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Models of Neural Systems I, WS 2008/09
Computer Practical 8

Exercises

1. **Synaptic current**

   Simulate linear membrane which receives an external synaptic input:

$$\tau_m \frac{dV(t)}{dt} = -V(t) + E_m - r_m g_{syn}(t)(V - E_{syn}) \tag{1}$$

   where $g_{syn}(t)$ is a time-dependent conductance which can be approximated by:

$$g_{syn}(t) = \begin{cases} g_{max} t/\tau_{syn} \exp(-t/\tau_{syn}) & \text{if } t \geq 0, \\ 0 & \text{if } t < 0. \end{cases} \tag{2}$$

   Here take τ_{syn}=10 ms, $r_m = 1\,\Omega\text{m}^2$, $g_{max} = 0.5\,\text{S/m}^2$. Plot the following curves on one figure:

   (a) Plot on one figure: synaptic conductance $g_{syn}(t)$, synaptic current $I_{syn}(t) = g_{syn}(t)(V(t) - E_{syn})$, channel current $I_m(t) = 1/r_m(E_m - V(t))$, total current flowing through the membrane, membrane potential $V(t)$. Consider inhibitory ($E_{syn} = -100\,\text{mV}$) and excitatory ($E_{syn} = 0\,\text{mV}$) synapses separately.

   (b) Shunting inhibition. Insert into membrane both inhibitory and excitatory synapses with constant conductances ($g_{exc}(t) = 0.5\text{S/m}^2$, $g_{inh}(t) = \hat{g}_{inh}$). Simulate for several values of $\hat{g}_{inh}$ and show that inhibition has a divisive effect on steady-state potential.

2. **Potassium channel**

   The gate model was first introduced by Hodgkin and Huxley to describe voltage and time dependence of ion conductances in the squid axon. Today it is still the standard model of the ion current flow through transmembrane channels. One of its main assumptions is that the probability of openning and closing of an ion gate is described by the first-order kinetic equation:

$$\frac{dn}{dt} = \alpha_n(V)(1-n) - \beta_n(V)n \tag{3}$$

where $\alpha_n(V)$ and $\beta_n(V)$ are voltage-dependent transition rates.

The potassium current in the Hodgkin-Huxley model is given by:

$$I_K = \bar{g}_K n^4 (E_K - V) \tag{4}$$

where $E_K = -77\,\mathrm{mV}$ is the reversal potential and $\bar{g}_K = 36\,\mathrm{mS/cm^2}$ is the maximum conductance. Rates $\alpha_n(V)$ and $\beta_n(V)$ are given by:

$$\alpha_n(V) = 0.01 \frac{V + 55}{1 - \exp(-0.1(V + 55))}, \qquad \beta_n(V) = 0.125 \exp(-0.0125(V+65)). \tag{5}$$

(a) Write a Python function defining $\alpha_n(V)$ and $\beta_n(V)$.

(b) Plot steady-state activation $n_\infty(V) = \alpha_n(V)/(\alpha_n(V) + \beta_n(V))$ and activation time constant $\tau_n(V) = 1/(\alpha_n(V) + \beta_n(V))$ in a voltage range of $-150\,\mathrm{mV} \leq V \leq 150\,\mathrm{mV}$.

(c) Define a system of differential equations describing a membrane potential with potassium channels. Solve the system for various initial conditions.

(d) Explain the obtained results refering to the plots of activation variables n_∞ and τ_n.

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