Computational Neuroscience Coursework3 Report nl17247

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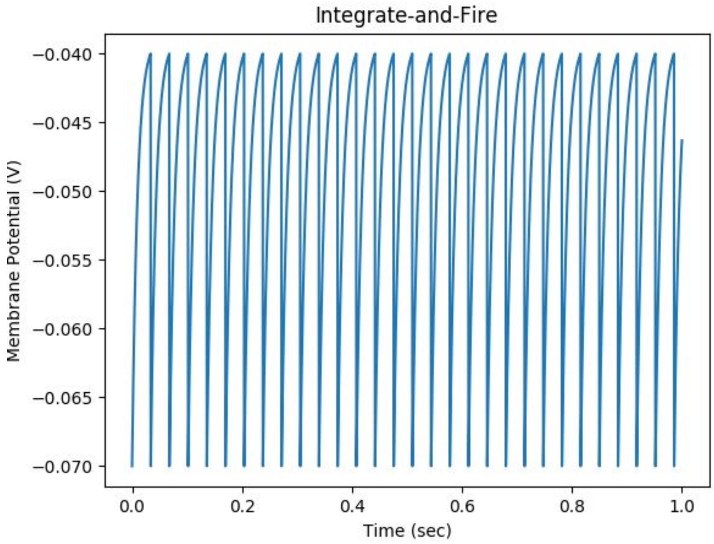
Part A: Integrate and Fire Neurons

Question1

The following plot represents the voltage of an integrate and fire model as a function of time over the period of 1 second. The neuron does not have a refractory period.

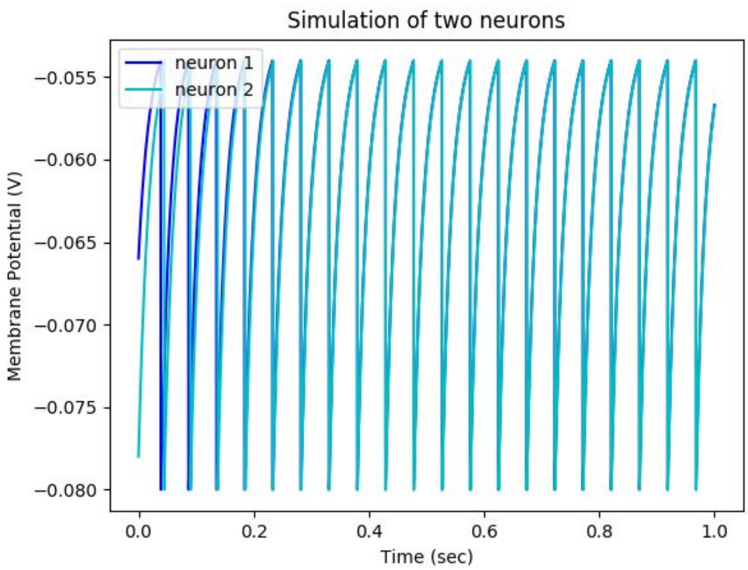


Question2

a) *The following plot represents the voltages of two neurons simulated, they have synaptic connections between each other, which are assumed to be excitatory. One neuron projects to the next, which in turn projects back to the first.*

From the plot, it is noticeable that neuron 1 spikes, then followed by neuron 2. And in turn, neuron 1 spikes, then followed by neuron 2 again. This repeats during the early section of the simulation. As the simulation continues, the voltage of both neurons start to converge, and eventually synchronise.

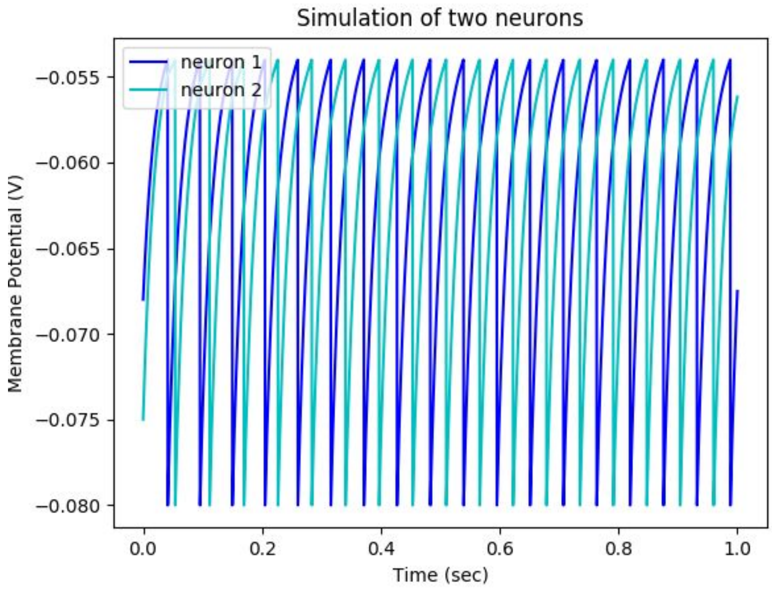
This happens as with the synapses being excitatory, a spike from a neuron triggers a positive change in the target neuron's membrane potential, making it more likely to fire its own action potential, in other words, is more likely to exceed the threshold and spike. The increasing firing rate results in the convergence and eventual synchronisation.



b) *Likely, the following also represents the voltages of two neurons which have synaptic connections between each other, but assuming the synapses are inhibitory.*

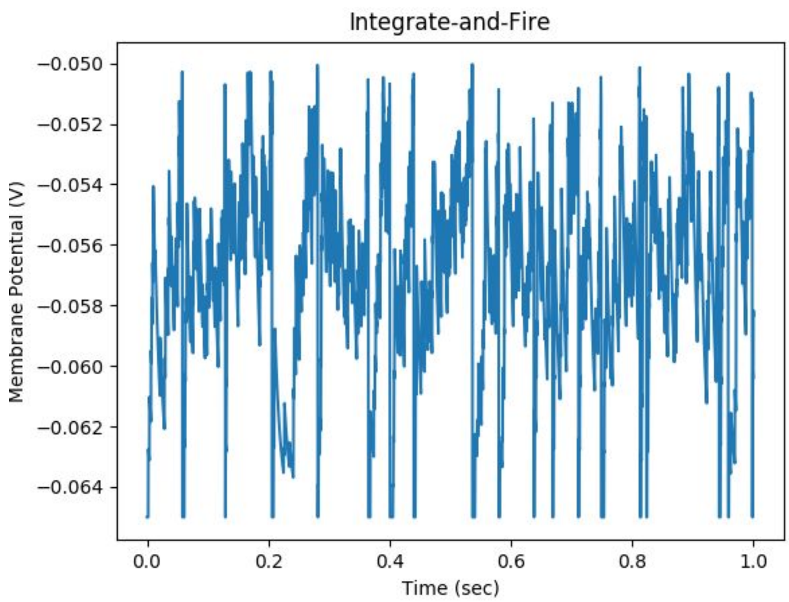
From the plot, neuron 1 fires first, then neuron 2, and this continues for the rest of the simulation. However, the firing of the two neurons becomes equidistant from each other when compared to the beginning, where neuron 2 fires almost right after neuron 1 fires.

With the synapses being inhibitory, an action potential is less likely to be generated as there is a smaller change(negative) in membrane potential than with excitatory synapses, causing a delay in spikes. This eventually reaches a point where spikes are evenly spaced and kept that way. The firing rate is lowered.



Part B: STDP

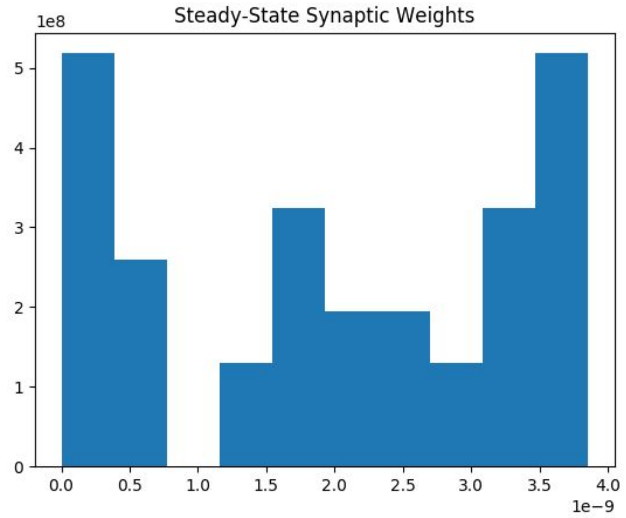
Question1
Below is a plot representing the simulation of a single leaky-integrate-and-fire neuron with 40 incoming synapses for a second. All synapses are set at the same strength(4nS).



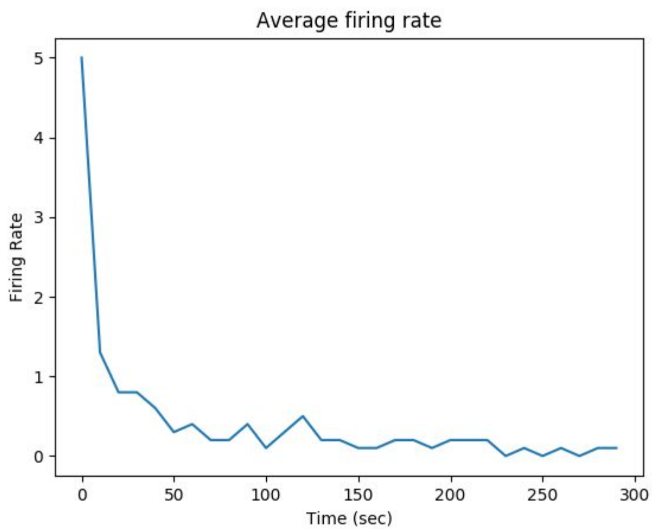
Question2

With STDP on, syntactic weights overall are more towards the lower and higher end, closer to the max strength of 4nS and lowest 0, as it has been capped. The synaptic strength distribution converges towards a qualitative shape of a u-shaped curve.

The plot below is a histogram of the steady-state synaptic weights after one run of the simulation.



The following plot represents the average firing rate of the postsynaptic neuron as a function of time over the entire 300seconds simulation with 10-second time bins.



Having averaged over 5 simulations, the steady-state firing rate averaged over the last 30 seconds of the simulation with STDP on is 0.1035 Hz. Whereas the steady-state firing rate averaged over the last 30 seconds of the simulation with STDP off with synaptic strengths set as the mean of the synaptic strengths results from being on is 0.0132Hz.

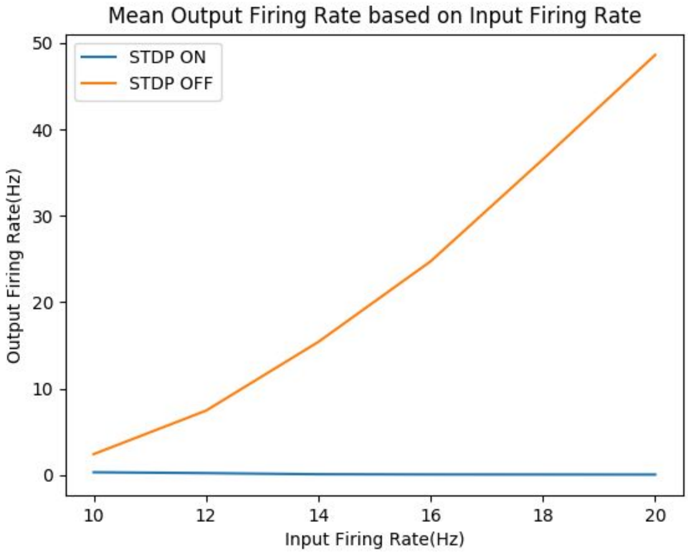
Question3

A total of 5 simulations have been run to aid observation, hence, the following values are averaged over 5 simulations.

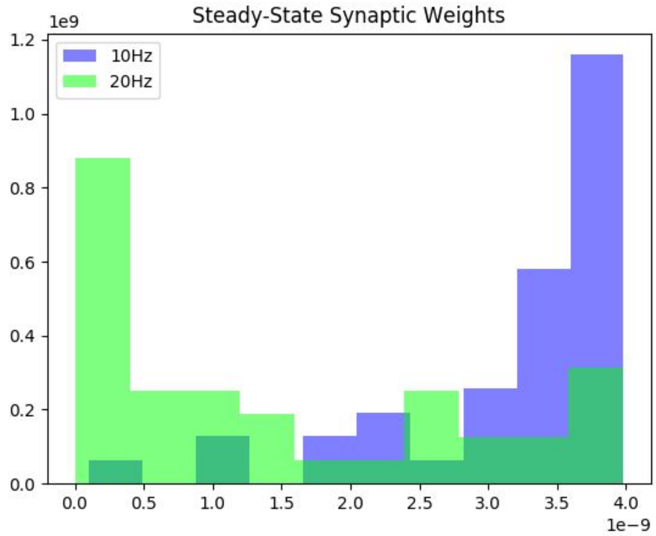
With STDP switched on, the output firing rate maintains a small value that is above 0Hz and decreases as the input firing rate is being increased. These are the values recorded for the input firing rates of [10,12,14,16,18,20]: [0.31, 0.21, 0.08, 0.06, 0.05, 0.04].

With STDP switched off, instead, the output firing rate increases with the increase in input firing rate.

The plot below represents the mean output firing rate as a function of the input firing rate for both STDP on and off.



This plots the steady-state synaptic strength distribution for 10Hz and 20Hz with STDP on.



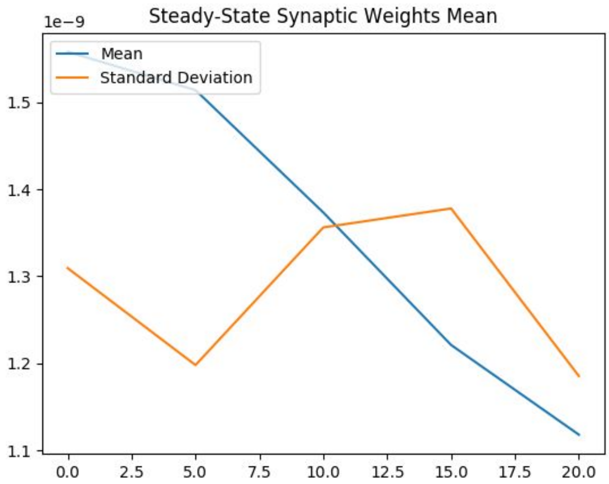
When STDP is off, synapse weights are kept constant at 4nS, and the increase in input firing rate triggers a larger increase in synapse currents, this contributes to a larger increase in the postsynaptic neuron's voltage and results in a spike. Therefore, increasing the input firing rate would increase the output firing rate.
However, when STDP is on, synaptic weights are updated by depression or potentiation, or both. An increase in input spikes would cause depression to happen more frequently. This leads to lower values for synaptic weights than for when STDP is off. This in turn contributes to a smaller increase in synapse currents and the neuron's voltage as well, hence, reducing its firing

rate. This is further illustrated in the second plot where with a higher input firing rate, more synapses have a lower weight.

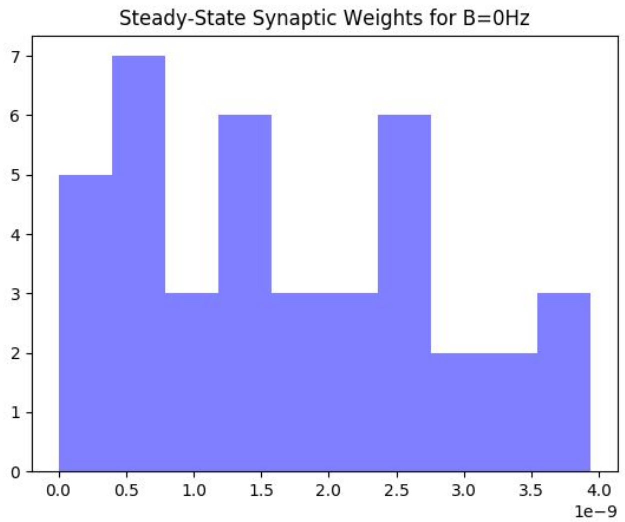
Question4

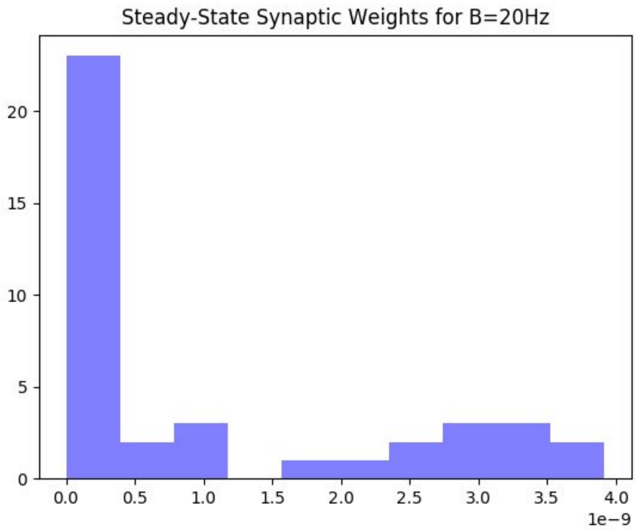
The degree of correlation(B) affects the steady-state synaptic weights in a way where the mean value of synaptic weights decline with its increase. The standard deviation of the weights fluctuates within the range of 1.2-1.4 as B is being increased.

Below is a plot of the mean and standard deviation of the steady synaptic strengths as a function of B.



The two plots below are histograms of the steady-state synaptic strengths for B=0 and b=20Hz respectively.





The decrease in mean and standard deviation fluctuation can be further explained and supported by the histograms. This could be reasoned that synaptic weights shift from higher values to lower values as B is being increased to 20Hz. When B = 0Hz, synaptic weights are more evenly spread, hence the relatively higher standard deviation. As B is increased from 5 to 15, the most weights start shifting to lower values, resulting in the drop in mean and increase in standard deviation. And at 20Hz, most weights are capped at 0, hence the low mean and low standard deviation.