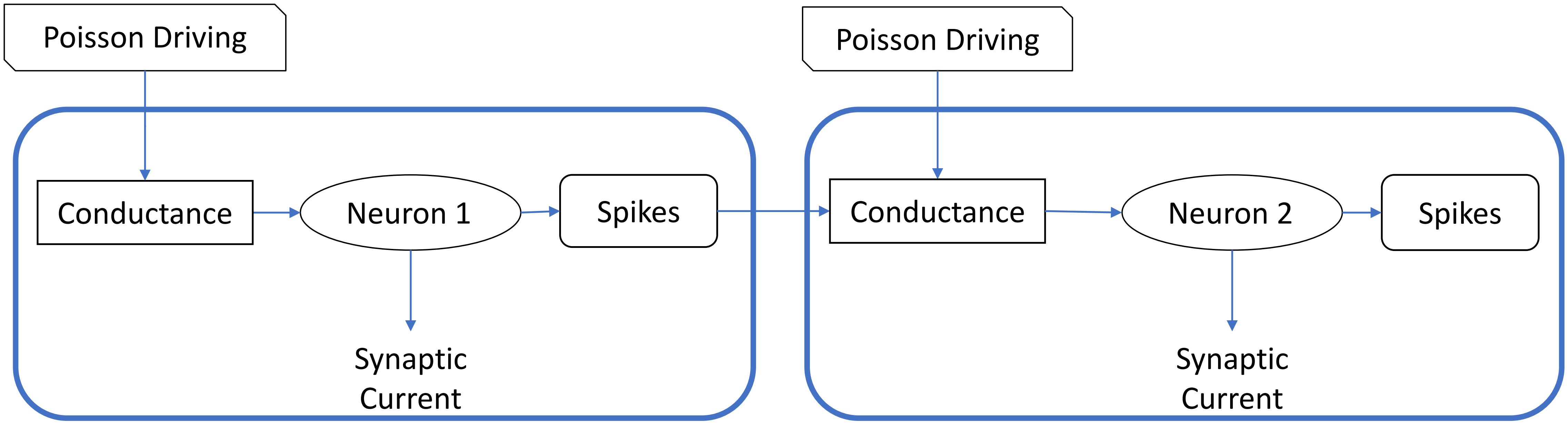
Studies of TDMI Analysis based on Simulation of IF Neurons

Kai Chen Jan. 2018

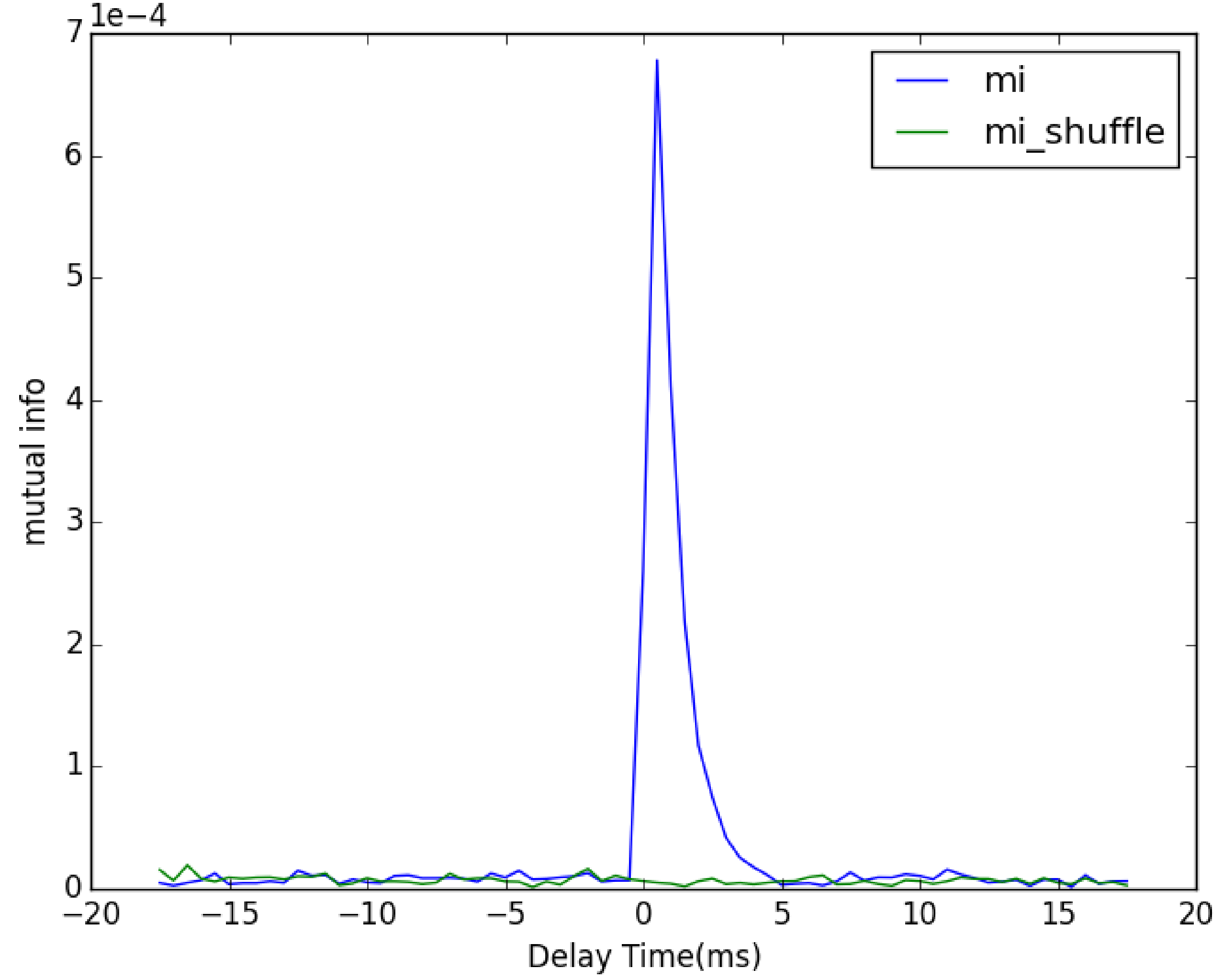
Paradigm of simulation



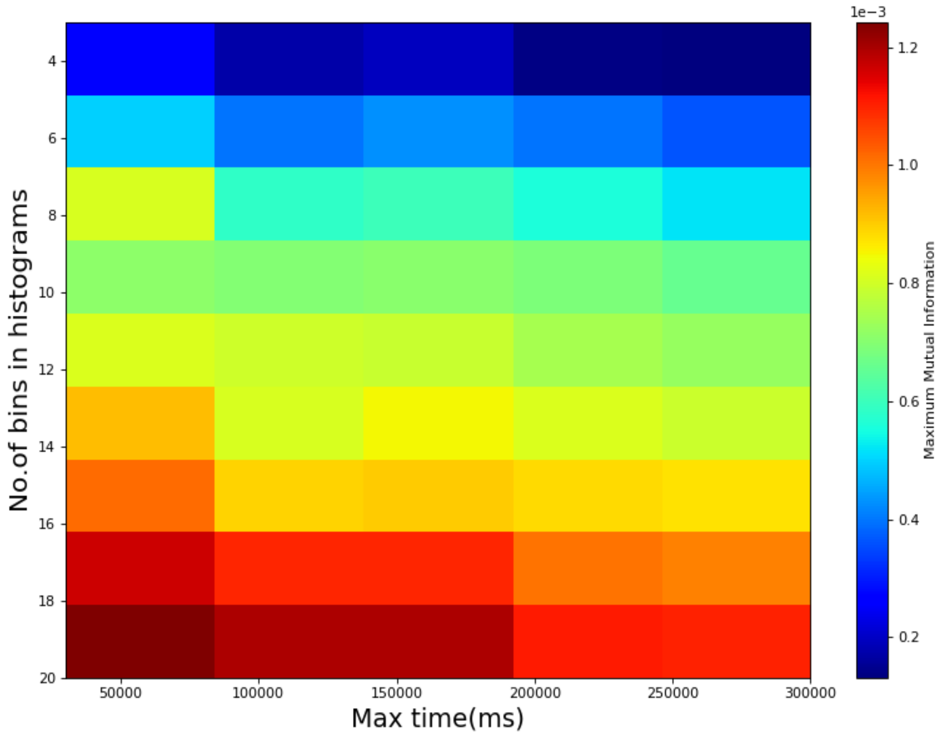
Sample Figure

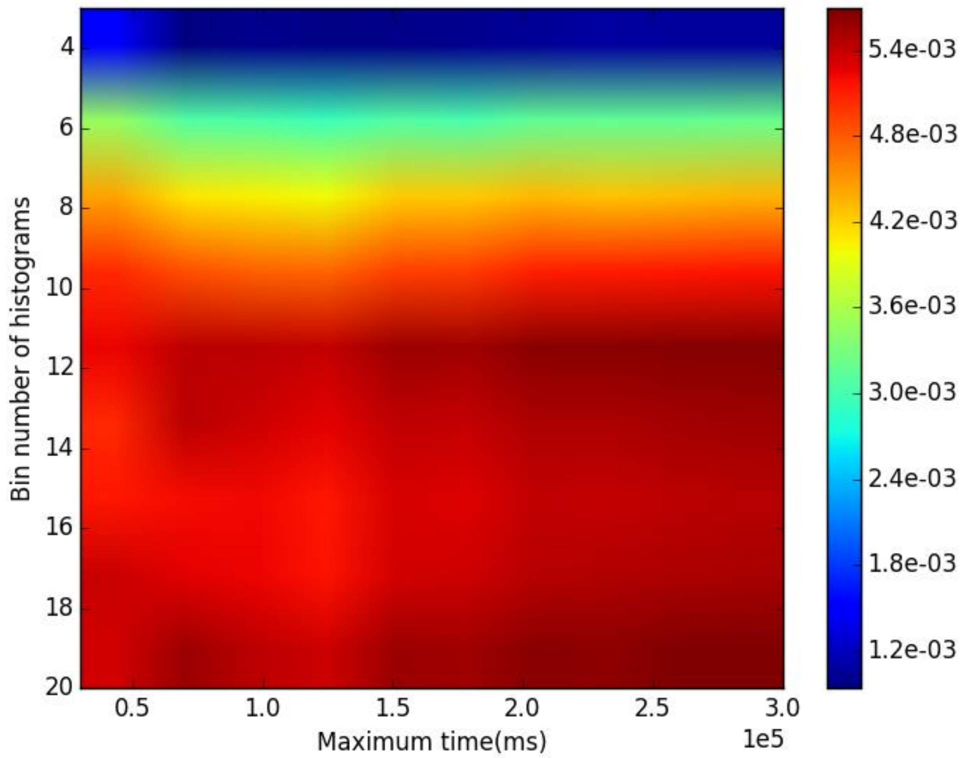
The peak lying on the positive side of the graph indicates the same direction of neuronal information as the physical connection does.

dt	0.5 ms
#bins	10
Poisson Rate	0.15kHz
Forward Strength	0.05
Synaptic Strength	0.005
T	5 mins



Mutual information calculation



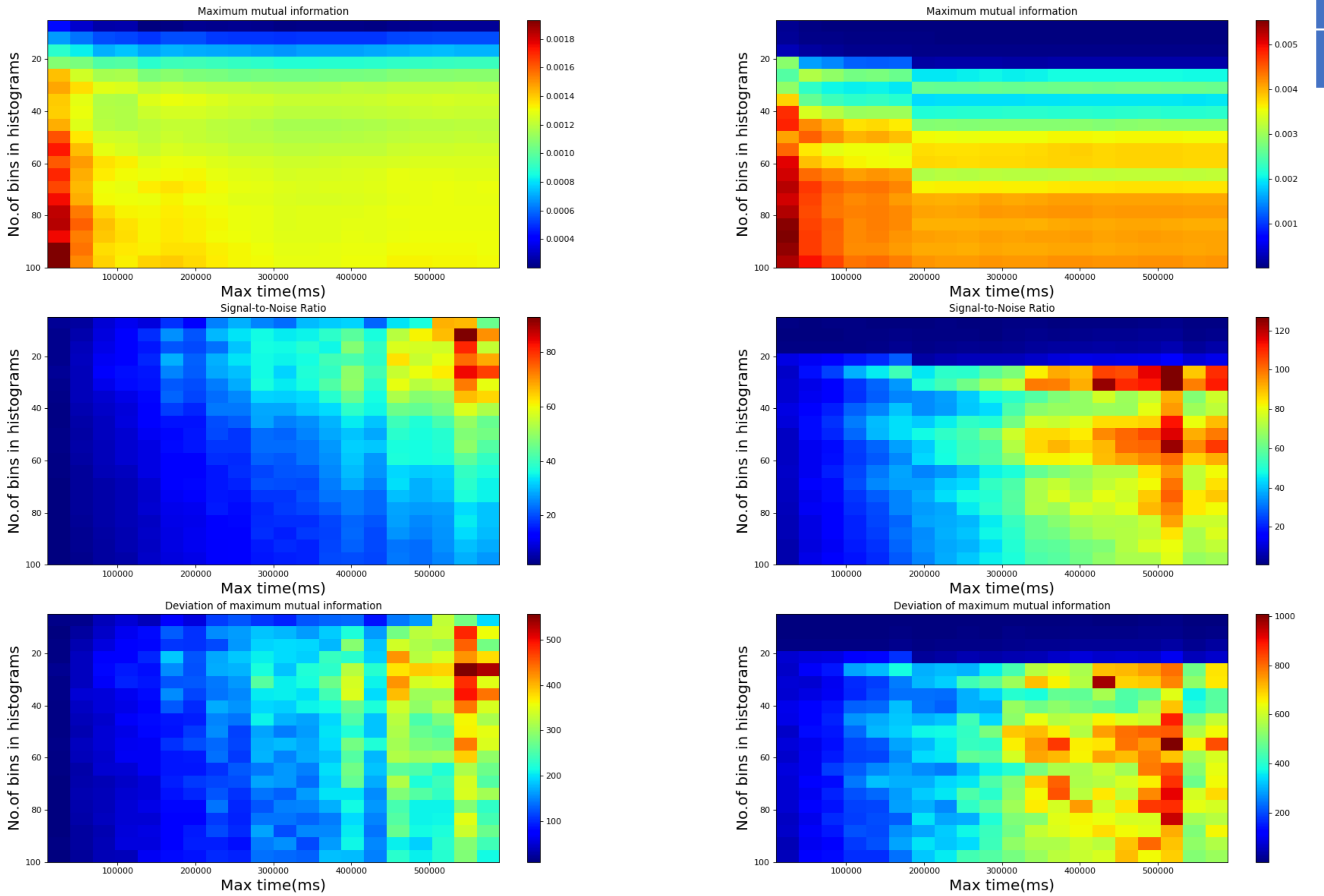


Direct method

dt	0.5 ms
#bins	10
T	10 mins

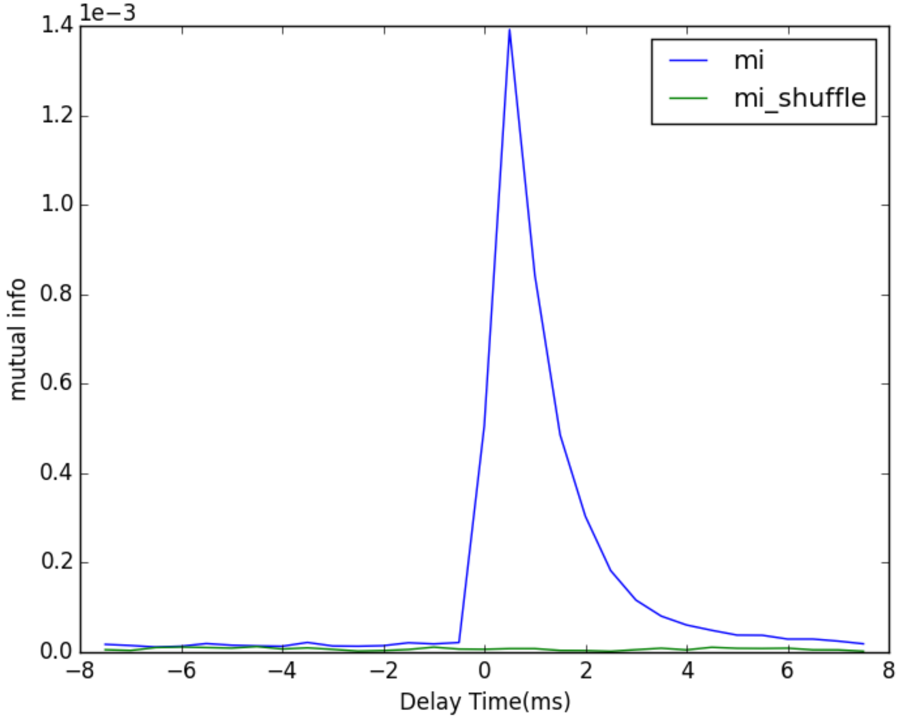
S = 0.015

S = 0.075

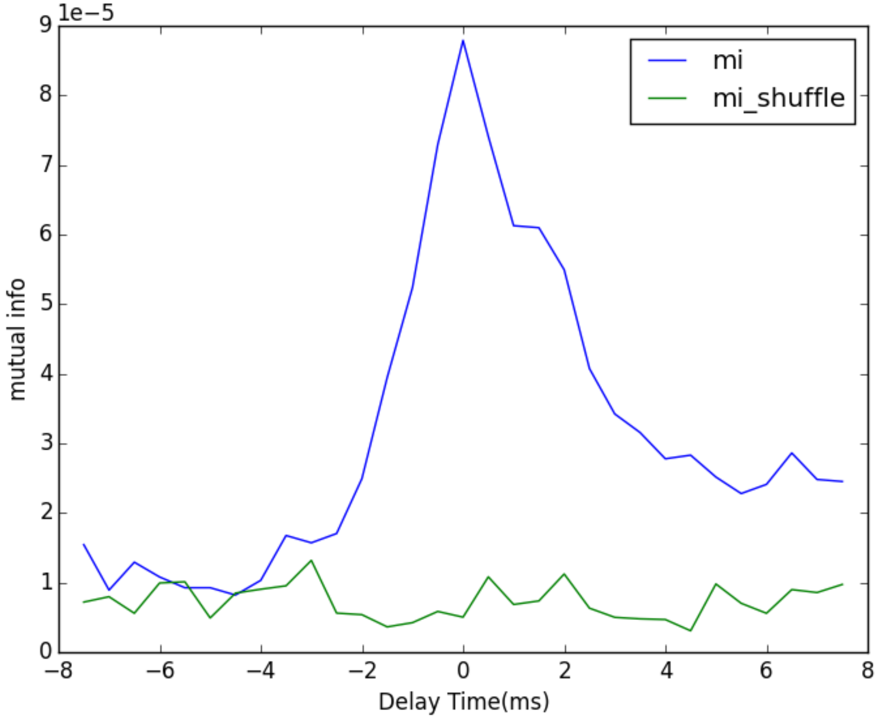


Mono-direction

Poisson Rate	1.5 kHz
S	0.005
F	0.005
dt	0.5 ms
#bins	20
T	10 mins

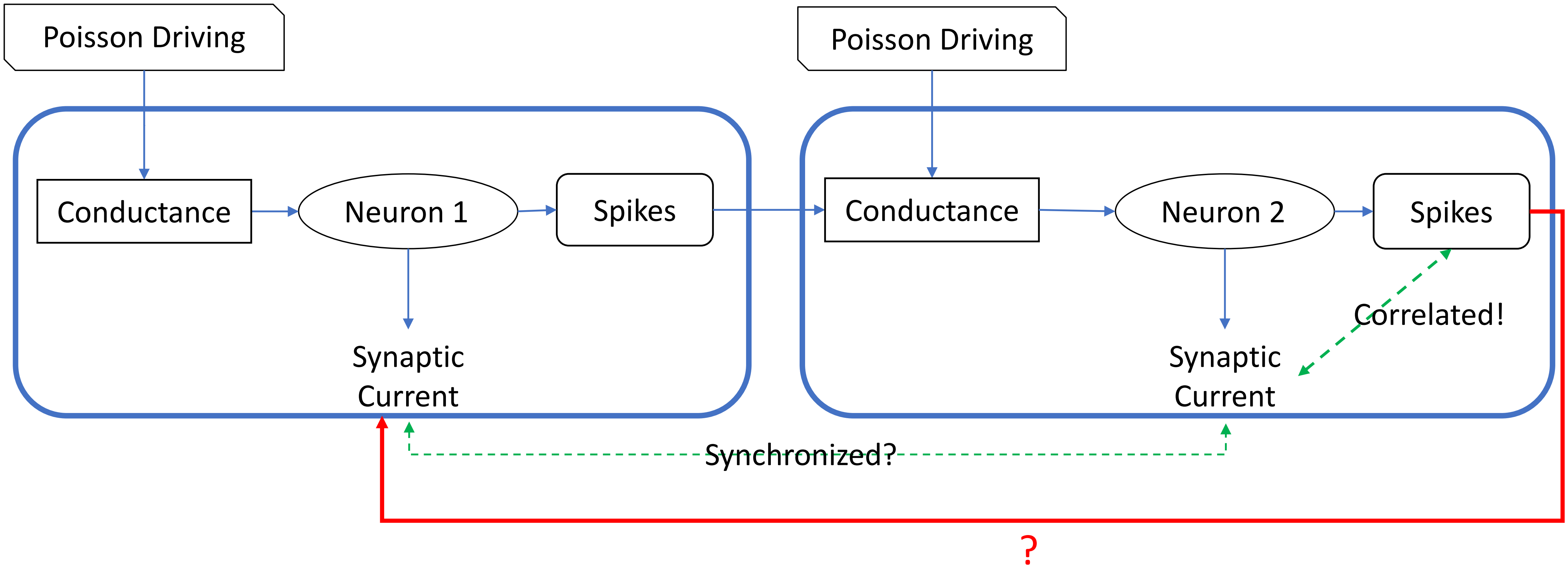


From 1 to 2



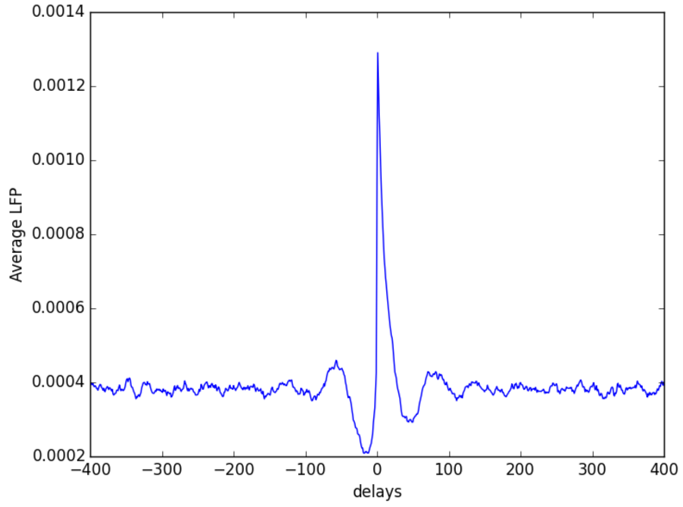
From 2 to 1

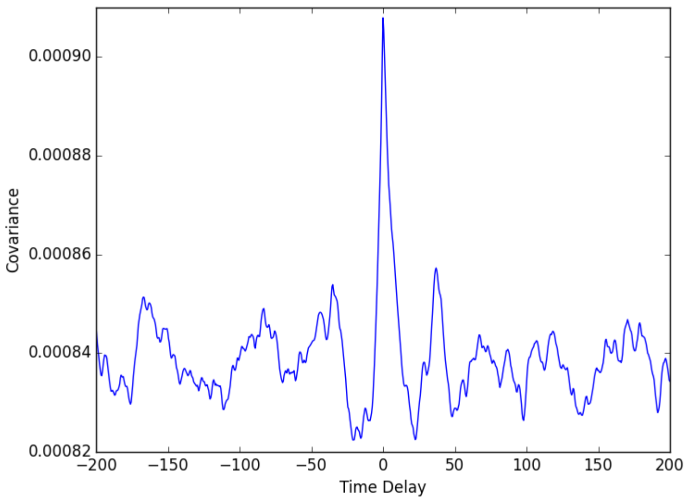
Neuronal Interaction layout



Poisson Rate	1.5 kHz	dt	0.5ms
S	0.005	#bins	20
F	0.005	T	10mins

Covariance
Spike 2
to
Current 2



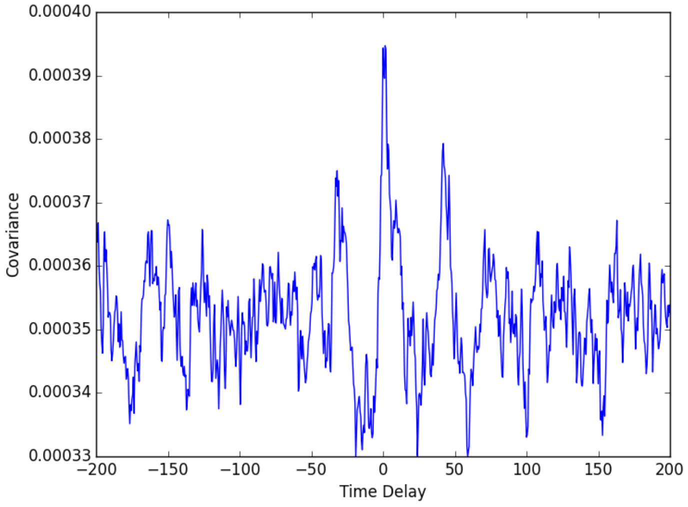


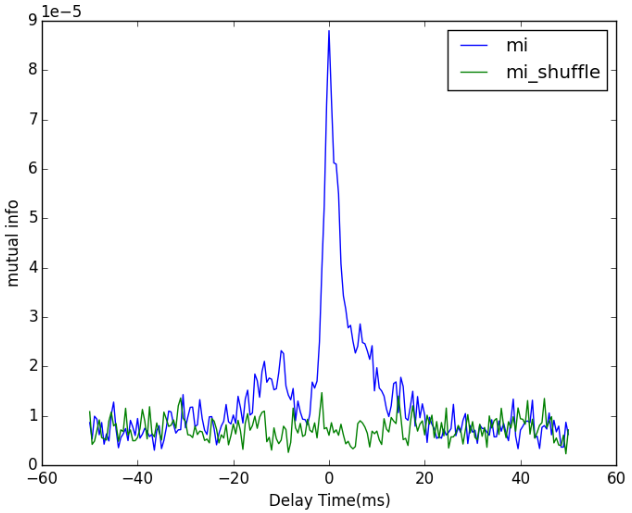
Covariance

Current 2
to
Current 1

Covariance

Spike 2
to
Current 1

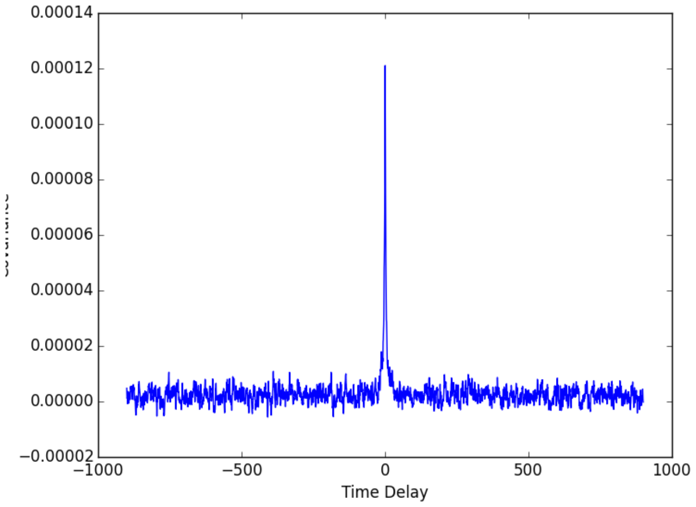


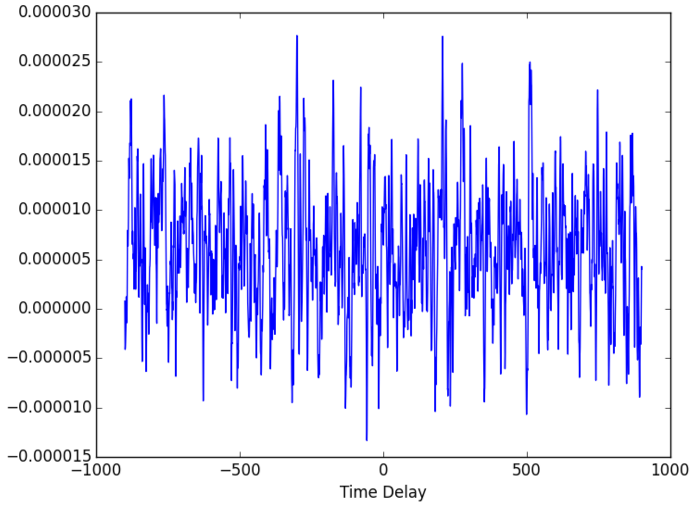


Mutual info
Spike 2
to
Current 1

Poisson Rate	0.1 kHz	dt	0.5ms
S	0.005	#bins	30
F	0.030	T	10mins

Covariance
Spike 2
to
Current 2



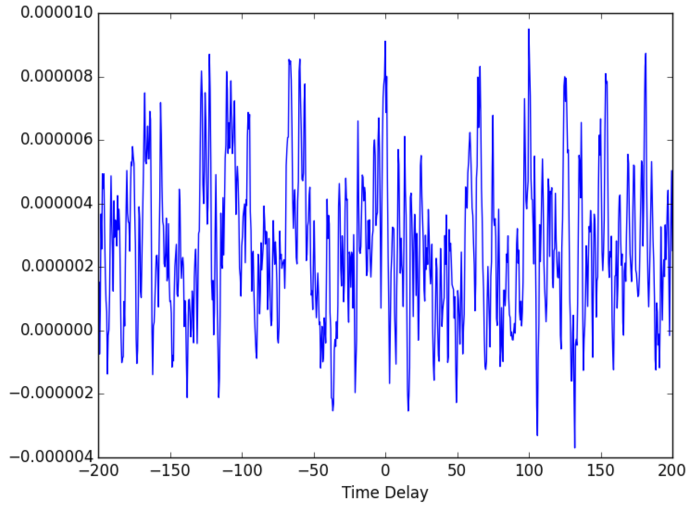


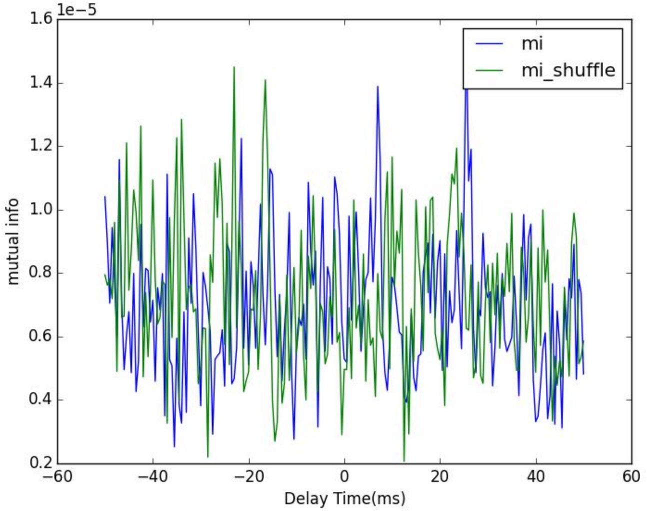
Covariance

Current 2
to
Current 1

Covariance

Spike 2
to
Current 1



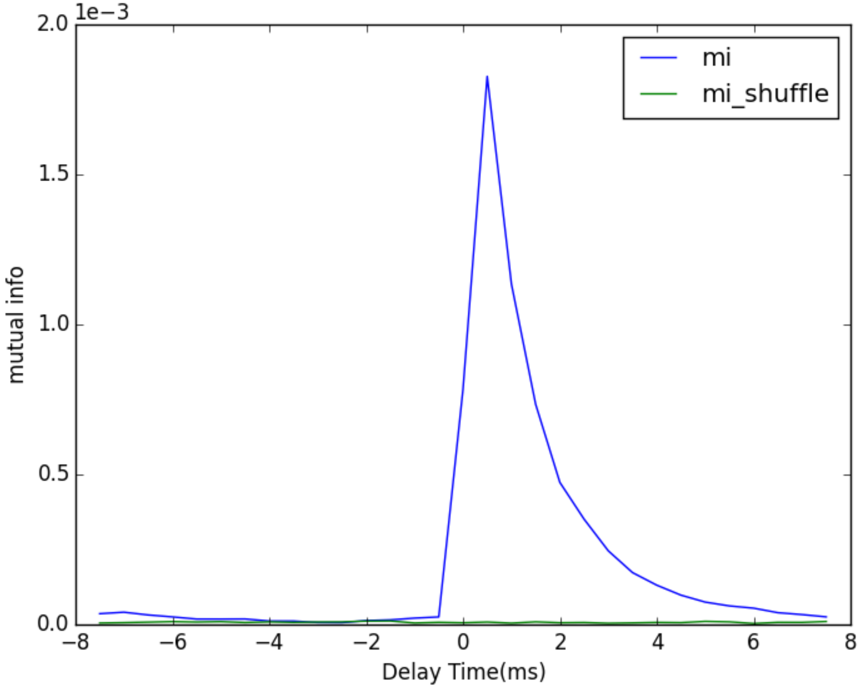


Mutual info
Spike 2
to
Current 1

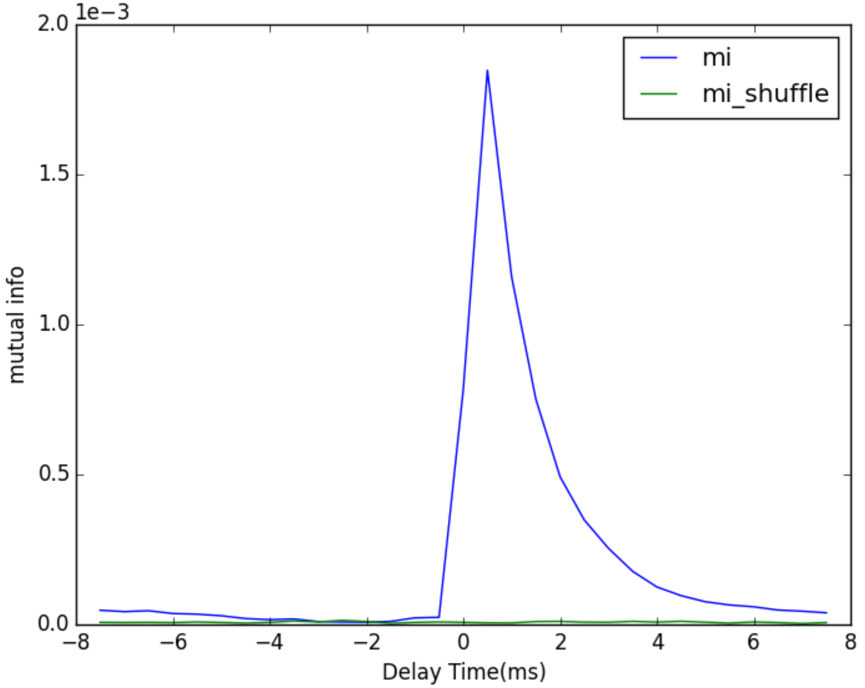
Bi-direction

Poisson Driving Rate	1.5 kHz
Synaptic Strength	0.005
Feedforward Strength	0.005

From 1 to 2



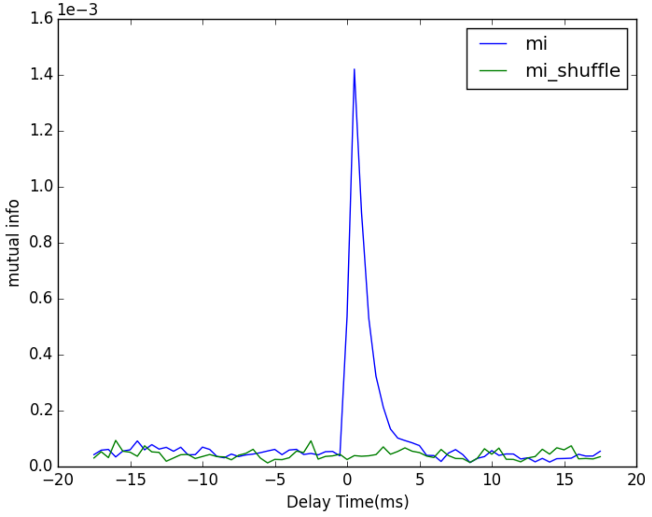
From 2 to 1



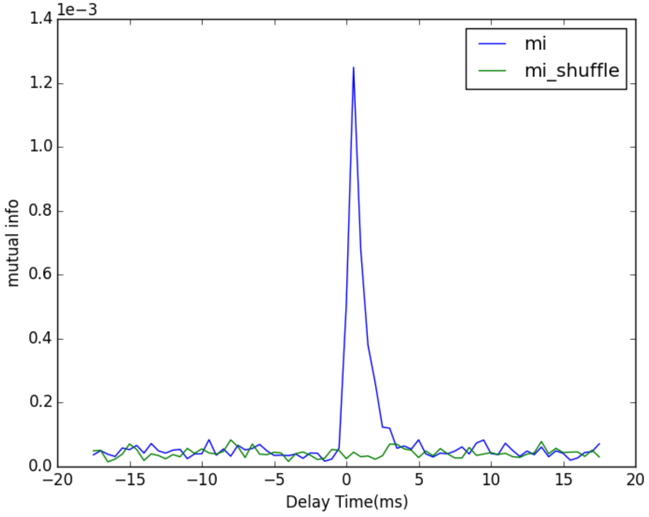
dt = 0.5 ms
#bins = 20
T = 10 mins

Robustness

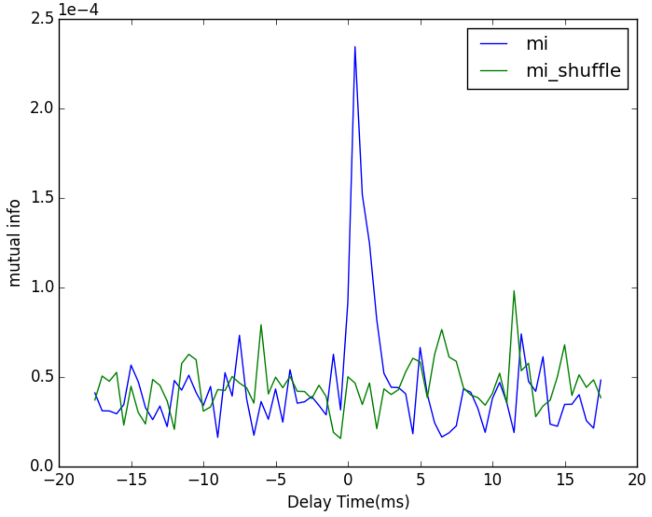
Fix the product of Poisson driving rate and feedforward strength. Change the Poisson driving rate and investigate the change of mutual information pattern



1.5 kHz



0.15 kHz



0.1 kHz

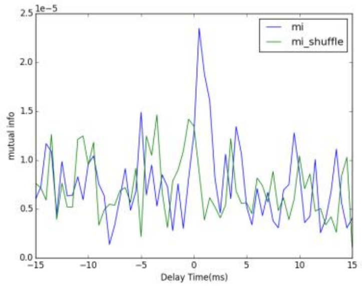
dt	0.5 ms
#bins	20
T	10 mins
Synaptic Strength	0.005

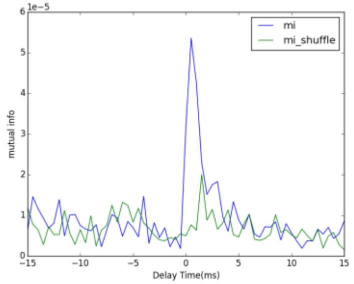
Direct calculation

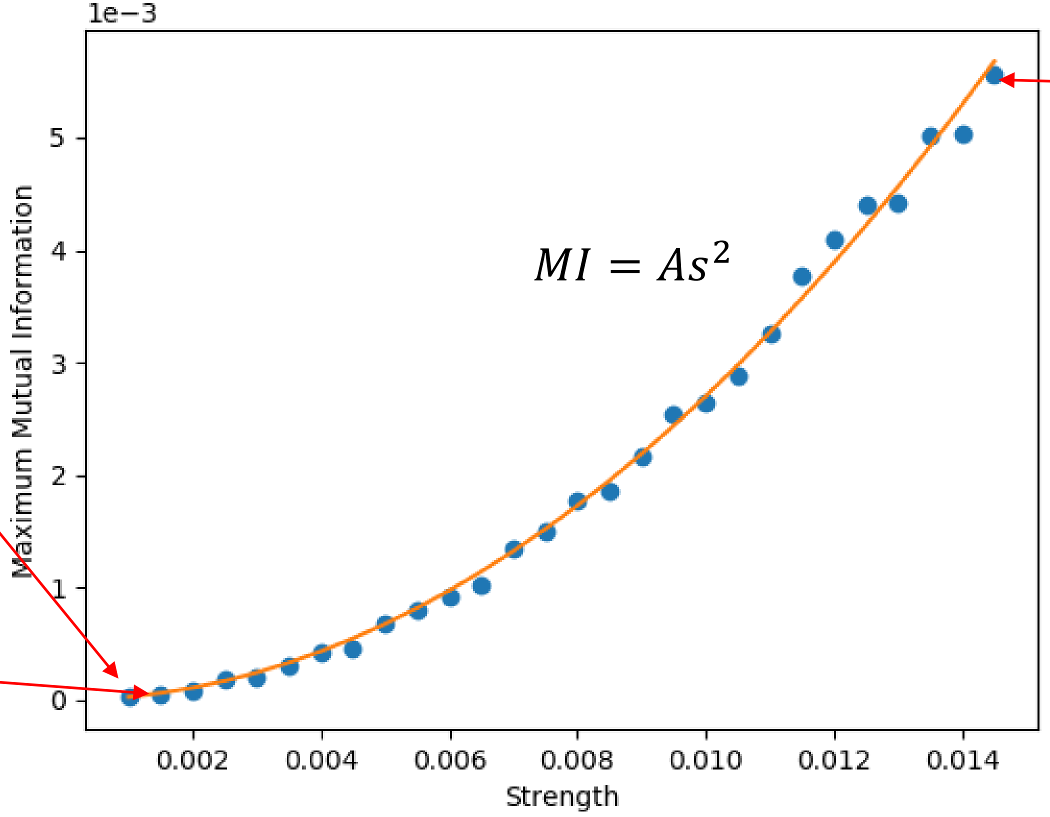
- Relation between synaptic strength and values of maximum mutual information

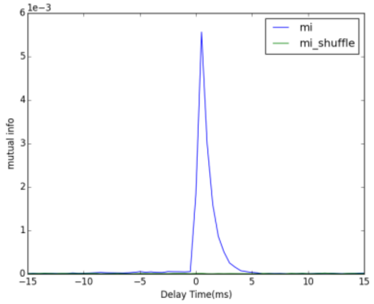
- Synaptic strength ranging from 0.001 to 0.0145
- Mean firing rate for presynaptic neuron is 25.5 Hz
- Mean firing rate for postsynaptic neuron is ranging from 25.32 Hz to 28.06 Hz

dt	0.5 ms
#bins	10
T	5 mins









Mutual information of Gaussian random variables

$$X_n = \alpha X_{n-1} + \varepsilon_n$$
$$Y_n = \beta Y_{n-1} + \xi X_{n-1} + \eta_n$$

$$I(X,Y) = H(X) + H(Y) - H(X,Y)$$

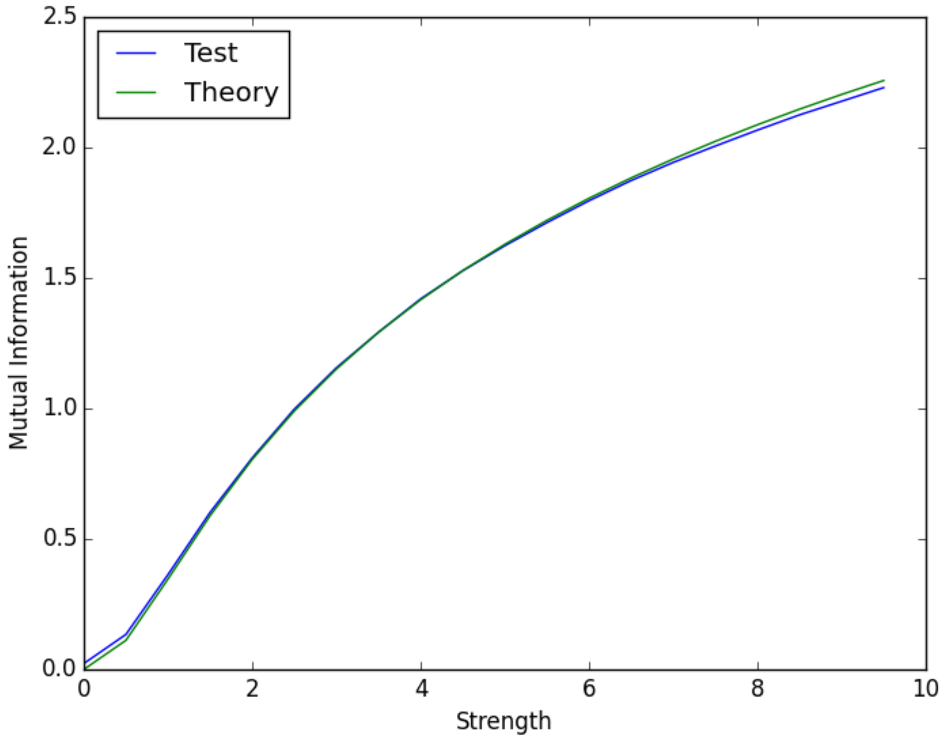
$$I(X,Y) = -\frac{1}{2}\log(1-\rho^2)$$

$$\rho = \rho(\xi,\alpha,\beta)$$

α and β are smaller than 1, suppose $n \gg 1$,

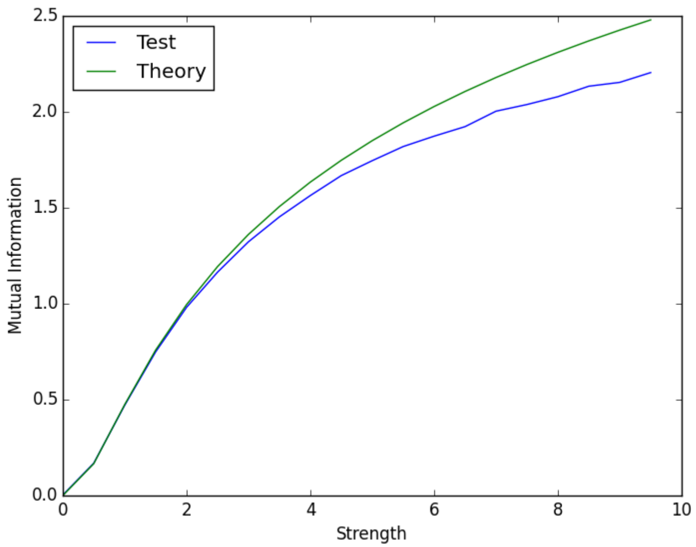
$$\rho(\xi)^2 = \begin{cases} \dfrac{\xi^2}{(1-\alpha^2)^2+\xi^2(1+\alpha^2)} & \alpha = \beta \\ \dfrac{\xi^2(1-\beta^2)}{(1-\alpha\beta)^2(1-\alpha^2)+\xi^2(1-(\alpha\beta)^2)} & \alpha \neq \beta \end{cases}$$

$\alpha = 0.01$， $\beta = 0.01$ #bin=50 T= 300000

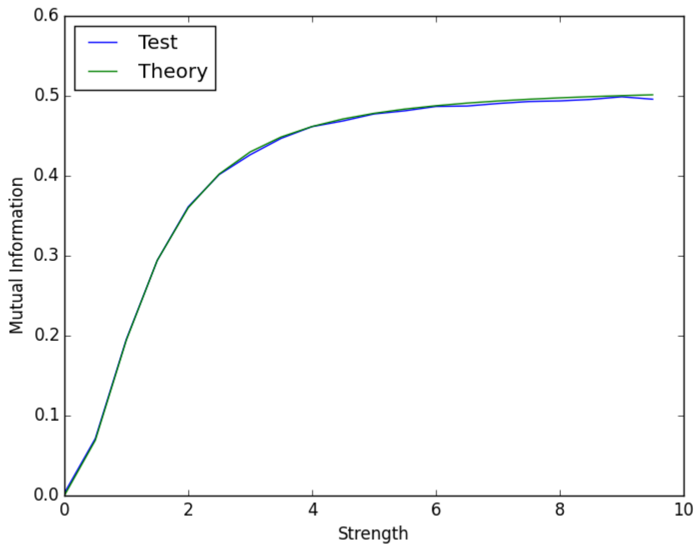


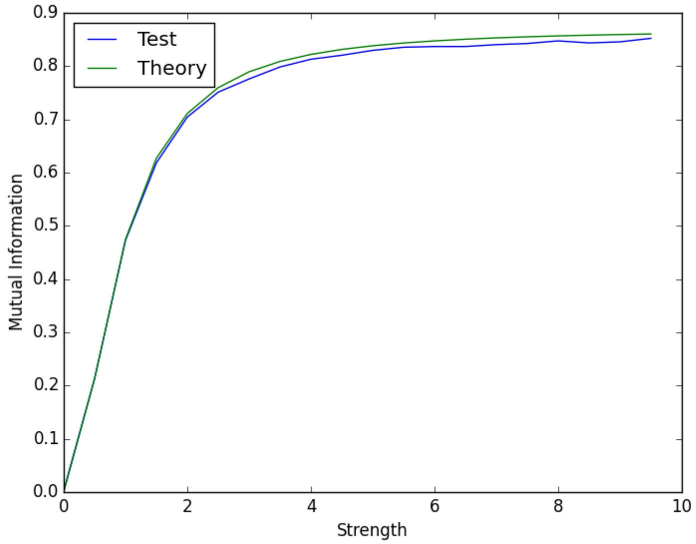
#bins = 150 300000 trials

$\alpha = 0.6, \ \beta = 0.01$ #bin=50 T= 300000

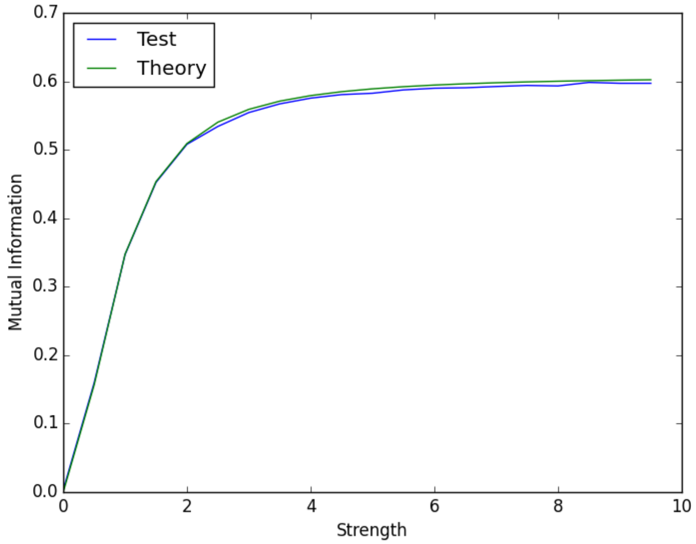


$\alpha = 0.01, \ \beta = 0.6$ #bin=50 T= 300000



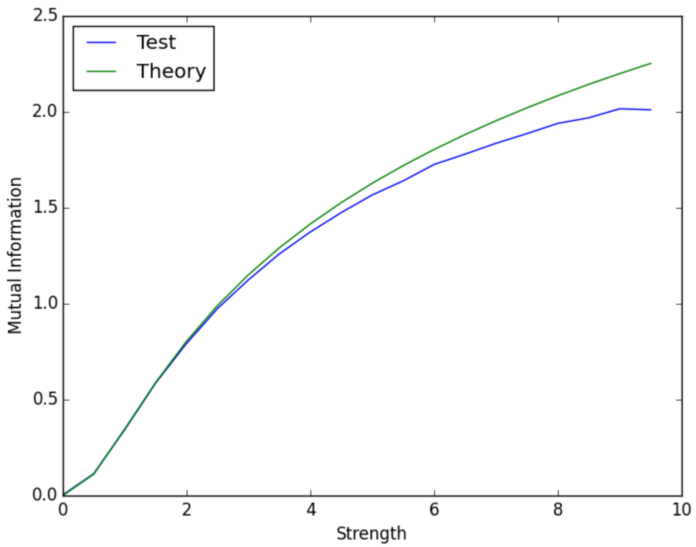


$\alpha = 0.6, \ \beta = 0.5$ #bin=50 T= 300000

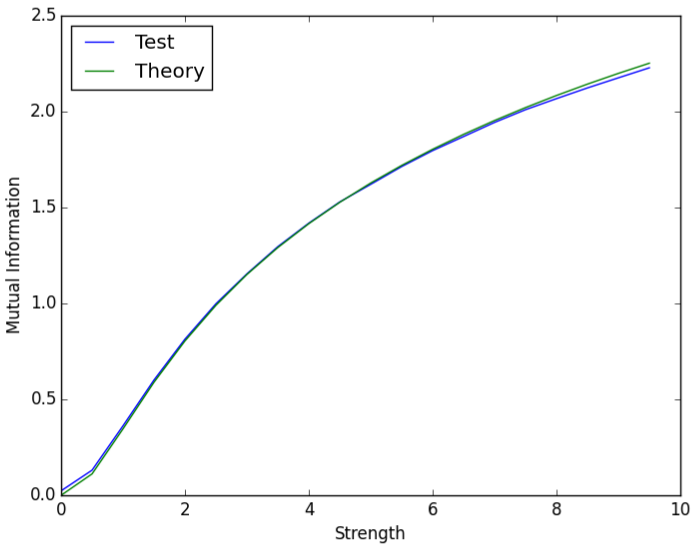


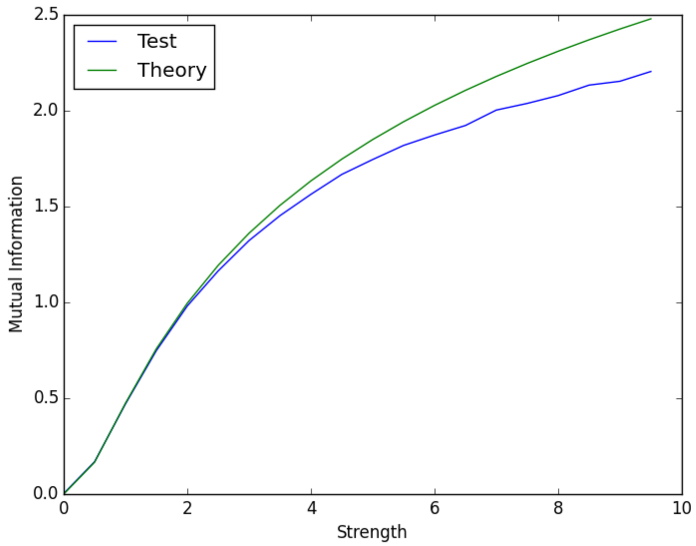
$\alpha = 0.5, \ \beta = 0.6$ #bin=50 T= 300000

$\alpha = 0.01$， $\beta = 0.01$ #bin=50 T= 300000

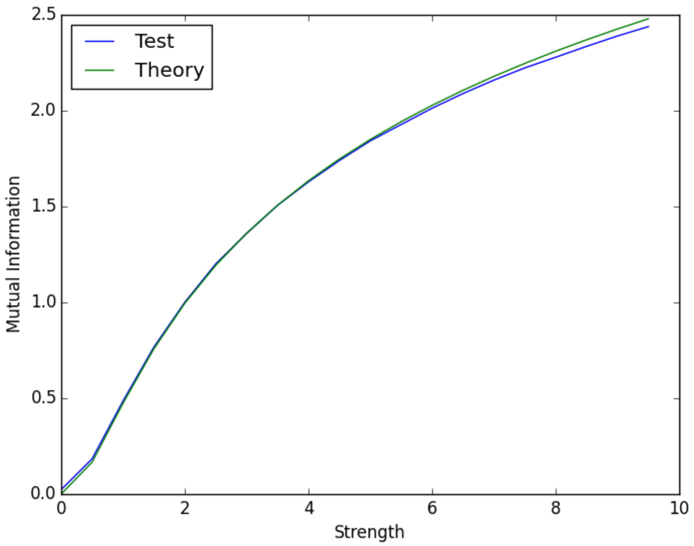


$\alpha = 0.01$， $\beta = 0.01$ #bin=150 T= 300000





$\alpha = 0.6$， $\beta = 0.01$ #bin=50 T= 300000



$\alpha = 0.6$， $\beta = 0.01$ #bin=150 T= 300000

Next Steps:

- Take the dynamical properties of LFP into account. Up to current hypothesis and model of LFP, Synaptic current, neuronal morphology and dynamical states of local neuron population are three components that attributed to the mechanism of LFP.
- How far at most the LFP spread in space can be captured by TDMI.
- How does TDMI reflect the causal relation in different dynamical regime.