EC60007: COMPUTATIONAL NEUROSCIENCE
PROJECT-3

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Part 1:

Q 1: Stimulus nature:

The autocorrelation function of the stimulus resembles the Dirac-delta function to a great extent, though it is not exactly the Dirac-Delta function. Since, we know that the Autocorrelation function of a White Gaussian Noise Process is Dirac-Delta function in Tau (time lag), so we can say that the stimulus is a White Gaussian Noise (though not a perfect one) with some noise.

The peak of the graph is around 0.33, which is also the variance of the stimulus. Hence, this confirms that the stimulus is White Gaussian with some noise.
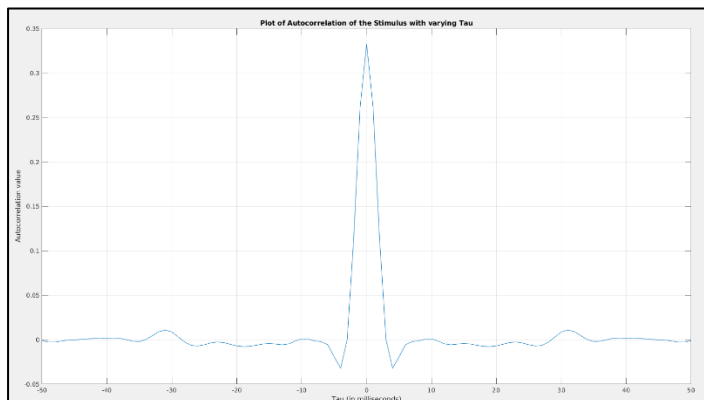

Fig 1. Auto-correlation function of the stimulus

Q 2: PSTHs and mean firing rate
The PSTH of the four neurons for a bin size of 1 ms are depicted in the following figures:
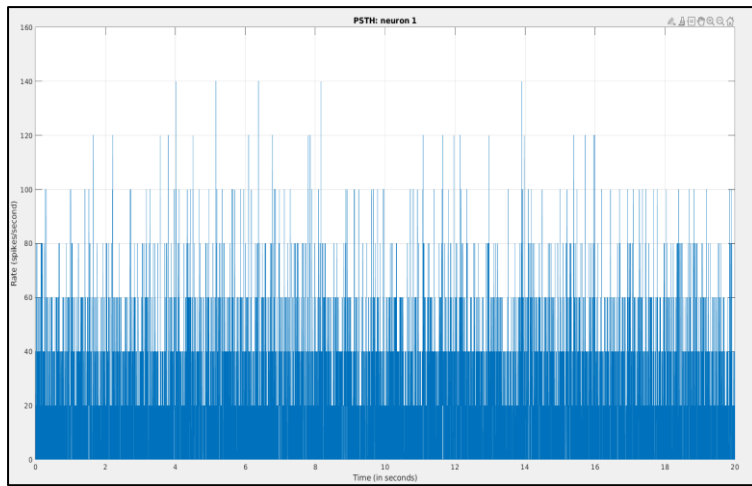
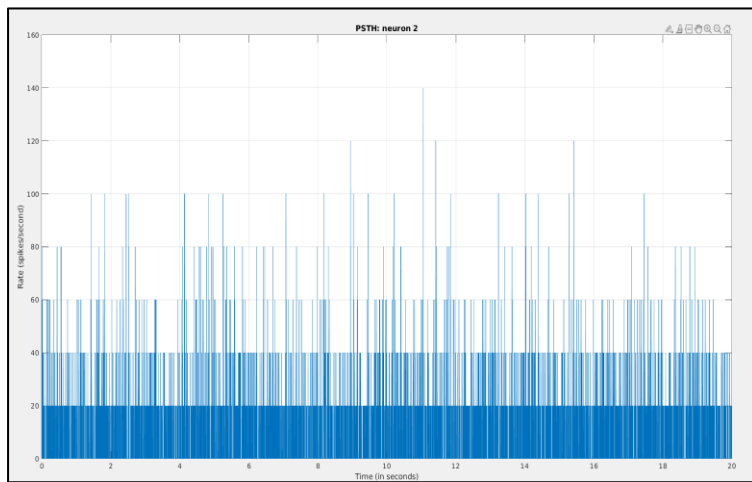Fig2. PSTH for neuron 1 for bin-size of 1 ms
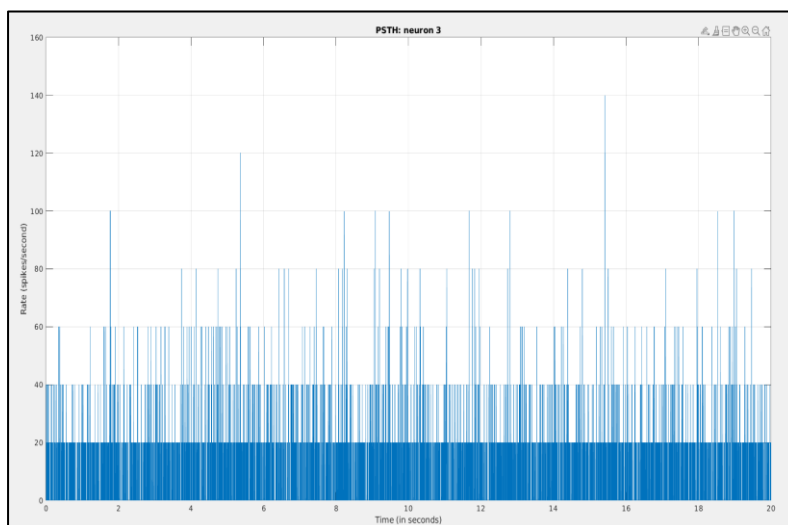

Fig3. PSTH for neuron 2 for bin-size of 1 ms
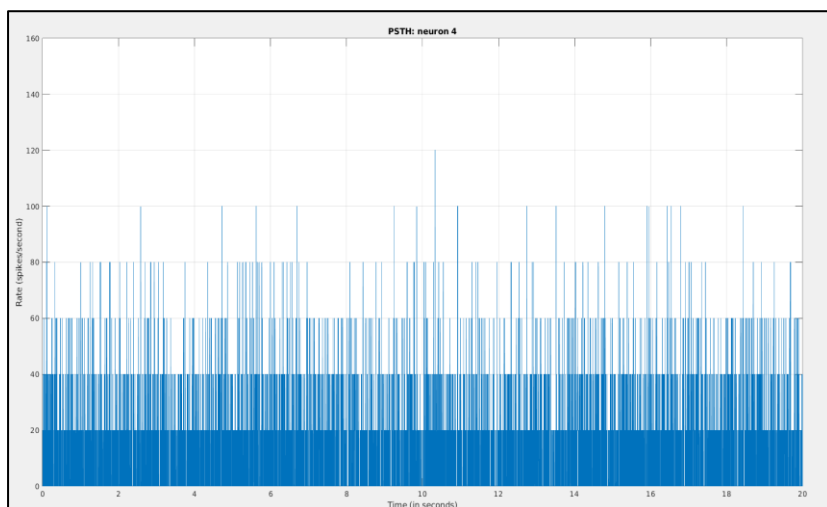

Fig4. PSTH for neuron 3 for bin-size of 1 ms

Fig5. PSTH for neuron 4 for bin-size of 1 ms

Q 3: Poisson or Non-Poisson nature of spiking for each neuron at different time scales

(a) Time scale of 10 ms
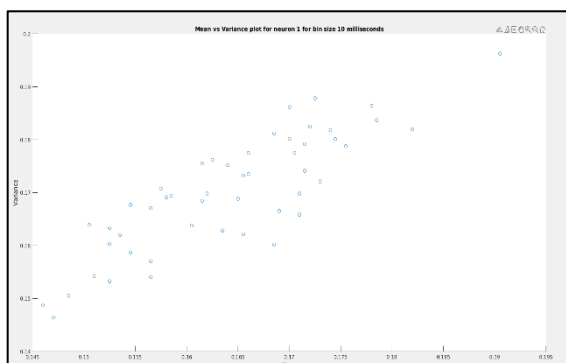Spiking appears to be approximately Poisson for all 4 neurons

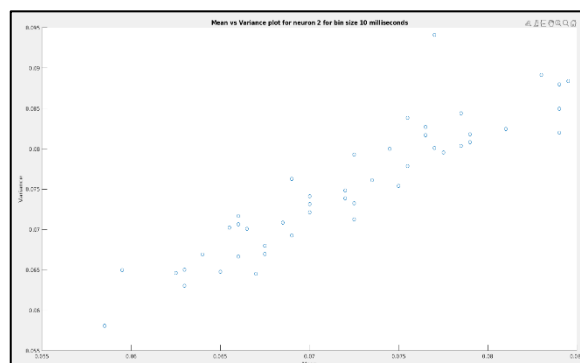Fig6. Variance vs Mean plot for neuron 1 for 10ms

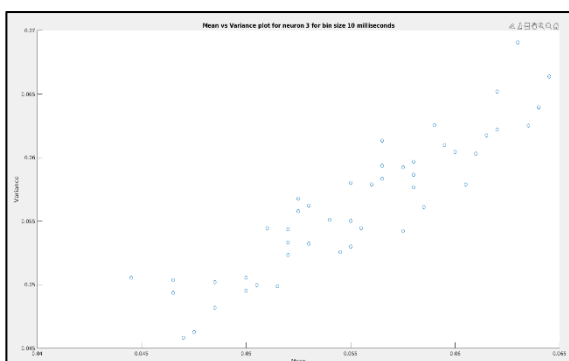Fig7. Variance vs Mean plot for neuron 2 for 10ms

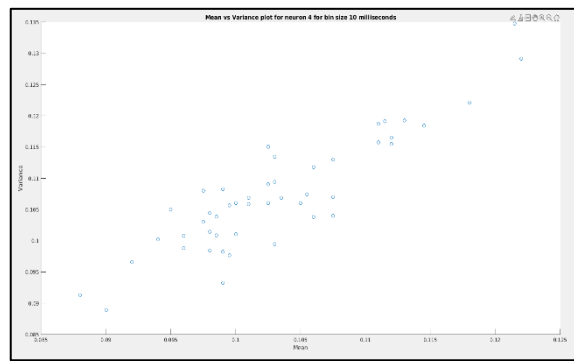Fig8. Variance vs Mean plot for neuron 3 for 10ms

Fig9. Variance vs Mean plot for neuron 3 for 10ms

(b) Time scale of 20 ms

Spiking appears to be approximately Poisson for all 4 neurons
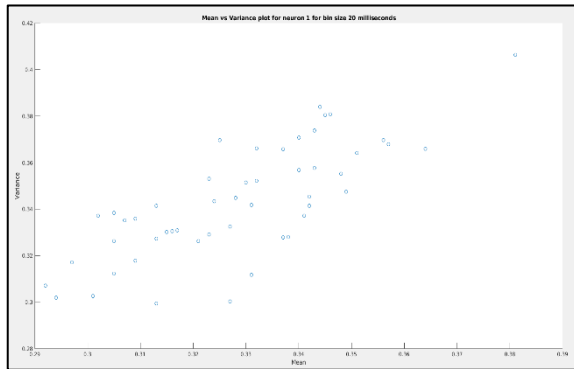
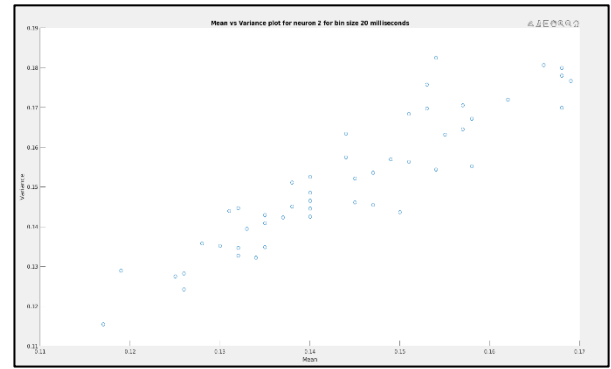

Fig10. Var vs Mean plot for neuron 1 for 20ms

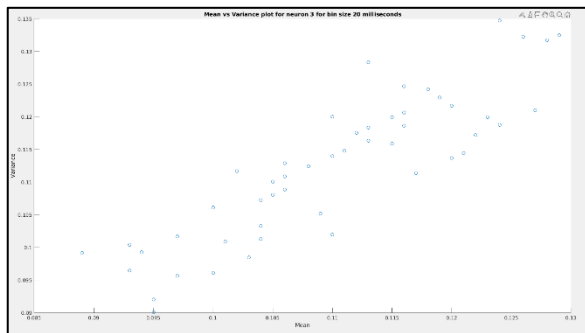
Fig11. Var vs Mean plot for neuron 2 for 20ms

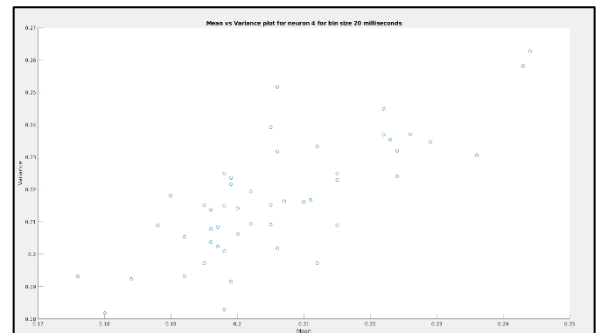Fig12. Var vs Mean plot for neuron 3 for 20ms

Fig13. Var vs Mean plot for neuron 4 for 20ms

(c) Time scale of 50 ms

Spiking appears to be Non-Poisson for Neuron 1 and 4 as its var vs mean plot is quite scattered around y = x line.

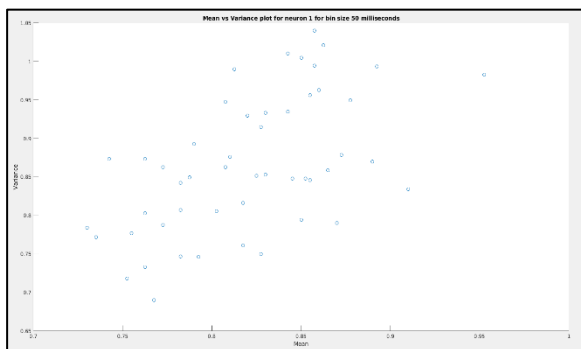For Neurons 2 and 3, it appears to be Poisson to some extent.
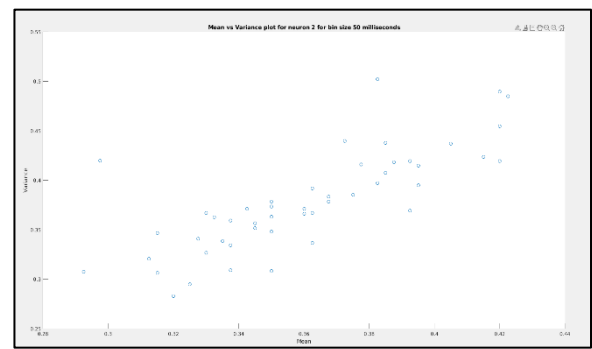

Fig14. Var vs Mean plot for neuron 1 for 50ms
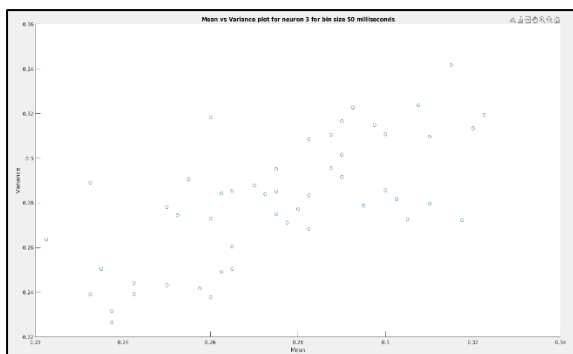

Fig15. Var vs Mean plot for neuron 2 for 50ms
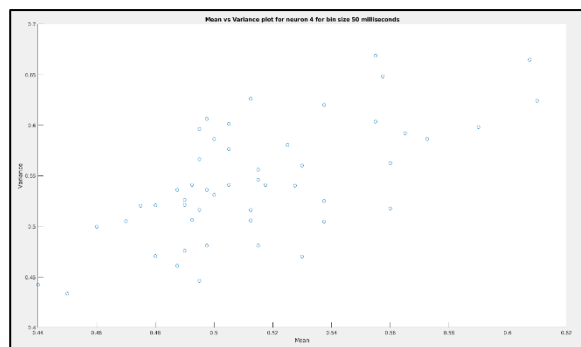
Fig16. Var vs Mean plot for neuron 3 for 50ms

Fig17. Var vs Mean plot for neuron 4 for 50ms

(d) Time scale of 100 ms:

Spiking appears to be Poisson for Neuron 2, and Non-Poisson for Neuron 1, 3 and 4.
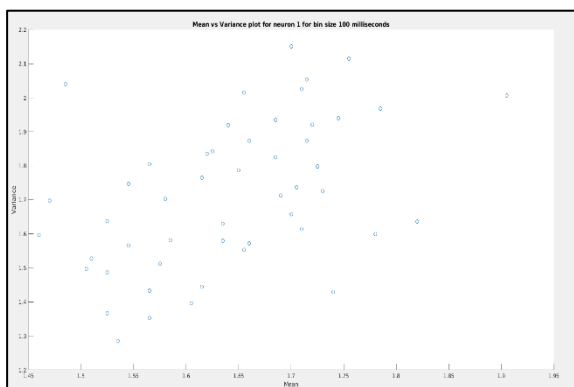

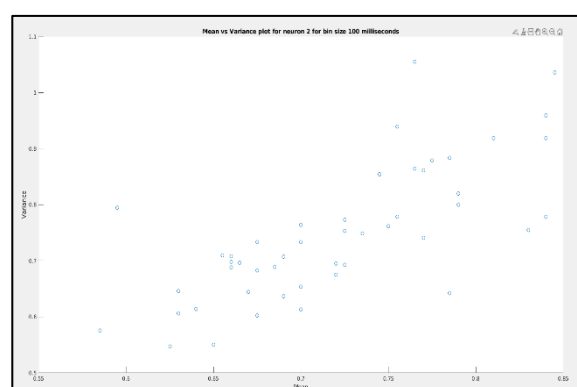Fig18. Var vs Mean plot for neuron 1 for 100 ms

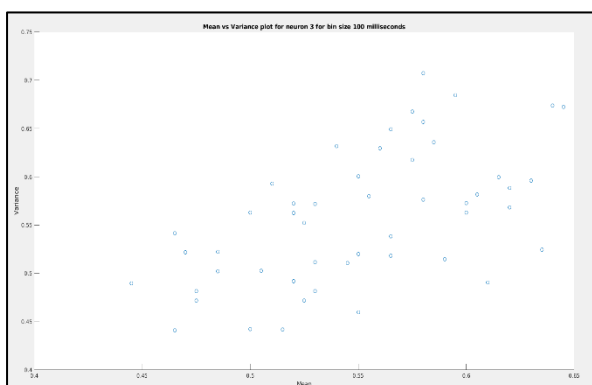Fig19. Var vs Mean plot for neuron 2 for 100 ms
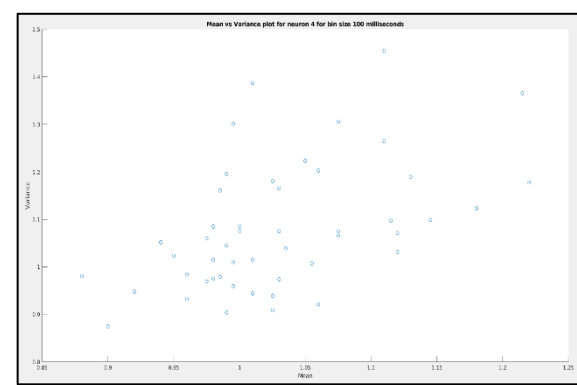

Fig20. Var vs Mean plot for neuron 3 for 100 ms

Fig21. Var vs Mean plot for neuron 4 for 100 ms

(e) Time scale of 200 ms

Spiking appears to be Poisson for Neuron 2, and Non-Poisson for Neuron 1, 3 and 4.
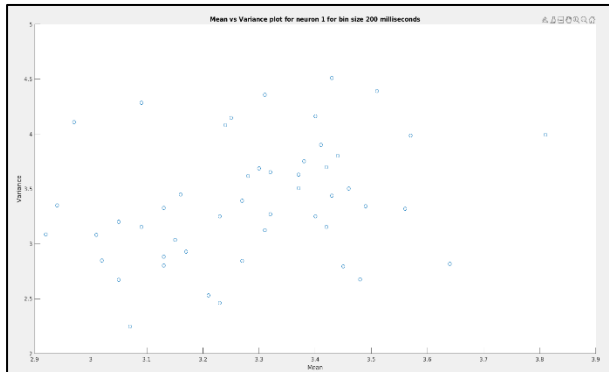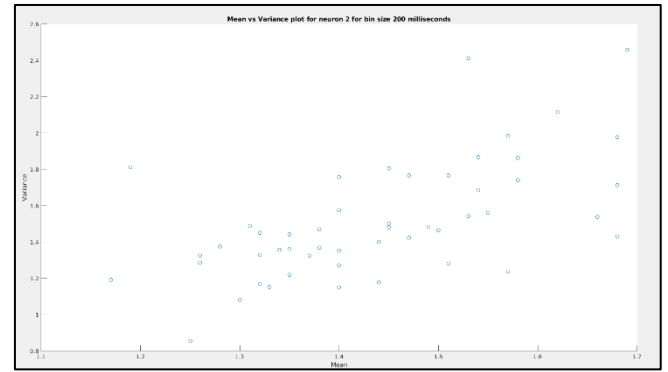

Fig22. Var vs Mean plot for neuron 1 for 200 ms

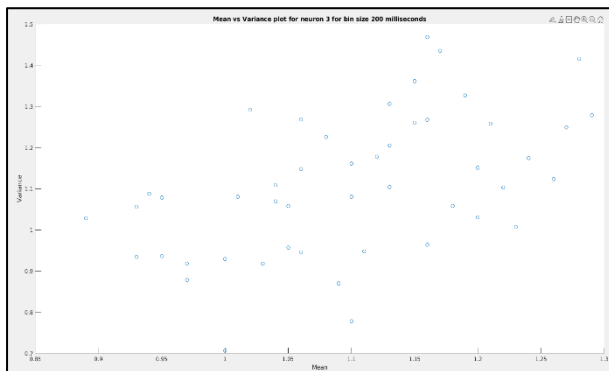Fig23. Var vs Mean plot for neuron 2 for 200 ms

Fig24. Var vs Mean plot for neuron 3 for 200 ms
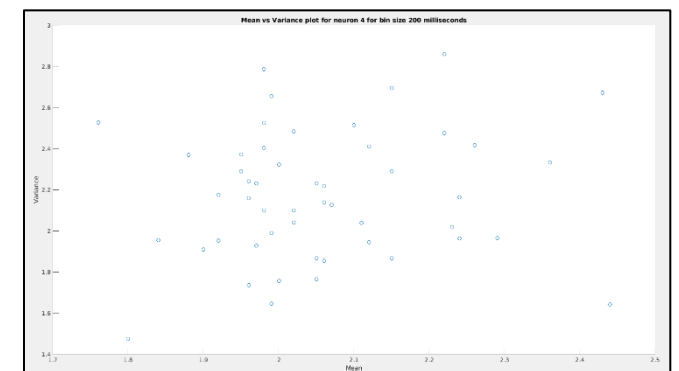

Fig25. Var vs Mean plot for neuron 4 for 200 ms

(f) Time scale of 500 ms

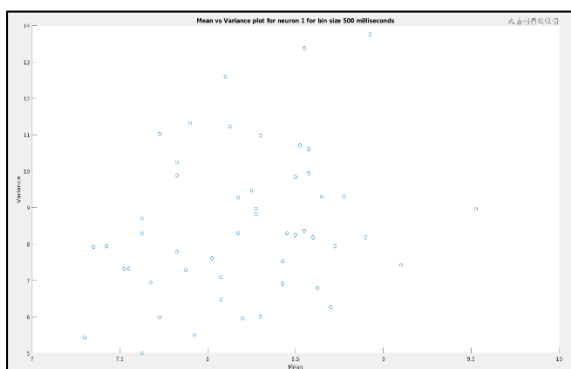Spiking is Non-Poisson for all 4 neurons

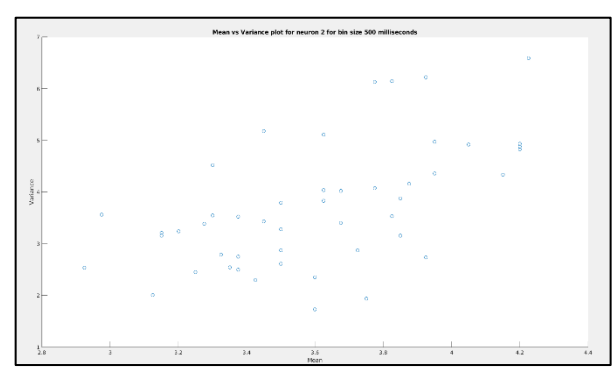Fig26. Var vs Mean plot for neuron 1 for 500 ms

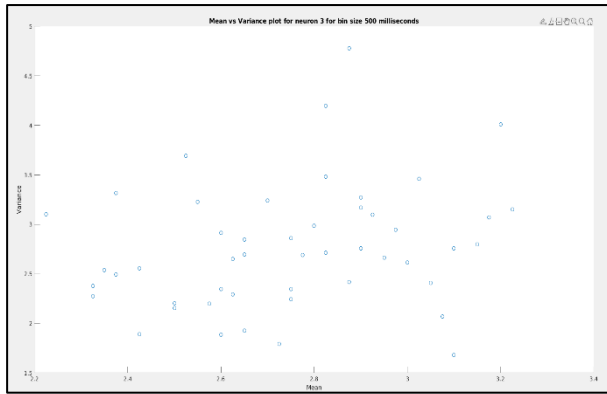Fig27. Var vs Mean plot for neuron 2 for 500 ms

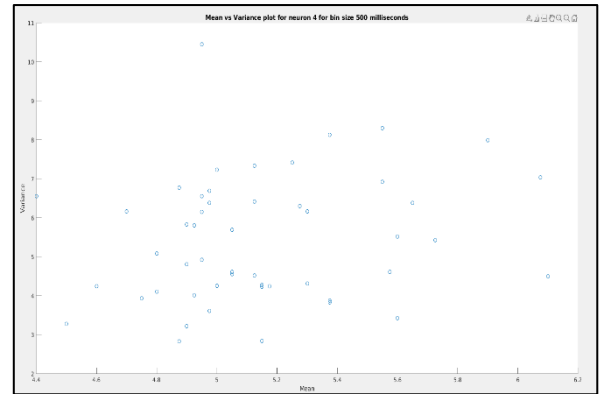Fig28. Var vs Mean plot for neuron 3 for 500 ms

Fig29. Var vs Mean plot for neuron 4 for 500 ms

Q 4: Spike-Triggered Average (STA) and Correction for Non-Gaussianity

Since the Stimulus is not an ideal White Gaussian Process, we need to add a correction term in our estimate of h(t) (h(t) proportional to STA) which was derived assuming stimulus to be WGN.

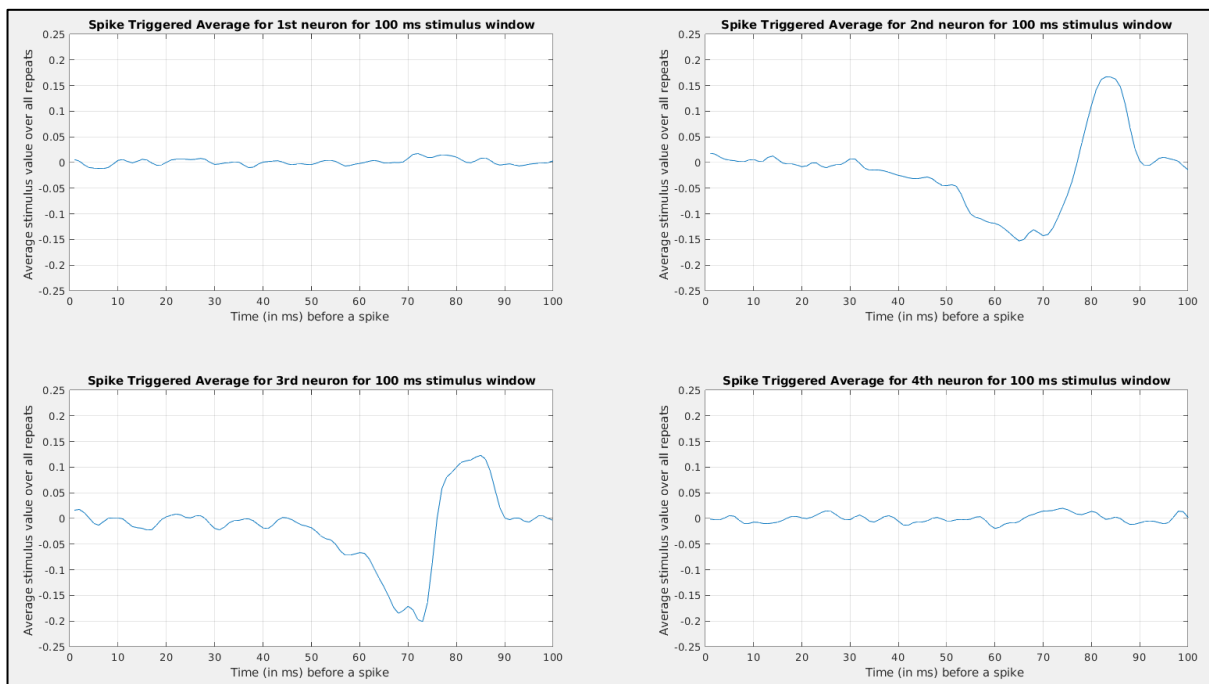- Linear filter h(t) (estimated as proportional to STA) for the 4 neurons with a window of 100 ms

Fig 30. Spike Triggered Average for the 4 neurons

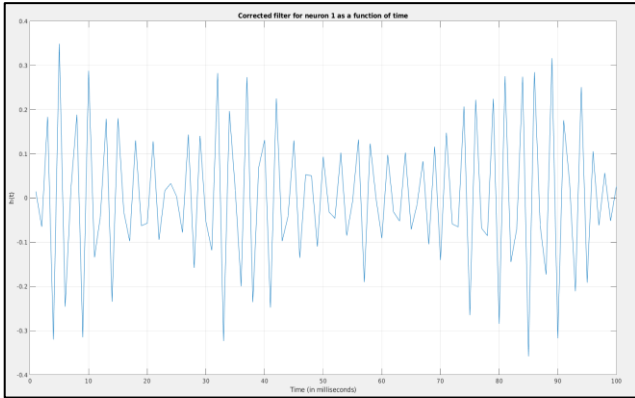- H(t) for the 4 neurons after applying the correction term
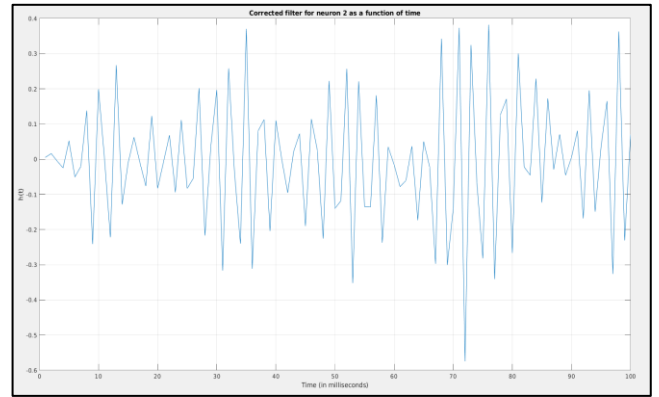

Fig31. Corrected filter for neuron 1
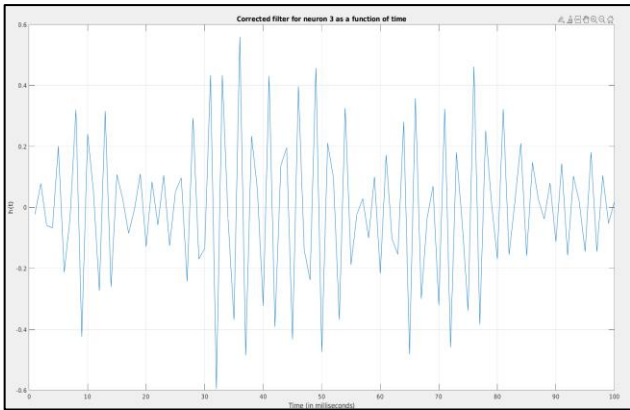

Fig32. Corrected filter for neuron 2

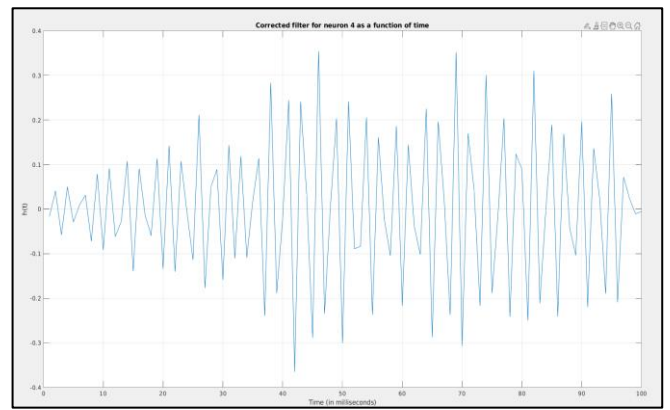Fig33. Corrected filter for neuron 3

Fig34. Corrected filter for neuron 4
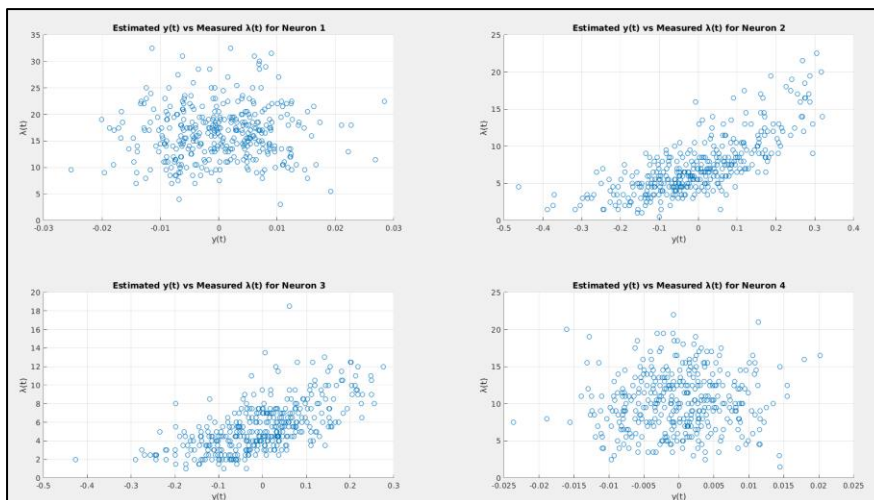
Q 5: Determining the Output Non-Linearity

Fig35. Plot of measured $\lambda(t)$ vs estimated $y(t)$ for the 4 neurons

- Estimation of the Non-Linearity (sigmoid function):

The fitting is not at all appropriate for the Neuron 1 and 4, and is somewhat approximately sigmoid at least in the middle range.
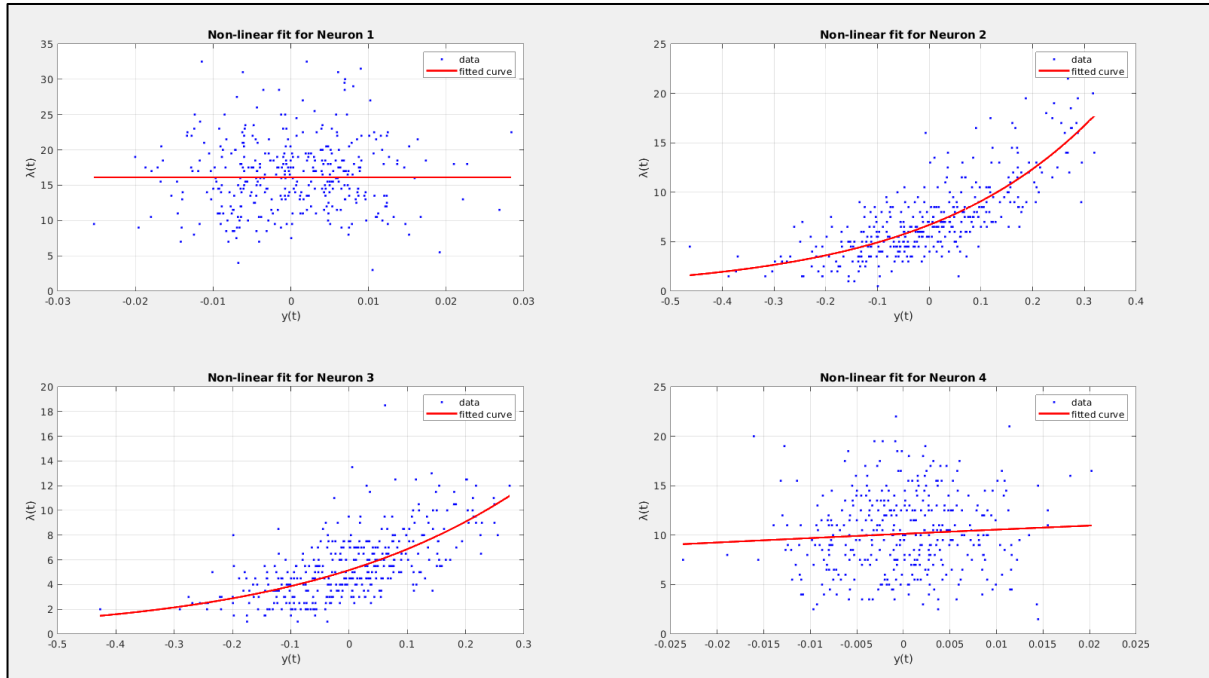

Fig36. Non-Linear fitting sigmoid for the four neurons

Q 6: Prediction performance and pruning of filter parameters

- **Plotting the predicted and actual firing rates for the last 5 seconds before pruning:**
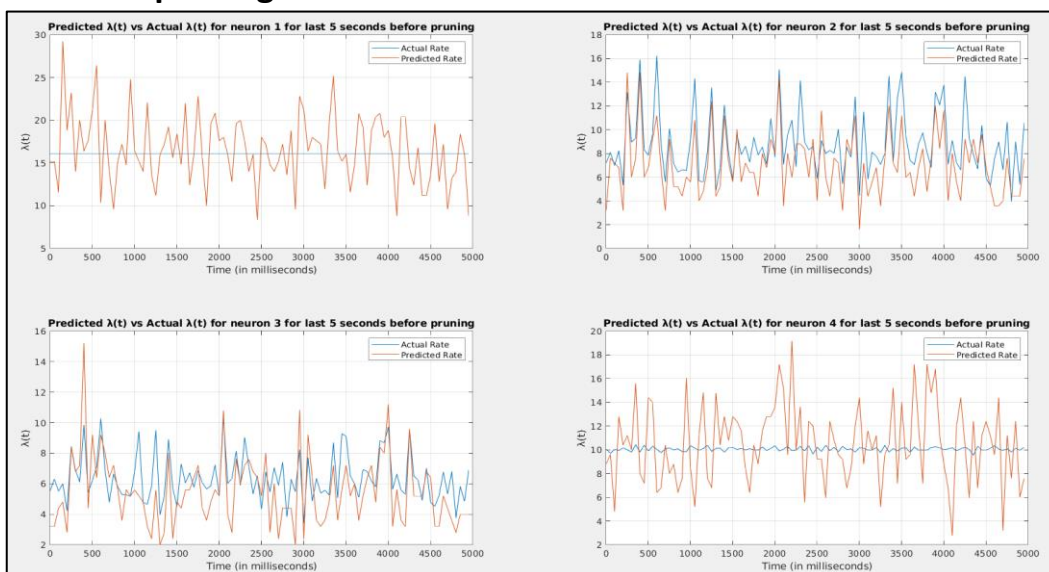

Fig37. Predicted and actual rates (calculated as PSTHs) for last 5 seconds before pruning

- Pruning: Is done for only neurons 2 and 3 and not for neurons 1 and 4 as the r-squared value of neurons 1 and 4 is very low and their respective filters do not lead to correct predictions of rate.
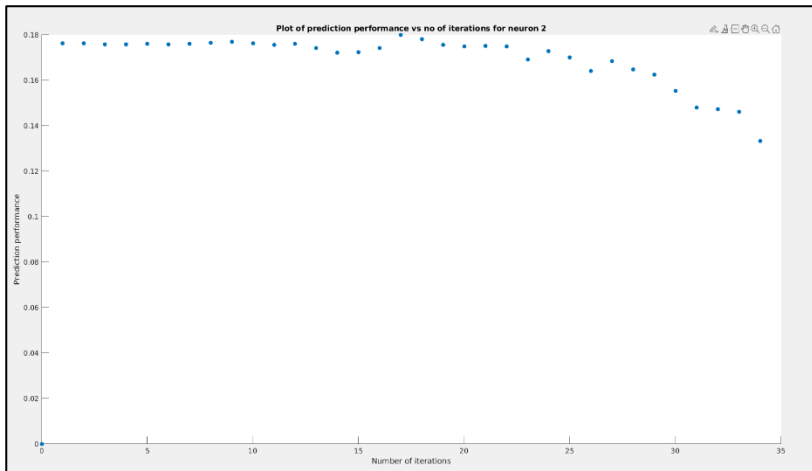

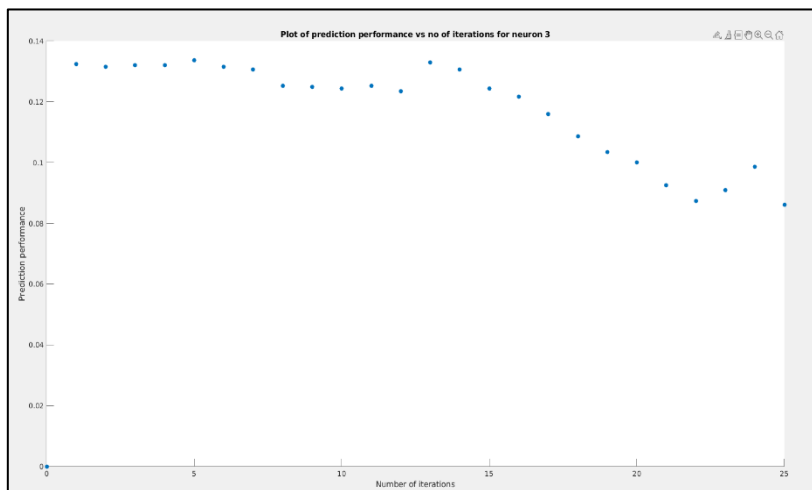Fig38. Prediction performance vs no of pruning iterations for neuron 2

Fig39. Prediction performance vs no of pruning iterations for neuron 3

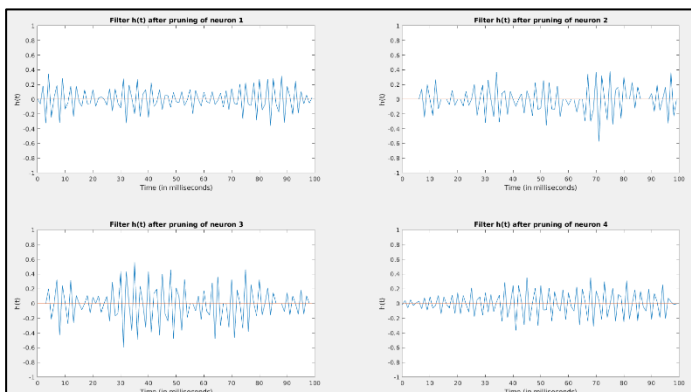- On Pruning, we obtain the new filters which do not overfit on the train data (0-15 seconds)

Fig 40. Filter after pruning for each neuron

- Fourier Transform of the pruned filters: On computing the Fourier Transform of the pruned filters, we observe that the filters act as band-pass filters and they allow both very low and very high frequencies to pass through, but not the frequencies in the middle ranges.
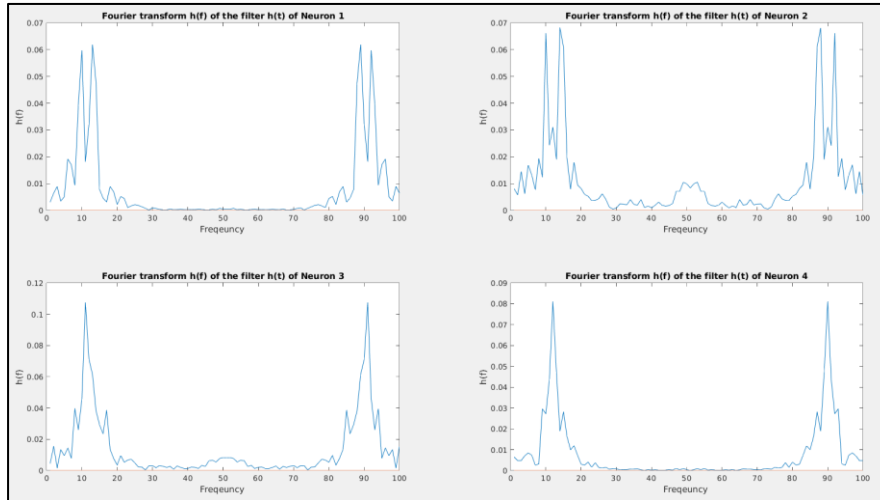

Fig 41. Fourier Transform of the pruned filters

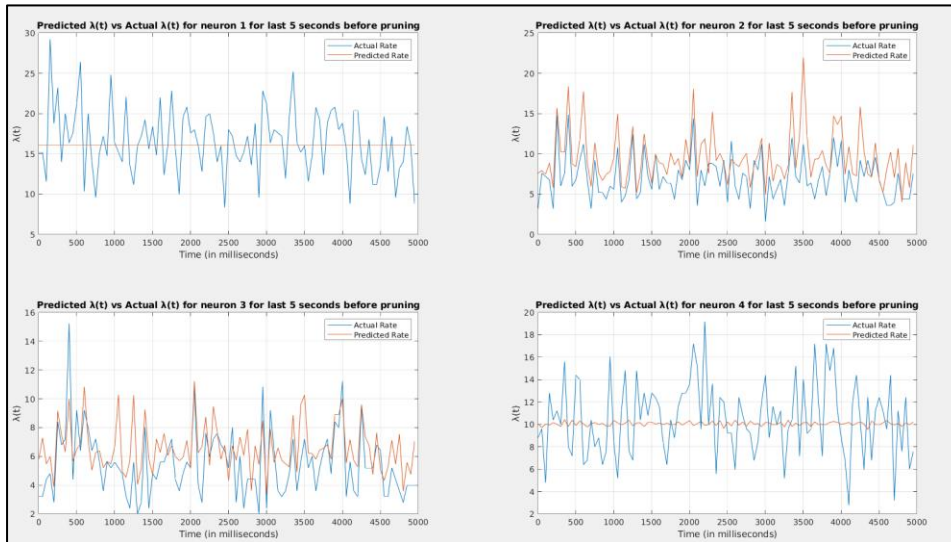- Predictions of firing rate after pruning of filter params:

Fig 42. Predicted and actual rates (calculated as PSTHs) for last 5 seconds after pruning
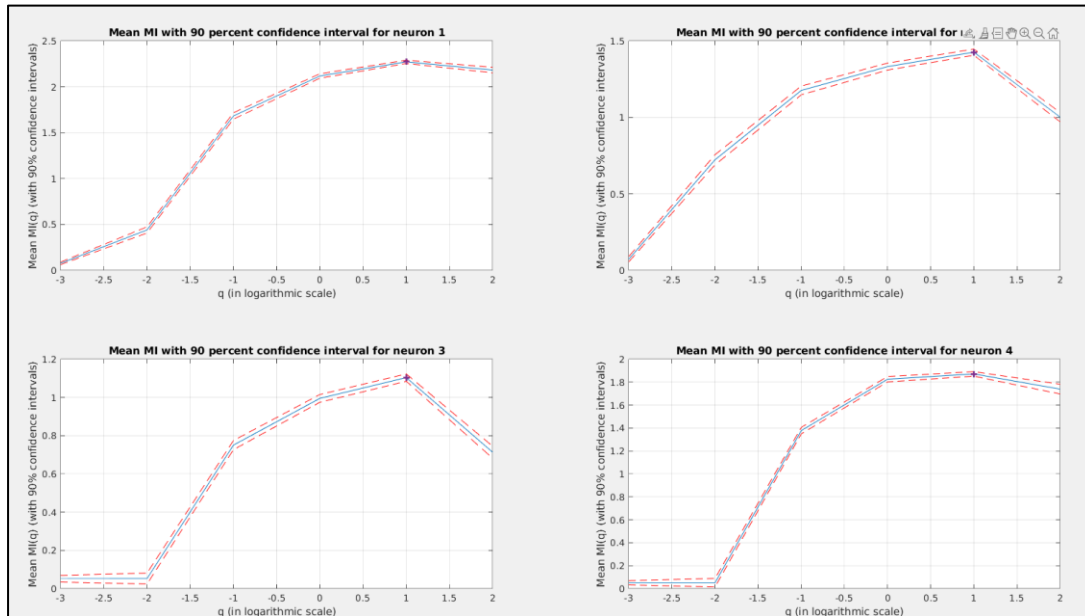
Part 2: Victor-Purpura Spike Distance Measure

Fig 43. Plot of Mean MI (90 % C.I.) for the 4 neurons