AXON, BITS Pilani, Goa

Spring’21 Induction Assignment

January 2021

This is the official Assignment for induction into the Neuroscience club of BITS Goa, Axon. Please join our slack channel (link also given on the website) and switch to inductions tab for regular updates and ask general doubts. Please also fill this form to register yourself for the inductions. The last date to submit this assignment is 13th February 11:59:59pm. We encourage you to use Google for help but for specific question doubts please contact anyone from the list of people given at the end of this document.

We do not expect anyone to complete assignment in its entirety but what we would definitely consider is your honest attempt in doing so. Even if you are not able to submit the assignment, ensure that you submit how so much ever work has been done by you because **evaluations will be primarily done on the efforts you have put in**. The assignment is designed in such a way that we don’t expect you to have a very deep knowledge in the field while ensuring that a basic knowledge of the field and a will to explore around will carry you through

The questions of this assignment can be attempted in any programming language of your liking, although we do prefer if you do so in Python3 or MATLAB.

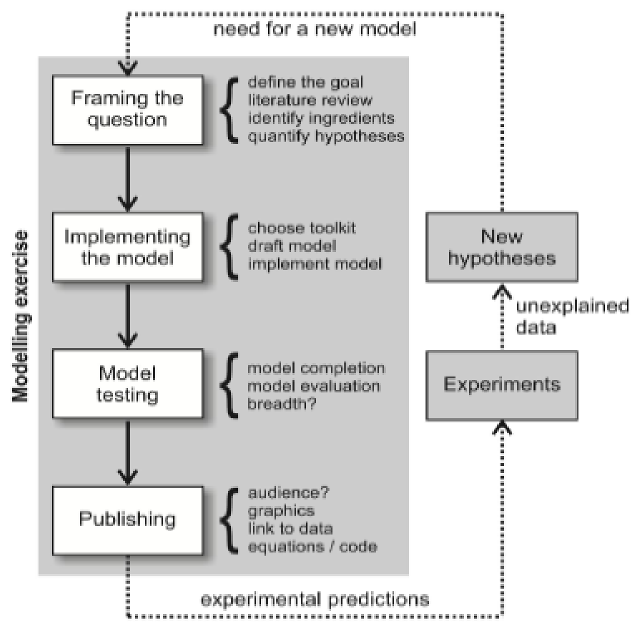
Section 1 of this assignment is compulsory for all, you have a choice to attempt either Section 2, or Section 3 based on your liking.

Please note-: We know that questions may be of unequal difficulty and the same would be kept in mind while the evaluation is being done.

Best of Luck!

Section 1 (Experiment Design and Analysis)

**A recent paper by Gunnar Blohm, Konrad P. Kording, and Paul R. Schrater, titled "A How-to-Model Guide for Neuroscience" (Some notes for this paper), breaks down the process of doing research into 10 practical steps. Although this paper is for Neuroscience, it applies to other fields as well because the steps are not neuroscience specific



Your task is to **break down any new project idea/existing project into these steps** (if needed, you can skip the last step,i.e.,publishing). No code is required (if needed, you can just assume that the code was implemented for steps 7 and 8), only a plan for a project broken down into these steps; however , if you are writing about an existing project, you can provide a link to the code. The project can be anything as long as it is related to Neuroscience. Please assume no constraints on the dataset and computational power, focus on the questions and hypothesis, not on the datasets or feasibility. **There is no word limit, but we would recommend keeping it short and to the point. We want to instill critical thinking. Hence the task is very subjective and has no right or wrong answers.**

If you don't have an existing idea/project can also take inspiration/buildupon/use your knowledge from any one of the other questions in the assignment.

Please go through the paper for an example. Also, note that any new idea that you come up with belongs to you, **we do not store/use/take any credit for it**

**Question Inspired from SAiDL Summer Induction Assignment 2020 [Link]

Follow up question-:

In the previous question, you broke down a research project into various small steps consisting of a modelling exercise and experimental predictions. While being fully aware that this process is a complete loop, let's now focus on a small step - "Experiments".

In this question you'd be asked to come up with a hypothesis of liking, or choose one of the following. (If you choose one of your liking, don't pick it up from a published paper, and be of comparable complexity to one of the example hypotheses). Given you want to test this hypothesis, how would you come up with an experimental setup to do so?

<u>An example hypothesis/goal from pain neuroscience research:</u>

How are "external" pain sensors mapped to brain regions that process it and are these regions different from interoceptors? Pain differs in the following ways, (1) **Exteroceptory pain** - this is an externally verifiable pain - e.g. You touch a hot pan, you'll feel pain, someone else can touch the "same" hot pan to feel a similar sensation of pain and can verify the "source" of the pain for you. (2) **Interoreceptory pain** - e.g. You have a stomach ache, no one else can verify the degree or the source of your pain, but if you feel pain, of course you certainly are in pain. "External pain" can further be broken down into, (1) having a source in the environment and (2) actually experiencing it through interaction with it. In that case it'd also make sense to perform that distinction when mapping to the brain regions, and shed light on how brains generate a cognitive map of anticipated pain regions in an environment.

1) Few obvious questions to ask when coming up with an experiment:
2) Who are the subjects of the experiment? (Humans, mice)
3) What "technique" is best suited for pinpointing brain regions, here?
4) Does your experimental setup facilitate the exploration/movement required by the subject?
5) Will the pain measures be self-reported? (If yes, is your subject capable of doing so, I'm afraid mice will have trouble speaking to you). How would one control for differences in pain tolerance among subjects?
6) Stretch your imagination - Can I use monetary rewards, punishments? virtual reality? motion capture with pain feedback?

Section 2 (Computational Neuroscience)

(Use the numpy library only for this question)

1) Implement a Leaky Integrate and Fire model considering it equivalent to a RC circuit (Refer to section 4.1 of the book Spiking Neuron Models: Single Neurons, Populations, Plasticity) in Python using the libraries numpy and matplotlib. The LIF neuron is modeled using the following equation:

$$\tau \frac{du}{dt} = -u + IR$$

$$u(t^{(f)}) = \nu$$

$$\lim_{t \to t^{(f)}, t > t^{(f)}} = u_{rest}$$

$$u = u_{rest} \ if \ t^{(f)} < t < t^{(f)} + t_{refrac}$$

Values: C = 5 uF, R = 2 KOhm, urest = 0 mV, trefrac = 5 msec, ν = 1 mV

(Hint: See Runge Kutta method)

a. Simulate the model for 100 msec with a suitable timestep. Plot the input current vs. time graph and the membrane potential (u) vs. time graph for when the input current (I)is:

A. I = 1.5uA for 25ms<= t<= 65ms; I = 0Amp otherwise
B. I = 0.75uA for 0ms<= t<= 100ms
C. I = 5sin(ωt) uA {where ω= 75deg/msec}
D. I = -2sin(ω_1t) + 3sin(ω_2t) + cos(ω_3t) uA {where ω_1= 30deg/msec, ω_2= 45deg/msec, ω_3= 60deg/msec}

b. Notice that for steady current, the neuron constantly fires with a frequency vfiring. This is dependent on the input current (I). Show this dependency by plotting the vfiring vs. I curve.

2. Create an Artificial Neural Net (One Hidden Layer) in numpy which computes the XOR of two, 2-bit binary and passes it through a NOT/INVERTER gate. The following table shows the input and outputs. Additionally answer the following questions to show your understanding of ANNs.

1. What would be the minimum number of neurons needed to solve 1 bit XOR ? Justify

2. What are the minimum number of neurons to solve 2 bit XOR + NOT gate ? Justify

3. Show your justification by using the same settings for the ANN as designed above.

4. What happens when the neurons exceed the minimum?

Input Bits of Number 1		Input Bits of Number 2		NOT gate	Output NOT+XOR Bits	
0	0	0	0	0	0	0
0	0	0	0	1	1	1
0	0	0	1	0	0	1
….						
1	1	1	1	1	1	1

Section 3 (Cognitive Neuroscience)

1) A randomized controlled trial compared 12 different variants of a goal setting app, with a control group (which wasn't given the goal setting app). The researcher recruited 50 participants per condition and used RescueTime (an Android/iOS app) to obtain a productivity score for each participant. The resulting data are contained in the attached csv file (first column is the control group). How would you interpret these results?

Hint: Control for multiple comparisons (a potentially useful paper).

2) In an attempt to study the correlation between alpha brain activity and fatigue of an individual, the following experiment was conducted which had EEG data from 20 participants. The data is accessible in both .mat and .csv format here. Perform analysis and interpret the results from the dataset to provide a general trend followed in the same analysis. The demographics of the participants can be found in the same attachments.

Hint: Look for alpha band power in the appropriate of the brain.
Bonus: Go through the literature and suggest better ways to perform fatigue analysis.

Contact Information-:

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