Dynamics of pruning in simulated large-scale spiking neural networks

Javier Iglesias[1,2,3]

joint work with J. Eriksson[2], F. Grize[1], M. Tomassini[1], A.E.P. Villa[2,3]

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1: Information Management Department, University of Lausanne, Switzerland

2: Laboratory of Neuro-heuristics, University of Lausanne, Switzerland

3: Laboratory of Neurobiophysics, University Joseph-Fourier, France

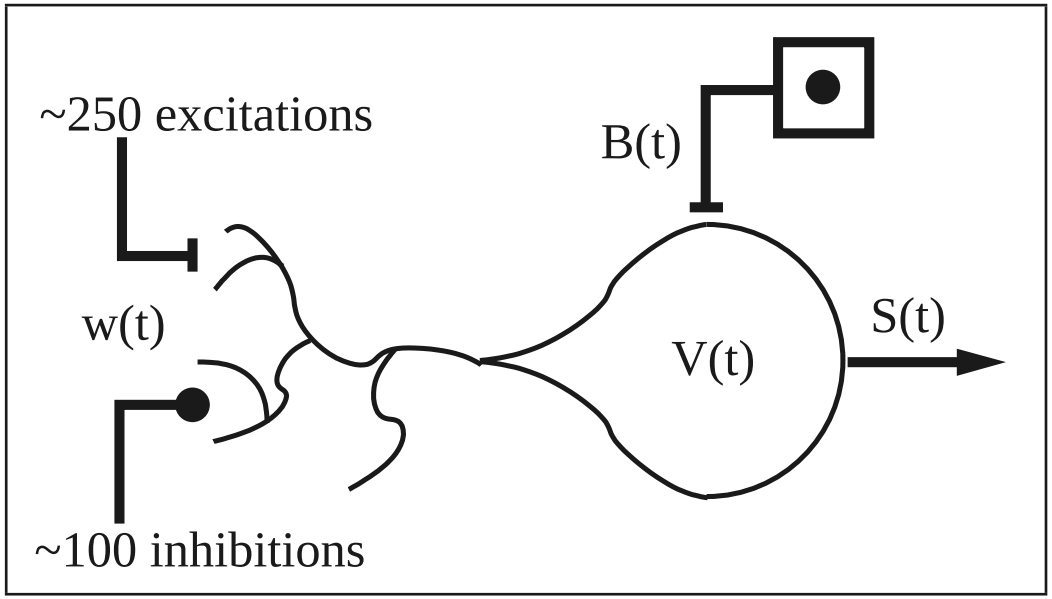
<javier.iglesias@hec.unil.ch>

- model synaptic pruning after over-growth observed during brain maturation

- size: 100 $\times$ 100 2D lattice, torus wrapped
- duration: $1 \cdot 10^6$ time steps (ms)
- compatible with hardware implementation

- Iglesias, J., Eriksson, J., Grize, F., Tomassini, M., Villa, A.E.P., *submitted*. Dynamics of pruning in simulated large-scale spiking neural networks. BioSystems.

leaky integrate and fire neuro-mimetic model



Type I = excitatory 80%
Type II = inhibitory 20%
=

V_{rest}	=	-76	[mV]
θ_i	=	-40	[mV]
τ_{mem}	=	8	[ms]
t_{refract}	=	1	[ms]
λ_i	=	10	[spikes/s]
n	=	50	

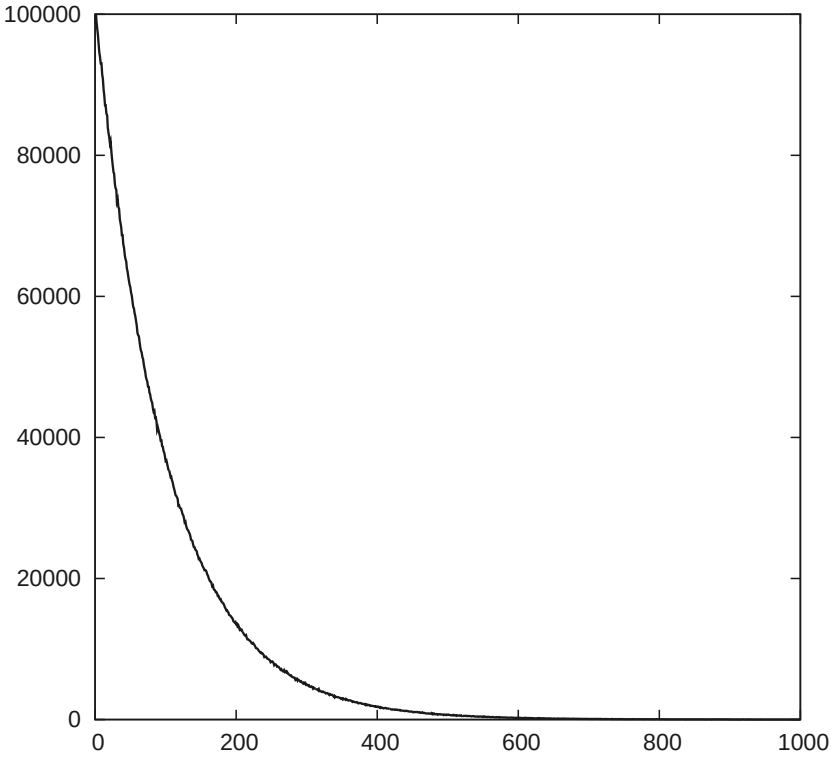
$$V_i(t+1) = V_{\text{rest}[q]} + (1 - S_i(t)) \cdot ((V_i(t) - V_{\text{rest}[q]}) \cdot k_{\text{mem}[q]}) + \sum_j w_{ji}(t) + B_i(t)$$

$$S_i(t) = \mathcal{H}(V_i(t) - \theta_{q_i})$$

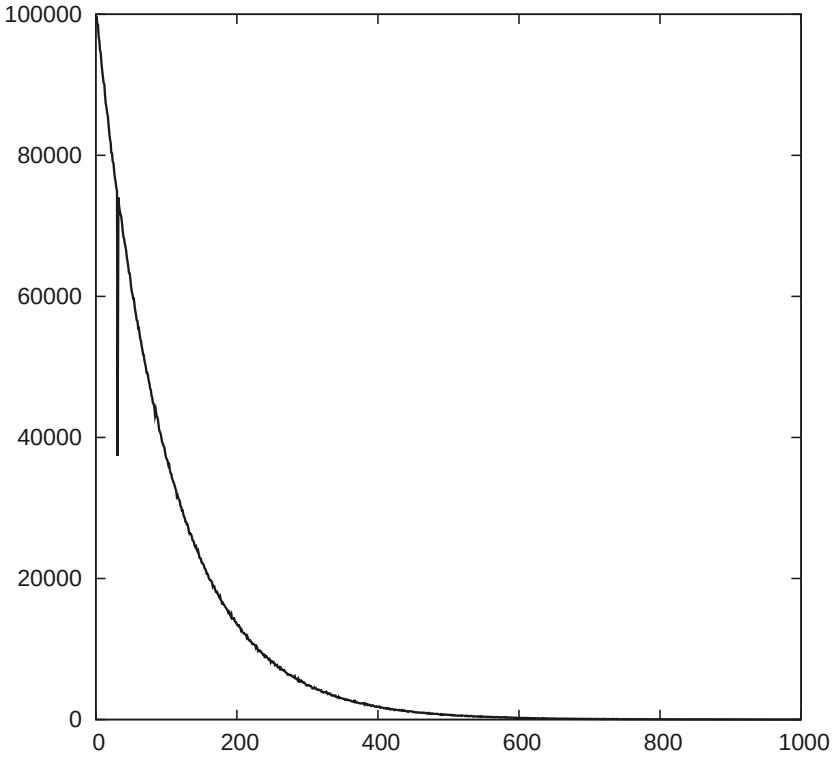
$$w_{ji}(t+1) = S_j(t) \cdot A_{ji}(t) \cdot P_{[q_j, q_i]}$$

$$B_i(t+1) = \mathcal{P}_{reject}(\lambda_{q_i}) \cdot n \cdot P_{[q_1, q_i]}$$

acceptance/rejection Poisson process of $\lambda = 10$ spikes/s, $n = 10^7$



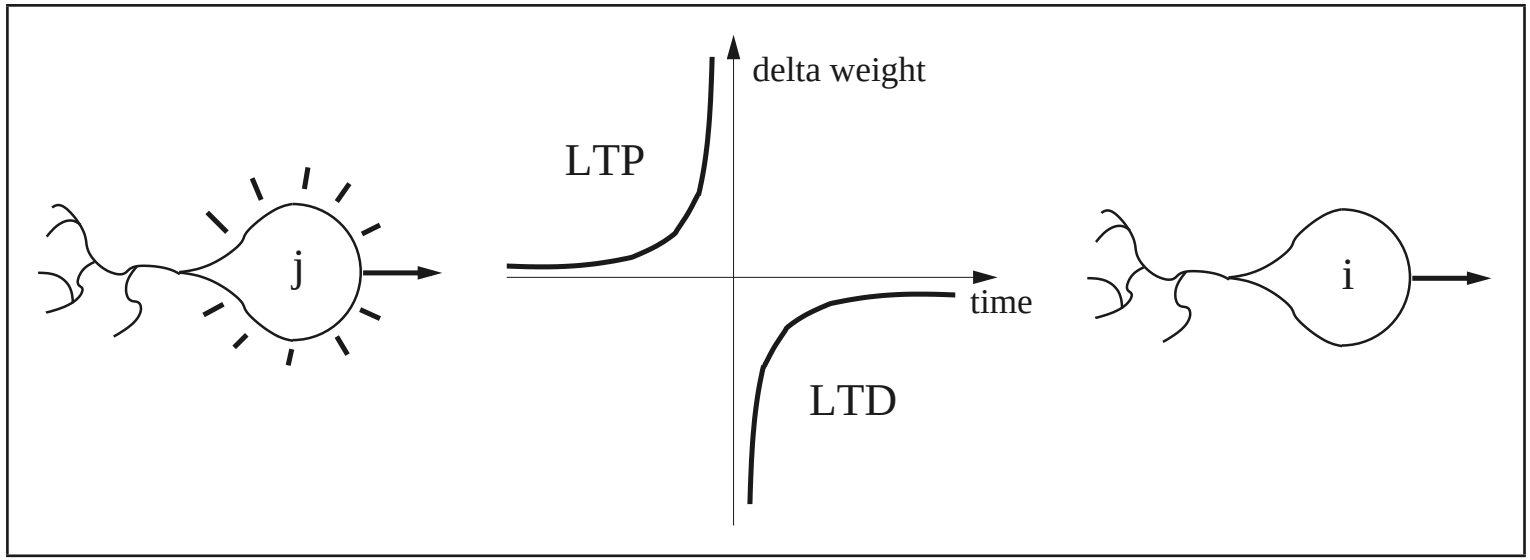
default GSL GNU Scientific Library RNG implementation



default C RNG implementation (GNU/Linux, MacOS X, ...)

STPD - spike timing dependent plasticity

$$w_{ji}(t+1) = S_j(t) \cdot A_{ji}(t) \cdot P_{[q_j,q_i]}$$

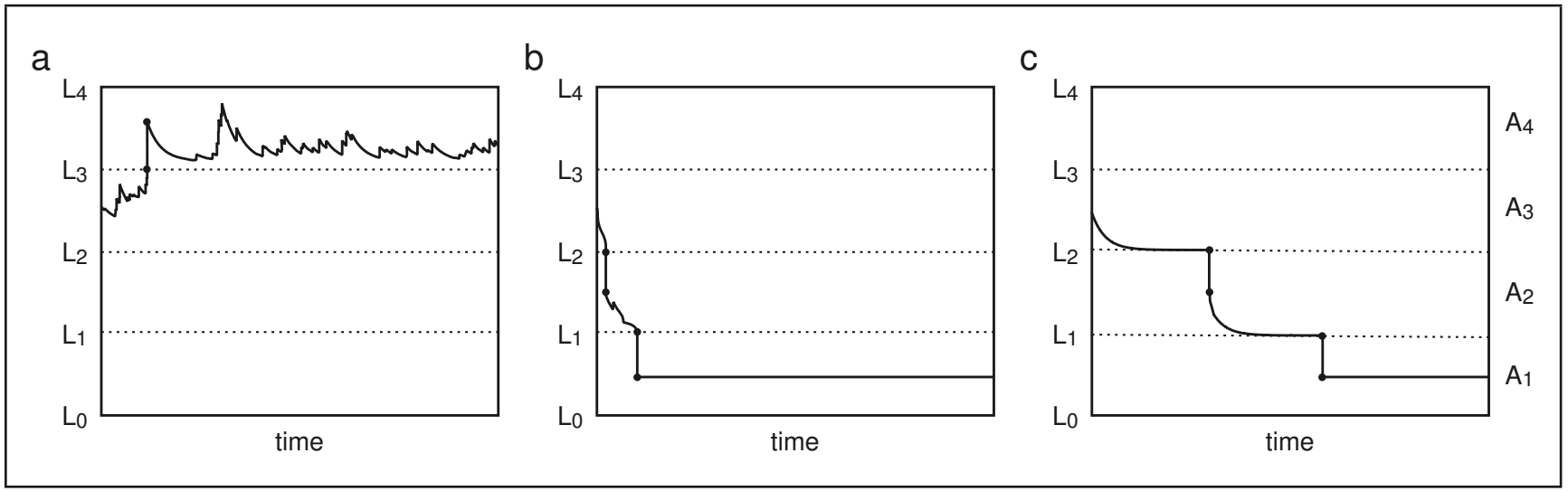


$A_{ji}(t) \in \{0, 1, 2, 4\}$ for $P_{[1,1]}$, *LTP*: Long Term Potentiation

$A_{ji}(t) = 1$ for the others; *LTD*: Long Term Depression

$P_{[1,1]} = P_{[1,2]} = +1.34[mV]$
$P_{[2,1]} = P_{[2,2]} = -2.40[mV]$

pruning dynamics



$$L_{ji}(t+1) = k_{act} \cdot L_{ji}(t) + (S_i(t) \cdot M_j(t)) - (S_j(t) \cdot M_i(t))$$

$L_{ji} \in]0, L_{\max}]$

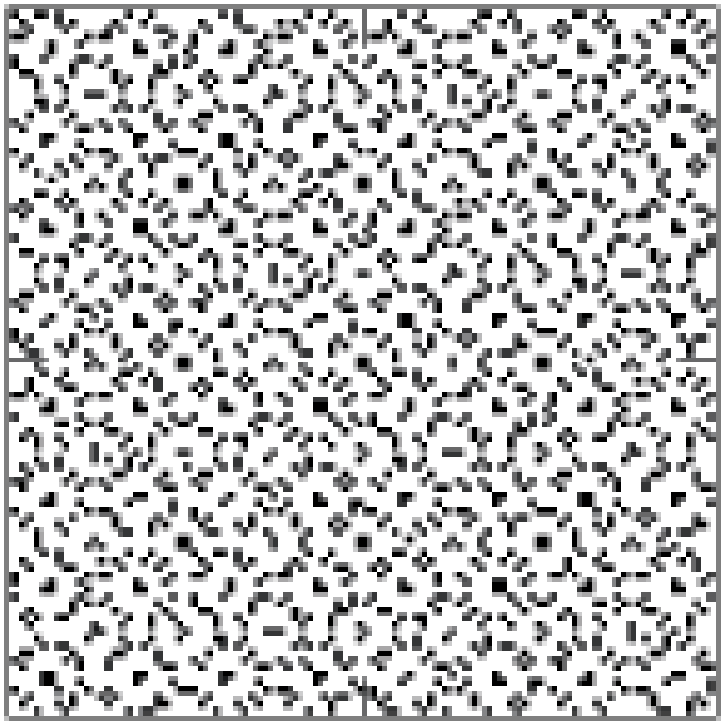
$\tau_{act} = 11000$[ms]

$$M_i(t+1) = S_i(t) \cdot M_{\max} + (1 - S_i(t)) \cdot (M_i(t) \cdot k_{learn})$$

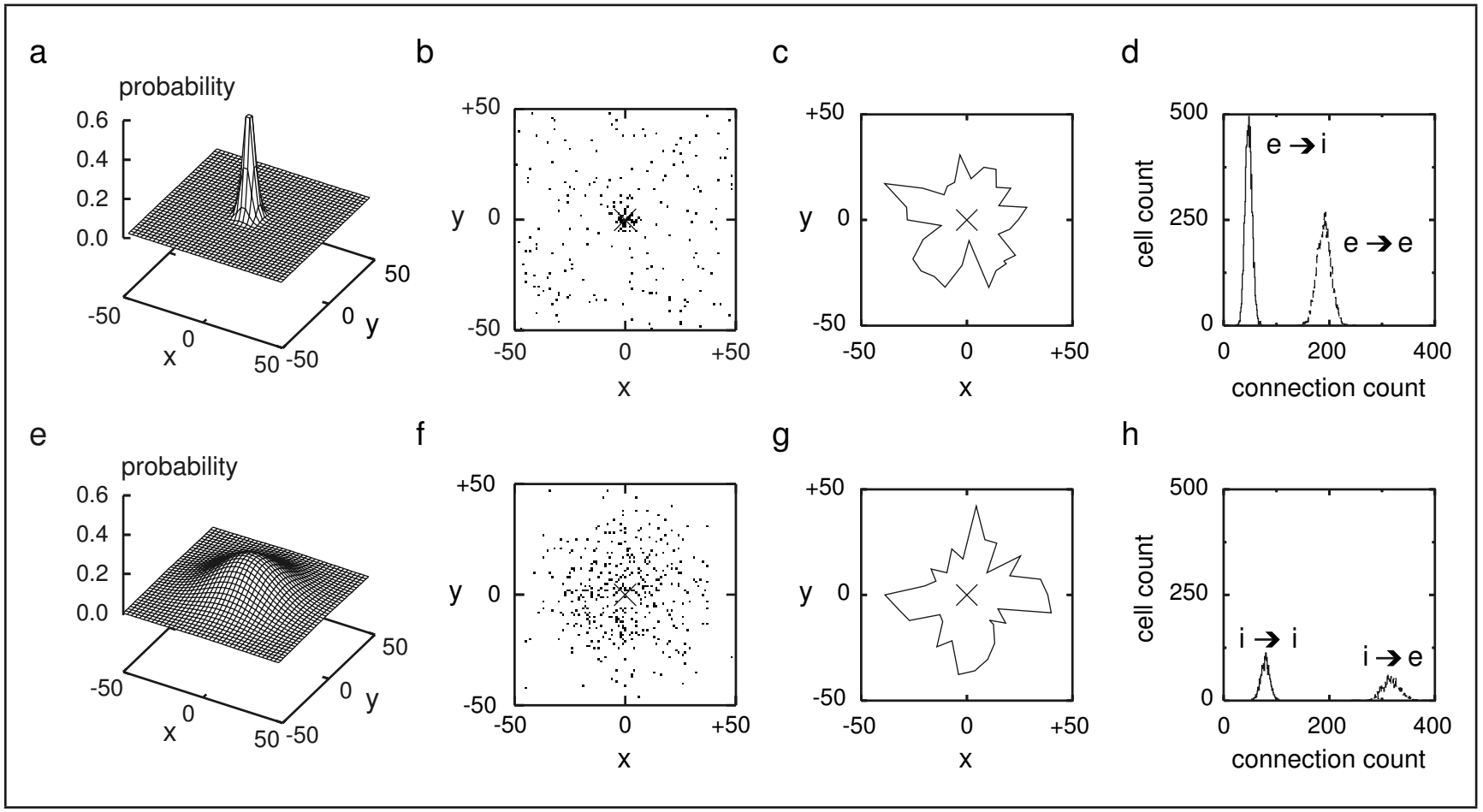
$L_{\max} = 10 \cdot M_{\max}$

$\tau_{learn} = 2 \cdot \tau_{mem}$

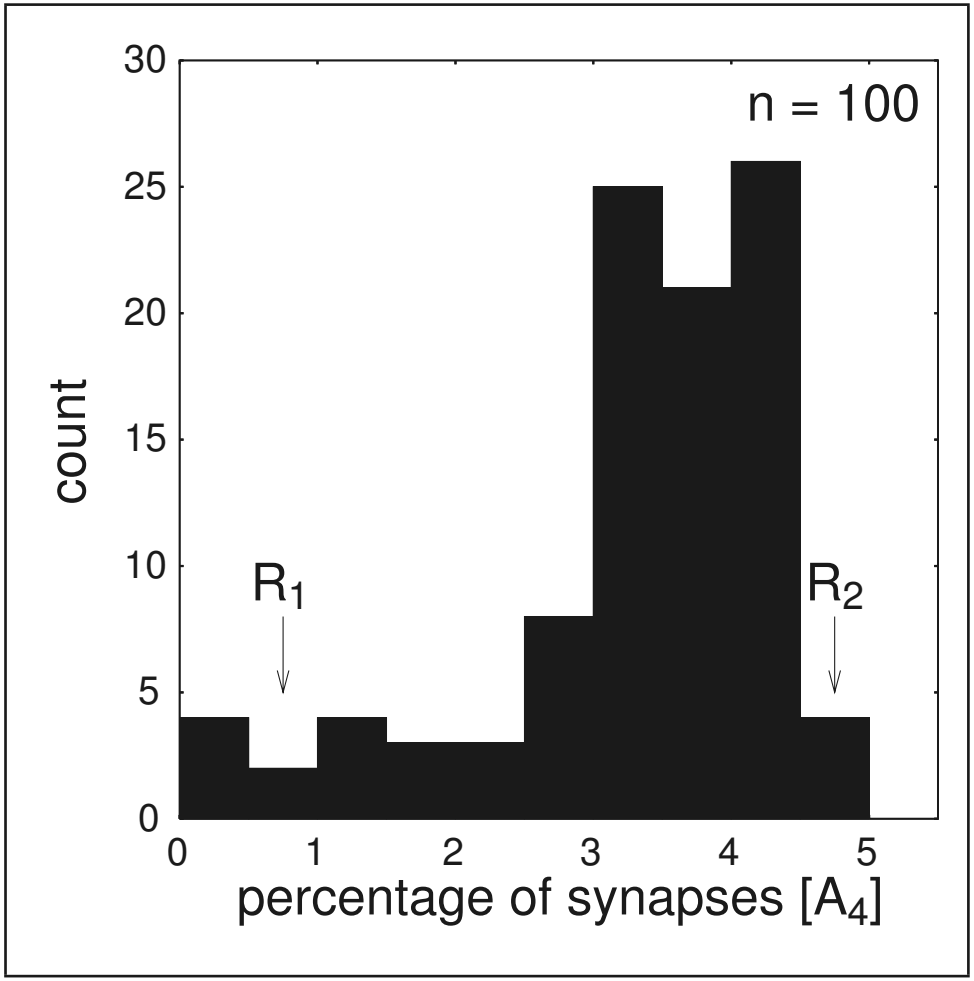
space-filling quasi-random Sobol distribution of 20% of inhibitory neurons on the 100 $\times$ 100 2D lattice



random local connectivity



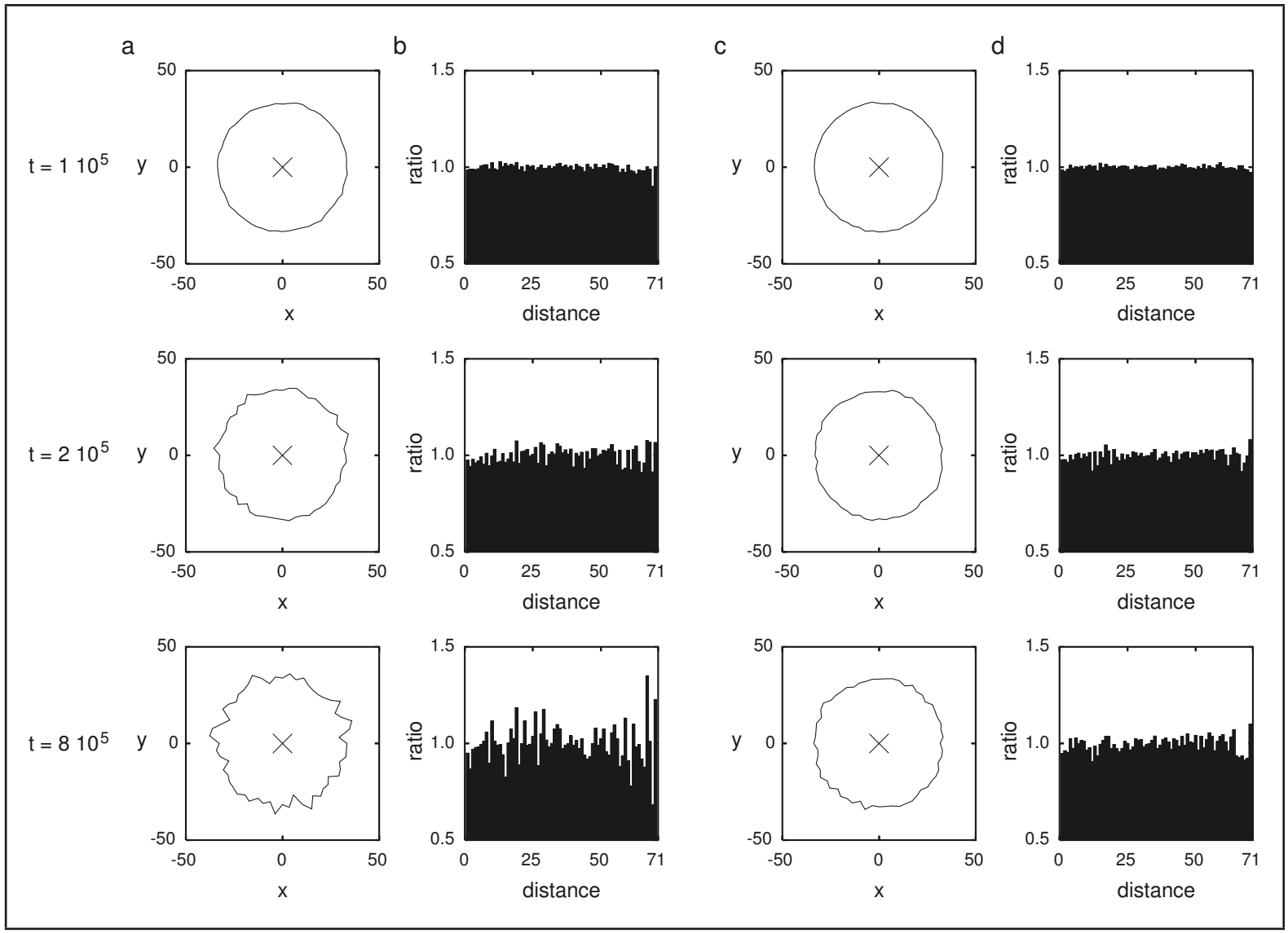
result 1: effect of random generator seed



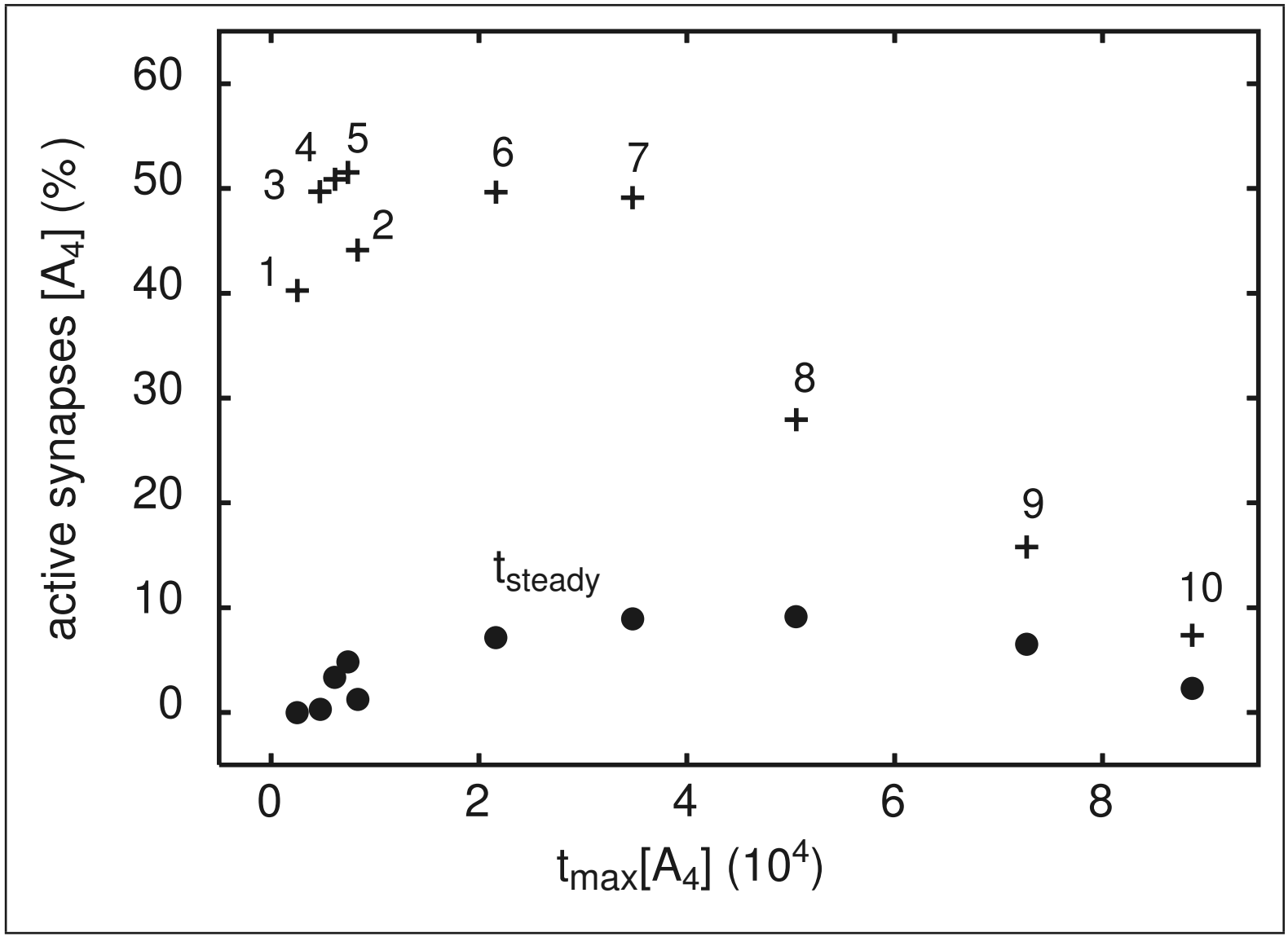
Same simulation settings, except random generator seed: variation

Same network, different random generator seed: small variation (not shown)

result 2: no change in preferential direction or length



result 3: effect of size of network



- lots of oversimplified hypotheses

- bimodal distribution of activation levels at steady state
- no distortion of geometrical properties induced

- try other synaptic transfer functions
- use more realistic transfer functions for other projection types
- add content-related inputs