Computational Neuroscience
Assignment: ORGaNICs
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Implement a simplified version of an **O**scillatory **R**ecurrent **Ga**ted **N**eural **I**ntegrator **C**ircuit (ORGaNICs) using the equations below. This circuit has 3 neurons, a primary neuron and 2 modulatory neurons and an input neuron. In these equations, $y(t)$ is the membrane potential of the primary neuron and $y^+(t)$. The membrane potential responses of the modulator neurons are $a(t)$ and $u(t)$, and their firing rates are $a^+(t)$ and $u^+(t)$. The value of $x^+(t)$ is the firing rate of the input neuron. The value of b_0 is a constant that determines the input gain. The value of σ is constant that determines the contrast gain.

$$\tau_y \frac{dy}{dt} = -y + \frac{b_0}{1+b_0} x^+ + \frac{1}{1+a^+} \hat{y} \qquad (1)$$

$$y^+ = y^2 \qquad (2)$$

$$\hat{y} = \sqrt{y^+} \qquad (3)$$

$$\tau_a \frac{da}{dt} = -a + u^+ + a u^+ \qquad (4)$$

$$a^+ = a \qquad (5)$$

$$\tau_u \frac{du}{dt} = -u + u y^+ + u_{\min} \qquad (6)$$

$$u^+ = \sqrt{u} \qquad (7)$$

Use the following values for the various constants and the time step:

$$u_{\min} = \left(\frac{\sigma b_0}{1+b_0} \right)^2$$

$$b_0 = 0.2$$

$$\sigma = 0.1$$

$$\tau_y = 1 \text{ ms}$$

$$\tau_a = 2 \text{ ms}$$

$$\tau_u = 10 \text{ ms}$$

$$\Delta t = 1 \text{ ms}$$

The firing rate of the input neuron $x^+(t) = \text{xAmp}$ (a positive non-zero value) for $t = 0$ to $t = 500$ ms, and then $x^+(t) = 0$ for $t = 500$ to $t = 1000$ ms.

1) Graph the firing rate responses of the principal neuron over time from $t = 0$ to $t = 1000$ ms for each of several values of the input firing rate: $\mathrm{xAmp} = 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 1.0$. You should get results that look like the blue curves in Fig. 3E of Heeger & Zemlianova (2020).
2) Compute the the mean response of the principal neuron from $t = 250$ to $t = 500$ ms for each value of the input firing rate and make a graph of the mean responses versus the input rate (xAmp). Plot this on a log axis for the input rate and you should get a result that looks like the blue curve in Fig. 3A of Heeger & Zemlianova (2020).
3) Repeat parts 1 and 2 with $\tau_u = 1$ ms. You should get results that look like the blue curves in Figs. 3F and 3A of Heeger & Zemlianova (2020).