Equations and parameters

The model neuron is described by two differential equations, the membrane potential (*V*) and the fraction of activated delayed rectifier K^+ channels (*n*):

$$C\frac{dV_j}{dt} = -\left[I_{Na_j} + I_{K_j} + I_{l_j} + I_{syn,e_j} + I_{syn,i_j} - I_{app}\right] \tag{1}$$

$$\frac{dn_j}{dt} = \alpha_n(V_j)(1-n_j) - \beta_n(V_j)n_j \tag{2}$$

$$a_n(V) = 0.01(10.0 - V)/(e^{0.1(10.0-V)} - 1.0) \tag{3}$$

$$\beta_n(V) = 0.125e^{-V/80} \tag{4}$$

The neuron diversity activity is established in the population by randomly choosing the applied current parameter, I_{app}, from a uniform distribution over the range -10 to $5\mu A/cm^2$

The Na^+ current is simplified and assumes instantaneous activation, as in Rinzel (1985):

$$I_{Na} = g_{Na}m_\infty^3(V_j)(0.8 - n_j)(V_j - V_{Na}) \tag{5}$$

$$m_\infty(V) = am(V)/(am(V) - bm(V)) \tag{6}$$

$$am(V) = 0.1 * (25 - V)/(\exp\big(0.1 * (25 - V)\big) - 1) \tag{7}$$

$$bm(V) = 4.0 * \exp\left(-V/18\right) \tag{8}$$

The K^+ and leakage currents are, respectively:

$$I_{K_j} = g_K n_j^4\big(V_j - V_K\big) \tag{9}$$

$$I_{l_j} = g_l(V_j - V_l) \tag{10}$$

A subgroup of the *N* neurons in the population are inhibitory (N_i neurons), while the remainder are excitatory (N_e neurons). The synaptic currents have the form:

$$I_{syn,e_j} = g_{syn,e_j}(V_j - V_{exc}) \tag{11}$$

$$I_{syn,i_j} = g_{syn,i_j}(V_j - V_{inh}) \tag{12}$$

where the excitatory and inhibitory synaptic conductances are:

$$g_{syn,e_k} = \frac{\bar{g}_{syn}}{N} \sum_{j=1}^{N_e} a_j s_j - a_k\, s_k \tag{13}$$

$$g_{syn,i_k} = \frac{\bar{g}_{syn}}{N} \sum_{j=Ne+1}^{N} a_j s_j - a_k\, s_k \tag{14}$$

The maximum strength of any one synapse is $\bar{g}_{syn}$. The sums are over all neurons except for the postsynaptic neuron itself (shown by the subtraction term $a_k s_k$). Both synaptic conductance terms drive the voltage of the actual neuron (Equation 1).

The neuron activity a_j and neuron efficacy s_j for each N of neurons are described by:

$$\frac{da_j}{dt} = \Pi(V_j)\alpha_a(1 - a_j) - \beta_a a_j \tag{15}$$

$$\frac{ds_j}{dt} = \alpha_s(1 - s_j) - \Pi(V_j)\beta_s s_j \tag{16}$$

The function $\Pi(V_j) = 1/(1 + e^{(v_{th} - V_j)/kv_j})$ reflects synaptic release when the presynaptic voltage V_j depolarizes above V_{th} during an action potential. The average network activity and synaptic efficacy are $\langle a \rangle = \frac{1}{N}\sum_{j=1}^{N} a_j$ and $\langle s \rangle = \frac{1}{N}\sum_{j-1}^{N} s_j$, respectively.

The network model parameters are shown in Table 1.

Table 1 - Parameters of the network model using Hodgkin-Huxley-type neurons.

Parameter	Description	Value
g_l	Leak conductance	0.1 S/cm^2
V_l	Leak reversal potential	10.6 mV
g_{Na}	Sodium conductance	36 mS/cm^2
V_{Na}	Sodium reversal potential	115 mV
g_k	Potassium conductance	12 mS/cm^2
V_k	Potassium reversal potential	-12 mV
$\bar{g}_{syn}$	Max. synaptic conductance	3.6 mS/cm^2
V_{exc}	Excitatory reversal potential	70 mV
V_{inh}	Inhibitory reversal potential	70 to -12 mV
I_{app}	Input or applied current	-10 to 5 μA/cm^2
α_a	Synaptic activation rate	1 ms^{-1}
β_a	Synaptic decay rate	0.1 ms^{-1}
α_s	Synaptic recovery rate	0.0015 ms^{-1}
β_s	Synaptic depression rate	0.12 ms^{-1}
V_{th}	Threshold for activation/depression	40 mV