

CN510 Assignment 6: Communication in Spiking Network

Due Thursday Oct 24, 2013

The purpose of this assignment is to get more comfortable with simulating synaptic dynamics using Rotter-Diesman exact integration method and to prepare the setting for STDP assignment later in the course.

Poisson input

Generate 100 independent Poisson spike trains with rate $\nu = 5Hz$. You can use something like

```
s=exprnd(0.2, 1, 60)
s=cumsum(s)
```

for each output s_i or come up with your own solution. Parameters of `exprnd` set the rate ($1/\nu$), the magnitude, and the number of events, respectively. This gives you the time intervals between consecutive spikes, and the `cumsum` call produces the spike timings from the beginning of the simulation for your 60 spikes. Set the end of simulation time T at the time when the shortest trace emits the last spike (minimal of last elements of all s_i) plus 50 ms.

We will be doing the simulation on the grid with time step of 1ms, and we will simplify our calculations by aligning all input spikes on this grid. You would need to adjust the above traces shifting individual spikes earlier or later in such a way that resulting spike timings align with the grid. In your report mention how you did this alignment and why you have chosen this way.

Plot two of the resulting spike traces against time so that they can be clearly seen. Provide a zoom in on the plot for times between 1000 and 2000 ms. Additionally create a rastergram plot of all spikes against time where each spike of a certain cell is represented as a dot in a row corresponding to this cell. Here the individual spikes do not matter that much, but the overall input activity is, the resulting dots shall show no correlations between different cells.

Rotter-Diesmann Synaptic Traces

Use the following equation for the synaptic traces

$$\frac{dx_i}{dt} = -Ax_i + \sum_{k=1} (B - Cx_i)\delta(t - s_{ik}) \quad (1)$$

Here i is the index of the input and k is the index of the spike coming from this input, which will go up to 60 for the fastest input, and close to it for the slower traces. Assume the synaptic time constant $\tau_s = 20ms$, so the parameter $A = 50$. $B = 1$, and C you vary as 0, 1, and 0.5.

Please note, that in the lecture I told you that Rotter-Diesmann only works for linear time-invariant systems, while here it appears that we have a dependency on x_i in the input term. What helps us is that this dependency is discretized in time by the spike arrival. Therefore, we will use the exact solution

$$x_i(n+1) = x_i(n)e^{-A(t_{n+1}-t_n)} + s_i(n+1)(B - Cx_i(n)) \quad (2)$$

Plot the synaptic traces corresponding to the two input traces that you have plotted in the previous part, ensure that the synaptic response matches the input. Provide a zoom in on the plot for times between 1000

and 2000 ms. Do this for all three values of C and discuss the differences which these values impose on the traces.

Note that neither here nor below you need to do the computation on every time step. To compute correctly individual traces you only need to do the computation when spikes arrive from a particular input. To compute cumulative traces, you only need to do the computations when any spike arrives. Since we do need a cumulative trace, the best strategy is to compute all traces when any of the spikes arrives.

Add all traces together to get the cumulative synaptic trace x_{cum} through time and plot it for all three values of C . Provide a zoom in on the plot for times between 1000 and 2000 ms.

As we discussed in the lecture, if we do not intend to modify the synapses, we can lump together all Rotter-Diesmann traces into one. Use

$$x(n+1) = x(n)e^{-A(t_{n+1}-t_n)} + \sum_i s_i(n+1)(B - 0.01Cx(n)) \quad (3)$$

to compute the alternative version of the cumulative trace and compare it with the x_{cum} above for all three values of C . Again, Provide a zoom in on the plot for times between 1000 and 2000 ms. Do we need a 0.01 multiplier? Why?

Fat extra credit (up to 25pts): Repeat the simulations using alpha synapse instead of the exponential synapse (use the same $\tau_s = 20ms$).

Rotter-Diesmann Postsynaptic Cell

Assume that the synaptic input is provided above in terms of current. Then you can use

$$V(n+1) = V(n)e^{-D(t_{n+1}-t_n)} + x_{cum}(n) \frac{\tau_s \tau_m}{\tau_m - \tau_s} \left(e^{-D(t_{n+1}-t_n)} - e^{-A(t_{n+1}-t_n)} \right) \quad (4)$$

to compute the membrane potential of the postsynaptic cell. Use $D = 20$ (corresponding to membrane time constant of $\tau_m = 50ms$). Compute and plot the membrane potential for all three values of C . Provide a zoom in on the plot for times between 1000 and 2000 ms. Discuss differences in synaptic integration for the three values of C .

Grading Rubric:

- | | |
|----------------------|--|
| 25 points x 3 | Synaptic traces for each of three values of C of which |
| 5 points | Well-formatted plots with readable labels and parameter meanings listed in the caption |
| 10 points | Correctness of results |
| 10 points | Discussion of results including the effect of C and 0.01 multiplier |
| 25 points | Postsynaptic voltage trace of which |
| 5 points | Well-formatted plots with readable labels and parameter meanings listed in the caption |
| 10 points | Correctness of results |
| 10 points | Discussion of results including the effect of C |