SYDE 556/750

Simulating Neurobiological Systems
Lecture 2: Neurons

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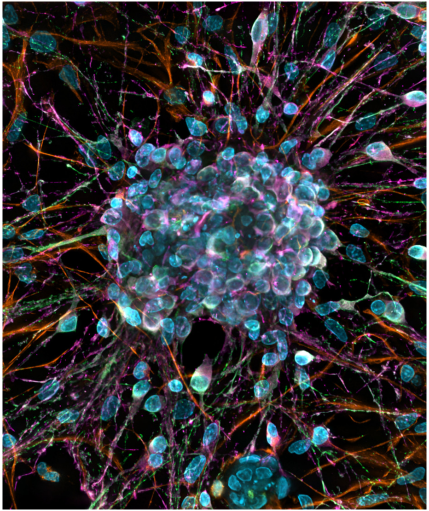
January 9, 2020



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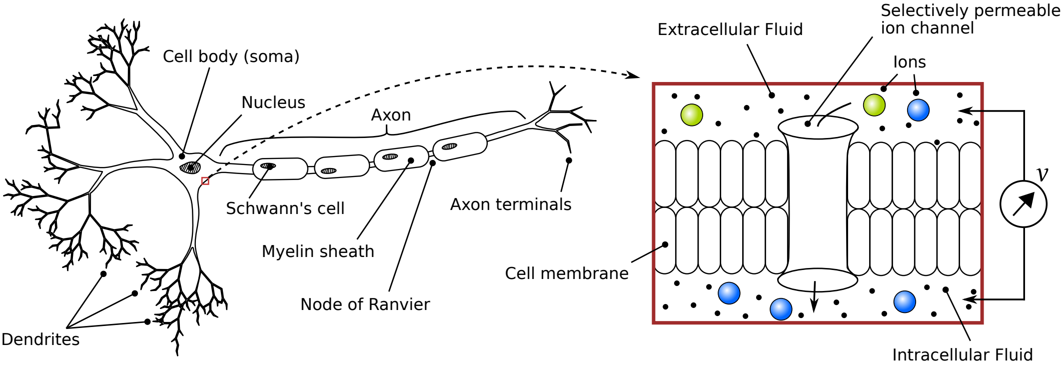
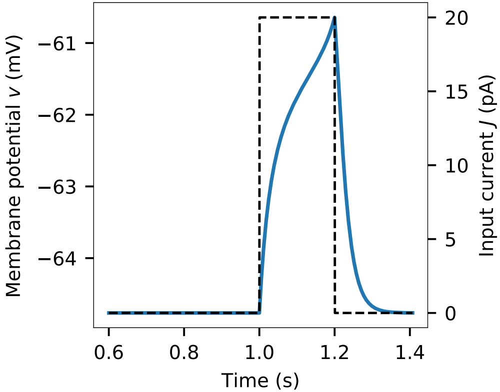
Textbook Neuron and Cell Membrane

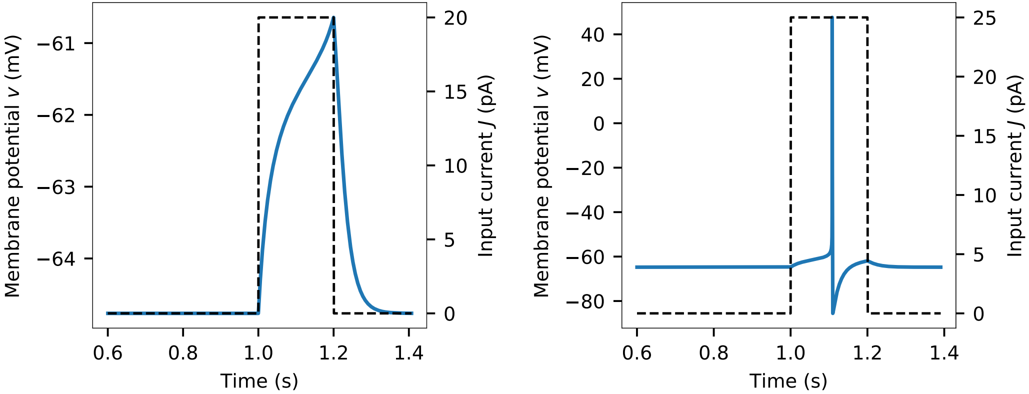


Injecting a Current Into a Detailed Neuron Model



Computer simulation of an Hodgkin-Huxley type neuron with Traub kinematics (Roger D. Traub and Richard Miles, *Neuronal Networks of the Hippocampus*, Cambridge University Press, 1991)

Injecting a Current Into a Detailed Neuron Model



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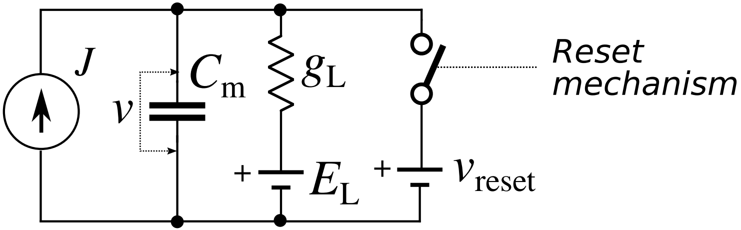
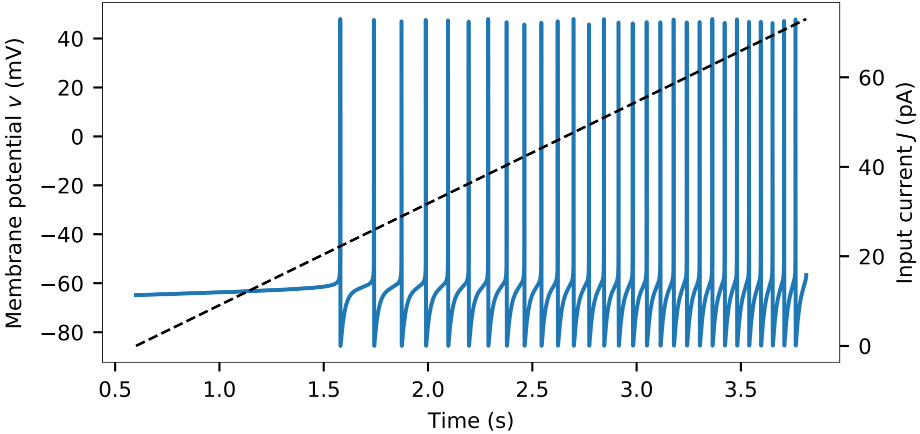
The Leaky Integrate-and-Fire Equivalent Circuit

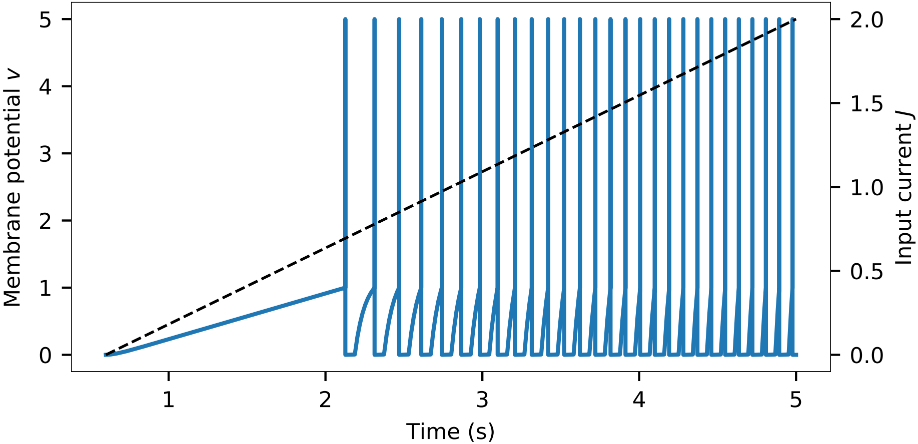


Injecting a Current Ramp into a Detailed Neuron Model

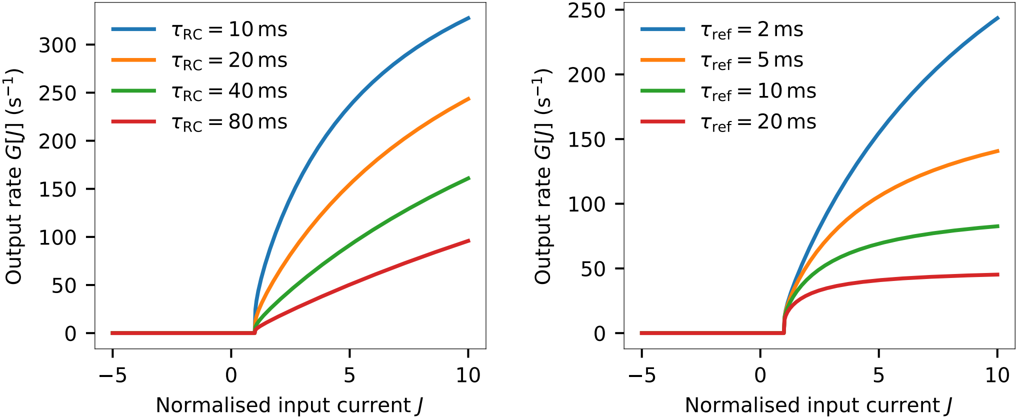


Computer simulation of an Hodgkin-Huxley type neuron with Traub kinematics (Roger D. Traub and Richard Miles, *Neuronal Networks of the Hippocampus*, Cambridge University Press, 1991)

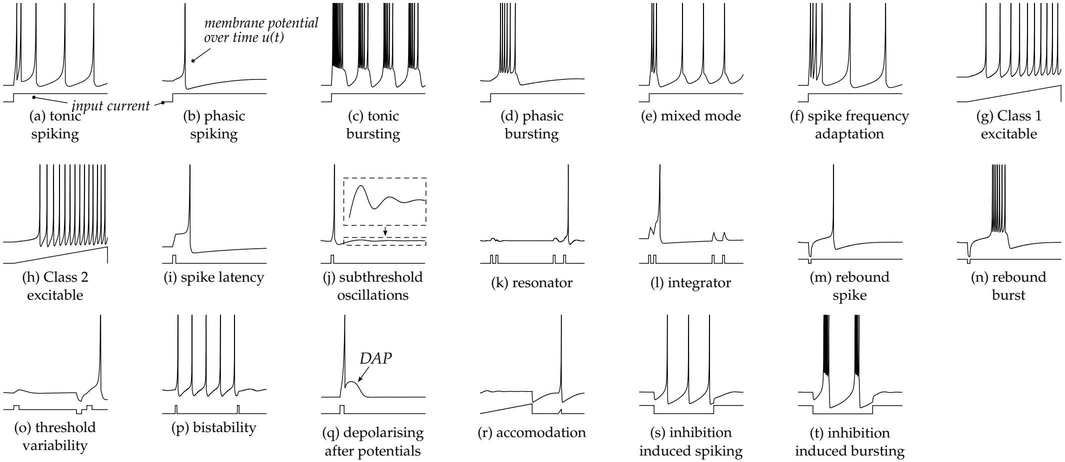
Injecting a Current Ramp into a LIF Neuron Model



Exploring the LIF Rate Approximation



Limits of the LIF Rate Approximation



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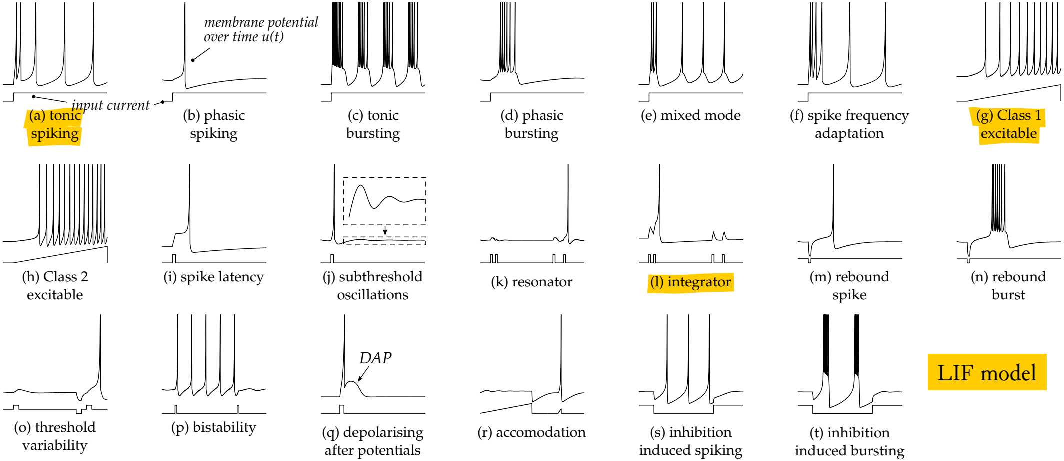
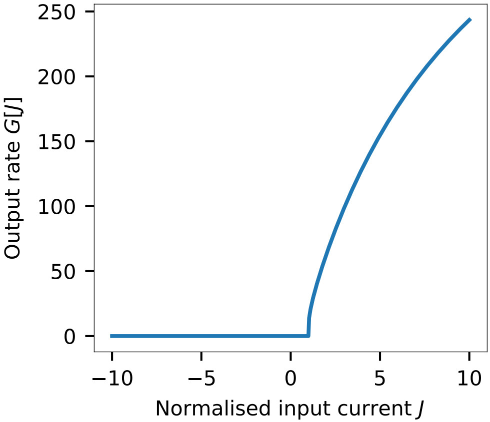


LIF model

Artifical Rate Neurons: LIF

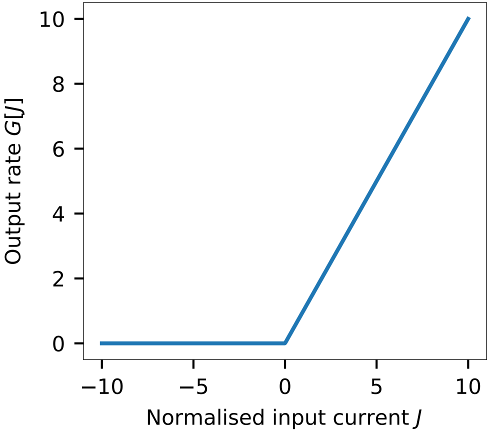


$$G[J] = \frac{1}{\tau_{\mathrm{ref}} + \tau_{\mathrm{RC}} \log\left(1 - \frac{1}{J}\right)}$$

Usefulness to neurobiological systems modellers:

- ⊕ Biologically motivated
- ⊕ Captures saturation effects
- ● Relatively slow to evaluate numerically (for machine-learning people)
- ⊖ Spike onset is smooth in noisy systems

Artifical Rate Neurons: ReLU

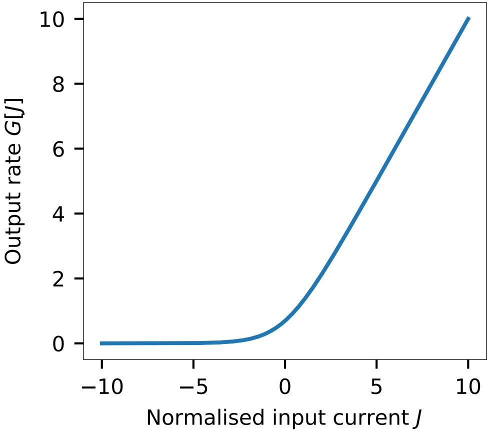


$$G[J] = \max\{0, J\}$$

Usefulness to neurobiological systems modellers:

- ⊕ Fast to evaluate
- ● Rough approximation of the LIF response curve
- ⊖ Does not capture saturation effects
- ⊖ Spike onset is smooth in noisy systems

Artifical Rate Neurons: Smooth ReLU (Softplus)

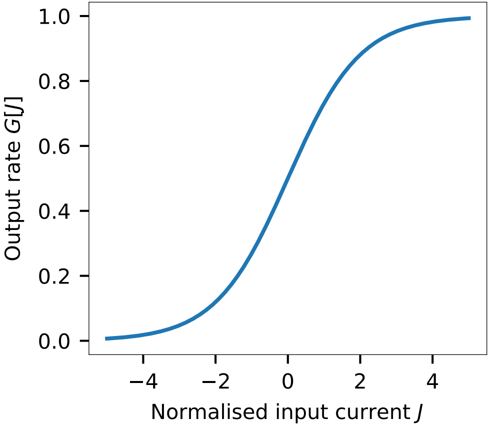


$$G[J] = \log(1 + \exp(J))$$

Usefulness to neurobiological systems modellers:

- ⊕ Models smooth spike onset
- ● Rough approximation of the LIF response curve
- ⊖ Does not capture saturation effects

Artifical Rate Neurons: Logistic Function

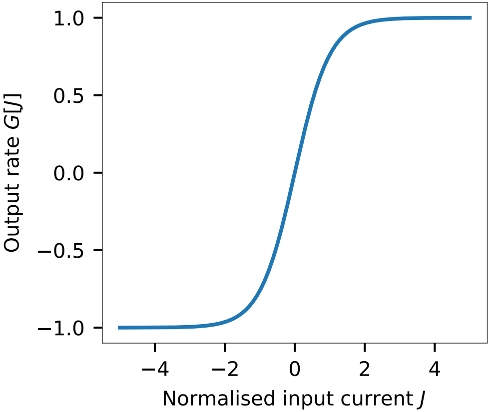


$$G[J] = \frac{1}{1 + e^{-J}}$$

Usefulness to neurobiological systems modellers:

- Models smooth spike onset and saturation (?)

Artifical Rate Neurons: Hyperbolic Tangent



$$G[J] = \tanh(J) = \frac{e^{J} - e^{-J}}{e^{J} + e^{-J}}$$

Usefulness to neurobiological systems modellers:

- Models smooth spike onset and saturation (?)
- Negative rates