Networks and Computational Neuroscience
Neurosci 613 Fall 2014
Computer Lab 2

Due: Friday, November 21, 2014 by 5pm

1. Use the matlab code ILIF2cells.m to simulate 2 ILIF neurons, Cell 1 and Cell 2, with an excitatory synapse from Cell 1 to Cell 2, but no synaptic connection from Cell 2 back to Cell 1 (connection matrix W = [0 0; 1 0]). Let both cells have parameter values a = 0.02, b = 0.2, c = -65 and d = 8. Set the synaptic weight gsyn = 3 and synaptic decay time constant taus = 15. In this small network, we can consider that the synaptic input from Cell 1 to Cell 2 provides Cell 2 with periodic forcing. When the applied current in Cell 1, I_1, is set to higher values than the applied current in Cell 2, I_2, so that the frequency of firing in Cell 1 is higher than in Cell 2, the synaptic input to Cell 2 can entrain its firing so that the network displays stable *m:n* periodic firing with Cell 1 firing *m* spikes for every *n* spikes that Cell 2 fires. To set different applied currents to each cell, set pulsei = [I_1;I_2] in the program call command.

   a. Keep I_2 fixed at 4 and increase I_1 starting from 4 by integer values. Find values of I_1 that result in 1:1, 2:1 and 3:1 firing patterns. Also find one I_1 value with *m:n* firing where *m/n* is between 1 and 2, and another I_1 value where *m/n* is between 2 and 3. Provide plots of firing patterns for each case. Note: there exist I_1 values that result in *m:n* firing for all rational numbers *m/n*.

   b. Find the interval of I_1 values where 1:1 firing is stable (to integer values of I_1).

   c. The stability of *m:n* phase-locked solutions is dependent on the strength of the synaptic input gsyn. Find intervals of I_1 values where 1:1 firing is stable (to integer values of I_1) when gsyn = 2, 5 and 8.

   d. Using the values found in b) and c), construct a plot with gsyn values on the y-axis and I_1 values on the x-axis that shows the I_1 intervals where 1:1 firing is stable. If you assume that when gsyn = 0, 1:1 firing is stable only when I_1 = 4, then this plot should define the triangular region known as an Arnold Tongue.

2. Use the matlab code ILIF2cells.m to simulate 2 ILIF neurons with reciprocal inhibitory synapses between them (connection matrix W = [0 1; 1 0]). Let both cells have parameter values a = 0.02, b = 0.2, c = -65 and d = 8. Set the synaptic weight gsyn = -8 and applied current to both cells pulsei = 8. As we discussed in class, if the synaptic input is short lasting (taus small) then this small network will display anti-phase firing and if the synaptic input is very long lasting (taus very large) then 1 cell will be able to completely suppress firing in the other cell. For values of taus between these two regimes, the cells will synchronize. In this mechanism for synchronization, the frequency of synchronized firing depends on synaptic weight and the synaptic time constant taus.

   a. For taus values greater than 1, find the intervals of taus values where the cells fire in anti-phase, are synchronized and where one cell is suppressed (to integer values of taus).

Provide plots of firing patterns for taus values resulting in each of these behaviors.

b. Compute the frequencies of the synchronized firing (in Hz, assuming time units of the model are ms) for the taus values where synchronous firing occurs. What is the relationship between synaptic decay time constant taus and frequency? How do the frequencies of synchronous firing compare to the frequency of each cell when they are uncoupled (synaptic weight gsyn=0)?

c. Set taus to a value in the middle of the above interval and keep it fixed. Increase and decrease gsyn to find the interval of gsyn values where the cells are synchronized (this interval will be small, so consider gsyn values to the first decimal place). Compute the frequencies of synchronized firing (in Hz) for gsyn values in this interval. What is the relationship between synaptic strength and frequency?

d. Now consider the same 2 cell network with reciprocal excitatory synapses by setting gsyn = 3. Compute the frequency of synchronized firing for taus values between 5 and 20. Then set taus = 15 and compute the frequency of synchronized firing for gsyn values between 1 and 8. What are the relationships between frequency and synaptic decay time constant taus and synaptic strength gsyn? How do the frequencies of synchronized firing compare to the frequency of each cell when they are uncoupled (gsyn=0)? How do these relationships compare to the relationships computed in b and c?