18-847 Lab Assignment 2

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2. Spike Response Models

The removed 2nd order terms are:

$$-r_M g_t^E \quad -r_M g_t^I$$

Take the excitatory as an example and the inhibitory is similar. Given that the conductance decay model:

$$\tau_E dg_t^E/dt \; = \; -g_t^E$$

Convert it into discrete form:

$$g_t^E = g_{t-1}^E(1 - \Delta t/\tau_E)$$

And given $r_M = \Delta t/C^M$

We may conclude that the 'second-order term' refers to a second-order function of Δt. A similar conclusion can be found for the inhibitory term.

Some constants are founded in the following table:

parameter	value
τ_E	2.45ms
τ_I	6.11ms
C^M	0.90 $\mu F/cm^2$
τ_M	40.3ms

Let $\Delta t = 10^{-5}s$

First order term:

$k_M = 1 - \Delta t/\tau_M = 1 - 10^{-5}s/40.3ms = 0.999975$

Second order term:

$$r_M g_t^E = \Delta t / C^M g_{t-1}^E (1 - \Delta t / \tau_E) = 11.02 g_{t-1}^E$$
$$r_M g_t^I = \Delta t / C^M g_{t-1}^I (1 - \Delta t / \tau_I) = 11.09 g_{t-1}^I$$

Since g_t^E, g_t^I are ~ 1e-3 scale,

$$\frac{r_M g_t^E + r_M g_t^I}{k_M} \approx \frac{0.01102 + 0.01109}{0.999975} = 2.211\%$$

To remove the second-order term, the error will be around 2%.

Reference:

[1] Berg, Rune & Vich, Cati & Ditlevsen, Susanne & Grabolosa, Toni. (2017). Estimation of Synaptic Conductances in Presence of Nonlinear Effects Caused by Subthreshold Ionic Currents. Frontiers in Computational Neuroscience. 11. 10.3389/fncom.2017.00069.

[2] Gentet, L.J., Stuart, G.J., & Clements, J.D. (2000). Direct measurement of specific membrane capacitance in neurons. Biophysical journal, 79 1, 314-20 .

[3]Resting and Active Properties of Pyramidal Neurons in Subiculum and CA1 of Rat Hippocampus Nathan P. Staff, Hae-Yoon Jung, Tara Thiagarajan, Michael Yao, and Nelson Spruston Journal of Neurophysiology 2000 84:5, 2398-2408

3.1 Explain the functional difference between FeedForward Inhibition (FFI) and Lateral Inhibition (LI).

The difference between FeedForward Inhibition and Lateral Inhibition is FeedForward Inhibition can potentially nullify the entire output whereas in Lateral Inhibition (LI) is winner take all functionality where the first spike in a volley is the “winner”, and only the winning spike is allowed to pass through.

Biologically, in Feedforward inhibition, a presynaptic cell excites an inhibitory interneuron (an interneuron is a neuron interposed between two neurons) and that inhibitory interneuron then inhibits the next follower cell. This is a way of shutting down or limiting excitation in a downstream neuron in a neural circuit.
However in Lateral inhibition, a presynaptic cell excites inhibitory interneurons and they inhibit neighboring cells in the network. This type of circuit can be used in sensory systems to provide edge enhancement.

3.4 list any parameters that you had to pick, the values that you picked for them, and why you picked those values.

We picked the threshold value for the Low pass filter that we implemented for the Feed forward inhibition. We picked the value as 6. The reason for is as we are classifying images between 0-9 we want only 10% of inputs to fire the neurons as we want to distinguish between the different classes. We tried different values of threshold and decided on 6.

4.3 report what response function you used.
We used step response function with no leak.

4.4 report the spiking threshold you chose. Why did you choose this threshold?
We chose spiking threshold of 2. We chose this threshold as we are classifying images between 0-9 we want only 10% of inputs to fire the neurons as we want to distinguish between the different classes. We tried different values of spiking threshold as well as threshold for low pass filter and decided on 2 for spiking threshold.