4G3 Computational Neuroscience Assignment 1

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February 22, 2016

1 Network Dynamics

1.1 Input amplification and integration with a feed-forward linear network

a) Firing rates with $\lambda = 1$

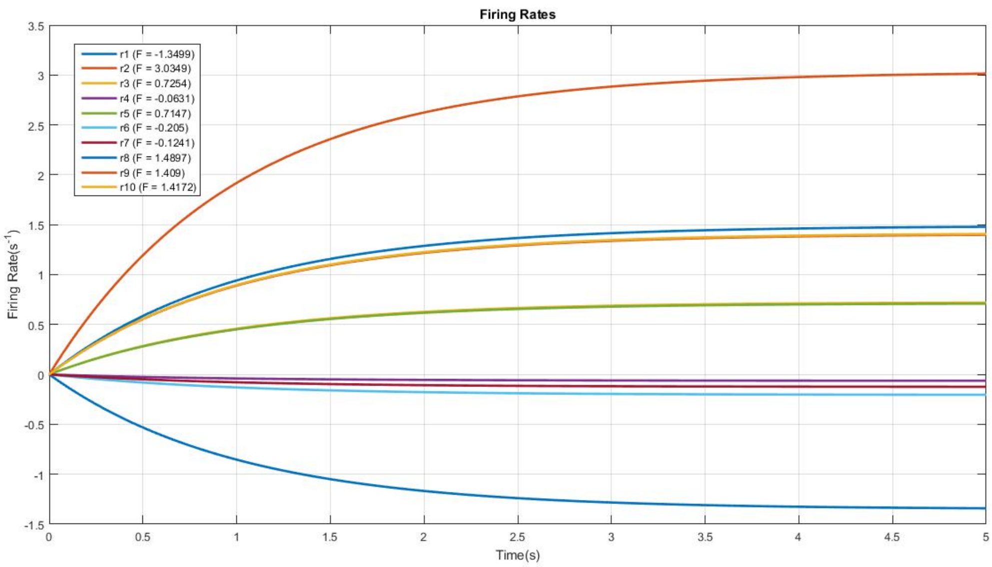

Figure 1: Caption

b) Firing rates with $\lambda = 0$

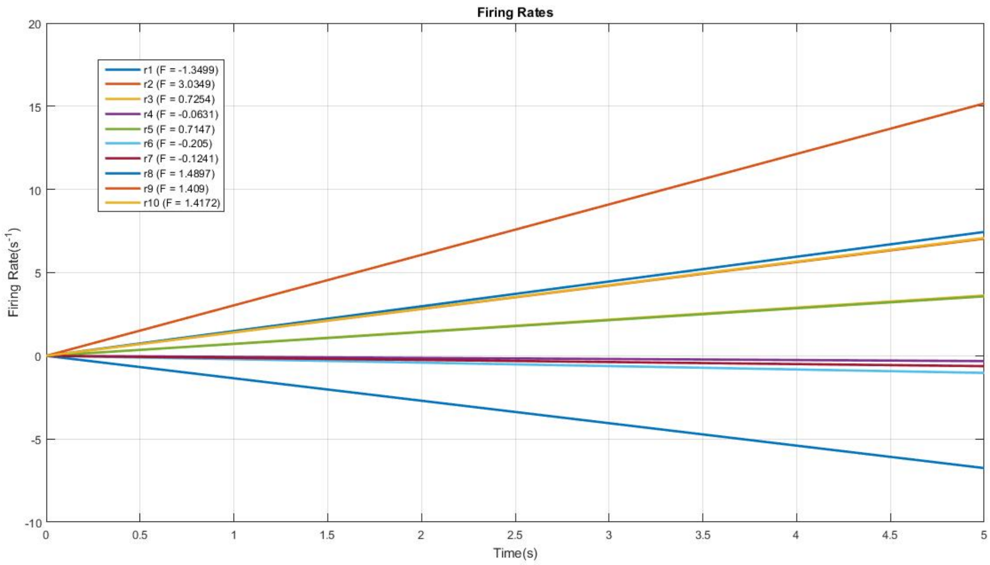

Figure 2: Caption

c) Firing rates with $\lambda = -1$

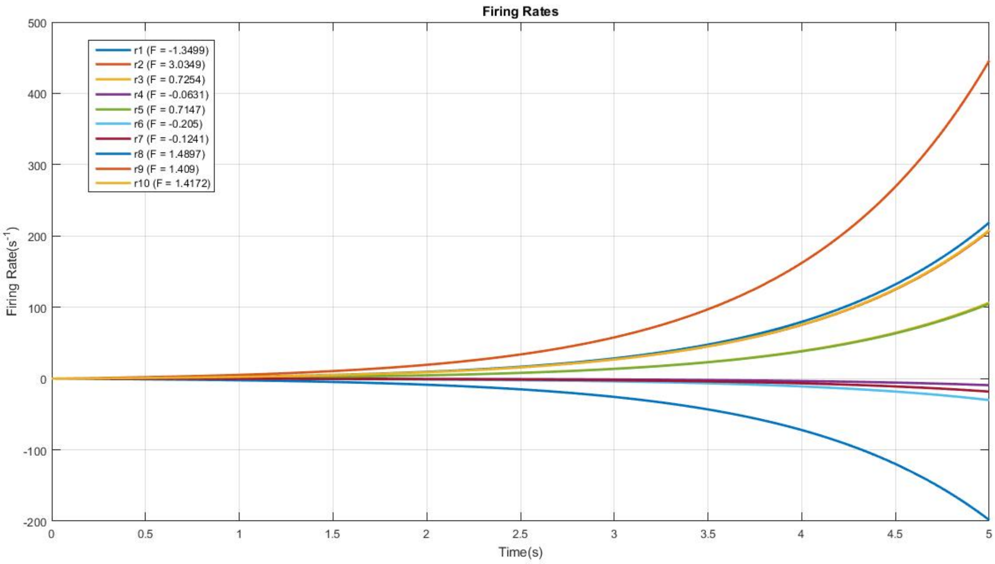

Figure 3: Caption

d) Equilibrium firing rates with $\lambda = 1$

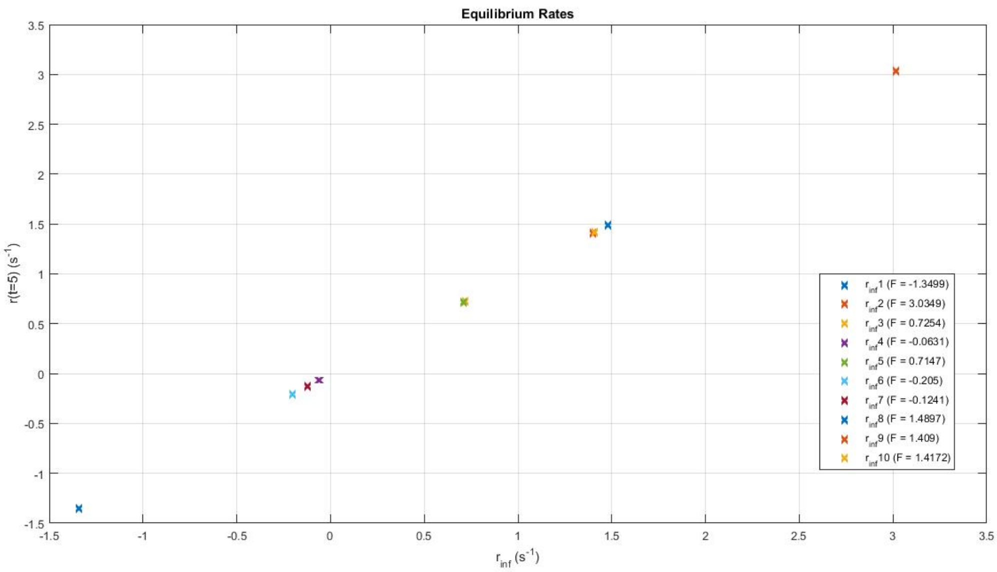

Figure 4: Caption

1.2 Randomly connected network

a) Firing rates with $g = 0$

i.

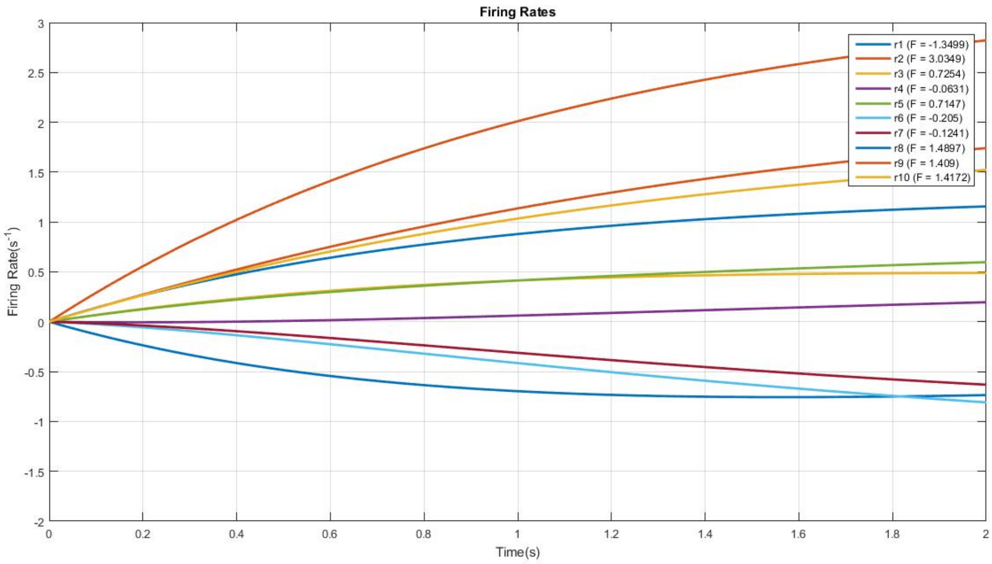

Figure 5: Caption

ii. Eigenvalues of the recurrent connectivity matrix W

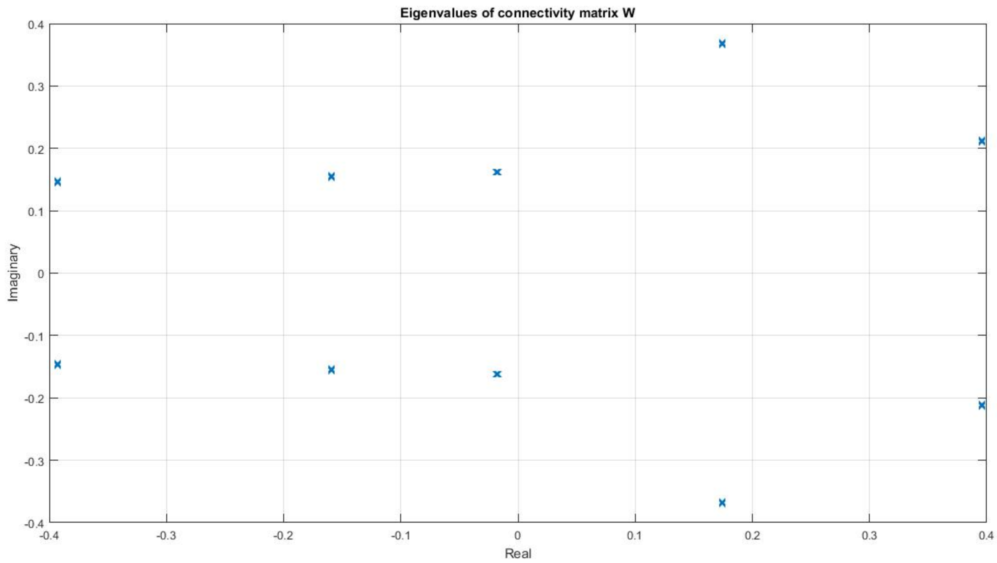

Figure 6: Caption

iii. Equilibrium firing rates

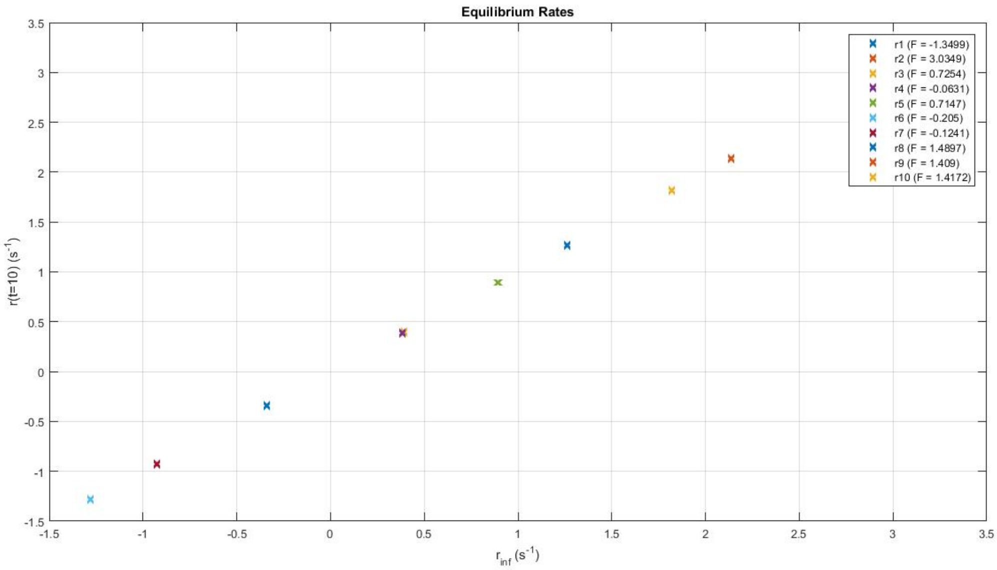

Figure 7: Caption

b) Firing rates with $g = 2$

i.

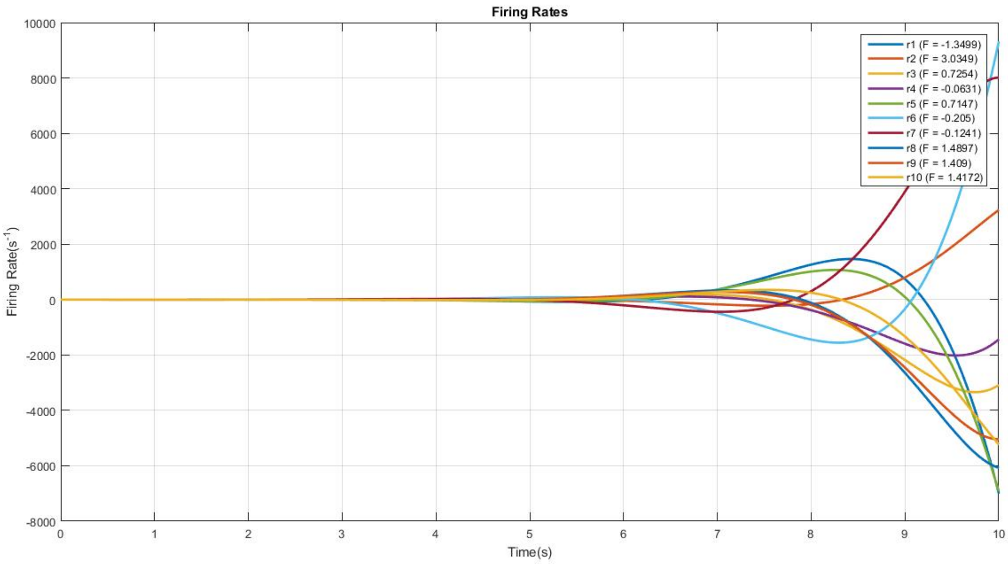

Figure 8: Caption

ii. Eigenvalues of the recurrent connectivity matrix W

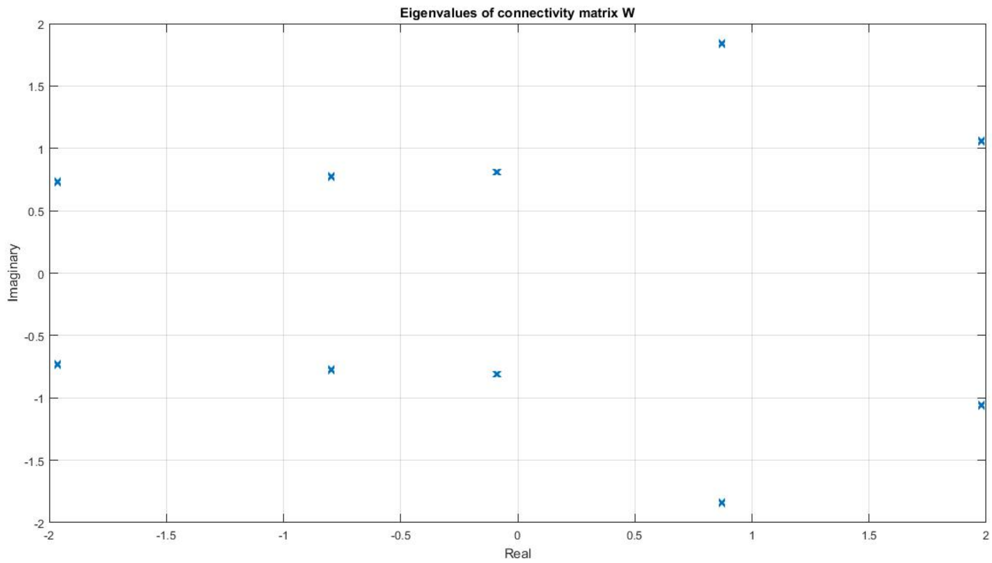

Figure 9: Caption

iii. Equilibrium firing rates

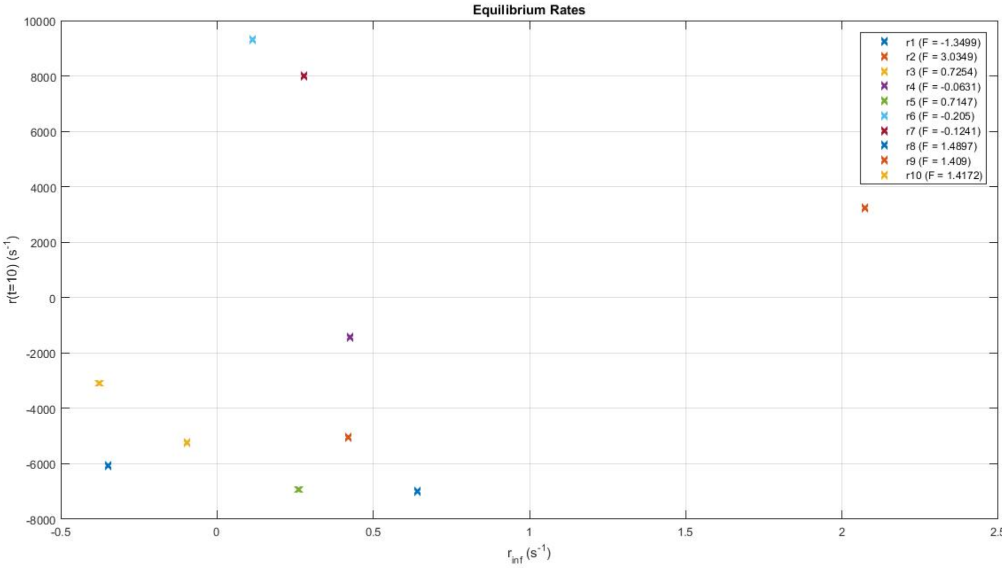

Figure 10: Caption

c) Firing rates with $g = 0.95$

i.

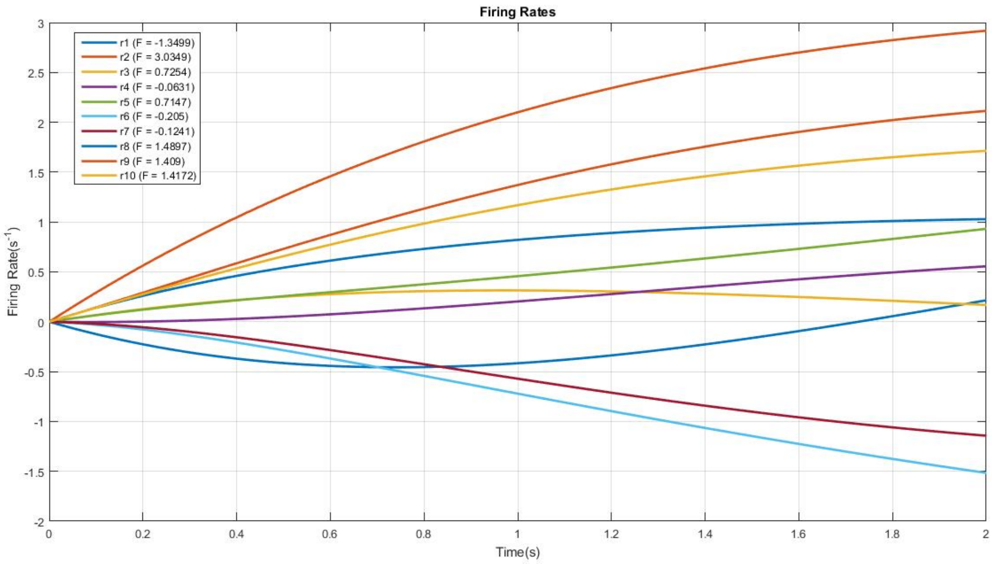

Figure 11: Caption

ii. Eigenvalues of the recurrent connectivity matrix W

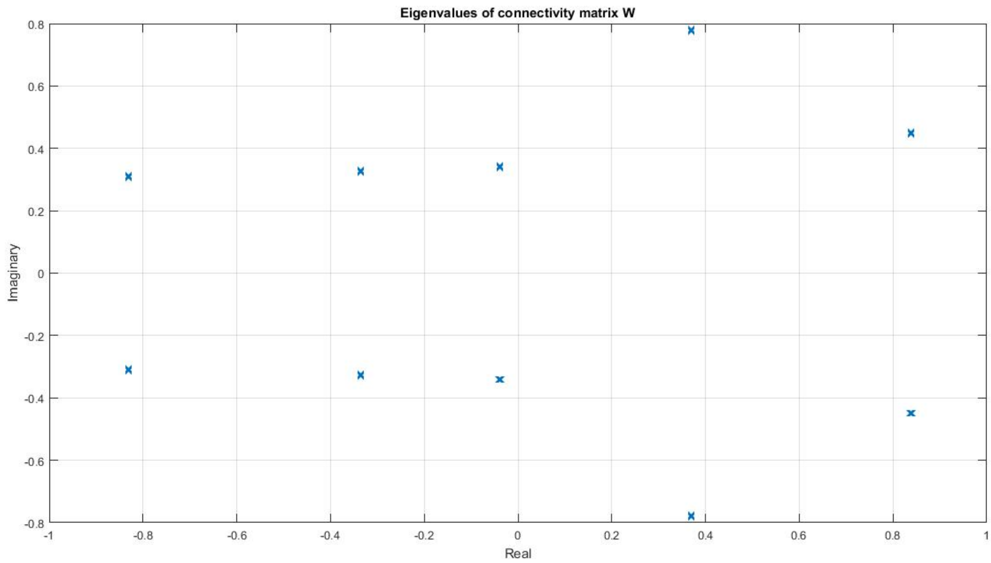

Figure 12: Caption

iii. Equilibrium firing rates

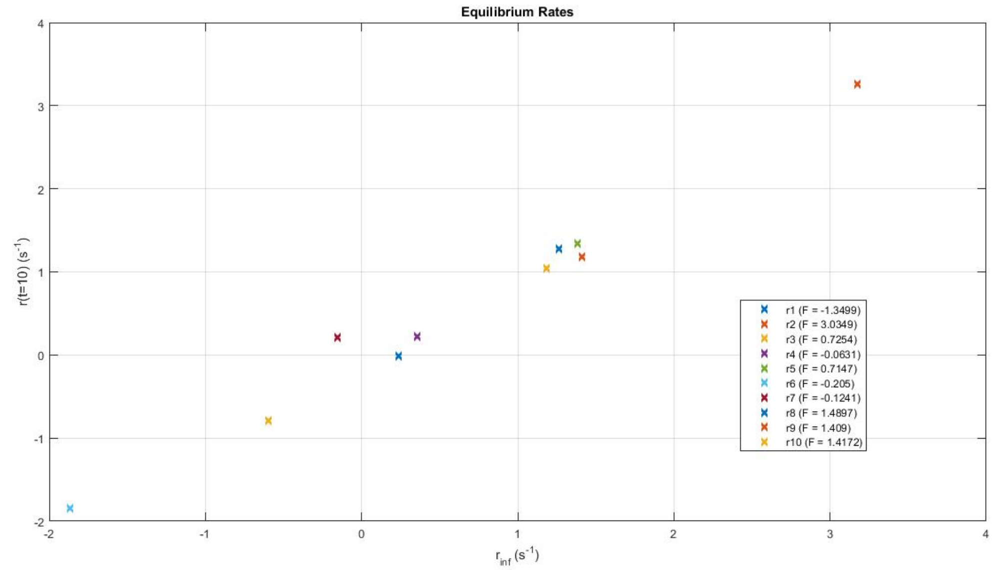

Figure 13: Caption

1.3 Visual cortex model

a) Denoising

i. Noisy input

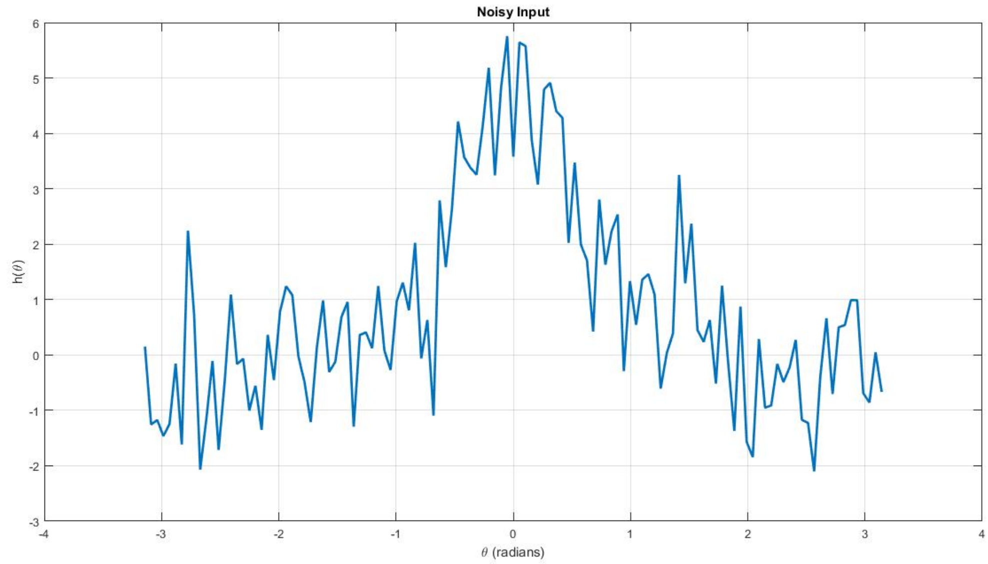

Figure 14: Caption

ii. Equilibrium population firing rate

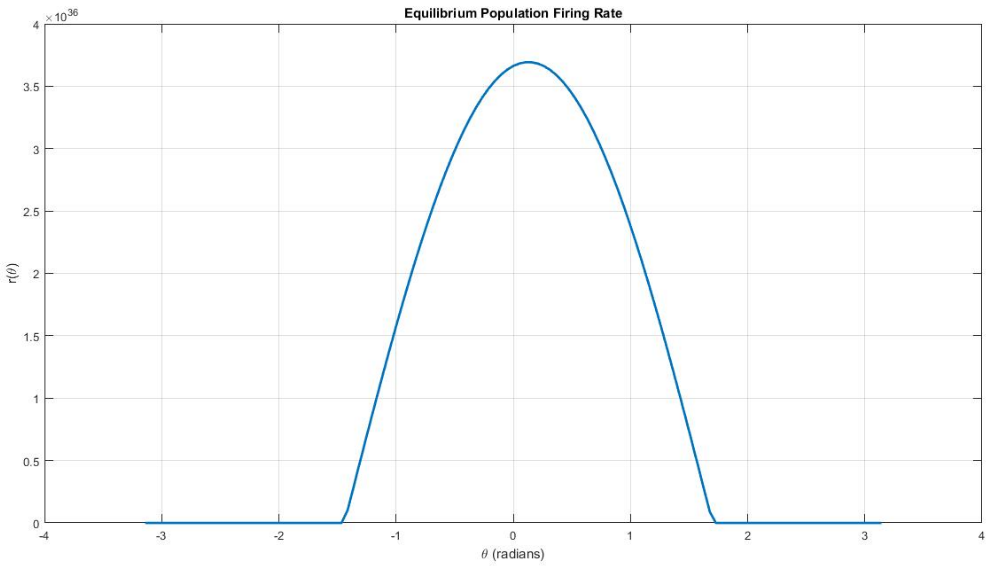

Figure 15: Caption

b) Gain modulation

i. Input

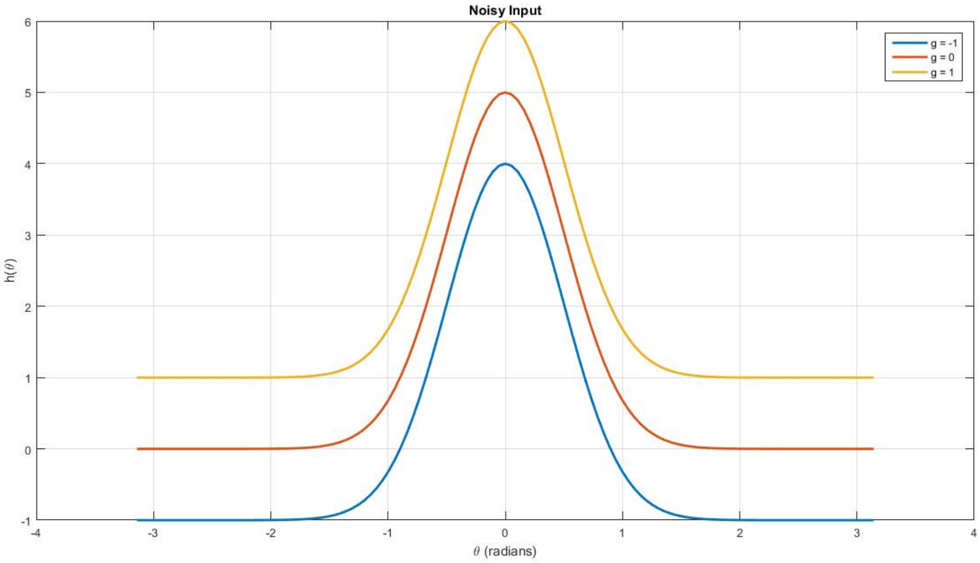

Figure 16: Caption

ii. Equilibrium population firing rate

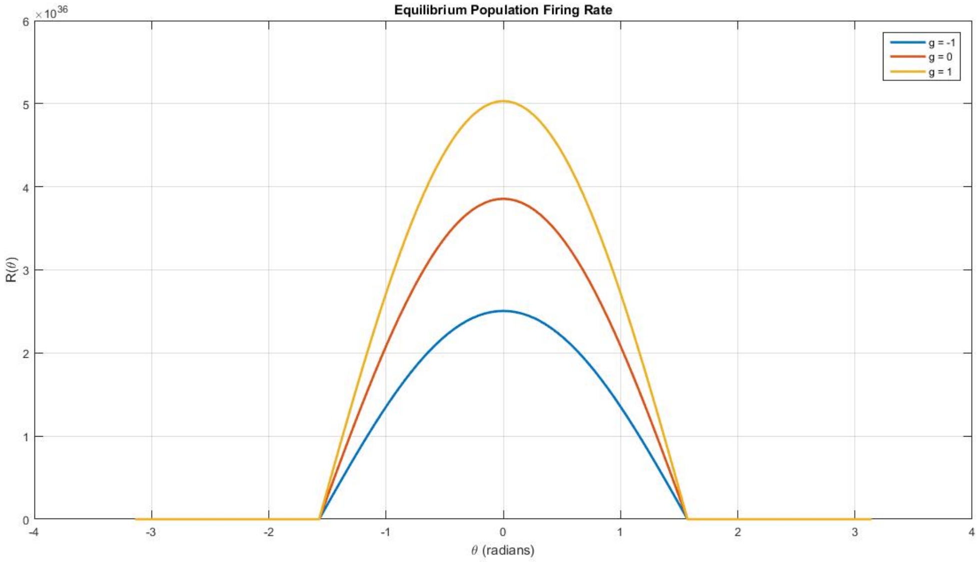

Figure 17: Caption

c) Winner-takes-all input selection and sustained activity

i. Input

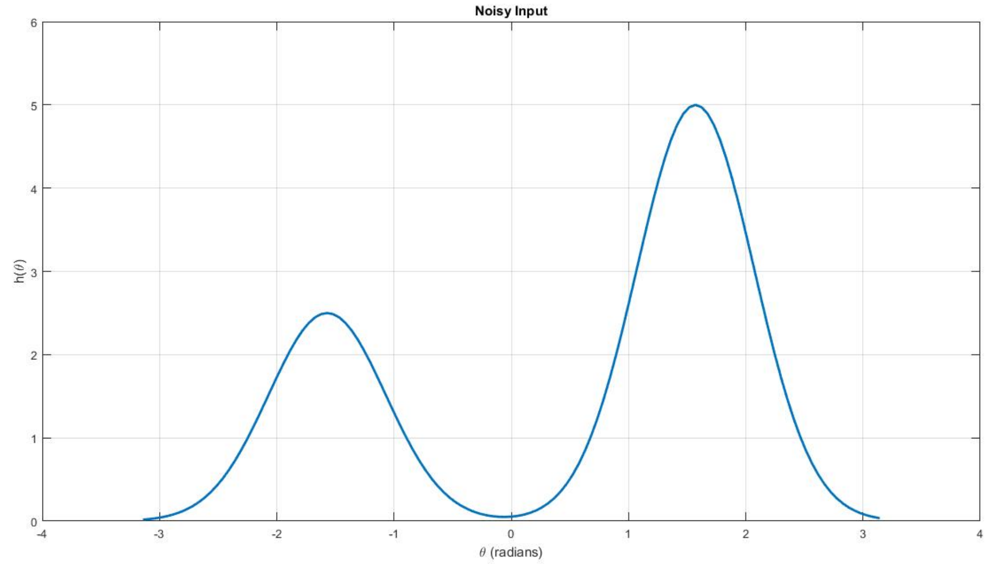

Figure 18: Caption

ii. Equilibrium population firing rate

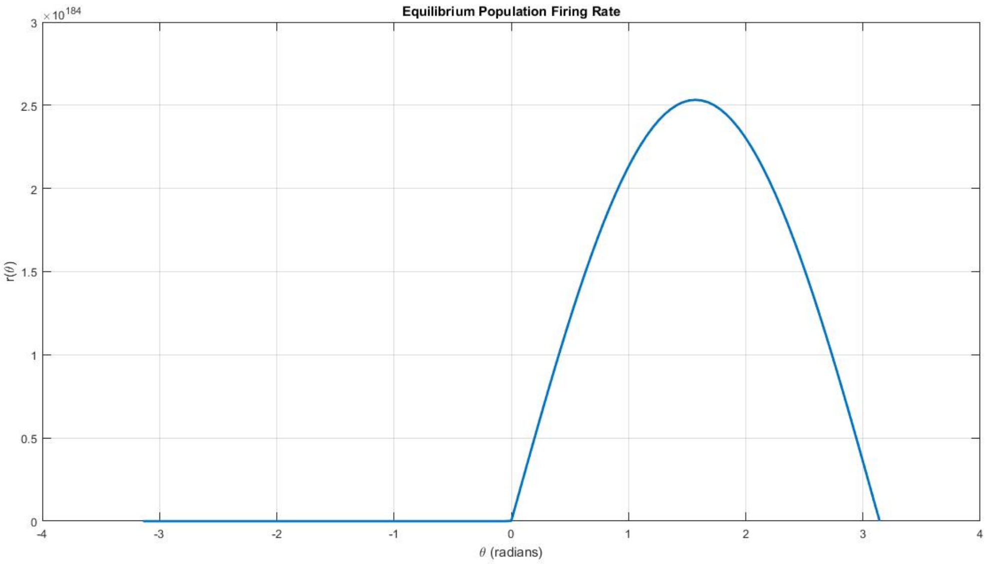

Figure 19: Caption

iii. Sustained activity

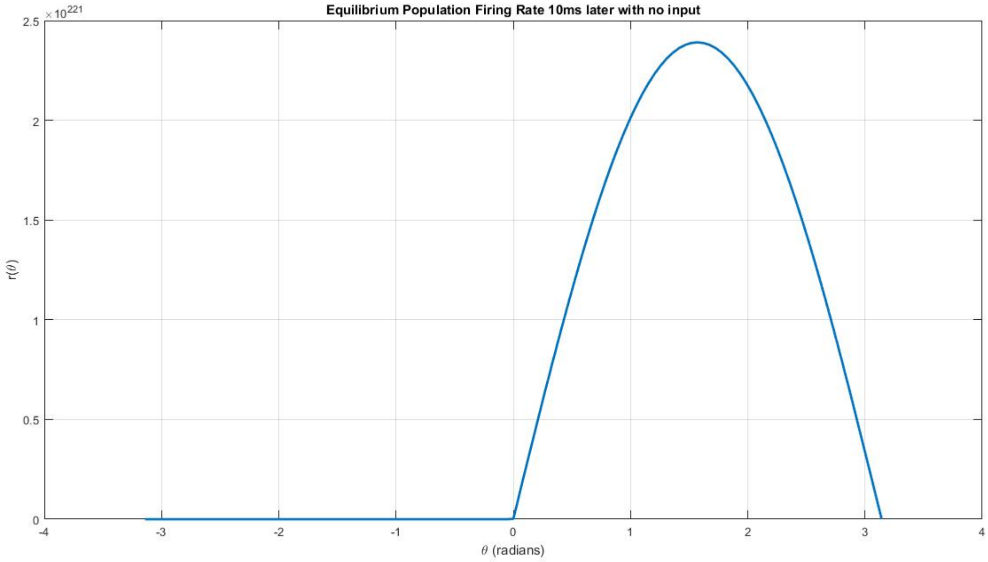

Figure 20: Caption

2 The asynchronous & irregular state of cortical circuits

a) Generating Poisson spike trains

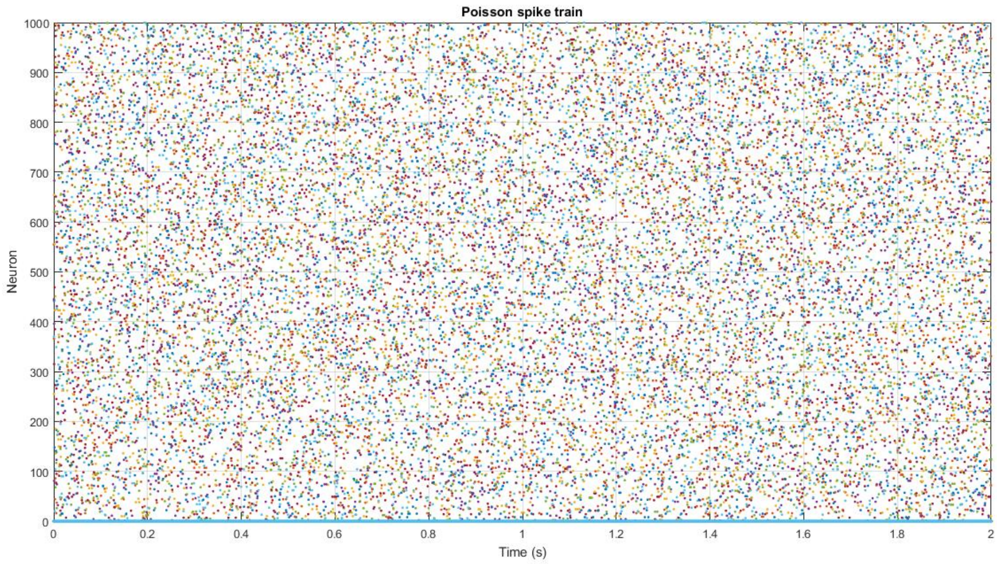

Figure 21: Caption

b) Single LIF neuron with one input spike train

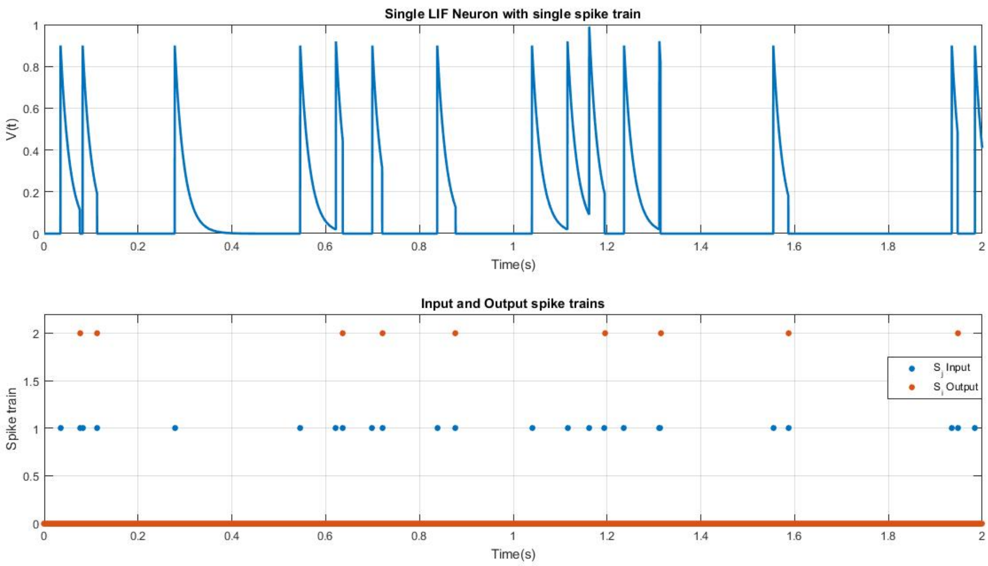

Figure 22: (a) Membrane potential dynamics

c) Single LIF neuron with many input spike train

(a)

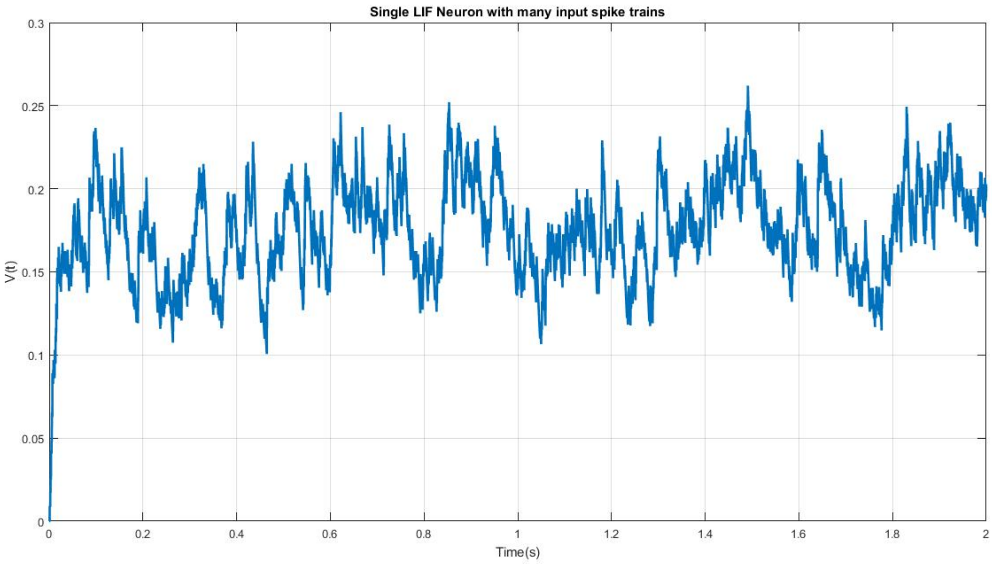

Figure 23: (a) Membrane potential dynamics without spike-reset ($w = 0.9$)

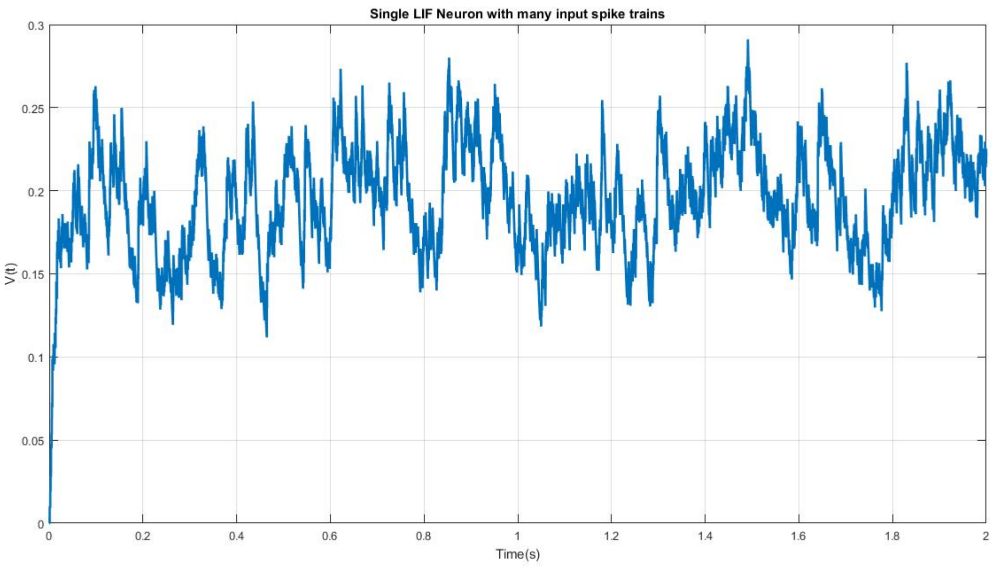

Figure 24: (a) Membrane potential dynamics without spike-reset ($w = 1$)

(b)

$$
\begin{aligned}
h(t) &= \frac{w}{K}\sum_{j=1}^{K} S_j(t) \\
\mathbb{E}[h(t)] &= \mathbb{E}[\frac{w}{K}\sum_{j=1}^{K} S_j(t)] \\
&= \frac{w}{K}\sum_{j=1}^{K} \mathbb{E}[S_j(t)] \\
&= \frac{w}{K}\sum_{j=1}^{K} r_X \\
&= w r_X
\end{aligned}
$$

$\mathrm{Var[h(t)]} = \mathrm{E[h(t)^2]} - \mathbb{E}[h(t)]^2$