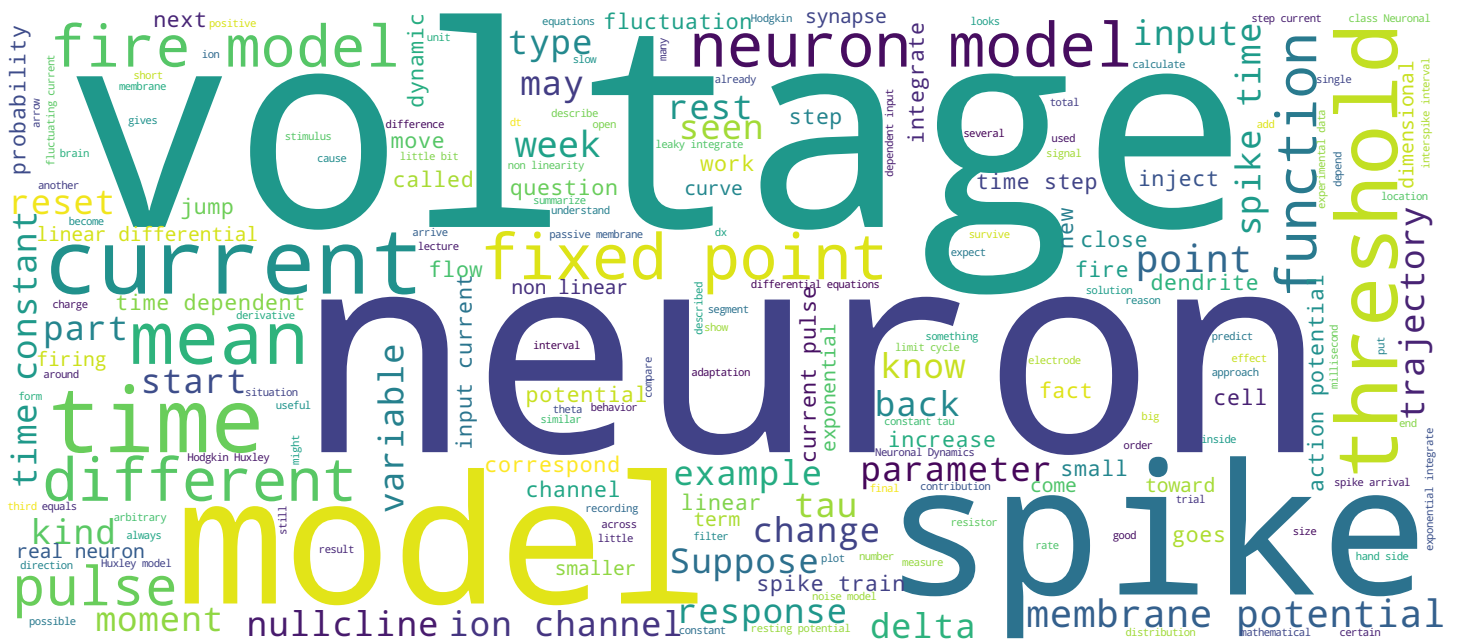


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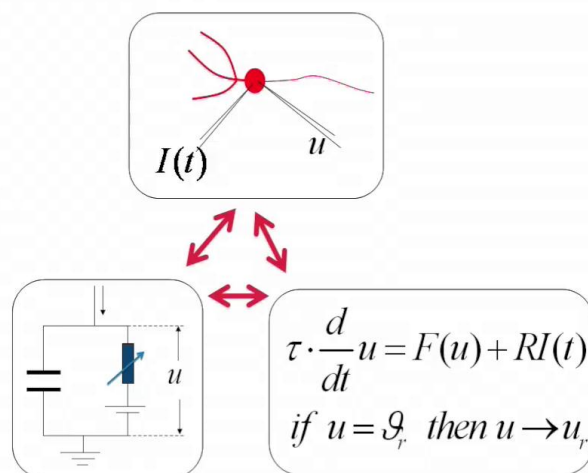
- Neuron models and experiments



EPFL



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



Welcome back. This is the final lecture of this first week of the class Neuronal Dynamics. In the previous lectures, we have discussed quite a bit of mathematics. We looked at linear differential equations as a model of a passive membrane. We added a threshold. Made a model non-linear. Still, it's a non-linear model. It's a simple model. With all this mathematical effort, what can we buy? Is it any good? Has this anything to do with neuroscience? Can we compare the model to experimental data?

Notes

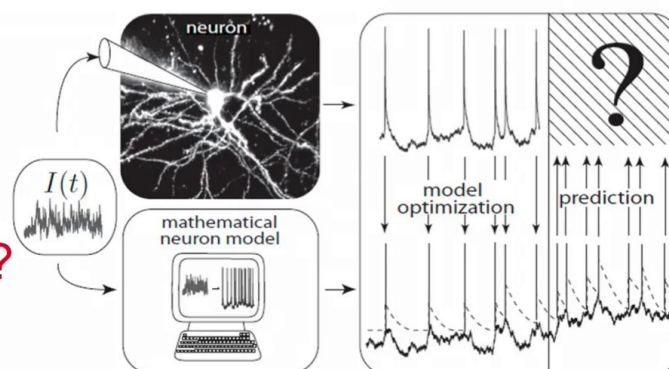
Summary



0m 06s

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?

So ideally, from a model of this kind, I would expect that if I inject a current into a real neuron, I can record the response. And I can use the response to optimize the parameters of my mathematical neuron model. But then the model should be good to make predictions. To predict for a new input current, a time-dependent input current, what's going to be the future? What's going to be the output of my real neuron? So what is a good neuron model?

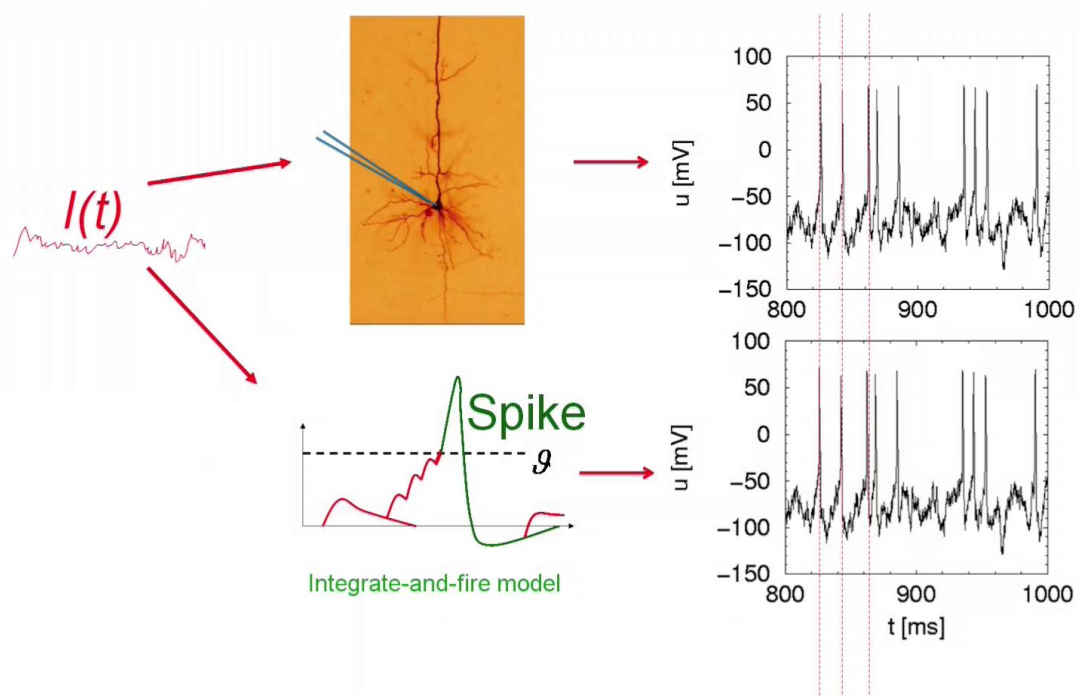
Notes

Summary



0m 42s

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



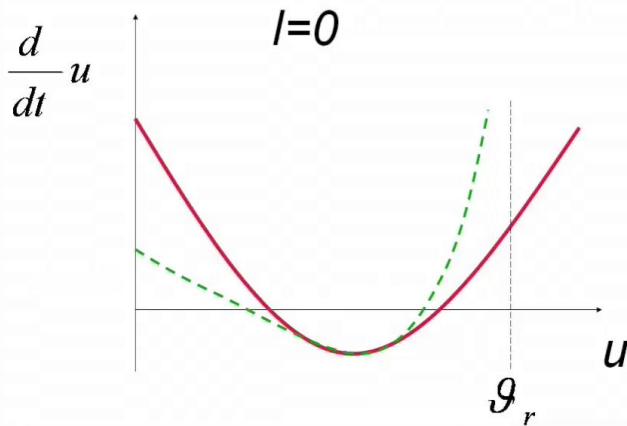
A neuron model, ideally, if I inject the same current into a real neuron and into my neuron model-- say, integrate-and-fire model, I would like the model to predict the spike times correctly, spike by spike. Now in this plot, it seems to work. The reason is, well, I just used copy and paste. But how would that work for a real integrate-and-fire model?

Notes

Summary



Nonlinear Integrate-and-fire Model



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

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

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

Quadratic I&F:

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

exponential I&F:

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

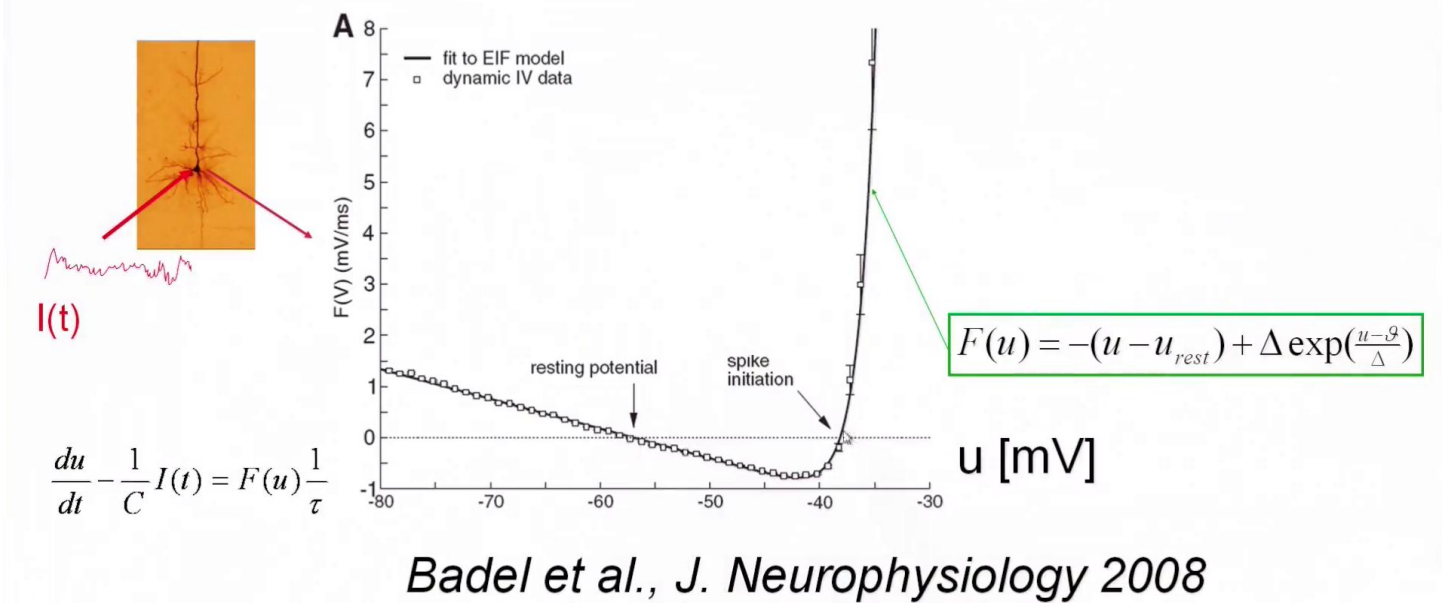
Well the first question is, what would be a good integrate-and-fire model? What's the right type of non-linearity? We have seen, as an example of a non-linear neuron model, the quadratic integrate-and-fire models, but we've also seen the exponential integrate-and-fire model. Can we measure the non-linearity? What is the correct form of the function F , if we compare with experimental data?

Notes

Summary



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



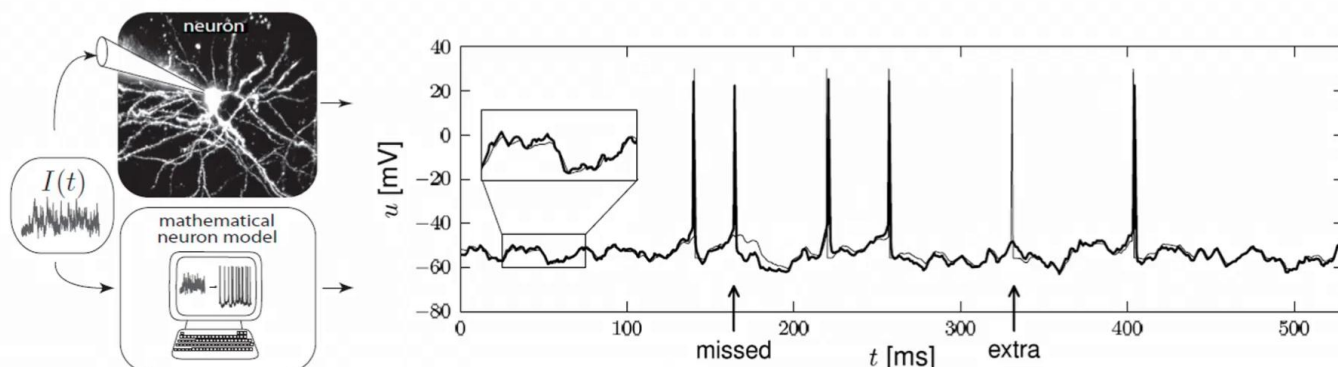
Now it's possible to do this. So in recordings of neurons in a slice, it's possible to inject a time-dependent current. It's a fluctuating current like we would expect a neuron to receive in an in vivo situation. So this fluctuating current is injected in the neuron with the first electrode. And with a second electrode, the voltage is recorded. Now since you know the current and since you know the voltage, you can essentially extract the function F of u , over many, many data points. And this is what it looks like. What you see is that this function has a linear part, and then it rises quickly. And it can be described fairly accurately by a linear term plus an exponential term. In other words, the non-linearity of the exponential integrate-and-fire model seems to be the correct one for this model. From the plot, one can identify the resting potential and the spike initiation point.

- Notes

Summary



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



Now how good is this model at performing in the task that we set ourselves? Well, here's a comparison. The neuron model and the real data. That real data is the thick line, the neuron model is the thin line. And you see that while the neuron stays in the subthreshold regime, the model captures the trajectory quite accurately. Moreover, many of the spike times occur at the correct moment. There are a few missed spikes, there are a few extra spikes. But overall, about 90% of the spike times, of the predictable spike times, can be predicted by this type of neuron model.

Notes

Summary



3m 26s

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



Nonlinear integrate-and-fire models
are good

Mathematical description $\rightarrow$ prediction

Need to add

- adaptation
- noise
- dendrites/synapses

Therefore, the symbol neuron models that we have studied in this first week are useful. It's useful to invest time into the mathematical development in order to arrive at mathematical models. The mathematical models will allow us to predict spike times of neurons. They'll allow us to model the fluctuations of the membrane potential in the presence of a time-dependent input current. However, such a simplified model is not sufficient. We may want to add adaptation. We may want to add noise. We may want to describe additional effects at the synapses and at the dendrites. Or we may want to add biophysical detail to the model. And this is the plan for the next few weeks.

Notes

Summary



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

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Notes

Summary



5m 01s