CN510 - Assignment 3: Analysis of Izhikevich neuron

Due Tuesday October 1, 2013

Base your work on the previous assignment code for Euler integration, but this time you will be working on simultaneous integration of the system of equations. Good news – Euler method is so simple that you do not need to worry about interactions between equations during the integration step, you can compute ΔV and Δu independently.

Implement the Izhikevich neuron:

$$V_{n+1} = \begin{cases} V_n + \Delta V_n, \\ c, \end{cases} \quad u_{n+1} = \begin{cases} u_n + \Delta u_n, & \text{if } V < 30 \\ u_n + d, & \text{if } V \geq 30 \end{cases} \tag{1}$$

where $\Delta V_n = \Delta t(0.04V_n^2 + 5V_n + 140 - u_n + I_n)$, $\Delta u_n = \Delta t(a(bV_n - u_n))$, n is the index of the previous time step, and $\Delta t = 1$ms and $\Delta t = 0.1$ms are the time steps of your integration (do everything with 1ms step first, this should work as a perfect replication, then switch to 0.1ms). Use $V_0 = -70$mV and $u_0 = -20$ as initial conditions unless you find out that these do not work. Run all your simulations for $T = 200$ms.

0.1 Replicating Figure 8.8

Figure 8.8 in the Chapter 8 (the reading assigned for Lecture 5) shows different firing regimes you can get from the model. The following table lists the parameters.

a	b	c	d	I	firing pattern
0.02	0.2	-65	6	14	tonic spiking
0.02	0.25	-65	6	0.5	phasic spiking
0.02	0.2	-50	2	15	tonic bursting
0.02	0.25	-55	0.05	0.6	phasic bursting
0.02	0.2	-55	4	10	mixed mode
0.01	0.2	-65	8	30	spike frequency adaptation
0.02	-0.1	-55	6	0	Class 1
0.2	0.26	-65	0	0	Class 2
0.02	0.2	-65	6	7	spike latency
0.05	0.26	-60	0	0	subthreshold oscillations
0.1	0.26	-60	-1	0	resonator
0.02	-0.1	-55	6	0	integrator
0.03	0.25	-60	4	0	rebound spike
0.03	0.25	-52	0	0	rebound burst
0.03	0.25	-60	4	0	threshold variability
1	1.5	-60	0	-65	bistability
1	0.2	-60	-21	0	DAP
0.02	1	-55	4	0	accommodation
-0.02	-1	-60	8	80	inhibition-induced spiking
-0.026	-1	-45	0	80	inhibition-induced bursting

Please note that the input current profiles change for different neuronal types in figure 8.8. We will assume that the I value in the table gives an amplitude of the current step whenever it is given. We will also assume

that for the first 10ms there is no input, and whenever input is given as a short pulse the pulse length is 3ms for cases I, J, M, N, and Q; 3ms and 2ms for cases K, L, and P; 5ms for case O.

At this point you are in the position of a scholar trying to replicate published data. You are free to dig more information from the chapter or other published sources, including the MatLab code from Izhikevich web site. You have to keep track of every additional bit of information you have found in your report. You are also free to guess the values of whatever missing inputs you need, in this case please keep track of your guesses in the report. For example, you can include something like: "I have found the amplitude of the pulse in case X having a value q from (citation) and tried values of x, y, and z for the maximal ramp amplitude in case Y. Out of these values z worked best." Provide some details why you think the value you have chosen works better than the others.

The main goal of this assignment is not only to replicate all spike patterns in figure 8.8, but also to show you the difficulties you might encounter while replicating other people's work. As such, please try to use Eugene's MatLab code for information fetching only as a last resort. Keep in mind that most of the people out there are not as willing to share their code.

If you fail to replicate some of the plots, please describe in the report which approaches/parameters you have tried, and why do you think they did not work. Finally, compare the results for 1ms and 0.1ms time steps and discuss for which cases the shorter time step qualitatively affects the solution.

Grading Rubric:

100 points	**Each of the 20 cases will be graded equally at 5 points each** Show the plot of your best match to Figure 8.8 If your plot differs from the original, describe the difference and its possible causes Describe you parameters and additional sources for these parameters (if any) Highlights what you found particularly interesting (or uninteresting) about this pattern of spiking or parameter settings Point out qualitative changes in neuronal behavior caused by the change of integration step (if you have found any of these)