Neuronify: a new tool for creating simple neural networks

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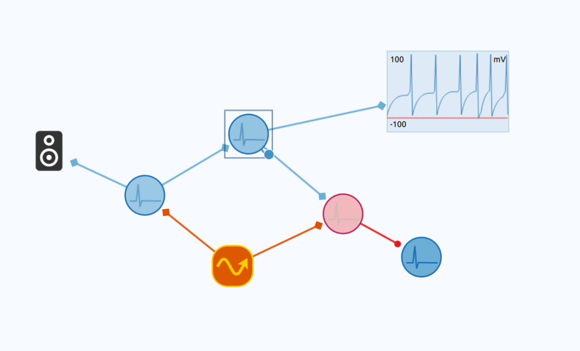

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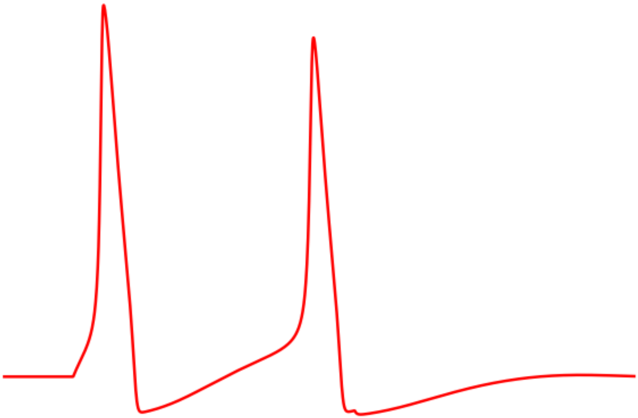
We do not need all information in the action potential for a neuron in a network and can create an approximation



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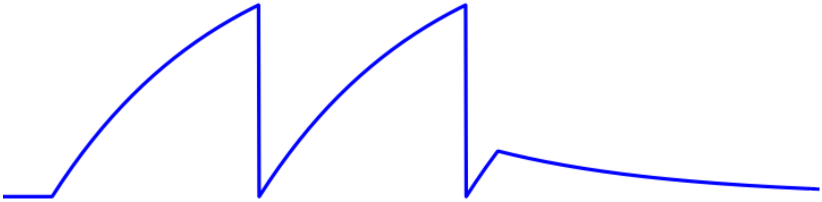

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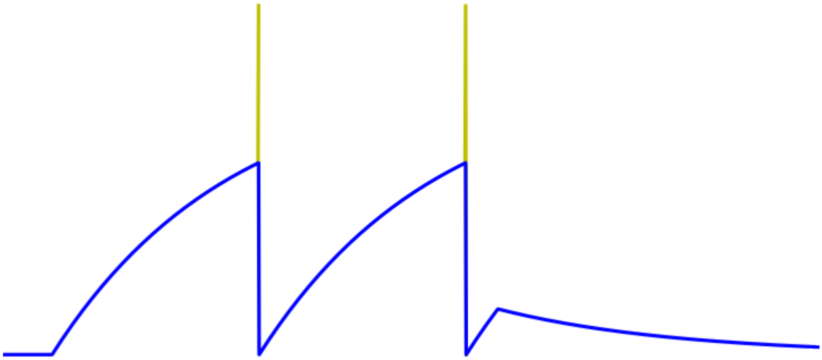

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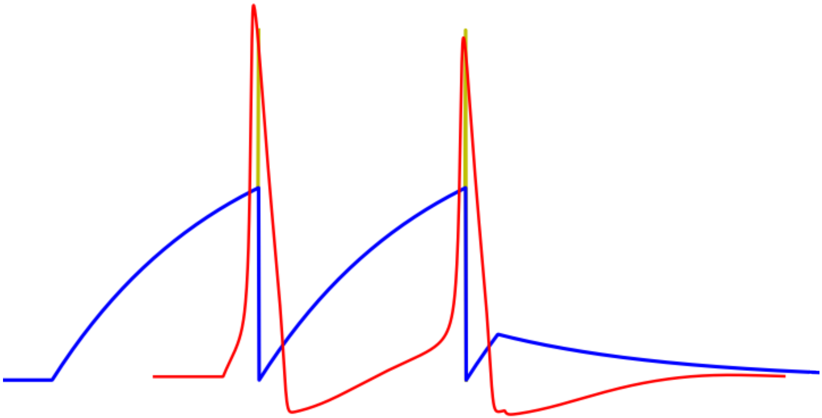

The integrate and fire neuron is much faster to evaluate than the Hodgkin-Huxley neuron

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Hodgkin-Huxley

$$C\frac{dV}{dt} = I_{inj} - \bar{g}_{Na}m^3h(V - V_{Na}) - \bar{g}_K n^4(V - V_K) - g_L(V - V_L)$$

$$\frac{dn}{dt} = \alpha_n(V)(1-n) - \beta_n(V)n \quad \frac{dm}{dt} = \alpha_m(V)(1-m) - \beta_m(V)m$$

$$\frac{dh}{dt} = \alpha_h(V)(1-h) - \beta_h(V)h \quad \alpha_n(V) = \frac{0.01(V+55)}{1-\exp[-(V+55)/10]}$$

$$\beta_n(V) = 1.125\exp[-(V+65)/80] \quad \alpha_m(V) = \frac{0.1(V+40)}{1-\exp[-(V+40)/10]}$$

$$\beta_m(V) = 4\exp[-(V+65)/18] \quad \alpha_h(V) = 0.07\exp[-(V+65)/20]$$

$$\beta_n(V) = \frac{1}{1+\exp[-(V+35)/10]}$$

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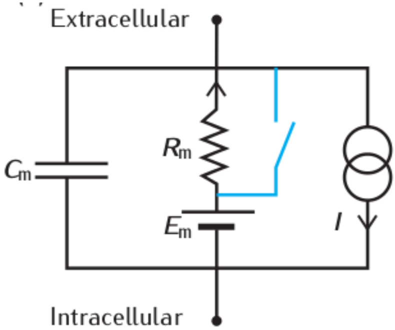
Integrate and fire

$$C_m\frac{dV(t)}{dt} = -\frac{V(t) - E_m}{R_m} + I$$

The integrate and fire model is modeled as a simple RC circuit that is shortcircuted once a threshold is reached



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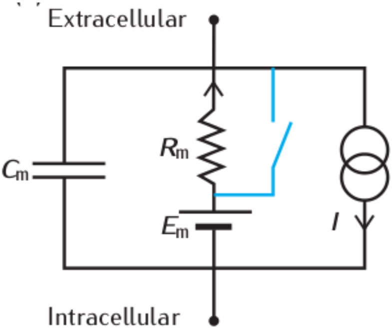

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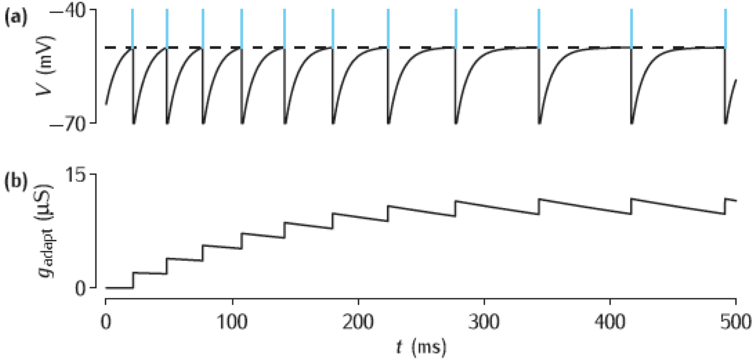
Adaptive Firing Rate



Adaptive Firing Rate

This can be modeled by a reverse current

$$I_{\mathrm{adapt}} = g_{\mathrm{adapt}}(V - E_m)$$

where the conductance is incremented by a step Δg on each action potential, and then decays.

$$\frac{\mathrm{d}}{\mathrm{d}t} g_{\mathrm{adapt}} = -\frac{g_{\mathrm{adapt}}}{\tau_{\mathrm{adapt}}}.$$

Adaptiv

Spike generators

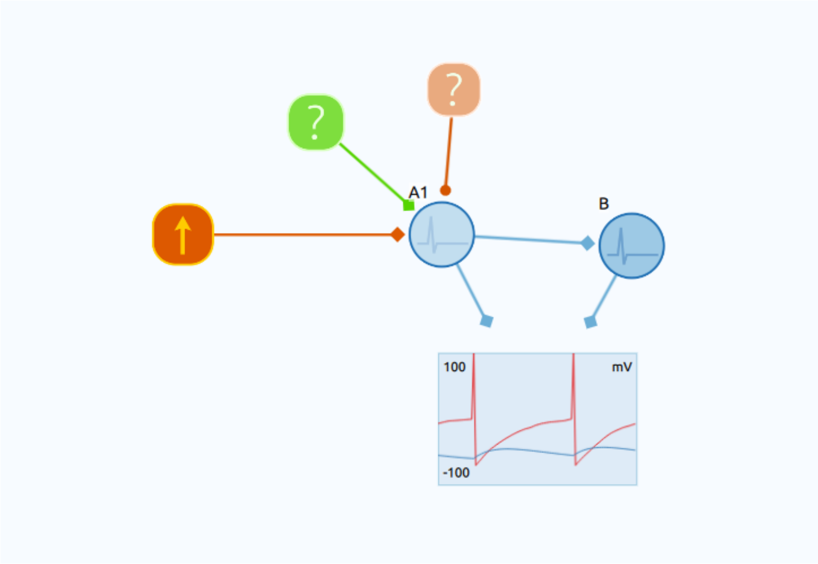
Neurons exhibit irregular firing patterns. In the Stein model this is achieved by letting the neuron receive random inhibitory and excitatory spikes, which follow a Poisson process,

$$Pr(X = n) = f(n) = \frac{\lambda^n e^{-\lambda}}{n!}$$

Spike generators - Implementation

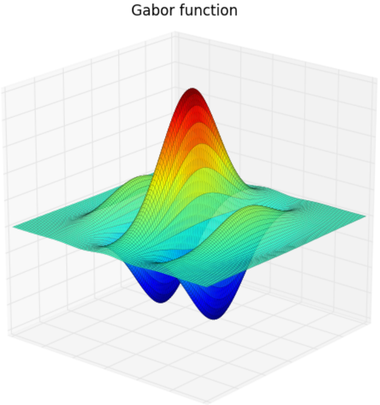
At each time step we draw a random number x. If $x < r\Delta t$, the generator fires. Otherwise it does not.

Spike generators - Neuronify



Receptive Field

$$r(t) = r_0 + \int \int D(\mathbf{r}, \tau) s(\mathbf{r}, t - \tau) d\tau d\mathbf{r} \qquad (1)$$



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