Conductance-Based Neuron Network Dynamics

Subthreshold evolution of voltage is the same as leaky integrate-and-fire (LIF) neurons:

$$C_m \frac{dV_i}{dt} = -g^L(V_i - V_L) - g_i^E(V_i - V_E) - g_i^I(V_i - V_I) \tag{1}$$

$$\frac{ds_i}{dt} = -\frac{s_i}{\tau_s} \tag{2}$$

$$g_i^E = \sum_j W_{ij} s_j + W_o b_i \tag{3}$$

$$g_i^I = g^{I\ glob} + g_i^{ada} \tag{4}$$

$$g^{I\ glob} = (A_g/N) \sum_j s_j \tag{5}$$

$$g_i^{ada} = A_a s_i^{ada}(t) \tag{6}$$

$$\frac{ds_i^{ada}}{dt} = -\frac{s_i^{ada}}{\tau_{ada}} \tag{7}$$

$$\tag{8}$$

Learning

$$\Delta_{ij}^{STDP}(t) = (\frac{W_{ij}}{w_{max}} + 0.001) \times [x_i(t)K(0)x_j(t) + \sum_{\tau=0}^{t} x_i(t)K(\tau)x_j(t-\tau) - x_i(t-\tau)K(\tau)x_j(t)] \tag{9}$$

$$W_{ij}(t) = W_{ij}(t-1) + \eta\Delta_{ij}^{STDP}(t) - \epsilon\eta\theta_{i*}(t) - \epsilon\eta\theta_{*j}(t) \tag{10}$$

$$\textbf{For the summed-weight limit } \theta_{i*} = \max(0, \sum_k (W_{ik} + \Delta_{ik}^{STDP}) - W_{max}) \tag{11}$$

$$\textbf{For the summed-weight limit } \theta_{*i} = \max(0, \sum_k (W_{ki} + \Delta_{ki}^{STDP}) - W_{max}) \tag{12}$$

$$\textbf{For the weight-growth limit } \theta_{i*} = \sum_k W_{ik}\Theta(\Delta_{ik}^{STDP}) \tag{13}$$

$$\textbf{For the weight-growth limit } \theta_{*i} = \sum_k W_{ki}\Theta(\Delta_{ki}^{STDP}) \tag{14}$$

$$W_{ii} = 0 \tag{15}$$

Parameters and Initial Conditions
$W_{ij} = w_{max}/N$
or
W_{ij} is random in the interval $[0, w_{max}/N]$, for all $i \neq j$.
$W_{ii} = 0$ for all i.

LIB neurons

$$dt = 0.02ms \tag{16}$$
$$C_m = 1\mu F/cm^2 \tag{17}$$
$$V_L = -60mV \tag{18}$$
$$V_E = 0mV \tag{19}$$
$$V_I = -70mV \tag{20}$$
$$g_L = 0.4mS/cm^2 \tag{21}$$
$$W_o = 0.5mS/cm^2 \tag{22}$$
$$V_\theta = -50mV \tag{23}$$
$$V_{reset} = -55mV \tag{24}$$
$$T_{burst} = 6ms \tag{25}$$
$$\tau_s = 4ms \tag{26}$$
$$r_{in} = 4Hz \tag{27}$$
$$\tag{28}$$

Summed-Weight Limit, LIB neurons

$$\textbf{Figure 4} \tag{29}$$
$$N = 50 \tag{30}$$
$$w_{max} = 0.14 \tag{31}$$
$$W_{max} = w_{max}(m = 1) \tag{32}$$
$$\eta = 0.002 \tag{33}$$
$$\epsilon = 72.5 \tag{34}$$
$$A_g = 0.4mS/cm^2 \tag{35}$$
$$A_a = 0.9mS/cm^2 \tag{36}$$
$$\tau_{STDP} = 20ms \tag{37}$$
$$t_{ada} = 15ms \tag{38}$$
$$\text{poisson rate of input neurons is 2Hz.} \tag{39}$$
$$\textbf{Wide chains (Figures 5D-5F)} \tag{40}$$
$$k = 5 \tag{41}$$
$$w_{max} = W_{max}/9(m = 9) \tag{42}$$
$$A_g = 0.2mS/cm^2 \tag{43}$$
$$W_{max} = 0.26 \tag{44}$$
$$\eta = 0.0001 \tag{45}$$
$$\epsilon = 30 \tag{46}$$
$$\text{poisson rate of 10Hz for the input neurons.} \tag{47}$$
$$\tag{48}$$

Weight-Growth Limit, LIB Neurons

$$g_L = 0.1mS/cm^2 \tag{49}$$
$$N = 80 \tag{50}$$
$$W_o = 0.5 \tag{51}$$
$$w_{max} = 3 \tag{52}$$
$$W_{max} = w_{max}(m = 1) \tag{53}$$
$$\eta = 0.038 \tag{54}$$
$$\epsilon = 4.8/N \tag{55}$$
$$A_g = 0mS/cm^2 \tag{56}$$
$$A_a = 0.5mS/cm^2 \tag{57}$$
$$\tau_{STDP} = 20ms \tag{58}$$
$$\text{poisson rate of input neurons is 2Hz.} \tag{59}$$
$$\tag{60}$$

The synaptic activation has an exponential rise-time of 1ms and decay-time of 4ms. The input is annealed away starting at 3s. Annealing was done by exponentially decaying the input firing rate, with a time-constant of 6s.