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ABSTRACT BOOK

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P005 The role of intra-striatal synaptic interactions for shaping cortico-striatal network dynamics

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The basal ganglia consist of several interconnected subcortical nuclei that are supposedly involved in many motor and cognitive functions. The striatum, the input stage of the basal ganglia, is a major recipient of massive glutamatergic inputs from the cerebral cortex and thalamus. Medium spiny neurons (MSNs) dominate in the striatum (up to 95% in rodents). They are inhibitory (GABAergic) and have membrane properties that give them a high threshold for activation [1]. MSNs interact with each other through weak recurrent inhibitory synapses and with low connection probability [2]. Fast-spiking GABAergic interneurons (FSNs) can delay or prevent the emission of an action potential in MSNs [3]. FSNs receive convergent inputs from a wider range of distinct cortical regions compared to nearby MSNs, and despite the fact that they are relatively sparse elements (1-2%) it seems that they have very prominent role in shaping the output of the striatum [4]. Neuronal avalanches are a type of spontaneous activity first observed in vitro by recording local field potentials in cortical neural networks using slices of rat cortex as well as cultured networks [5]. Propagation of spontaneous activity is balanced and shows a branching parameter close to 1. In addition, the number of electrodes driven over threshold during activity is distributed approximately like a power law with an exponent of $-3/2$ for event sizes suggesting a critical dynamics [5]. Neural avalanches have been shown to provide: optimal information transmission [5, 6], maximal information capacity [6] and maximal dynamic range [7]. We are studying simultaneously striatal and cortical activity in vitro. Preliminary results show that neuronal avalanches in cortex induce activity clusters in striatum whose size distribution can be approximated by a steeper power law than observed in cortex. Based on this we have developed network models in order to determine the impact of different striatal neurons on the more negative exponent. In particular, we are investigating whether FS or MS neurons have any roles in shaping the striatal dynamics.

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P022 Effective generators for superpositions of non-Poissonian spike trains

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Networks of spiking neurons are widely studied in computational neuroscience. Simulations typically represent only a part of the brain in a network model. To compensate for the missing excitatory and inhibitory inputs from neurons external to the represented part, randomly generated spike trains are often injected to the simulated neurons. If all external spike trains are Poisson processes (PP), their superposition is again a PP, with a rate equal to the sum of the individual rates. To represent the sum of all external inputs, it is, therefore, only necessary to generate a single spike train with a higher rate. In most areas of the neocortex, however, neural spike trains are either more or less regular than a PP [1]. In this case, the superposition (pooled input) is not a PP any more [2]. In fact, our analyses of statistical properties of superpositions of non-Poissonian (NPP) processes, and of the dynamics of leaky-integrate-and-fire neurons driven by such inputs, showed that NPP superpositions exhibit profound differences to the PP, to which neurons are sensitive [2]. Suppose we can model the external input as N independent and identical renewal processes. To generate the superposition, the naive approach is to generate N realizations of the renewal process, and then collect all the spikes in a pooled spike train. Since this has to be repeated for each of M simulated neurons, the procedure results in computational costs proportional to $M*N$. Depending on the details of the modeled system, N can be on the order of 1000. In contrast, in the case of external PP inputs, it suffices to generate a single PP only. Using NPP external inputs thus can slow down a simulation by a factor of N , which is why PPs are commonly used. Here, we present two optimised algorithms to generate superpositions of NPP spike trains directly [2]: One for gamma processes with integer shape parameter, and one for PPs with dead time. Both generators have a computational cost which is independent of N . The generators exploit a population description of the superimposed processes, require time-discrete simulation, and have been implemented in NEST [3].

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[3] Gewaltig & Diesmann (2007), *Scholarpedia*, <http://dx.doi.org/10.4249/scholarpedia.1430>

P013 Spiking neuronal network simulation technology for contemporary supercomputers

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Functional neuronal networks, like the visual cortex of primates, comprise on the order of 100 million neurons, consisting of areas that exceed 10 million neurons and 100 billion synapses. The memory demands of such simulations are only met by distributed simulation software and supercomputers, like the Jugene BG/P supercomputer in Juelich and the K computer in Kobe. Though connectivity between brain areas is sparse, there are fewer constraints within areas. A general simulation tool needs to be able to simulate networks of 10 million neurons with arbitrary connectivity, often assumed to be random. This presents the worst case scenario: Firstly, there is no redundancy that allows to compress the representation of synaptic connectivity. Secondly, communication between the compute nodes is potentially all-to-all. Here we quantitatively demonstrate the recent advances of neural simulation technology [2] on the example of the simulator NEST [1], which have lead to a readily usable tool for the neuroscientist. As the memory rather than run time limits the maximal size of a neuronal network, we explain the systematic improvements of the distributed data structures adapted to the sparse and random connectivity. High performance and good scaling of network setup and simulation are achieved with a hybrid code combining OpenMP threads and MPI, exploiting the multi-core architectures of K and Jugene. We parameterize and employ a model of memory consumption to estimate the machine size needed for a given neuroscientific question; a crucial tool not only to plan simulations, but also for computation time grant applications. Simulations of networks exceeding 10 million neurons on K and Jugene are shown to determine the limits of the current technology and computer architectures.

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