Homework 1

Problem #1

Simulation of single regular spiking neuron with five different levels of external inputs and should be stacked vertically. Also, calculation of the mean spike rate for the last 800 steps vs synaptic currents.

Results:

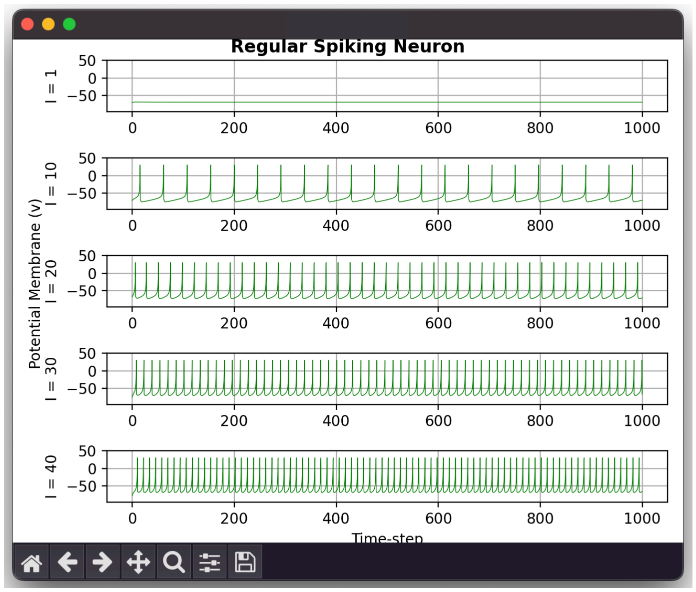

Figure 1.1: *Regular spiking neuron: full 1,000-step time-series of the membrane potential (v) for the synaptic currents I = 1; 10; 20; 30, and 40*

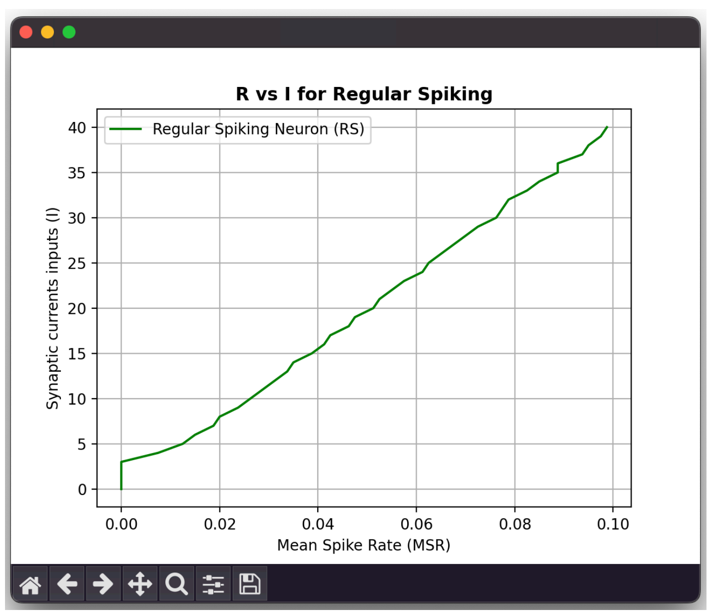

Figure 1.2: *Regular spiking neuron: R vs I which R is the mean spike rate, and I is the external input or the synaptic currents inputs*

Problem #1

Discussion:

In figure 1.1 it shows the simulation of a thousand step time-series of the membrane potential for five different synaptic currents inputs which are 1, 10, 20, 30, and 40 of a regular spiking neuron and it clearly shows in the pattern that excitatory neurons were exhibited. The pattern exhibits a positive correlation between the spike and current because the spike frequency increases when the strength of the synaptic currents increases. And the neuron fires at a constant steady rate by the given stimuli. Also, regarding the behavior of membrane recovery (u) and membrane potential (v) has a factor in figure 1.1, it shows that as the membrane potential goes up, it is being pulled back down by the membrane recovery while when the membrane recovery goes up, it will be pulled up by membrane potential and pulled down by itself. Figure 1.2 shows that the Mean Spike Rate (R) and External Inputs (I) or the synaptic currents has a positive correlation and also as the synaptic current increases it becomes more even, unlike for the first few values (e.g. synaptic current = 1) because the membrane potential is still at its resting potential which is -65mV and later on it reaches the highest number of spikes for the neuron when the synaptic current is at 40. The neuron is performing a useful function whenever the membrane potential (v) reaches the threshold because the neuron will be fired and in real life application, a signal will be transmitted to nearby neurons that affects their response to the signal that will be triggered.

Problem #2

Implement the problem #1 but for fast spiking neuron using the values for a, b, c, and d from the figure 2 in Izhikevich. Also, plot R v. I in one graph for fast spiking neuron and regular spiking neuron.

Results:

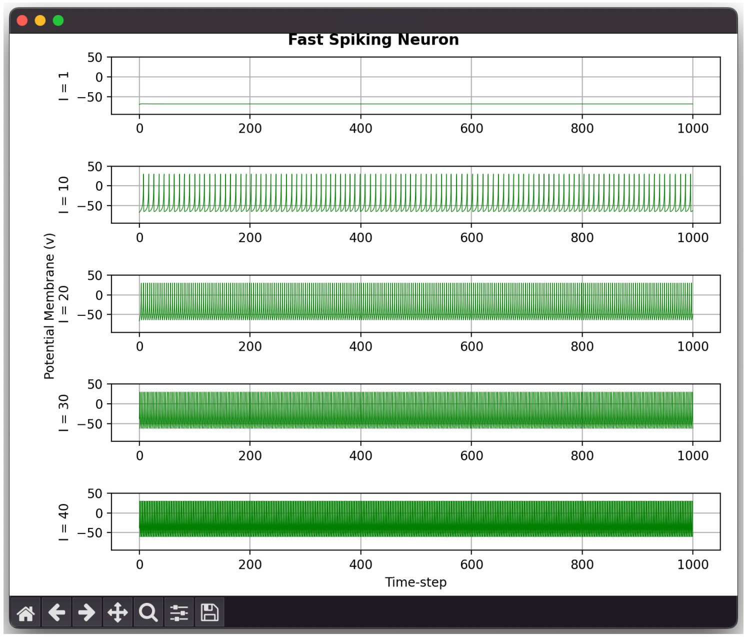

Figure 2.1: *Fast spiking neuron: full 1,000-step time-series of the membrane potential (v) for the synaptic currents I = 1; 10; 20; 30, and 40*

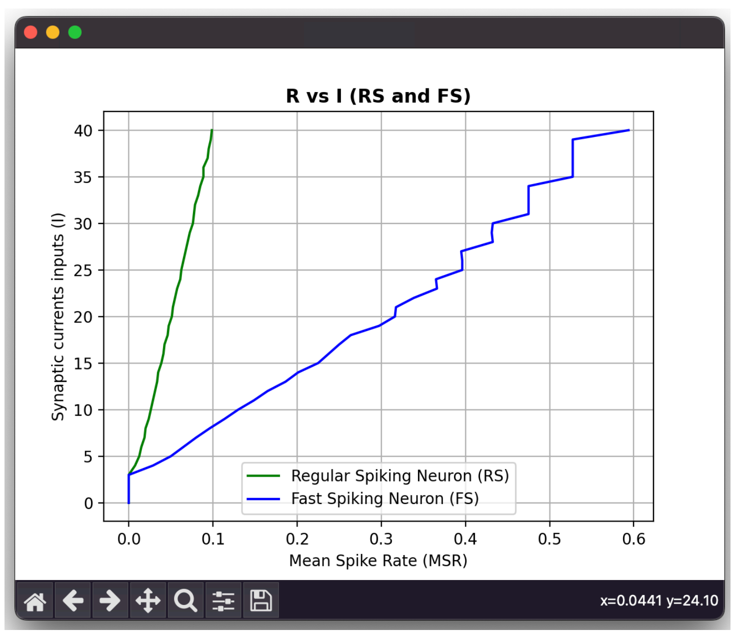

Figure 2.2: *R vs I of Regular spiking neuron and Fast spiking neuron which R is the mean spike rate, and I is the synaptic currents inputs or the external input.*

Problem #2

Discussion:

Figure 2.1 shows that without slowing down, fast spiking neurons can fire recurrent patterns of impulses at an excessively high frequency compared to the regular spike neurons behavior. This behavior from figure 2.1 supports its function as a neuron that release inhibitory control the balance of excitatory-inhibitory signals in the brain by reducing or inhibiting neuronal and circuit excitability [1]. And these inhibitory neurons are typically designated the role of reflexes. In figure 2.2 it shows that the Mean Spike Rate (R) and External Inputs (I) or the synaptic currents has a positive correlation for fast-spiking neuron and regular spiking neuron. However, regular spiking neuron has stronger correlation than the fast-spiking neuron because it is more spread out. With this, the regular spike neurons attained the highest R value of 0.1 while the fast-spiking neuron attained the highest R value of almost 0.6 which has a huge difference. Therefore, we can conclude from figure 2.2 that fast spiking neuron has higher mean spike rate and it depends on the values of the parameters. In example, the bigger the value of parameter ‘a’ will result to fast recovery which we set 0.02 for regular spike and 0.1 for fast spike.

Problem #3

Implementation of 2-neuron network of chattering (bursting) neurons using the values of a, b, c, and d from Izhikevich. The two neurons A and B will have steady inputs of amplitude Ia = 5.0 and Ib = 2.0.

Results:

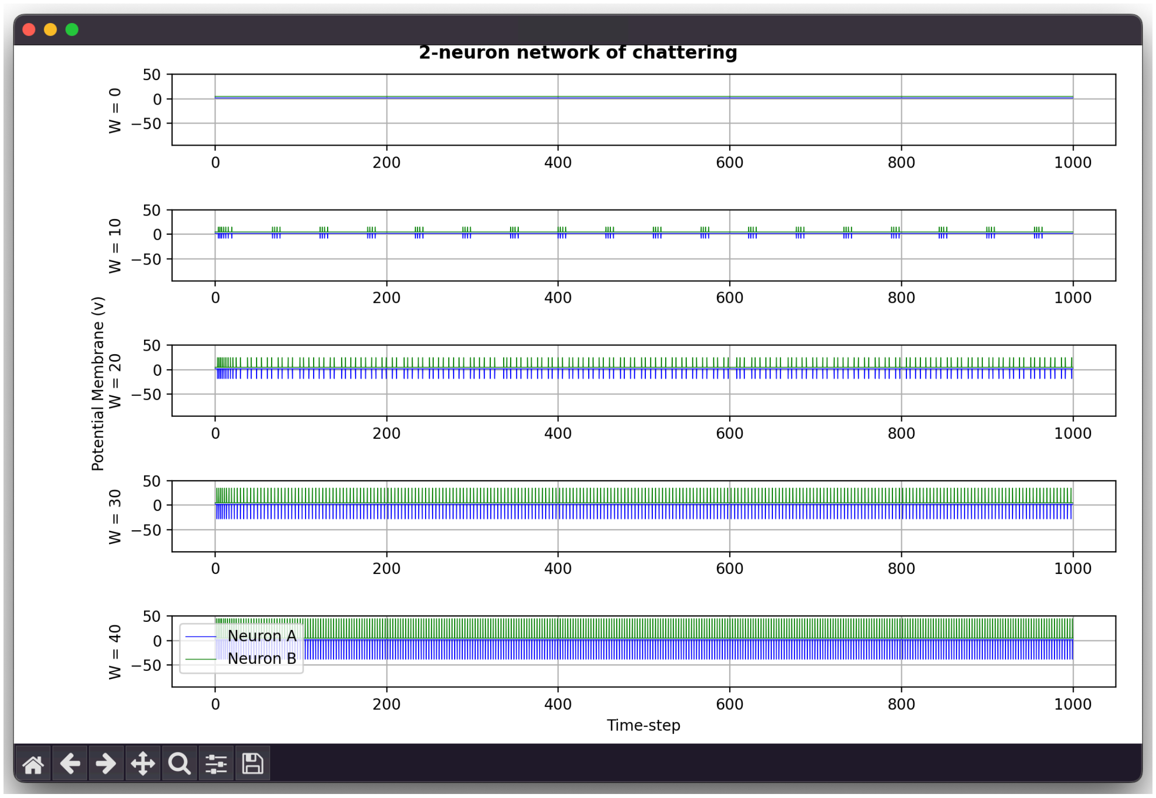

Figure 3: *2-neuron network of chattering (bursting) neurons*

Discussion:

In figure 3 depicts that high frequency burst of densely packed spikes are fired by the chattering neuron. In these bursts, the inter spiking frequency is extremely high. It is possible for the inter-burst frequency to reach 40 Hz. Also, in figure 3 we input a very high voltage reset which is -65 and a moderate after-spike jump of membrane recovery thus in W=0, we cannot see an after-spike yet, but it became more visible when W increases. This shows that neuron A excites neuron B while neuron B inhibits A through the same magnitude of the weight and this implies that an inhibition process is triggered after an initial excitatory process, and it feeds back to stop the excitatory process.

Reference:

[1] Puig, M. V., Ushimaru, M., & Kawaguchi, Y. (2008). Two distinct activity patterns of fast-spiking interneurons during neocortical up states. *Proceedings of the National Academy of Sciences*, *105*(24), 8428–8433. https://doi.org/10.1073/pnas.0712219105