Advanced Neural Networks - Homework 4b

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1 Leaky Integrate and Fire Model with Many Synapses

This assignment will implement the Leaky Integrate and Fire model with Many Synapses. The synapses can be excitatory or inhibitory, and we will test out various methods for simulating the firing rate on the input neurons.

1.1 Evenly spaced Shift

In this section, I ran the integrate and fire model with 10, 100, and 500 neurons. Each of the neurons had constant Risi of 5 htz, but the fire time of each neuron was shifted by a constant amount for each. When there were 10 neurons, they were spaced out by 200 timesteps (dshift = 0.02), the 100 neurons were spaced out by 20 timesteps (dshift = 0.002), and the 500 neurons were spaced out by 4 timesteps (dshift = 0.0004). With each grouping of neurons, I ran the integrate and fire model 10 times, each with a different ratio of excitatory synapses, and inhibitory synapses. The results can be seen in Figure 1.

In Figure 1, we can see the risi of the output neuron decrease as the ratio of inhibitory neurons to excitatory neurons increases. Though the fraction of inhibited synapses increases, the Risi does not decrease at a linear rate. The exact results of this experiment can be seen in the table below.

n total	n excite	n inhibit	risis (Hz)	w	<risi> (Hz)	σ_{isi}
10	10	0	5.0	0.7	14.6648	10.6349
10	9	1	5.0	0.7	11.3615	10.8569
10	8	2	5.0	0.7	8.3911	10.2695
10	7	3	5.0	0.7	5.6318	8.9015
10	6	4	5.0	0.7	2.9509	6.2319
10	5	5	5.0	0.7	1.0101	2.2478
10	4	6	5.0	0.7	0.3650	1.3512
10	3	7	5.0	0.7	0	0
100	100	0	5.0	0.07	13.2244	8.9758
100	90	10	5.0	0.07	9.7244	8.9942
100	80	20	5.0	0.07	6.9598	8.3523
100	70	30	5.0	0.07	4.5082	6.9713
100	60	40	5.0	0.07	2.1649	4.1558
100	50	50	5.0	0.07	0.9957	2.2317
100	40	60	5.0	0.07	0.3535	1.3298
100	30	70	5.0	0.07	0	0
500	500	0	5.0	0.02	33.3996	15.9603
500	450	50	5.0	0.02	27.0272	19.1139
500	400	100	5.0	0.02	21.9961	20.1214
500	350	150	5.0	0.02	17.3484	19.9011
500	300	200	5.0	0.02	12.8704	18.5909
500	250	250	5.0	0.02	8.4496	15.9862
500	200	300	5.0	0.02	4.1062	11.3643
500	150	350	5.0	0.02	0.5497	1.6582
500	100	400	5.0	0.02	0	0

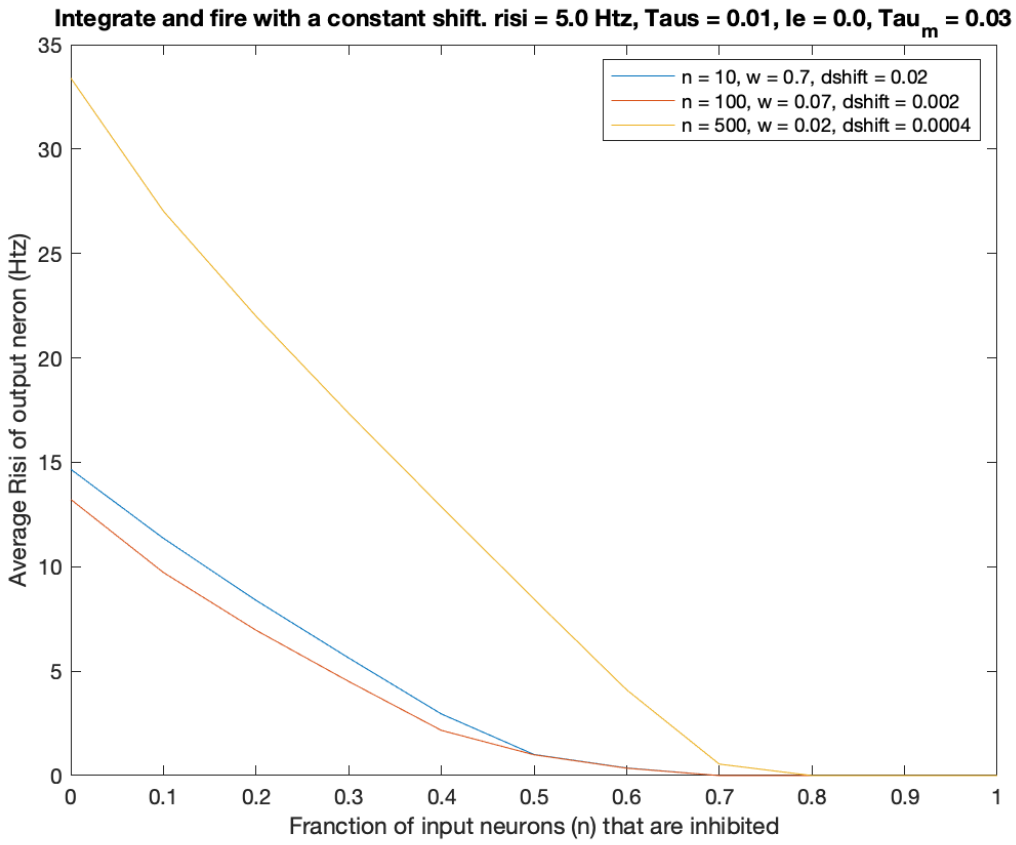
Integrate and fire with a constant shift. risi = 5.0 Htz, Taus = 0.01, Ie = 0.0, Tau m = 0.03
n = 10, w = 0.7, dshift = 0.02
n = 100, w = 0.07, dshift = 0.002
n = 500, w = 0.02, dshift = 0.0004
Average Risi of output neron (Htz)
Franction of input neurons (n) that are inhibited
0
5
10
15
20
25
30
35
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Figure 1:

1.2 Uniformly Random Firing

Instead of evenly spacing the firing of the input neurons, in this section I am having all the input neurons fire at a uniformly random rate. Similar to the last section, we have groups of 10, 100, and 500 neurons, and they are all firing at around 5.0 htz, though the timing of the firing for each neuron is distributed at a uniformly random rate. Similar to the last section, each grouping of neurons has been run with various ratios of with a different ratio of excitatory synapses, and inhibitory synapses. Each trial of i excitatory neurons and j inhibitory neurons has been run 100 times. The average Risi of the output neuron with the varying ratio of excitatory and inhibitory neurons can be seen in Figure 2. The corresponding standard deviations can be seen in Figure 3. The exact table of results can be seen below.

n total	n excite	n inhibit	risis (Hz)	w	<risi> (Hz)	σ_{isi}
10	10	0	5.0	0.7	29.4706	22.2719
10	9	1	5.0	0.7	25.2077	20.0874
10	8	2	5.0	0.7	20.7131	22.5555
10	7	3	5.0	0.7	13.2355	16.3553
10	6	4	5.0	0.7	10.2315	17.8607
10	5	5	5.0	0.7	6.7272	13.9633
10	4	6	5.0	0.7	3.6161	12.4349
10	3	7	5.0	0.7	1.2662	6.9915
10	2	8	5.0	0.7	0.2980	2.3624
10	1	9	5.0	0.7	0	0
100	100	0	5.0	0.07	14.1631	6.3640
100	90	10	5.0	0.07	6.9257	5.9314
100	80	20	5.0	0.07	2.3493	4.4405
100	70	30	5.0	0.07	0.5969	2.1594
100	60	40	5.0	0.07	0	0
500	500	0	5.0	0.02	31.2916	2.9290
500	450	50	5.0	0.02	21.9806	3.3334
500	400	100	5.0	0.02	11.0735	3.7631
500	350	150	5.0	0.02	1.5537	2.8248
500	300	200	5.0	0.02	0	0

Overall the $n = 10$ category was able to fire when 70-80% of the synapses were inhibited, but it should be noted that this category had the highest standard deviation. This result is surprising, but there is always a certain probability that the excitatory synapses would fire around the same time, which would cause the output neuron to fire.

Another surprising result, is that the $n = 10$ category had a similar average firing rate as the $n = 500$ category when the fraction of inhibited neurons was less than or equal to 0.1, and a higher average risi overall.

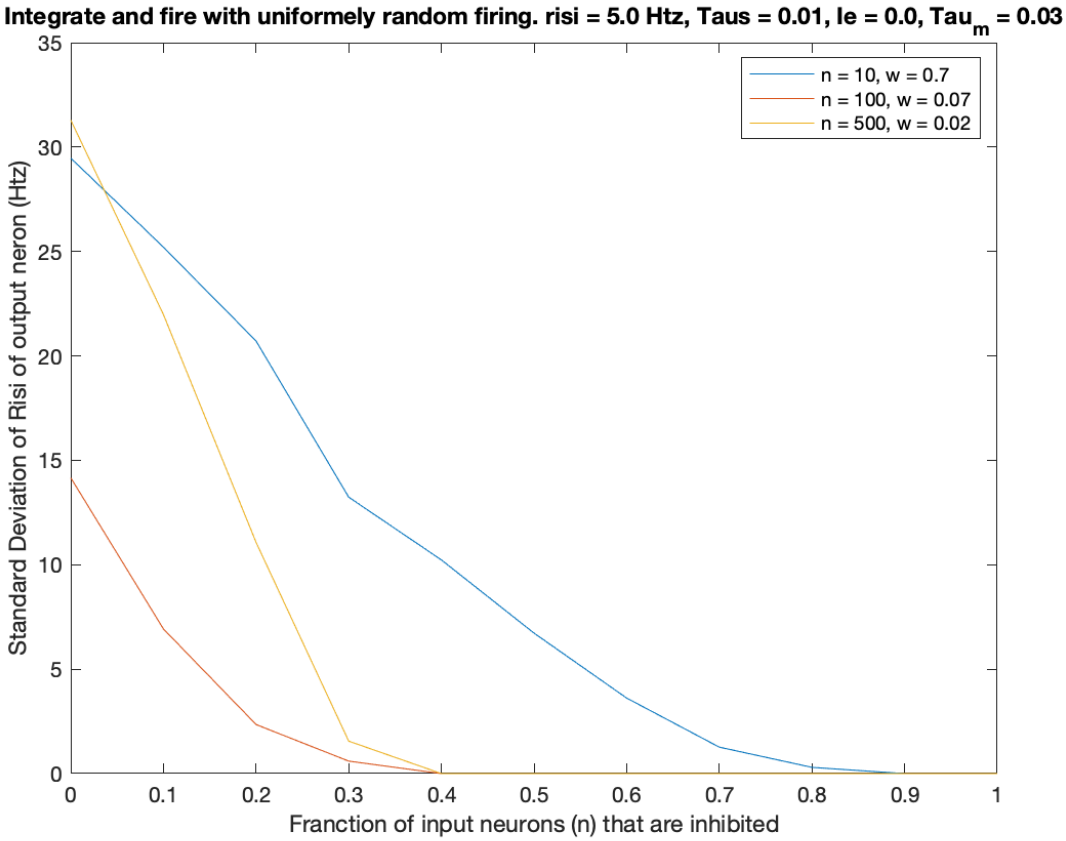

Figure 2: Average firing rate of output neuron, while varying the fraction of synapses that are inhibitory.

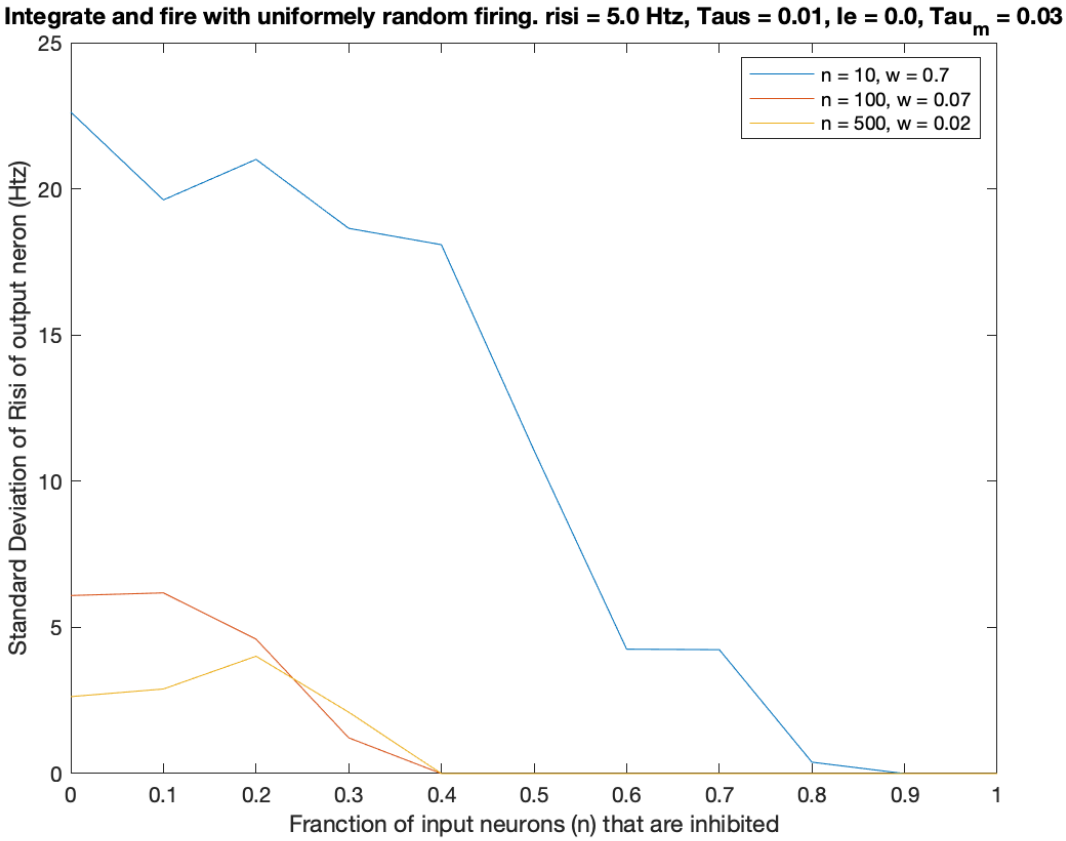

Figure 3: Standard deviation of firing rate.

1.3 Normally Distributed Firing

In this section we will see the average Risi of the output neurons, while the input neurons fire at a normally distributed rate. There are two types simulation that we run with normally distributed synapses. The first simulation is in section 1.3.1, and it is similar to previous simulations in that we are varying the ratio of inhibited to excited synapses. The second simulation detailed in 1.3.2 instead varies the standard deviation of the normal distribution, essentially varying the width of the curve.

1.3.1 Normally Distributed with varying ratio of inhibited to excited synapses

The firing rate of a neuron with normally distributed synapses can be seen in Figure 4. The simulation was run over 2000 timesteps, and each input neuron fired at a normally distributed rate, where the average time of firing was at 1000 timesteps, and the standard deviation was 250. Overall, the output firing rate was much higher than the previous scenarios as the neurons are no longer firing at 5.0 htz. In this scenario, the output neuron continued to fire up to 60% inhibitory synapses, for all groups of n. This result differs from the simulation with uniformly firing synapses. Another difference between the previous simulation, is that the n=500 group had the highest rate of firing. The exact results can be seen in the table below.

n total	n excite	n inhibit	w	μ (timesteps)	σ (timesteps)	<risi> (Hz)	σ_{isi}
10	10	0	0.7	1000	250	630.5545	239.1886
10	9	1	0.7	1000	250	554.4265	205.2063
10	8	2	0.7	1000	250	463.8930	196.2810
10	7	3	0.7	1000	250	374.9473	142.0973
10	6	4	0.7	1000	250	284.5227	101.4796
10	5	5	0.7	1000	250	185.8268	72.2432
10	4	6	0.7	1000	250	0.9814	2.2156
10	3	7	0.7	1000	250	0	0
100	100	0	0.07	1000	250	641.2004	228.6592
100	90	10	0.07	1000	250	557.2156	198.1529
100	80	20	0.07	1000	250	474.5796	176.3287
100	70	30	0.07	1000	250	372.7109	146.0145
100	60	40	0.07	1000	250	281.0690	110.3578
100	50	50	0.07	1000	250	181.7491	73.8006
100	40	60	0.07	1000	250	0	0
500	500	0	0.02	1000	250	909.0824	319.6855
500	450	50	0.02	1000	250	769.1622	261.3417
500	400	100	0.02	1000	250	657.5823	234.3644
500	350	150	0.02	1000	250	542.9127	199.3299
500	300	200	0.02	1000	250	408.6617	153.7922
500	250	250	0.02	1000	250	267.0123	105.9352
500	200	300	0.02	1000	250	79.6313	38.5432
500	150	350	0.02	1000	250	0	0

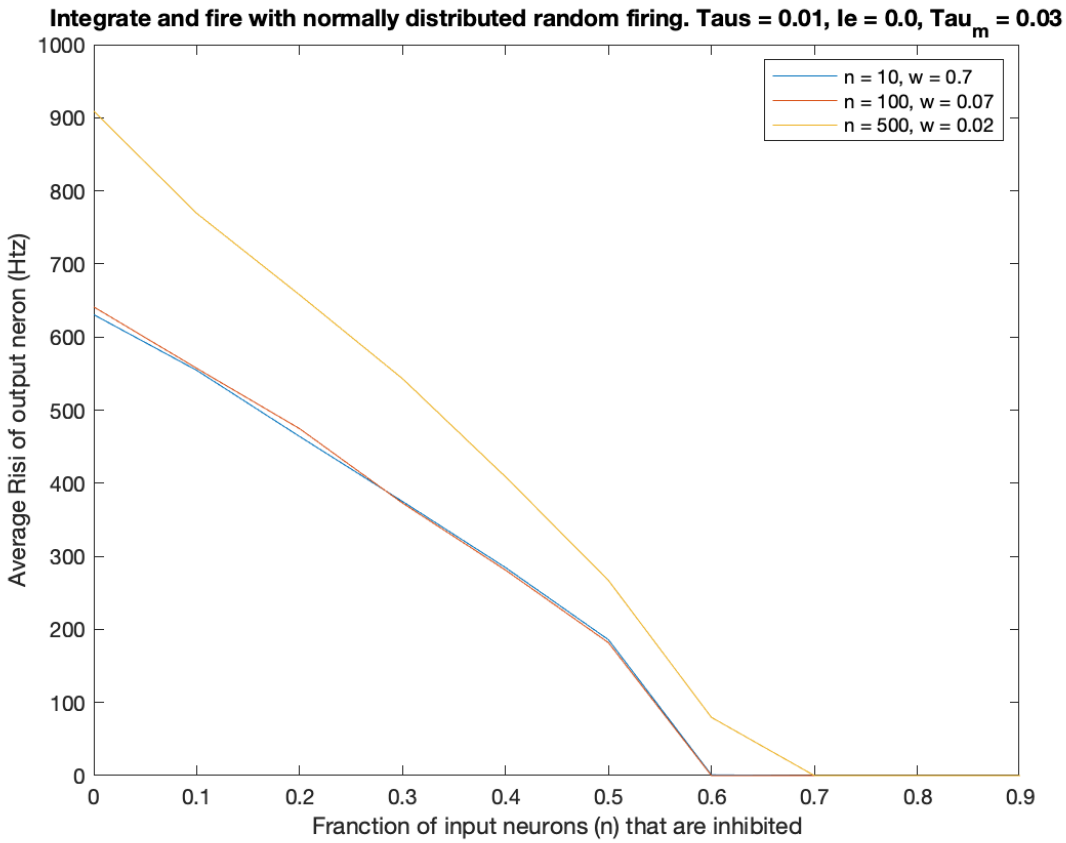

Figure 4: Average firing rate of output neuron, while varying the fraction of synapses that are inhibitory.

1.3.2 Normally distributed synapses with varying standard deviation

In this section, we varied the standard deviation of the normally distributed input synapses in order to see how it affected the firing rate of the output neuron. This simulation was run with 80% excitatory synapses, and 20% inhibitory synapses, on groups of 10, 100, and 500 synapses. The standard deviation of the normal firing rate of the input neurons was varied from 10 to 100 timesteps, while the mean remained consistent at 1000 timesteps for each 2000 timestep trial. The results can be seen in Figure 5, and also in the table below. Overall, the risi tends to increase as the standard deviation increases, and as the input spikes get less concentrated in one area.

n total	n excite	n inhibit	w	μ (timesteps)	σ (timesteps)	<risi> (Hz)	σ_{isi}
10	8	2	0.07	1000	20	0	0
10	8	2	0.07	1000	40	4.0847	4.5194
10	8	2	0.07	1000	60	4.6177	4.8051
10	8	2	0.07	1000	80	17.3235	19.3518
10	8	2	0.07	1000	100	18.9033	19.6690
10	8	2	0.07	1000	120	19.7777	19.3495
10	8	2	0.07	1000	140	22.0263	19.6074
10	8	2	0.07	1000	160	22.3337	18.9796
10	8	2	0.07	1000	180	24.0878	19.1213
10	8	2	0.07	1000	200	25.6087	18.1667
100	80	20	0.007	1000	20	0	0
100	80	20	0.007	1000	40	4.0436	4.4967
100	80	20	0.007	1000	60	4.6548	4.8244
100	80	20	0.007	1000	80	17.3454	19.3548
100	80	20	0.007	1000	100	18.8811	19.6677
100	80	20	0.007	1000	120	20.0510	19.4038
100	80	20	0.007	1000	140	21.6906	19.5698
100	80	20	0.007	1000	160	22.6163	18.9729
100	80	20	0.007	1000	180	24.2626	19.0527
100	80	20	0.007	1000	200	25.0278	18.1453
500	400	100	0.002	1000	20	4.3131	4.6441
500	400	100	0.002	1000	40	29.1108	32.6263
500	400	100	0.002	1000	60	29.7423	30.9745
500	400	100	0.002	1000	80	35.1704	34.2822
500	400	100	0.002	1000	100	37.2178	33.9791
500	400	100	0.002	1000	120	39.2386	33.3853
500	400	100	0.002	1000	140	40.7821	32.5063
500	400	100	0.002	1000	160	42.6571	31.5192
500	400	100	0.002	1000	180	43.7124	30.4022
500	400	100	0.002	1000	200	44.9460	29.4809

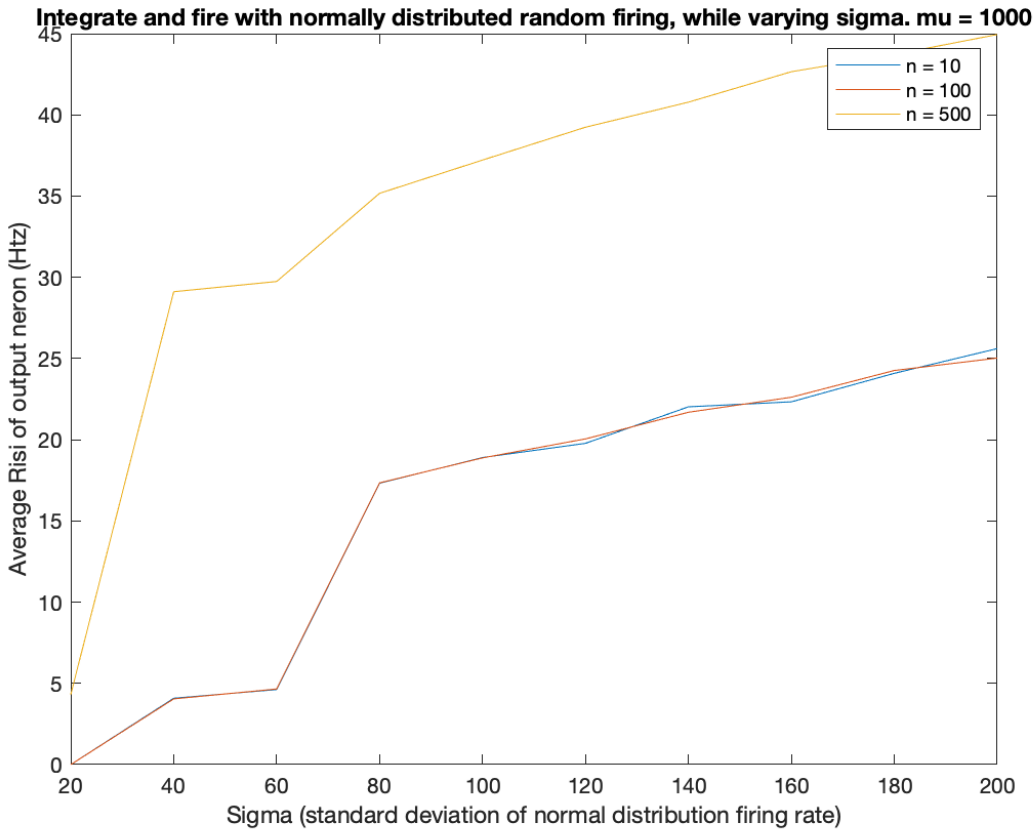

Figure 5: Average firing rate of output neuron, while varying the standard deviation of the normal distribution of input synapses