Tutorial 3.3 Receiver-Operating Characteristic of a Noisy Neuron

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1 Overview

The neuroscience goal for this tutorial is to practice in how a neuron's distribution of spike counts and the ROC curve depends on noise level, stimulus duration, and stimulus-responsiveness. AELIF neuron model is used for simulation. The parameters can be found in textbook(p121).

2 Tutorial

2.1 Question 1

Set the mean input current in trials with no stimulus to be 0 and in trials with a stimulus present to be 0.1nA. For each time step, add a random number taken from the normal distribution of zero mean and standard deviation of $\sigma/\sqrt{t}$ where δt is the timestep of 0.01ms. Set $\sigma = 20pA.s^{0.5}$ in both conditions(stimulus-absent and stimulus-present).//

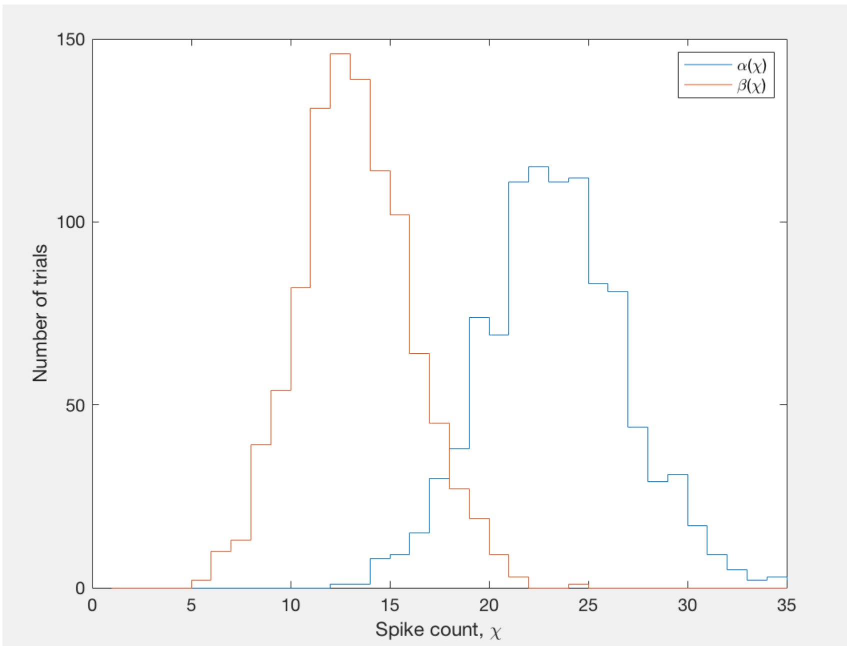

Fig 1.

Fig 1. represents histograms of the number of spikes produced by a noisy AELIF neuron across 1000 trials with a time window of 0.5s and a stimulus of 0.1nA($\alpha(x)$) or no stimulus($\beta(x)$) combined with input noise with $\sigma = 20pA.s^0.5$.

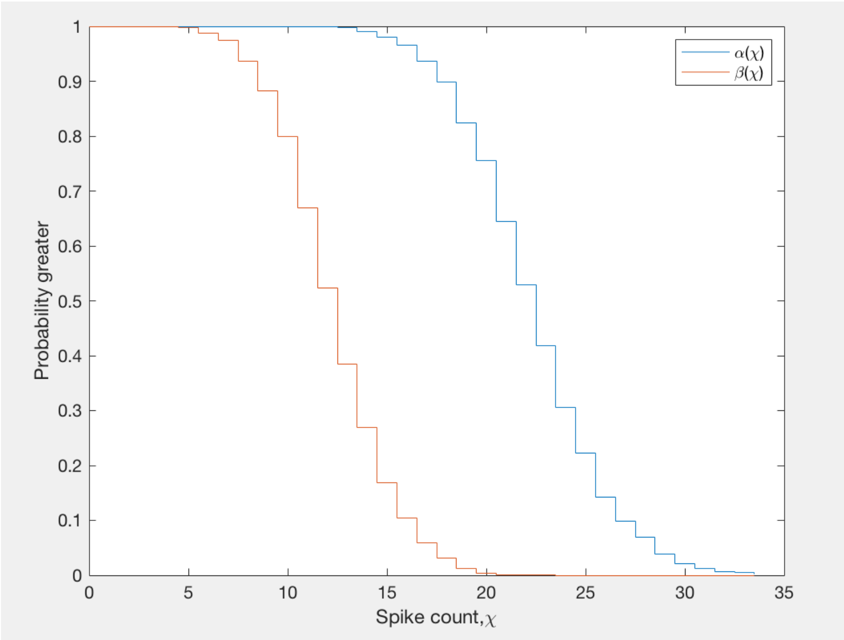

Fig 2.

The cumulative sum of each histogram is calculated and divided by the total number of trials, then subtracted from 1 to obtain the fraction of trials with more spikes than a give spike count.

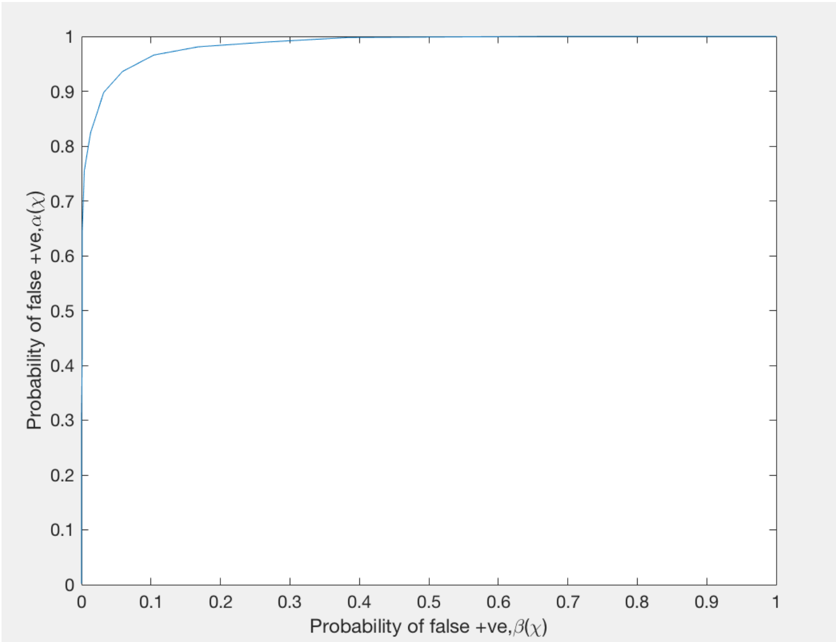

Fig 3.

The y-values for each of the curves in Fig 2. at the same x-value are plotted against each other to produce the ROC curve as the x-value varies.

2.2 Question 2

For this question, we are required to repeat Q1, but reduced the stimulus duration from 0.5s to 0.2s.

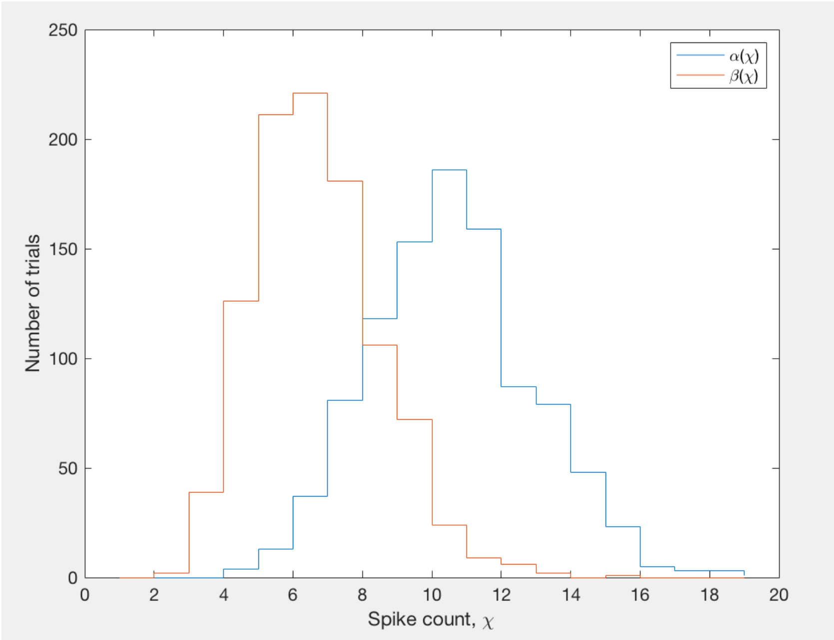

Fig 4.

Compared to Fig 1., the two histograms in Fig 4. overlap more with each other. The deviation for spike count is smaller, while the deviation for the number of trials is larger.

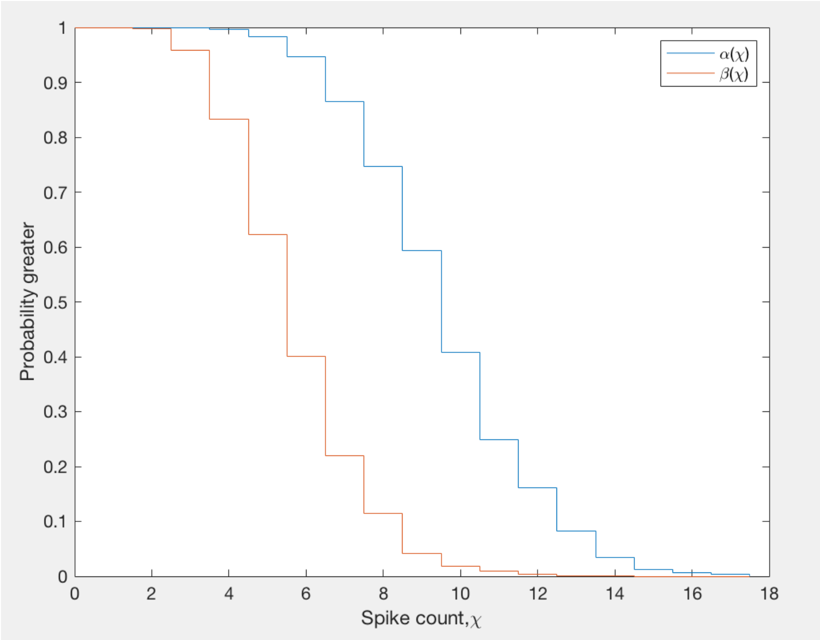

Fig 5.

As for Fig 5., the spike count range is smaller than which in Fig 2. And the probability greater decreases faster.

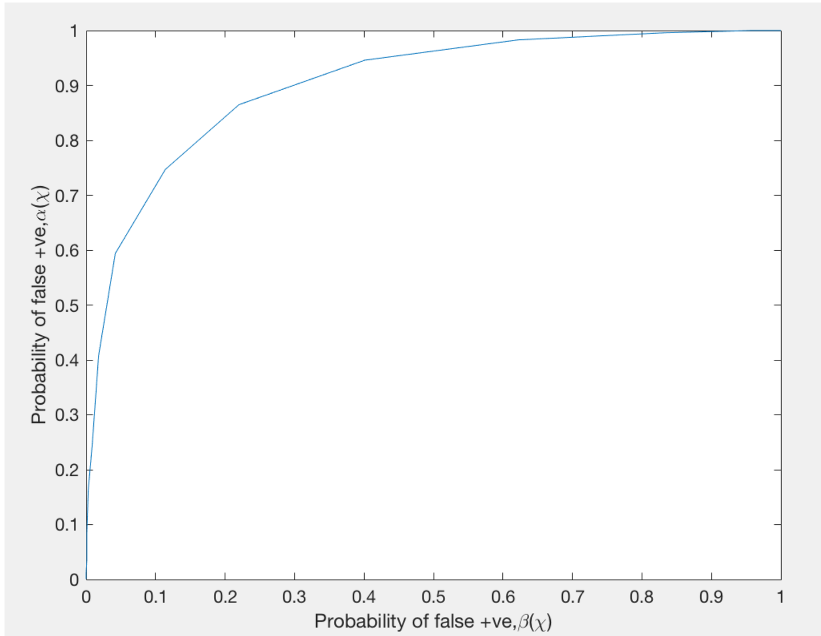

Fig 6.

Compared to Fig 3., the ROC curve in Fig 6. is farther from left and top border. This means, with shorter stimulus duration, it is harder for us to determine a spike is from stimulus present condition or not.

2.3 Question 3

We repeated Question 1 with a stimulus duration of 0.5s, but with several alterations: Mean applied current is 0.5nA in the presence of a stimulus. The noise is reduced in the presence of a stimulus($\sigma = 5pA.s^{0.5}$) and increased in the absence of a stimulus($\sigma = 50pA.s^{0.5}$).

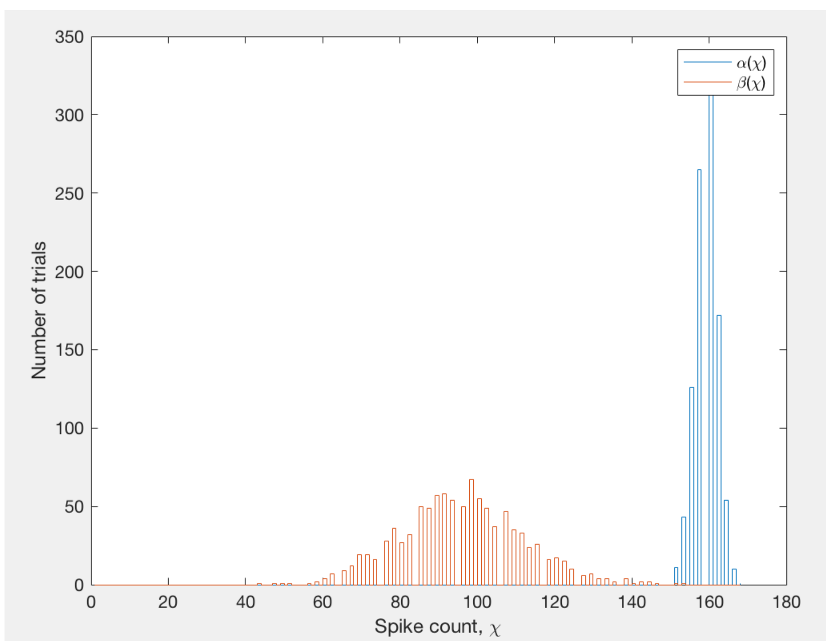

Fig 7.

There is almost no overlap in Fig 7, which means those two distributions are well seperated.

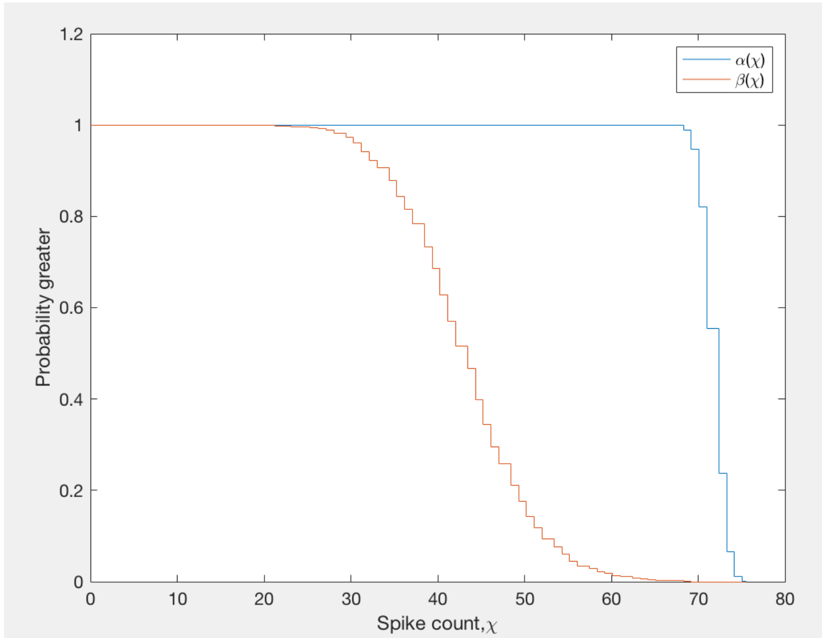

Fig 8.

The probability greater of $\alpha(x)$ begins at where $\beta(x)$ about to start decreasing, and it stays at 1 almost until $\alpha(x)$ turns to zero.

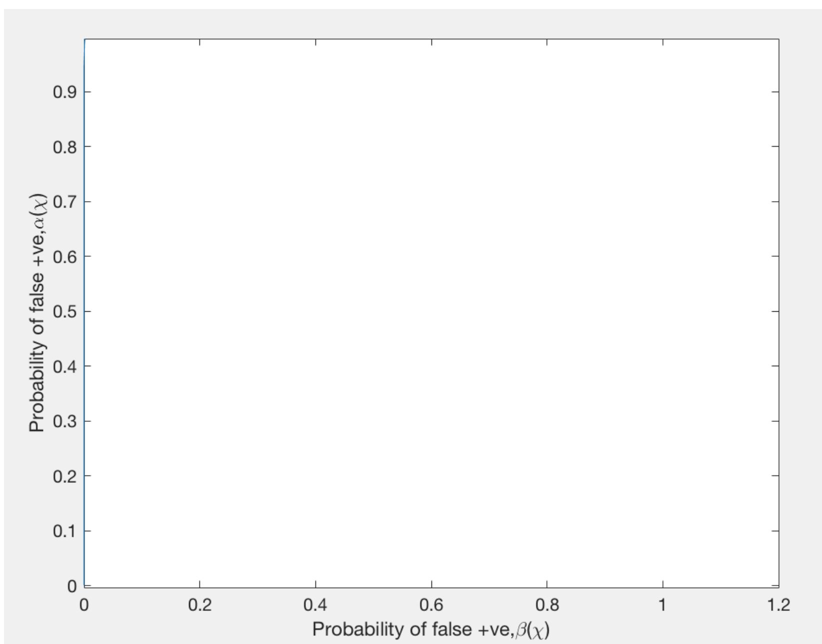

Fig 9.

We can barely see the ROC curve in Fig 9. But if we take a closer look, we could find that it overlaps with the left and top borders. It means that just by counting spikes in a trial, we could be nearly certain that a stimulus is present or absent.