BME 503 : Exploration 2
Due September 21 7:00 PM

The goal of this exploration is to explore nonlinear IAF models, the Izhikevich model, and to investigate different models of synapses used in computational neuroscience and get a feel for the limitations and advantages.

Part 1: Compute the firing-rate as a function of the applied input current for the exponential integrate-and-fire model.

The equations has the form

$$\tau_m \frac{dV}{dt} = (E_L - V) + F(V) + R_m I_{stim}$$

with

$$F(V) = \Delta_E \exp\left(\frac{(V - V_T)}{\Delta_E}\right)$$

for the exponential integrate-and-fire model (EIAF). Use the parameters $E_L = V_{reset} = -65mV$, $V_{th} = -50mV$, $\tau_m = 10ms$ and $R_m = 10M\Omega$ with, $\Delta_E = 5.0mV$, $V_T = -55mV$ and $V_{\max} = 30mV$.

For the EIAF model, reset the potential to $V = V_{reset}$ whenever it gets to or above V_{max}.

Show a trace of the potential and compute firing rate as a function of I_{stim} for the EIAF model.

Part 1) Izhikevich model

Using the information on http://www.izhikevich.org/publications/spikes.htm (see Exploration 2 Links on sakai), implement the Izhikevich model in Brian 2. Try to reproduce 4 of the models with the proper choices of parameters.

Part 2) Alpha Conductance and Biophysical Model

A) Using synalpha_skel2018.py create a model of alpha synapse conductance and the 4 biophysical synapses conductances and modify the parameters to give a reasonable match to the 4 biological conductance changes driven by the 1 msec pulse signifying transmitter release. For NMDA- assume B(V)= 1. You will use the two odes to generate the alpha functions. The expressions for the conductance changes for the various biophysical synapses can be found in Chapter 8 of "Foundations of (Mathematical) Neuroscience" in the Relevant Online Texts section under Resources in Sakai. For which biophysical models does the alpha synapse conductance best compare? What biophysical models are not fit well with the alpha synapse conductance.

B) A paper was uploaded to the sakai site under Task 2 - Synapses called "Modeling Synapses" by Roth and van Rossum. This paper gives a modified form for the two odes – namely

$$\dot{g} = \frac{dg}{dt} = \frac{-g}{\tau_{decay}} + z(t)$$

$$\dot{z} = \frac{dz}{dt} = \frac{-z}{\tau_{rise}} + \overline{g}_{syn2}u(t)$$

where you can separately define the rise time constant and decay time constant. Adjust your code for Part B and play with the parameters τ_{rise} and τ_{decay} to see how this affects the shape of the conductance and the comparisons to the biophysical models for which the alpha model did not fit well.

Here you should be aware that the conductance peaks at

$$peaktime = \frac{\tau_{decay}\tau_{rise}}{\tau_{decay} - \tau_{rise}} \ln(\frac{\tau_{decay}}{\tau_{rise}})$$

and the scale factor above so the conductance reaches g_{peak} at peaktime is

$$\bar{g}_{syn2} = g_{peak} \Big/ \left(\left(\frac{\tau_{decay}\tau_{rise}}{\tau_{decay} - \tau_{rise}} \right) \left(\exp\left(-\frac{peaktime}{\tau_{decay}} \right) - \exp\left(-\frac{peaktime}{\tau_{rise}} \right) \right) \right)$$

Also note that if you make the decay and rise time constants "almost" the same, you should get the single time constant alpha function back. Note that if they are exactly the same, the expression for peaktime will not be defined.