Problem 1

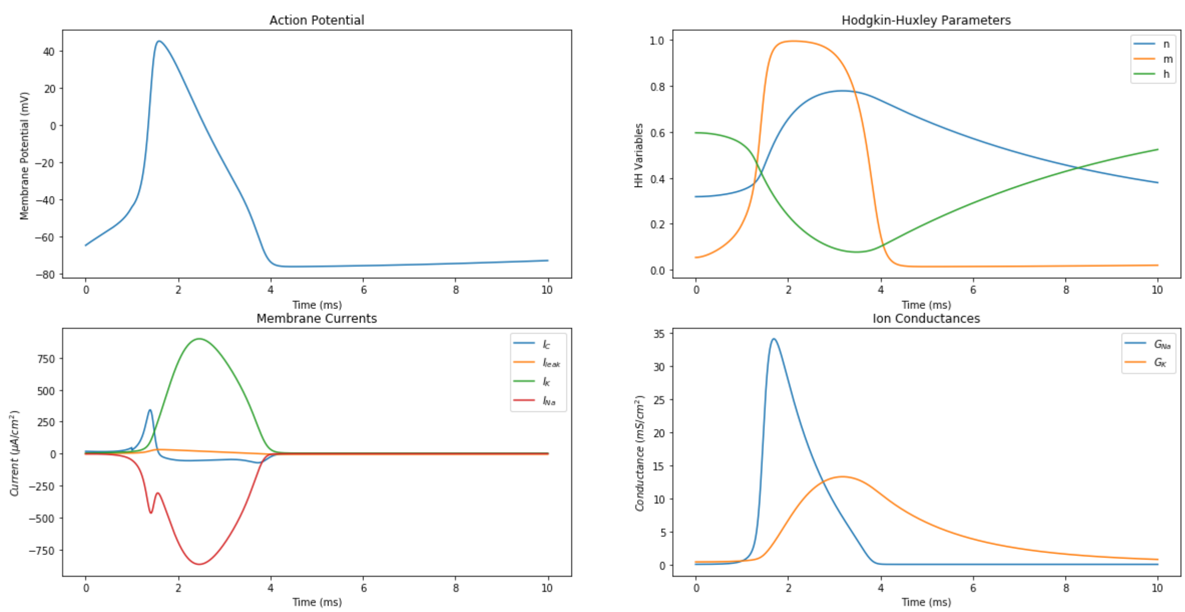
Out[1]: Toggle Code

Methods

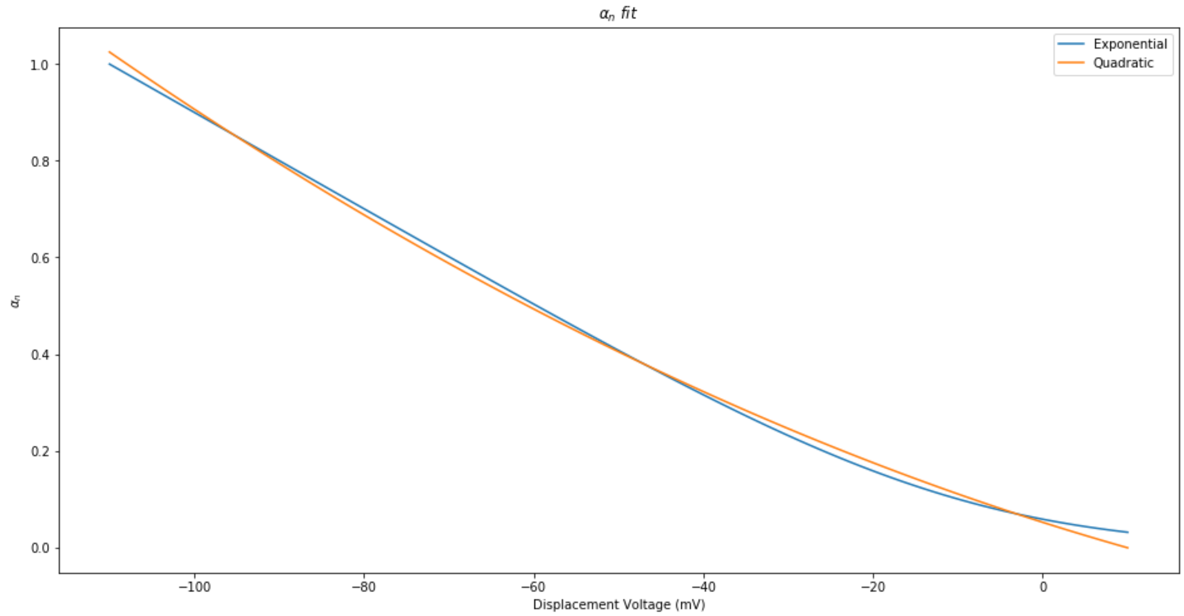
a.) We implement the Hodgkin-Huxley model using the parameters and equations described in the problem. An injective current of 20 μA applied for 1 ms to simulate the Hodgkin-Huxley model. We simulate the model for 10 ms. In the second part, we fit replace the exponential fit between α_n and V with a quadratic fit. The model was then run again with the same parameters.

b.) We implement the reduced version of the Hodgkin-Huxley model. m is replaced with it's steady-state value, m_∞, while h is replaced with the linear fit of n, $(0.89 - 1.1n)$. We also run the the reduced model with the quadratic fit between α_n and V.

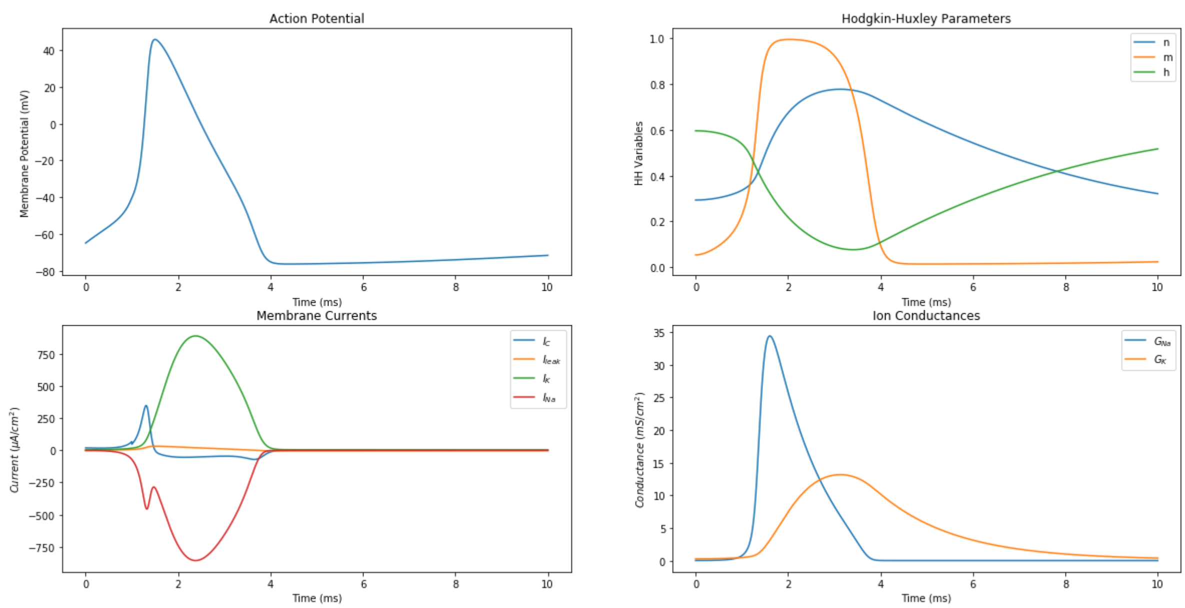
(i) Hodgkin-Huxley Model



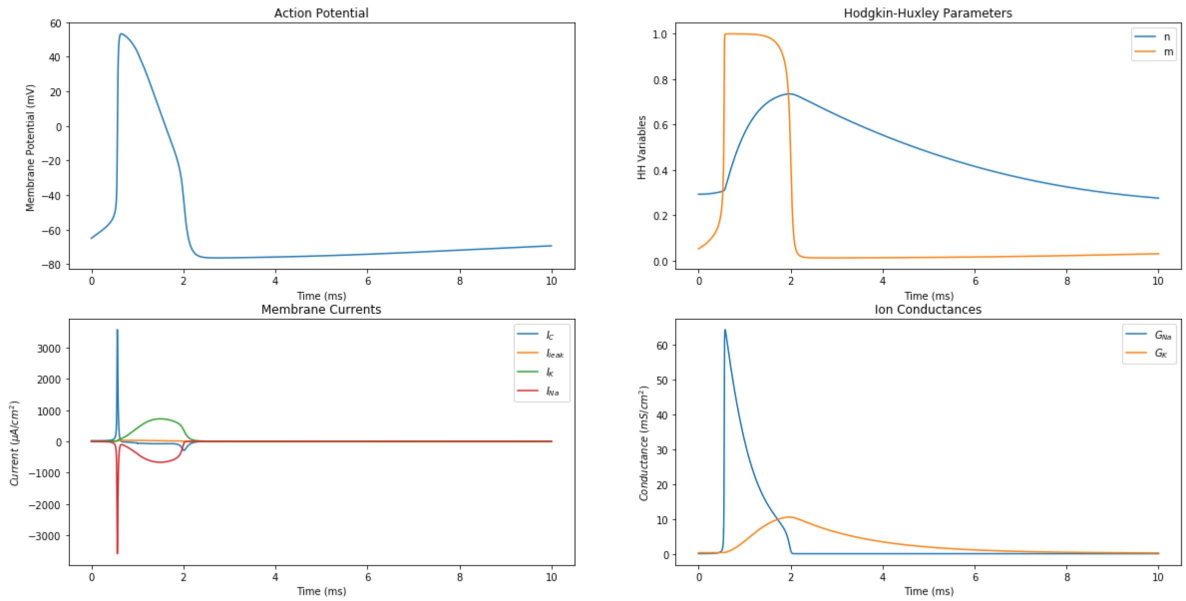
(ii) Fit Quadratic



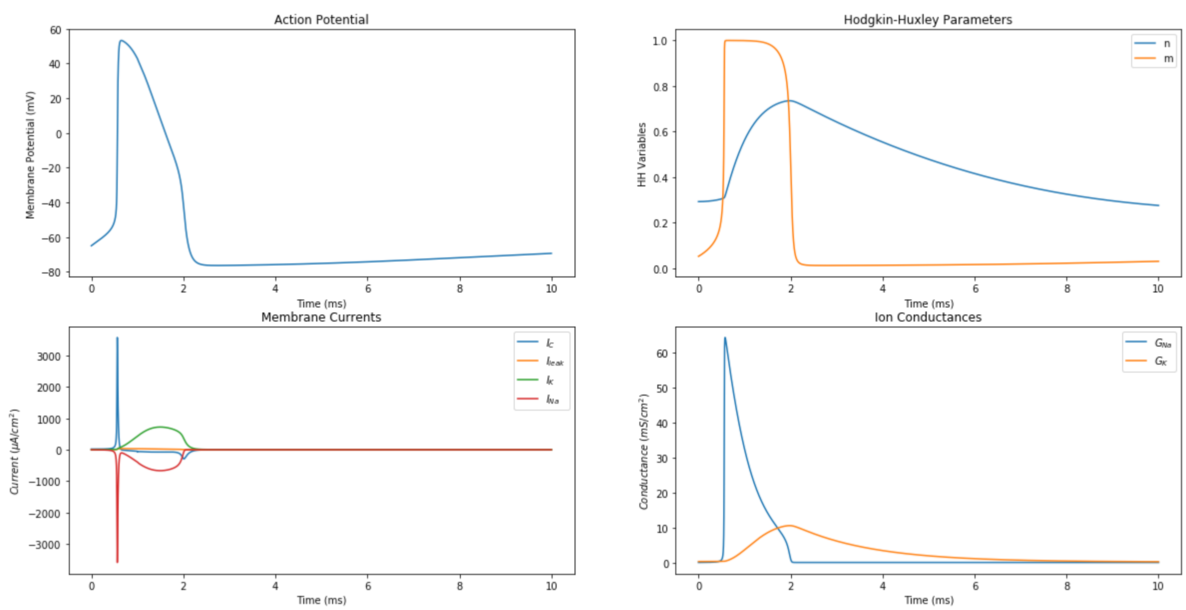
(iii) Hodgkin-Huxley Model with Quadratic Fit



(iv) Reduced Hodgkin-Huxley Model



(v) Reduced Hodgkin-Huxley Model with Quadratic Fit



Discussion

a.) (i) depicts the simulation of this neuron model over 10 ms. In the top-left plot, we model the membrane potential of the neuron model over time. In the top-right, the model parameters (n, m, h) were plotted over time. In the bottom-left plot, a decomposition of the currents of the neuron (representing the capacitive, leaks, sodium, and potassium currents) over time. In the bottom-right plot, we plot the sodium and potassium conductances of the neuron over time. We note that the action potential of the Hodgkin-Huxley model closely follows the action potential of the a real, biological neuron (i.e. depolarization, repolarization, etc.). The model reflects that parameter n is proportional to the potassium conductance of the membrance. We can easily see this in the plot by the fact that the 2 track each other fairly closely. A similar argument can be made for parameters m, and h and the sodium conductance. Finally the membrane currents can be seen to be mostly symmetrical in the plot (they sum to 0, since the injective current is fairly small, and only lasts 1 ms). The injective current causes a peturbation in the resting state of the neuron, and the model further simulates the similar step of the action potential.

In (ii) and (iii), we replace the exponential relation between α_n and V with a quadratic fit. (ii) compares the exponential to the quadratic fit, while (iii) shows the plots same variables as (i) for the new quadratic fit. We do not note any significant differences between (i) and (iii), indicating that the fit is only an empirical observation. Any curve fit to the data would be sufficient for the Hodgkin Huxley model.

b.) (iv) plots the same plots as (i) for the reduced model. We see that replacing m in the model with it's steady-state value causes the sodium conductance to respond instantaneously. We note that compared to the original Hodgkin-Huxley model, the action potential of the reduced model is narrower and slightly taller.

(v) shows the reduced Hodgkin-Huxley model, but with the quadratic fit. Like in the original model, we see no significant differences in the quadratic fit over the exponential fit.