

# Introduction to Computational Neuroscience

## Practice on Single Neuron Models

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**A request:** Please track how long it will take to complete this set of exercises. Add this time to your final report.

In this session we will have a brief look on three different computational models of a neuron: McCulloch-Pitts, Integrate-and-Fire and Hodgkin-Huxley.

### Exercise 1: Logic gates (1pt)

On the lecture we have seen how to construct AND, OR and NOT logic gates using the the McCulloch-Pitts model of a neuron. Your task is to construct more. Please construct the following two gates:

1. NAND
2. XOR

**Hint 1** For the XOR gate you will need more than one neuron.

**Hint 2** Same input can go simultaneously to several neurons.

### Exercise 2: Integrate and Fire neuron model (2.5pt)

Integrate and Fire neuron accumulates voltage until it reaches the *threshold*. After that it fires and resets voltage back to initial value. In this exercise we will model behaviour of such neuron and study its properties. Follow the instructions in the `integratefire.m` file and report all figures, essential pieces of code, answers, interpretations and conclusions you will make during the work.

**Note** The `TODO` marker will indicate the places where you have to do something: complete the code, plot and report a figure, give an interpretation, etc.

The very final result in this exercise should look something like this

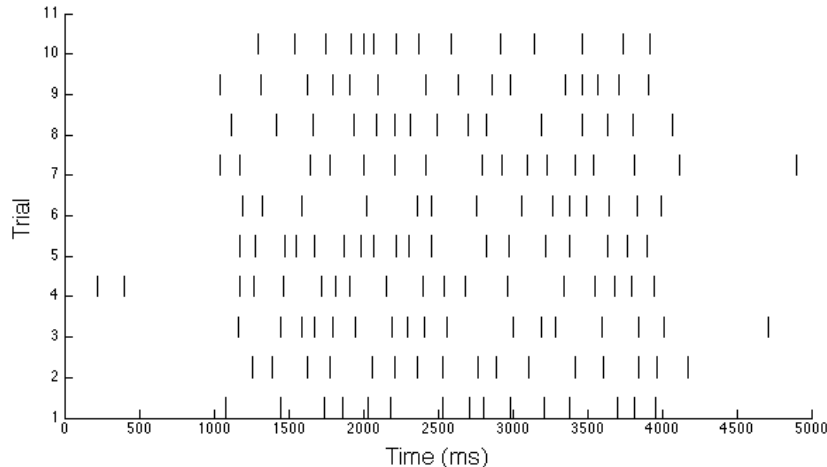


Figure 1: 10 trials of data generated using Integrate-and-Fire neuron model.

### Exercise 3: Hodgkin-Huxley neuron model (1.5pt)

Hodgkin-Huxley model is considered to be the most important computational neuronal model in the neuroscience today. We have the model already implemented in the file `HH0.m`, study it. Follow the instructions in the `hodgkinhuxley.m` file and report all figures, thoughts, interpretations and conclusions you will have during the work.

**Note** The TODO marker will indicate places where you have to do something: complete the code, plot and report a figure, give an interpretation, etc.

### Exercise 4: Integrate and fire with synapses (1pt)

In this exercise we will play with somewhat more realistic version of integrate-and-fire model, which receives input not from constant current as we did before, but from incoming (*presynaptic*) spikes. *Temporal summation* can lead to the voltage reaching the threshold and then the *postsynaptic* neuronal response (firing) occurs. Read the tutorial<sup>1</sup> and study the code given there. Slightly modified code is provided to you in the file `integratefiresynapses.m`. Your task is to come up with three different configurations of spikes on the line 41:

1. Inside the time window from 0 to 200 ms there will be 4 incoming spikes and 1 output spike.
2. Inside the time window from 200 to 400 ms there will be 5 incoming spikes and 0 output spikes.
3. Is it possible to produce 2 output spikes with 5 incoming spikes? If yes, then produce it in time window 400 to 600 ms, if not show the maximal voltages you can achieve with 5 input spikes.

### Exercise 5\*: Simulate memory with $\neg S-\neg R$ latch (bonus 2pt)

In electronics there is a circuit, which can *store* a state. This means that after we *set* it to some state, it will remain there until we *reset* it. The whole thing is called *D latch*, it has a sub-part called *SR latch*, which again has a subpart called  $\neg S-\neg R$  latch.

<sup>1</sup><http://www.dreamincode.net/forums/topic/72868-a-simple-neuron-model-the-integrate-and-fire-neuron>

1. Watch this video <https://www.youtube.com/watch?v=PCT76PsDr6g> (until 12:26)
2. and build  $\neg S\text{-}\neg R$  latch using McCulloch-Pitts neurons.

Please submit a **pdf** report with answers to the questions and comments about your solutions. Include figures, explanations and essential pieces of code. Do not include the code itself as a separate file, your report should give good understanding of what you have done. Please mark how long it took to complete this set of exercises. Upload the **pdf** to the practice session page on the course website.