

Week 1 – part 5: How good are Integrate-and-Fire Model?



Neuronal Dynamics: Computational Neuroscience of Single Neurons

Week 1 – neurons and mathematics:
a first simple neuron model

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√ 1.1 Neurons and Synapses:

Overview

1.2 The Passive Membrane

- Linear circuit
- Dirac delta-function

√ 1.3 Leaky Integrate-and-Fire Model

√ 1.4 Generalized Integrate-and-Fire Model

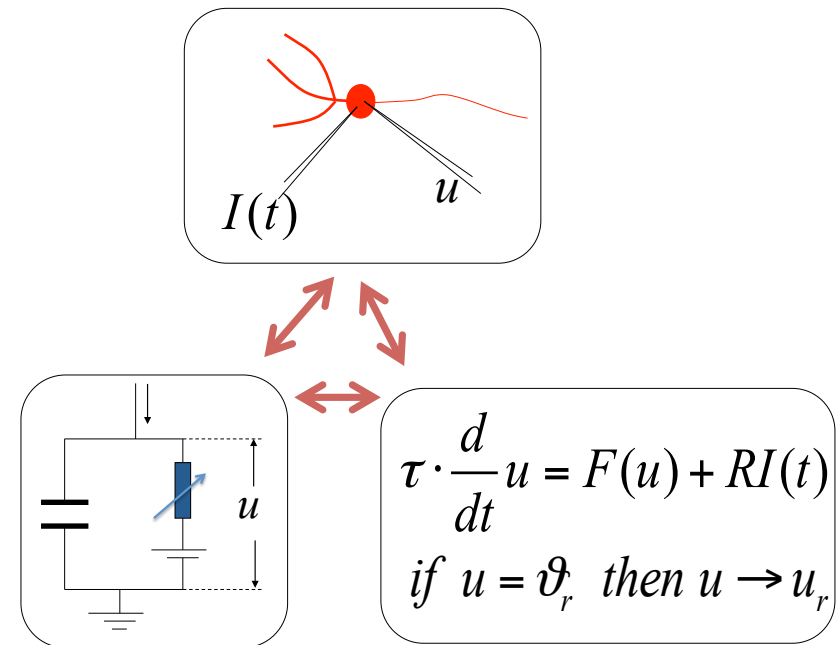
- where is the firing threshold?

1.5. Quality of Integrate-and-Fire Models

- Neuron models and experiments

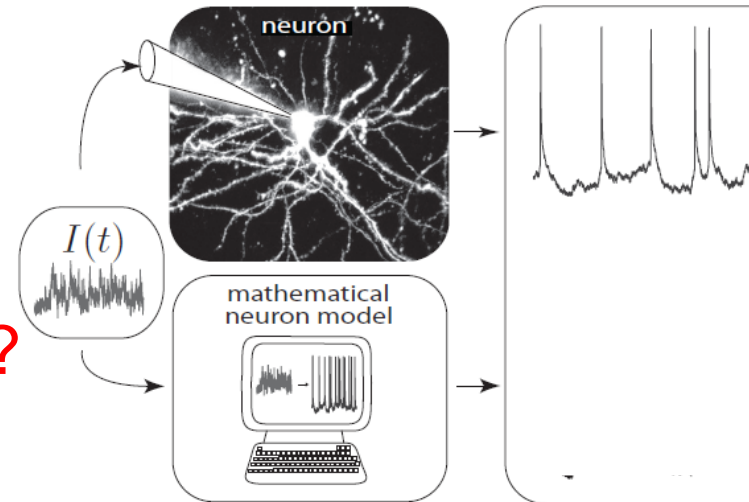
Neuronal Dynamics – 1.5. How good are integrate-and-fire models?

Can we compare neuron models with experimental data?



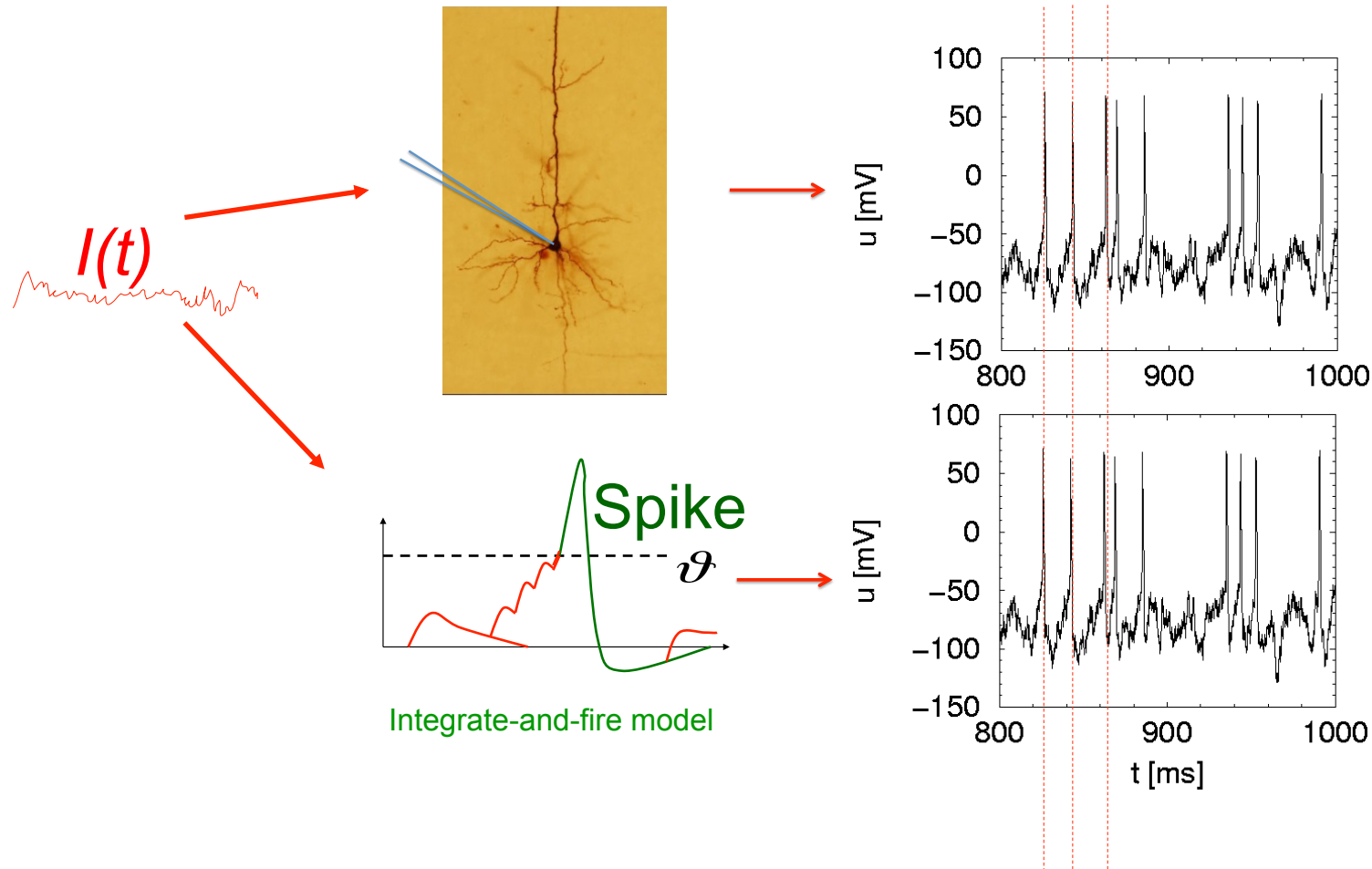
Neuronal Dynamics – 1.5. How good are integrate-and-fire models?

What is a good neuron model?

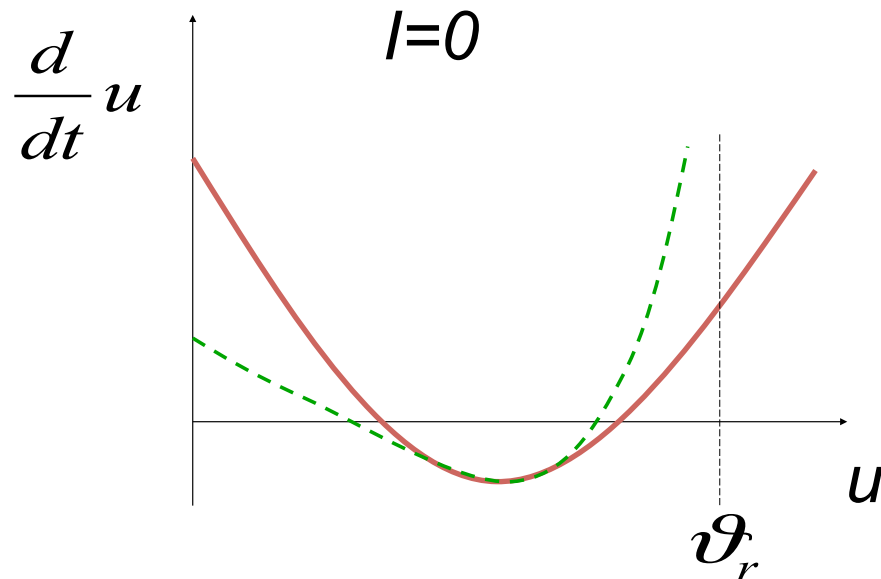


Can we compare neuron models
with experimental data?

Neuronal Dynamics – 1.5. How good are integrate-and-fire models?



Nonlinear Integrate-and-fire Model



Can we measure
the function $F(u)$?

$$\tau \cdot \frac{d}{dt}u = F(u) + RI(t)$$

$$u(t) = v_r \Rightarrow \text{Fire+reset}$$

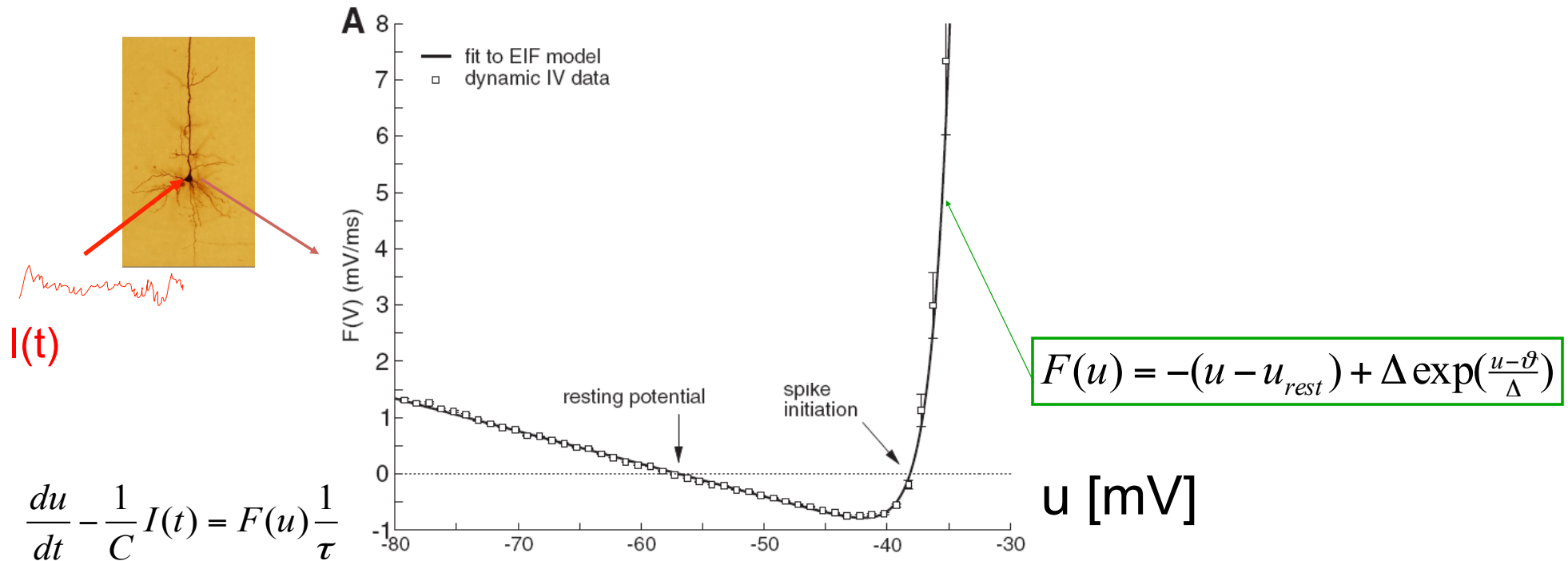
Quadratic I&F:

$$F(u) = c_2(u - c_1)^2 + c_0$$

exponential I&F:

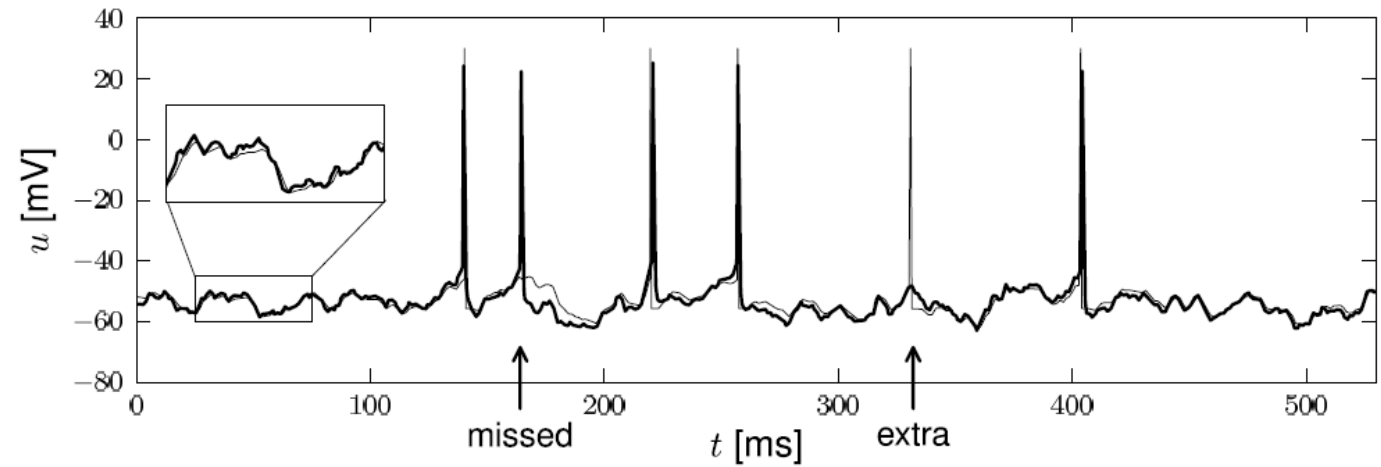
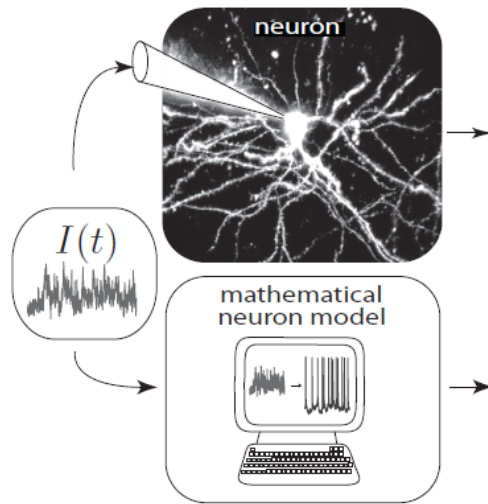
$$F(u) = -(u - u_{rest}) + c_0 \exp(u - v)$$

Neuronal Dynamics – 1.5. How good are integrate-and-fire models?



Badel et al., J. Neurophysiology 2008

Neuronal Dynamics – 1.5. How good are integrate-and-fire models?



Neuronal Dynamics – 1.5. How good are integrate-and-fire models?

Nonlinear integrate-and-fire models
are good

Mathematical description → prediction

Need to add

- adaptation
- noise
- dendrites/synapses

Neuronal Dynamics – References and Suggested Reading

Reading: W. Gerstner, W.M. Kistler, R. Naud and L. Paninski,
Neuronal Dynamics: from single neurons to networks and models of cognition. Chapter 1: *Introduction*. Cambridge Univ. Press, 2014

Selected references to linear and nonlinear integrate-and-fire models

- Lapicque, L. (1907). *Recherches quantitatives sur l'excitation électrique des nerfs traitée comme une polarisation*. J. Physiol. Pathol. Gen., 9:620-635.
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- Ermentrout, G. B. (1996). *Type I membranes, phase resetting curves, and synchrony*. Neural Computation, 8(5):979-1001.
- Fourcaud-Trocme, N., Hansel, D., van Vreeswijk, C., and Brunel, N. (2003). *How spike generation mechanisms determine the neuronal response to fluctuating input*. J. Neuroscience, 23:11628-11640.
- Badel, L., Lefort, S., Berger, T., Petersen, C., Gerstner, W., and Richardson, M. (2008a).. Biological Cybernetics, 99(4-5):361-370.
- Latham, P. E., Richmond, B., Nelson, P., and Nirenberg, S. (2000). *Intrinsic dynamics in neuronal networks. I. Theory*. J. Neurophysiology, 83:808-827.