EE746 Assignment 2 Report

Sahil Garg, Prateek Neema and Pranava Singhal
200070070, 20d070061, 200070057

Contents

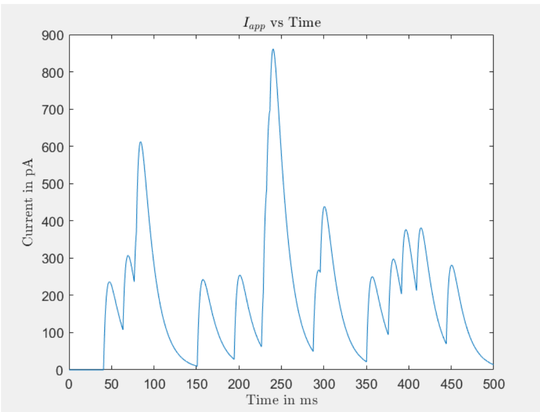
1 Problem 1: AEF neuron driven by a synapse receiving Poisson stimulus

1.1 Create a Poisson stimulus with T = 500 ms, Δt = 0.1 ms and λ = 10/s. Determine the time instants when stimulus arrives, t_k

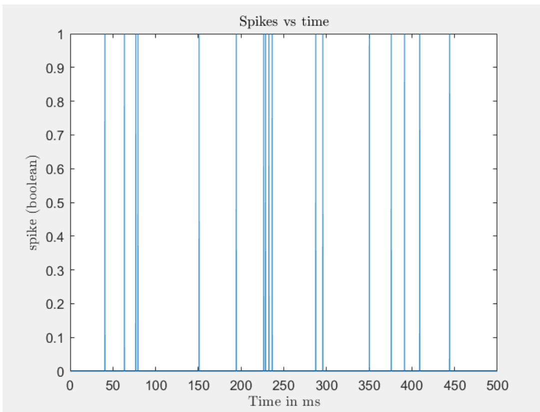
The Poisson stimulus is defined by a rate λ and a sampling time Δt, which defines the level of discretisation of time. The expected number of spikes in an interval of length Δt is given by $p = \lambda \Delta t$ which is less than 1 for sufficiently small Δt. In this case p can be thought of as the probability of a spike occuring in this time interval. Thus, we can generate a Poisson stimulus by sampling $N = \frac{T}{\Delta t}$ values from a Bernoulli distribution with probability p for 1. This returns a list of binary values, where 1 corresponds to a spike in the interval of length Δt.

1.2 Plot the response of an AEF RS neuron along with the input current and Poisson stimulus to convince yourself that the neuron emits spikes only if closely spaced stimulus are present

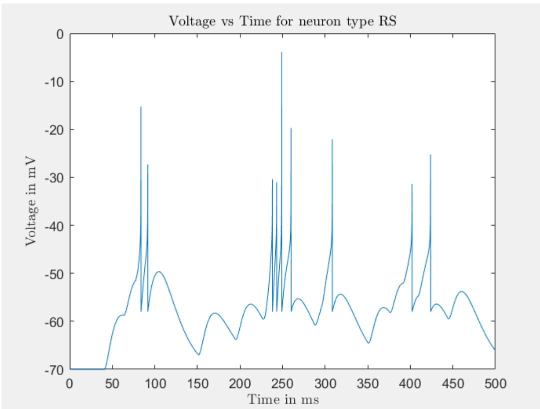
The plots for a particular Poisson stimulus reveal that $I_{app}(t)$, the current entering the post-synaptic neuron increases with spike frequency. Higher spike frequency also leads to more post-synaptic spiking.



(a) Current



(b) Input Spikes



(c) Voltage

Figure 1: Effect of spiking frequency on post-synaptic response

2 Problem 2: AEF neuron driven by multiple synapses

2.1 Assume $w_0 = 50$ and $\sigma_w = 5$ and create a population of N_s synapses. For each synapse, create a Poisson stimulus with T = 500 ms, $\Delta t = 0.1ms$ and $\lambda = 1/s$. Determine the total current flowing into the neuron based on equation (1) and plot the response of the neuron. How many spikes are issued by the neuron in the interval [0, T]?

The current flowing as a function of time is represented in the following figure:

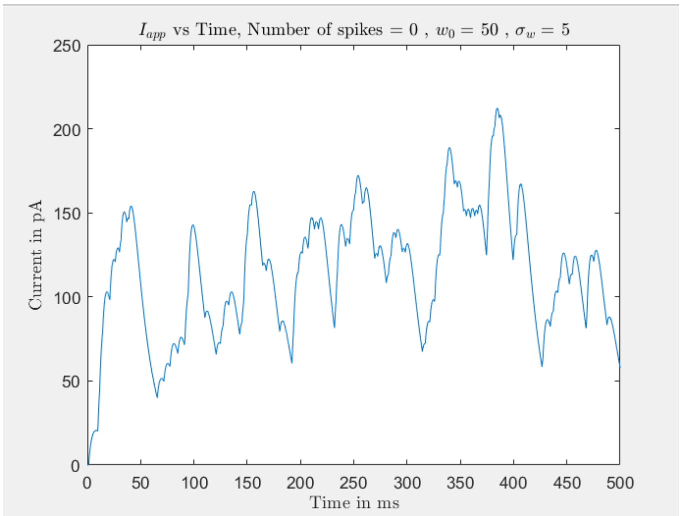


Figure 2: Total Current

Not even a single spike is issued by the neuron at these strengths of synapses.

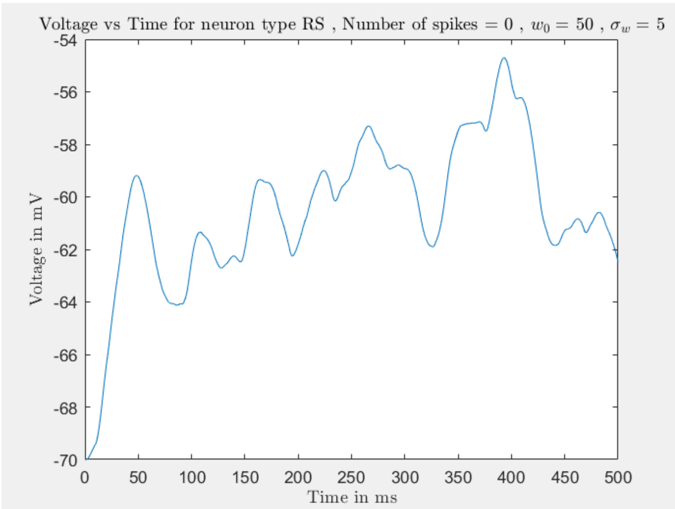


Figure 3: Neuron Response

2.2 For the same stimulus in (a), plot the total current and the response of the neuron, but with a new configuration of synaptic strengths defined by a Gaussian distribution whose mean is $w_0 = 250$ and $\sigma_w = 25$. How many spikes are issued by the neuron in the interval [0, T]?

The current flowing as a function of time is represented in the following figure:

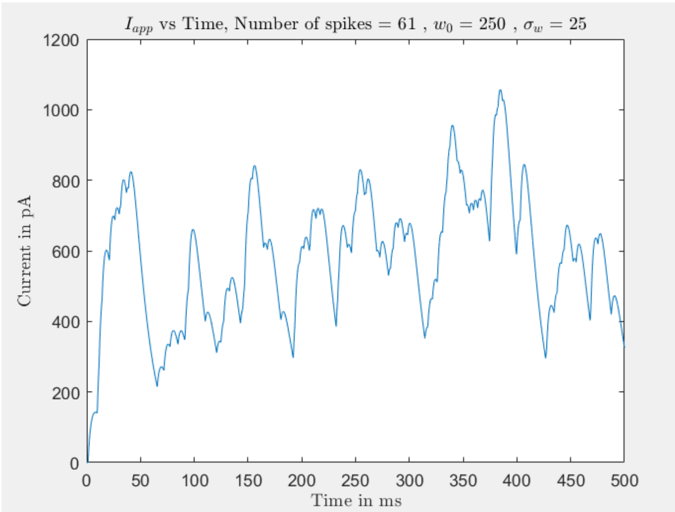


Figure 4: Total Current

In this particular test run, a total of 61 spikes are issued by the neuron.

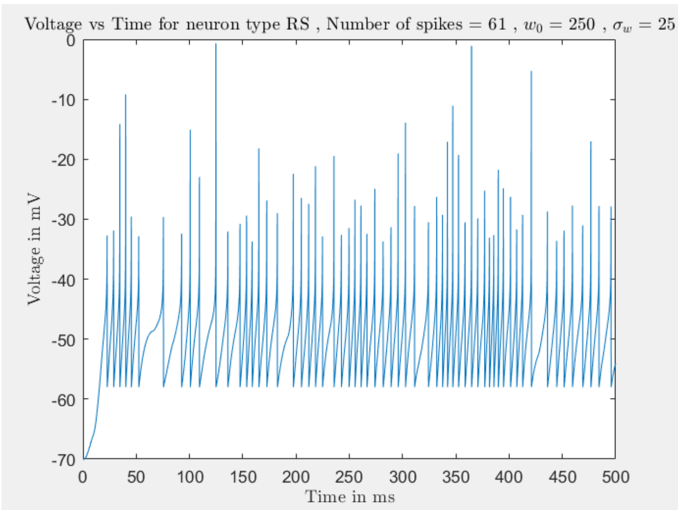


Figure 5: Neuron Response

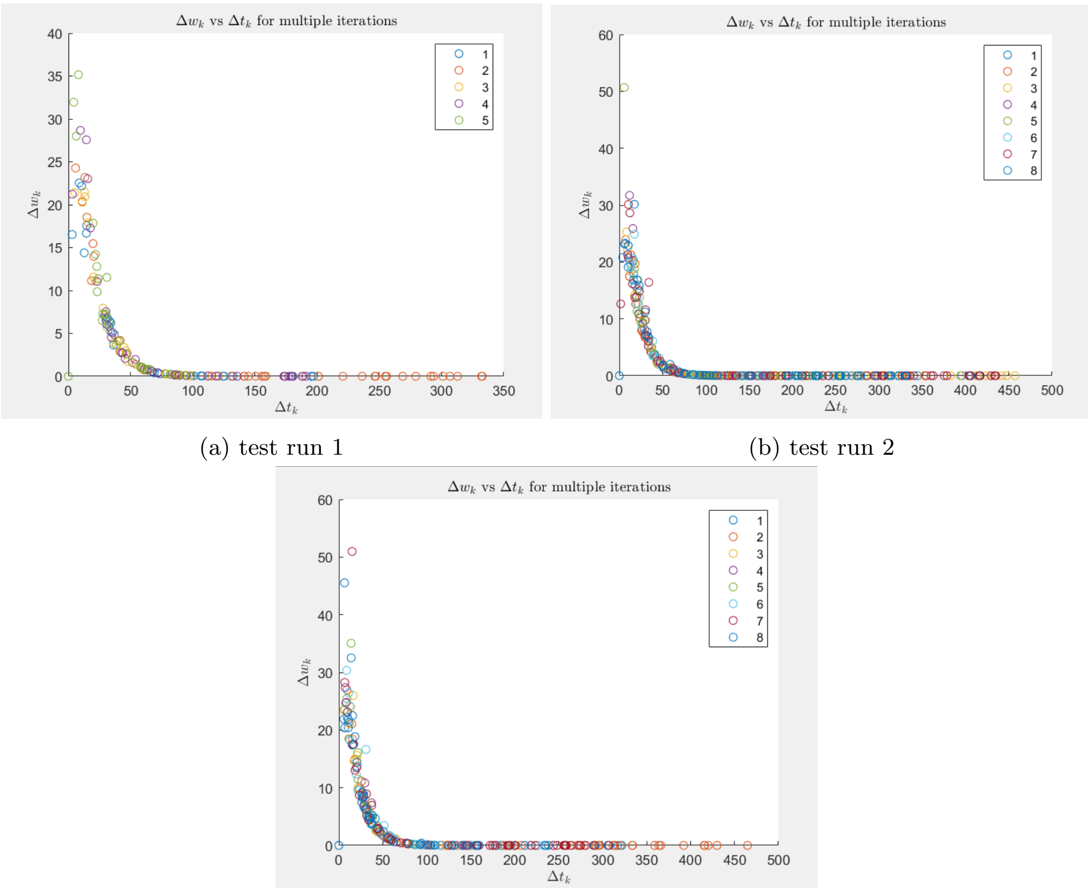
3 Problem 3: Adjusting the weights to elicit a spike response

3.1 Write a program to implement this learning rule and determine the number of iterations that are required to cause the neuron to create at least one spike for $\gamma = 1$. The output of your code should be the set of weights after training

The given update rule is $\Delta w_k = +w_k \gamma (e^{-\Delta t_k/\tau} - e^{-\Delta t_k/\tau_s}) h(\Delta t_k)$. We implemented the update rule as follows, first we generate a new random spiking pattern in each iteration and use this to generate $I_{app}(t)$. This is followed by calculating post-synaptic potential using Euler's method and simultaneously calculating the maximum voltage and time instants where it occured. Once we know the time instant of peak voltage within a time window of width T, we iterate over the neurons and for each neuron we obtain the nearest spike prior to the time of maximum voltage. If no spike occured before this time, we don't update weights for this neuron. After this weights are updated using the above mentioned update rule.

For three tests that we did, the number of iterations needed were 5, 8 and 8 respectively.

3.2 Plot, on the same graph, the value of Δw_k vs Δt_k for every synapse and every training iteration



(a) test run 1

(b) test run 2

(c) test run 3

Figure 6: Relationship between Δw_k and Δt_k

4 Problem 4: Adjusting the weights to remove all spike responses

4.1 Write a program to implement this learning rule and determine the average number of iterations that are required to remove all the spikes of the neuron. The output of your code should be a set of weights that results in removing all the spike from the neuron. In this experiment, start with a new population of synaptic strengths with $w_0 = 250$ and $\sigma_w = 25$, but the same pattern of stimulus as before.

The average number of iterations required to remove all the spikes from the neuron is 4-5. The membrane potential for the neuron for different iterations can be seen in the figures below.

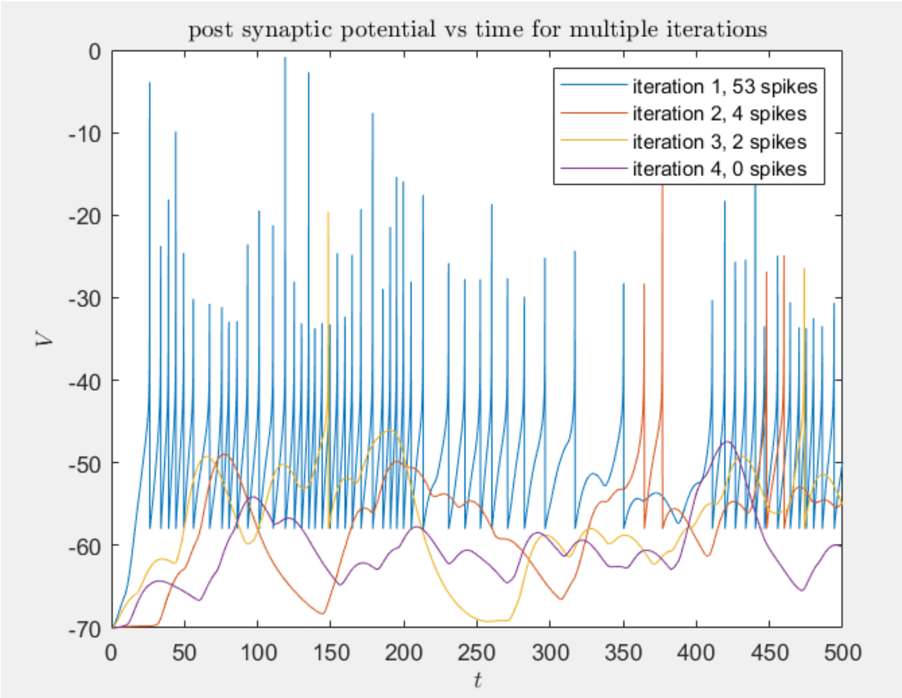


Figure 7: Membrane Potential for first test run

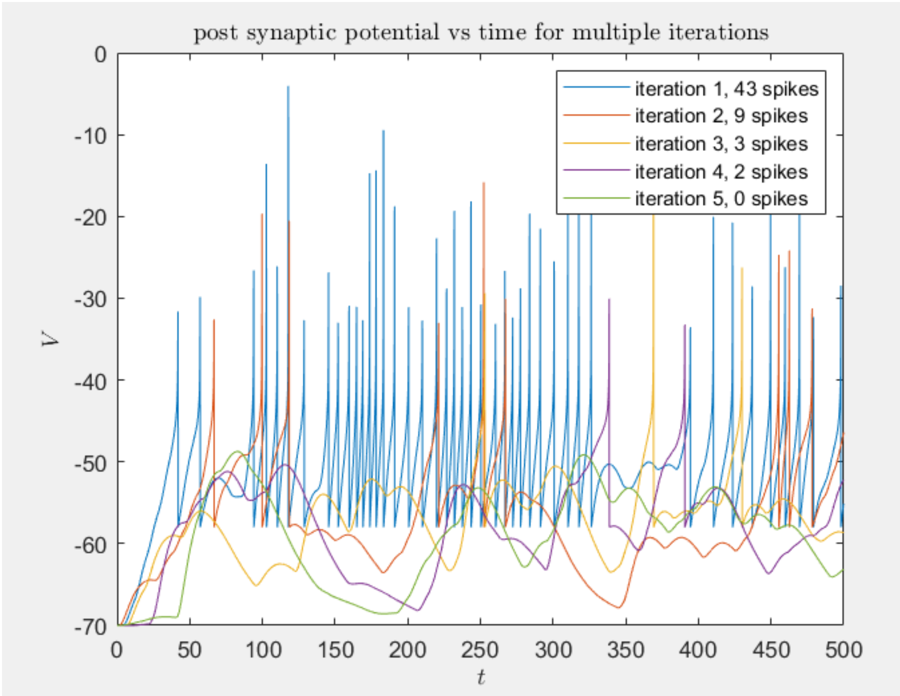


Figure 8: Membrane Potential for second test run

4.2 Plot, on the same graph, the value of Δw_k vs Δt_k for every synapse and every training iteration.

The plot of Δw_k vs Δt_k is as follows:

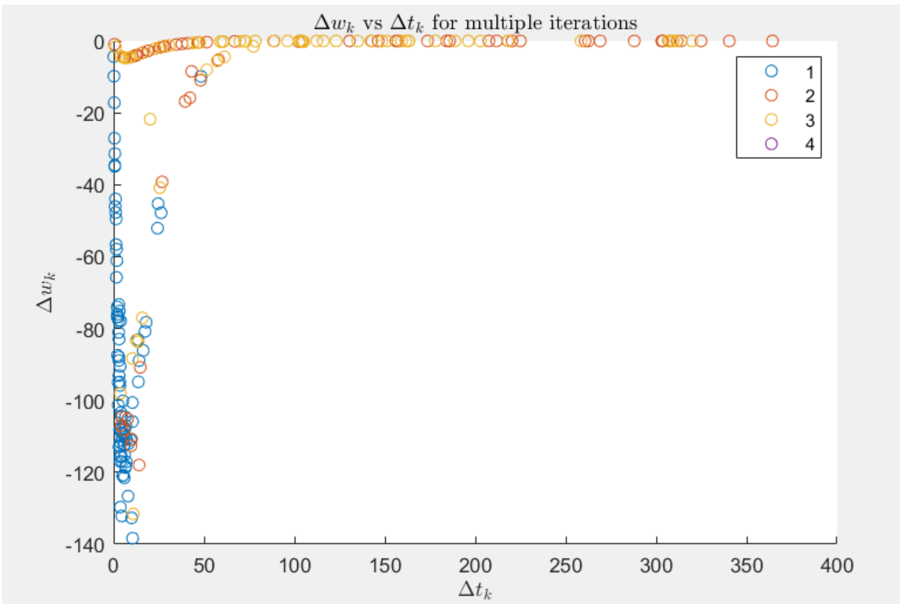


Figure 9: Plot for test run 1

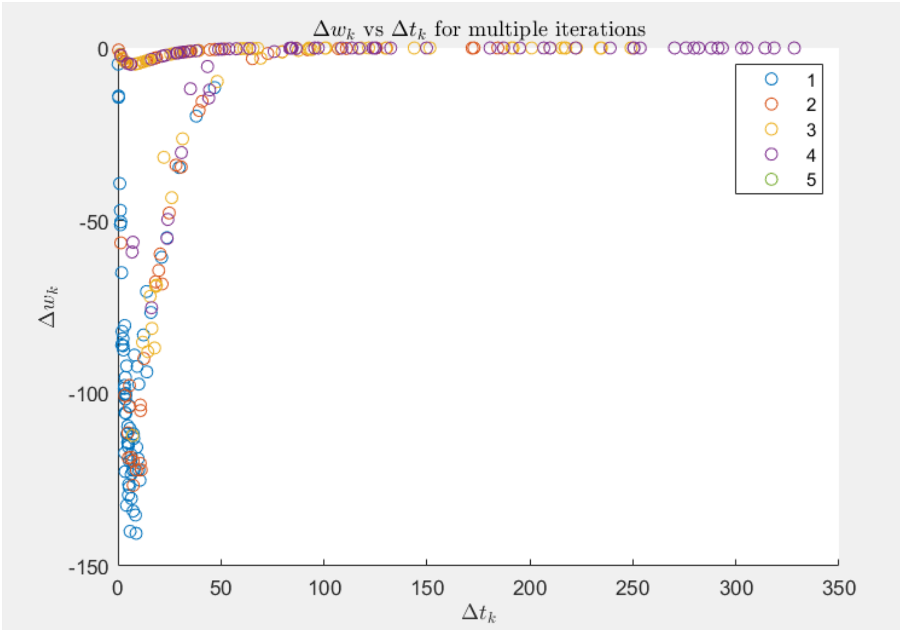


Figure 10: Plot for test run 2