EECE6036 - Homework 1

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1 Problem 1

1.1 Problem Statement

This problem involved of generating simulation of the behavior of a single regular spiking neuron defined by Izhikevich model using the following differential equations with different I values input through 1000 steps:

$$\frac{\partial v}{\partial t} = 0.04v^2 + 5v + 140 - u + I(t) \tag{1}$$

$$\frac{\partial u}{\partial t} = a(bv - u) \tag{2}$$

$$if\ v \geq 30,\ v = c,\ u = u + d \tag{3}$$

1.2 Results

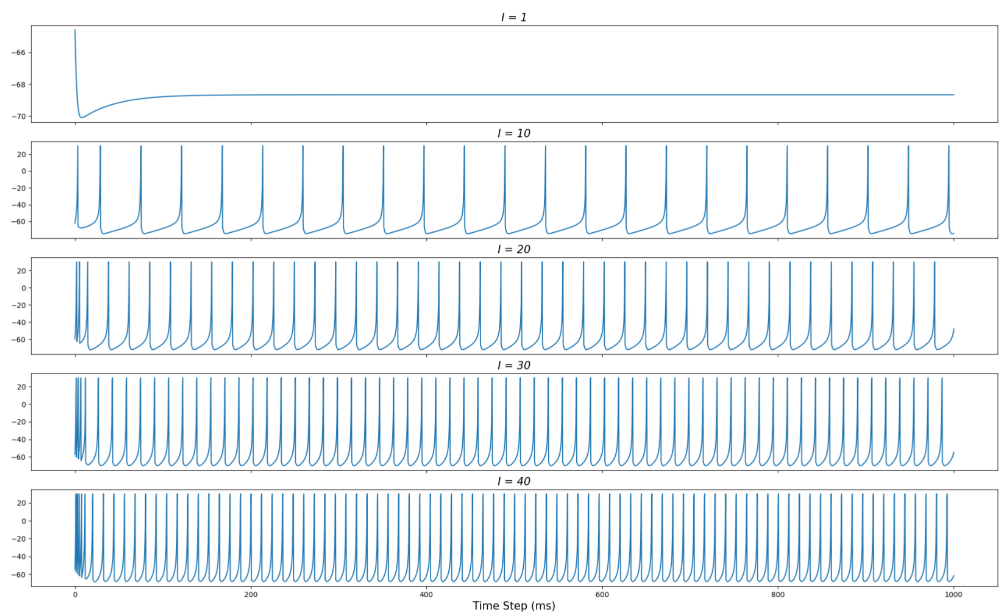

Figure 1.2a: Membrane potential as a function of time for various input currents for a single neuron.

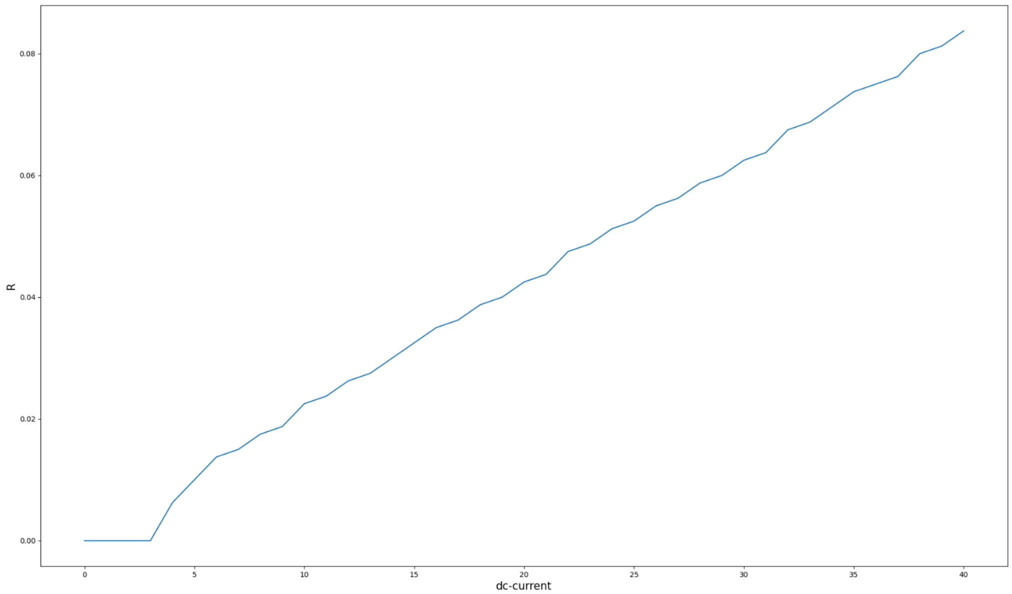

Figure 1.2b: Mean spiking rate as a single neuron overtime. The firing rate is calculated by averaging over 800 series time steps.

1.3 Discussion

According to figure 1.2a, when inputting I with the value of 1, the neuron did not fire any spike (there was no sight of excitation), as the membrane potential is around -70mV and -60mV, for this particular case, the resting potential was around -65mV. When the dc-current changes (among 1, 10, 20, 30, 40), the neuron starts bursting spikes frequently and becomes a steady sequence of spikes. The initial burst is why the first 200 ms of simulation are discarded before calculating the mean spiking rate. Moreover, when I value increases to 20, 30, and 40, the period of time starts to get smaller, in order to keep up with it, the regular spiking gets denser and refractory shorter period. Nevertheless, the simulation demonstrates the use of a Regular Spiking (RS) neuron to translate a dc-current input to a spike train, in which higher dc-current level interprets to a higher repetition spike train. Also, according to figure 1.2b, we can see that there is a linear trend of increase of the interspike frequency as the current increases. Overall, the work would represent that a semi-realistic artificial neuron can be simulated using computational overhead.

2 Problem 2

2.1 Problem Statement

Based on the Izhikevich (2003) model, generate the fast spiking neuron based on the function of differential equations defining on problem 1.

2.2 Results

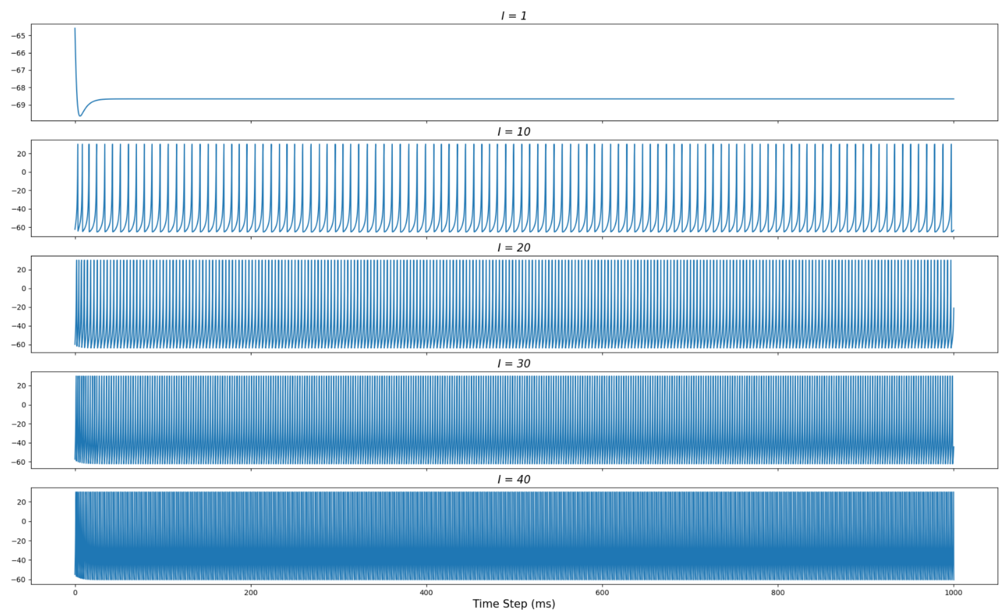

Figure 2.2a: Membrane potential as a function of time for various input currents for a single neuron, in order to explore the behavior of fast spiking (FS) neurons.

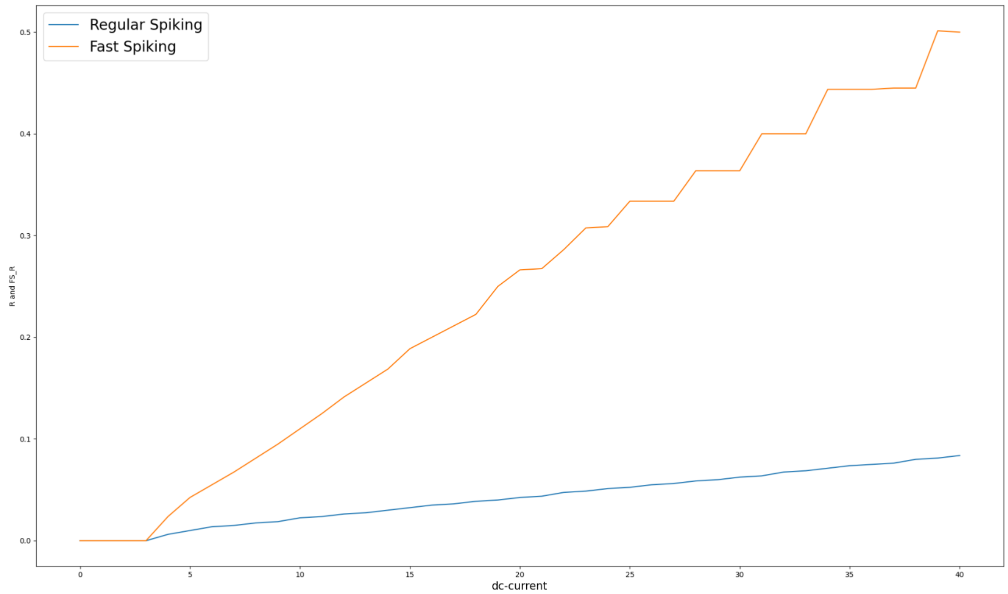

Figure 2.2b: Comparison between regular spiking neuron and fast spiking neuron, to research the difference in behavior on the same series time-steps.

2.3 Discussion

According to the figure 2.2a, when inputting the dc-current with value of 1, the neuron did not fire any spike, which is the same behavior with the regular spiking (RS) neuron, and during the first 200 ms with not much firing. After 200 ms, the firing appears more frequently, this is where we can see the difference between the Regular Spiking and Fast Spiking, the shooting of Fast Spiking appears far more frequent compared with Regular Spiking due to change in the values of a and d. Also, based on Izhikevick's paper (2003), there is a general definition that the neuron recovery rate according to its a value, when there is a bigger value of a, the recovery rate is faster as well. Lastly, the Fast Spiking (FS) had a linear relationship but more to a pattern of stairs later.

3 Problem 3

3.1 Problem Statement

Using Figure 2 of Izhikevich (2003), plotting the chattering of neuron A and B using the following equations:

$$I_A^{total}(t) = I_A + w_{AB}y_B(t) \quad (5)$$

$$I_A^{total}(t) = I_A + w_{AB}y_B(t) \quad (6)$$

$$y_i(t) = 1 \; if \; v_i(t) > 30, \; else \; y_i(t) = 0 \quad (7)$$

3.2 Results

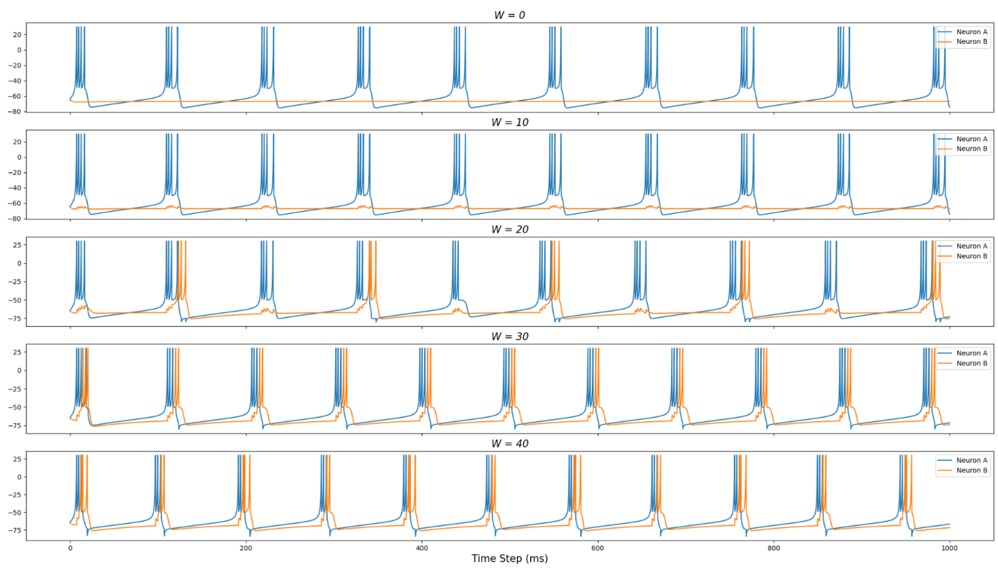

Figure 3.2: Plot of chattering rate of 2 neurons as a function of input I. The calculation was done using Izhikevich (2003) functions.

3.3 Discussion

According to Figure 3.2, as the value of W is equal to 0, we can see that there was almost no action from neuron A, while neuron B is resting since the current is not strong enough. As W increases, the fire rate of A starts to happen, also since A excites B, B fires the burst. According to Figure 3.2, we can see that when W = 10, there is not much change compared to W = 0. However, starting at W = 20, there is some significant change to B. At W = 30 and W = 40, A excites B, therefore, the frequency that B fires burst starts to appear more and similar to the frequency of A. As W increases and B inhibits A, at some points the membrane potential seems to drop slightly.