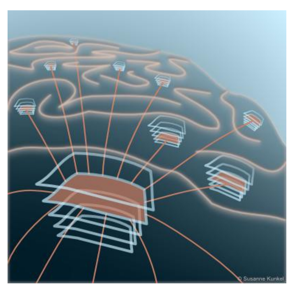
20 years of NEST: a mature brain simulator



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Introduction

Efficient and reliable simulation tools are essential for progress in brain research. A wide range of simulators has been developed, each specialized on one or few spatial and temporal scales [1]. But the reliable and reproducible simulation of complex systems such as the brain is a very demanding challenge.

Thus, the Computational Neuroscience community concentrated on a few reliable and widely used simulation tools in recent years. This concentration was not least the result of a series of large-scale EU funded projects, such as FACETS, BrainScaleS and the recently announced Human Brain Project.

The Neural Simulation Tool NEST [2] saw its first incarnation in 1993. By tightly coupling software development with research in Computational Neuroscience, simulator technology evolved steadily and NEST is a powerful simulation tool for brain-scale simulations today.

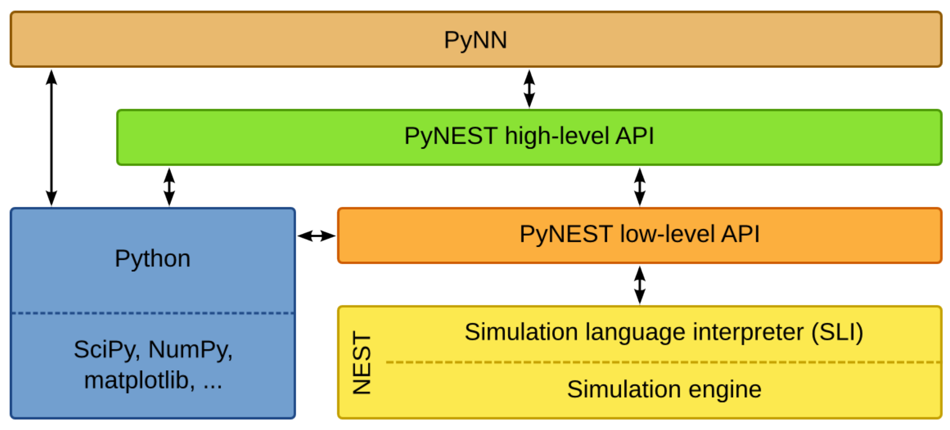
Python based user interfaces

PyNEST is the standard interface to NEST. It allows to specify
- complex stimuli and stimulation patterns
- the organization and connectivity of the network and
- data analysis

in a single programming language [3].

PyNN is a simulator-independent description language and an interface for Python that supports many simulators and controls them through simulator-specific backends [4].

Figure 1: The different software layers, which make up the Python UI subsystem of NEST. Users can access all of the layers from their simulation scripts.



Optimized for simulations on the brain-scale

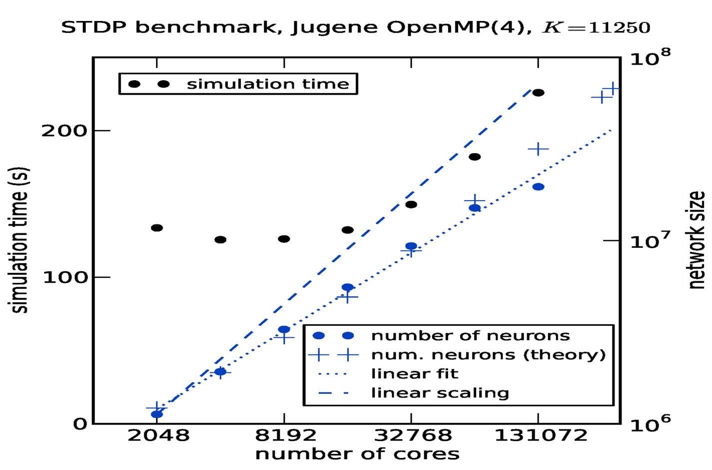


Figure 2: Scaling of NEST on the BlueGene/P JUGENE [7].

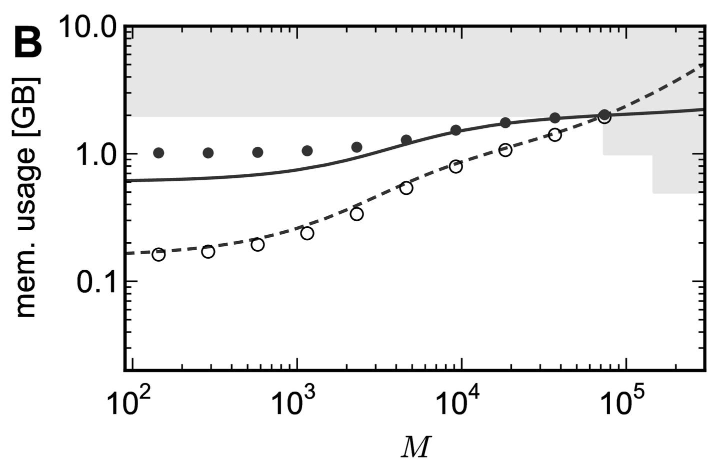


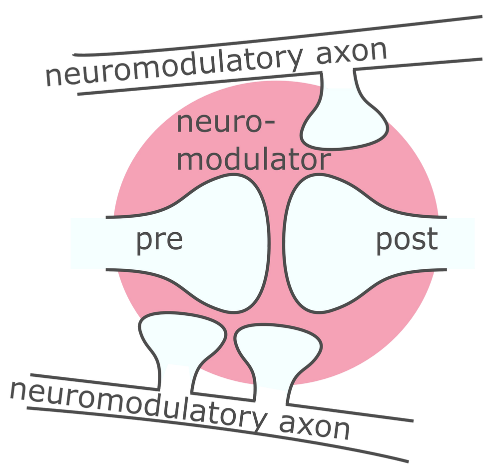
Figure 3: Memory usage of old and new NEST [6].

Efficient parallelization is the prerequisite for using modern multi-core desktop computers and HPC facilities such as clusters and supercomputers. To this end, NEST supports OpenMP and MPI to parallelize both the wiring and the simulation phase [5].

Optimized memory requirements allow to run bigger simulations on the same machine. The memory footprint of NEST was reduced significantly with the help of a memory model that allows to find and later optimize inefficient data structures by comparing their actual memory usage with the expected [6].

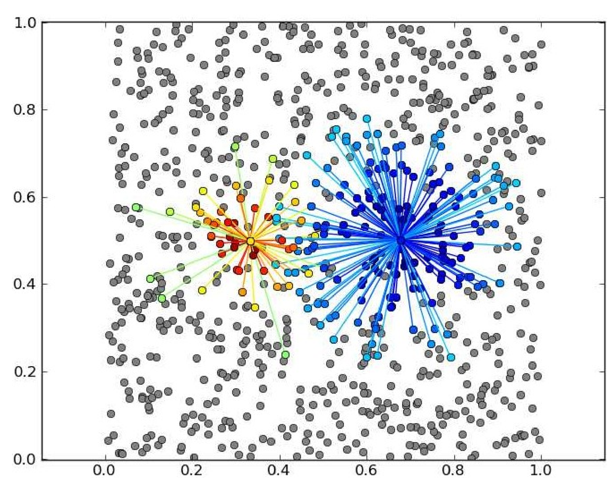
Tools for modern Neuroscience research

Synaptic plasticity in the form of short-term dynamics, spike-timing dependent plasticity (STDP) [8] and neuro-modulation via dopamine [9] allow to study learning and adaptation in neuronal networks.



Precise spike timing enables one to study synchronization in networks without side-effects caused by using a discrete time grid, on which the spikes are forced during the simulation [10].

The topology module and an **interface to the CSA** support the user with the construction of structured networks and spatial connectivity patterns [11, 12].



A MUSIC interface allows to couple NEST to other simulators at runtime and send and receive spikes as well as continuous values to bridge multiple scales, and to bind NEST to ones own program code [13].

Correctness and release stability

A battery of unit tests helps to make sure that all parts of NEST are working as expected both in serial and parallel scenarios. For neuron and synapse models, the tests compare simulated results to the analytical solutions [14].

Continuous integration (CI) techniques allow to build NEST with different compiler and library options upon every check-in and thus increase release stability and correctness [15].

Regular open source releases under the terms of the GPL give the users the chance to use and test the newest technology, while developers get feedback via bug reports and mails on the NEST mailing list. The releases are available on the homepage of the NEST Initiative at **http://www.nest-initiative.org**.

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