Report of I&F Neuronal Network Simulation

Report of Week 3 & 4

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Four hypotheses to be verified

* Spike trains from excitatory and inhibitory neurons have different performance on the TDMI signal towards their first order connected neurons;
* The magnitude of MI peak is positively related to the number of neurons that generated LFP.
* The excitatory and inhibitory neuron contribute nearly the amount of effect of MI based on point current source model of local field potential;
* Second order connected neuron have much less effect on MI peak.

Summary about simulation setups

Basically, the simulating system consists of two one dimensional integrate-and-fire neuronal network, called it two-network system.

1. Each network contains 100 neurons;
2. Neuronal connecting density is 3. It means that each neuron directly connects with 6 other neurons within its own loop;
3. Each network has a regular structure, which means each of its neuron connects with 6 nearest neurons;
4. Each neuron in loop 1 has 10% probability connecting with every single neuron in loop 2;
5. Spiking signals generatd by one of those two network, which called 'loop 1' or pre-network, can transmit to the other network, which I called it 'loop 2' or post-network; and the spiking information flow cannot transmit backwards;

Neuronal Parameters

1. 80% of neurons are excitatory, and 20% of them are inhibitory; both kinds of neurons are random located in networks;
2. Neurons are driven by feedforward excitatory spiking signal generated by Poisson process with 1500 Hz driving rate; Roughly speaking, a neuron receives 30 spikes from feedforward Poisson process and its membrane potential, as a result, would increase from resting potential to firing threshold.
3. The intensity of neuron-neuron interaction is identical to the intensity of feedforward inputs; And the effect of single neuron towards the change of conductance of ion channel for both excitatory and inhibitory are identical, too.

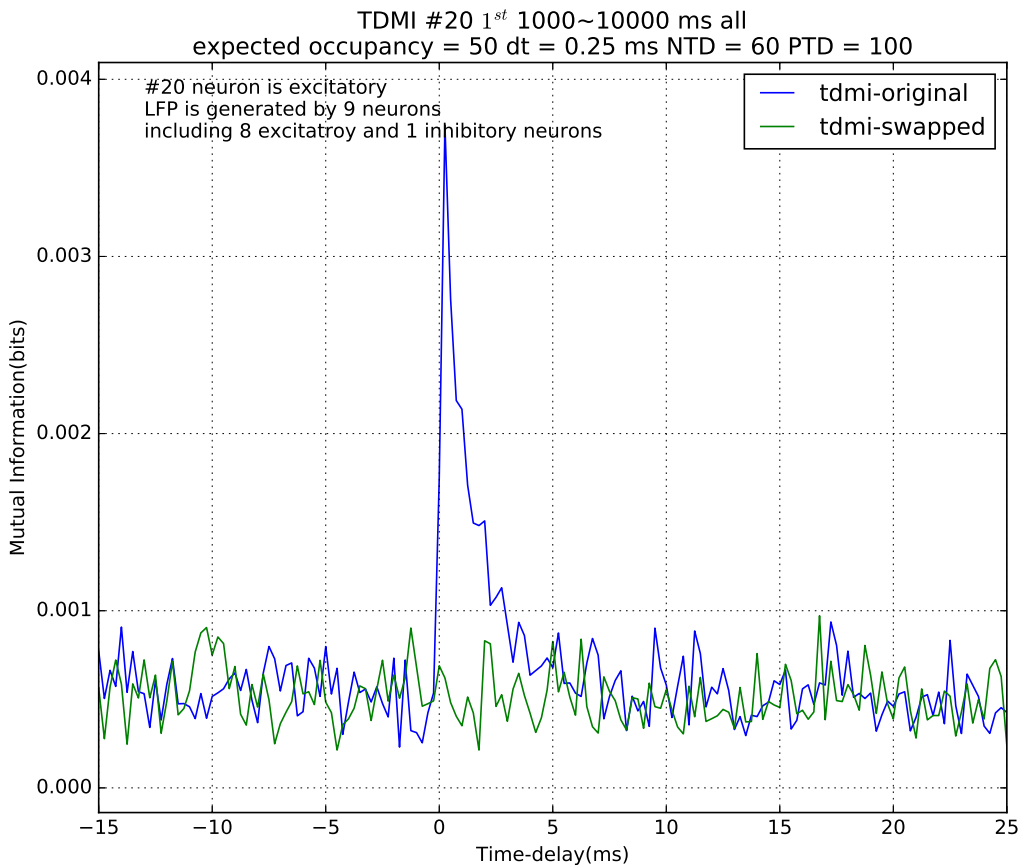
Detailed parameters in simulation

name	val
time range	[0, 10000] ms
timing step	1/32 ms

About LFP model

* In the following results, I choose neuronal data, including membrane potential and different component of membrane conductance, from 1000 to 10000 ms to generate local field potential, which can prevent the disturbance from the transition process of network dynamics at the first one second.
* First order LFP: local field potential generated by neurons directly connected with target neuron in post-network;
* Second order LFP: local field potential generated by neurons connected with first order connected neurons of target neuron; a neuron cannot be first order neuron and second order neuron at the same time;

Figure descriptions

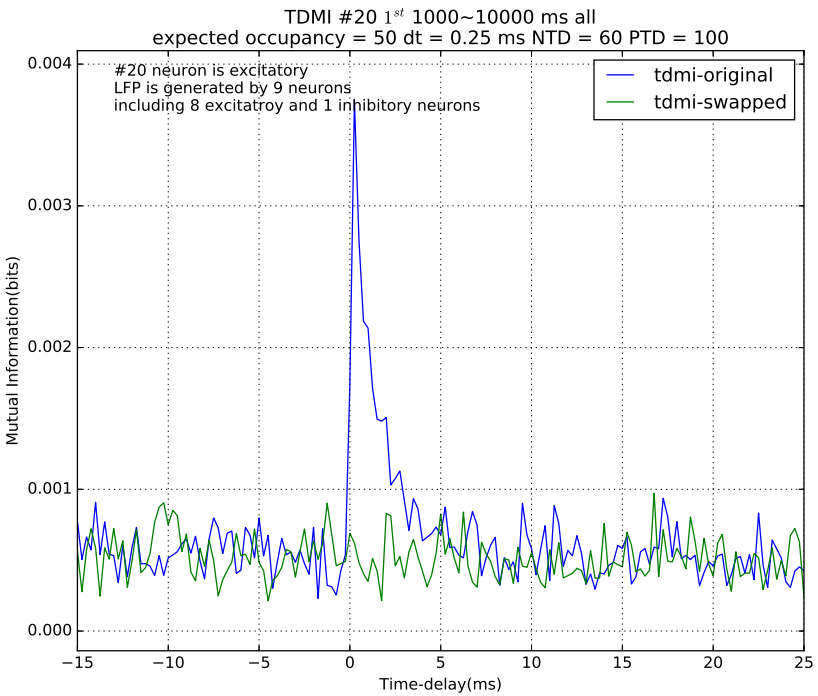


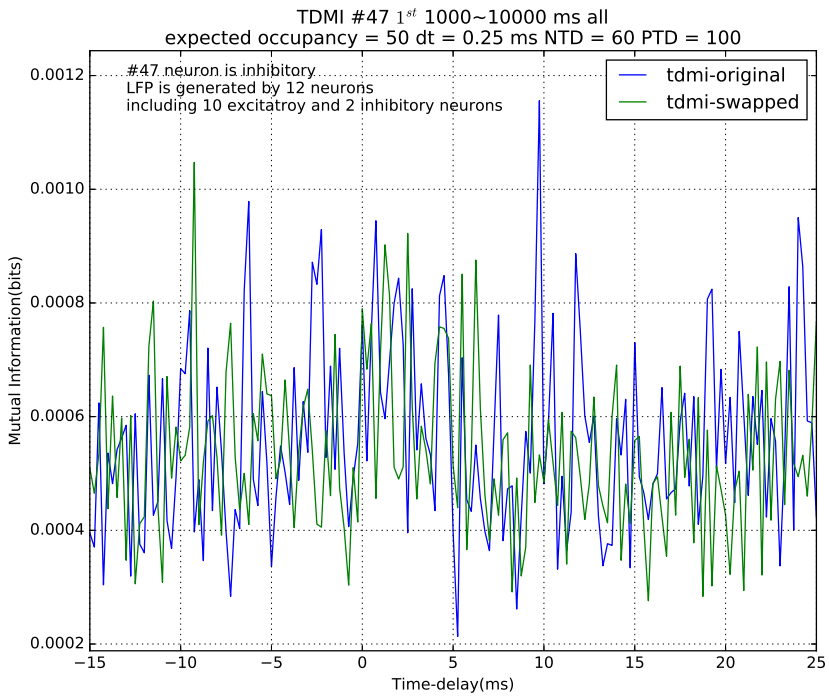
- The title illustrates the index of target neuron, the time range of its data adapted in TDMI analysis, and the detailed parameter applied in TDMI calculation;
- The text box in figure shows the propertis of target neuron in loop 1 and the number of neurons contributes to LFP as well as their types in loop 2;
- The blue line indicates the TDMI of original spike train and local field potential, and the green line indicates that of randomly swapped spike train and local field potential under the same testing condition;

Notations in Figures

Notations	Meaning
expected occupancy	expected occupancy of each bin in historgram of LFP
dt	actual time interval for single time-delayed step
NTD	maximum number of negative time-delayed step in the graph
PTD	maximum number of positive time-delayed step

TDMI of spike train and LFP





Dynamics of pre-synaptic neurons

In the simulating system, #20 neuron is excitatory and #47 neuron is inhibitory. Under the driving of feedforward inputs with same average rate, which is 1500 Hz, their average firing rate from 1s to 10s is 14 Hz and 12 Hz respectively. However, comparing the TDMI signal which they interact with their directly connected neuron clusters, TDMI in excitatory cases do indicate the neuronal interactions and the direction of information flow, while in inhibitory cases it fails.

Conclusion 1

The correlation between excitatory neuron and its first order connected neurons can be clearly reflected by TDMI plot, while those of inhibitory neuron cannot.

Denote: the conclusion is drawed after 20 neurons in loop 1 were investigate. Among those target neurons, 13 of them are excitatory, others are inhibitory.

LFP contributed by excitatory neurons

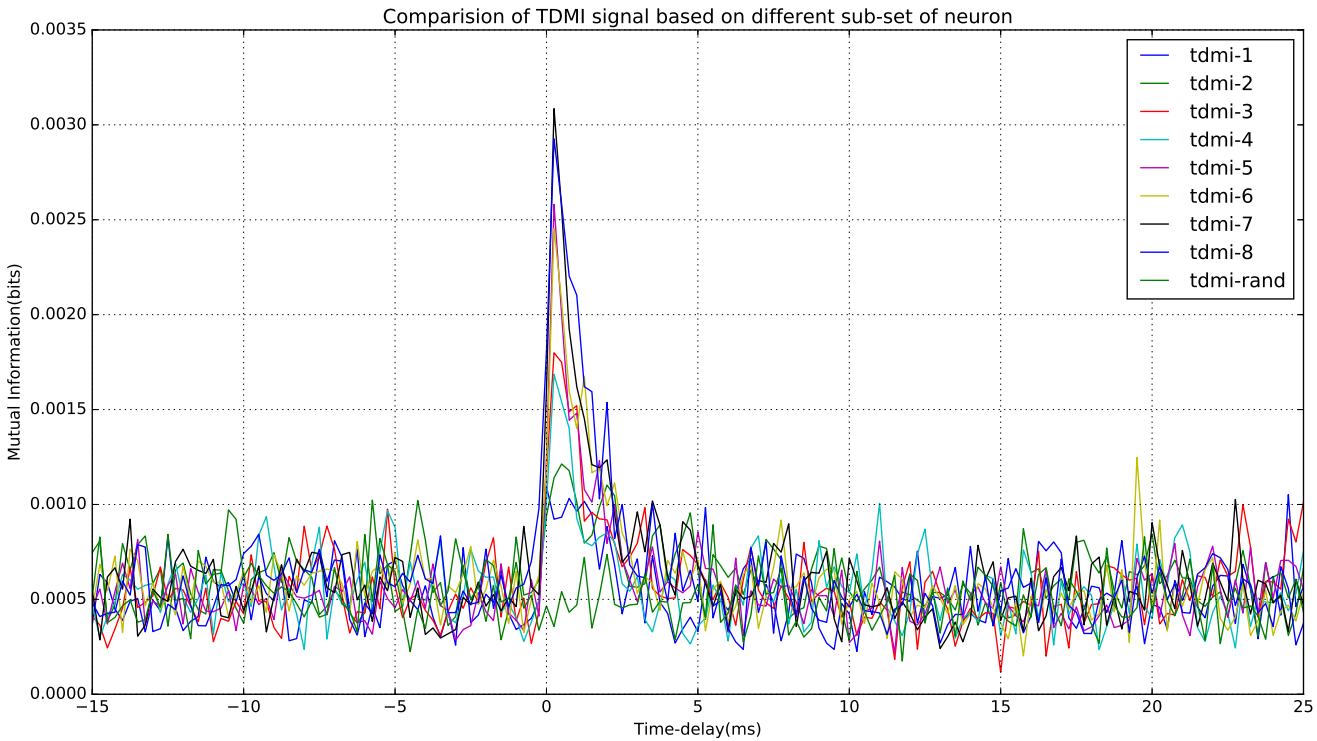


Figure descriptions

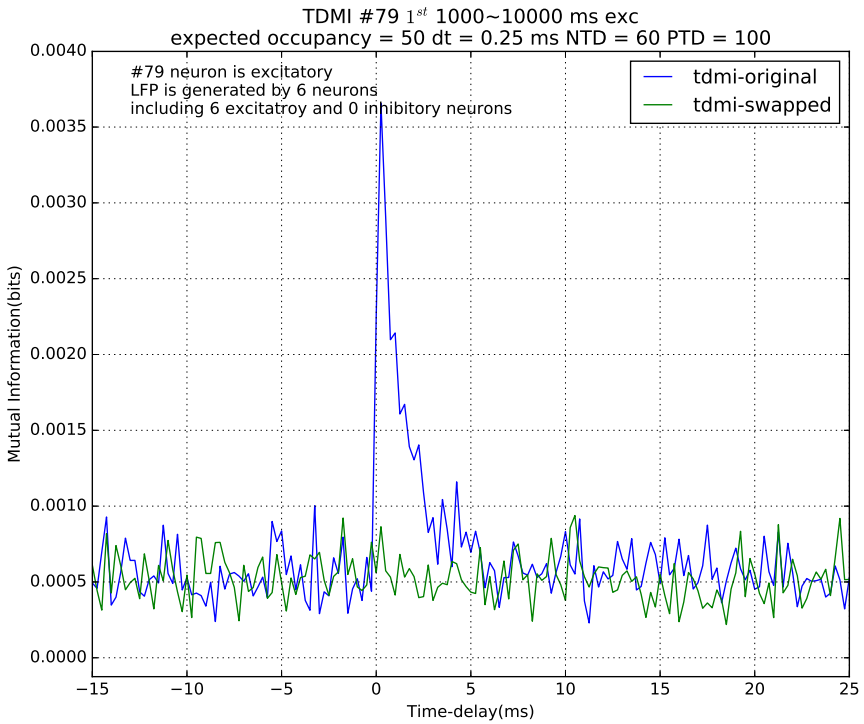
Here, I plot TDMI signal of #20 neuron's spike train and several sub set of its first order connected neuronal clusters. The index contained in the legend "tdmi-i" represents that the sub neuronal cluster consists of i neurons which are random chosen from all first order connected neurons. The legend "tdmi-rand" represents the TDMI of randomly swapped spike train and LFP, which reflects the noise level of MI signal.

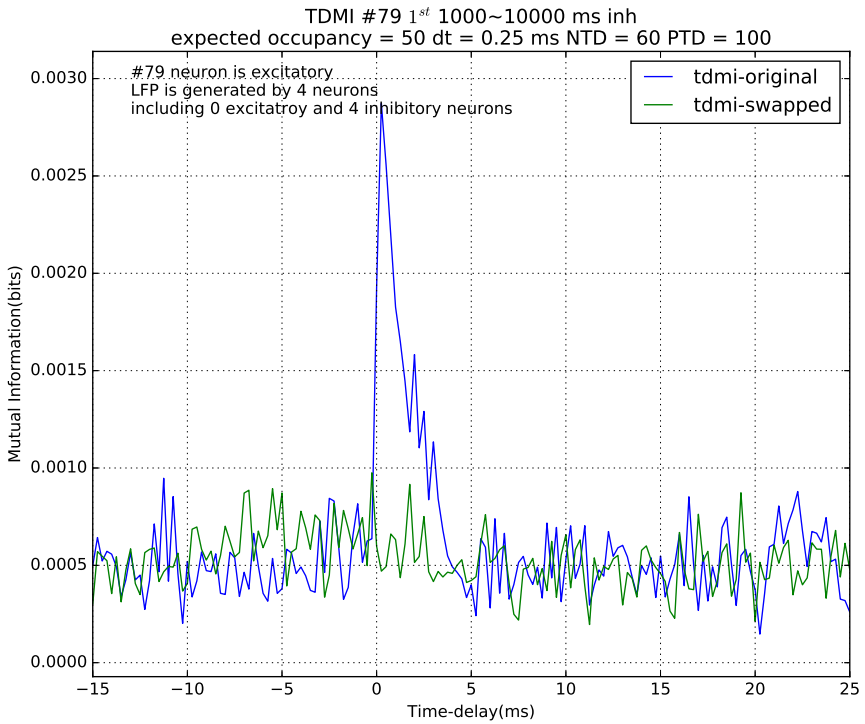
Conclusion 2

The magitude of MI signal depends on the number of neurons in neuron cluster of LFP. Here is a hypothesis. Since each neuron in the cluster of LFP contains information from pre-network neuron and its neighborhood in post-network. Neurons have more connections with their neighbors rather than cross network connections. When the number of LFP cluster is small, the current signal of neuron is dominant by local network dynamics which is not correlated across neurons in cluster. When the number goes up, those non-correlated signal is averaged. However, their cross-network signals originate from the same neuron in pre-network. The effect of these parts would accumulate, and as a result, MI signal would increase.

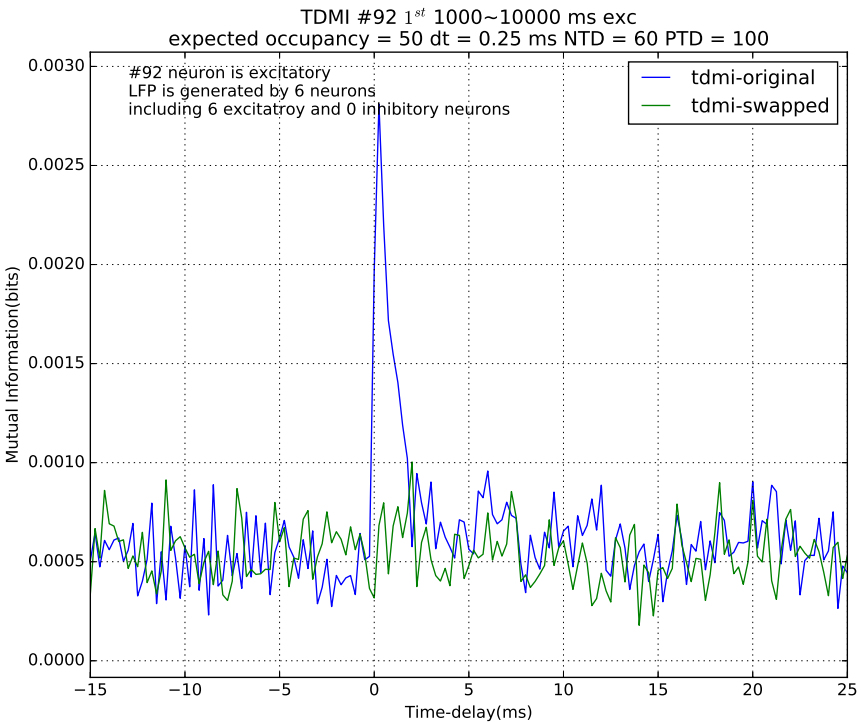
For excitatory neurons:

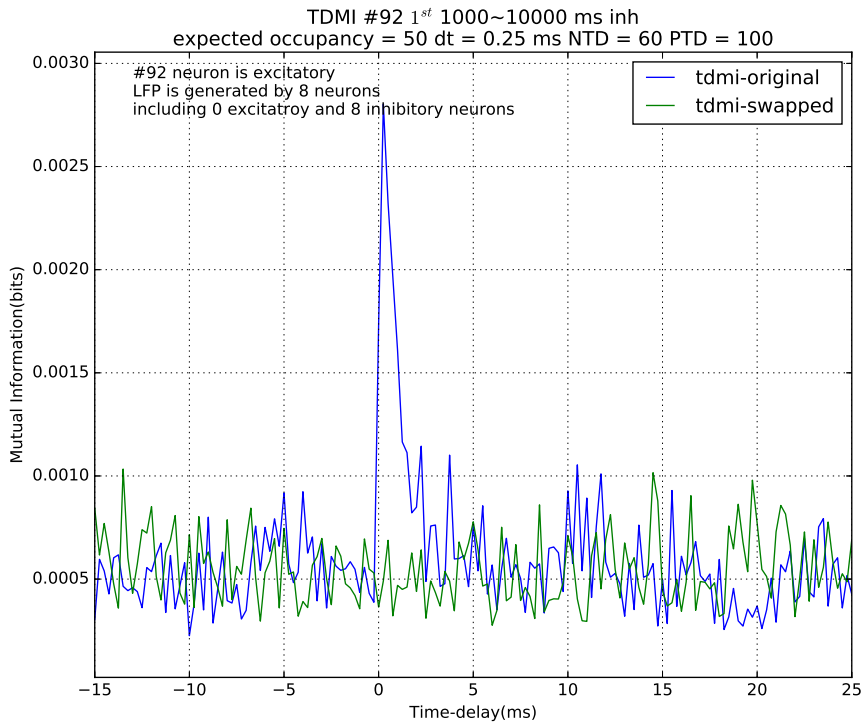
All excitatory neurons in first-order connected neuron cluster are chosen as a sub-set to generate another LFP sequence. So do inhibitory neurons.



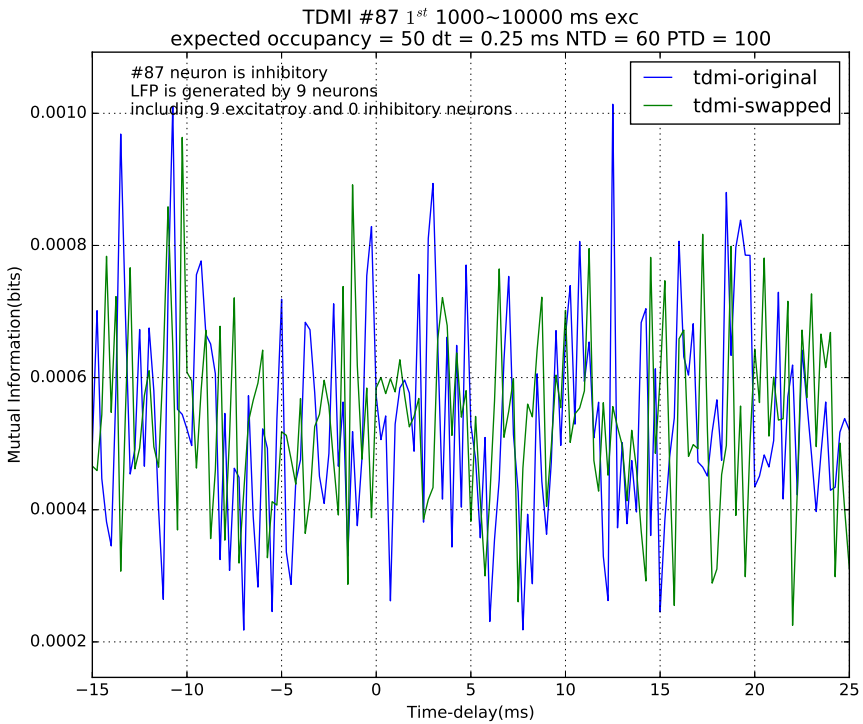


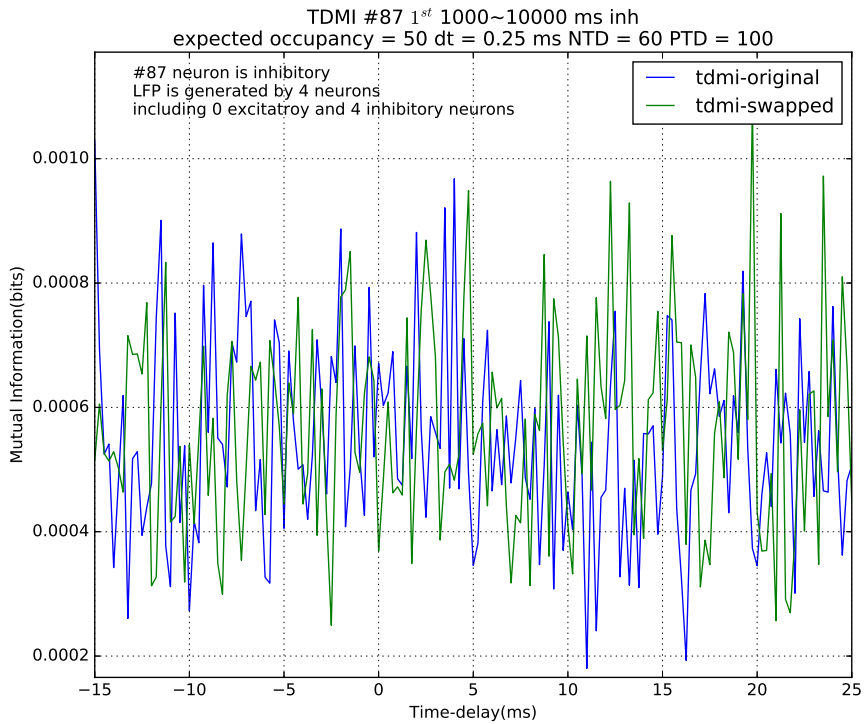
For excitatory neurons:





For inhibitory neurons:

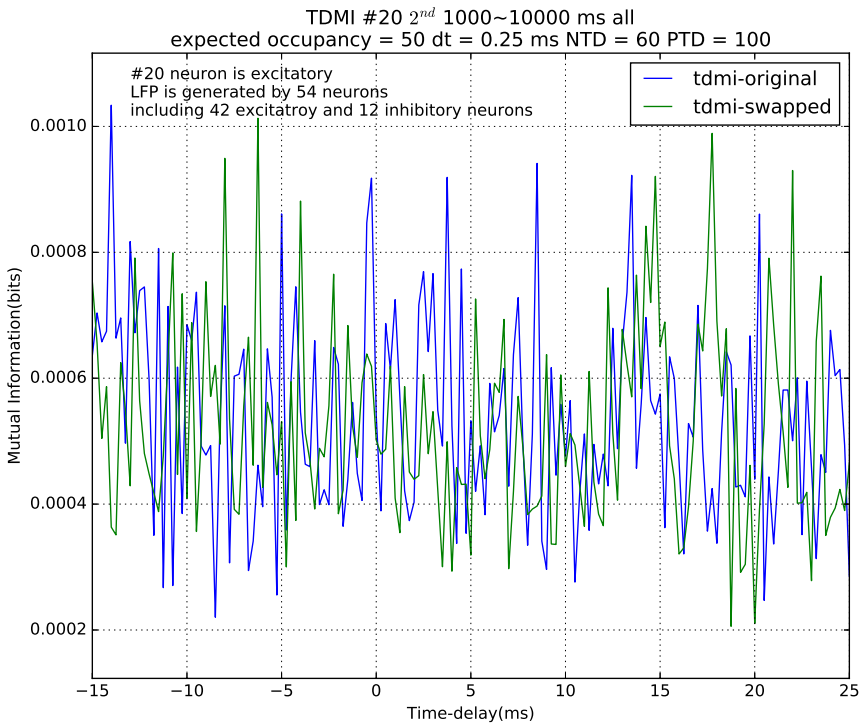


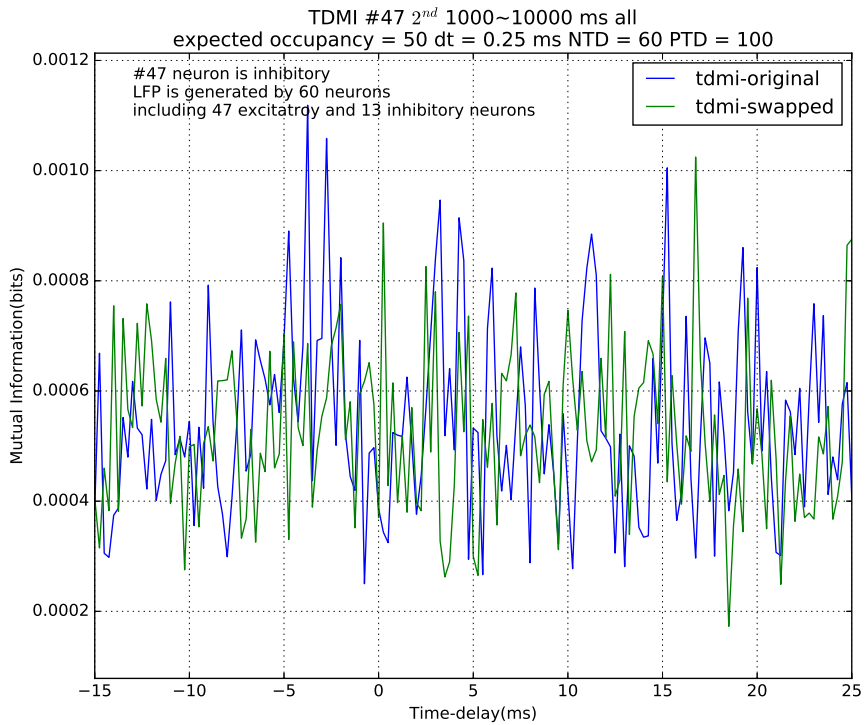


Conclusion 3

Excitatory and inhibitory neurons in post-network contribute the similar effect on the amount of MI.

TDMI of spike train and 2^{nd} order LFP





Conclusion 4

The TDMI of spike trains for both excitatory and inhibitory neuron and second order LFP fluctuate at noise level. As a result, we can see the 2^{nd} order connecting pattern between neurons in terms of TDMI plot.

Denote: This conclusion is drawn in current neuron-neuron interaction scheme. If the intensity of neuronal interaction increases, there might be different results. This case would be discussed in my next report.

Working plans for next week

1. Check the dynamical states of different neuron in both pre- and post- networks. Study the different impacts toward MI from cross-network communication and neuronal interaction within single network.
2. Study the time delay between MI peak and zero time point; Find the parameter that impact the length of it by changing parameters related to neuron-neuron interaction;
3. Try to run test on networks with different network structures, to see whether there is any different TDMI pattern;