Model's description

N. Brunel, 1999, Dynamics of Sparsely Connected Networks of Excitatory and Inhibitory Spiking Neurons

N integrate-and-fire (IF) neurons

→ N_E excitatory

→ N_I inhibitory

Each neurons receives C randomly chosen connections from other neurons in the network

→ $C_E = \varepsilon\ N_E$ connections from excitatory neurons

→ $C_I = \varepsilon\ N_I$ connections from inhibitory neurons

With $\varepsilon = C_E/N_E = C_I/N_I \ll 1$

→ C_{ext} connections from excitatory neurons outside the network

Depolarization $V_i(t)$ of neuron at its soma obeys the equation:

$$\tau.\frac{dVi}{dt} = -V_i(t) + R.I_i(t)$$

where $I_i(t)$ are the synaptic currents arriving at the soma. These spike contributions are modulated as delta functions in our basic IF model:

$$R.I_i(t) = \tau \sum_j J_{ij} \sum_k \delta(t-t^k_j-D)$$

With postsynaptic potential (PSP) amplitude J_{ij}, the emission time t^k_j and D the transmission delay

$$J_{ij} = \begin{cases} \mathrm{J} > 0 \text{ for excitatory external synapses} \\ J\ for\ excitatory\ recurrent\ synapses\ (internal) \\ -gJ\ for\ inhibitory\ synapses\ (internal) \end{cases}$$

When $V_i(t)$ reaches the firing threshold Θ, an action potential is emitted by neuro i, the depolarization $V_i(t^+)$ is reset to V_r after a refractory period τ_{rp} during which the potential is insensitive to stimulation.

External synapses are activated by independent Poisson processes (random input) with rate $\nu_{ext} \sim \Theta/(JC_E\tau)$

Model A = inhibitory and excitatory neurons have IDENTICAL characteristics

Characteristics	Excitatory & Inhibitory
Membrane time constant	τ = 20 ms
Amount of Neurons	N = 12 500
Amount of Exhibitory Neurons	NE = 0.8 N = 10 000
Amount of Inhibitory Neurons	NI = 0.2 N = 2 500
Connections from other Neurons (input & output)	C = 0.1 N = 1250
Connections from Exhibitory Neurons (input & output)	C_E = 4/5 C = 1000
Connections from Inhibitory Neurons (input & output)	C_I = 1/5 C = 250
Connections from external Neurons (input only)	$C_{Ext} = C_E$
Firing threshold	Θ = 20 mV
Reset potential	Vr = 10 mV
Refractory period	τ_{rp} = 2 ms
Relative strength of inhibitory synapses	g
Frequency of the external input	ν_{ext}
EPSP amplitude	J
Transmission delay	D

Model B = inhibitory and excitatory neurons have DIFFERENT characteristics

Characteristics	Excitatory	Inhibitory
Membrane time constant	τ = 20 ms	τ_I
Total amount of Neurons	N = 12 500	
Amount of Neurons per type	N_E = 0.8 N = 10 000	N_I = 0.2 N = 2500
Total number of connections (input & output)	C = 0.1 N = 1250 and C_E = 4 CI	
Number of connections per type (input & output)	C_E = 4/5 C = 1000	C_I = 1/5 C = 250
Connections from external Neurons (input only)	$C_{Ext} = C_E$	
Firing threshold	Θ = 20 mV	
Reset potential	Vr = 10 mV	
Refractory period	τ_{rp} = 2 ms	
Relative strength of inhibitory synapses	g_E	g_I
Frequency of the external input	ν_{Eext}	ν_{Iext}
EPSP amplitude	J_E	J_I

+ 4 delays
  - D_{IE} (Excitatory to Inhibitory)
  - D_{EE} (Excitatory to Excitatory)
  - D_{EI} (Inhibitory to Excitatory)
  - D_{II} (Inhibitory to Inhibitory)

+ 3 synaptic efficacies
  - $J_{EI} = g_E J_E$ (Inhibitory to Excitatory)
  - $J_{EE} = J_E$ (Excitatory to Excitatory)
  - $J_{II} = J_I$ (Inhibitory to Inhibitory)