Week 7 – part 1 : Models and data

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Neuronal Dynamics:

Computational Neuroscience of Single Neurons

Week 7 – Optimizing Neuron Models For Coding and Decoding

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7.1 What is a good neuron model?
- Models and data

7.2 AdEx model
- Firing patterns and adaptation

7.3 Spike Response Model (SRM)
- Integral formulation

7.4 Generalized Linear Model
- Adding noise to the SRM

7.5 Parameter Estimation
- Quadratic and convex optimization

7.6. Modeling in vitro data
- how long lasts the effect of a spike?

7.7. Helping Humans

Week 7 – part 1 : Models and data

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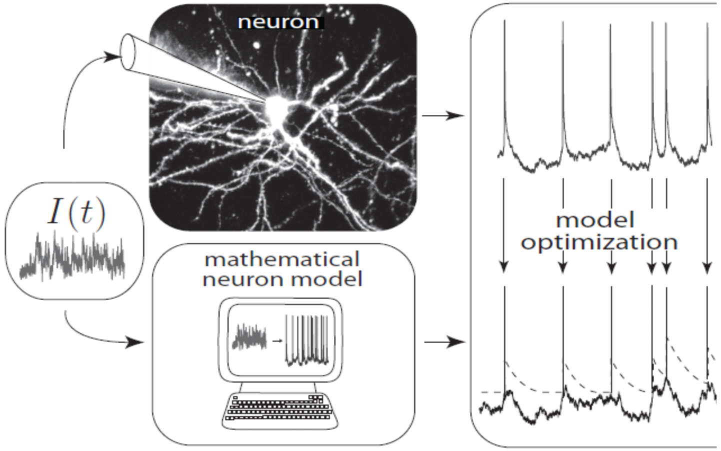
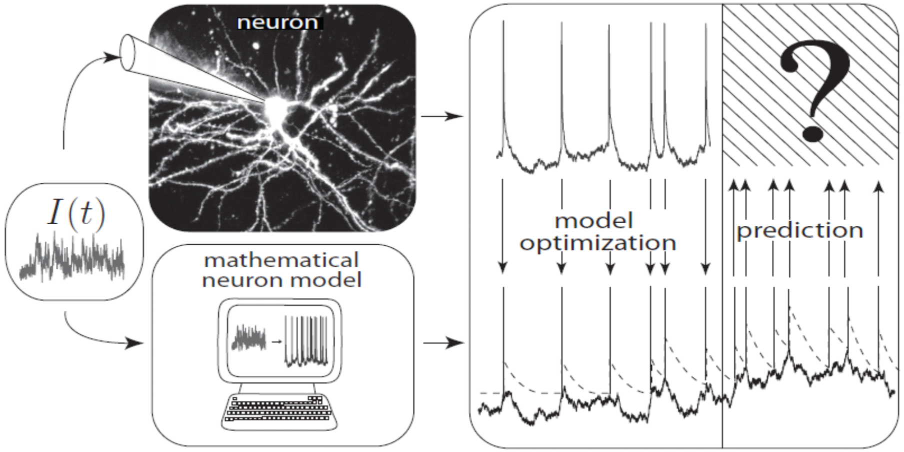
Neuronal Dynamics – 7.1 Neuron Models and Data



-What is a good neuron model?
-Estimate parameters of models?

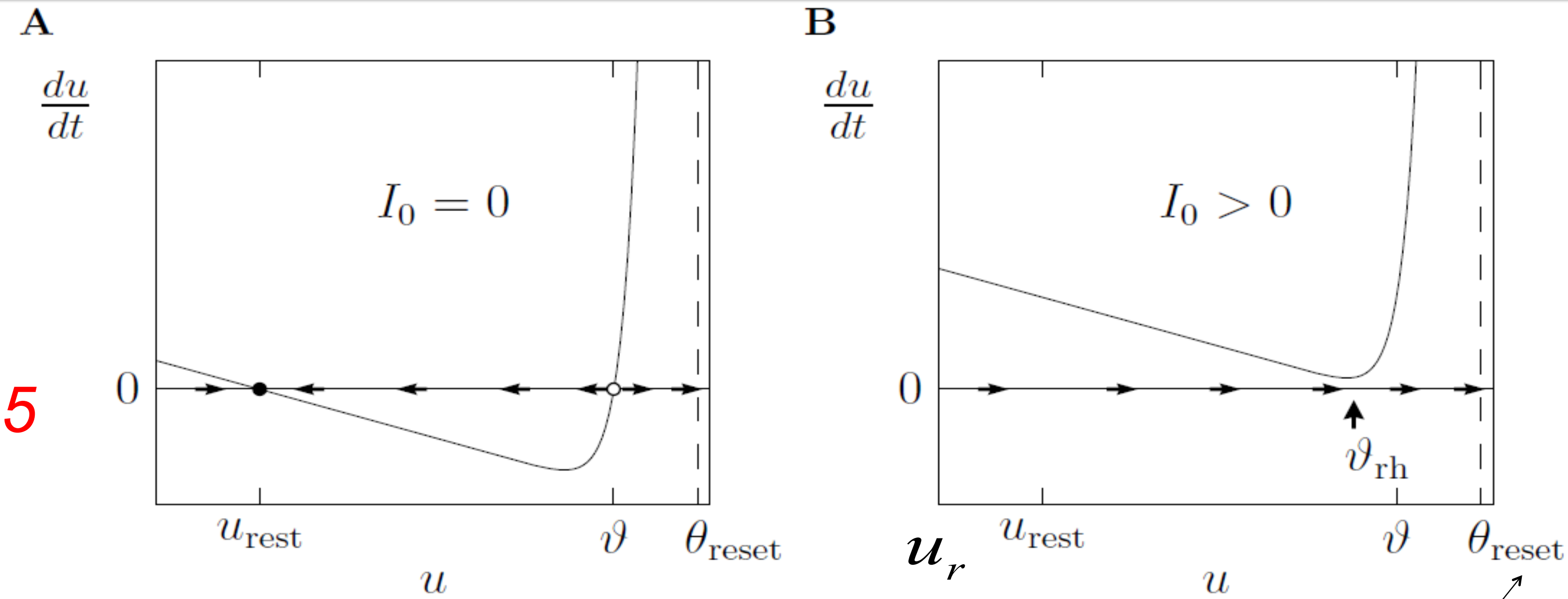
Neuronal Dynamics – 7.1 What is a good neuron model?



A) Predict spike times
B) Predict subthreshold voltage
C) Easy to interpret (not a ‘black box’)
D) Flexible enough to account for a variety of phenomena
E) Systematic procedure to ‘optimize’ parameters

Neuronal Dynamics – Review: Nonlinear Integrate-and-fire

See:
week 1,
lecture 1.5



$$\tau \frac{du}{dt} = f(u) + R\,I(t)$$

What is a good choice of **f** ?

If $u = \theta_{reset}$

then reset to

$u = u_r$

Neuronal Dynamics – Review: Nonlinear Integrate-and-fire

(1) $$\tau \frac{du}{dt} = f(u) + R\,I(t)$$

(2) $$If \;\; u = \theta_{reset} \;\; then \;\; reset\, to\; u = u_r$$

What is a good choice of ***f*** ?

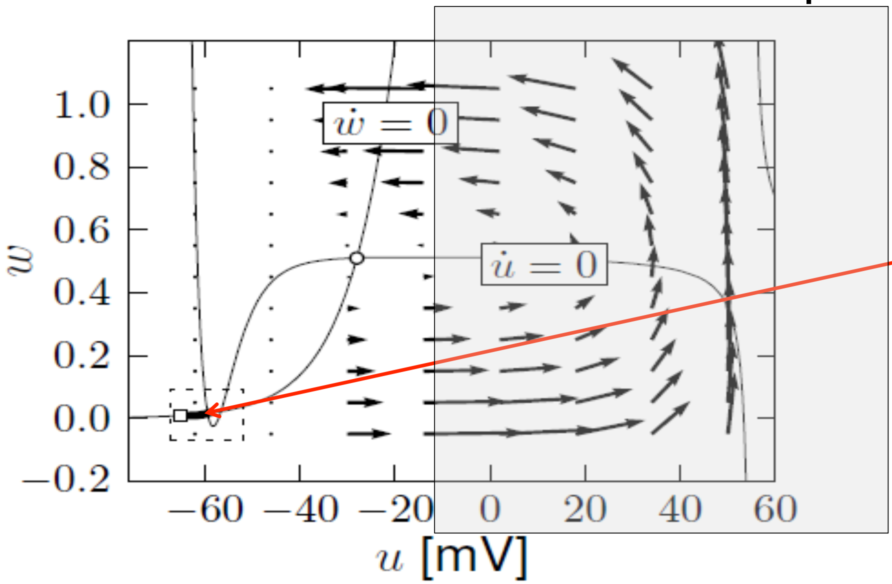
(i) Extract *f* from more complex models

(ii) Extract *f* from data

Neuronal Dynamics – Review: Nonlinear Integrate-and-fire

(i) Extract *f* from more complex models

$$\tau \frac{du}{dt} = f(u) + R\,I(t)$$



A. detect spike and reset

resting state

Separation of time scales:
Arrows are nearly horizontal

Spike initiation, from rest

$w \approx w_{rest}$

See week 4:
2dim version of
Hodgkin-Huxley

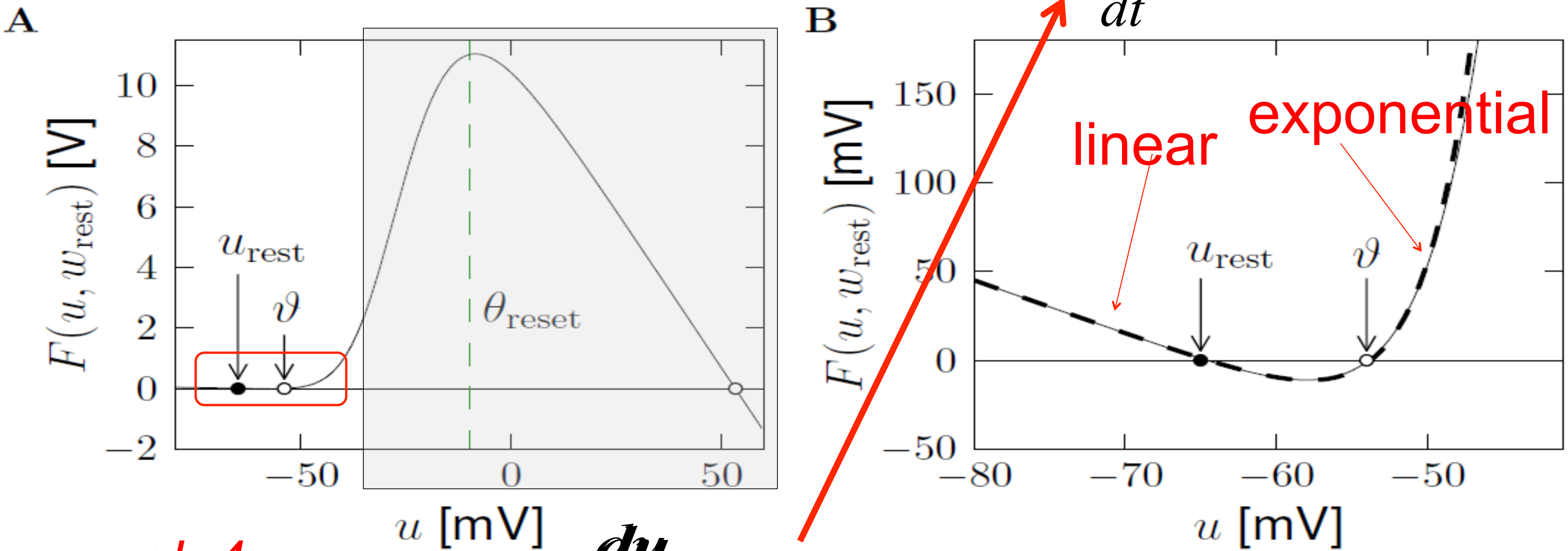
$$\tau \frac{du}{dt} = F(u,w) + R\,I(t)$$

$$\tau_w \frac{dw}{dt} = G(u,w)$$

B. Assume $w = w_{rest}$

Neuronal Dynamics – Review: Nonlinear Integrate-and-fire

(i) Extract f from more complex models $\tau \frac{du}{dt} = f(u) + R\,I(t)$



See week 4:
2dim version of
Hodgkin-Huxley

$$\tau \frac{du}{dt} = F(u, w_{rest}) + R\,I(t)$$

Separation of time scales

$$\tau_w \frac{dw}{dt} = G(u, w) \longrightarrow w \approx w_{rest}$$

Neuronal Dynamics – Review: Nonlinear Integrate-and-fire

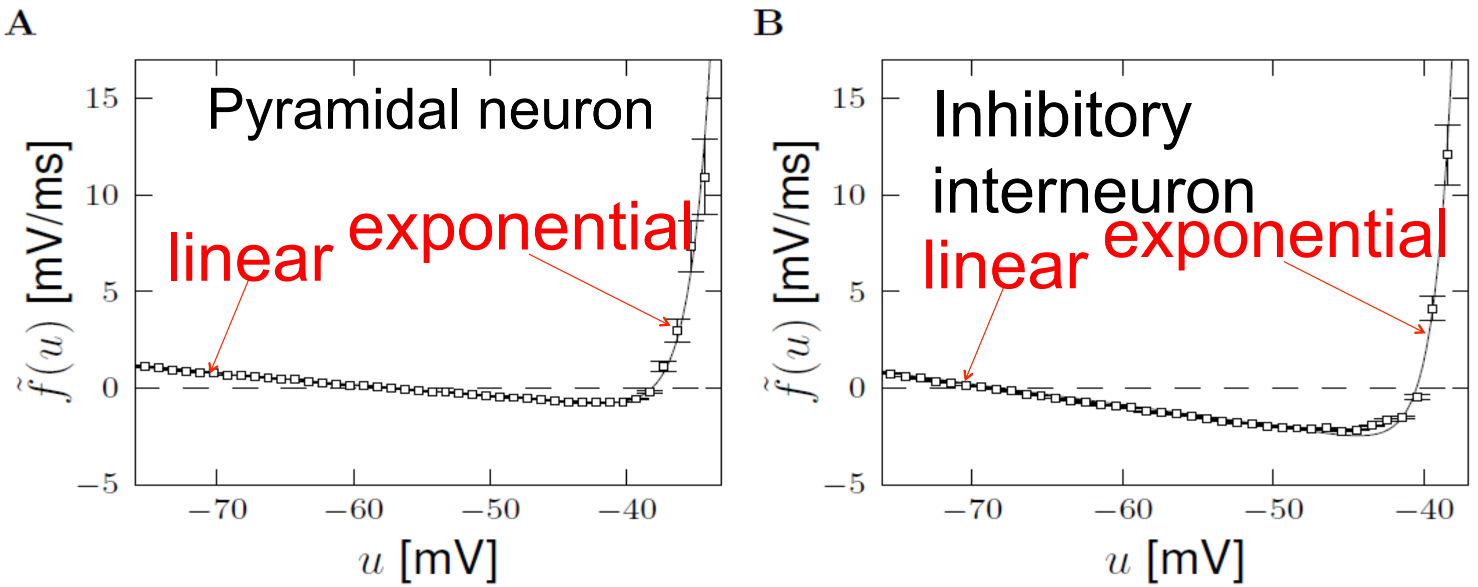
(ii) Extract *f* from data *Badel et al. (2008)*

$$\tau \frac{du}{dt} = f(u) + RI(t)$$

$$\tilde{f}(u) = \frac{f(u)}{\tau}$$

$$\tau \frac{du}{dt} = -(u - u_{rest}) + \Delta \exp\left(\frac{u - \vartheta}{\Delta}\right)$$

Exp. Integrate-and-Fire, *Fourcaud et al. 2003*



Badel et al. (2008)

Neuronal Dynamics – Review: Nonlinear Integrate-and-fire

$$(1) \quad \tau \frac{du}{dt} = f(u) + R\,I(t)$$

$$(2) \quad If \;\; u = \theta_{reset} \;\; then \;\; reset\,to\; u = u_r$$

Best choice of ***f*** : linear + exponential

$$\tau \frac{du}{dt} = -(u - u_{rest}) + \Delta \exp\left(\frac{u - \vartheta}{\Delta}\right)$$

BUT: **Limitations – need to add**

- -Adaptation on slower time scales
- -Possibility for a diversity of firing patterns
- -Increased threshold ϑ after each spike
- -Noise

Neuronal Dynamics – Quiz 7.1.

The exponential integrate-and-fire model

[ ] can be extracted from data

[ ] can be extracted from two-dimensional neuron model under the assumption of a separation of time scales

[ ] has a linear and an exponential term in the voltage equation

[ ] accounts for adaptation

[ ] accounts for bursting