THE EFFECT OF LONG-RANGE CONNECTIVITY ON THE OCCURRENCE OF SPATIOTEMPORAL FIRING PATTERNS IN SIMULATED SPIKING CORTICAL NEURAL NETWORKS

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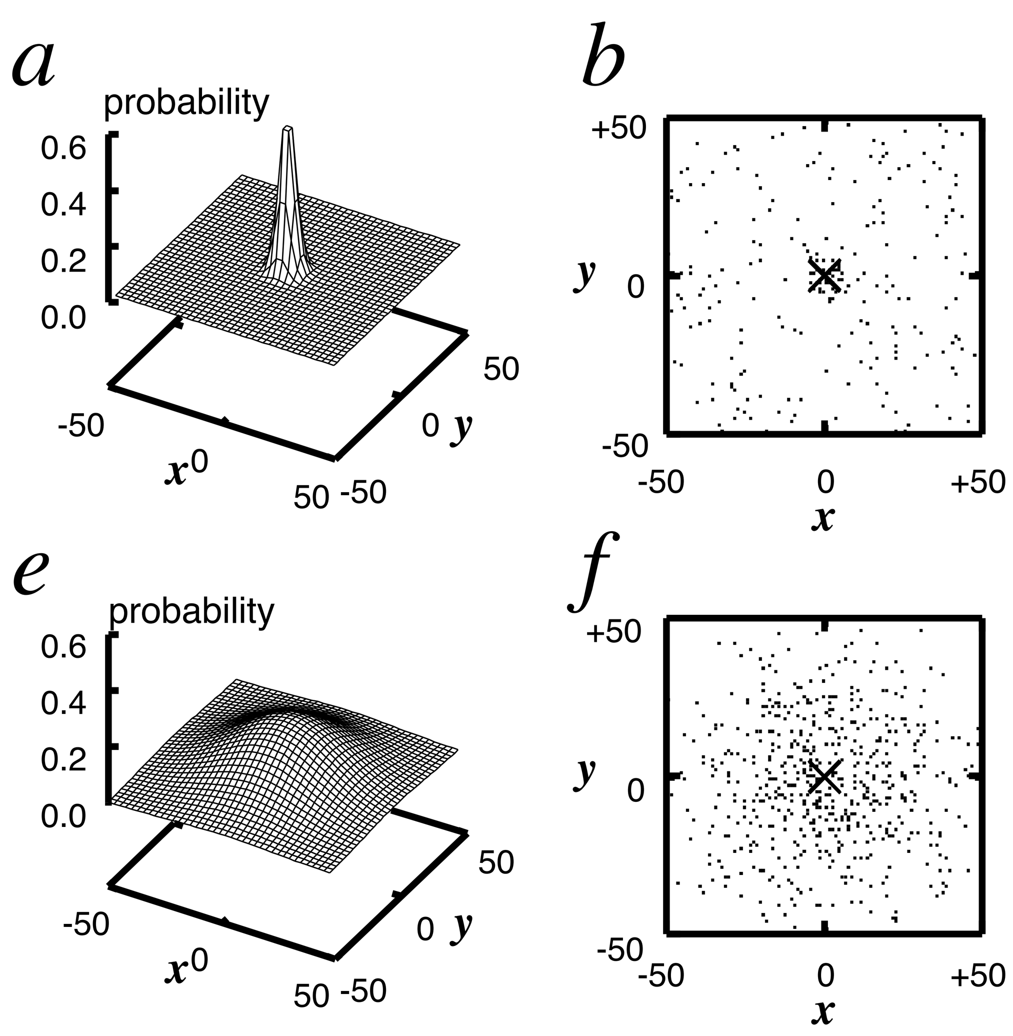
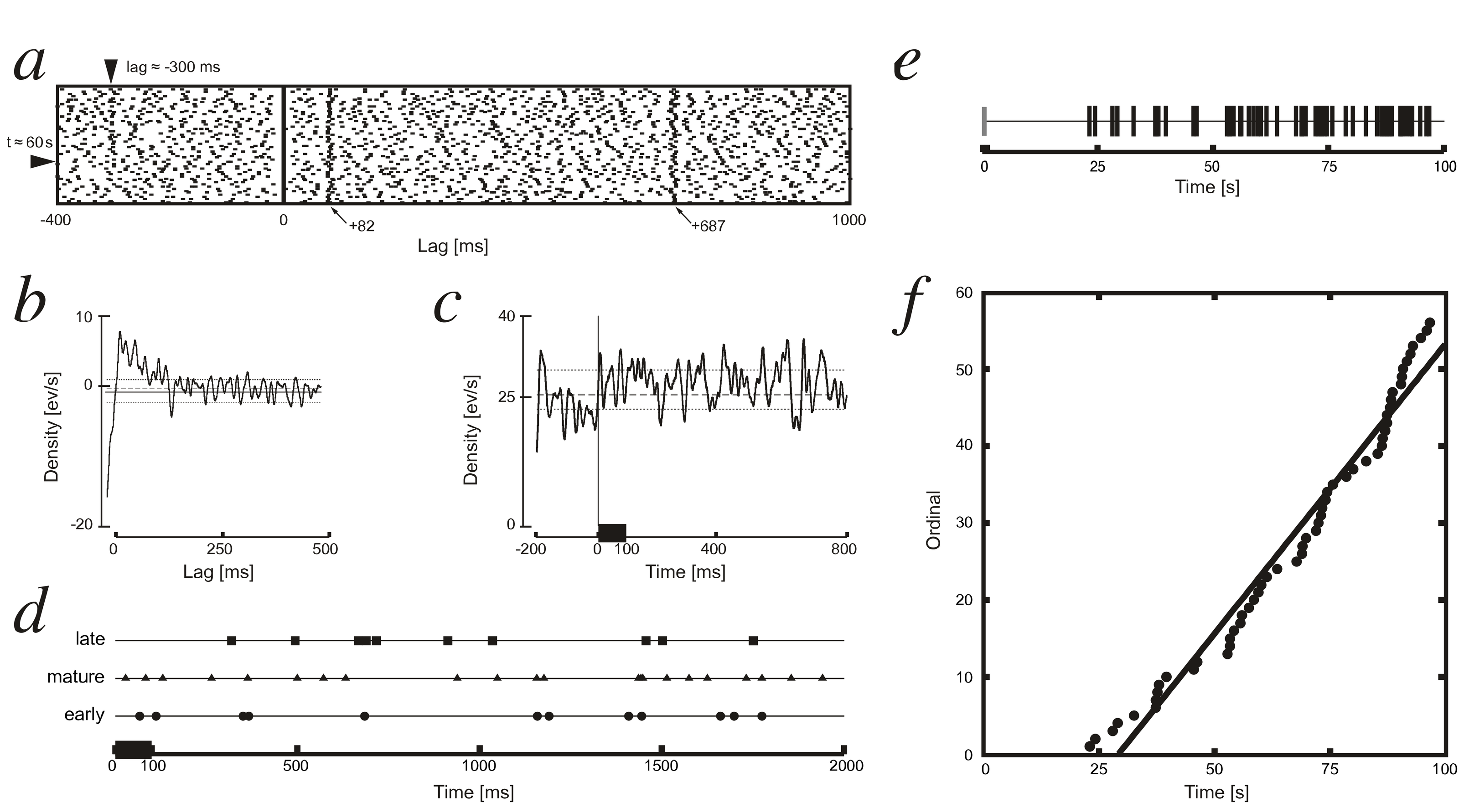
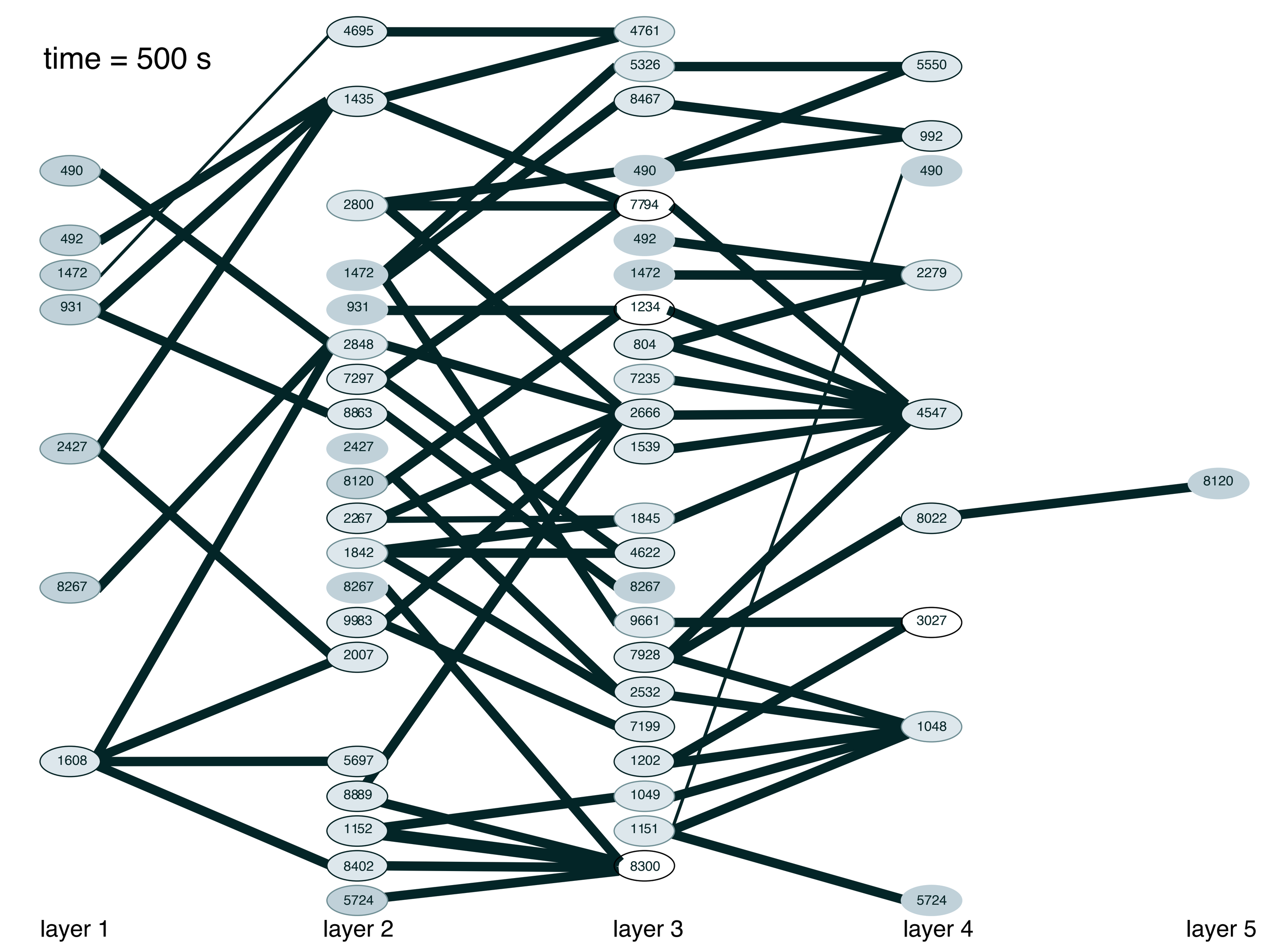
An excitatory and an inhibitory population of spiking neural networks were initially connected according to selected probabilty density functions. The inhibitory population was characterized by sparse local connectivity, whereas the excitatory neurons were characterized by a dense local connectivity and a very sparse but flat probability to send projections anywhere else in the network. The excitatory-excitatory and excitatory-inhibitory synapses are modifiable and take discrete strength values that may change according to a spike-timing dependent plasticity (STDP) rule [1]. In case the synaptic strength decreased below a certain threshold the synapse was pruned out.



In the current implementation we assume a background noise of 5 spikes/s during an initial developmental phase featuring cell death associated to an excessive firing rate, somewhat akin to the neurotoxic effect of glutamate. This cell death affected both populations of neurons and preserved approximately the same initial Excitatory/Inhibitory balance. This phase is followed by the onset of STDP and by recursive spatially and temporally organized stimuli [2].



We have shown that this network dynamics is able to generate detectable preferred firing sequences [3]. This term refers to ordered and precise (in the order of few ms) sequences of intervals within spike trains of individual neurons and across spike trains recorded from different neurons and encompasses both their precision in time and the fact that they can occur across different neurons at any spatial location.



The simulations were stopped when the network reached a steady state. At this time strongly interconnected units (SI-units) are defined as excitatory neurons that were not directly excited by the external stimulus and that maintained at least 3 strong afferent and 3 strong efferent connections with neurons with the same properties. SI-units tended to form pools of neurons organized following a layered structure that suggests a synfire chain characterized by diverging/converging connections from a pool (layer) to the next pool of the network [4]. However, the degree of convergence (convergency) tended to be higher than the divergency and few neurons of the last detectable layer were receiving the funneled activity of the network in accordance with the formal investigation of this kind of network [5].

Table 1: Number of SI-Units at t=500s with normalized number of connections at t=0.

	probability [%]						
diameter	40	45	50	55	60	65	70
0	16	17	16	11	9	16	8
5	8	12	16	13	12	17	12
10	14	11	17	10	13	12	10
15	8	11	17	14	5	9	6
20	7	10	5	16	13	11	10
25	7	9	9	15	20	12	16

The preferred firing sequences often involved SI-units but their participation to this patterned activity was deeply affected by changing the ratio of short vs. long-range connections of the excitatory neurons. We investigated the network within a range of 3 to 18% short-range connections and found that near 5-6% of these connections we observed a higher number of SI-units. This outcome is favorable to increase the divergency within the interconnected cell assembly and sustain preferred firing sequences in the network activity.

It is possible that during early development phases a differential pruning mechanism may act in addition to the two mechanisms implemented so far in order to progressively decrease the amount of local connections without affecting the long-range ones and bring the ratio close to some optimal level. Such ontogenetic mechanism would add an argument in favor of the plausibleness of the unsupervised emergence of synfire chains in cortical connectivity during natural brain development.

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