Homework 3

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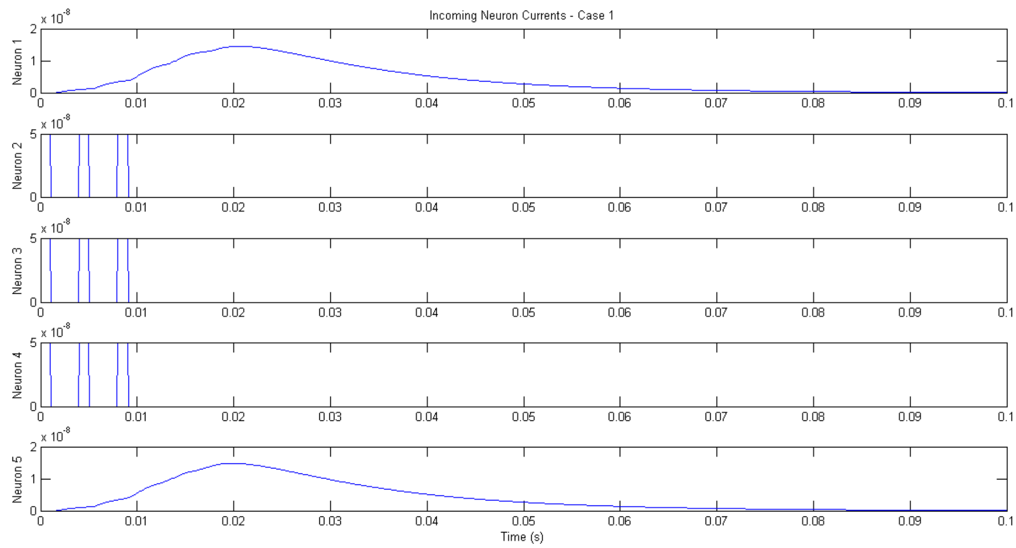
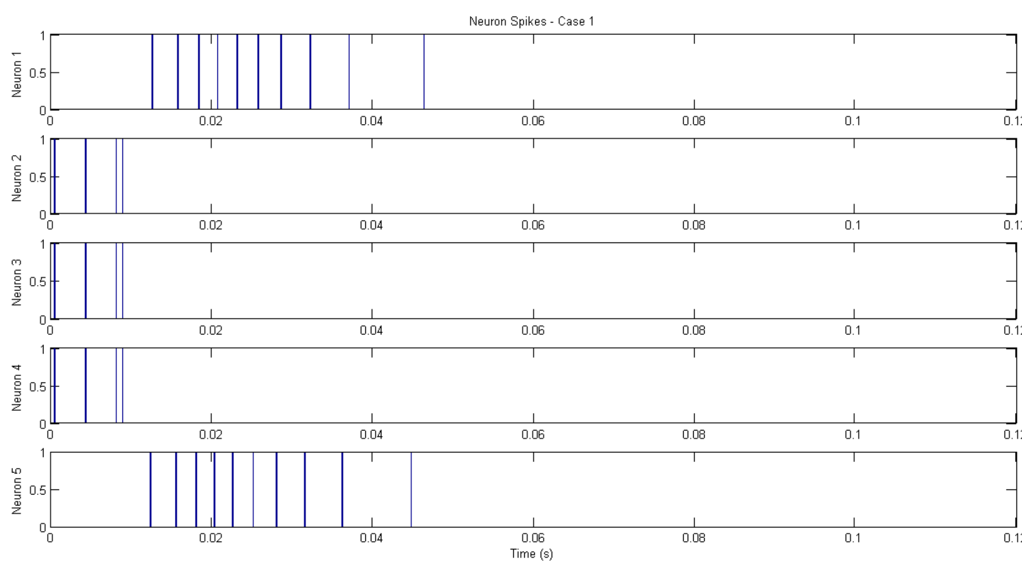
Problem 1

a) Go into the folder 'Problem 1' and load either one of 'problemOne1.mat' or 'problemOne2.mat'. Observe the cell arrays loaded into the MATLAB workspace, they contain the connectivity information of the neural network shown in Figure 1.

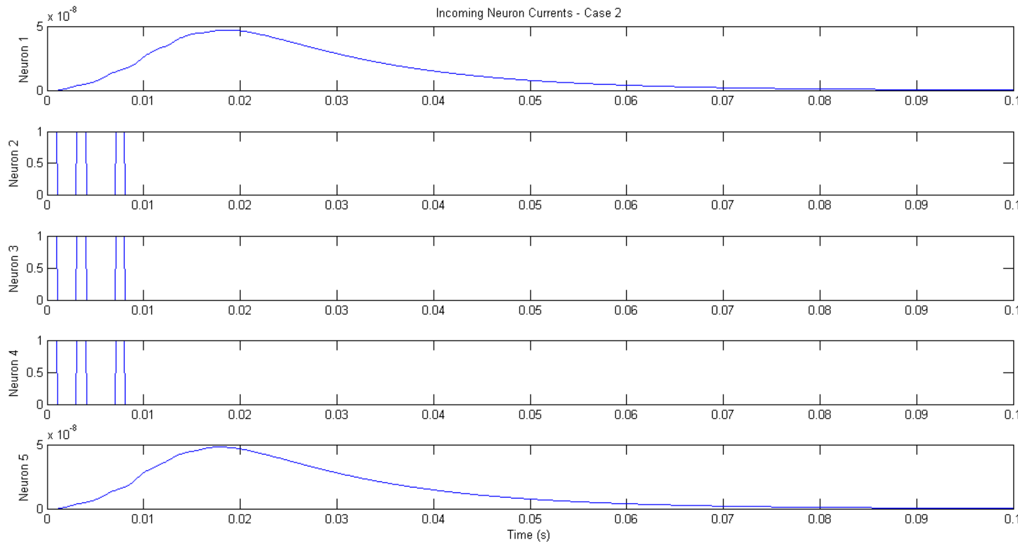
b) In case 2, more spikes are seen and they persist longer, since the current pulses going into the network (through neurons b, c, and d) are more closely spaced:

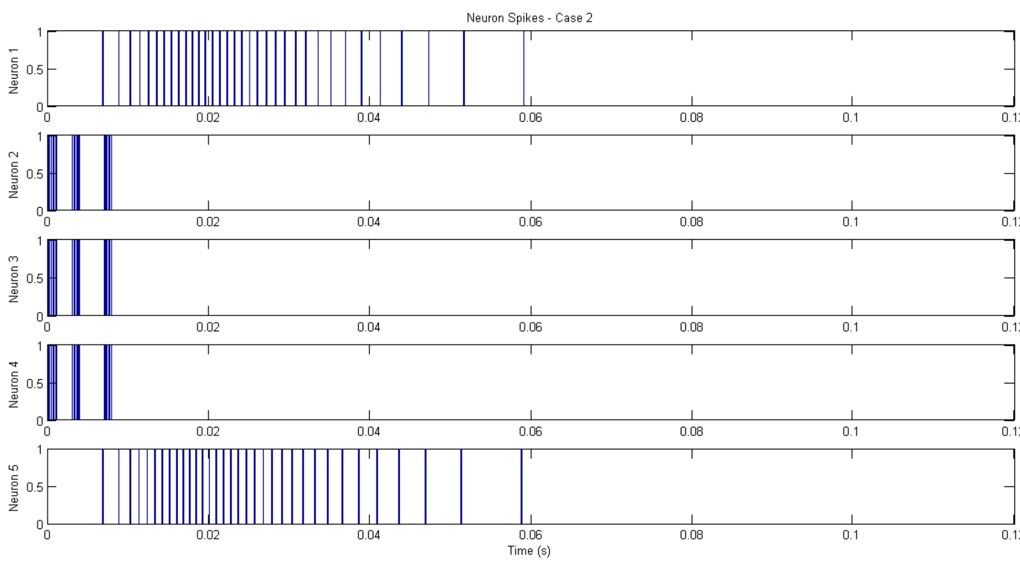
CASE 1:





CASE 2:

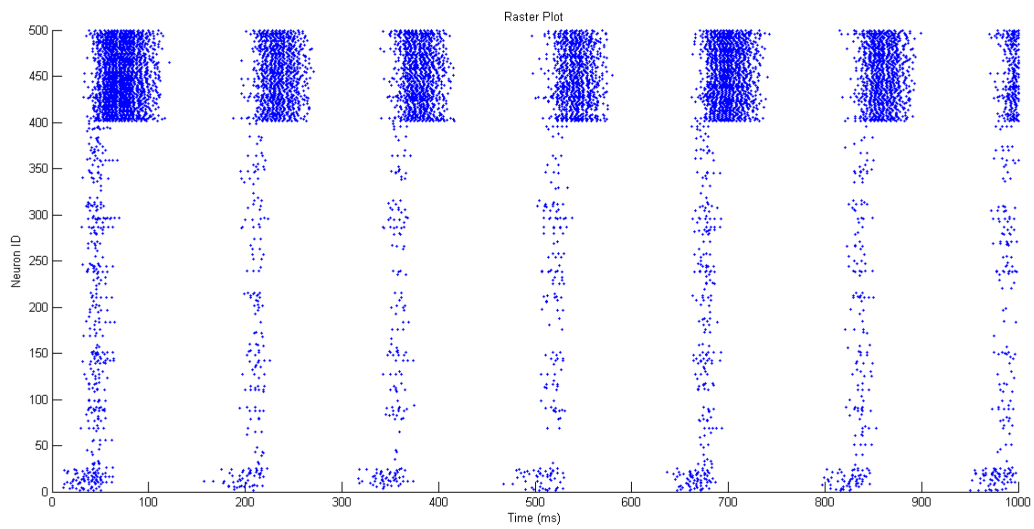




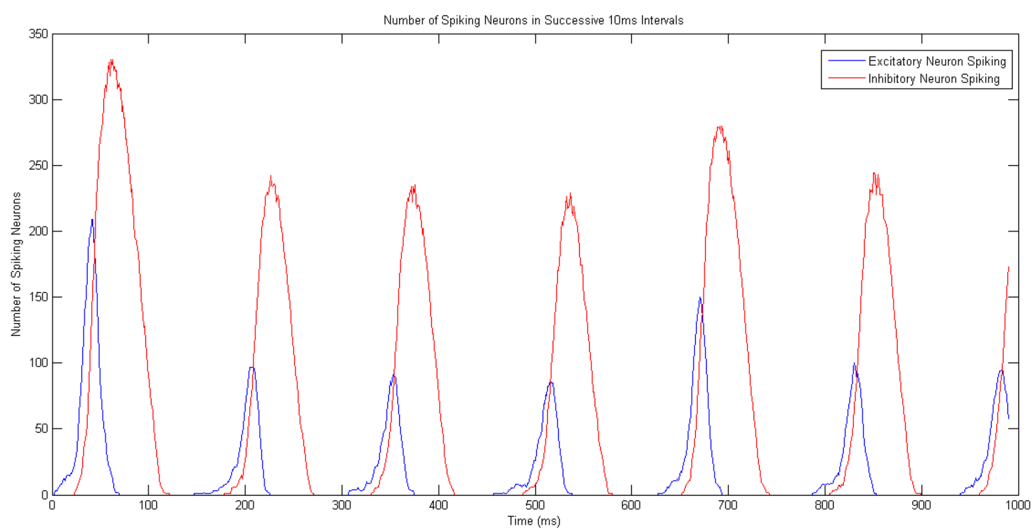
The refractory LIF neuron is implemented in the function written in the 'LIF_Refractory.m' file, and the major network-level simulation is done in the 'networkSolver.m' script.

Problem 2

a) The random initializations are done in ‘randomInitializer.m’ after loading ‘preRandInit.mat’. The ‘main.m’ file uses already generated random data stored in ‘postRandInit.m’, but that can be replaced with the actual initialization by commenting and uncommenting appropriate parts of the code (it’s self-explanatory, see the file ‘main.m’). The Raster Plot obtained:



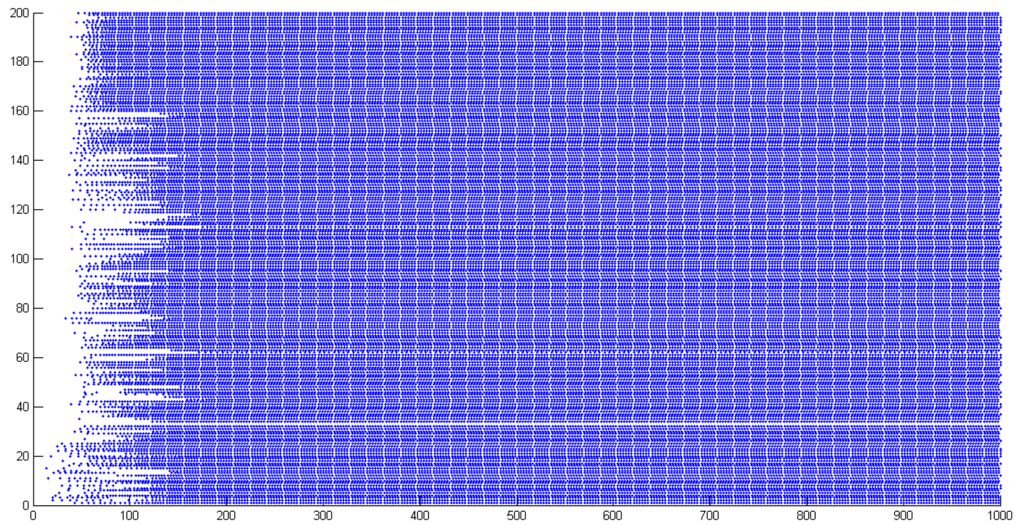
b) Plots for Ri(t) and Re(t). They exhibit heavy regularities:



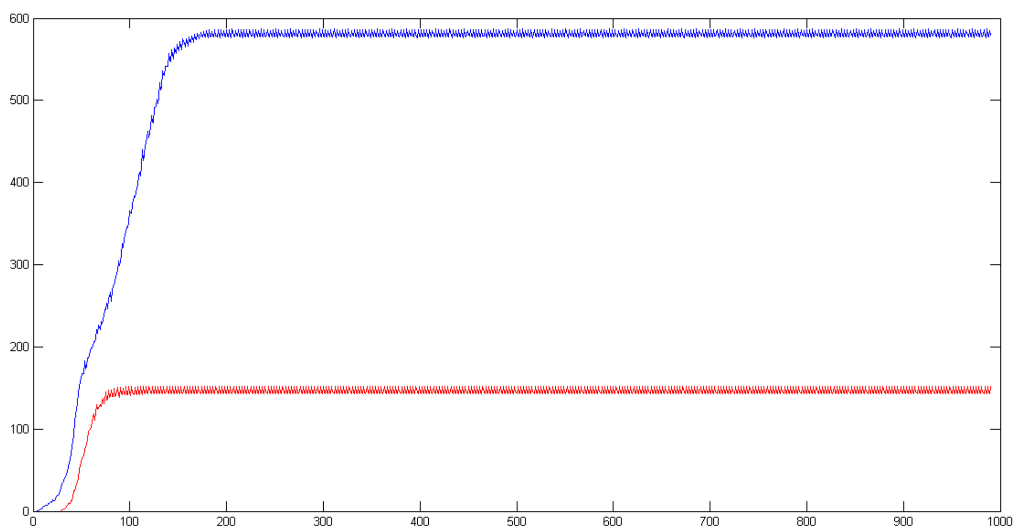
c) The inhibitory connections are the crucial part enabling the dynamics of this network. When the excitatory weights increase, they inevitably increase the spiking in the inhibitory neurons (since there is always a chance that some of the N/10 connections made by each excitatory neuron will be to inhibitory neurons), which are able to bring down the overall spiking in the network's excitatory neurons. The inhibitory neurons are able to overpower the excitatory neurons since they are exclusively connected to excitatory neurons and not at all among themselves (no inhibitory feedback within the 'inhibitory section' of the network). This causes the oscillating behavior.

Problem 3

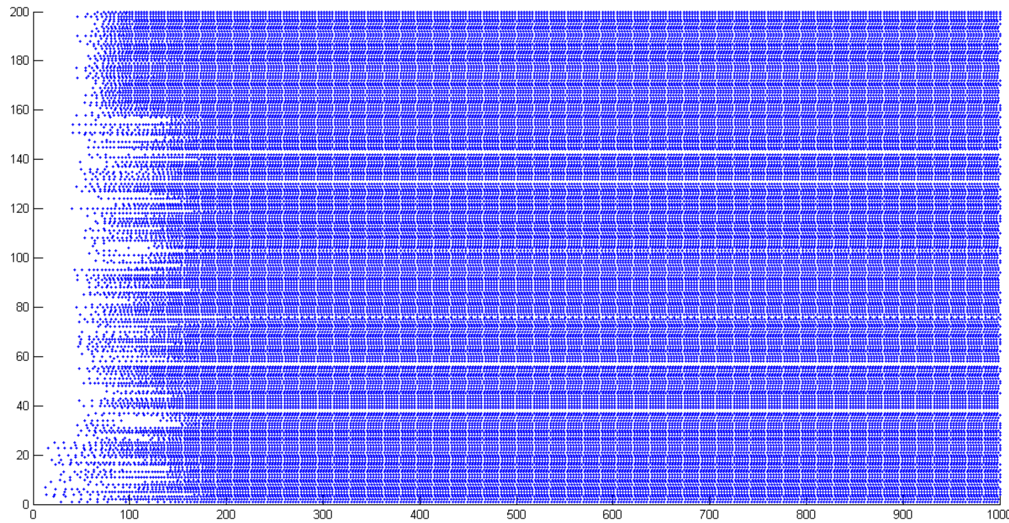
a) The neuron spiking increases without bound:

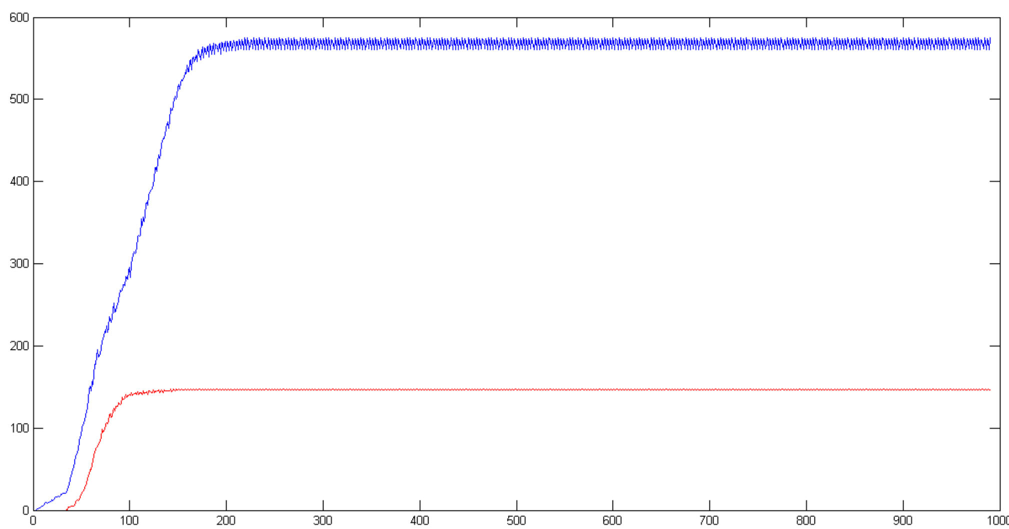


The Re(t) and Ri(t) plots look like this:

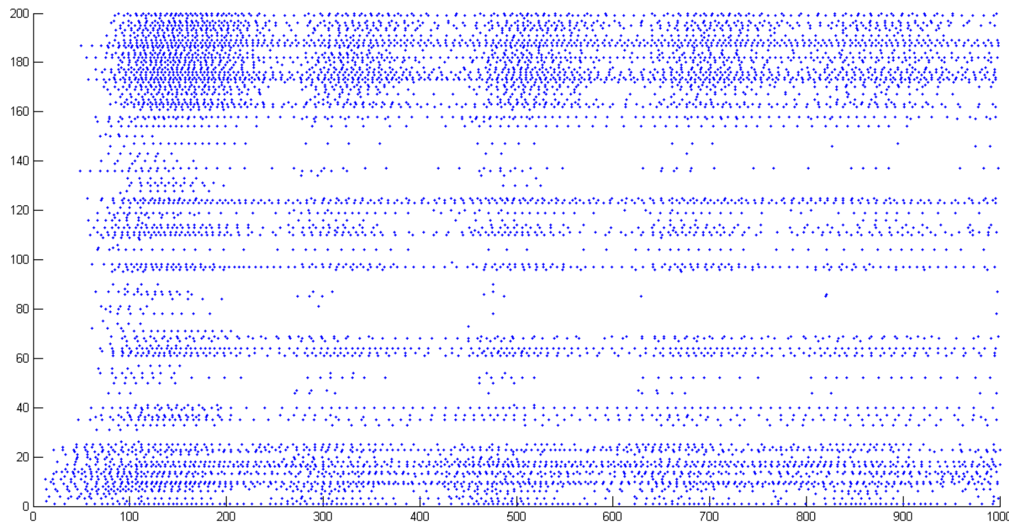


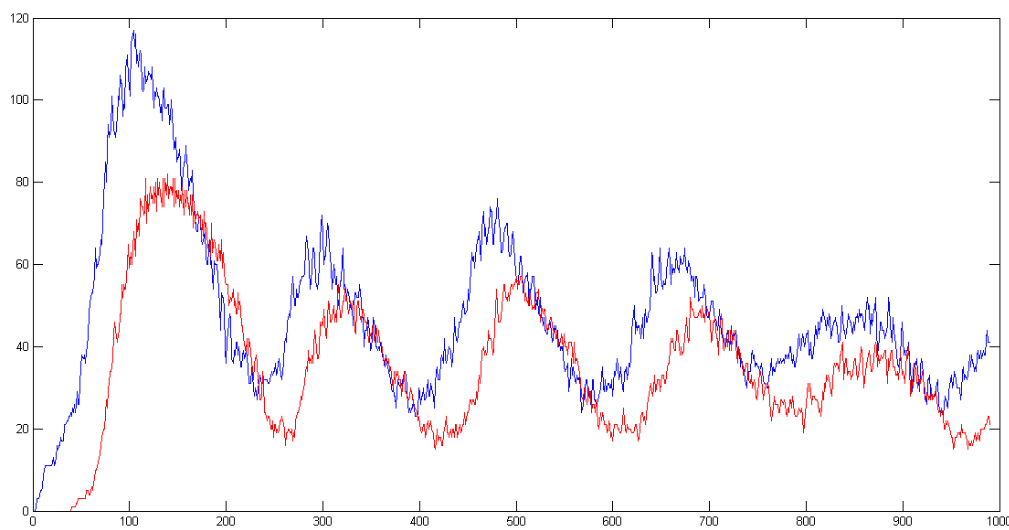
b) At first glance, one would expect that decreasing the weights should prevent the runaway condition observed. These are the results for cases where we=2000:





and we=1000:



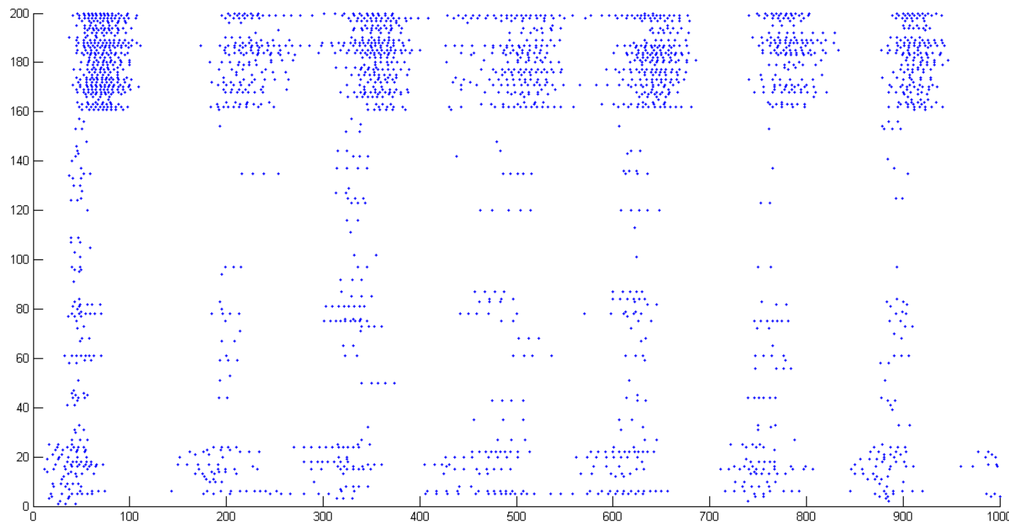


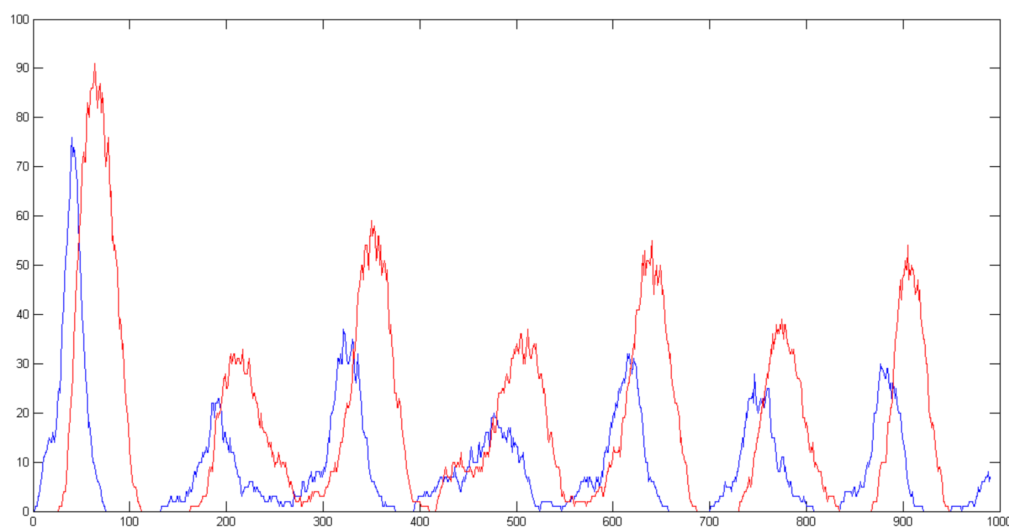
Though when we=1000, the spiking does not blow up, the excitatory spikes still always overpower the inhibitory spikes. This can be seen from the Re(t) and Ri(t) graph and can also be explained by the fact that we have a lot of external input (25 out of 160 excitatory neurons continually receiving Poisson stimulus), and this overpowers the effects of the inhibitory neurons.

To see the kind of periodic behavior that was observed in Problem 2, we must put in less external input, or we must ensure that Ri(t) overpowers Re(t) when it tries to increase, so that it is brought back to zero.

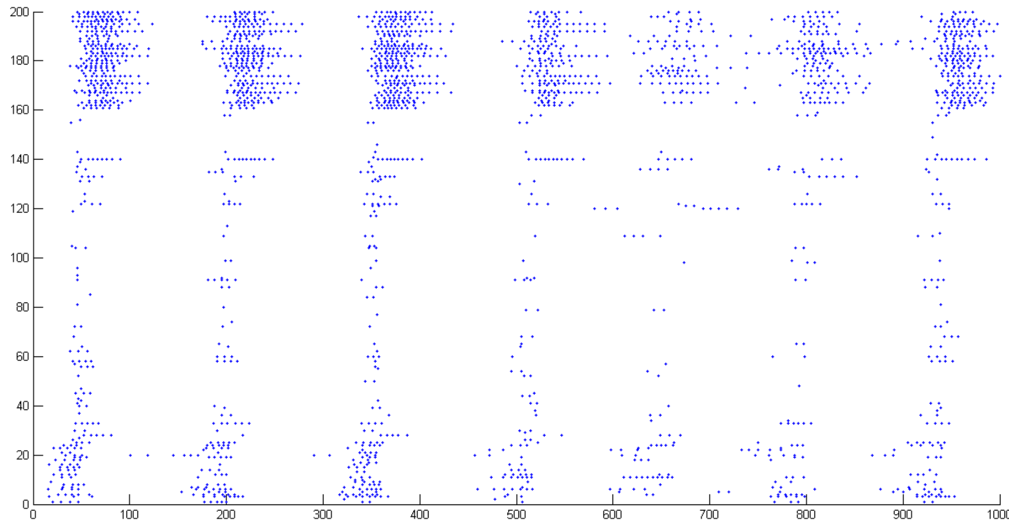
c) The net INHIBITION in the circuit should b INCREASED in order to observe the network behavior observed in Problem 2.
Alternatively, EXCITATION and DECREASED.

d) Gamma is taken greater than 1 (this increases inhibition). Reasonably good behavior was seen at gamma = 3.2. The behavior at gamma=2 is shown for reference:

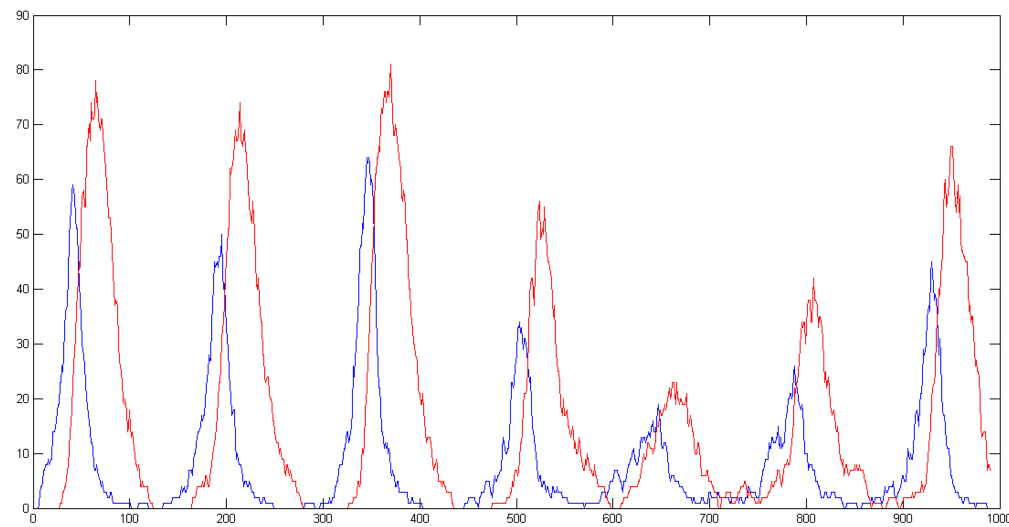




At gamma = 3.2:



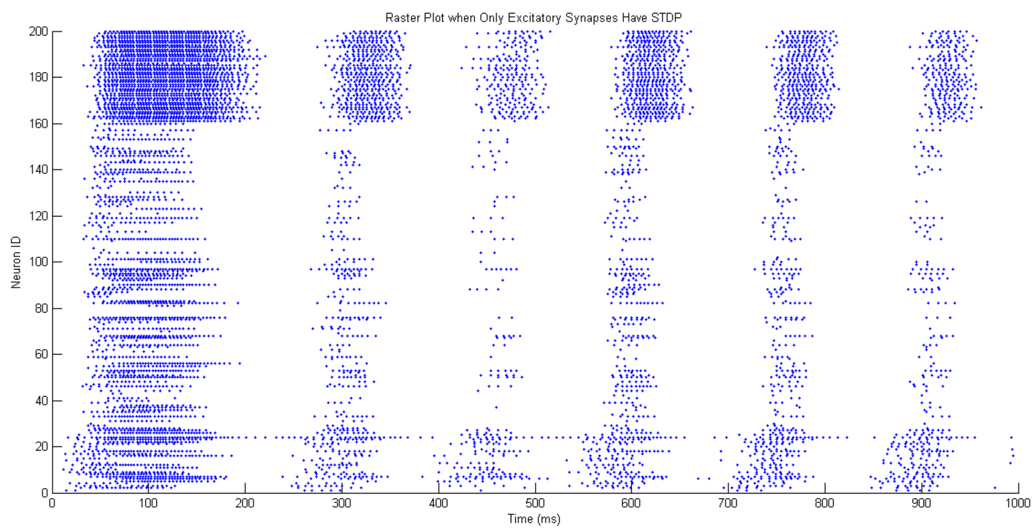
200
180
160
140
120
100
80
60
40
20
0
0
100
200
300
400
500
600
700
800
900
1000

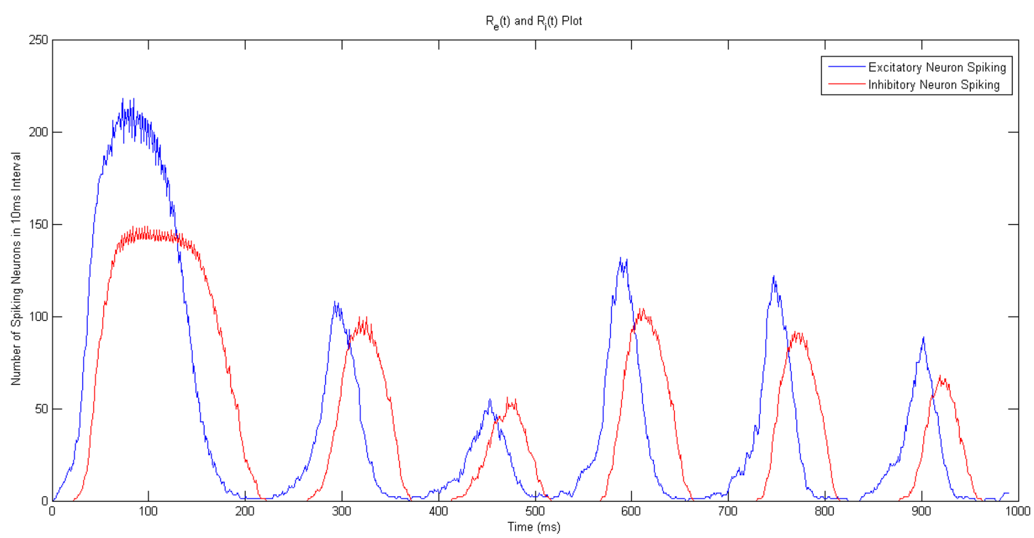


90
80
70
60
50
40
30
20
10
0
0
100
200
300
400
500
600
700
800
900
1000

Problem 4

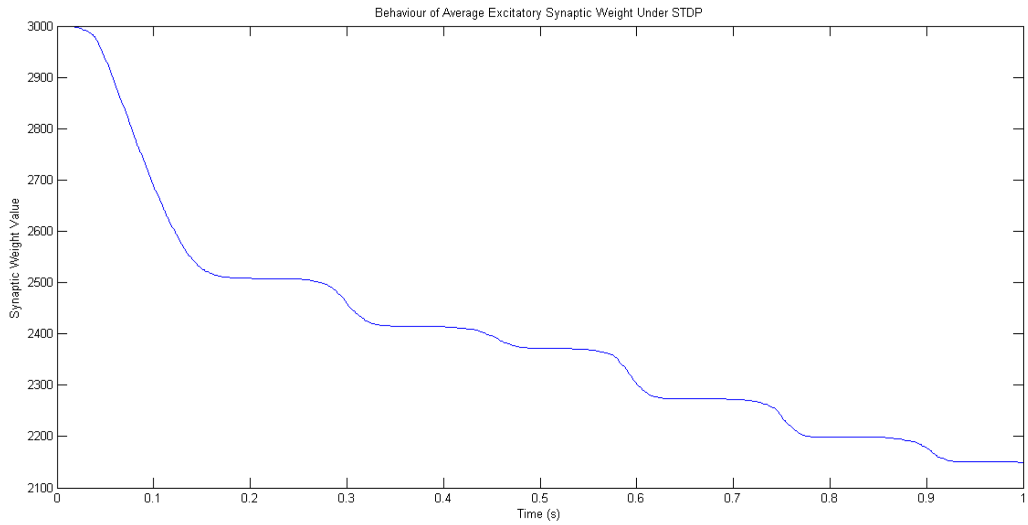
a) The resultant behavior surprisingly resembles that of the periodic variation seen in Problem 2:





The average excitatory synaptic weights value doesn't necessarily only drop. From the plot of Re(t) above, it is evident that at some point (3rd peak), the excitatory synapses became too weak. While STDP had begun removing the spurious associations (weights 'pointing' in the 'non-causal' direction), it hadn't strengthened 'causal' connections, which it does in later stages, wherein the excitatory spiking rises up again.

b)



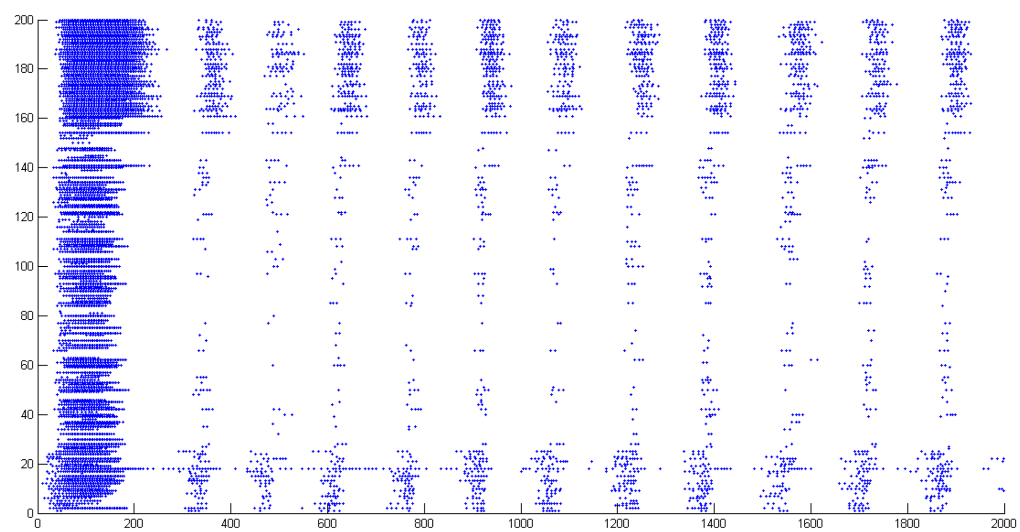
This graph exhibits flatness around the parts where the overall spiking had decreased (se Re(t) and Ri(t) plot above). This is expected, since STDP requires continuous asynchronous firing to be able to make changes based on the information in that firing.

Problem 5

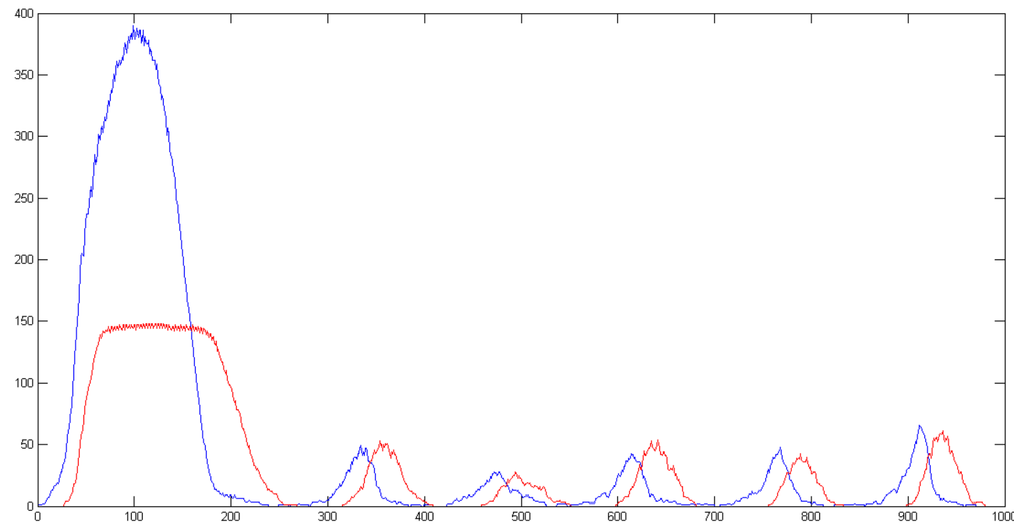
a) The solution to Problem 3(d) suggests that it would make sense to increase the inhibitory synapses strengths. But, this alone is not enough, as the reason the results in Problem 2 were so good was because the relative difference between the spiking of inhibitory neurons and excitatory neurons was very large. Thus, the STDP rule must at the same time ensure that excitatory synapses are reduced. The following model is proposed:

1. Downstream inhibitory synapses exhibit strong anti-STDP. This means that when an inhibitory neuron sees it's downstream excitatory neuron increase spiking, it will overpower it quickly. This rate is set to 0.03.
2. This will be combined with a downstream excitatory STDP. This will increase spiking throughout the network in general and acts as a safeguard against the above-mentioned anti-STDP becoming too strong. By increasing the excitatory spiking this way, we are also creating massive stimulus to the inhibitory section of the network (whose only pre-synaptic connections are in the excitatory section of the network). This rate is set to 0.02, so it is still lower than the inhibitory synapse anti-STDP.

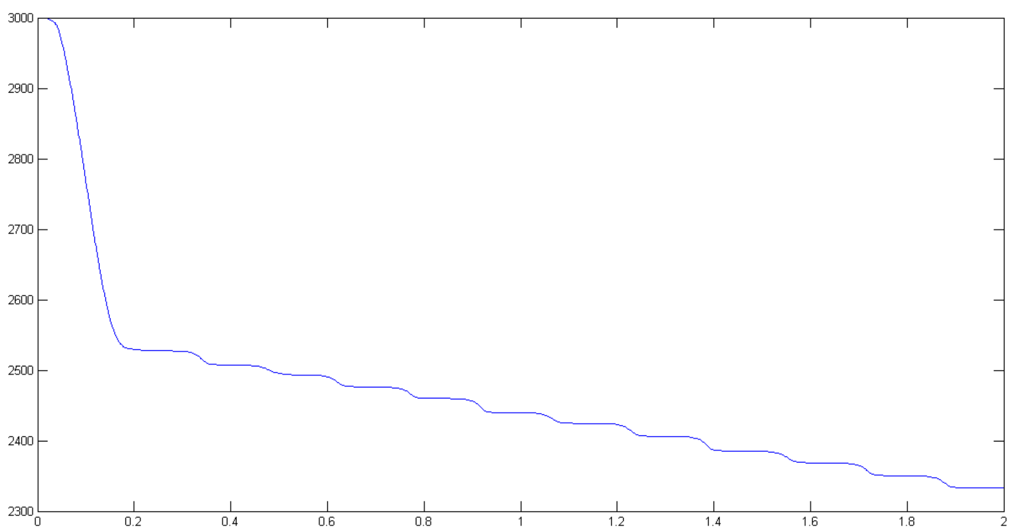
b) Raster:



c) Re(t), Ri(t):



Average excitatory weights:



Average inhibitory weights (notice how they become more negative, i.e., the inhibition increases; also notice how large the drops are in comparison to the average drop in excitatory weights):