Brain Inspired Computing (SS 19): Exercise sheet 1

Hand in on 24.04.2019, 11:15

Name(s): Group:

Question:	1	2	3	4	Total
Points:	20	30	25	25	100
Score:					

Exercise 1: Brain Power (20 points)

(a) (5 points) Estimate the average energy consumption in the human brain using the approximate numbers given in the course

- per action potential and
- per synaptic event

(b) (5 points) For simulating 1 s in a network consisting of 1.23×10^9 neurons, each with an average firing rate of 1 Hz and an average number of 6×10^3 presynaptic partners, the K supercomputer needs 40 minutes (`http://www.riken.jp/en/pr/press/2013/20130802_1/`). During this time, it consumes 12.6 MW of power. Calculate the energy consumption per spike and per synaptic event of this simulation.

(c) (5 points) Scale up the simulation in b) to the size of the human brain (in terms of both, number of synapses and number of neurons). Assuming one could simply stack K computers to be able to perform this simulation. How much power would they require?

(d) (5 points) Now assume that the energy/flop is constant and that you could magically speed up the K computer to real-time.

How much power would it consume? Compare your result to the output of a typical nuclear power plant in Japan (1780 MW)[1]. How many reactors would you then need?

Exercise 2: Stimulating currents (30 points)

Use the simplified equivalent circuit of a LIF neuron from the course to calculate the effect of various stimulus currents on the membrane potential of a cell. Sketch the results.

(a) (10 points) A Dirac delta function: $I(t) = I_0 \cdot \frac{c_m}{g_l} \delta(t - t_0)$.

(b) (10 points) A step current: $I(t) = I_0 \cdot \Theta(t - t_0)$, where Θ represents the Heaviside step function.

[1] Sendai Nuclear Power Plant, c.f. `https://en.wikipedia.org/wiki/Nuclear_power_in_Japan#Nuclear_power_plants`

(c) (10 points) An exponential current: $I(t) = I_0 \cdot \Theta(t - t_0) \cdot \frac{c_m}{\tau_s g_l} \cdot \exp(-\frac{t-t_0}{\tau_s})$. Later in the lecture, we will discuss why this is a good approximation of the synaptic input current following a spike.

Hint: From your result from c) you should obtain the result from a) in the limit of very short synaptic time constants ($\tau_s \to 0$).

Exercise 3: Introduction to Python (25 points)

Get familiar with python for the course. There are several ways to run python code. You can directly install Python 3 on your computer (c.f. `https://wiki.python.org/moin/BeginnersGuide/Download`), or you can use a online source e.g. google colab notebooks (c.f. `https://colab.research.google.com`).

(a) (10 points) If you have not yet worked with Python, reproduce the first 7 chapters of the Python tutorial `https://docs.python.org/3.7/tutorial/`. (You can omit sections 2.2, 4.7, 4.8, 5.8, 6.4 since they discuss more advanced topics) It is assumed that you successfully solved this task.

(b) (10 points) Implement the Seive of Eratosthenes `https://en.wikipedia.org/wiki/Sieve_of_Eratosthenes`, an ancient algorithm for finding prime numbers.

(c) (5 points) Using your implementation, find the sum of all the primes below two million (`https://projecteuler.net/problem=10`).

Exercise 4: Basic data analysis with Python (25 points)

Use Python to do the following:

(a) (10 points) draw a sample set of 1000 samples from a Gaussian distribution with mean 1.0 and standard deviation 0.5.
(Hint: Use the `numpy.random` package)

(b) (5 points) check the mean and standard deviation of the set
(Hint: Use `numpy.mean` and `numpy.std`)

(c) (5 points) plot a histogram over the set
(Hint: Use `matplotlib.pyplot.hist`)

(d) (5 points) fit a Gaussian to the distribution of the set and compare its moments to those of the original distribution
(Hint: Use `scipy.optimize.curve_fit`)