

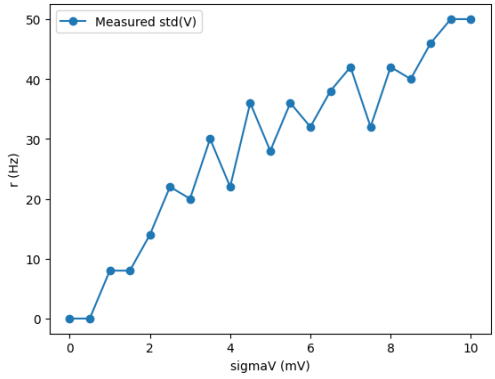

Figure 3: firing rate in relation with noise level in the IF model