Neural Networks

Lab assignment 1

The biological neuron

General instructions

Print your report and put it in the box of Neural Networks near 216 in the Bernoulliborg. Also send the pdf including the code by e-mail to neuralnets2018@gmail.com. The assignment is due Thursday 26th of April at 11:00am. You should e-mail just one archive file containing at least your code and your report, so the easiest way of doing this is just to archive all of your files at once. Name it as follows:
s1234567_DonaldTrump_s7654321_SantaClaus.zip.

Introduction

The activity of a neuron is dependent on various factors. For a biologic neuron, the configuration of the ion channels determines the neuron's behavior. This configuration can be modeled with the conductance coefficients: (g_{Na}, g_K, g_{Na}) in the Hodgkin-Huxley equation 1.

$$I_m = C_m \frac{dV_m}{dt} + g_{Na}(V_m - E_{Na}) + g_K(V_m - E_K) + g_{Cl}(V_m - E_{Cl}) \tag{1}$$

This equation was formulated by Alan Lloyd Hodgkin and Andrew Huxley in 1952 and it describes the spiking behavior of the giant squid neuron in terms of the flow of ions. It has been a highly influential model for describing the spiking behavior of neurons ever since.
As early as 1907, the French physiologist Louis Lapicque discovered that the spiking characteristics can be simulated by what is known as an RC-circuit[1]. This is a simple electric circuit consisting of three basic components: the resistor R, the capacitor C, and a threshold-detector θ. This configuration mimics the dynamics of a normal RC-circuit, but as soon as a certain threshold is reached a switch closes and the intra-cellular charge that was built up flows out. This results in an action potential or spike.

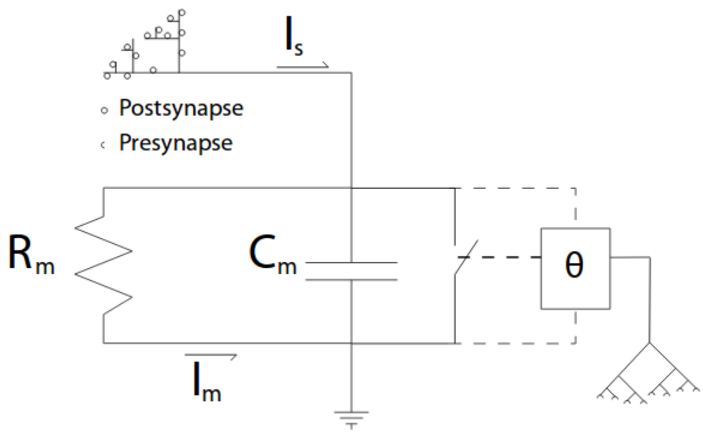

Figure 1: Circuit scheme of the Integrate-and-fire circuit. The capacitor C_m resembles the membrane capacitor of the neuron. The charge builds up here which causes a potential difference on the capacitor overtime. Note that when reaching the threshold the switch closes which causes the membrane charge to reach 0 again.

[1]The original paper from 1907 is written in French, but in the folder for this lab session on Nestor you will find two briefly worded papers in English which you can read for additional theoretical background for this lab assignment

Figure 1 depicts a circuit scheme of the integrate-and-fire neuron. This configuration implies that the charge on the capacitor can be described with the following differential equation 2.

$$\frac{dV}{dt} = \frac{-V + R_{in}I_0}{\tau} \tag{2}$$

Since it is difficult to investigate the behaviour of the neuron from this equation alone, we are going to simulate the Lapicque integrate-and-fire neuron with MATLAB. We are going to look at how the values of the model's parameters affect the spiking behaviour of the integrate-and-fire neuron.

Aim of the assignment

The aim of this assignment is to get acquainted with the MATLAB-environment and to get to know how MATLAB can be used to experiment with neural networks. Additionally, the aim is to get a sense of the error messages in MATLAB what they mean and how you trace and fix your bugs. Please refer to the MATLAB neuroscience tutorial by David Sterratt et al. A pdf-version of this tutorial can be found on Nestor.

Assignment

This part of the assignment is to implement the integrate-and-fire neuron from the neuroscience tutorial `matlab-neuro.pdf`. This neuron is covered in section 4 through 6 of the tutorial. Our artificial integrate-and-fire neuron captures the factors that influence the behavior in 3 parameters: tau, theta, and Rin. A straightforward way to study the influences of these parameters is by conducting a *parameter sweep*. This means that you run the simulation for a number of times in which you vary one of the parameters while keeping the others constant. Look at how the plots differ and also elaborate on the intervals d in the tutorial. Use the `noisyifneuron` to perform the experiments.

What to hand in

For this assignment you have to hand in the following:

1. Write a report in which you address the influence of tau, Rin and theta on the activity of the neuron. You should perform a parameter sweep in which you vary each parameter with a low/medium/high setting. Report the mean spike interval time for each setting. Use the `isi` function to measure this. Explain how your experiment was set up, which parameters were addressed, and what you can conclude from your results. Relate your results to the interaction between variables in equation 2.

2. Use plots (different colors) to clarify your discussion of interesting spiking behaviors. Please add corresponding legends, captions, titles, and axis labels.

3. Hand in your code (add it to your report by using `lstinputlisting`, see the template report in Nestor). Add clarifying comments to the code and make sure it is easy to understand (this is done using % for a single line comment, or %{ __comment_block__ %} for a comment block).

Tips

- You can plot multiple graphs with the command `hold on`. MATLAB comes with a large and extensive documentation (access via help-menu) along with a lot of examples.

- If you don't like using commands to configure your plots, you can also change them through a GUI. Use the edit-menu in a pop-up plot window to do this.

- If you are stuck at something, do not hesitate to ask for help at neuralnets2018@gmail.com or during the lab sessions.

- We recommend to use LaTeXfor writing your report. To make things easier, we added a template report in Nestor as a zip-file that includes a neat code listing style. Store code files in the *src* folder and your images in the *im* folder to keep your files well organized.