Neural model optimization tool

Neural computer models are a great resource in studying the nervous system, and muscle control, they allow in studying cellular mechanisms and simulating neural signals that is impossible in acquisition from living animals.Neuron computer models are complex non-linear systems that require high computational resources in operation and development. To bring these models into their optimum use, They require optimization to certain electrical behaviors and measurements to match and mimic experimental recordings from living cells, so that simulated data from these models would be related to the living systems. Due to the high complexity of these models, manual hand tuning is the main method used in developing these models and calibrating them to experimental data.

The goal of this project is to build a semi/full automated optimization tool using reinforced learning to help save time and resources in calibrating neural computer models to experimental measurements. This optimization tool should be able to learn the system parameters that reproduce experimental data.

The projects includes:

1. Learning how to measure electrical features from experimental data.
2. Learn how to work on the NEURON simulator.
3. Using machine learning algorithms to simplify and optimize neural models.
4. Learning about the physiological impact and role of the different ion channels in neurons.
5. Designing the optimization tool to work on super-computer systems
6. Estimating neural models complexity and providing estimations of the computational power required to run such models.

Expectations from of the optimization tool

- The tool should be able to load a neural model (A cell template) that may include at least 5 compartments
- The tool should allow the user to enter the experimental measurements set that would be used as a criterion to validate the neural model parameters.
- The tool should provide a list of the neural channels parameters that were successfully able to reproduce experimental measurements provided by the user.

Phases:

- Preparation stage: (1.5 Month)
    - Learn how to operate the Neuron models.
    - Learn how to measure electrical features
    - Parameter space { conductances , activation threshold , etc}
- Optimizations on Na, Kdr
    - The tool should estimate the Na, Kdr conductance as various values.

Difficulty Levels:

1. Simplified model, with only conductances optimization (minimize) + (Rn, spike Height, AHP depth)
    a. Same but more properties to fit (half width, AP width)
    b. Rheobase , introduction to threshold kinetics.
2. Simplified model with some kinetics + conductances
3. Full 3D model

Meeting #1 (16/11/2020)

- Goals
- Tools (simulator, python)
- Project components (AI part, neuron, GUI)

Full list of properties:

With exemplary values

Passive properties:
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1. Input resistance/ conductance
2. Time constant

Action Potential Parameters:
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1. The AP height = 94.55 mv 70 : 100
2. The AP width = 7.77 ms
3. The AP half height width = 0.56 ms
4. The Time-to-peak of AP   = 0.55 ms
5. Max Rising Slope = 942.23 mV/ms
6. Max Decay Slope = -325.49 mV/ms
7. Average Rising Slope = 285.76 mV/ms
8. Average Falling slope= -127.29 mV/ms

AHP Parameters:
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1. The AHP depth   = 1.86 mv
2. The AHP duration = 73.77 ms
3. The Time-to-peak of AHP = 11.70 ms
4. The AHP half-decay time = 19.45 ms (measured from AHP trough)
5. The AHP 2/3 decay time = 45.42 ms (measured from AP start)
6. The AHP 1/2 Duration   = 28.58 ms (from half Amp to Half Amp)

ADP Parameters:
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1. AP width at ADP undershot = 1.49 ms
2. ADP delay from the AP peak = 2.07 ms
3. ADP overshot voltage   = -66.33 ms

Spike initiation:
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1. Rheobase
2. Recruitment current
3. Threshold voltage

Current Frequency relationship:
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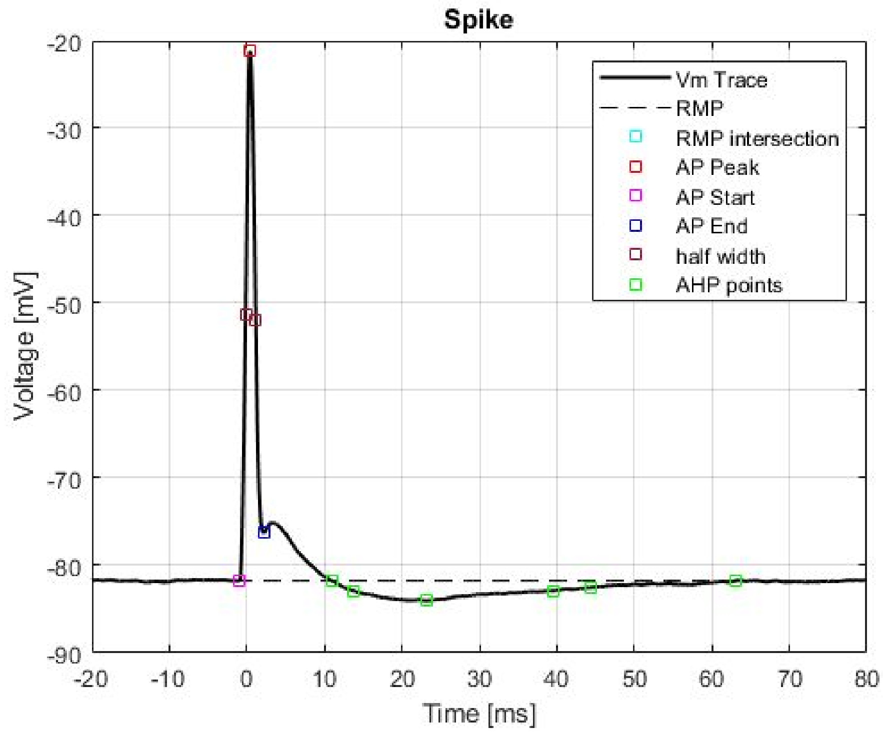
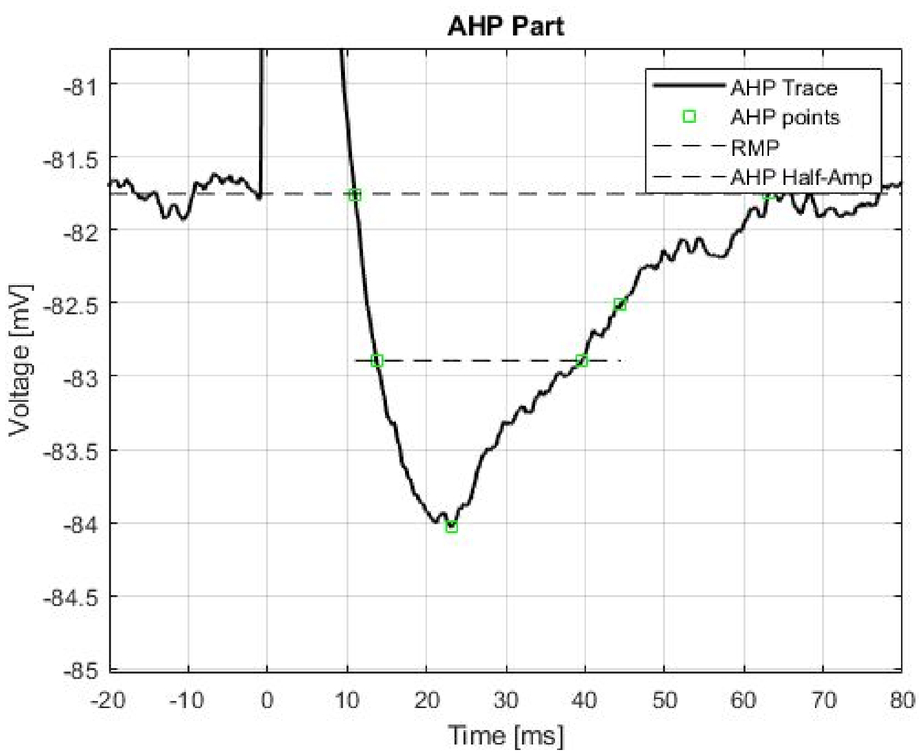
1. Gain
2. Initial firing rate
3. Maximum firing rate


Spike
Vm Trace
RMP
RMP intersection
AP Peak
AP Start
AP End
half width
AHP points
-20
-30
-40
-50
-60
-70
-80
-90
-20
-10
0
10
20
30
40
50
60
70
80
Voltage [mV]
Time [ms]


AHP Part
AHP Trace
AHP points
RMP
AHP Half-Amp
-81
-81.5
-82
-82.5
-83
-83.5
-84
-84.5
-85
-20
-10
0
10
20
30
40
50
60
70
80
Voltage [mV]
Time [ms]