Assignment 1

Project 1

Description

Implement a LIF neuron model in Python with configurable parameters. Then, for at least 5 set of parameters, draw potential difference and F-I curve plots.

Experiments

In this project, I implemented a piece of code in Python, which simulates the behavior of a LIF neuron model with a constant input. At each tick, the change in potential difference is as below:

$$\begin{aligned} du = (-(u - u_{rest}) + R * I(t)) * \frac{dt}{\tau} \\ u = u_{rest} \quad if \quad \theta \leq u. \end{aligned} \tag{1}$$

Then, I ran 5 experiments for different set of parameters to investigate their effect on the neuron behavior. The duration of each experiment was 60 seconds and all the variables were updated every 10ms(dt = 0.01). You can find the details on the parameters and the results in table 1 and Fig. 1, respectively.

Exp.	τ	θ	u_{rest}	R
1	20	-50	-65	1
2	15	-50	-65	1
3	20	-50	-65	1
4	20	-50	-65	1
5	20	-50	-65	1

Table 1: Parameters of each experiments

Result and Discussion

In the first experiment I used the default parameters, inherited from here, for a LIF neuron. As you can see with increasing electric current (I), the firing rate of the LIF neuron increases. For other experiments I investigated the effect of

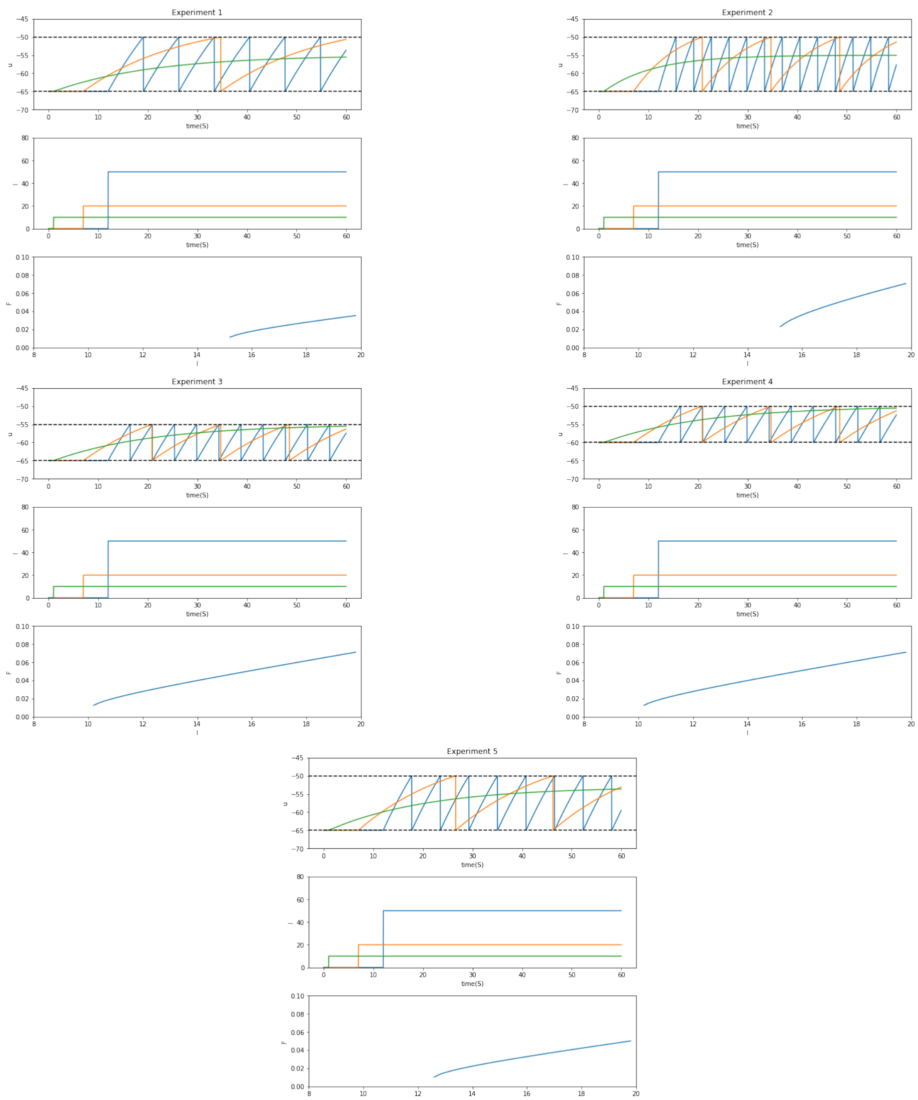

Figure 1: Plots of the simulations for LIF neuron model with a constant input

each parameters on the spike frequency, changes in the potential difference and F − I curve. The following bullet points provide the result for each experiment:

- Exp. 2- In this experiment I decreased .As you can see, according to Eq. 1, controls the overall changes in the potential difference so decreasing it means the effect of the input I is higher. Therefore, The firing rate of the neuron increases and The F − I curve goes a little higher than it was before.
- Exp. 3- In this experiment I decreased the threshold ( ), and As it was expected it increases the firing rate of the neuron and shifts the F − I curve to the right which means for higher frequencies neuron doesn't need strong input if the difference between threshold and the resting potential is low.
- Exp. 4- The result of this experiment is the same as the last one, and the reason for that is LIF only considers the difference between threshold and the resting potential and they dont matter individually.
- Exp. 5-In the final experiment for this project, I investigated the effect of R. According to Eq. 1 the R controls the effect of the input I on the potential difference and increasing it means the with the same amount of electric current we can reach higher potentials and therefore, higher frequency.

I have to mention the reason that F − I curve is open ended and doesn't have any interception with x-axis is the limits caused by the time complexity of the simulation to find the frequency(or the time of the first spike).

Description

Implement a LIF neuron model in Python with configurable parameters and simulate its behavior in the case of having a random input. Then, for at least 5 set of parameters, draw potential difference and F-I curve plots.

Experiments

In this project, I implemented a piece of code in Python, which simulates the behavior of a LIF neuron model with a random input. At each tick, the change in potential difference is as below:

$$\begin{aligned} du = (-(u - u_{rest}) + R * I(t)) * \frac{dt}{\tau} \\ u = u_{rest} \quad if \quad \theta \leq u. \end{aligned} \tag{2}$$

Then, I ran 5 experiments for different set of parameters to investigate their effect on the neuron behavior. The duration of each experiment was 60 seconds and all the variables were updated every 10ms(dt = 0.01). You can find the details on the parameters and the results in table 2 and Fig. 2, respectively.

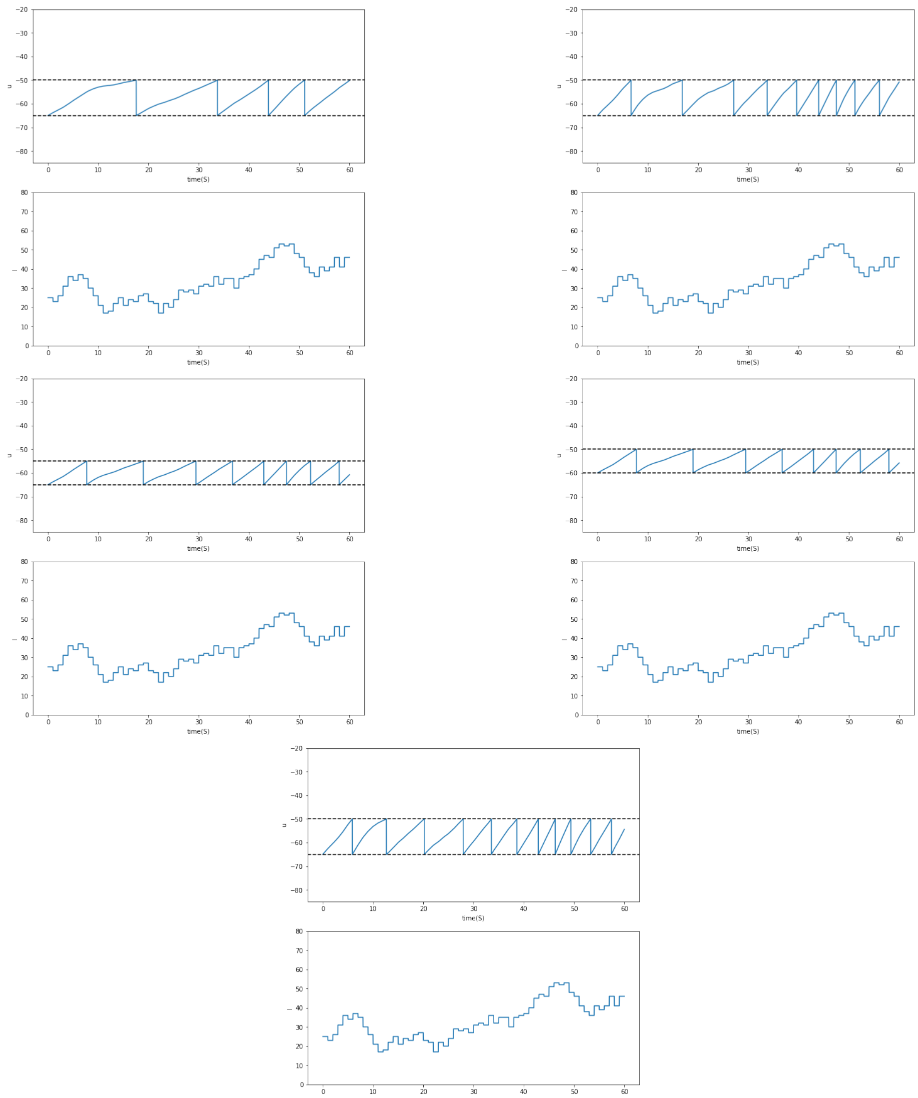

Figure 2: Plots of the simulations for LIF neuron model with a constant input

Exp.	τ	θ	u_{rest}	R
1	20	-50	-65	1
2	15	-50	-65	1
3	20	-55	-65	1
4	20	-50	-60	1
5	20	-50	-65	1.2

Table 2: Parameters of each experiments

Result and Discussion

In the first experiment I used the default parameters, inherited from here, for a LIF neuron. For other experiments I investigated the effect of each parameters on the spike frequency and changes in the potential. As it was expected, there is not a significant difference between the behavior of the neuron between the first project and the current configuration.

Project 2

Description

Implement an ELIF neuron model in Python with configurable parameters. Then, for at least 5 set of parameters, draw potential difference and F-I plots.

Experiments

In this project, I implemented a piece of code in Python, which simulates the behavior of an ELIF neuron model with a constant and random input. At each tick, the change in the potential difference is as below:

$$du = (-(u - u_{rest}) + \delta_T exp((u - \theta_{rh}/\delta_T) + RI(t))\frac{dt}{\tau} \\ u = u_{rest} \quad if \quad \theta_{reset} \leq u. \tag{3}$$

Then, I ran 5 experiments for different set of parameters to investigate their effect on the neuron behavior. The duration of each experiment was 120 seconds and all the variables were updated every 10ms(dt = 0.01). You can find the details on the parameters and the results in table 3 and Fig. 3, respectively.

Results and Descussion

In the first experiment I used the default parameters, inherited from here, for an ELIF neuron. As you can see there is not a significant difference between LIF and this neuron in term of dependency to the electric current (I), and the firing rate of the neuron increases as I does. The only difference is this neuron has a better presentation for spikes. For other experiments I investigated the effect of

Exp.	τ	θ_{reset}	θ_{rh}	u_{rest}	R	δ_T
1	20	-30	-50	-65	1	2
2	10	-30	-50	-65	1	2
3	20	-30	-55	-65	1	2
4	20	-40	-50	-65	1	2
5	20	-30	-50	-65	1	1

Table 3: Parameters of each experiment

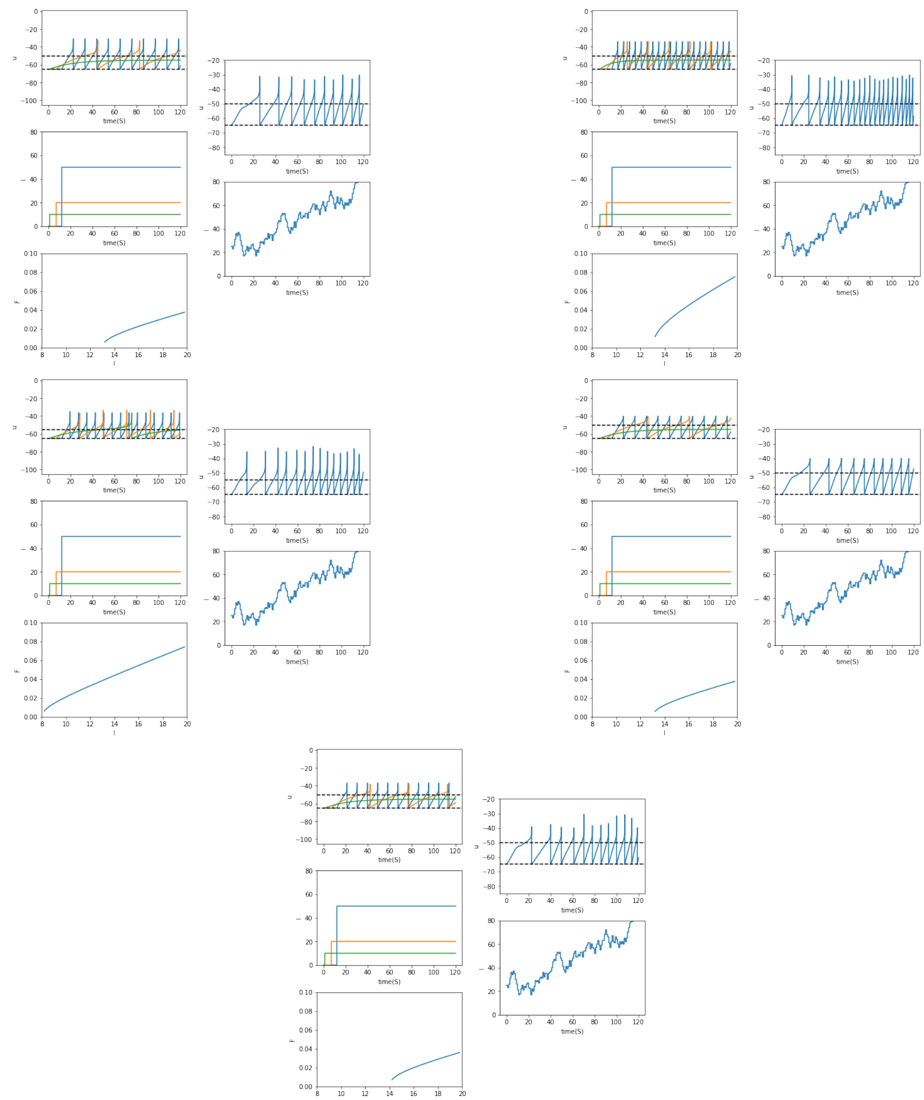

Figure 3: Plots of the simulations for LIF neuron model with a constant input

Figure 3: Plots of the simulations for ELIF neuron model with different constant inputs and random input each parameters on the spike frequency, changes in the potential difference and F − I curve. The following bullet points provide the result for each experiment:

- Exp. 2- In this experiment I decreased like previous projects and As you can see, There is no difference in the role of and still decreasing it increases The firing rate of the neuron and The F − I curve goes a little higher than it was before. Also in the case of having random input the neuron fires more than before.
- Exp. 3- In this experiment I decreased the firing threshold (rh), and the result was the same as LIF neuron.
- Exp. 4- One of the new parameters of this model is reset threshold(reset) which controls the pick of the spike. Obviously with decreasing it the potential difference has a lower pick than before and the result of this experiment confirms that.
- Exp. 5- Finally, for the last experiment I changed another new parameter which is sharpness parameter. As a result of decreasing sharpness parameter the neuron rich its reset threshold faster therefore, we have sharper spikes. also note that two last experiments shows that the effect of these two parameters on the spike frequency and F − I curve is negligible.

Project 3

Description

Implement an Adaptive-ELIF neuron model in Python with configurable parameters. Then, for at least 5 set of parameters, draw potential difference and F-I plots.

Experiments

In this project, I implemented a piece of code in Python, which simulates the behavior of an Adaptive-ELIF neuron model with a constant and random input. At each tick, the change in the potential difference is as below:

$$
\begin{aligned}
du = (-(u - u_{rest}) + \delta_t exp((u - \theta_r h)/\delta_T) + RI(t) - Rw)dt/\tau_m \\
u = u_{rest} \quad if \quad \theta_{reset} \le u \\
dw+ = (a(u - u_{rest}) - w)dt/\tau_w + b(spike(t))
\end{aligned}
\tag{4}
$$

Then, I ran 5 experiments for different set of parameters to investigate their effect on the neuron behavior. The duration of each experiment was 360 seconds and all the variables were updated every 10ms(dt = 0.01). You can find the details on the parameters and the results in table 4 and Fig. 4, respectively.

Exp.	τ_m	θ_{reset}	θ_{rh}	u_{rest}	R	δ_T	a	b	τ_w
1	20	-30	-50	-65	1	2	0	16	144
2	10	-30	-50	-65	1	2	0	16	288
3	20	-30	-55	-65	1	2	0	20	144
4	20	-40	-50	-65	1	2	9	16	144
5	20	-30	-50	-65	1	1	4	8	144

Table 4: Parameters of each experiment

Note that for $\mathrm{F} - \mathrm{I}$ curve I considered the average frequency since the firing pattern is not regular and the frequency changes during simulation.

Result and Discussion

In the first experiment I used the default parameters, inherited from here, for an Adaptive-ELIF neuron. As you can see there is no difference between LIF and this neuron in term of dependency to the electric current (I), and the firing rate of the neuron increases as I does. Also, you can see the adaptive property of this neuron in which the time distance between spikes increases over simulation. For other experiments I investigated the effect of each parameters on the spike frequency, changes in the potential difference and $\mathrm{F} - \mathrm{I}$ curve. The following bullet points provide the result for each experiment:

- Exp. 2- In this experiment I increased w which according to the Eq. 4 it controls the decay of w. By increasing w the effect of each spike stays more and therefore we have more regularized potential difference, and thus less spikes. In the case of having random input, at some points the neuron has potential difference less than resting potential, and the reason for that is the effect of adaptation parameters that keep decreasing the potential difference. Finally, as you can see $\mathrm{F} - \mathrm{I}$ curve shows the effect of adaptation on the decline in frequency of neuron in higher electric currents as well.

- Exp. 3- In this experiment I increased b which controls the effect of each spike on w. increasing it results in more increase in w and therefore more adaptation and thus less spikes. But the difference between this experiment and the last one is in this one it is barely possible for neurons to spike for a short time after a spike but in the previous one the effect of each spikes stays for longer time but the possibility of firing of neuron is more. This is the reason for longer time difference between 2 spikes in the second experiment.

- Exp. 4- As we know, different parameters a and b can result in different type of firing patterns in neurons. In this experiment I tuned these parameters in order to get a firing pattern similar to phasic spiking in the neuron which is quite strange because we know that Adaptive-ELIF can-not create this kind of pattern but as you can see if neuron gets a strong enough input it fires only once and stops after that but obviously if the simulation runs for a longer time, w will be zero and we will have another spike.(Note that I only considered the firing pattern not the potential difference)

- Exp. 5- In the final experiments the parameters are tuned in such a way that in the case of having a strong input, the neuron fire multiple times and then stops for a long time. The reason for this is small a and b so the neuron need multiple spikes to have a strong w to control the activity of the neuron and a big w that keeps the effect of the neurons for a longer time.

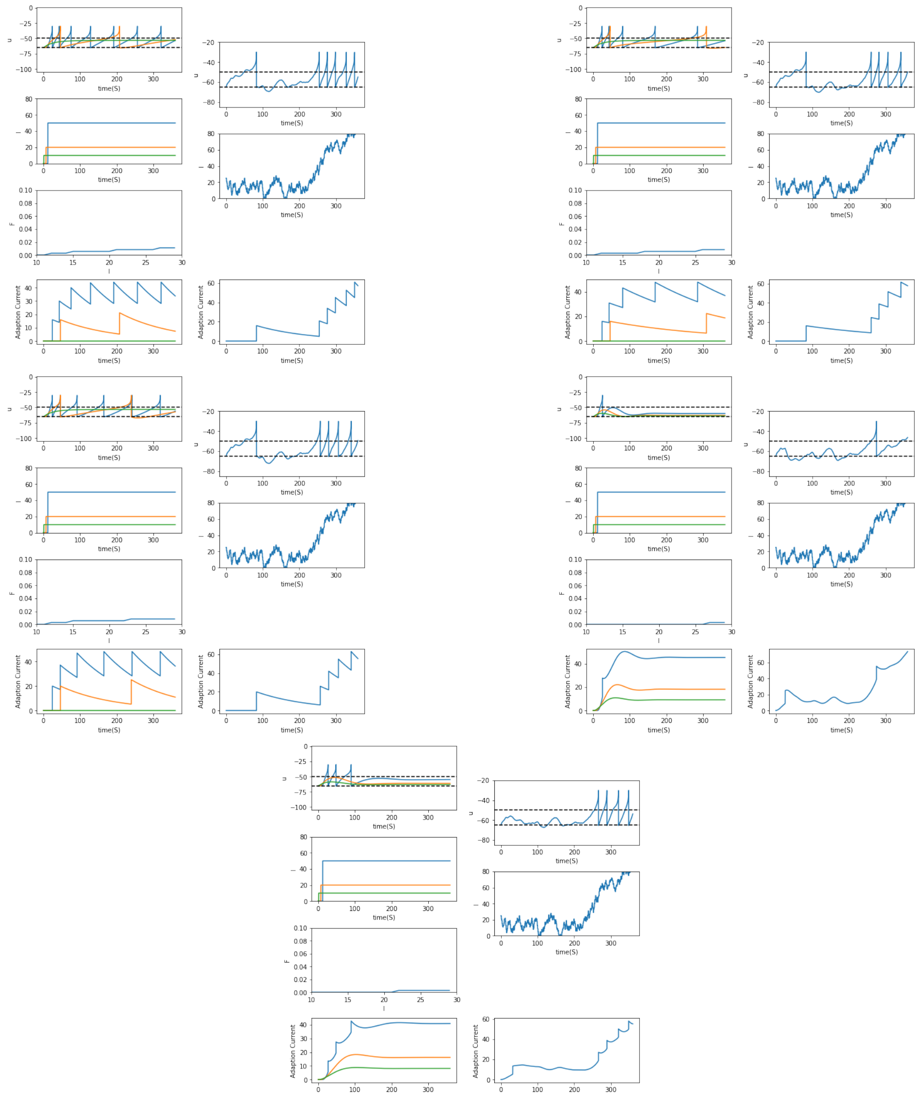

Figure 4: Plots of the simulations for AELIF neuron model with a constant input