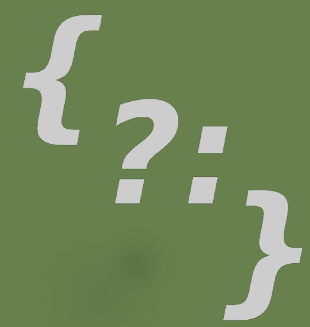
Neural Modeling and Computational Neuroscience

Claudio Gallicchio



General Info

- Solve all the assignments and put all the required files into a zipped folder including one subfolder for each laboratory.
- The subfolder for this lab should be called “LAB1”
  - Matlab/Python scripts & the other requested files
- Bonus track assignments?
  - those who finish early
  - not formally required for completing the Lab Assignment

Supporting Material

You will find a list of supporting materials.

For this assignment (Lab1)

- E.M. Izhikevich, "Simple model of spiking neurons." IEEE Transactions on neural networks 14.6 (2003): 1569-1572. Available online at: http://izhikevich.org/publications/spikes.pdf
- E.M. Izhikevich, "Which model to use for cortical spiking neurons?." IEEE transactions on neural networks 15.5 (2004): 1063-1070. Available online at: http://izhikevich.org/publications/whichmod.pdf
- Web page: http://izhikevich.org/publications/whichmod.htm

Supporting Material

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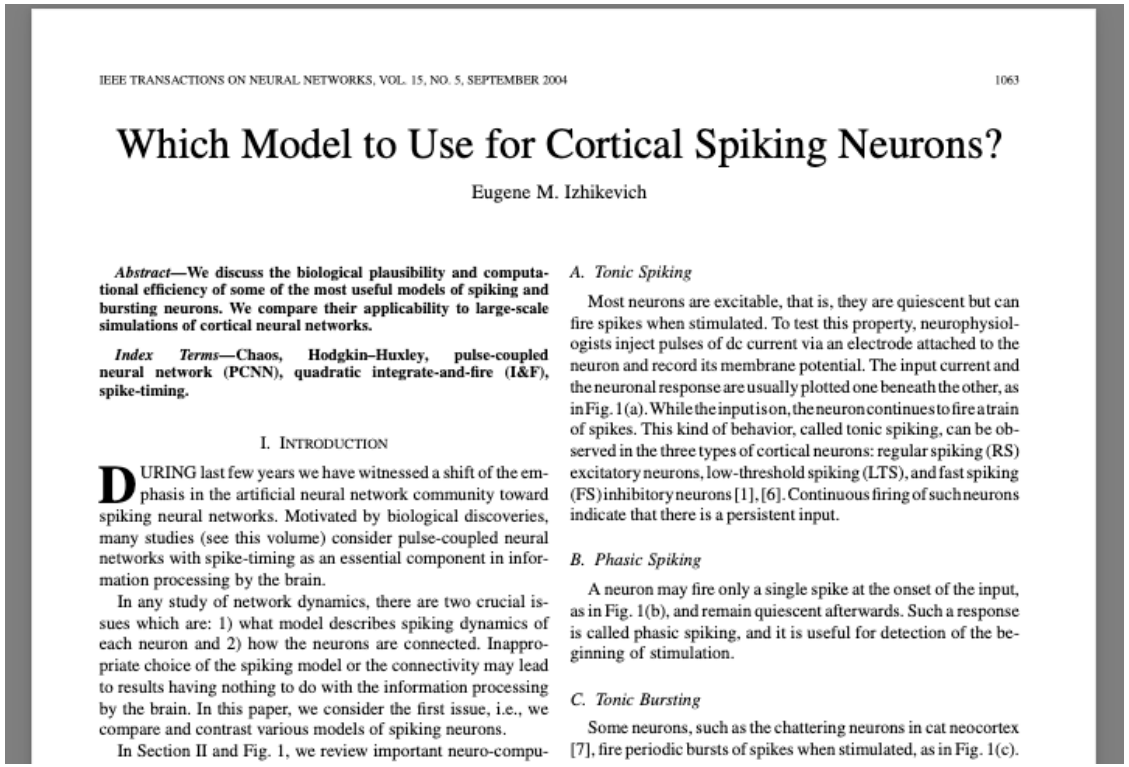
For this assignment (Lab1)

- MATLAB documentation - MATLAB User's Guide https://www.mathworks.com/help/index.html
- MATLAB onramp https://matlabacademy.mathworks.com/?s_tid=getstart_mlacad
- MATLAB documentation using the help command
- *…other supporting material in Python*

In a Nutshell

Implement all the 20 neuro-computational features using the Izhikevich model

Additional Material



IEEE TRANSACTIONS ON NEURAL NETWORKS, VOL. 15, NO. 5, SEPTEMBER 2004 1063

Which Model to Use for Cortical Spiking Neurons?

Eugene M. Izhikevich

***Abstract*—We discuss the biological plausibility and computational efficiency of some of the most useful models of spiking and bursting neurons. We compare their applicability to large-scale simulations of cortical neural networks.**

***Index Terms*—Chaos, Hodgkin–Huxley, pulse-coupled neural network (PCNN), quadratic integrate-and-fire (I&F), spike-timing.**

I. Introduction

DURING last few years we have witnessed a shift of the emphasis in the artificial neural network community toward spiking neural networks. Motivated by biological discoveries, many studies (see this volume) consider pulse-coupled neural networks with spike-timing as an essential component in information processing by the brain.

In any study of network dynamics, there are two crucial issues which are: 1) what model describes spiking dynamics of each neuron and 2) how the neurons are connected. Inappropriate choice of the spiking model or the connectivity may lead to results having nothing to do with the information processing by the brain. In this paper, we consider the first issue, i.e., we compare and contrast various models of spiking neurons.

In Section II and Fig. 1, we review important neuro-computational properties of biological spiking neurons. Shown are simulations of the same model (1) and (2), with different choices of parameters. Each horizontal bar denotes a 20-ms time interval. The MATLAB file generating the figure and containing all the parameters, as well as interactive matlab tutorial program can be downloaded from the author's website. This figure is reproduced with permission from www.izhikevich.com. (Electronic version of the figure and reproduction permissions are freely available at www.izhikevich.com).

A. Tonic Spiking

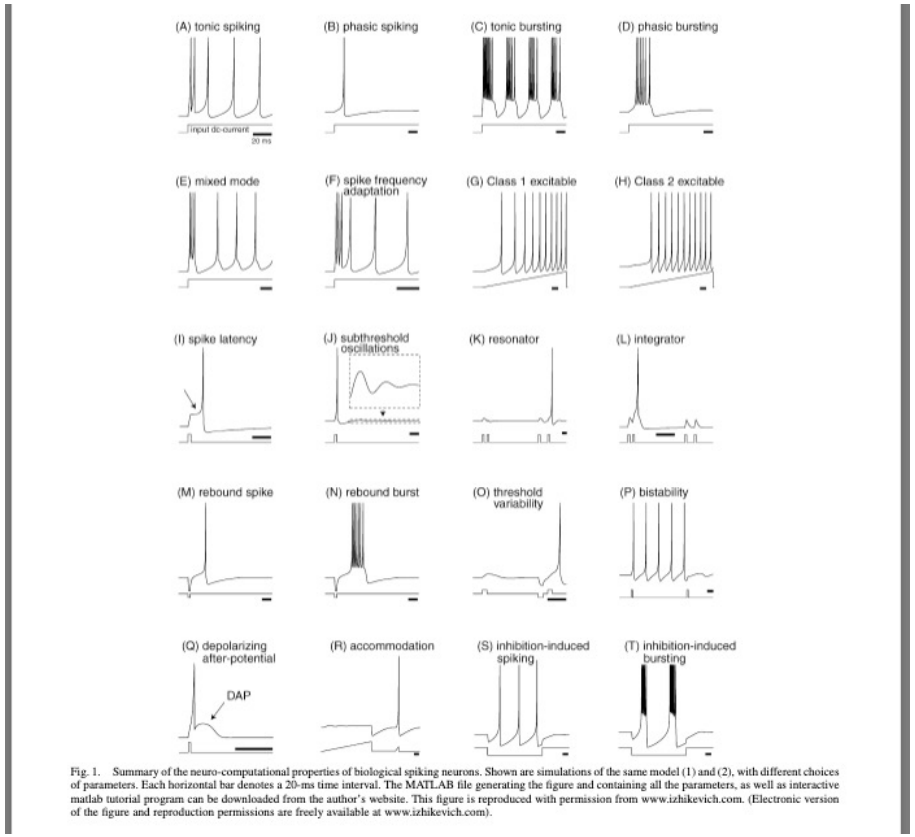
Most neurons are excitable, that is, they are quiescent but can fire spikes when stimulated. To test this property, neurophysiologists inject pulses of dc current via an electrode attached to the neuron and record its membrane potential. The input current and the neuronal response are usually plotted one beneath the other, as in Fig. 1(a). While the input is on, the neuron continues to fire a train of spikes. This kind of behavior, called tonic spiking, can be observed in the three types of cortical neurons: regular spiking (RS) excitatory neurons, low-threshold spiking (LTS), and fast spiking (FS) inhibitory neurons [1], [6]. Continuous firing of such neurons indicate that there is a persistent input.

B. Phasic Spiking

A neuron may fire only a single spike at the onset of the input, as in Fig. 1(b), and remain quiescent afterwards. Such a response is called phasic spiking, and it is useful for detection of the beginning of stimulation.

C. Tonic Bursting

Some neurons, such as the chattering neurons in cat neocortex [7], fire periodic bursts of spikes when stimulated, as in Fig. 1(c).



Izhikevich, Eugene M. "Which model to use for cortical spiking neurons?." *IEEE transactions on neural networks* 15.5 (2004): 1063-1070.

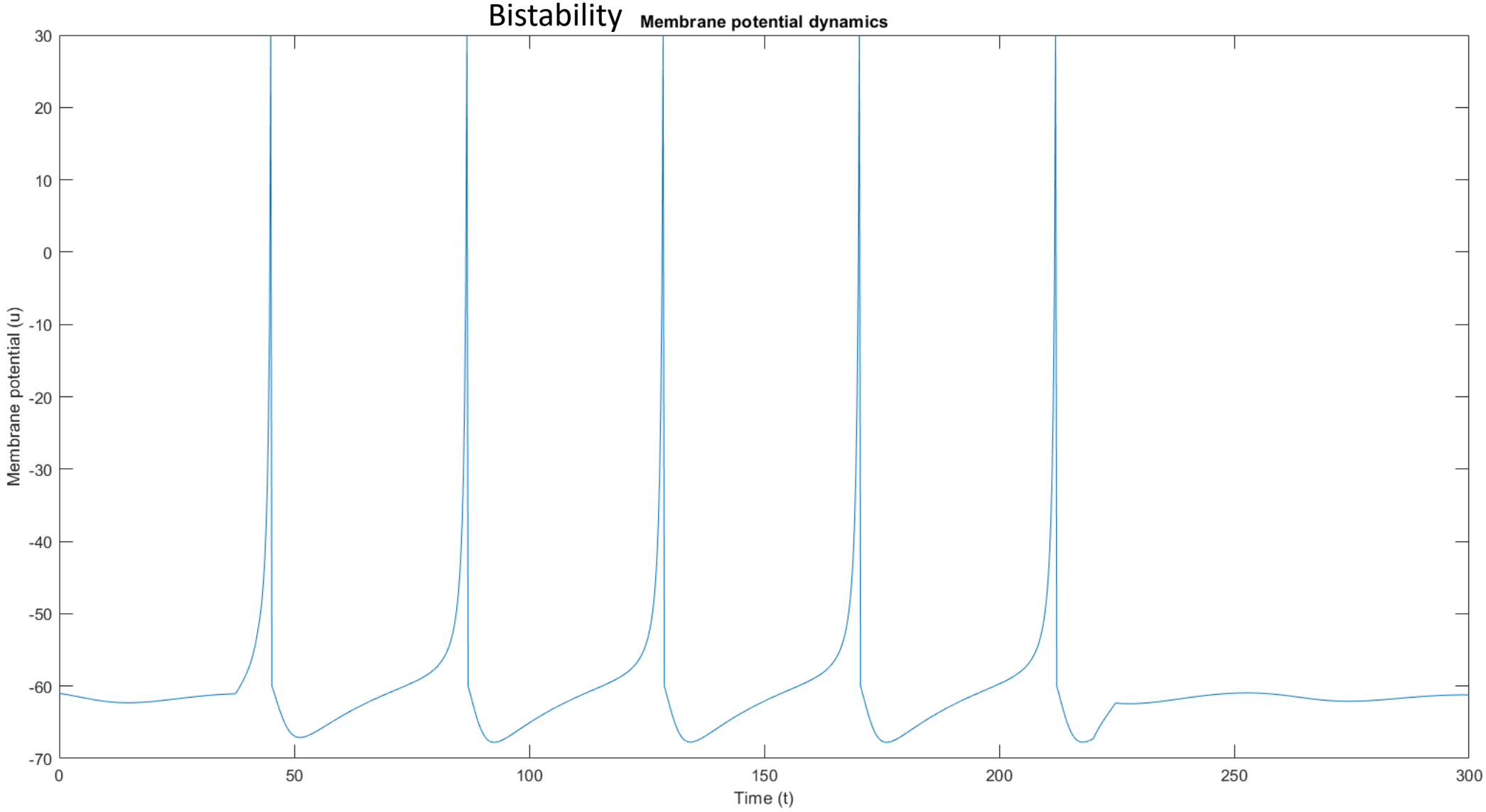
Additional Material

The values of the Izhikevich's model parameters and the shape of the input in all the cases are provided in:

http://izhikevich.org/publications/figure1.m

Do not copy/paste it! But use it!

Bistability



Bistability **Phase portrait**