

Critical states of slow pattern in neuronal networks

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Outline

- 1 Motivation
 - The Basic Problem That We Studied
 - Previous Work
- 2 Our Results/Contribution
 - Main Results
 - Basic Ideas for Proofs/Implementation

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Our Results/Contribution

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Network Dynamics

- Network response correspond to specific neuronal parameter, including fire rate, degree of irregularity, spatiotemporal patterns in neuronal spike trains and neuronal critical dynamics.
- Explor the influence of simulation size of neuronal network as well as the community structural network. 2000, 5000, 10000, ..., 100 million.
- Synapse density and input heterogeneity.(to be confirmed)

Theoretical explanation

Mainly three aspects. . .

- Explain the mechanism underly the trainsition dynamics.
 - input current variability analysis.
 - Mean-field equation and hopf bifuraction
 - The real part of fixed point is decreasing.
- fit the network response with a simple f unction.

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Biological plausible neuronal network

Consider a balanced E-I network with N neurons, in which 80% are excitatory neurons and the others inhibitory ones. Each neuron is equipped with a biological plausible neuronal model, leaky integrate and fire model,

$$C \frac{dV}{dt} = -g_l(V - V_l) + I_{syn} + I_{ext},$$

and the conductance-based synaptical filter

$$I_{syn}(t) = \sum_u g_u S_u(t) (V_{rev,u} - V)$$

$$S_{i,u}(t) = \frac{1}{\tau_u} e^{-t/\tau_u} * \sum_{n,j \in \partial^i} w_j \delta(t - t_j^n)$$

$$u = \{AMPA, NMDA, GABA_A, GABA_B\}.$$

Balance condition

Under the given network conditions and default neuron parameters, we need to seek for a group of appropriate parameters (g_u) to make the network self-sustaining in a stable firing state.

we can roughly estimate a group of parameter by adopting the first order diffusion approximation.

$$\frac{V_{th} - V_{reset}}{\sum_u \langle g_u S_u(V_u - V) \rangle - \langle g_l(V - V_l) \rangle} = \frac{1}{r_{equilibrium}},$$

and then we can dervie that

$$\begin{cases} 34g_{AMPA} + 250g_{NMDA} = 1 \\ 2g_{gaba_A} + 36g_{GABA_B} = 1 \end{cases}$$

For convenience, we denote the first term in the two equations as *AMPA Contribution* and *GABA_A Contribution* respectively.

Default Parameters

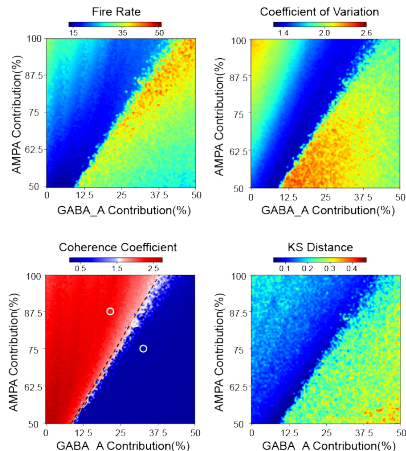
Symbol	Description	Value
N	Total number of neurons	2000
N_E	Total number of excitatory neurons	600
N_I	Total number of inhibitory neurons	400
K_{in}	Mean of in-degrees	400
τ_{ref}	Refractory period	5ms
τ_{au}	decay time of receptors	(8, 40, 10, 50)
$V_{rev,u}$	reverse voltage	(0, 0, -75, -100))

Table: Default values of model parameters used in numerical simulations

Rich dynamics in parameter submanifold

We find rich dynamics in this small balanced E-I network.

- Obvious transition in the fire rate.
- CV is larger than 1, and multi stratification.
- Coherence coefficient reflects the spike coherence.
- Critical dynamics occurs in the stratification line parameter space.



avalanches phenomena

Mainly due to E-I delay feedback. . .

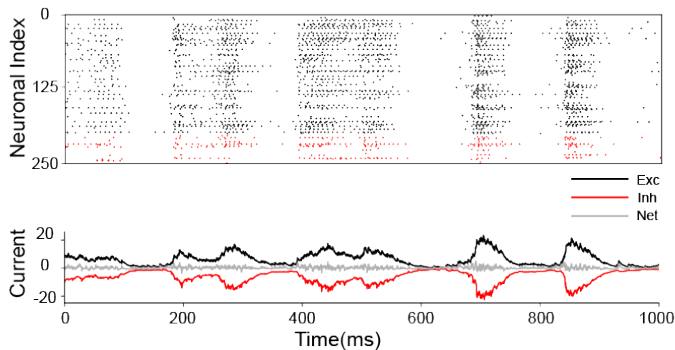


Figure: raster plot of slow dynamics

avalanches phenomena

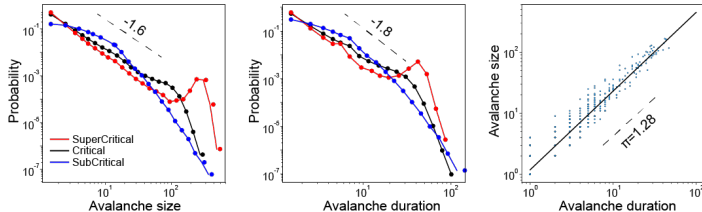


Figure: avalanches phenomena

The slope of best fit powerlaw distribution for avalanche size is -1.6 and avalanche duration is -1.8

Criticality in large-scale network

Fit to function $s \cdot \tanh(ax + by + c) + t$

- in the small block, slop is 1.6
- in the large-scale block, slop is 1.6

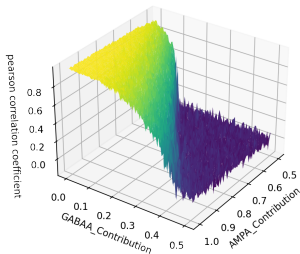


Figure: size=2k

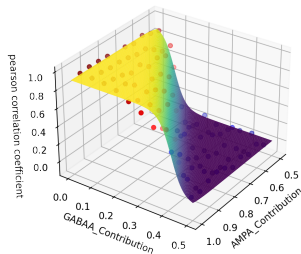


Figure: size=100m

Criticality in large-scale network

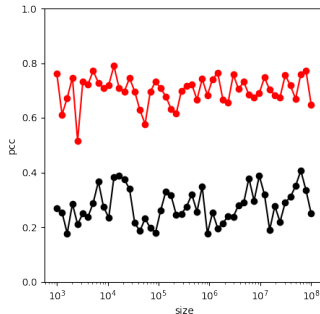


Figure: pcc with respect to different sizes

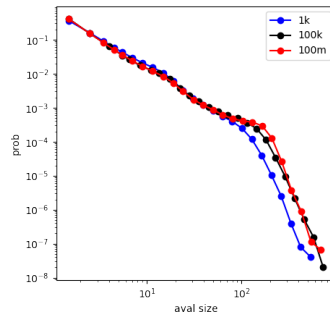


Figure: avalanches distribution

Criticality in large-scale network

Some simulation case from a fixed parameter of critical space.

- The avalanche size increases with the size of the simulation.

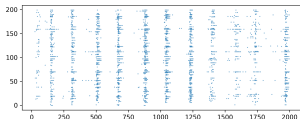


Figure: size=10k

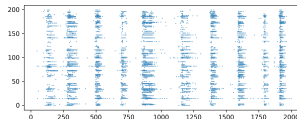
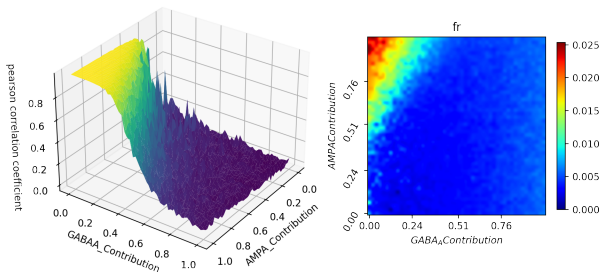


Figure: size=100m

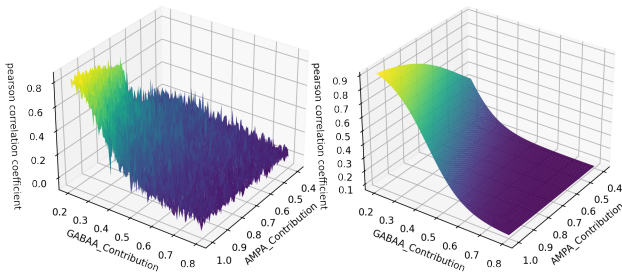
Dependence on connection density

grid search on network of 2000 neurons with 300 in-connections. x and y range is $[0, 1]$, each 50 points.



Dependence on connection density

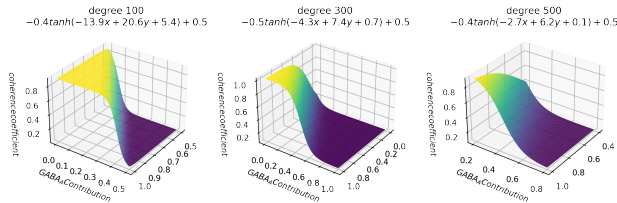
grid search on network of 2000 neurons with 500 in-connections.



As we can see, the plane is much more smooth than its in degree=100 and the one-dimensional linear submanifold disappears.

Dependence on connection density

If all case fit to function $s \cdot \tanh(ax + by + c) + t$. we can find that its slope is smaller with the degree increasing.



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Summary

- The **first main message** of your talk in one or two lines.
- The **second main message** of your talk in one or two lines.
- Perhaps a **third message**, but not more than that.
- Outlook
 - Something you haven't solved.
 - Something else you haven't solved.

For Further Reading I



A. Author.

Handbook of Everything.

Some Press, 1990.



S. Someone.

On this and that.

Journal of This and That, 2(1):50–100, 2000.