Report

Report Title:

Action Potential Quantification

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Date:

06.08.2020

Table Of Contents

- **Abstract 3**
- **Introduction 3**
- **Objectives 3**
- **Process 4**
- **Results 5**
- **Refrences 7**

Abstract

After first recording of the time course of the action potential in 1865, many approaches have been introduced for action potential quantification. Important parameters including number of action potentials, peak values in a train of action potential, zero-crossings, Threshold and refractory period needs to be considered for efficient and goal-oriented quantification. The following report describes the procedure of mentioned parameters quantification for a given data set. The output is stored in another csv file.

Introduction

Action potential occurs when membrane potential of a cell rapidly rises and falls. The whole process includes depolarization, repolarization and hyperpolarization. If the membrane voltage does not cross the threshold, action potential wont occur. Finding the voltage threshold is thereby of high importance. Depolarization can take place naturally in the cell or artificially by a lab scientist. In this project artificial depolarization step has been applied by a lab scientist. Data samples are acquired at the rate of 50KHZ. Action potential occurs when depolarization rate reaches 20mv/ms. Acquired action potentials train are quantified with python to provide scientists with in depth information about neurons function. It is important to note that the real data is not stable in action potential peak, threshold and other parameters. The output is thereby series of values for different parameters which are visualized in pandas dataframe.

Objectives

The goals of the project is answering following questions:

- How many action potentials has occurred?
- What is the range of the action potential threshold?
- When did zero-crossings occurred?
- What are peak values?
- What is the refractory period value?(here only absolute refractory period has been calculated)

Process

Each section concentrates on eacquiring values of different parameters.

1- Event number :

There are several ways to calculate event numbers. In python script number of events are calculated with a simple edge detection algorithm. Since edge detection algorithm is used several times in the code, class threshold_detector is defined to make the process more convenient. Two output of method defined in the class is used for the process. Threshold_edge_indices_high return the index of first element greater than threshold (in rising edge) and Threshold_edge_indices_low return the index of first element smaller than threshold (in falling edge). If the value crosses the threshold (in this case zero has been considered as threshold), one element will be added to the final required index array. Length of indexes in either rising of falling edge returns number of events. Number of peaks also returns number of events.

2-Event time :

Even time is defined as the time at which zero-crossing occures. Since zero-crossing indexes have already been calculated for number of events, timing of acquired indexes return event time.

3- Peak Values :

Scipy package has been used for calculating peaks. Index of peaks is calculated using scipy.signal.find_peaks and the membrane voltage for acquired indexes is calculated. This process returns peak values.

4- Threshold values :

It is important to note that threshold value is the voltage at which depolarization rate reaches 20mv/ms which means that we should define a window with length 1ms (number of steps which is required to reach to 1 ms is calculated as follows 1/(1/frequency) which is 50 in current case. Having the window with the length of 1ms, defined for loop shifts the window 1 step with each iteration while calculating the slope. The first index at which slope reaches or passes 20mv/ms, is

considered as threshold voltage. Needless to say that acquiring the exact number (20mv/ms) is not possible since values are given in a discrete array. Acquiring exact point requires interpolation techniques which has not been addressed in the current problem.

5- Refractory period :

Refractory period is divided into absolute and relative. Absolute refractors period is the duration of action potential (depolarization+repolarization) which is the time difference between resting and threshold time. The time at which neurons reach to their resting point after action potential has been calculated by threshold_edge_indices_low (falling edge) in Threshold_detector class.

** More parameters can also be be defined. Rise time is defined as follows:

Time(%80*signal)-Time(%20*signal). Mentioned parameter however has not been calculated and it requires interpolation techniques.

Results

63 action potentials have been acquired in current dataset. Peak values varies for each action potential. The range is approximately between 46 and 52. The value of threshold is also not stable and ranges between -38 and -42 with mean approximately -41. To better visualize action potential train and threshold values, the data set has been plotted. For convenience the output data has been returned in pandas dataframe to visualize all parameters and their values. The result has then been stored as a csv file.

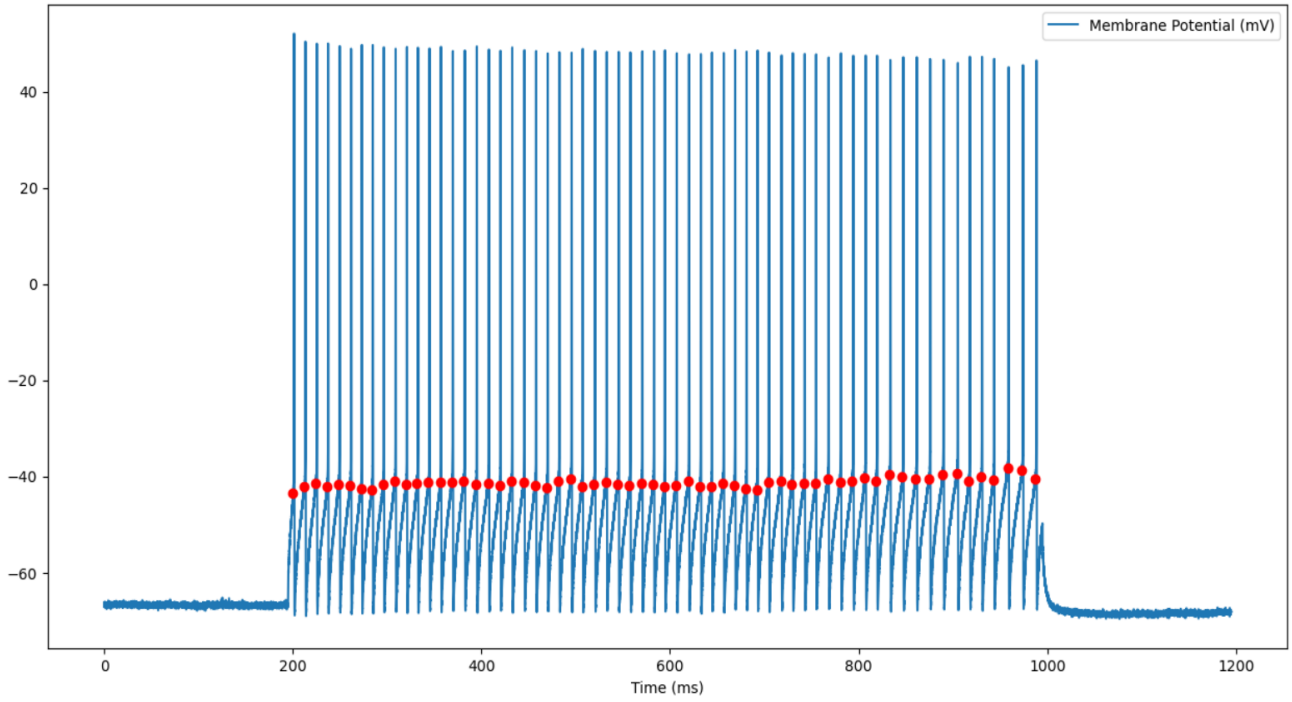

Figure1. action potential train. Red dots visualize thresholds

Refrences

Wikipedia, Action potential, https://en.wikipedia.org/wiki/Action_potential

Stephen .M Schuetze, Discovery of action potential (January 01,1983), https://www.cell.com/trends/neurosciences/fulltext/0166-2236(83)90078-4