Stimulus Response Latency Estimation

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Order

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- Change point
- Purpose
- Application and simulation results
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Stimulus response latency

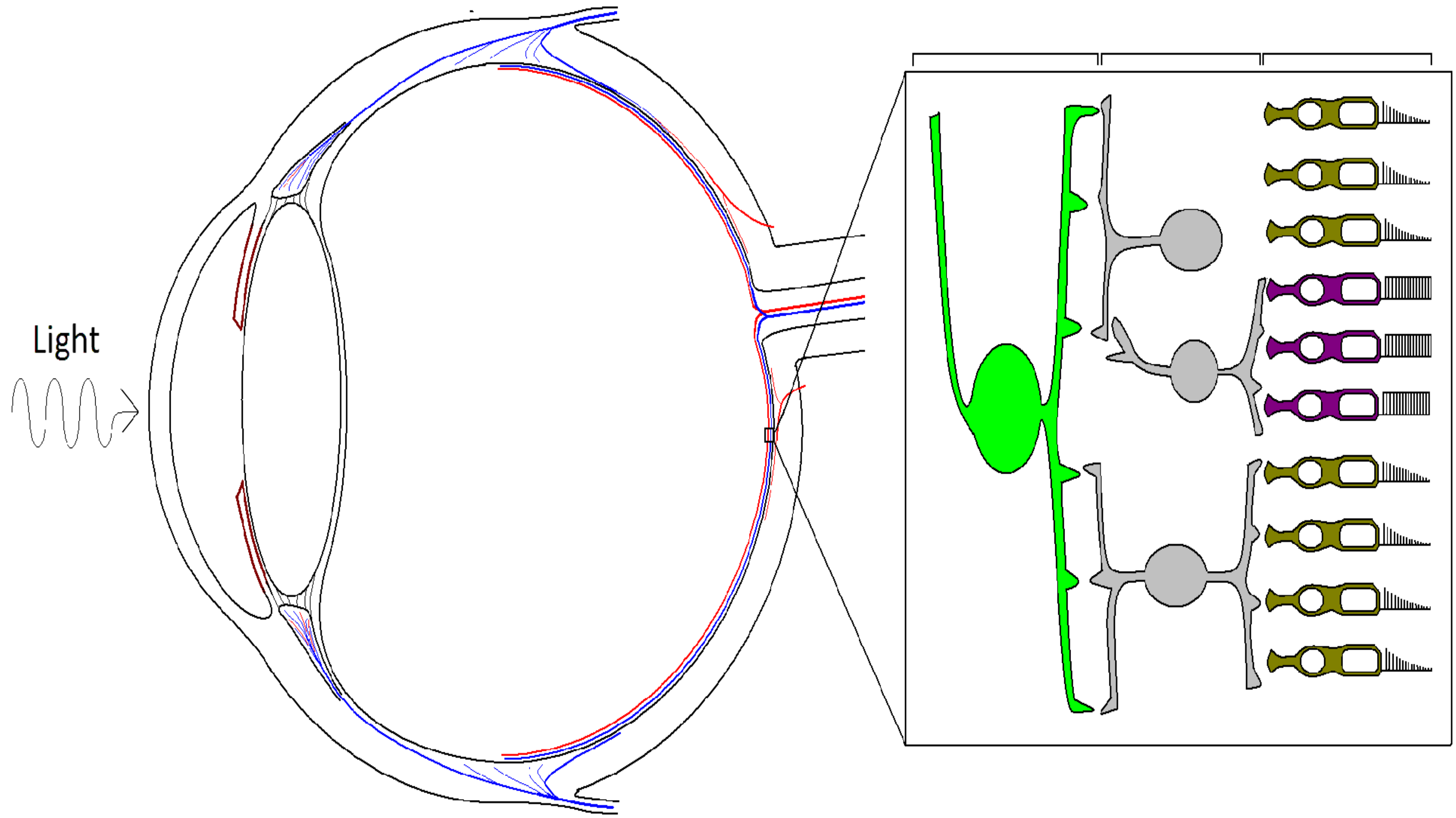
- It is the time between the stimulus and the neural activity (Friedman and Priebe, 1997).
- They compare different types of estimators: Maunsell-Gibson, Half-Height, Maximum Likelihood, Least Square.
- In order to obtain a good latency estimator, the MLE of the change point can be use.
- MLE works with the neural spikes rather than the peri-stimulus histogram.

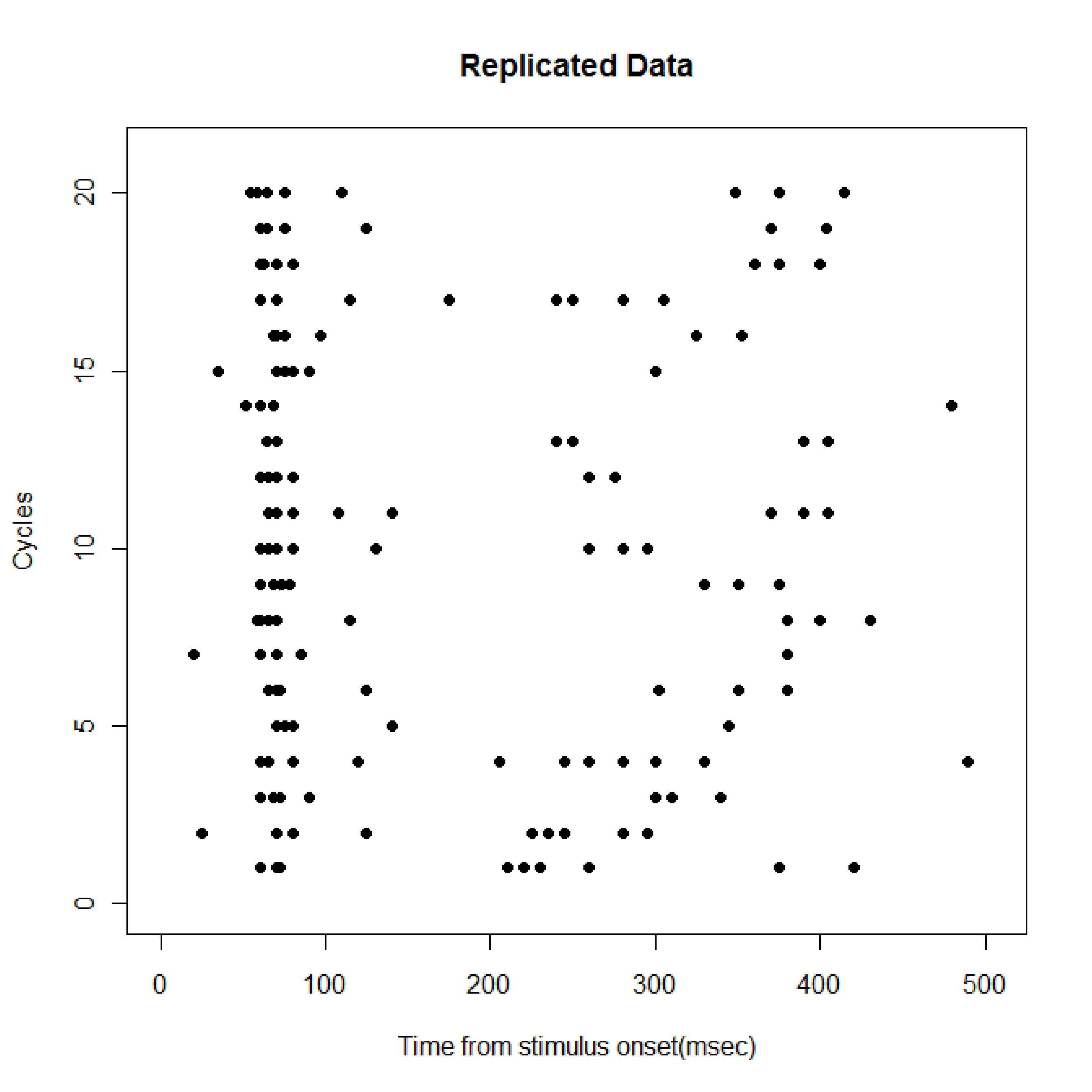
Cont.

- The point in which the histogram changes is call the change point.
- It is important to choose the optimal smoothing bandwidth for the peri-stimulus histogram to obtain a better way to represent the data. It can be obtained using bootstrapping (Friedman and Priebe, 1997).
- This smoothed histogram is use for the Half-Height technique, but that technique has limitations.

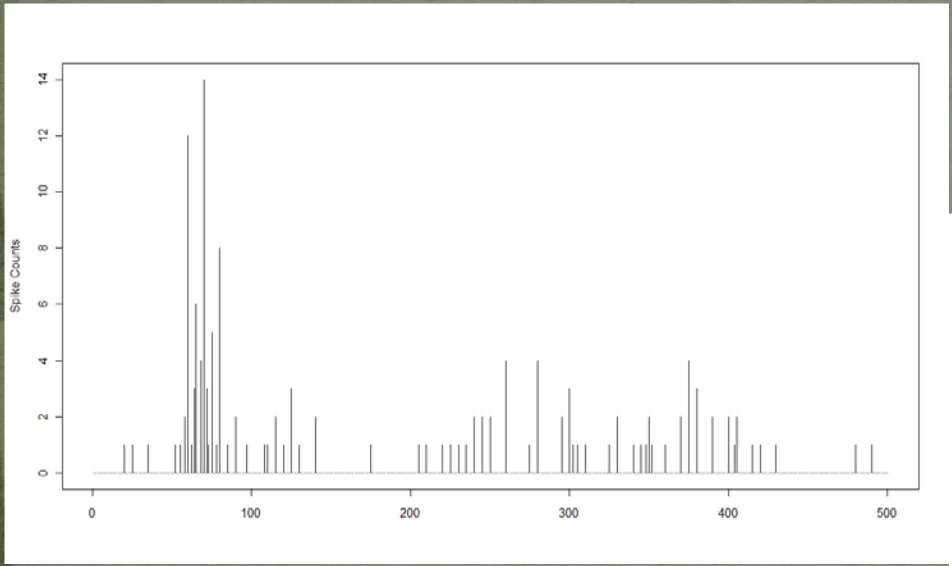
Neural response periods

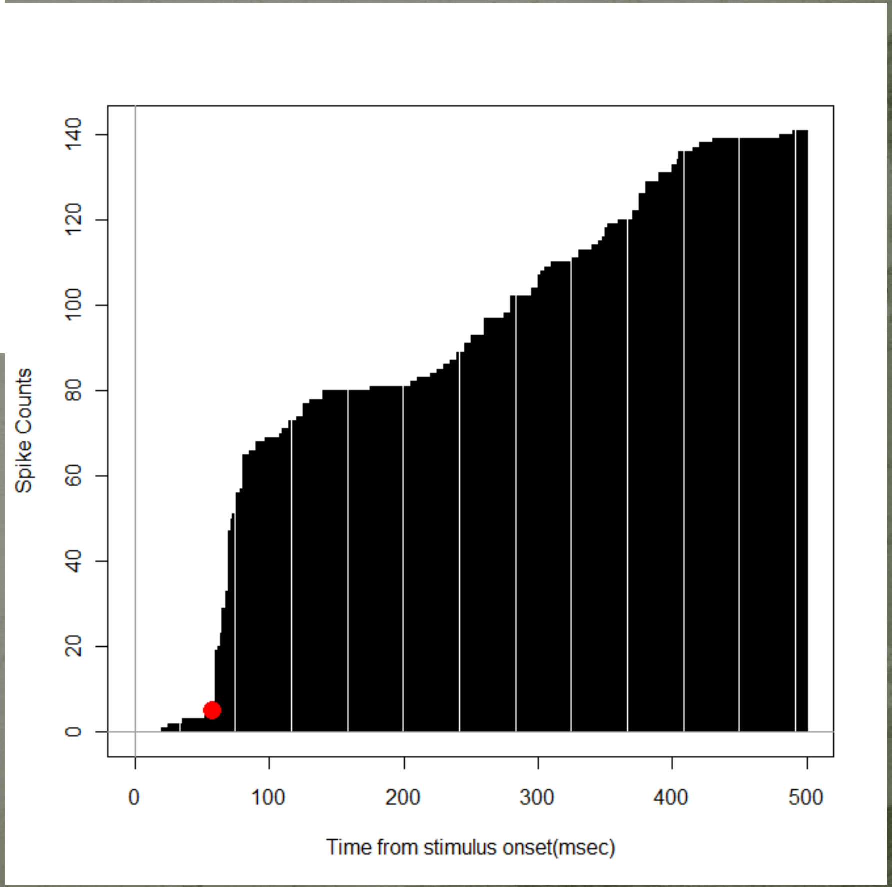
- Nonstimulus evoked rate
- Initial stimulus evoked rate
- Terminal stimulus evoked rate
- Transitions between periods are change points, but this project will concern only in the first.


Light

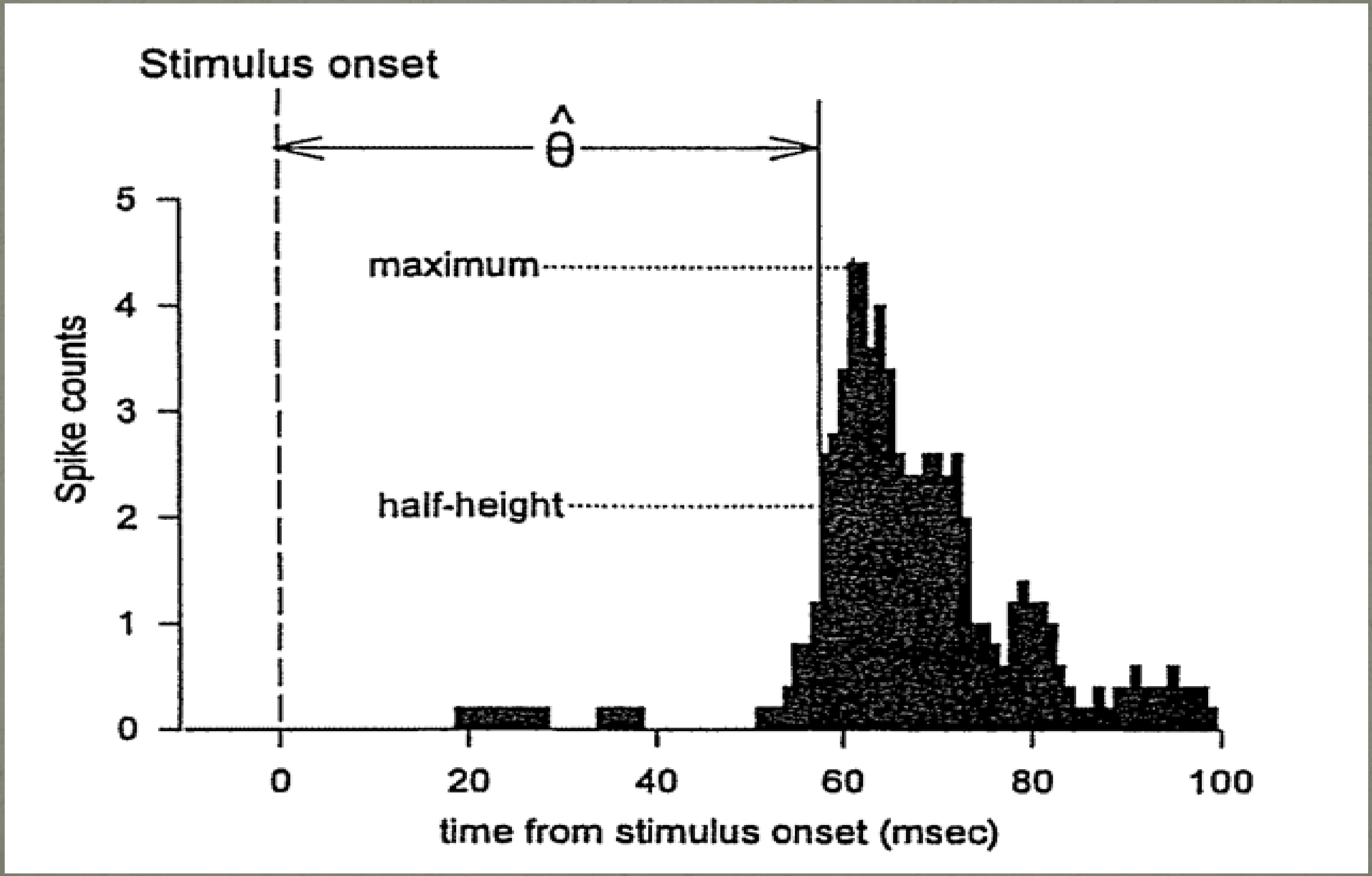

Replicated Data
Cycles
0
5
10
15
20
0
100
200
300
400
500
Time from stimulus onset(msec)

Peri-stimulus histogram of spike arrivals





Smoothed peri-stimulus histogram



Change point

- The change point technique is use to see shifts in mean or variance (Hawkins and Zamba, 2005).
- Change point technique,

$$X_i \sim \begin{cases} F(\mu 1, \sigma 1) \;;\; i \leq \tau \\ F(\mu 2, \sigma 2) \;;\; i > \tau \end{cases}$$

$$X_1, \ldots, X_\tau;\; X_{\tau+1}, \ldots, X_n$$

- Changes in mean, variance or both

Cont.

- If $\tau = k$, define

$$V_{i,k} = \sum_{j=i+1}^{k} (X_j - \overline{X}_{ik})^2 \quad \text{and} \quad S_{i,k} = V_{i,k} / (k-i)$$

- GLR for shift at time k is

$$GLR = k \log(S_{o,k} / S_{o,n}) + (n-k) \log(S_{k,n}/S_{o,n})$$

- $S_{i,k}$ is the MLE of variance

$$\overline{X}_{ik} = \sum_{j=i+1}^{k} X_j /(k-i)$$

- $G_{k,n} = \frac{GLR}{c}$; where c in the correction factor,

$c= 1+ 11/12[1/k + 1/(n-k) -1/n] +[1/k^2 + 1/(n-k)^2 -1/n^2]$

- $G_{max,n} = max_k\ G_{k,n}$
- The maximizing index is the likelihood ratio estimate of the change point.

Dynamically and sequentially

- Iteration process (about $G_{max,n}$)

  - if $G_{max,n} \le h_n$, no evidence

  - if $G_{max,n} > h_n$, evidence

- $\hat{\tau}$ will then be the maximizing index.
- The time from 0 to $\hat{\tau}$ is the latency.

Cont.

- The hazard function is the probability of failure of a unit at time n given that it did not fail before.
- h_n is chosen to maintain a constant hazard function
- For a specified type I error α

$$P[G_{\max,n} > h_{n,} \mid G_{\max,j,\alpha} \le h_{j,\alpha}\ ;\ j < n] = \alpha$$

$G_{max,n}$ and $h_{0.002,n}$

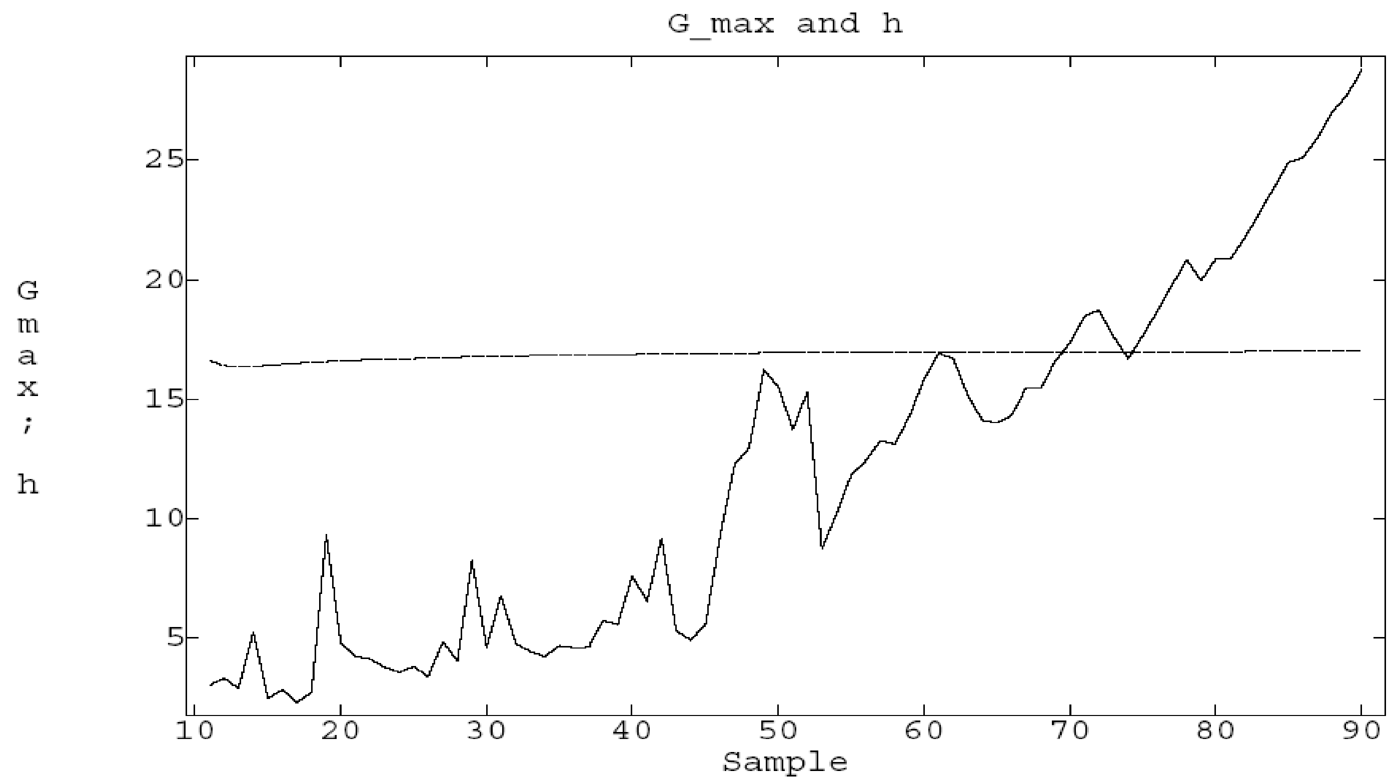


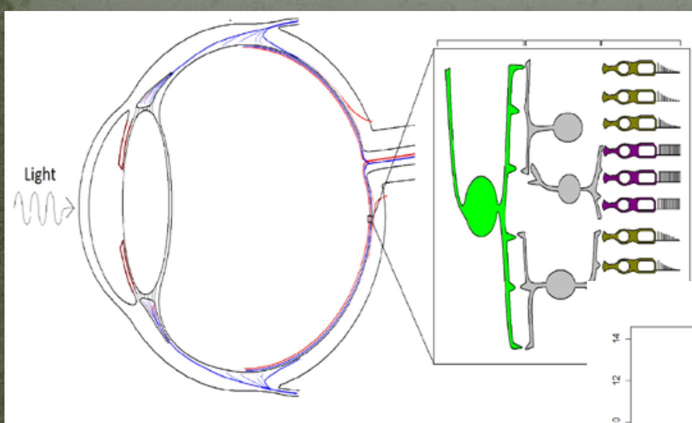
Figure 5: $G_{\max,n}$ and $h_{0.002,n}$

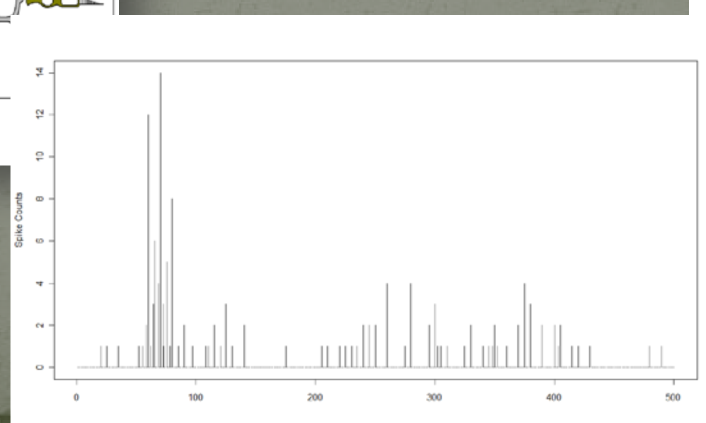
Purpose

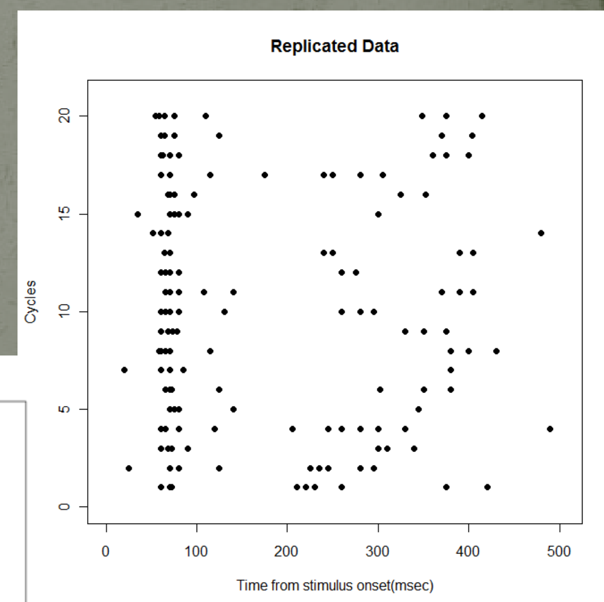
- This project explores the latency estimation by applying change-point methods (based on the generalized likelihood ratio test) to the empirical distribution of the spike arrival times. It further compares the change-point method to the peri-stimulus histogram approach.

Application and simulation results

- The data was taken from a laboratory where they applied a stimulus to a person and then they examined the spike arrivals in a peri-stimulus histogram.
- The change point is 61 if is used the cumulative density function (cdf) and 58 if is used the probability density function (pdf).





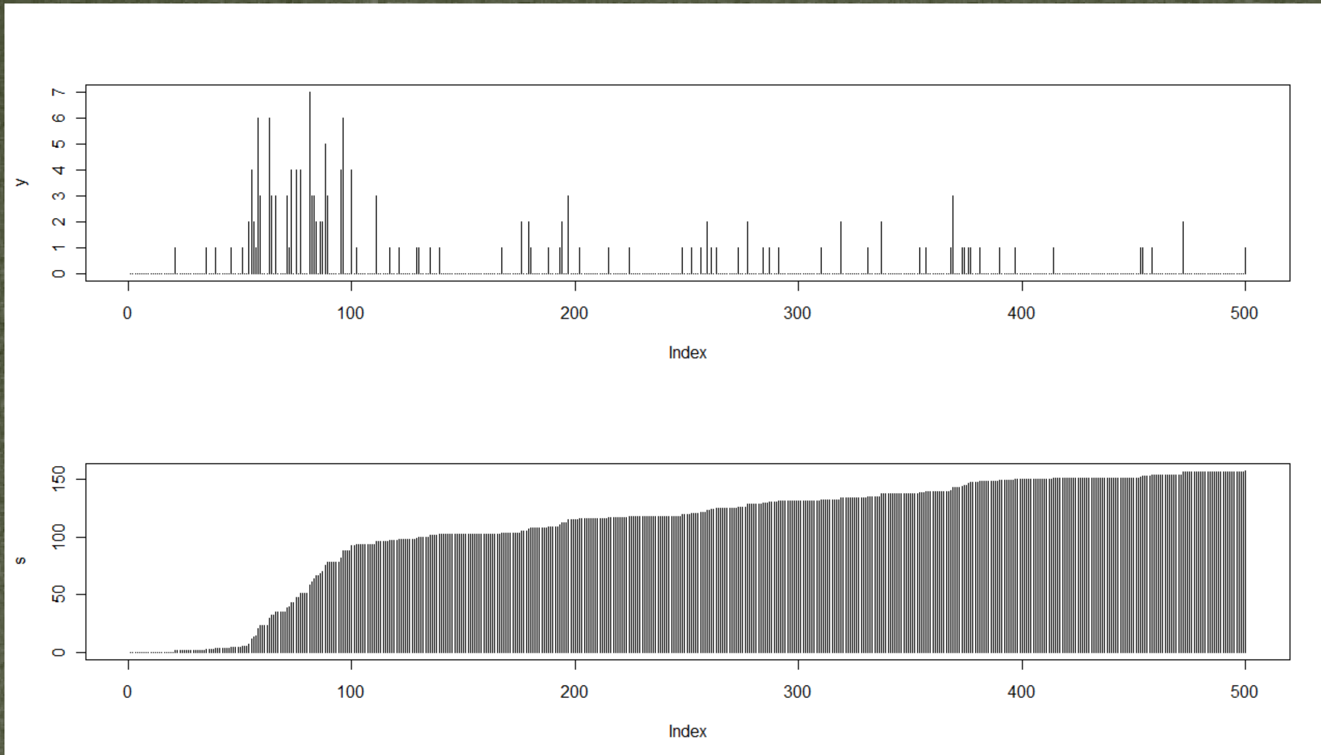


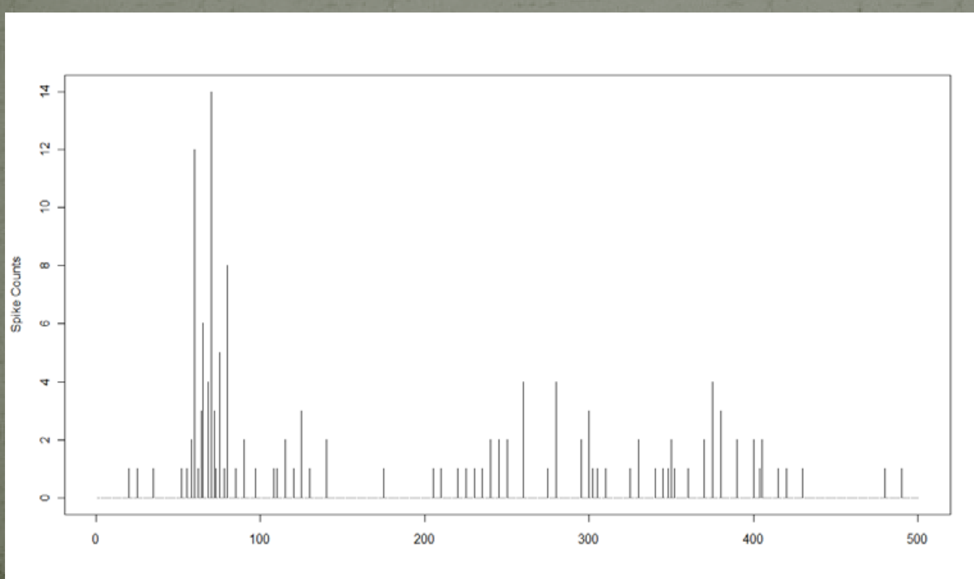
Cont.

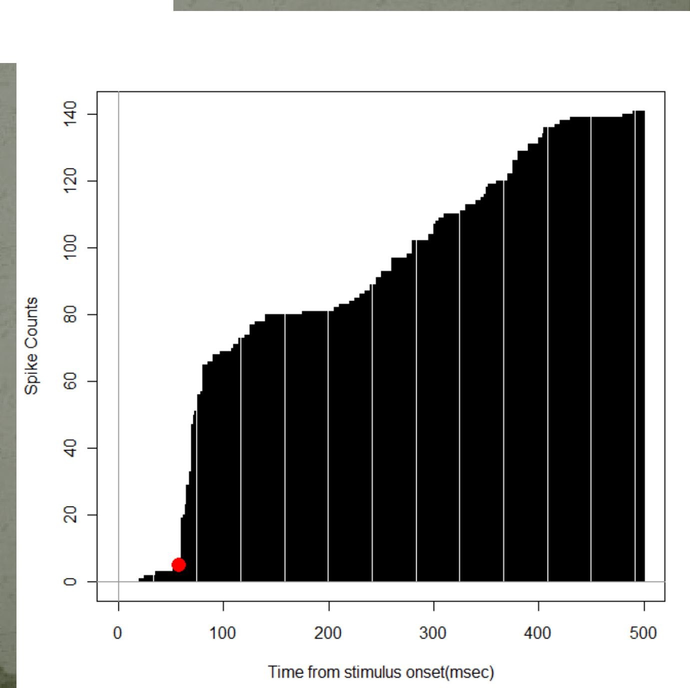
- With those results it can be shown that this method is more efficient than older methods, which requires 500 data to find the change point (avoid unnecessary data).
- Using the pdf:
  - The mean and variance before the parameter change [1:58] are $\mu_1 = .12$ and $\sigma_1 = .14$
  - The mean and variance after the parameter change [59:74] are $\mu_2 = 2.75$ and $\sigma_2 = 19.4$
  - The size of the change is $| \mu_1 - \mu_2 | = 2.63$

Cont.

- Using the cdf:
  - The mean and variance before τ [1:61] are $\mu_1 = 2.23$ and $\sigma_1 = 7.95$
  - The mean and variance after τ [62:71] are $\mu_2 = 28.2$ and $\sigma_2 = 71.96$
  - The size of the change is $| \mu_1 - \mu_2 | = 25.97$


y
0 1 2 3 4 5 6 7
0 100 200 300 400 500
Index
s
0 50 100 150
0 100 200 300 400 500
Index


Spike Counts
0 2 4 6 8 10 12 14
0 100 200 300 400 500


Spike Counts
0 20 40 60 80 100 120 140
0 100 200 300 400 500
Time from stimulus onset(msec)

Simulation and Comparison

- There were 1000 Monte Carlo simulations.
- The Half-Height technique had a 42% of efficiency, but the change point had 90%.
- The efficiency of the change point over the Half-Height is 2.14

References

- Friedman, H.S. & Priebe, C.E. (1997). *Estimating Stimulus Response Latency*. Journal of Neuroscience Methods, 83, 185-194.
- Hawkins, D.M. & Zamba, K.D. (2005). *Statistical Process Control for Shifts in Mean or Variance Using a Changepoint Formulation*. Technometrics, May 2005, Vol. 47, NO. 2