Worksheet and Project for Chapter 10 of Izhikevich's book

Entrainment of Hodgkin-Huxley neurons to a periodic pulse stimuli

PART 1.

Run the script Entrain.py *inside ipython*. It uses a function that tests the response of a given H-H model, named `test_f`. The output shown is for a Type I neuron. Figure 1 shows the voltages, Figure 2 shows the delay of each spike since the last stimulus pulse, and Figure 3 shows the Poincare map of successive spike time differences (similar to phase before division by the period).

Copy the commented call to `test_f` from the script and paste it into ipython. Run it. This is the output for the Type II neuron, which is working in a very different frequency range.

Look at Figure 10.16 in Izhikevich's chapter 10. Read the text about phase slipping / cycle skipping. Zoom in to see evidence of this occurring with the Type II neuron.

PART 2.

For either the Type I or II neuron (choose one), find examples of the following behavior regimes and record your parameter values, show me your results (appropriately zoomed) and record your parameter values in your script:

- Any 1:1 entrained periodic solution with period 1 (these are given). **Is your solution in-phase or anti-phase? Why?**
- Any 1:1 entrained periodic solution with period more than 5.
- Any chaotic solution.

The argument list for the `test_f` function is documented in the script.
For both neurons, vary stimulus amplitude between 0.5 and 2.
For the Type I neuron, vary stimulus frequency between 5 and 30 Hz.
For the Type II neuron, vary stimulus frequency between 30 and 130 Hz.

PART 3.

Find parameters and make figures depicting any 1:2 entrained periodic solution (1 response spike to 2 stimulus pulses). *Hint: Consider which figure will help you recognize such a solution.*

FINAL PROJECT (20 pts) due Friday, December 6th by midnight.

Write up your results for your neuron type, showing figures (appropriately zoomed to areas of interest). Clearly tabulate or list parameter values and label the regimes you have found in the corresponding figures using captions, etc.

Find one other, qualitatively distinct type of solution in your chosen neuron type, and present clear evidence for your findings. Examples are: 1:3 entrainment, a 1:2 entrainment with period other than 1, a 1:1 solution with period 2 or 3. If you are uncertain about your findings, send me a page with the figures and parameters attached (state which neuron you are looking at!).

For one neuron type only, demonstrate the presence of an Arnold tongue for the 1:1 entrainment regime in the same two-dimensional parameter space as Figure 10.15. You can do this by starting from the parameters you found earlier, then picking five stimulus amplitude levels starting at 1.0 and going up to 1.5 and down to 0.25. For each level, find the maximum and minimum extents of the forcing frequency that maintains the 1:1 locking to the nearest 0.1Hz. Plot the extents at each level as lines or points to show the growth of the tongue for increasing amplitude. **Important:** Note that you will need to *double* the maximum time argument to `test_f` from whatever it was for the neuron you chose. This is done to ensure that weak transients are gone by the time you judge the final state. Weak transients are expected most at the boundaries between the different entrainment regimes (the different tongues in the figure). The last four points of the trajectories are colored red to make it clearer whether the transients are gone. You may like to run uncertain cases for even longer. *Hint:* you are expecting a growing shape of the tongue *approximately* like the one in the figure. **In what way is what you find different?**

Report submission: Please export your final report in PDF format.

Please note: There can be no extensions for this project because your final grades are due a couple of days later than the deadline. If you need help you must contact me soon and we could arrange an appointment if we cannot resolve it by email. I will send you an email verifying that I received your report.