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BIOL 450

Dr. Liu

27 March 2022

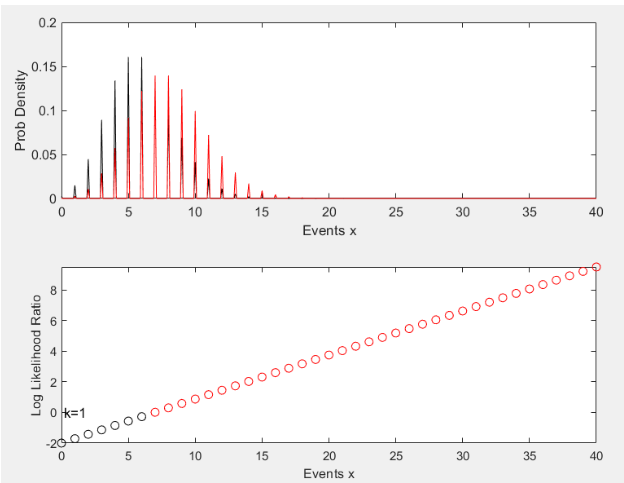
Assignment 8

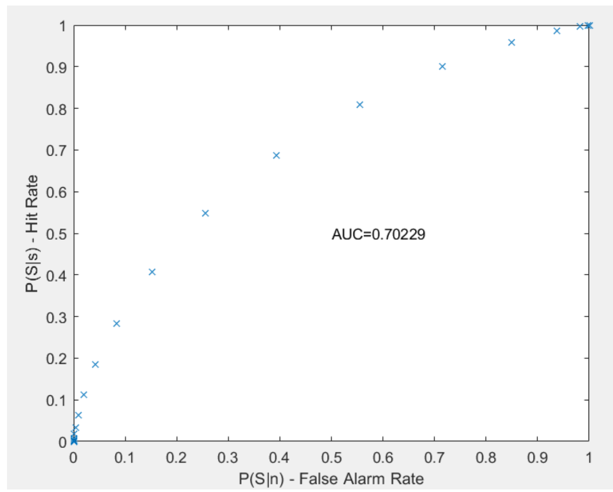
Part 1

Poisson Distribution

Question 1

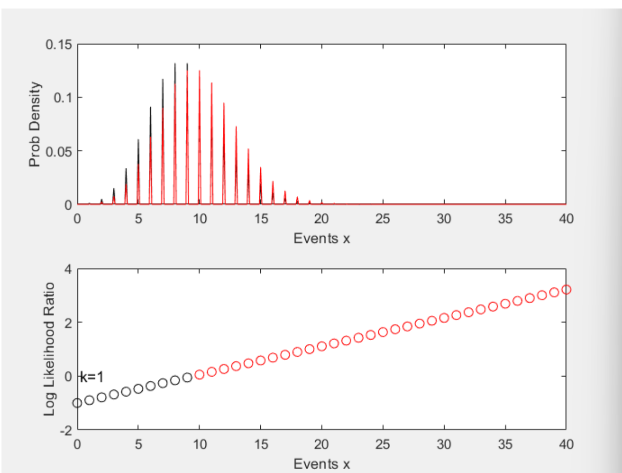
For a Poisson distribution of noise and signal, if the mean of the noise is 6 and the mean of the signal is 8, the AUC is 0.70229. This means that the detector decently detects the signal.

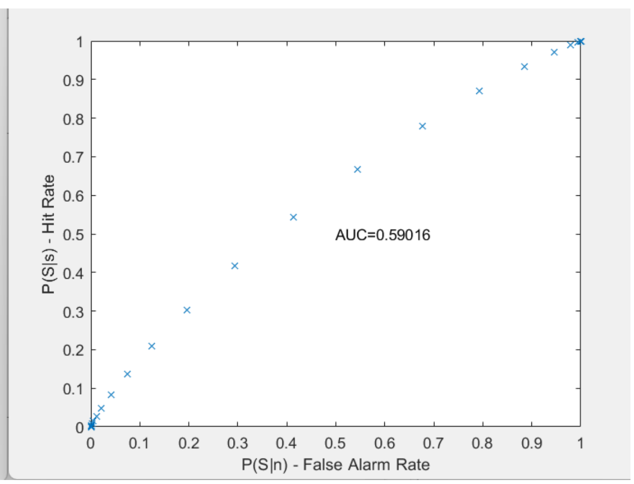




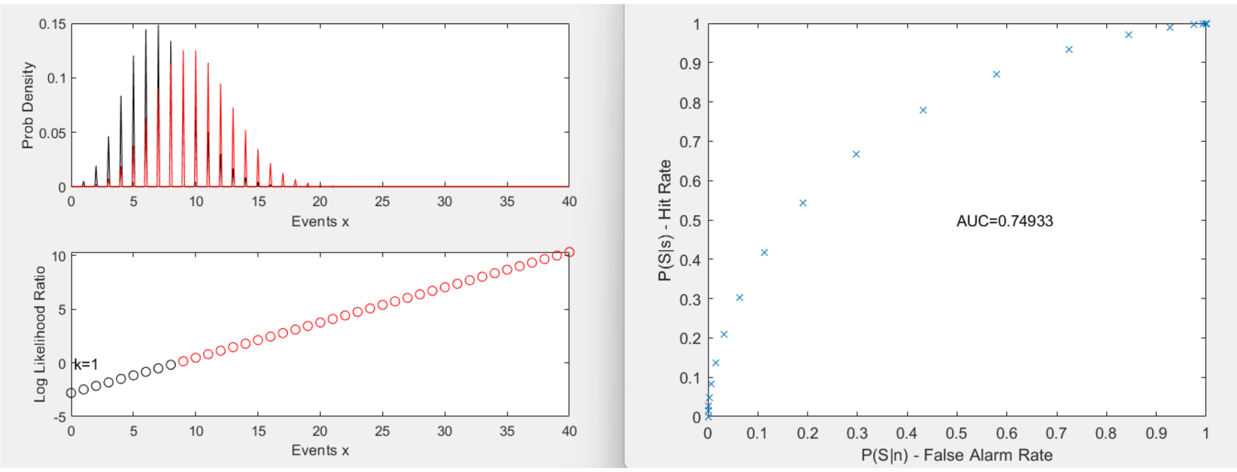
Question 2

If the mean of the noise is 9 and the mean of the signal is 10, the AUC is 0.59016.





If the mean of the noise is 7.2 and the mean of the signal is 10, the AUC is around 0.75. Since in a Poisson distribution the variance increases as the mean increases, the means will have to be further apart should the means increase. For example, a mean noise of 15 and a signal of 18 will yield an AUC of 0.69874. The means must be further apart, i.e., 15 and 19, for the AUC to remain at 0.75. Thus, as the means increase, the distance between the means must also increase for the AUC to stay at 0.75.



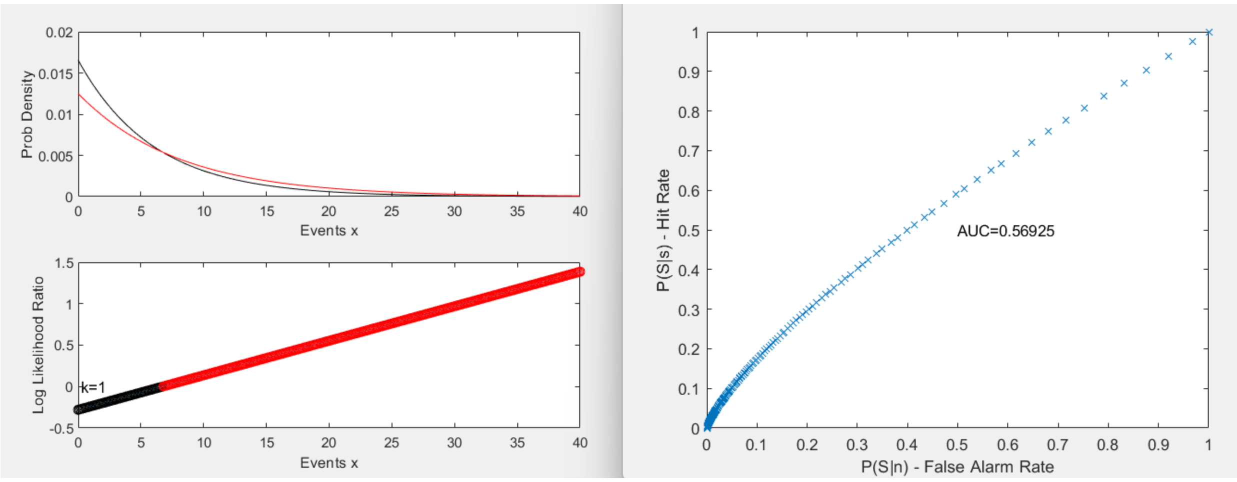
Question 3

A Poisson distribution reflects the probability of a certain number of events happening in a given time or space, with each occurrence being independent of one another, and with the mean rate of occurrences known and constant. For example, one can use the Poisson distribution to reflect the probability of a certain word appearing in a page of a book, or the probability of a call center receiving x number of calls. A type of detection task that would give rise to this kind of noise and signal distributions may be detecting the number of photons hitting a telescope or the number of tremors to signal an earthquake, since each deal with a certain number of occurrences happening in time or space.

Exponential Distribution

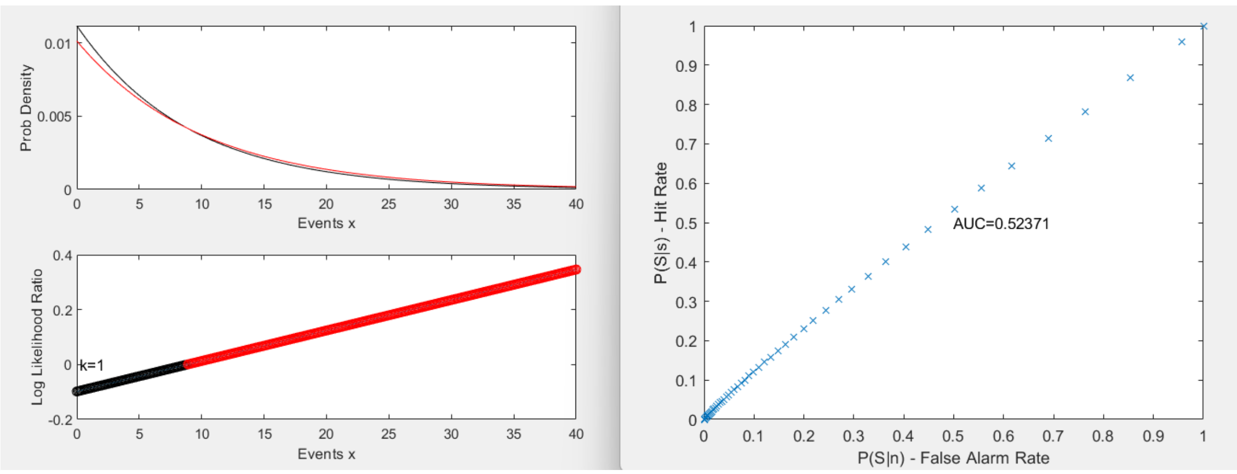
Question 1

For an exponential distribution of noise and signal, if the mean of the noise is 6 and the mean of the signal is 8, the AUC is 0.56925. This means that the detector is not very adequately detecting the signal, as an AUC of 0.5 would mean almost random selection.

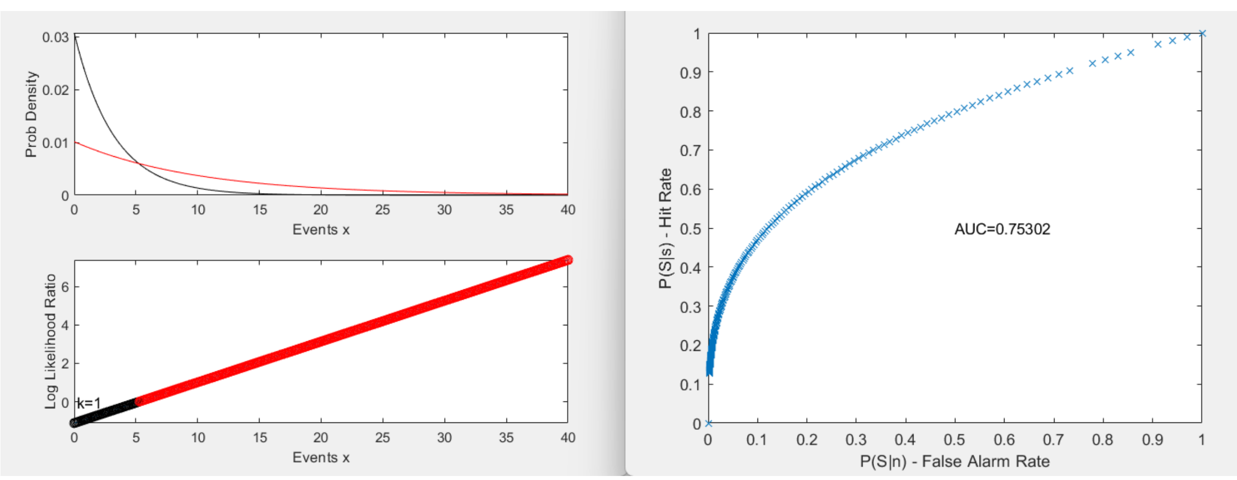


Question 2

If the mean of the noise is 9 and the mean of the signal is 10, the AUC is 0.52371.



If the mean of the noise is 3.2 and the mean of the signal is 10, the AUC is around 0.75. However, as the means increase, the variance also increases, so the difference between the means needs to increase as well. For example, a mean noise of 10 and a mean signal of 20 will only result in an AUC of 0.62709.



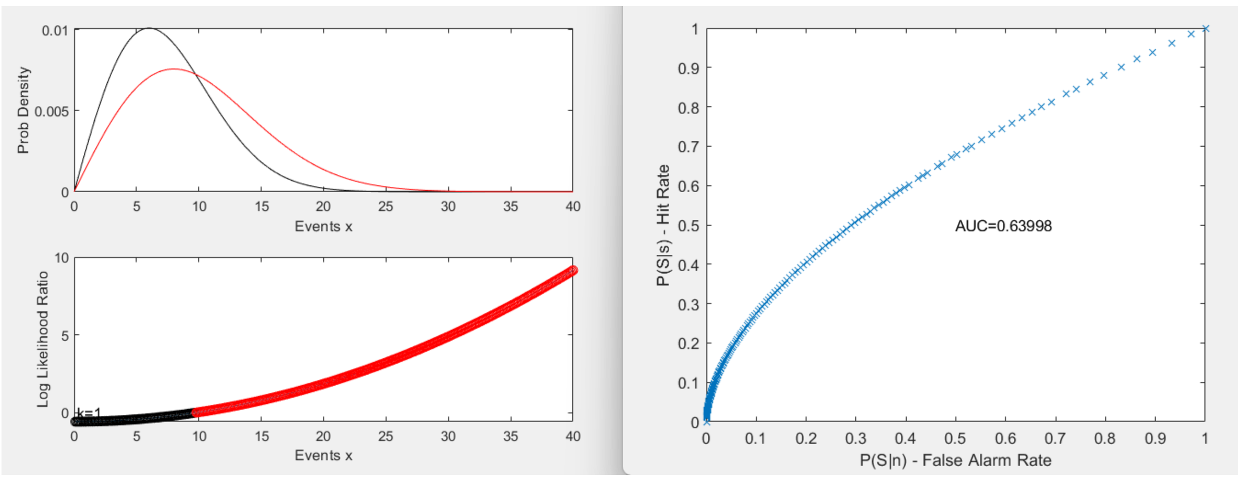
Question 3

An exponential distribution often reflects the wait time between two Poisson events. A type of detection task that would give rise to this kind of noise and signal distributions may be how long a battery will last, or the time between clicks on a Geiger counter, since both deal with time between events that have a known rate and are independent.

Rayleigh Distribution

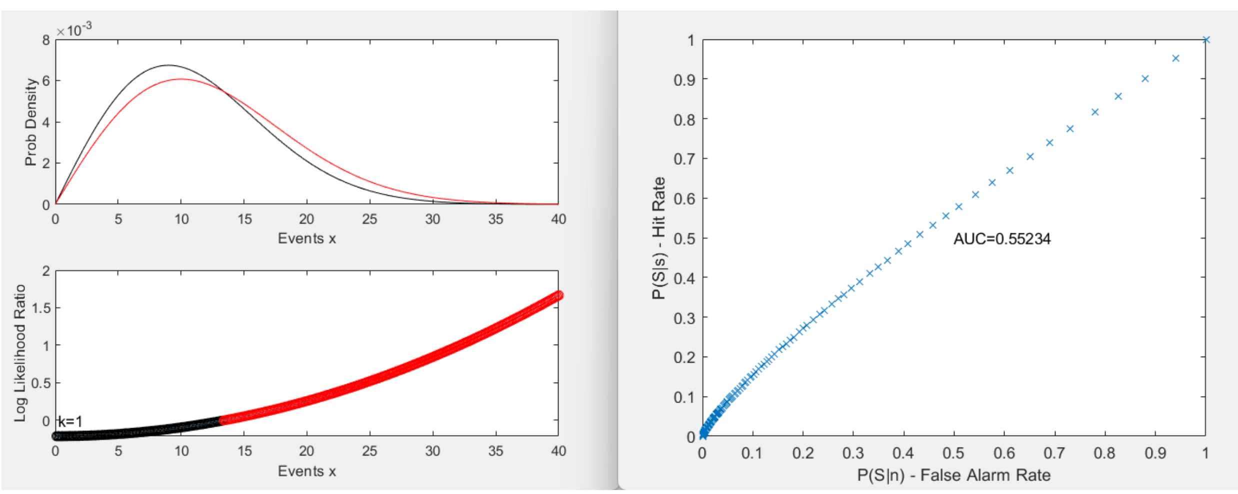
Question 1

For a Rayleigh distribution of noise and signal, if the mean of the noise is 6 and the mean of the signal is 8, the AUC is 0.63998.

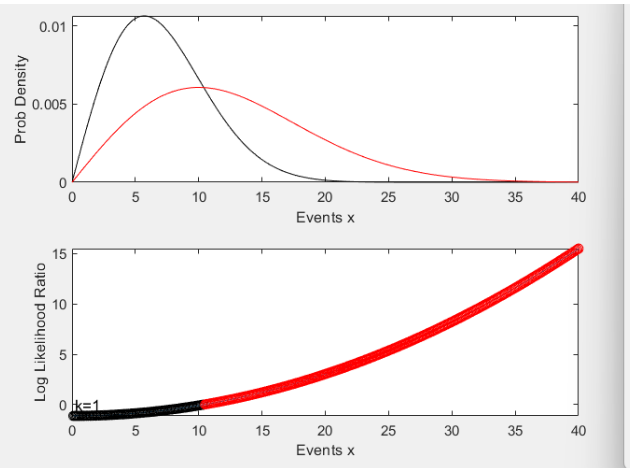


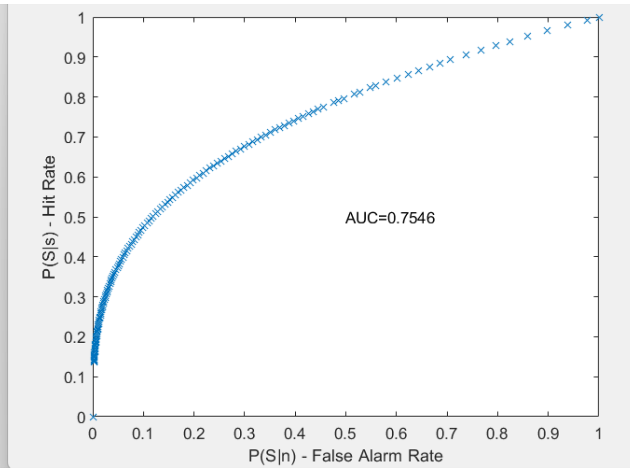
Question 2

If the mean of the noise is 9 and the mean of the signal is 10, the AUC is 0.55234.



If the mean of the noise is 5.7 and the mean of the signal is 10, the AUC is around 0.75. Like the Poisson and exponential distributions, to maintain an AUC of 0.75, it seems like the difference between the means must increase if the means themselves increase. For example, a mean noise of 15.7 and a mean signal of 20 yields an AUC of only 0.58424.





Question 3

A Rayleigh distribution models variables that can only have values equal to or greater than zero. A type of detection task that would give rise to this kind of noise and signal distributions may be looking at background signals during an MRI, since background noise in an MRI follows a Rayleigh distribution.

(This is my first time learning about the Rayleigh distribution. Earlier in the semester, we had a talk from Dr. Keilholz, whose research characterizes background noise in MRIs. I wonder if she works with the Rayleigh distribution and would be interested in seeing how this kind of signal detection plays out in the real world!)

Part 2

Question 1

Upon first observation of the raster plots and histograms, we predict that Unit 3065 has a better ability to detect the sound compared to silence. To the naked eye, the spike counts seem to clearly increase when the sound is presented, and they seem to quickly decrease when the sound ceases. Therefore, the difference between sound and no sound is easily distinguishable in the graph, making it presumably easier to detect between sound and silence. In contrast, while the spike counts of Unit 3009 increase quickly when the sound is presented, they do not seem to fall when the sound ceases. This means that there may be a lot of background noise in terms of spike count, and it is not easily distinguishable in the graph where sound differs from silence after the sound ceases. Thus, it may be more difficult to detect sound and silence in this scenario.

Question 2

Interestingly, to the naked eye, there seems to be more overlap in the probability distributions of spontaneous and sound-driven spike counts for Unit 3065 than for Unit 3009. While it seems like there is much overlap for Unit 3065, there seems to be more of a separation between the distributions in Unit 3009. This translates to the ROC curves, as the AUC for Unit 3065 is 0.77236, which is less than the AUC of Unit 3009, which in turn is 0.84432. The AUC difference means that Unit 3009 has a better ability to detect sound compared to silence, while Unit 3065 fares slightly worse. This contrasts with our prediction, which was the opposite. To see why Unit 3009 may have a better ability to detect sound versus silence, we can look at the average spike rates of each unit instead of small time bins. While it seems like

Unit 3065 has a clear difference between sound and silence at small time bins, the average spike rate may tell a different story. In contrast, for Unit 3009, spike counts were measured for a larger window, resulting in average spike rates that allow it to be easier to distinguish between sound and silence.

Distribution of spike counts, likelihood ratios, and ROC curves for Unit 3065 (top plot) and Unit 3009 (bottom plot).