Neuronal Dynamics

Professor Wulfram Gerstner
Laboratory of Computational Neuroscience

Adaptive Exponential Integrate-And-Fire Model

The goal of these exercises is to acquire some familiarity with Adaptive Exponential Integrate-And-Fire model. Download AdEx.py from the book's webpage. AdEx.py is a python module containing a function: AdEx_model. With this function, you can simulate a step current with amplitude of I_amp and specific neuron properties. The specific formulas implemented are described on page 137 of the book. Once you have started ipython -pylab in the directory containing expLIF.py, simply type:

```
>> import AdEx
```

to port AdEx.py onto your current session. Then you can simulate a step current in an adaptive exponential integrate-and-fire model by typing the following commands:

```
>> AdEx.AdEx_model()
```

which should trigger a plot with two panels, one is membrane voltage as a function of time, and the other is w vs. vm. To have information on the arguments of the function, simply open AdEx.py in any text editor. Using appropriate values of arguments, specifically a, b, τ_w, I_{amp} you can generate many different firing patterns with this model, which was not possible using exponential integrate-and-fire model or other linear models that you have seen in previous exercises.

Exercise 1

First, try to get some intuition on shape of nullclines by plotting or simply sketching them on a piece of paper and answering the following questions.

1.1 How nullclines change with respect to values of a and I_{amp}?

1.2 What is the interpretation of parameter b?

1.3 How flow arrows change as τ_w gets bigger?

Exercise 2

Can you predict what would be the firing pattern if a is relatively small? To do so, consider the following 2 conditions:
1- A large jump (b) and a large time scale (τ_w).
2- A small jump (b) and a small time scale (τ_w).
Now try to simulate the above conditions, to see if your predictions were true. You can use the following parameters:

sets	C (pF)	gL (nS)	EL (mV)	VT (mV)	$DeltaT$ (mV)	a (nS)	tau_w (ms)	b (pA)	Vr (mV)	I_amp (pA)
set 1	200	10	-70	-50	10	2	30	0	58	200
set 2	200	12	-70	-50	2	2	300	60	58	500

C,gL,EL,VT,DeltaT,a,tauw,b,Vr,I_amp=200.0*pF,10.0*nS,-70.0*mV,-50.0*mV,10.0*mV,2.0*nS,30.0*ms,0.0*pA,-58.0*mV,200.0*pA
C,gL,EL,VT,DeltaT,a,tauw,b,Vr,I_amp=200.0*pF,12.0*nS,-70.0*mV,-50.0*mV,2.0*mV,2.0*nS,300.0*ms,60.0*pA,-58.0*mV,500.0*pA

2.1 How the inter spike interval (ISI) change in the above produced firing patterns? (You can use spike times stored in Spike$_Timesarraytocompute ISI$.)

Exercise 3

The goal of this exercise is to generate some other spiking patterns.

3.1 Using the following parameters and an appropriate value for I_amp which you should find, generate a delayed accelerating pattern. (In a delayed accelerating pattern, spiking starts with a delay, and ISI decreases over time.)

C (pF)	gL (nS)	EL (mV)	VT (mV)	$DeltaT$ (mV)	a (nS)	tau_w (ms)	b (pA)	Vr (mV)	I_amp (pA)
200	12	-70	-50	2	-10	300	0	-58	?

3.2 Try to plot nullclines in the same subplot which represents w vs. v_m and try to explain how that firing pattern is generated with respect to this plot.

3.3 Try to produce some other patterns such as regular bursting, delayed regular bursting, transient spiking, irregular spiking,etc.
To get an idea about appropriate range of values you can either refer to page 140 of the book or the article by Naud et al. (2008).

Naud, R., Marcille, N., Clopath, C., Gerstner, W. (2008). Firing patterns in the adaptive exponential integrate-and-fire model. Biological cybernetics, 99(4-5), 335-347.