Human Brain Project

Point neuron network modeling in the HBP

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Human Brain Project

and few-compartment

Point neuron network modeling in the HBP

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A collaborative effort to simulate the brain

STEPS
STochastic Engine for Pathway Simulation

EBRAINS

arbor

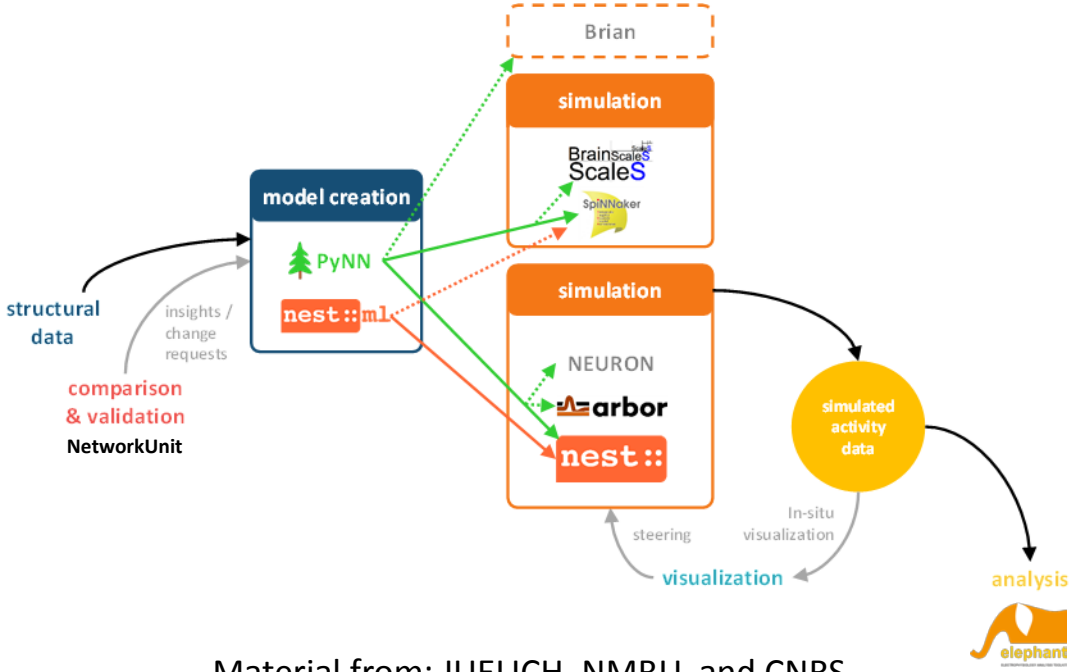
NEURON &
CoreNEURON

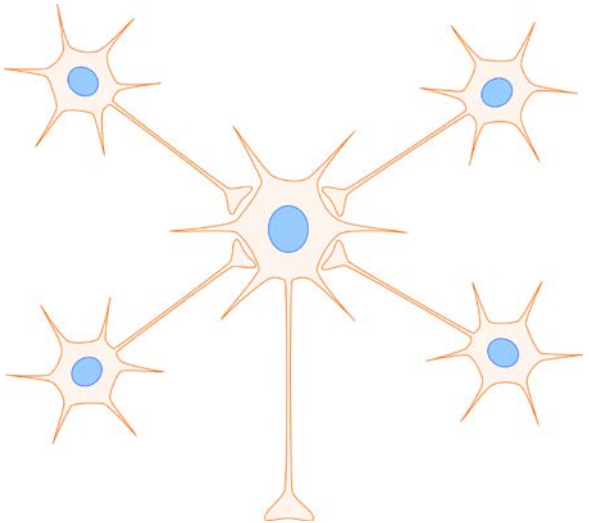
nest::

THEVIRTUALBRAIN.

Co-funded by
the European Union

Neuronal network simulation tools





Material from: JUELICH, NMBU, and CNRS

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NEST (NEural Simulation Tool)

neuron models

- integrate-and-fire (IaF) neuron models with current-based synapses (delta-, exponential- and alpha-function shaped)
- IaF models with conductance-based synapses
- adaptive exponential IaF model (AdEx) (Brette & Gerstner, 2005)
- binary neuron models
- Izhikevich model
- MAT2 neuron model (Kobayashi et al. 2009)
- augmented MAT model (Yamauchi et al. 2011)
- Hodgkin-Huxley-type models with one compartment
- neuron models with few compartments

connection models

- static synapses
- spike-timing-dependent plasticity (STDP)
- short-term plasticity (Tsodyks et al. 2000)
- neuromodulatory synapses using dopamine
- distance-dependent connectivity

extensively tested

user support

accurate integration (appropriate solvers)

option of computing precise spike times
not restricted to time grid

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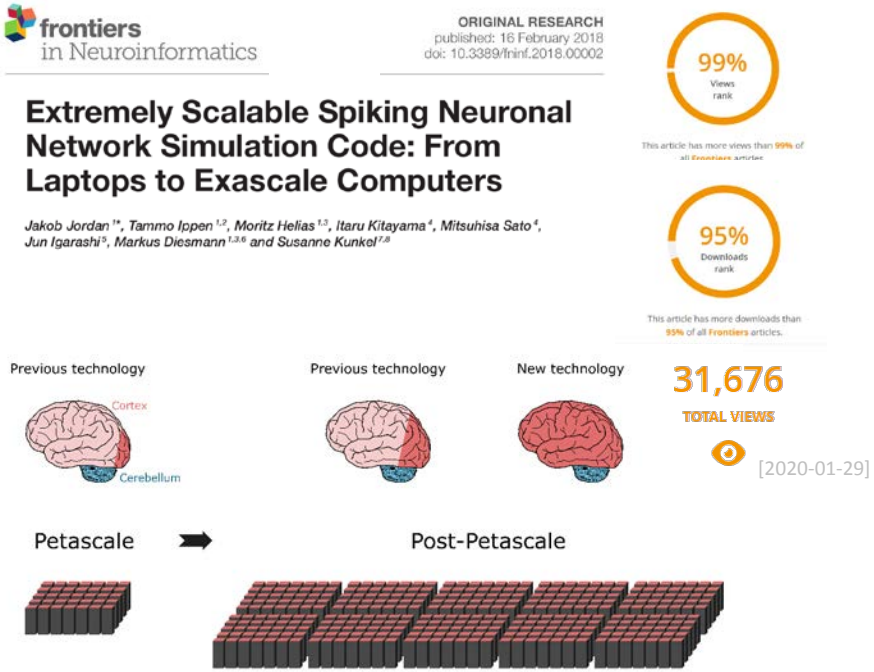
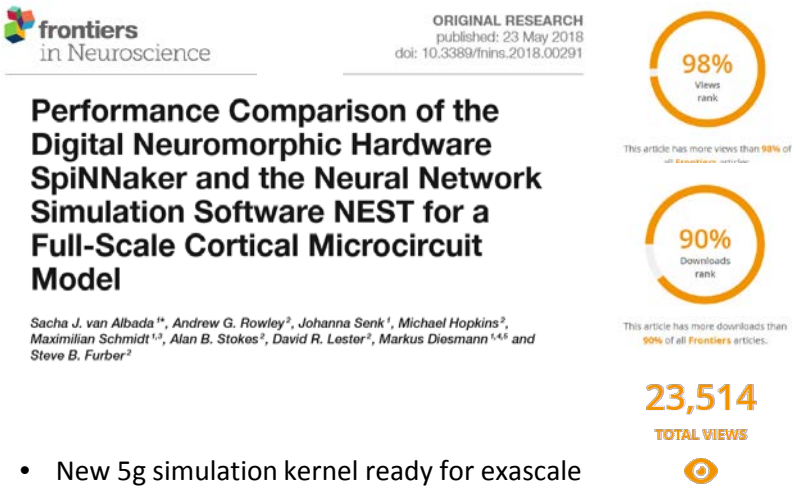
Simulation technology from laptops to supercomputers and co-design with neuromorphic hardware





- New 5g simulation kernel ready for exascale computers
- Reference for neuromorphic hardware development

Contact: diesmann@fz-juelich.de, hans.ekkehard.plesser@nmbu.no

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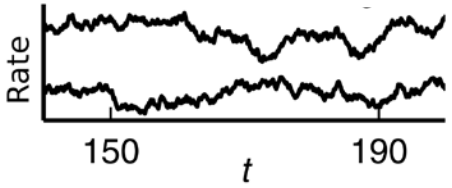
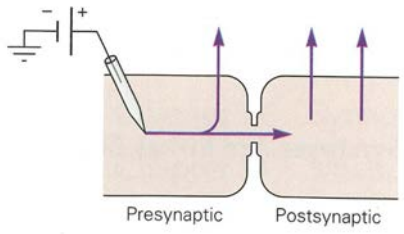
Recently added features and modeling language

Rate neurons



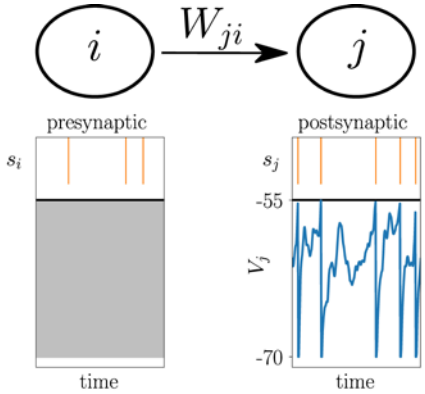
Gap junctions



Kandel et al. Principles of Neuronal Science

Advanced plasticity rules

- Urbanczik, Senn (2014)
- Clopath et al. (2010)



Applications:

- Eprop (Bellec et al. 2019)
- dendritic cortical microcircuits (Sacramento et al. 2017)

Model definition language

nest::ml

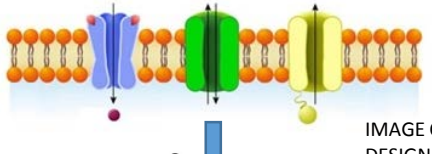
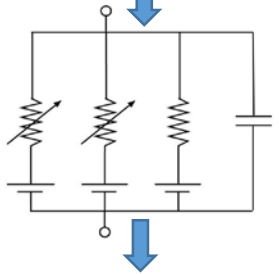


IMAGE CREDIT: DESIGNUA / SHUTTERSTOCK



```
neuron rc_neuron:

  equations:
    V_m' = -V_m/tau_m + I_syn/C_m
  end
```

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HBP & Dutch Neuroscience: Shaping Collaborations

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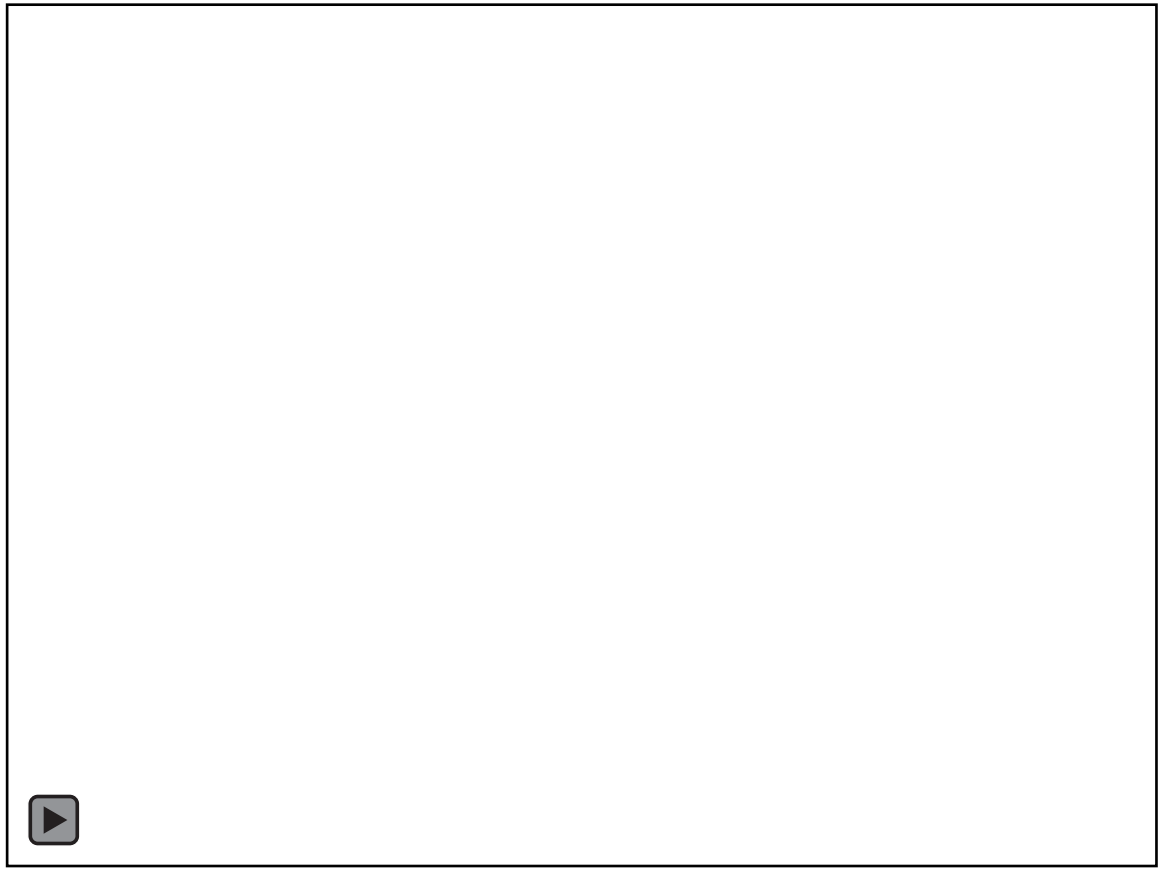
NEST Desktop

Online use of NEST

e.g. for education



Sebastian Spreizer

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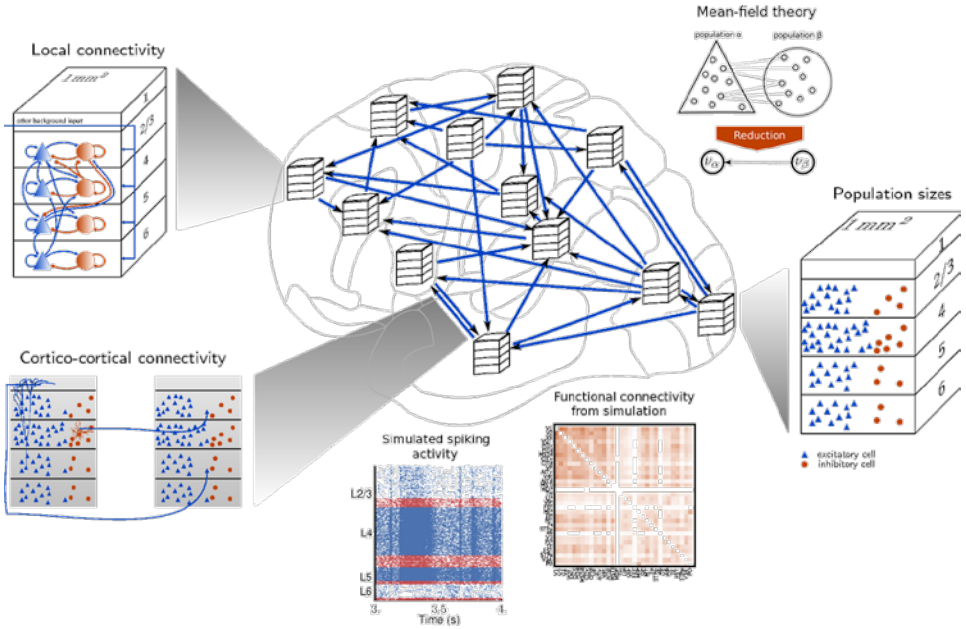
Multi-area macaque cortex model

nest::

Supercomputational model of all vision-related areas of macaque cortex

- based on microcircuit building block
  - use case for neuromorphic benchmarking
- novel area-, layer-, and population-specific connectivity map
- model relates connectivity to microscopic and macroscopic resting-state dynamics



- Schuecker, Schmidt, van Albada, Diesmann, Helias (2017) *PLoS Computational Biology 13(2): e1005179*
- Schmidt, Bakker, Shen, Bezgin, Diesmann, van Albada (2018) *PLoS Computational Biology 14(10): e1006359*
- Schmidt, Bakker, Hilgetag, Diesmann, van Albada (2018) *Brain Structure Function 223: 1409*

- Re-use of the model: forked 19 times on GitHub (14 external) (https://inm-6.github.io/multi-area-model/)
- Tutorial videos watched >1000 times

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THANK YOU!

& Sandra Diaz for slides

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