Assignment 2

Project 1

Description

Implement a code that simulates the activity of a population of neurons consisting 800 excitatory neurons and 200 inhibitory neurons, with different types of connection, for a random input current and finally, plot the results.

Simulation

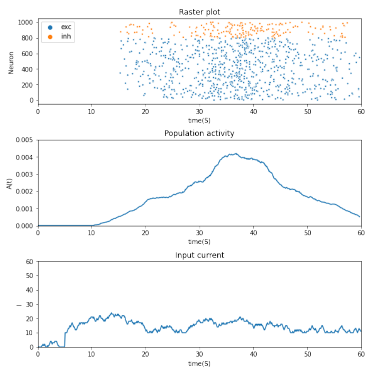
In the simulation I used the LIF neuron model that was used in the previous projects with the standard parameters inherited from here. The population has 1000 neurons consisting 800 excitatory and 200 inhibitory neurons. All the neurons are identical and they receive the same random input current but with a small noise on the membrane potential, therefore the population is homogeneous. After Implementing the model I ran the simulation for 60 seconds with $dt = 0.1$ for 4 different types of connections:

1. Fully connecte with $J_0 = 4.5$ and $w_{i,j} = N(J_0/N, \sigma_0/N)$
2. Gaussian fully connected with $J_0 = 4.5, \sigma_0 = 1 and w_{i,j} = N(J_0/N, \sigma_0/N)$
3. Randomly connected with coupling probability $p = 0.01, j_0 = 4.5$ and $w_{i,j} = J_0/pN + N(0, 0.01)$
4. Randomly connected with fixed number of pre-synaptic partners $N_p = 10$ and $w_{i,j} = N(0.45, 0.01)$

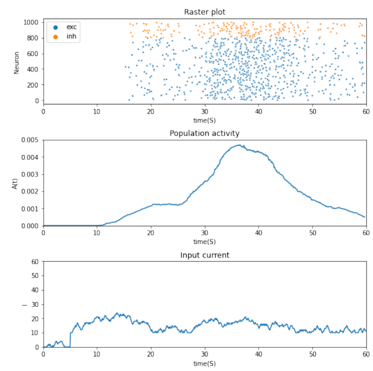
The reason for the random part of the weights, is to avoid the similar behavior of neurons, because in the case of having identical weights and not having noise on membrane potential all the neurons would show the same action at any time(e.g. fire together). Finally, I plot the output of simulation which is spike train and the popula- tion activity with $\delta t = 5dt$.

Result

The Fig. 1 provide the results of the simulation for mentioned types of connection. Note that all the parameters are set in a way that the neurons get the same amount of input from their partners independent from the type of connection.

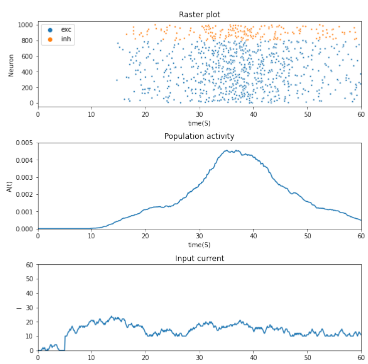


(a) Fully connected

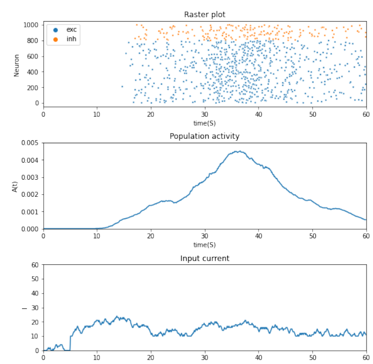


(b) Gaussian fully connected

Trial 1



(c) Fixed coupling probability



(d) Fixed pre-synaptic partners

Trial 2

Figure 1: Output of the simulation for different types of connection

As you can see as soon as the input current gets strong enough, the neurons start to fire and the population activity grow. Although all the neurons of the experiments have the same external and expected internal input, there is a slight difference in their population activity. For example, in the case of having fully connected population, the population activity is more smooth and we don't have any sharp change during the simula- tion time and comparing these two types of full connectivity, in the Gaussian the neurons doesn't have the same behavior but overall population activity is the same as the Uniform one. On the other hand, when the population is randomly connected, in the case of having fixed pre-synaptic partners the population ac- tivity have less standard deviation comparing to the fixed coupling probability connectivity.

Project 2

Description

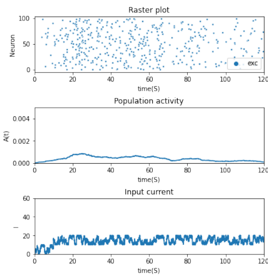
Implement a code that simulates the decision making process in a model with two excitatory populations and one inhibitory population with random input for different types of connection.

Simulation

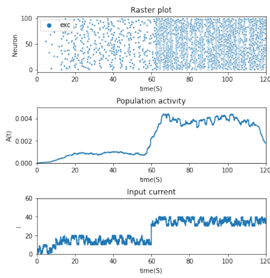
In the simulation I used the LIF neuron model that was used in the previous projects with the standard parameters inherited from here. Each population contains 100 neurons and all these neurons are identical and they receive the same random input current but with a small noise on the membrane potential, therefore the populations are homogeneous. In each experiment I ran the simulation for 120 seconds with dt = 0.01 for different types of connection.

Results

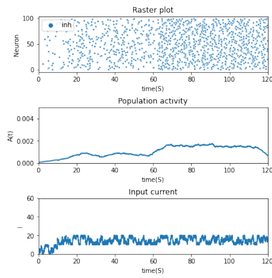
Firstly I ran the simulation for a model with fixed pre-synaptic partners connectivity. As I've mentioned before all the populations have 100 neurons, But, in order to have a balanced network every excitatory neuron have 30 pre-synaptic neuron in its own population and 10 pre-synaptic neuron in inhibitory population, and every inhibitory neuron have 10 pre-synaptic neurons in each excitatory population. As a result of mentioned configuration, we have a balanced network the amount of inhibition and excitation between populations is zero, in additions all the neurons get approximately equal input from other neurons. I ran the simulation with described configurations for two trials. In the first one, after a while the second excitatory population received a strong random input current and in the second one the first excitatory population received a strong random input current. The Fig. 2 provides the result of these two trials. As soon as an excitatory population get a strong input, the activity of in- hibitory population increases and as a result of that the activity of other excitatory population decreases. Fig. 3 shows the trace of activity of excitatory populations in both trials. At the time that one of excitatory populations got activated, the other one got deactivated. These property of the network can be interpreted into the decision making capability of the model with mapping two different decisions to the excitatory populations. In other words, at every stimulus, the network makes the decision that is corresponded to the population with the higher activity. After the first two trials I ran the simulation for other 3 types of connection and Fig. 4 provides their results. Note that in these type of connections I adjusted the parameters for setting weights in a way that the network stays balanced in term of the amount of inhibition and excitations. The results of this experiment is the same as the first project. In the case of having a random connectivity we have sharper changes in the activity of the populations compared to full connectivity. And, the behavior of neurons in the



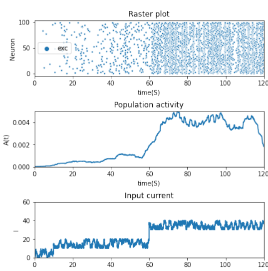
(a) Excitatory population 1



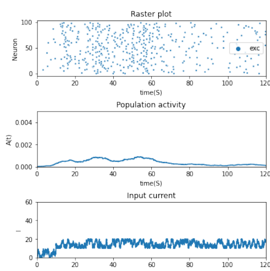
(b) Excitatory population 2



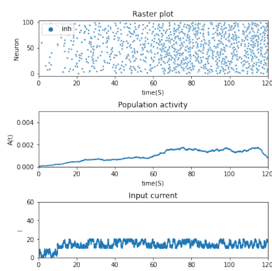
(c) Inhibitory population



(d) Excitatory population 1



(e) Excitatory population 2



(f) Inhibitory population

Figure 2: Output of the simulation for fixed pre-synaptic partners connectivity

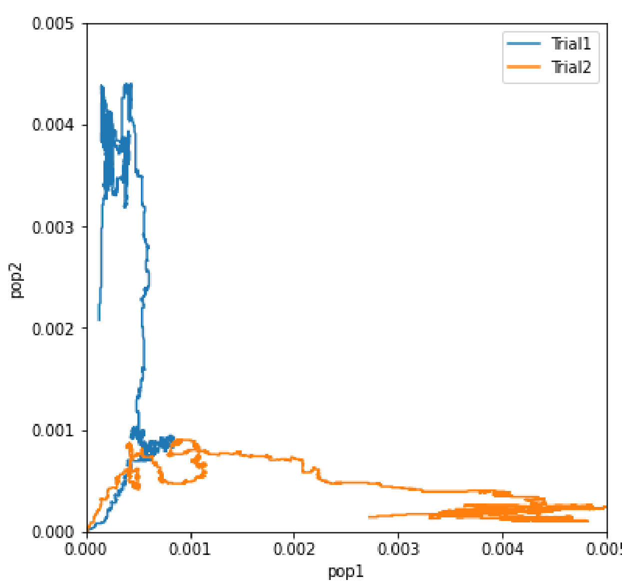
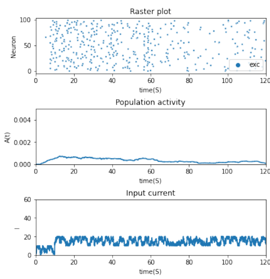
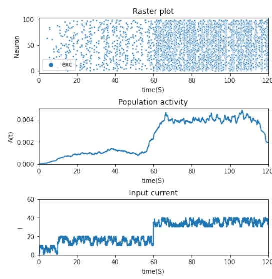


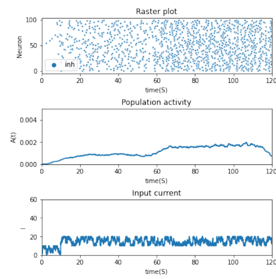
Figure 3: Trace of activity of excitatory populations in both trials



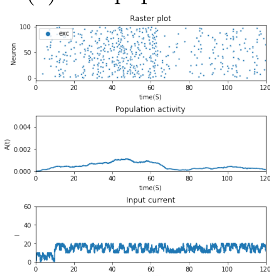
(a) Exc-population 1



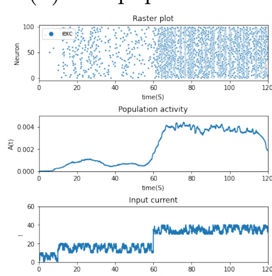
(b) Exc-population 2



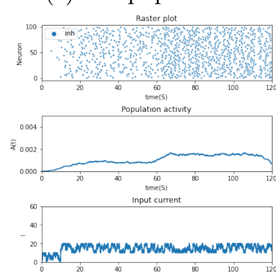
(c) Inh-population



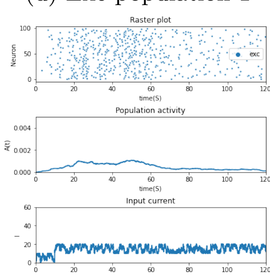
(d) Exc-population 1



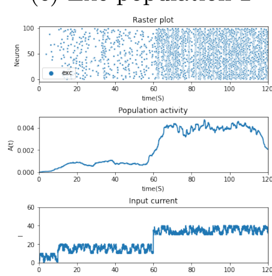
(e) Exc-population 2



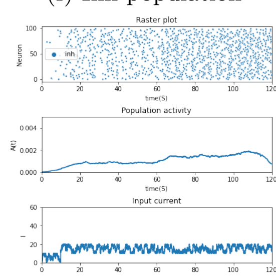
(f) Inh-population



(g) Exc-population 1

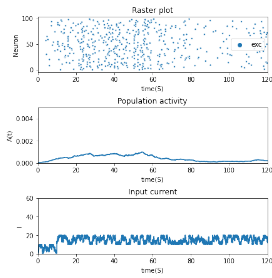


(h) Exc-population 2

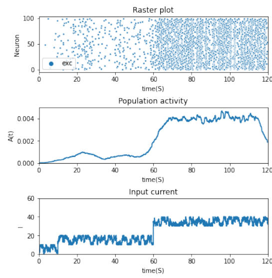


(i) Inh-population

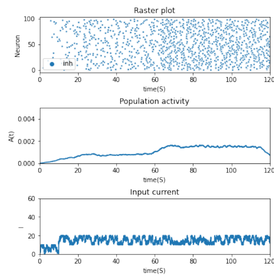
Figure 4: Output of the simulation for fixed pre-synaptic partners connectivity a,b,c is Fixed coupling probability d,e,f is Fully connected g,h,i Gaussian fully connected



(a) Excitatory population 1

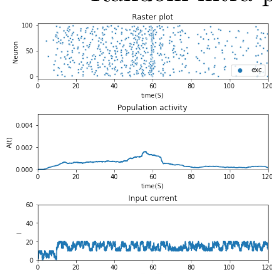


(b) Excitatory population 2

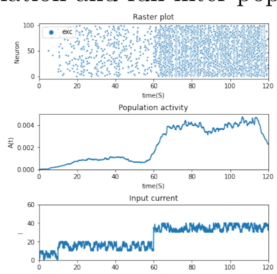


(c) Inhibitory population

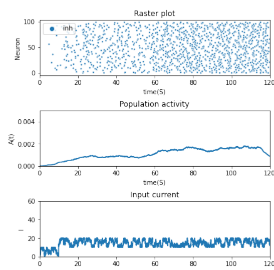
Random intra-population and full inter-population connectivity



(d) Excitatory population 1



(e) Excitatory population 2



(f) Inhibitory population

Random inter-population and full intra-population connectivity

Figure 5: Output of the simulation for fixed pre-synaptic partners connectivity

Fully connected model is more similar than Gaussian fully connected. In other words, the model went toward having a periodic pattern, in the case of negligible changes in the input current, since all the neurons have identical inputs. Finally I ran two more experiments in which the intra-population connec- tions is differ from the inter-population connections. Since the behavior of full connectivity are almost the same, I only chose "Fully connected" type and due to the same reason for random connectivity I only chose "Fixed pre-synaptic partners" type. The results of this trials are provided in Fig. 5.