Modeling A Simple Non-Associative Learning Mechanism in the Brain of C. elegans

Ramin Hasani 1, Magdalena Fuchs 1, Victoria Beneder 2, Radu Grosu 1

1 Vienna University of Technology, 2 University of Natural Resources & Life Sciences

Learning the Learning Mechanism
We deterministically model and learn the dynamics of a simple form of non-associative learning mechanism in the brain of the worm, C. elegans.

C. elegans’ Nervous System Mapping

Habituation
The simplest type of non-associative learning exhibited by C. elegans, is habituation. It is defined as the decrease of the reflexive response of the worm, in the presence of repetitive exposure to a particular kind of stimulus.

Single Neuron Habituation Model

K+ flux reduction: (Response of an ODE)

\[ g_k = 10 e^{-0.02 t} + 3 \]

Rise of the Ca2+ conductivity:

\[ G_{pump} = \frac{10}{1 + e^{-0.01(t+200)}} + 3.6 \]

Inactivation of Ca2+ channel:

\[ \frac{dh}{dt} = \frac{h_{\infty} - h}{\tau_h}, \quad h_{\infty} = \frac{1}{1 + H e^{-V/V_{1/2}}} \]

Simulation Platform

Neuron Representation

ODE in Simulink

Model of a Neuron (Bio)

Model of Chemical Synapses

Model of Electrical Synapses

Model of Synaptic Plasticity for Habituation

Presynaptic neuron activation rate

\[ \frac{d m}{dt} = \frac{(m_{\infty} - m)}{\tau_m} + \frac{1}{V_{th} - V_{pre} + V_{th} - V_{pre} + \delta_t} \]

Probability of neurotransmitter binding to the postsynaptic receptors

\[ \frac{d S}{dt} = -\frac{S}{\tau_F} + \frac{S}{\tau_R} \]

\[ \frac{d h}{dt} = -\frac{h}{\tau_R} + h_0 \cdot \delta(t - t_0) \]

\[ I_{chem} = g_{max} m(t) S(t) n(t) (E_{chem} - V_{post}) \]

Results

Simulation of Neuronal Habituation

The state of the activation of a sensory neuron can be modified by repeatedly induced stimulus, by means of an intrinsic parameter which is dynamically altered, as a function of time, input amplitude and its frequency.

References