EEE3548 Assignment – H&H Model Simulation (python)

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The reference code of this report can be found here. This is the same Jupyter Notebook file that has been uploaded to LearnUs. Get a copy of the file on Google Drive, then use Google Colab to open it. Run the cell in sequence, it should be working fine.

The "Preparation" section of the jypnb file contains a few testing and noting of mine. In the "Model Buildup" section, we constructed two classes, Model and Sims for lated convenience. The class Model contains 3 gate objects, where the information of m, n, and h are stored, some initial values according to the assignment instruction. The class sims contains a model, and a few lists for data storage. Its method reads a series of input current in a list, then record the data as the time goes. We can read the lists of the class to get the simulation sesult. This structure was inspired by Harden, 2019.

The function setupMod() creates a Model object with input current, then returns the sim object containing the data of simulation. The showMod method read a sim object then visualize the data with a set of graph. We are able to run the simulation easily with these functions.

5-1.

We ran simulation with input current of 2, 6, 10 ($\mu A/cm^2$) and get the result below, from Figure 1 to Figure 3.

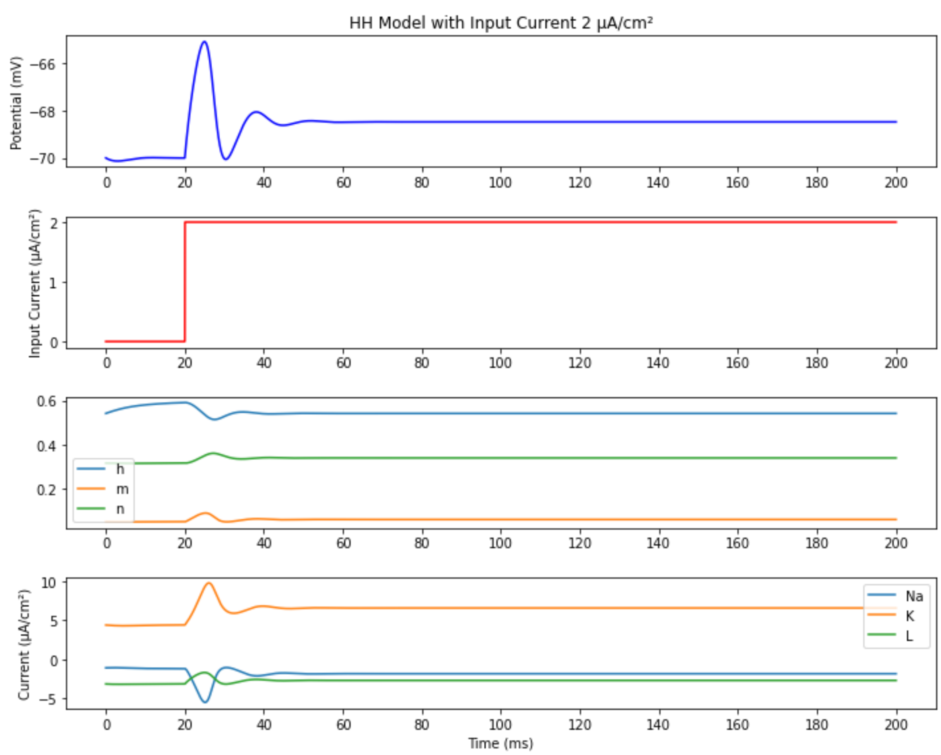

Figure 1. Simulation recult of HH model with input current 2 ($\mu A/cm^2$)

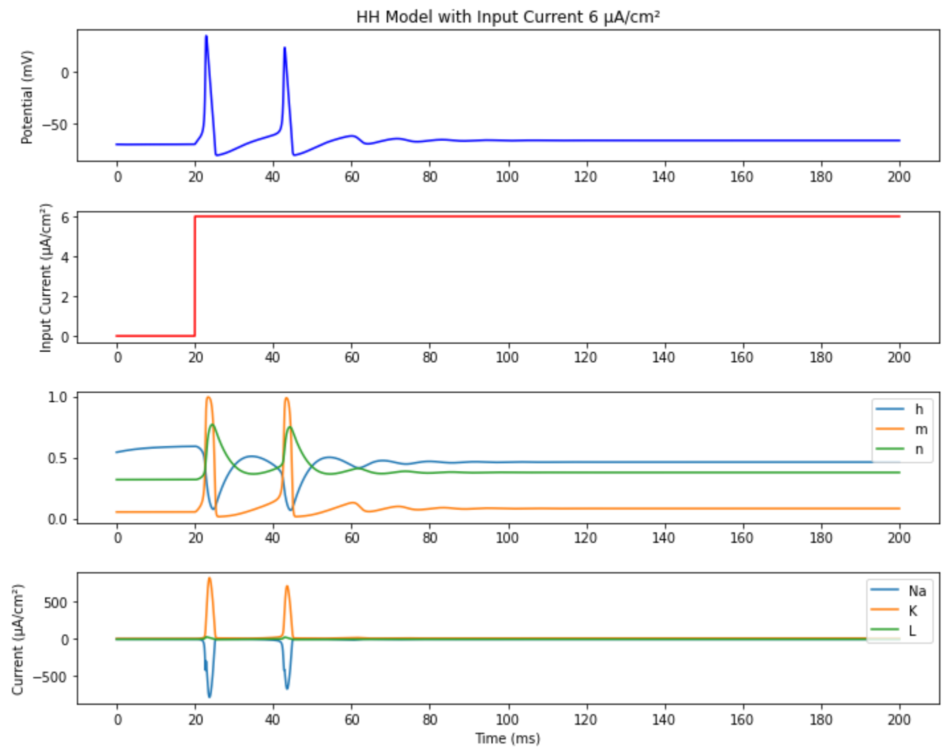

Figure 2. Simulation recult of HH model with input current 6 (μA/cm²)

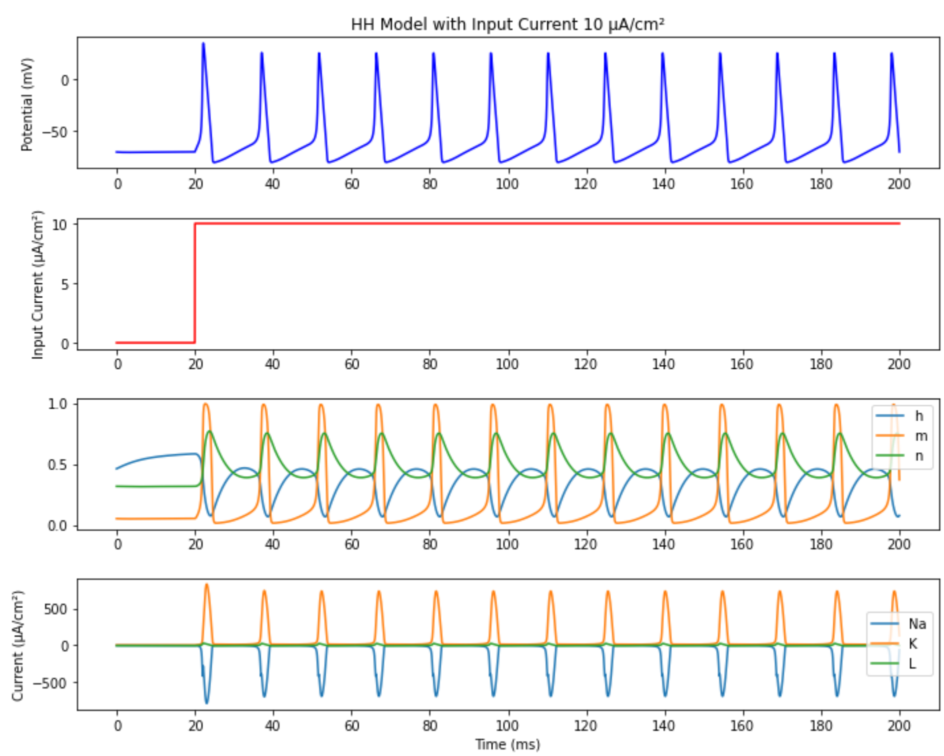

Figure 3. Simulation recult of HH model with input current 10 (μA/cm²)

We can observe that in Figure 1, with input current of 2 (μA/cm²), the potential barwly flucturates, with the peak at around -66mV, which is about 2 mV in difference. With input current of 6 (μA/cm²), it generated a wave with 2 peaks, and faded after the second one. This happens to the Potential, hnm, and the subcurrents. With input of 10 (μA/cm²), it generated a waveform seemingly periodic signal in potential, and so are hnm and subcurrents.

It seems that there is a margin somewhere inbetween 6 and 10 that the signal can be periodic. Out of curiosity, we conducted simulation with infinite approximation of the input, and find that that it falls somewere in between 6.22 and 6.23.

5-2

With the 3 figures above, we can roughly get refractory period of the membrane. With Figure 1, there is only one full period. But with Figure 10, we can get the refractory period by measuring the distance between the 2 peak, and get the value of around 21 ms. With Figure 3, we can measure the average of distance between waveforms and get the value of around 14.58 ms (with average of 12 periods and the total distance of 175). With the result, we can roughly conclude that increasing the input current can result in increasing of freuency, vice versa.

5-3

We modified the function setupMod to change the the value of GNA, reducing the value by fector of 2. With the iuput current 10, it generated the result on Figure 4. Comparing with Figure 3, there is only one peak on the wave on Figure 4.

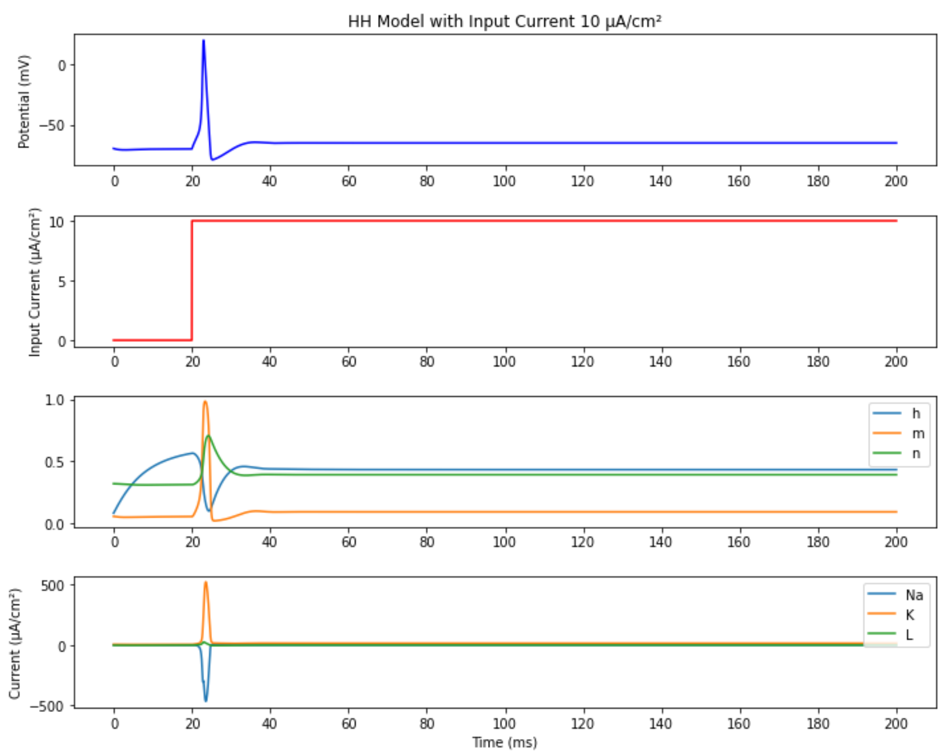

Figure 4. Reduce G_{Na} by factor of 2 with input current 10 (μA/cm²)

5-4

The Goldman-Hodgkin-Katz Equation (Malmivuo and Plonsey, 1995, p89) implies that di/dt = Vm/h, where h is the thickness of the membrane. From this equation, we assume that an increase by a factor of 5 result in a 5 times increasing of current with unchanged potential difference or a 5 times increasing of potential difference with unchanged current.

5-5

We ran the simulation with unified input of 10, with modification on conductance of different channel. As a result, Figure 5, a -30% modification on G_{Na} failed to generate periodic waves, and a +30% modification on G_{Na} result in increacing of frequence, as the period got deduct to around 13.3, (an average of 13 periods with total distance of around 176).

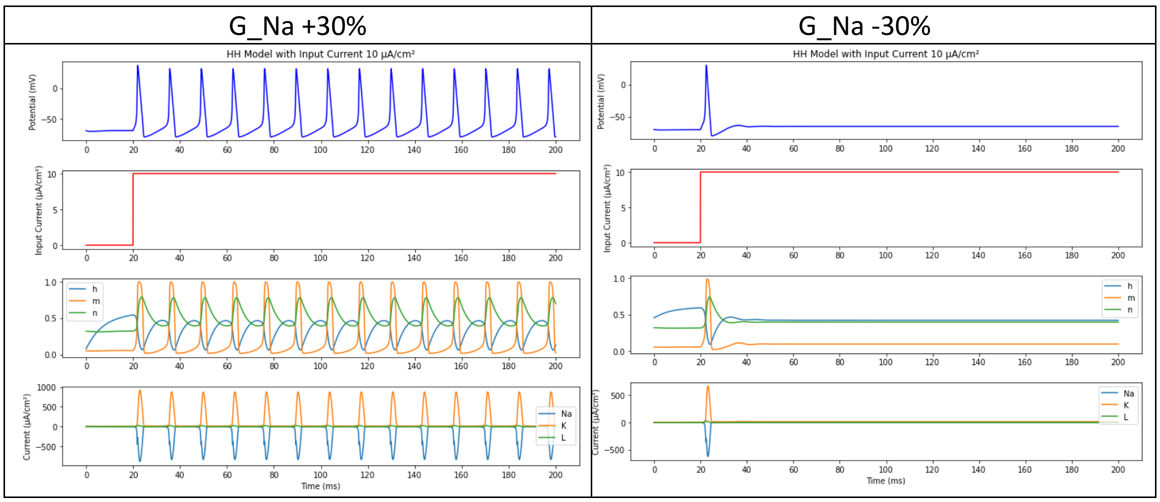

Figure 5, simulation with modified G_Na value

Applied to G_K, Figure 5, a +30% modification on G_{Na} failed to generate periodic waves, and a -30% modification on G_{Na} result in increacing of frequence, as the period got deduct to around 12.8, (an average of 13 periods with total distance of around 166).

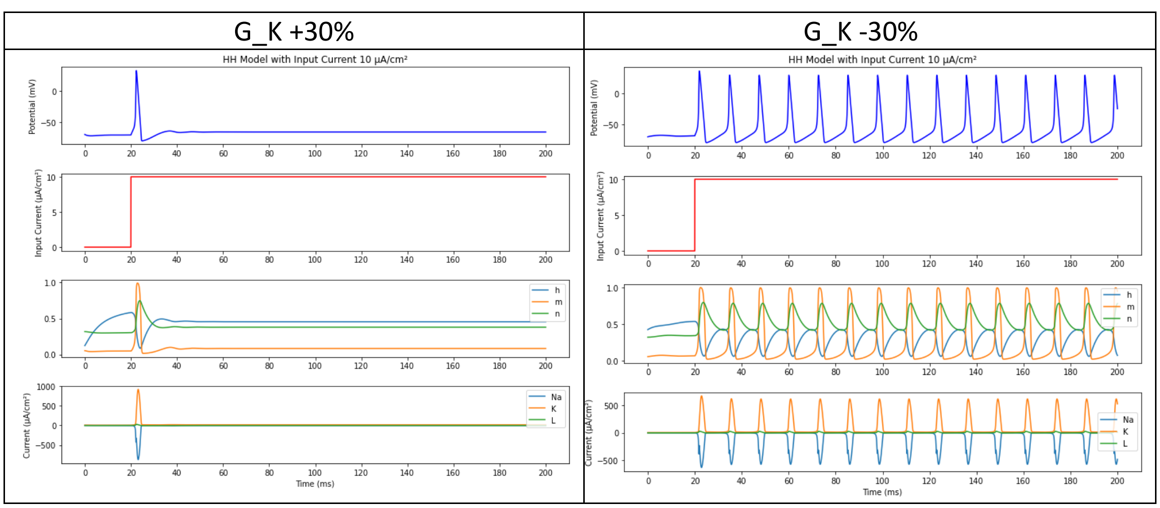

Figure 6, simulation with modified G_K value

Appendix

Chunbo Yuan, Robert J. O'Connell, Paula L. Feinberg-Zadek, Linda J. Johnston, Steven N. Treistman, *Bilayer Thickness Modulates the Conductance of the BK Channel in Model Membranes*, *Biophysical Journal*, Volume 86, Issue 6, 2004, Pages 3620-3633.

Jaakko Malmivuo and Robert Plonsey, Bioelectromagnetism: Principles and Applications of Bioelectric and Biomagnetic Fields Page 89, 1995

Scott Harden, *pyHH a a simple Python implementation of the Hodgkin-Huxley spiking neuron model*, 2019, retrieved from https://github.com/swharden/pyHH