Izhikevich Neuronal Spiking model

Izhikevich et al. 2003, 2004

- This model provides a computationally efficient approach to replicate the rich spiking dynamics of cortical neurons (single neuronal level and large-scale network level).
- This model explains the different firing patterns for different current impulses that the neurons might receive.

Model Characteristics:

- Dynamic model
- Continuous in time
- Mechanistic model (derived from bifurcation analysis)
- Deterministic model
- Single scale model

Model Variables and Parameters:

v – membrane potential
u – membrane recovery variable

a – time scale of u
b - sensitivity of u, to subthreshold fluctuations in v
c - after-spike reset value of v
d - after-spike reset of u

Salient features:

- **2 Variable model** – Uses two dimensional system of ODEs involving membrane potential and membrane recovery variable.
- Change in model parameters could **explain 20 different cortical spiking dynamics**.
- Most computationally efficient model – 13 flops to simulate 1ms of neuronal spiking.

Limitations:

- Not biophysically exact (due to membrane potential resetting function and unaccountability of specific ion concentration variations).
- Cannot effectively explain amplitude encoding of information (due to the resetting function, as $dt \rightarrow 0$, the $v(firing) \rightarrow 30\ mV$).

Model Equations:

$$\frac{dv}{dt} = 0.04v^2 + 5v + 140 - u + I \quad \text{and} \quad \frac{du}{dt} = a(bv - u)$$

Voltage resetting ($v \geq 30\ mV$):

$$v \leftarrow c$$
$$u \leftarrow u + d$$

Model Results: