Laboratory Assignment 1 (LAB1)
Implementing Spiking Neurons using Izhikevich's Model

Solve the following assignment, whose completion is required to access the oral examination. Upload the assignments all-together in the Moodle platform of the course (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 "LAB1" 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

The values of a, b, c and d parameters of the Izhikevich model for all the neuro-computational features are reported in the LAB1-AdditionalMaterial.pdf document (section LABS in the Moodle platform).

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)
    - the phase portraits that correspond to each of the neuro-computational features (one figure for each neuro-computational feature)

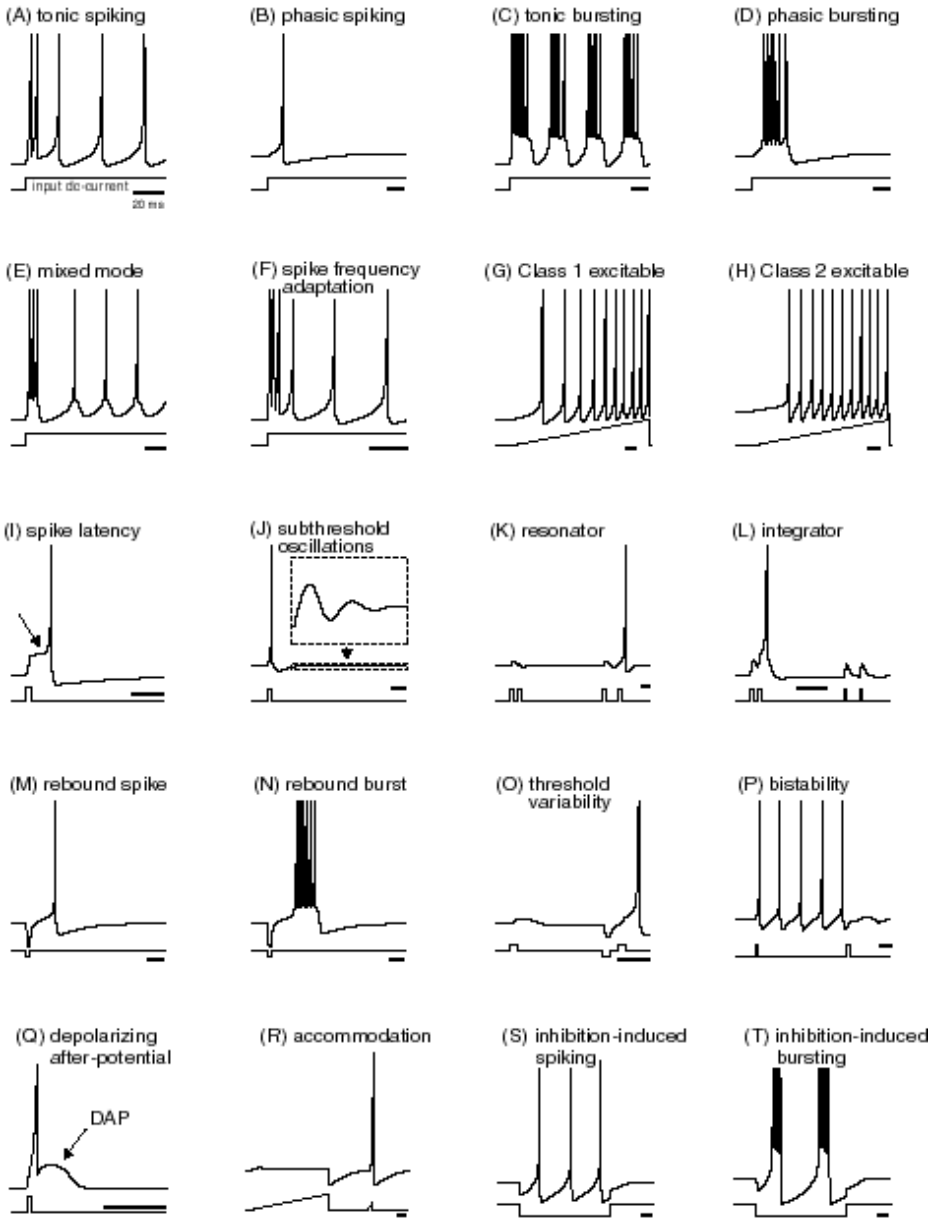
Recall that the Izhikevich's model is described by the following equations:

$$\begin{cases} \dot{u} = 0.04u^2 + 5u + 140 - w + I \\ \dot{w} = a(bu - w) \\ \text{if} \quad u \geq 30 \\ \qquad u \leftarrow c, w \leftarrow w + d \end{cases}$$

(see further info in the slides in Part1_lecture4.pdf)

The system can be solved (simulated) by using the Euler's method or any other of the numerical methods analyzed in the lecture Part1_lecture4.

The 20 neuro-computational features to develop are described in the Izhikevich's paper [2]. They are summarized in the following figure (from www.izhikevich.com):



The different features are obtained by using different values of the model's parameters (a, b, c and d) and different types of (externally 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 feature.
- The 20 images of the membrane potential time course for the 20 neuro-computational features. 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 feature. The figures can be provided either in .fig (Matlab format) or in .png.
  NOTE: Prepare a separate image file for each neuro-computational feature (20 image files).
- The 20 images of the phase portraits for the 20 neuro-computational features. Note: use labels on X and Y axis (membrane potential variable, recovery variable). The name of each figure should indicate the name of the corresponding neuro-computational feature. The figures can be provided either in .fig (MATLAB format) or in .png.
  NOTE: Prepare a separate image file for each neuro-computational feature (20 image files).

Bonus Track Assignment1: In-depth analysis of particular cases

Focus (at least) on the following neuro-computational features: Resonator, Integrator, Bistability.

For each of the considered features, provide a vector (in MATLAB) representing the input that led to the desired observed neuronal behavior and another vector that corresponds to a case in which the desired neuronal behavior does not emerge.

Moreover, for each of the considered features, also write a brief comment in which you explain why the neuronal behavior is not emerging in the second case.

Use different variable names for the input vectors (e.g. input_ resonator_ok, input_resonator_nok), and save all of them in a unique .mat file. Save all your comments into a unique .txt file (e.g. “lab1-bonus.txt”) in which different paragraphs refer to different neuro-computational features. Finally zip both the .mat file and the .txt file into a unique file (e.g. “lab1-bonus.zip”).