Case Study of an Extended Fitzhugh-Nagumo Model with Chemical Synaptic Coupling and Application to C. Elegans Functional Neural Circuits

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Identifying the neural activity which translates a sensory input into behavioral output is one of the central tasks of neuroscience. The nematode C. elegans serves as a model organism in biology and its connectome of neural connections has been completely mapped. C. elegans are capable of some simple behavior responses to external influences such as chemotaxis and thermotaxis. The responsible neural circuits consisting of sensory neurons, interneurons and motor neurons are subject of recent studies. We use an extended Fitzhugh-Nagumo model to study the dynamics of simple neural circuits. The neurons are coupled via chemical synapses, which can excite and inhibit the post-synaptic neuron. The neurotransmitter-receptor dynamics are governed with a gating dynamic, which allows for the distinction between fast and slow synapses. In our studies of the neural circuits we find frequency enhancement, chaotic spiking, synchronization of fast and slow firing neurons and periodic bursting. We apply the model to the temperature sensing circuit of the AWC, AFD and AIY neurons of the C. elegans and reproduce the activity response to temperature change.