Appendix S1: Equations of the neuron models

CPG-neurons and interneurons

The constituent currents are

I_{NaP}: slowly inactivating Na- current;

I_L: leakage current;

I_{syn}: synaptic current from other neurons;

I_{app}: input current (e.g. from sense organs or from the brain).

The model equations read:

$$
\begin{aligned}
C_m dV/dt &= -(I_{NaP} + I_L + I_{syn} + I_{app}) \quad \text{with} && (1)\\
I_{NaP} &= g_{NaP} m_\infty(V) h (V - E_{Na}) && (2)\\
I_L &= g_L (V - E_L) && (3)\\
I_{syn} &= g_{syn} s_\infty(V_{syn})(V - E_{syn}) && (4)\\
I_{app} &= g_{app}(V - E_{app}) \quad \text{and} && (5)\\
dh/dt &= (h_\infty(V) - h)/\tau_h(V). && (6)
\end{aligned}
$$

The membrane potential $V(t)$ and the inactivation variable $h(t)$ of I_{NaP} are the model variables, both are functions of time. The function $m_\infty(V)$ is the steady-state value at V of the activation variable m of I_{NaP}, and $h_\infty(V)$ is the steady-state value (at V) of h. In eqn. 4, the function $s_\infty(V_{syn})$ is the actual value of the synaptic activation induced by *another* cell with membrane potential V_{syn}. All of these voltage functions have the same form:

$$z_\infty(V) = 1/(1 + \exp(\gamma_z(V - V_{hz}))) \tag{7}$$

where $z = m, h, s$, while the formula for 'time constant' $\tau_h(V)$ reads

$$\tau_h(V) = \frac{1}{\epsilon} \frac{1}{\cosh(\gamma_\tau(V - V_{\tau h}))}. \tag{8}$$

The coefficients g_x in eqns. 2-5 are the maximal conductances of the membrane currents, and the parameters E_x the corresponding reversal potentials; C_m is the membrane capacitance.

Motoneurons

The constituent currents are:

I_{Na}: fast inactivating Na-current of the action potential;

I_K: delayed rectifier K-current of the action potential;

I_q: 'adaptation' (K-)current;

I_L: leakage current;

I_{syn}: synaptic current from other neurons;

I_{app}: input current (e.g. from sense organs or from the brain).

The current balance equation reads:

$$C_m dV/dt = -(I_{Na} + I_K + I_q + I_L + I_{syn} + I_{app}) \tag{9}$$

The individual membrane currents are of the form:

$$I_x = g_x m_x^p h_x (V - E_x). \tag{10}$$

where $x = Na, K, q, L$ (I_{syn} and I_{app} are of the same form as in the CPG neuron model: eqns. 4, 5). The parameters g_x and E_x have the same meaning as before (see preceding section). The parameter p is an integer. The (in)activation variables h_x and m_x, respectively, obey a differential equation of the form:

$$dy/dt = \alpha_y(V)(1 - y) - \beta_y(V)y \tag{11}$$

where y stands for h_x or m_x. The coefficients of eqn. 11 are nonlinear functions of the membrane potential V. They can have different forms depending on the type of the membrane current. The specific $\alpha(V)$ and $\beta(V)$ functions are listed below for each individual current type.

I_{Na} current

m_{Na}:

$$\alpha_{m_{Na}}(V) = \frac{a_{m1}(a_{m2} - V)}{\exp(a_{m3}(a_{m2} - V)) - 1} \tag{12}$$

$$\beta_{m_{Na}}(V) = \frac{b_{m1}(b_{m2} - V)}{\exp(b_{m3}(b_{m2} - V)) - 1} \tag{13}$$

h_{Na}:

$$\alpha_{h_{Na}}(V) = a_{h1} \exp(a_{h3}(a_{h2} - V)) \tag{14}$$

$$\beta_{h_{Na}}(V) = \frac{b_{h1}}{\exp(b_{h3}(b_{h2} - V)) + 1} \tag{15}$$

I_K current

m_K:

$$\alpha_{m_K}(V) = \frac{a_{m1}(a_{m2} - V)}{\exp(a_{m3}(a_{m2} - V)) - 1} \tag{16}$$

$$\beta_{m_K}(V) = b_{m1} \exp(b_{m3}(b_{m2} - V)) \tag{17}$$

Adaptation current I_q

$$m_{q\infty} = \frac{1}{1 + \exp(s_q(V - V_{hq}))} \tag{18}$$

$$r_q = const. \tag{19}$$

$$\alpha_{m_K}(V) = m_{q\infty} r_q \tag{20}$$

$$\beta_{m_K}(V) = (1 - m_{q\infty}) r_q \tag{21}$$

where $m_{q\infty}$ is the steady-state value of m_q at a given value of V and r_q is the rate constant. For further details see [1, 2].

References

1. Daun S, Rybak IA, Rubin J (2009) The response of a half-center oscillator to external drive depends on the intrinsic dynamics of its components: a mechanistic analysis. J Comput Neurosci 27: 3-36.

2. Daun-Gruhn S, Toth TI (2011) An inter-segmental network model and its use in elucidating gait-switches in the stick insect. J Comput Neurosci 31: 43-60.