

Comparison of Simulated Extracellular Spikes from Pyramidal Neurons and Interneurons

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Master Thesis Presentation

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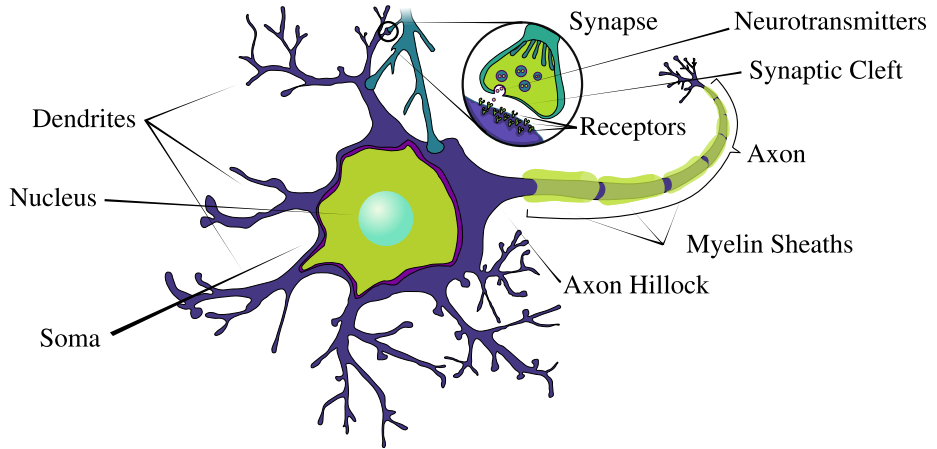
Topic and Motivation

Topic: Differentiate 2 types of neurons, pyramidal neurons and interneurons, based on extracellular spike shape using computer modelling.

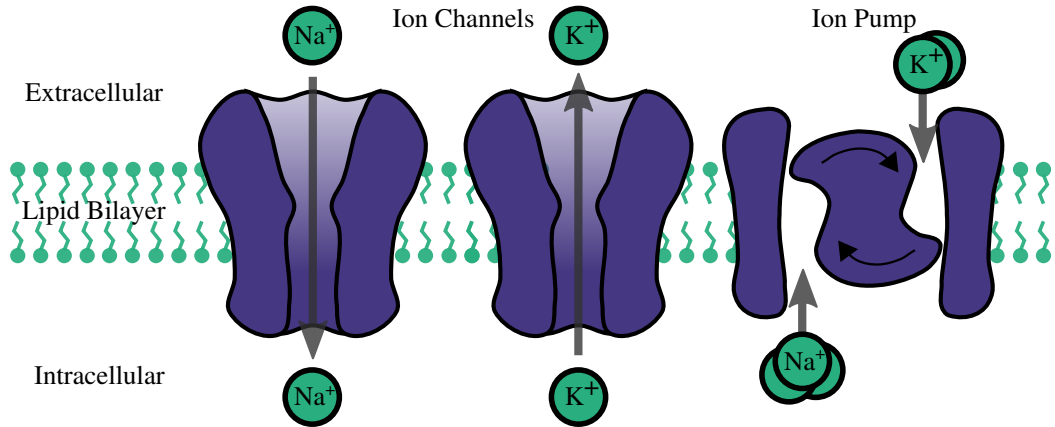
Motivation:

- ▶ Neurons of different types have different functions. Classifying them is important.
- ▶ Some neurons have shorter spikes than others.
- ▶ Electrodes only record electrical potential, they listen in the "dark".
- ▶ There has been debate whether using spike width can reliably classify neurons.

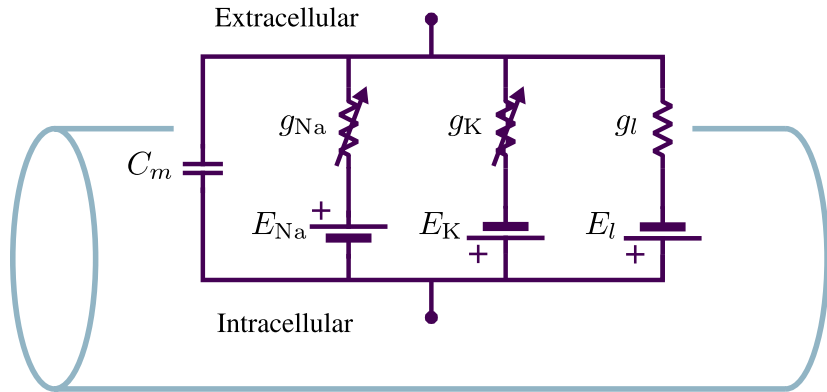
Theory: What are Neurons



The Neuron Membrane



The Membrane Equivalent Circuit: Hodgking and Huxley

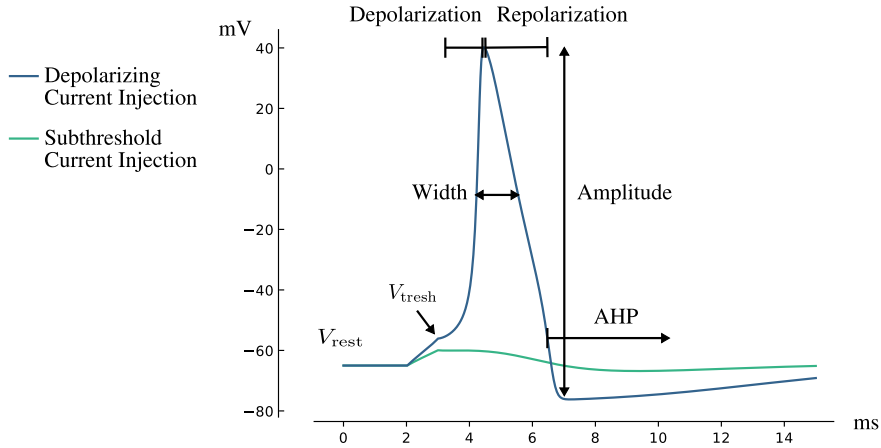


Action Poential: Toilet Model

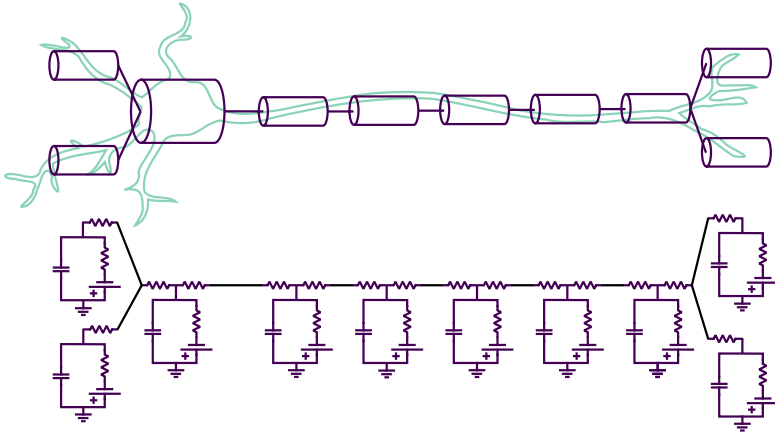


- ▶ Flushing requires a "strong" push on the button.
- ▶ Too little and water will only trickle down.
- ▶ When flushed, the intensity is the same every time.
- ▶ After a flushing there is a recovery period before we can flush again.

Action Potential: Anatomy

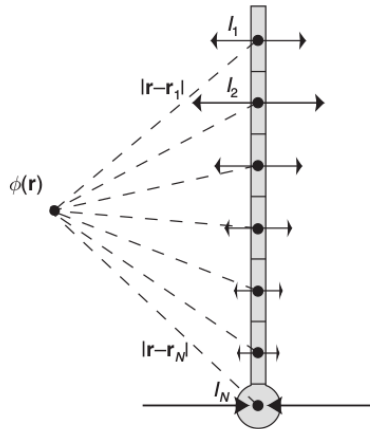


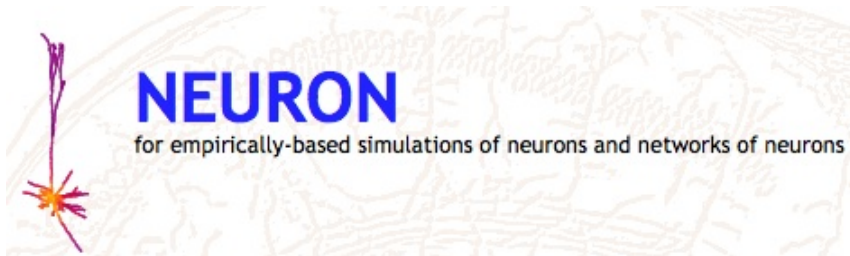
Multicompartmental Models



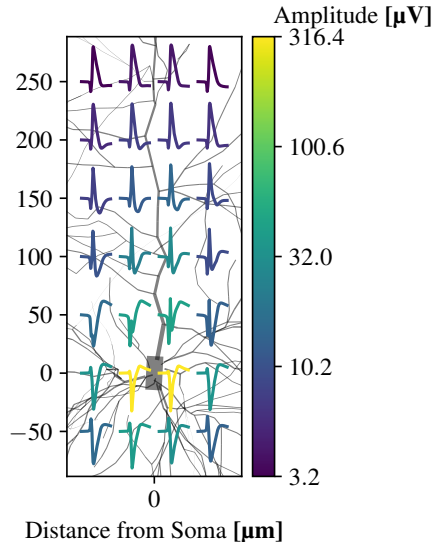
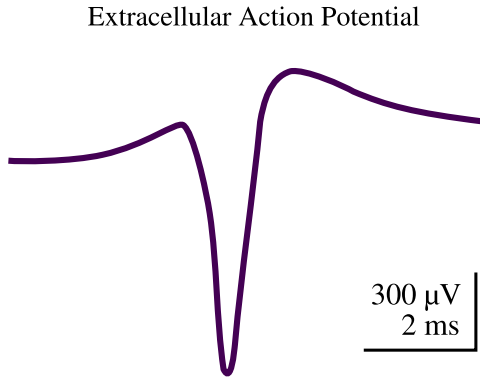
Extracellular Action Potentials (EAPs)

$$\phi(r, t) = \sum_{n=1}^N \frac{1}{4\pi\sigma} \frac{I_n(t)}{r_n}$$

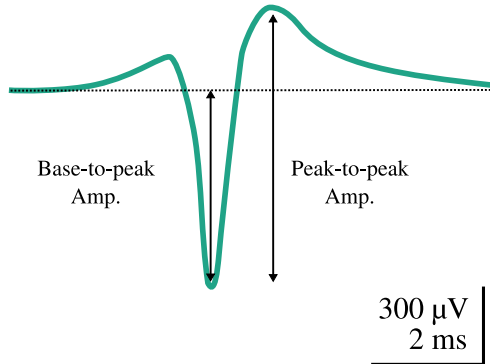
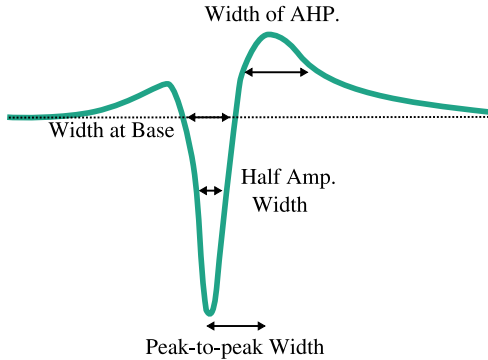




EAPs Vary in Shape and Amplitude



Spike Width Definition

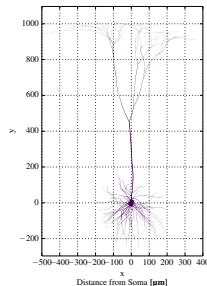
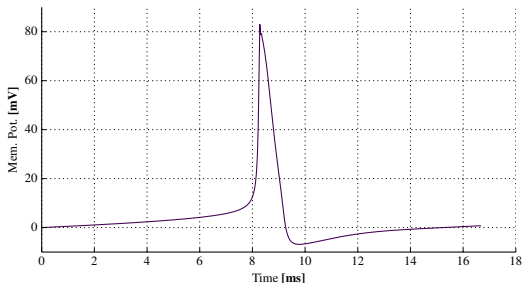


Results Part I: Model Validation

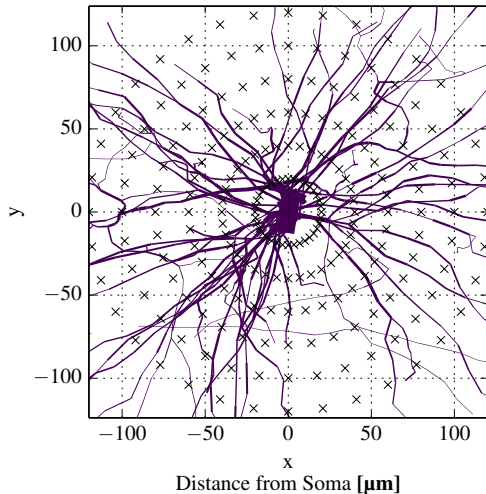
Goal: Reproduce spike width and amplitude at increasing distance from soma.

Setup:

- "Play back" an action potential into soma.



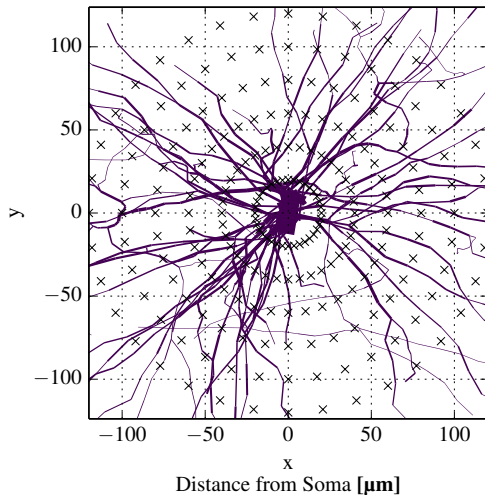
- ▶ Electrodes placed in the same way as the article.
- ▶ Spike width and amplitude measured at every position.



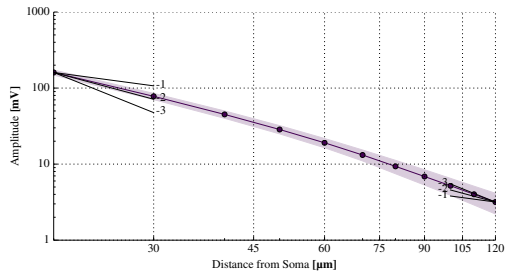
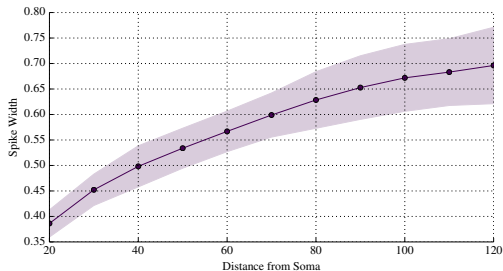
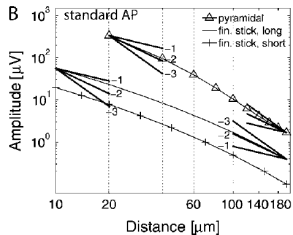
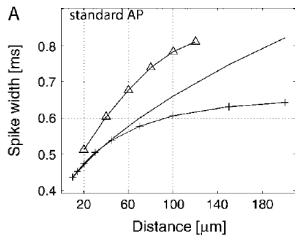
- ▶ Electrodes placed in the same way as the article.
- ▶ Spike width and amplitude measured at every position.

Conclusion:

- ▶ Results are quantitatively similar.

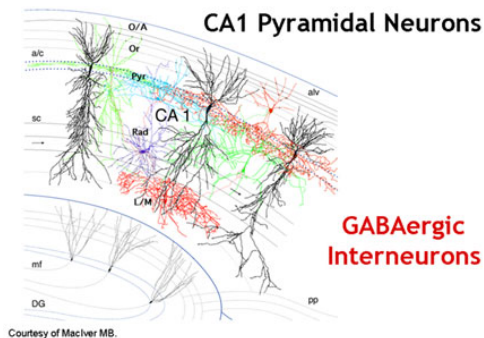


Pettersen and Einevoll 2008



Results Part II: Comparing Pyramidal Neurons and Interneurons

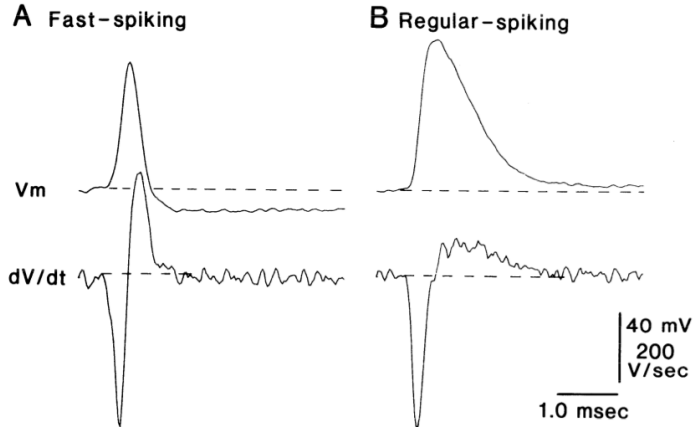
- ▶ Neurons have commonly been classified by shape (morphology) and electrical activity.
- ▶ Pyramidal neuron and interneurons are 2 types based on shape and location.
- ▶ Though the types have also been associated with other properties such as the spike duration and if they excite other neurons or not.



Goal

- ▶ Does computer models show a difference between interneuron and pyramidal neurons.
- ▶ Are certain width and amplitude definitions better suited for differentiation.
- ▶ Can amplitude be used to improve classification.
- ▶ How does filtering effect the results.

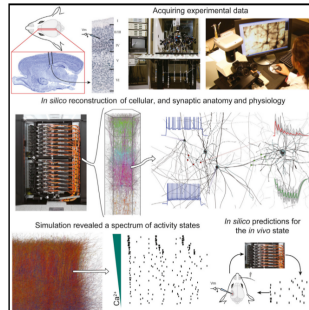
McCORMICK, ET AL.



Cell

Reconstruction and Simulation of Neocortical Microcircuitry

Graphical Abstract



Authors

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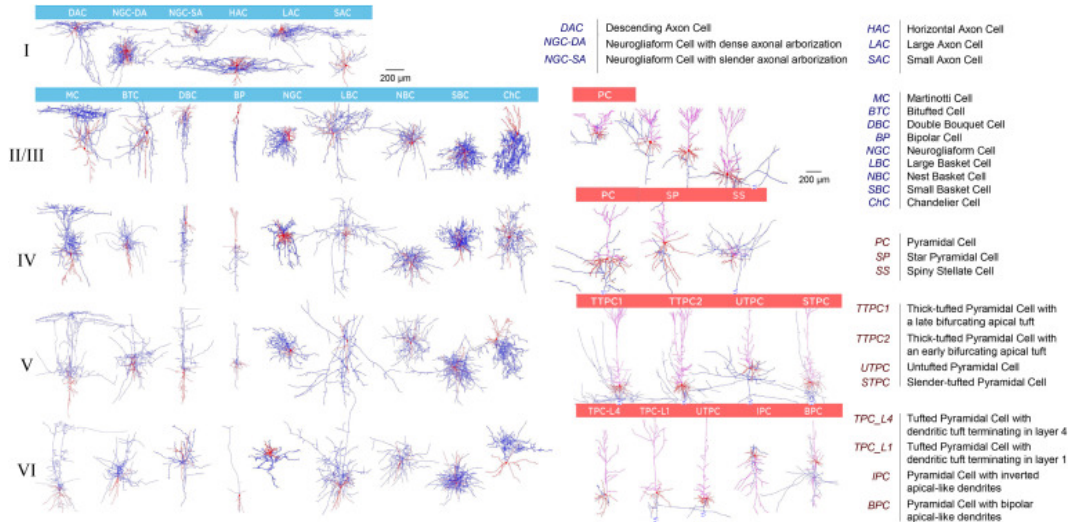
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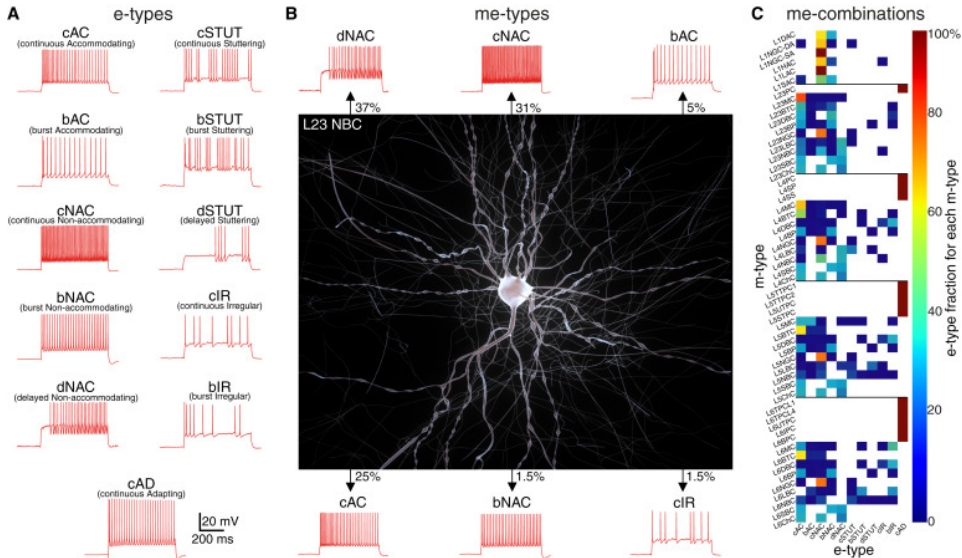
In Brief

A digital reconstruction and simulation of the anatomy and physiology of neocortical microcircuitry reproduces an array of in vitro and in vivo experiments without parameter tuning and suggests that cellular and synaptic mechanisms can dynamically reconfigure the state of the network to support diverse information processing strategies.

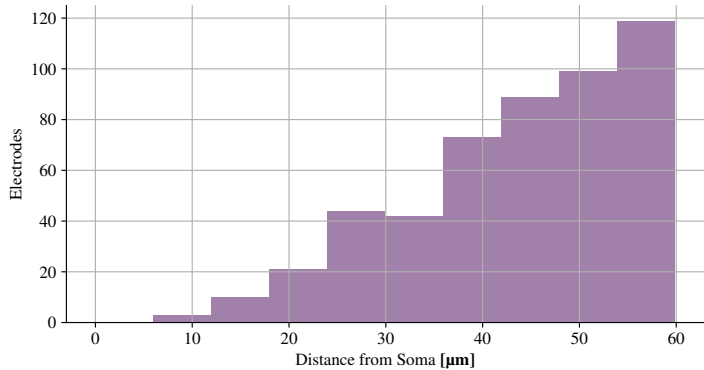
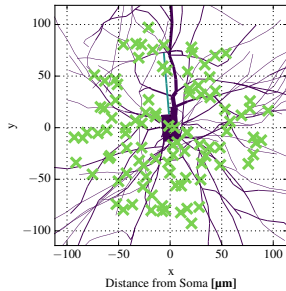
Blue Brain M-types



Blue Brain E-types

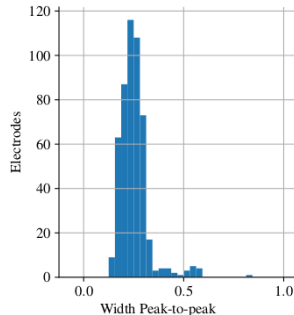


Placing Electrodes

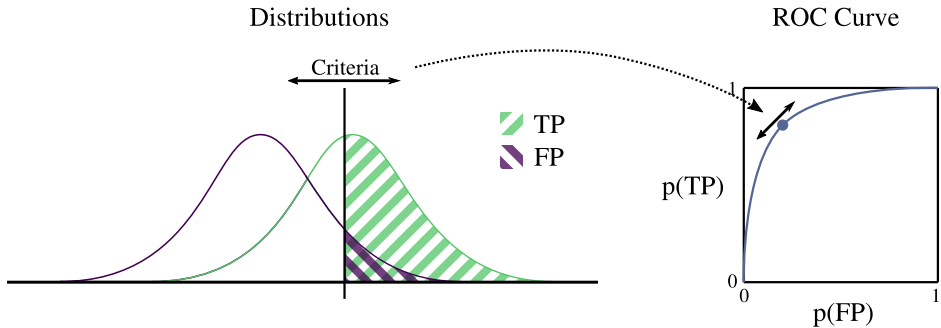


Gather Data

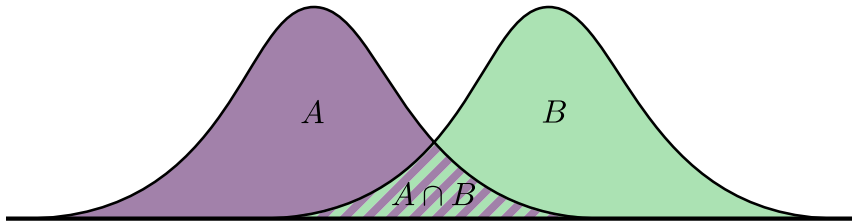
- ▶ 20 pyramidal models and 240 interneuron models.
- ▶ Excite the neurons using a square pulse current.
- ▶ Record spike width and amplitude using all definitions.
- ▶ Binned data into histograms.



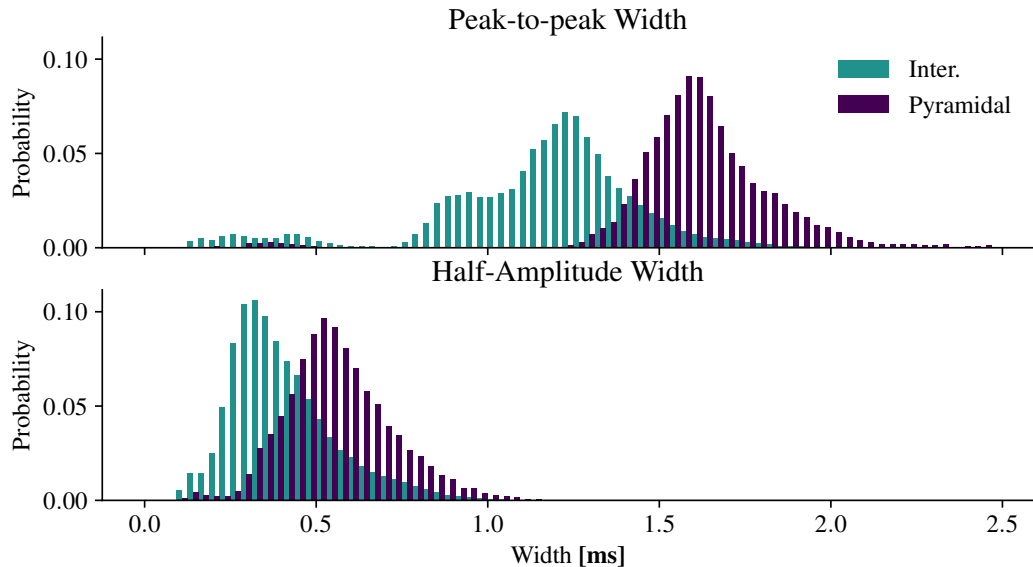
Histogram Comparison: ROC Curve



Histogram Comparison: Overlap

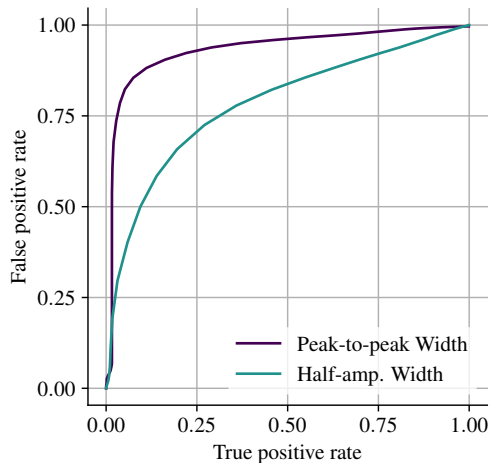


Choosing the Optimal Width Definition

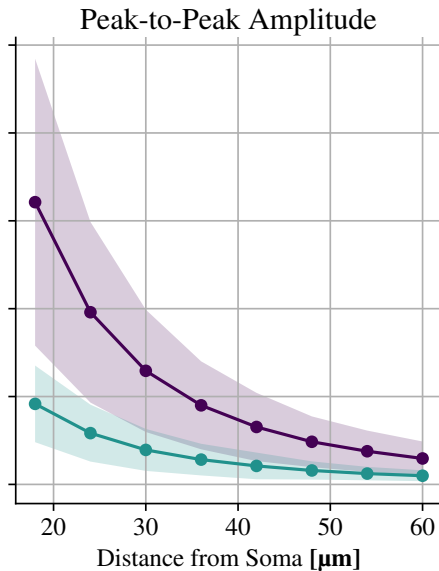
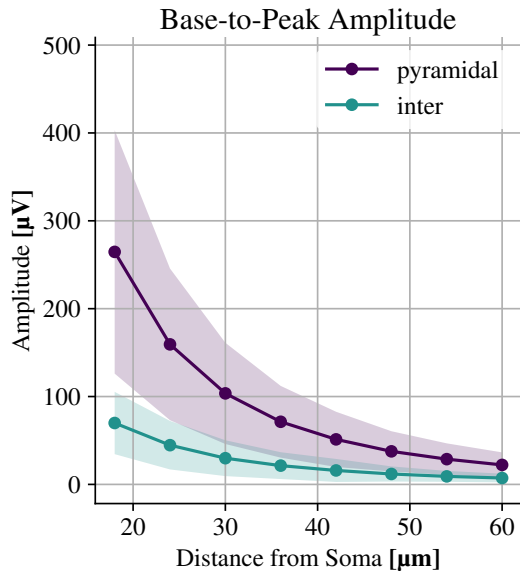


Choosing the Optimal Width Definition

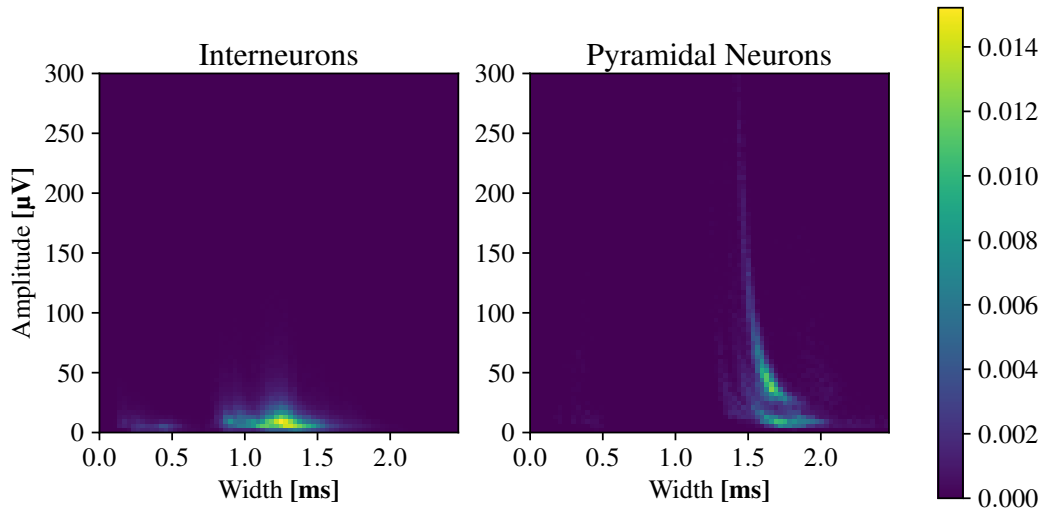
- ▶ ROC area under curve (ROC AUC).
- ▶ ROC AUC Peak-to-peak: 0.94.
- ▶ ROC AUC Half-amp: 0.78.



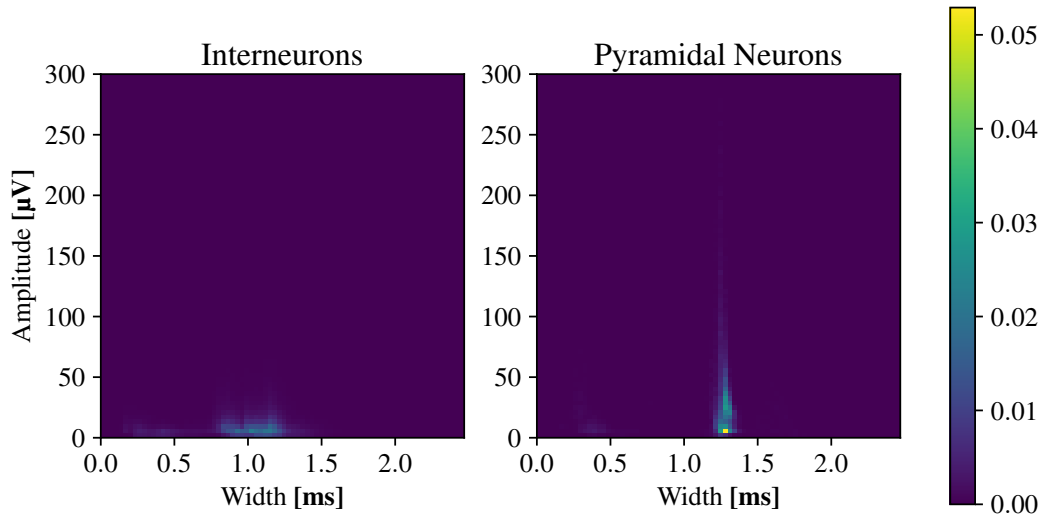
Choosing the Optimal Width Amplitude



Combining Spike Width and Amplitude



Effects of Filtering



Comparison to Other Sources

www.neuroelectro.org:

- ▶ Database of AP data and related properties gather from published articles.
- ▶ Intracellular AP half-amp width (1.20 ± 0.53) ms.
- ▶ Current results found an AP half-amp width of (0.70 ± 0.10) ms.

Anastassiou et al 2015:

- ▶ Measured extracellular and intracellular at the same time.
- ▶ Measured the shape of the AP at increasing firing frequency.
- ▶ Current results did not match in shape or value.

Bartho et al 2004:

- ▶ Measured half-amp and peak-to-peak width.
- ▶ Pyramidal neurons: 0.5 ms - 1.5 ms. Current: >1.5 ms
- ▶ Interneurons: 0.2 ms - 0.4 ms. Current: >0.5 ms

Summary

- ▶ Reproduced Pettersen and Einevoll 2008.
- ▶ Qualitatively similar but not identical.
- ▶ Used models from Blue Brain to compare interneurons and pyramidal neurons.
- ▶ Placed electrodes and gathered data in histograms.
- ▶ Spike peak-to-peak width gave better separation between the types.
- ▶ Using the spike amplitude gave less overlap, suggesting it is a valuable parameter for classification.
- ▶ Separation still possible after filtering, but values are changed.

Conclusion

- ▶ Modelling EAPs is a valuable tool for neuroscience.
- ▶ Supports that spike width can differentiate interneurons and pyramidal neurons.
- ▶ Certain spike width definitions are better suited for classification.
- ▶ Spike amplitude increases separation between interneuron and pyramidal neurons.

Other remarks:

- ▶ Might be possible to designate areas in the amp. width space to certain kinds of neurons.
- ▶ LFPy_util
 - ▶ Can help the workflow of creating and running simulations.
 - ▶ Can be used as a template for creating and sharing simulations.