Week 4: Connecting simple excitatory neurons with inhibitory neurons

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1 GABA synapses

I tried implementing the non-linear NMDA synapse and failed miserably. While I work on it, I will instead implement the simpler GABA channels that are linear and obey the superposition principle, because the synapses do not saturate for realistic inputs and therefore different spike trains coming in from other neurons can be summed up linearly and passed to the same gating variable.
In this week's simulation we implement simplified inhibitory neurons with GABA channels and AMPA channels for receiving input and excitatory neurons with AMPA receptors. We connect the two groups via the inhibitory GABA channels and feed each group with Poisson spikes with frequency 1.8 kHz through the AMPA channels. The toy inhibitory and excitatory neurons have different parameters as specified by (1). We then observe the spiking patterns in the excitatory cells.

2 Results

Figure 1 shows the excitatory spiking neurons without inhibition and figure 2 shows the spiking neurons with inhibition. It is apparent that the inhibitory GABA synapses have a profound impact on the excitatory neurons, silencing the activity.

3 Code

The code for the simulation is given below. It is also available on GitHub www.github.com/mariakesa

```
from brian import *

eqs_inhibitory='''
dv/dt=(-gl_i*(v-El_i)-g_ext_e*s_ext*(v-E_ampa)-g_gaba*s_gaba*(v-E_gaba))/Cm_i:
volt
ds_ext/dt=-s_ext/t_ampa : 1
ds_gaba/dt=-s_gaba/t_gaba : 1
'''
```

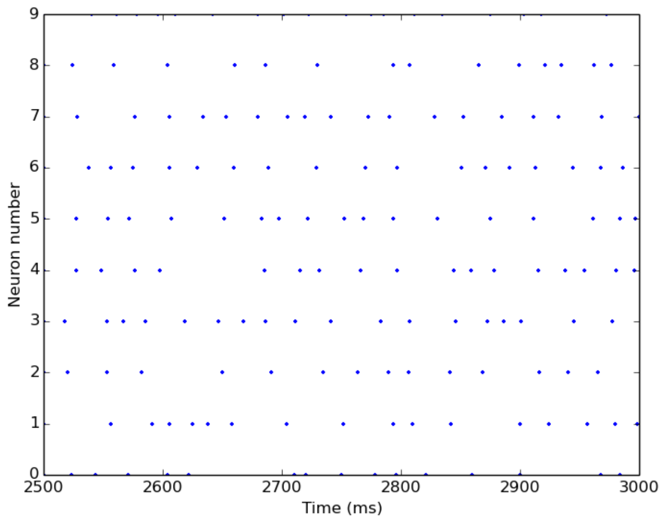

Figure 1: Excitatory neurons without inhibition (frequency 1.8 kHz)

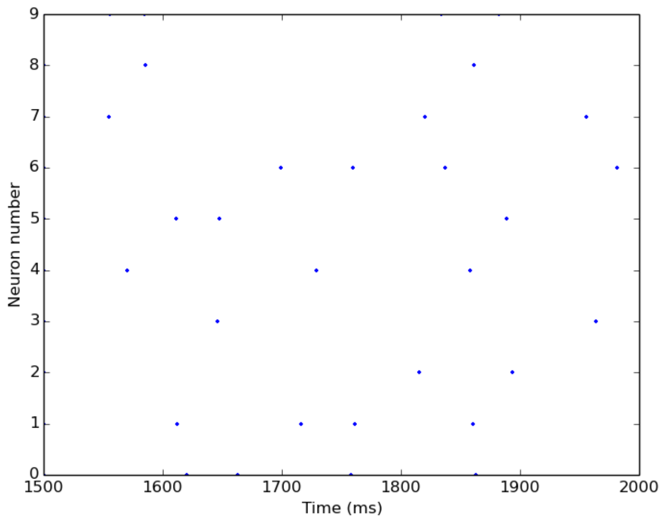

Figure 2: Excitatory neurons with GABA-ergic inhibition (frequency 1.8 kHz)

```
eqs_excitatory='''
dv/dt=(-g_leak*(v-El_leak)-g_ext_i*s_ext*(v-E_ampa))/Cm_exc: volt
ds_ext/dt=-s_ext/t_ampa : 1
'''

nr_of_neurons=10
Cm_exc=0.5*nF
El_leak=-70*mV
g_leak=25*nS
V_th_exc=-50*mV
reset_exc=-60*mV
t_ref_exc=2*ms
Cm_inh=0.2*nF
gl_i=20*nS
El_i=-70*mV
V_th_inh=-50*mV
reset_inh=-60*mV
t_ref_inh=1*ms
t_ampa=2*ms
t_gaba=10*ms
fext=1.8*kHz
g_ext_e=3.1*nS
g_ext_i=2.38*nS
g_gaba=2.70*nS
E_gaba=-70*mV

exc_neurons = NeuronGroup(nr_of_neurons, eqs_excitatory,threshold=V_th_exc, res
inh_neurons = NeuronGroup(nr_of_neurons, eqs_inhibitory,threshold=V_th_exc, res

inputs = PoissonGroup(nr_of_neurons,fext)

input_connections = IdentityConnection(inputs,exc_neurons,'s_ext',weight=1.0)
input_conns = IdentityConnection(inputs,inh_neurons,'s_ext',weight=1.0)

inter_connectivity = Connection(exc_neurons,inh_neurons,'s_gaba',weight=1.0,spa

M = SpikeMonitor(exc_neurons)
run(simulation_time)
spikes=M.spikes
raster_plot(M)
```

4 Citations

(1)Compte, A., Brunel, N., Goldman-Rakic, P., Wang, X-J. “Synaptic Mechanisms and Network Dynamics Underlying Spatial Working Memory in Cortical Network Model”, Cerebral Cortex, 2000