Neural Networks

Lab 1

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Code

The code below, Listing 1, was changed from the matlab tutorial, in order to add the functionality which create a histogram of how many spikes are in 100 milliseconds. Furthermore, to see what's happen if we change the values *theta*, *tau* and *Rin*, we create a vector in which we simulate the minimum, maximum and medium values. As we can see in **line 6** of Listing 1, we create the vector which we were talking above. This value is changed also in **lines 7 and 9**, keeping always one value changing, and the other two constant. **Note:** The variable that change will have as maximum value, 10. As medium value, 5, and as minimum value, 2.

```
1  for i = 1:3
2      nstep = 100; %Number of timesteps to over
3      Inoise = 0.1;
4      IO = 1+Inoise*randn(1,nstep);%Input current in nA
5      dt = 1;
6      tau = [2 5 10];
7      theta = 4; %threshold in mV
8      v = zeros(1, nstep);
9      Rin = 5; %Input resistance in MOhm
10     tspike = [];
11     isi_result = [];
12     t = (1:nstep)*dt;
13     for n=2:nstep
14         v(n) = v(n-1) + dt*(-v(n-1)/tau(i) + Rin*IO(n)/tau(i));
15         if (v(n) > theta)
16             v(n)=0;
17             tspike = [tspike t(n)];
18
19         end
20     end
21     figure(i);
22     plot(t,v);
23     xlabel('Time');ylabel('Voltage');
24     title(['Tau: ', num2str(tau(i)), '   Theta: ', num2str(theta), '   Rin: ',
       num2str(Rin)]);
25     figure(i+3);
26     hist(isi(tspike), 1:100); xlabel('ISI/ms'); ylabel('Counts');
```

```
    title(['Tau: ', num2str(tau(i)), '   Theta: ', num2str(theta), '   Rin: ',
    num2str(Rin)]);
    hold on;
end
```

Listing 1: noisyifneuron

Listing 2 takes the vector which contains the number of spikes in each step. Although, it returns the value of the difference between the spikes on each step.

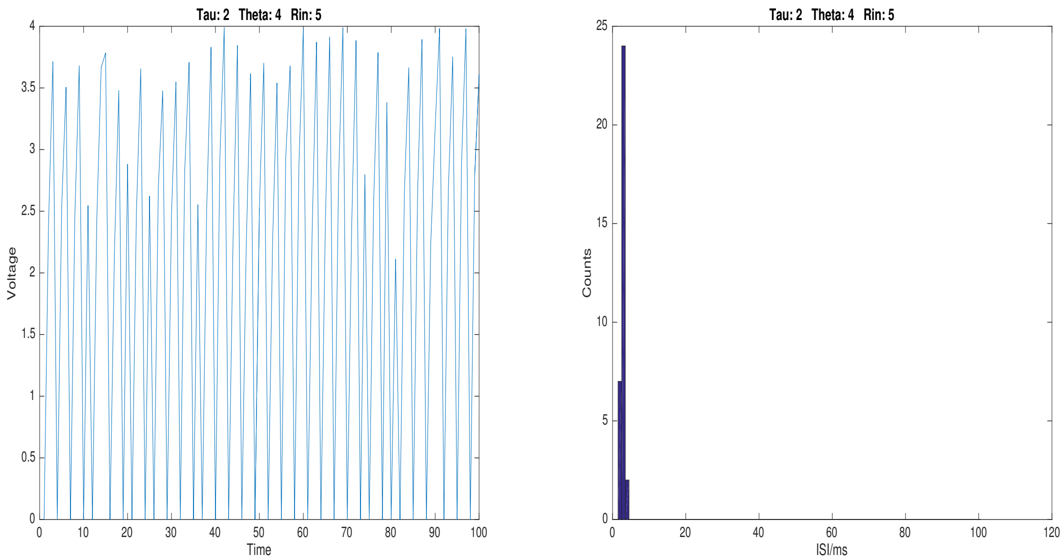
```
function isi_result = isi(spiketimes)
    if(length(spiketimes)>1)
        isi_result = diff(spiketimes);
    else
        isi_result = [];
end
```

Listing 2: isi

Changing Tau

Tau is low

In order to see what happens when the value is small, we decide to set it equal to 2. We can see the plotted result in Figure 1. In Sub figure 1a, we can see the behavior of the neuron, and how many spikes at which time interval are produced. As we can see, if $Tau = 2$, the neuron have a a high frequency, so that means that the neuron produce a lot of spikes. Furthermore the voltage created by the spikes vary somewhat from 2 to 4 voltage. In Sub figure 1b we can observe that the most frequently occurring interval between spikes is about 5 milliseconds since the count of spikes is close to 25 at this interval.



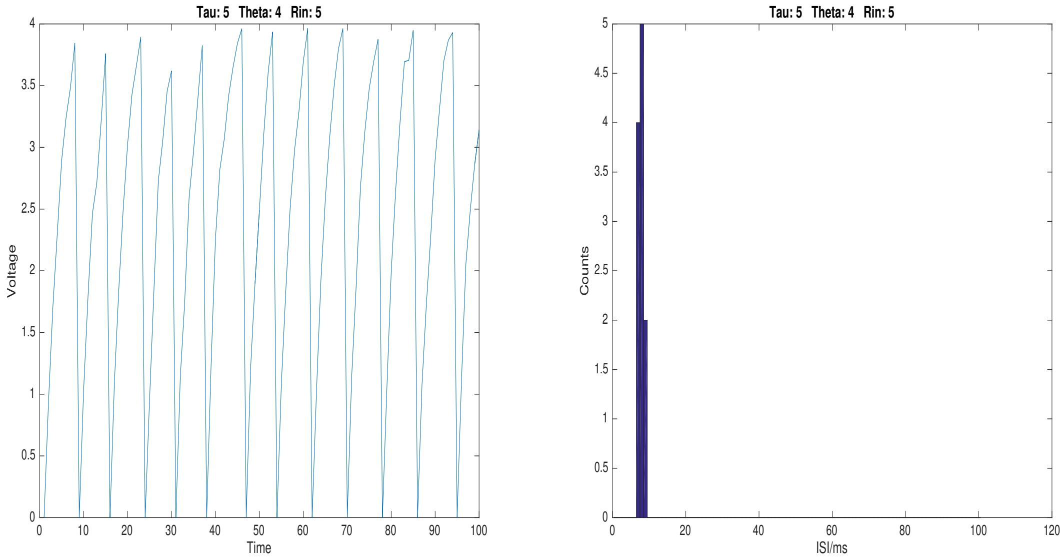
(a) Graph

(b) Histogram

Figure 1: Tau = 2

Tau is medium

This time, we are going to explain what happens if Tau is set to a medium value, for us, it will be $Tau = 5$. As we can see in 2a, now the frequency is smaller than before. The number of spikes is reduced, also the time interval between each spike is increased. When looking at the voltage we see that the spikes vary between 3.5 and 4 voltage, this is a much smaller difference than in the case when Tau was small. In sub figure 2b we can see that now, instead of 5 milliseconds, it takes around 10 milliseconds between each spike.

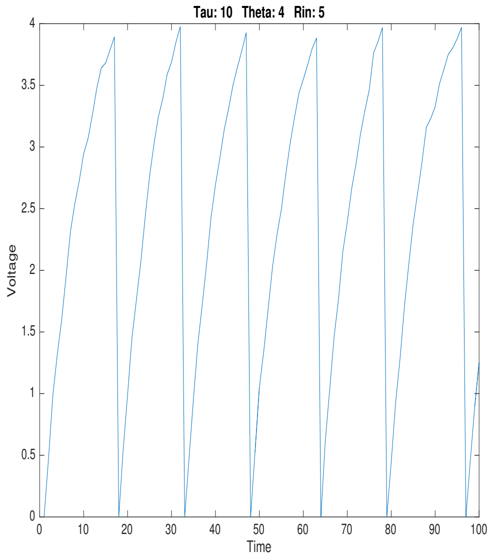


(a) Graph (b) Histogram

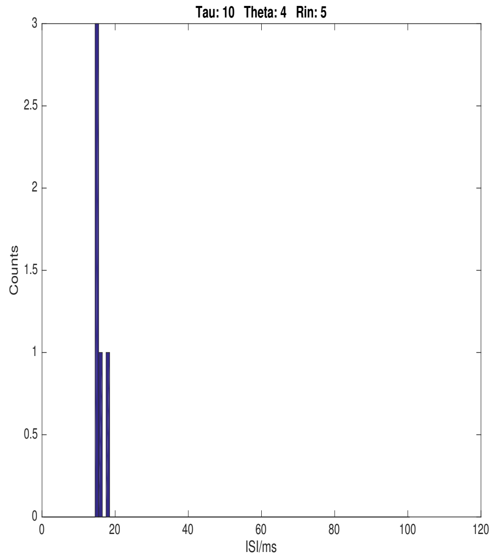
Figure 2: Tau = 5

Tau is high

As maximum value, we are going to use $Tau = 10$. As we can see in Sub figure 3a, the frequency has been reduced again. That means that the neuron will produced less spikes, and the time interval will increase, as we can see in Subfigure 3b.



(a) Graph



(b) Histogram

Figure 3: Tau = 10

Conclusion Tau

In conclusion, we can say that if the value of Tau takes a small value, the neuron will produce more spikes than if Tau takes greater values. This is logical when we look at the formula 1 for the voltage:

$$Vchange = \frac{-V + R_{in}I_0}{\tau} \tag{1}$$

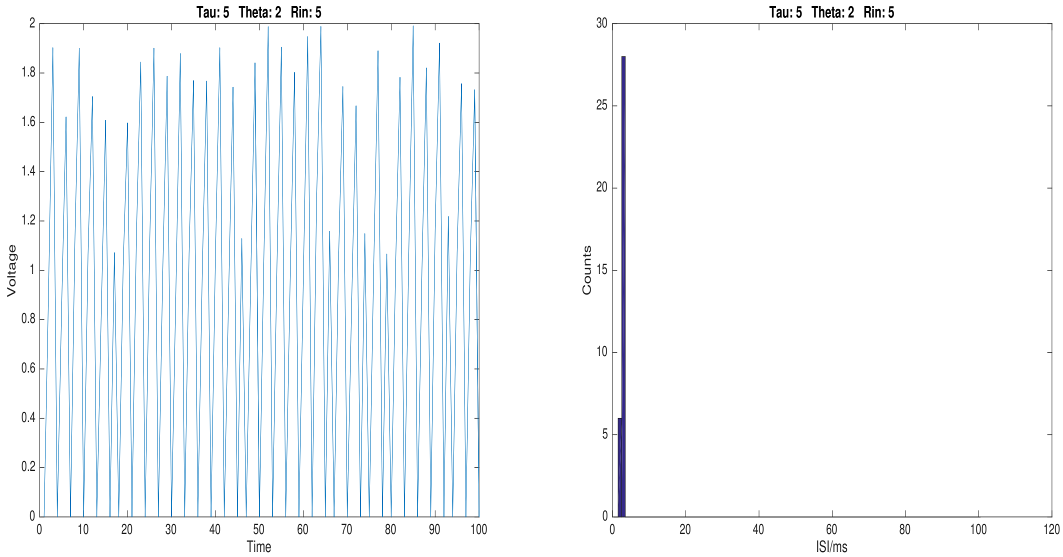
Tau is located in the denominator and so when it takes a low value the voltage will rise and with a voltage that is increasing more, it is more likely at at each iteration the threshold will be reached and a spike created. Furthermore the difference in voltage between spikes is also greater when Tau is small because each iteration the voltage will increase with much more when Tau is small making spikes at much lower voltages. But the difference in voltage when the frequency is high can also be because of the noise that will be more present when there are many spikes.

Changing Theta

Theta is small

So far, we have seen what happens if we change the value of Tau 1, now, we are going to see what happens if we change the value of Theta.

As before, we are going to take as low, medium and high value, 2, 5, and 10, respectively. In Figure 4 we see that Theta takes the low value. As we can see in Sub figure 4a, the neuron has a high frequency, as we can see in Subfigure 4b the interval between spikes is below 5 milliseconds. The voltage is below 2 because of the threshold.

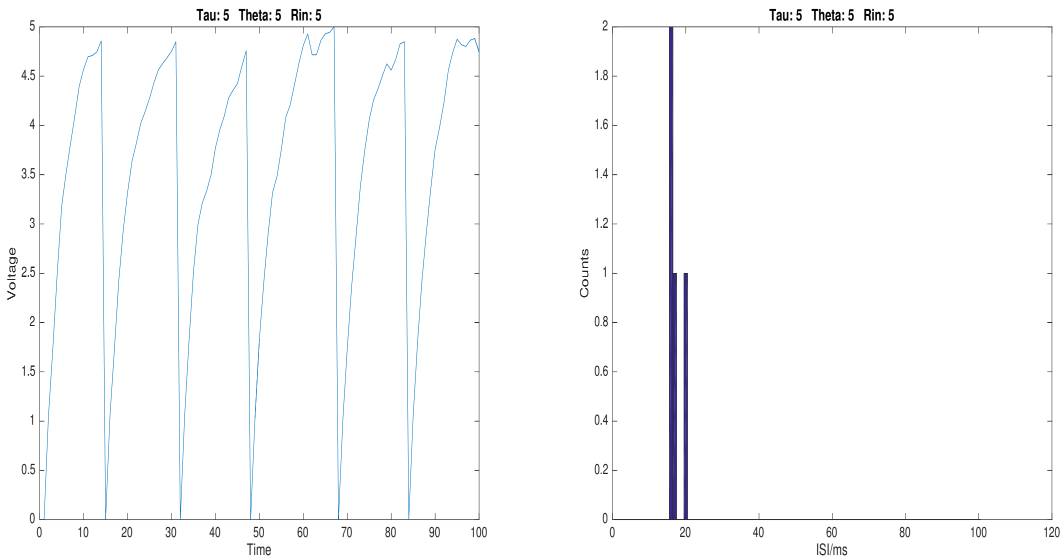


(a) Graph (b) Histogram

Figure 4: Theta = 2

Theta is medium

Now, it is time to set the variable Theta to its medium value 5. As we can see in Sub figure 5a, this time the frequency is smaller, that means that the spike interval is increased. This time, the periods will have a value around 17 or 20 milliseconds.

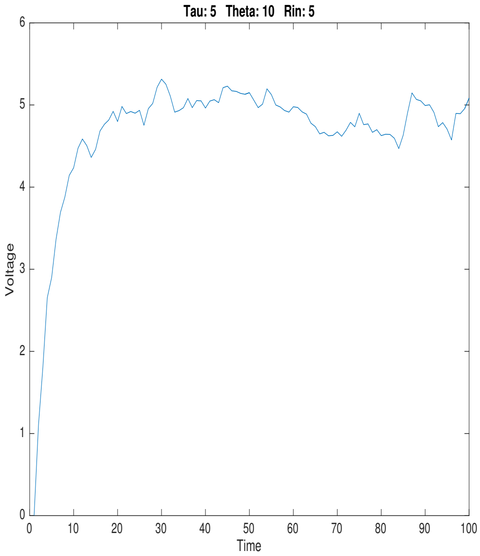


(a) Graph (b) Histogram

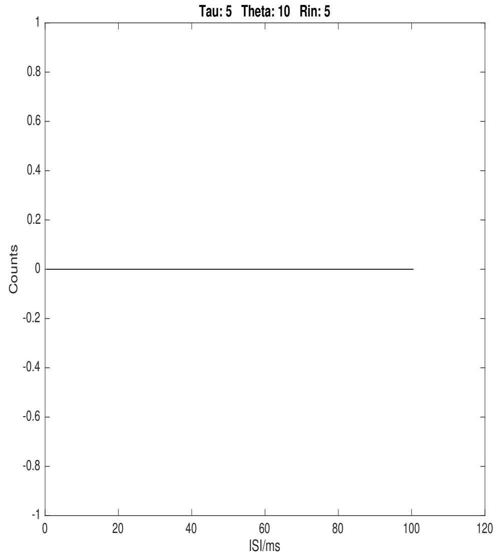
Figure 5: Theta = 5

Theta is large

For the maximum value, we set the value of Theta to 10. Now, as we can see in sub figure 6b the neuron does not produces spikes.



(a) Graph



(b) Histogram

Figure 6: Theta = 10

In sub figure 6a, we can see that the voltage increases and than stops increasing and varies around 5 volt and so producing no spikes.

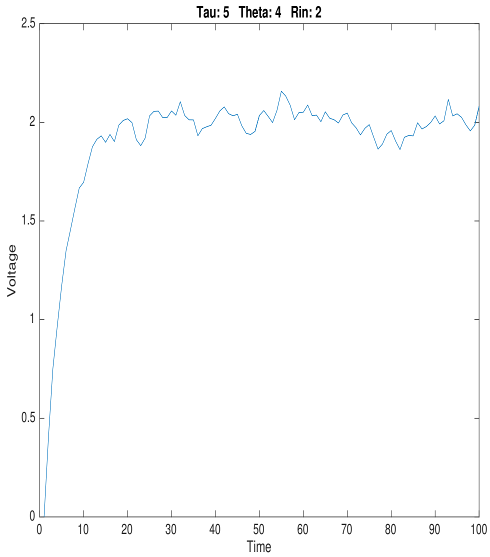
Conclusion Theta

When Theta is small the frequency of spikes will be large. This is again logical because if the threshold is low, a spike is reached at lower voltages. When Theta becomes larger we see less spikes and even null spikes when Theta equals 10. This can be explained when we look at the formula 1. Here we see that in the nominator the voltage is negative. So when the voltage reaches a certain value than it will become larger(in absolute value) that the positive values in the nominator producing a negative outcome for the voltage change and so decreasing voltage in the next step in time.

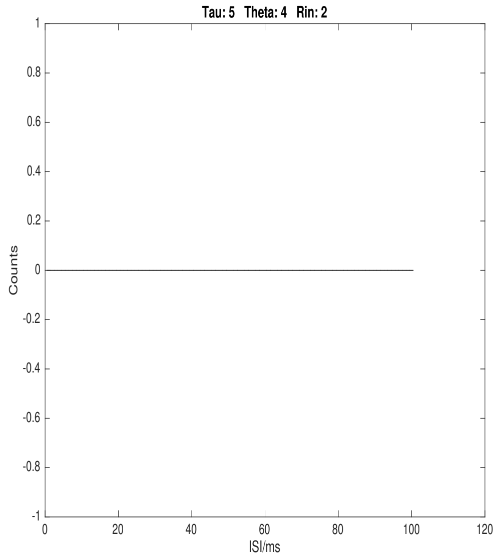
Changing the input resistance

Rin is small

When Rin is small (value of 2) we see that there will be no spikes produced. The voltage increases to 2 volt and then varies around this value.



(a) Graph

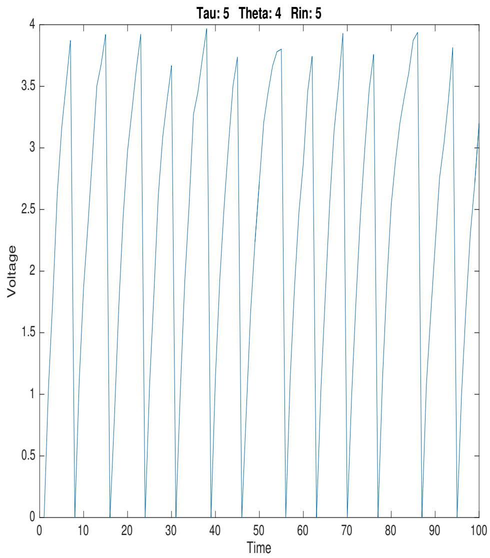


(b) Histogram

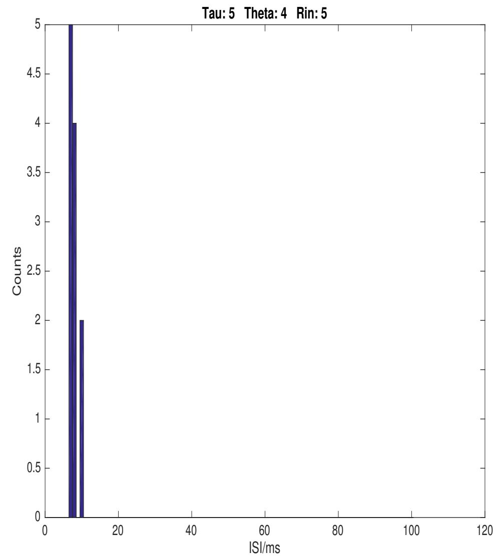
Figure 7: Rin = 2

Rin is medium

When Rin has a medium value(value of 5), The frequency of spikes increases and the time interval between them is around 10 milliseconds. The voltage maximum also increases to 4 volt.



(a) Graph

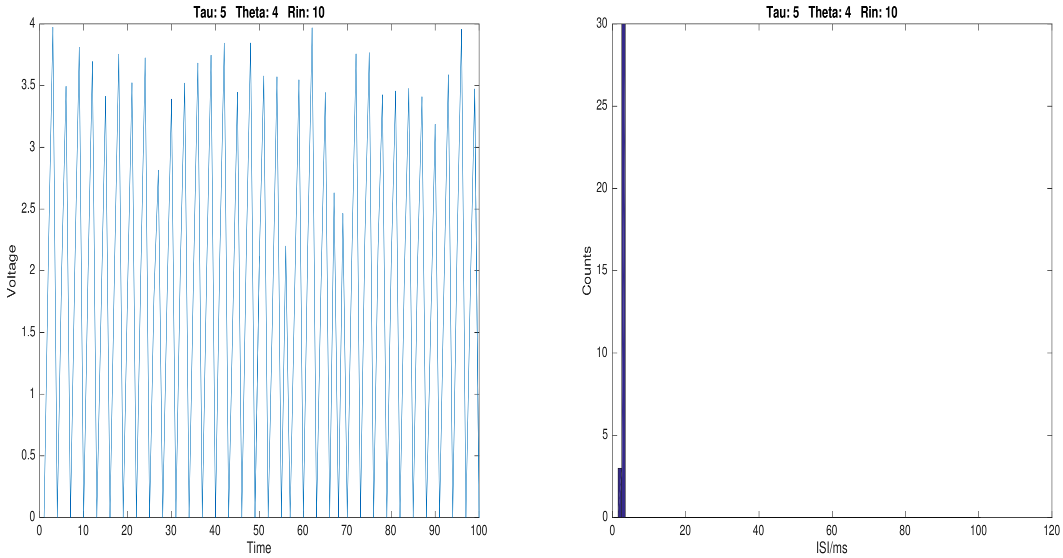


(b) Histogram

Figure 8: Rin = 5

Rin is large

When Rin is taken large we see in figure 9a that the spike frequency increases further but the max voltage stays about the same.



(a) Graph

(b) Histogram

Figure 9: Rin = 10

In figure 9b see that the interval between spikes is below 5 milliseconds.

Conclusion Rin

When Rin is taken small we see that there are no spikes. The explanation for this is somewhat the same for when Theta is taken large. When Rin is small the positive value in the nominator of formula 1 will become small and the (absolute)negative value (the voltage) in the nominator will be greater. This will end in a negative change in the voltage and so the voltage will decrease before reaching the threshold.

When Rin is taken larger we see that the spike frequency will increase. This is because the voltage change will be greater due to that a large Rin makes the positive value in formula 1 greater.