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, Intergrate-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

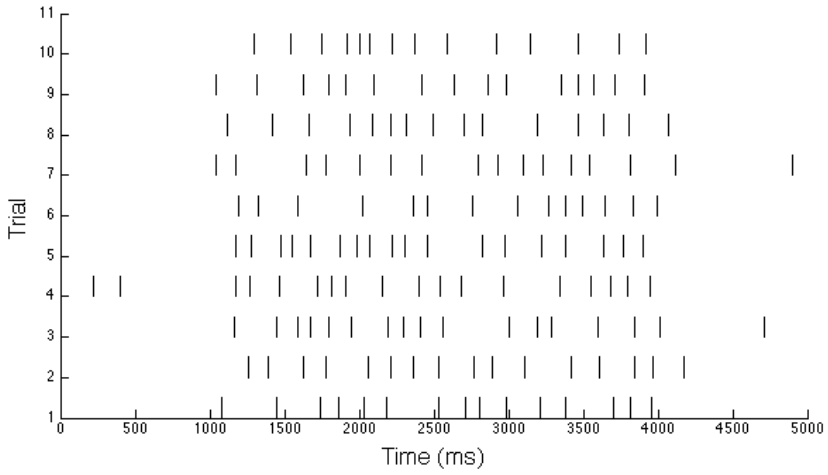

Figure 1: 10 trials of data generated using Integrate-and-Fire neuron model.

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[1] and study the code given there. Slightly modified code is provided to you in the file `integratefiresynapses.m`. Your task is to compe 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 5 incoming spikes and 0 output spikes.
3. Is is 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 X*: 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*.

[1] `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 $\neg S$-$\neg R$ 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.