Biological Electrochemical Activation for InFoMM C++ training

The FitzHugh-Nagumo model

$$\frac{dv}{dt} = v - v^3/3 - w + I,$$

$$\frac{dw}{dt} = 0.08(v + 0.7 - 0.8w),$$

is a two-dimensional simplification of the Hodgkin-Huxley model of spike generation in squid giant axons. As such, it is a mathematical model that approximates the electrical characteristics of excitable cells such as neurons and cardiac myocyte. The variable v models the membrane potential, while w acts as a recovery variable. The constant I is the activation current, and controls the behaviour of the model.

1. integrate the given FitzHugh-Nagumo equations in either (a) CVODE or (b) Boost.Numeric.Odeint. To start with, use initial values $v = -1$, $w = -1$, $I = 1$ and integrate over $0 \leq t \leq 200$ to see the periodic spiking behaviour of the membrane potential v.
2. Output t, $v(t)$, and $w(t)$ to a CSV file, using one column for each variable
3. Plot variables versus time using a method of your choice:
   (a) Gnuplot (`sudo apt-get install gnuplot` to install with Ubuntu)
   (b) Python Matplotlib (hint: use the `numpy` function `loadtxt` to read in the CSV file)
   (c) Matlab
   (d) Excel?
4. Plot the phase portrait along with the nullclines $\frac{dv}{dt} = 0$ and $\frac{dw}{dt} = 0$
5. Vary the activation current I between 0 and 2 and see the change in behaviour of the model. Observe the 3 modes of activation with increasing I:
   (a) resting (low constant v),
   (b) spiking and
   (c) blocked (high constant v)