Laboratory Assignment: Implementing Spiking Neurons using Izhikevich's Model

Solve the following assignment, whose completion is required to access the oral examination. Send the assignments all-together (once you have completed all the labs, not only this single one) as a compressed folder including one subfolder for each laboratory.

The subfolder for this lab should be called "spiking-lab1" (Spiking Neurons lab 1) and should include the Matlab scripts and the other files as requested in the assignment below. You can organize the code as you wish, implementing all the helper functions that you need provided that these are included in the subfolder and are appropriately called in the scripts.

Bonus track assignments are meant to be for those who finish early, but they are not formally required for completing the Lab Assignment.

Supporting material for this assignment is listed below:

Izhikevich's Model
[1] E.M. Izhikevich, "Simple model of spiking neurons." IEEE Transactions on neural networks 14.6 (2003): 1569-1572.
Available online at: http://izhikevich.org/publications/spikes.pdf

[2] E.M. Izhikevich, "Which model to use for cortical spiking neurons?." IEEE transactions on neural networks 15.5 (2004): 1063-1070.
Available online at: http://izhikevich.org/publications/whichmod.pdf
Web page: http://izhikevich.org/publications/whichmod.htm

Matlab documentation
Matlab User's Guide https://www.mathworks.com/help/index.html
Matlab documentation using the `help` command

Additional Material – IMPORTANT (DO NOT COPY-PASTE IT, BUT LOOK AT IT!!)
The values of the Izhikevich's model parameters and the shape of the input in all the cases are provided in the following .m file:
http://izhikevich.org/publications/figure1.m

Assignment – Implementation of the Izhikevich's Model

The assignment consists in the following points:

1) Implement the Izhikevich's model in Matlab;
2) Develop all the 20 neuro-computational features of biological neurons using the model developed at point 1) and plot the resulting membrane potential's time courses into individual figures (one figure for each neuro-computational feature).

Recall that the Izhikevich's model is described by the following equations:

$$\begin{cases} \frac{du}{dt} = 0.04\,u(t)^2 + 5u(t) + 140 - r(t) + I \\ \frac{dr}{dt} = a(bu(t) - r(t)) \end{cases}$$

If $u(t) \geq 30$ mV

$$\begin{cases} u = c \\ r = r + d \end{cases}$$

▸ u is the membrane potential,

▸ r is a recovery variable (Na+ inactivation/K+ activation) provides negative feedback to u

▸ a, b, c, d are the parameters of the model

▸ I is the applied current

that can be solved by using the Euler's method (see the slides of the lecture "Conductance-based and Spiking Neuron Models").

The 20 neuro-computational properties to develop are described in the Izhikevich's paper [2]. They are summarized in the following figure (from www.izhikevich.com):
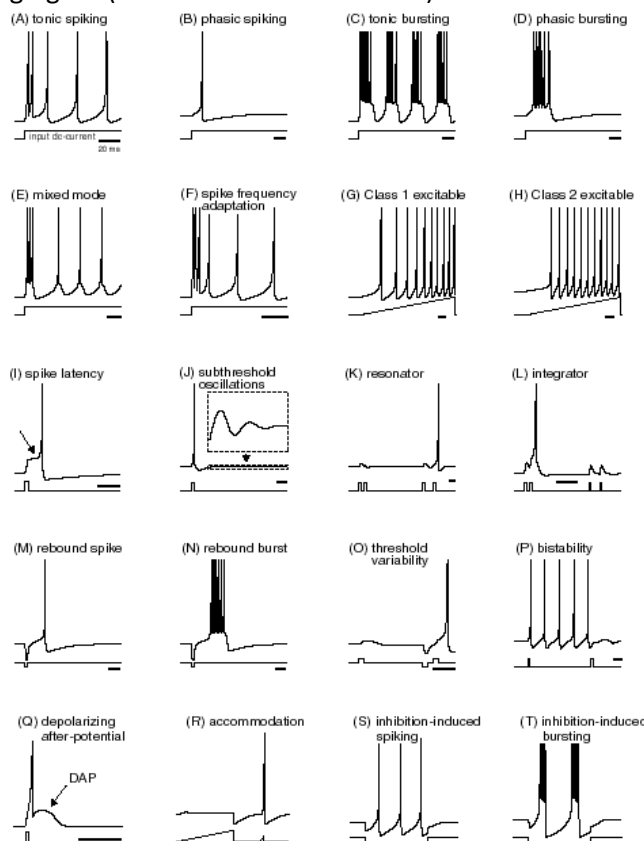
The different behaviors are obtained by using different values of the model's parameters (a, b, c and d) and different types of (applied) input.

The output of the assignment should then consist in the following data:

- The script .m file(s).
  Suggestion: one .m file for modeling the Izhikevich's equations and one .m file for every neuro-computational property.
  NOTE: for each neuro-computational-property a separate .m file.
- The 20 images of the membrane potential time course for the 20 neuro-computational properties. Note: use labels on X and Y axis (time, membrane potential). The name of each figure should indicate the name of the corresponding neuro-computational property. The figures can be provided either in .fig (Matlab format) or in .png.
  NOTE: for each neuro-computational-property a separate image file (20 image files).

Bonus Track Assignment

Plot the phase portraits for at least 5 of the neuro-computational properties developed for the assignment. Note: X-axis represents the membrane potential, the Y-axis represents the recovery variable. The name of each figure should indicate the name of the corresponding neuro-computational property. The figures can be provided either in .fig (Matlab format) or in .png.

NOTE: for each neuro-computational-property a separate image file.