

1 Description

The aim of this software is to find the levels (open, closed, ...) in a signal originating from a single-channel patch clamp experiment. For this purpose, the histogram of the signal is analyzed. Since a histogram is defined by a discrete number of $M \in \mathbb{N}$ bins or intervals, it can be viewed as a piecewise linear function $h_M : I \rightarrow \mathbb{R}$ with nodes defined by the ascending interval centers x_j , $j = 1, \dots, M$ and function values given by the number of cases in the corresponding bin. The domain of the function h_M is the interval $I = [x_1, x_M] \subset \mathbb{R}$. For the analysis, the histogram function $h_M : I \rightarrow \mathbb{R}$ is approximated by a function $f_N : I \rightarrow \mathbb{R}$ that can be represented as the sum of an arbitrary but fixed number $N \in \mathbb{N}$ of scaled Gaussian distributions, i.e.

$$f_N(x) := \sum_{i=1}^N \frac{\rho_i}{\sqrt{2\pi}\sigma_i} \exp \left[-\frac{(x - \mu_i)^2}{2\sigma_i^2} \right] \quad (1)$$

with scaling factors ρ_i , mean values μ_i and standard deviations σ_i , $i = 1, \dots, N$.

The corresponding optimization problem can then be formalized as follows.

Problem 1 *Let $h_M : I \rightarrow \mathbb{R}$ be a given piecewise linear histogram function and for $N \in \mathbb{N}$ let $f_N : I \rightarrow \mathbb{R}$ be defined as in Eq. 1. Find parameters ρ_i , μ_i and σ_i , $i = 1, \dots, N$, such that the norm $\|h_M - f_N\|$ is minimized.*

To simplify the optimization, parameters r_i , m_i , and s_i are introduced as

$$r_i := \frac{\rho_i}{\sqrt{2\pi}\sigma_i}, \quad m_i := \mu_i, \quad \text{and} \quad s_i := \frac{1}{\sqrt{2}\sigma_i} \quad (2)$$

and the function $f_N : I \rightarrow \mathbb{R}$ as given in Eq. 1 can be written equivalently as

$$f_N(x) = \sum_{i=1}^N \frac{\rho_i}{\sqrt{2\pi}\sigma_i} \exp \left[-\frac{(x - \mu_i)^2}{2\sigma_i^2} \right] = \sum_{i=1}^N r_i \exp \left[-(x - m_i)^2 s_i^2 \right].$$

Motivated by the above simplification, we define the function $g_N : I \rightarrow \mathbb{R}$ as

$$g_N(x) := \sum_{i=1}^N r_i \exp \left[-(x - m_i)^2 s_i^2 \right] \quad (3)$$

and Problem 1 can be reformulated as follows.

Problem 2 *Let $h_M : I \rightarrow \mathbb{R}$ be a given piecewise linear histogram function and for $N \in \mathbb{N}$ let $g_N : I \rightarrow \mathbb{R}$ be defined as in Eq. 3. Find parameters r_i , m_i and s_i , $i = 1, \dots, N$, such that the norm $\|h_M - g_N\|$ is minimized.*

A Python script to interactively create, plot, fit, and inspect the histogram and it's approximation was implemented. To solve the optimization Problem 2, a curve-fitting approach available in the scientific computing package *scipy* was applied. From (2), the optimal scaling factors ρ_i , mean values μ_i and standard deviations σ_i solving Problem 1 are derived.