NEST ROADMAP

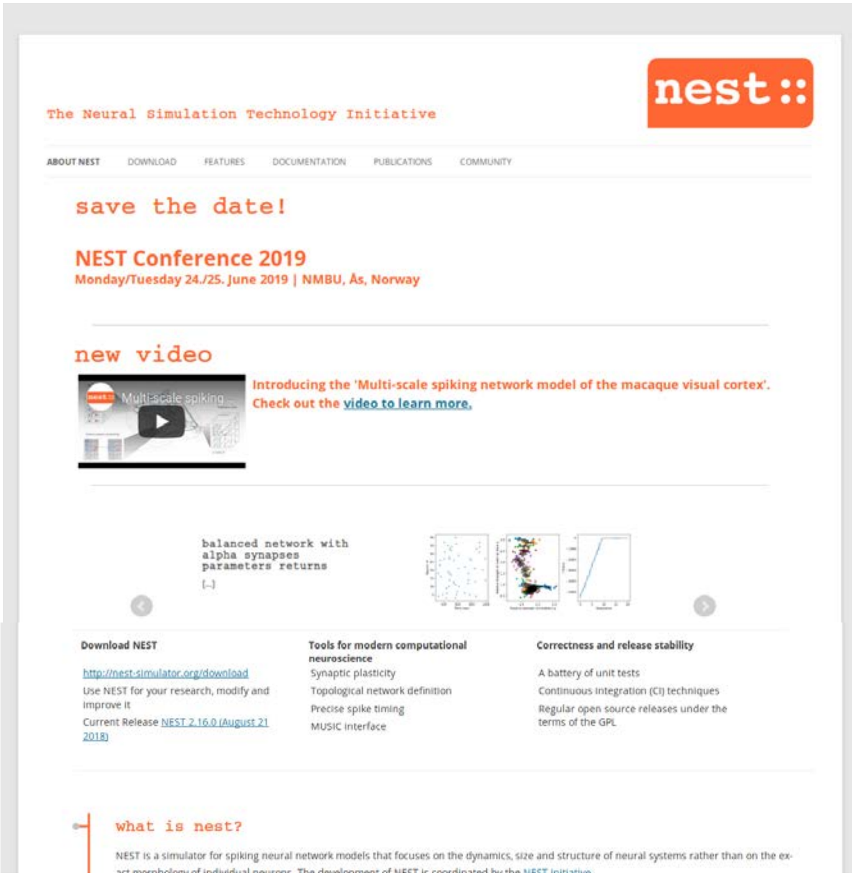
HBP CodeJam #9
Palermo, Italy

nest::

2018-11-26 I MARKUS DIESMANN
DENNIS **TERHORST**

THE NEST SIMULATOR

Open-Source Brain Simulations



- Brain-scale simulations of spiking neural networks
- International development since 1993
- Coordinated by public society
- GPL license
- Parallelization with OpenMP & MPI
- Model independent framework
- Python based user interface
- Extendable via MUSIC, NESTML,…
- One of the core simulators of the HBP

SP6 SP7

MANY MODELS

– ONE SIMULATION ENGINE

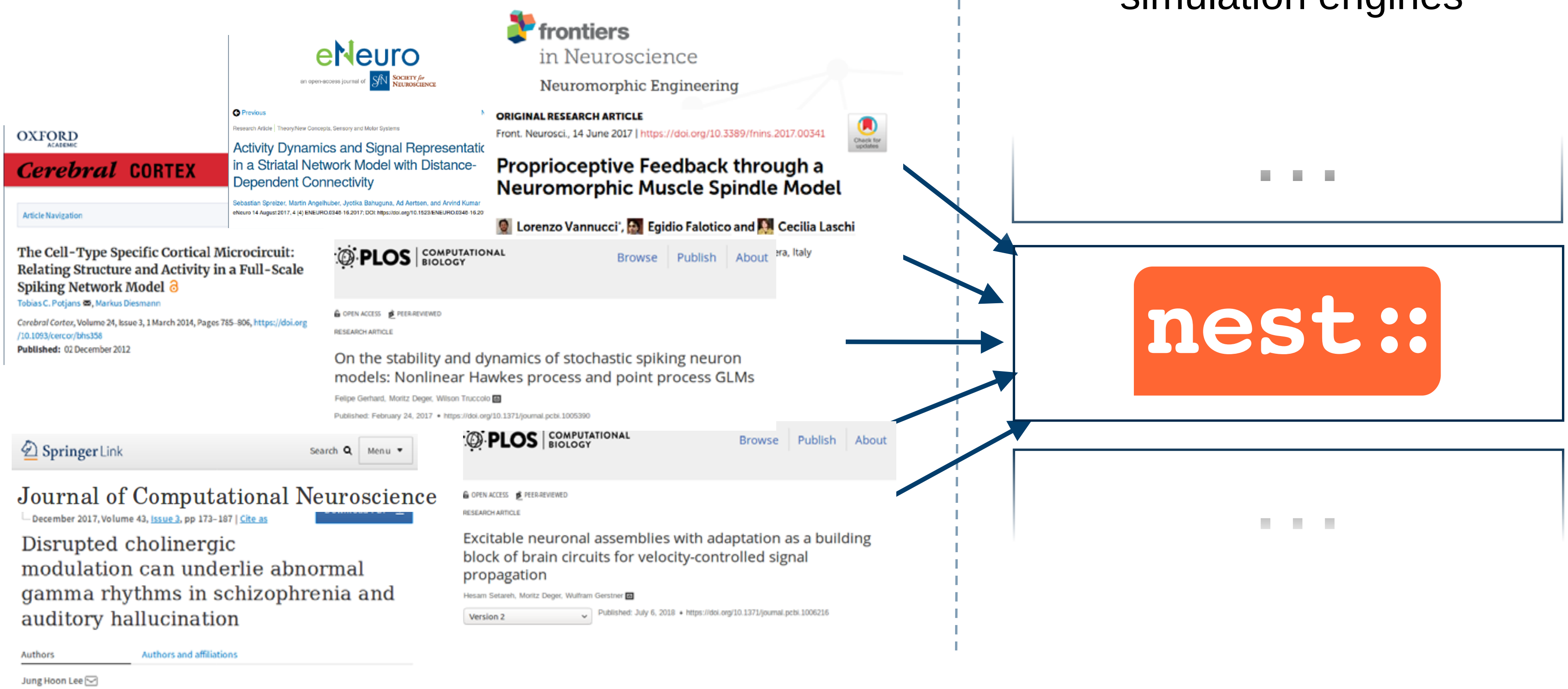
SP3 SP4 SP6

concrete mathematical model

SP7 SP6 SP9

JOINT PLATFORM

simulation engines



- enables use of validated and optimized simulation code

FOR SOME MODELS
– SEVERAL SIMULATION ENGINES

SP4

concrete mathematical model

Cerebral CORTEX

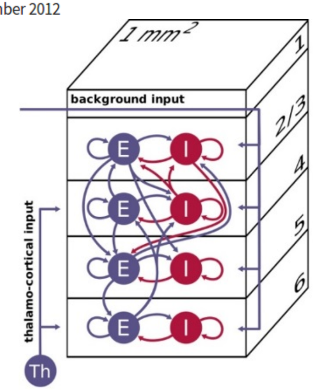
Article Navigation

The Cell-Type Specific Cortical Microcircuit: Relating Structure and Activity in a Full-Scale Spiking Network Model

Tobias C. Potjans, Markus Diesmann

Cerebral Cortex, Volume 24, Issue 3, 1 March 2014, Pages 785–806, https://doi.org/10.1093/cercor/bhs358

Published: 02 December 2012



PyNN

JOINT PLATFORM

simulation engines

nest::

SP7

SP6

NEURON

SP6

SpiNNaker

Biologically Inspired Massively Parallel Architectures

SP9

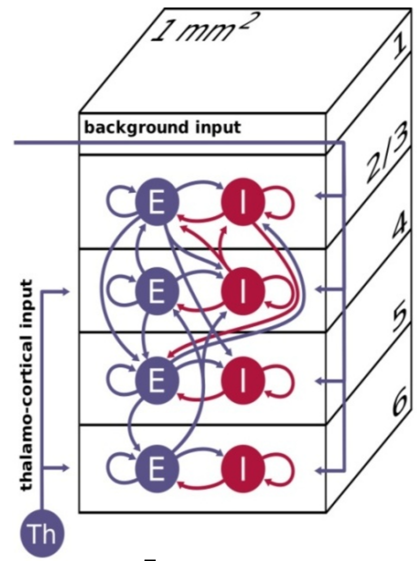
. . .

- enables cross-validation of results at highest level

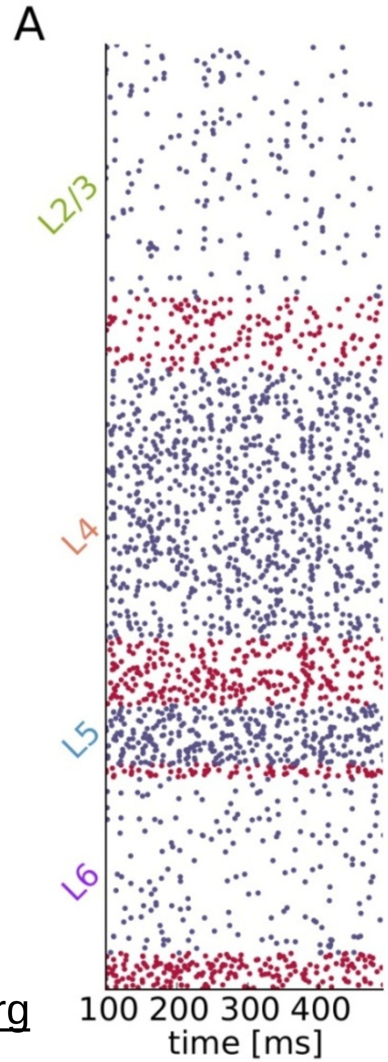
LOCAL CORTICAL MICROCIRCUIT

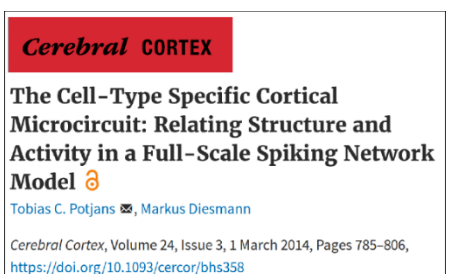
taking into account layer and neuron-type specific connectivity is sufficient to reproduce experimentally observed:

- asynchronous-irregular spiking of neurons
- higher spike rate of inhibitory neurons
- correct distribution of spike rates across layers
- integrates knowledge of more than 50 experimental papers



10^5 neurons
10^9 synapses





Cerebral CORTEX

The Cell-Type Specific Cortical Microcircuit: Relating Structure and Activity in a Full-Scale Spiking Network Model

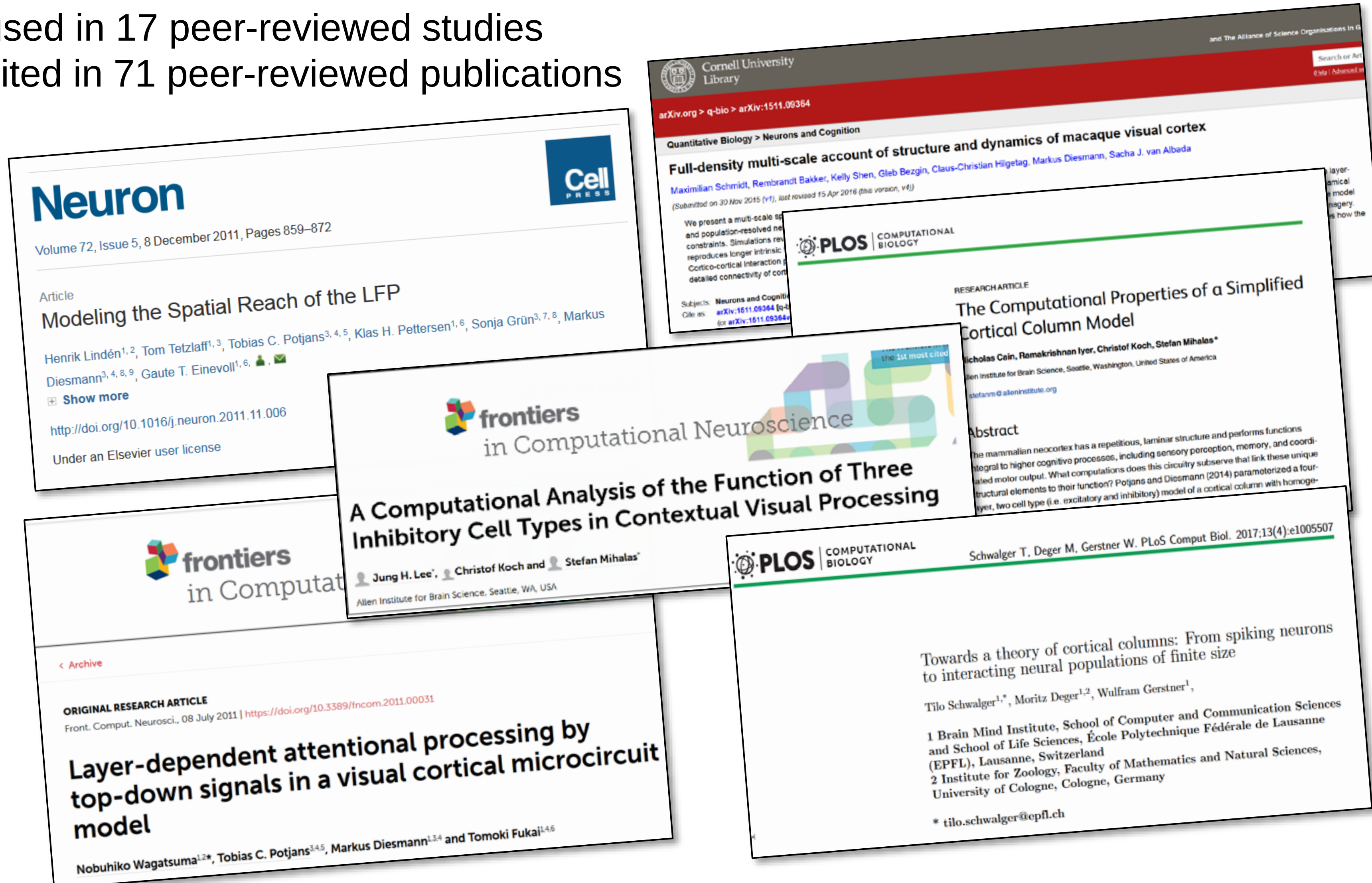
Tobias C. Potjans, Markus Diesmann

Cerebral Cortex, Volume 24, Issue 3, 1 March 2014, Pages 785–806,
https://doi.org/10.1093/cercor/bhs358

available at:
www.opensourcebrain.org

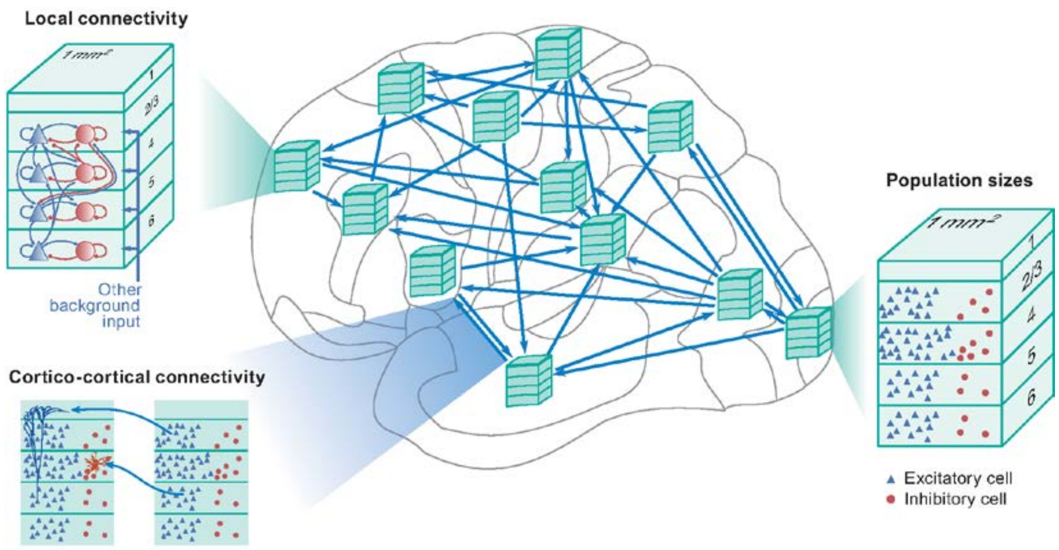
BUILDING BLOCK FOR FURTHER STUDIES

- used in 17 peer-reviewed studies
- cited in 71 peer-reviewed publications



MULTI-AREA MODEL OF MACAQUE VISUAL CORTEX

- rich anatomical data sets available (e.g CoCoMac)
- close to human
- 32 areas structured in layers comprising $8 \cdot 10^8$ neurons
- downscaled model with $4.1 \cdot 10^6$ neurons and $2.4 \cdot 10^{10}$ synapses

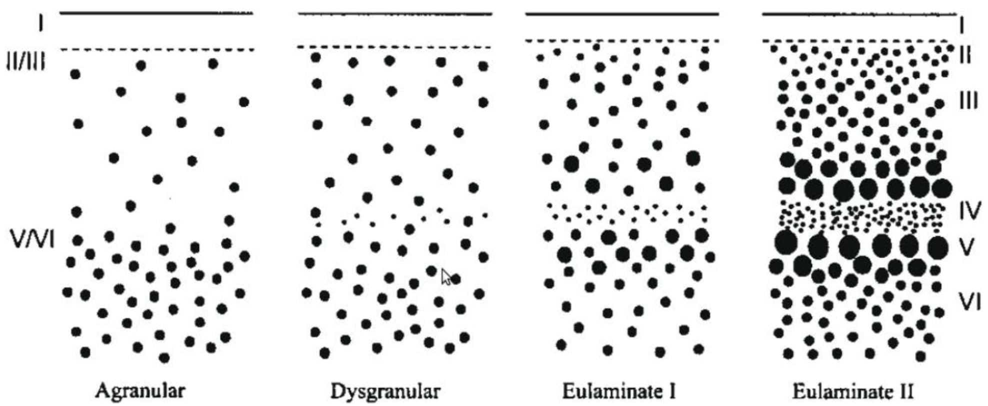


Co-funded by the European Union

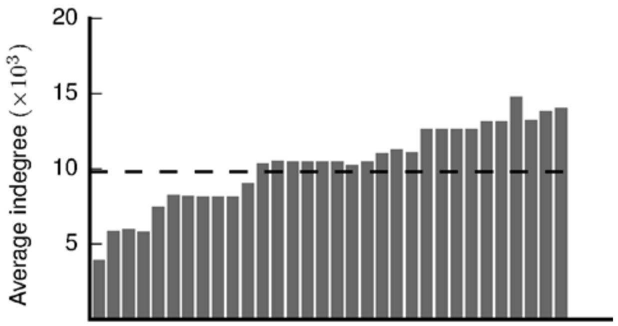
CORTICAL AREAS NOT ALL THE SAME

- architectural types
  - neuron densities and layer 4 thickness decrease up the hierarchy
  - total cortical thickness increases up the hierarchy

examples of architectural types



Dombrowski et al. (2001) *Cereb Cortex*

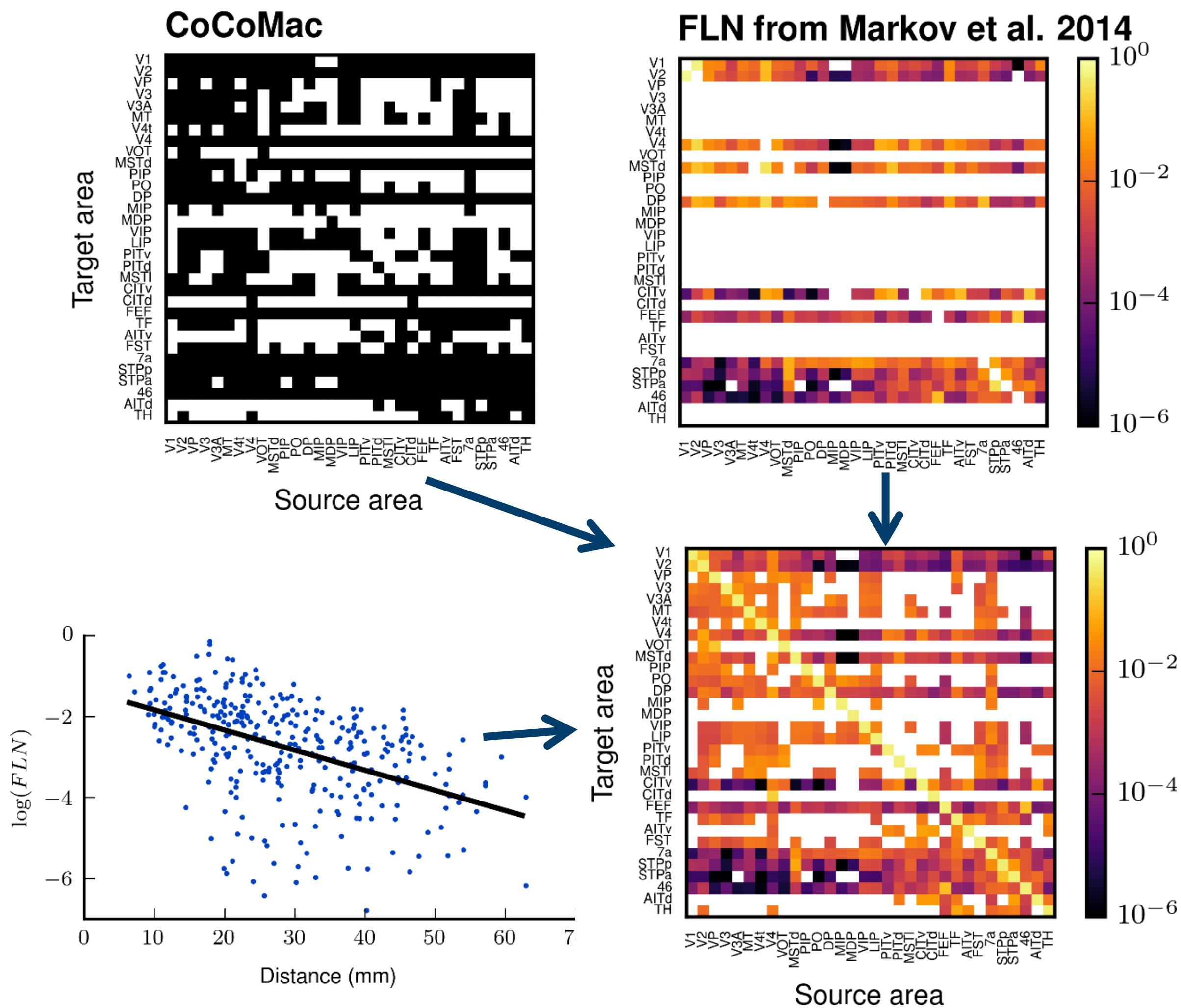


high neuron density → low neuron density

  - synapse density remains roughly constant
  - → higher areas receive more synapses per neuron

CONNECTIVITY MAP FROM TRACING DATA

- partly binary, partly quantitative data
- connection probability decays with distance also for inter-area connections
- use this decay to estimate missing data based on distance between areas
- roughly 2/3 of area pairs are connected
- more important: connection density, spanning ~6 orders of magnitude



Ercsey-Ravasz et al. (2013) *Neuron*

PUBLICATION OF MODEL STRUCTURE

Brain Struct Funct
DOI 10.1007/s00429-017-1554-4

ORIGINAL ARTICLE

Multi-scale account of the network structure of macaque visual cortex

Maximilian Schmidt[1] · Rembrandt Bakker[1,2] · Claus C. Hilgetag[3,4] · Markus Diesmann[1,5,6] · Sacha J. van Albada[1]

Received: 13 February 2017 / Accepted: 24 October 2017

Published online: 16 November 2017

Table 1 Overview of the data sources used

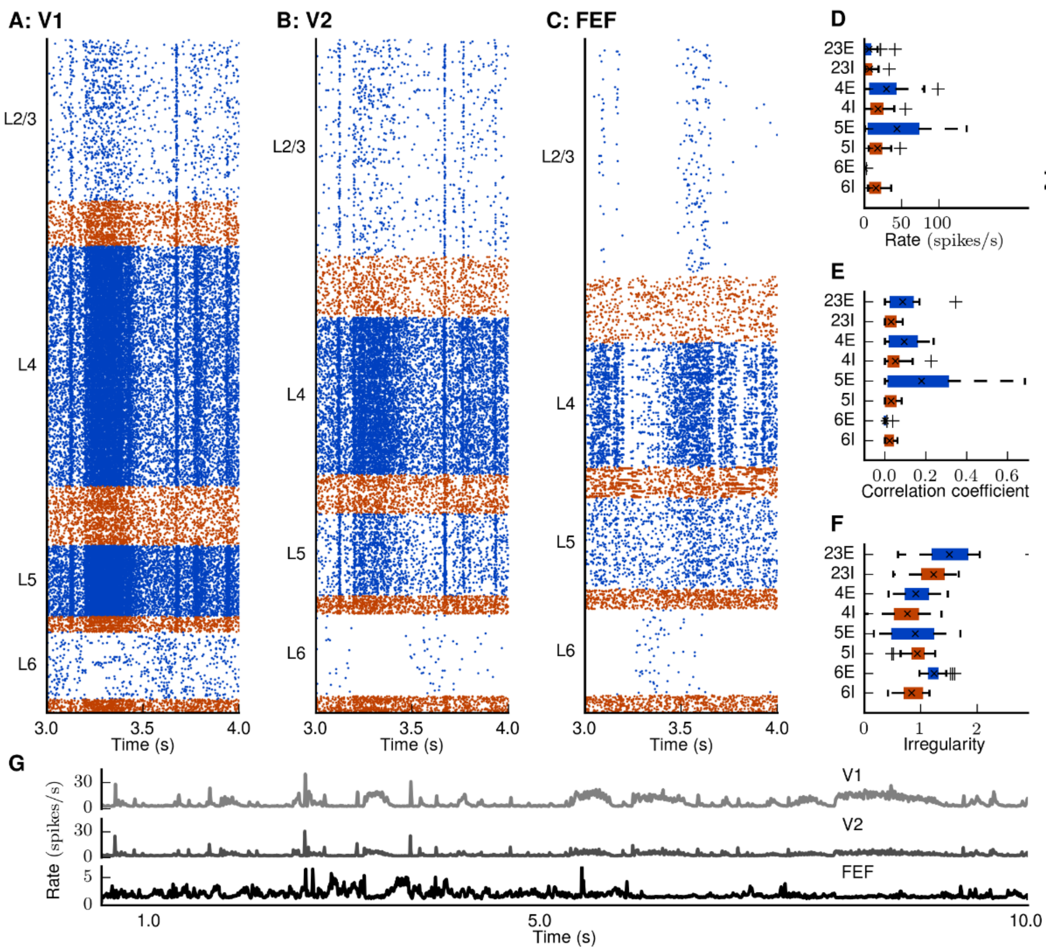
Data modality	Sources
Layer-resolved neuronal volume densities	Personal communication, H. Barbas a
Architectural types	Hilgetag et al. (2016, Table 4)
Total cortical thicknesses	Hilgetag et al. (2016, Table 4)
Laminar thicknesses, estimated from micrographs	O'Kusky and Colonnier (1982), Bous and Goldman-Rakic (1991), Rockla Pandya (1999), Angelucci et al. (20 (2003), Rozzi et al. (2006), Eggan a
Ratios of excitatory to inhibitory cell counts	Binzegger et al. (2004)
Surface areas	Computed with Caret (Van Essen et al on the F99 cortical surface (Van Es
Local microcircuit scheme	Potjans and Diesmann (2014, Table 5 (2004), Thomson and Lamy (2007)
Intrinsic fractions of labeled neurons (FLN_i)	Markov et al. (2011)
Average number of synapses per receiving neuron	Cragg (1967), O'Kusky and Colonnie

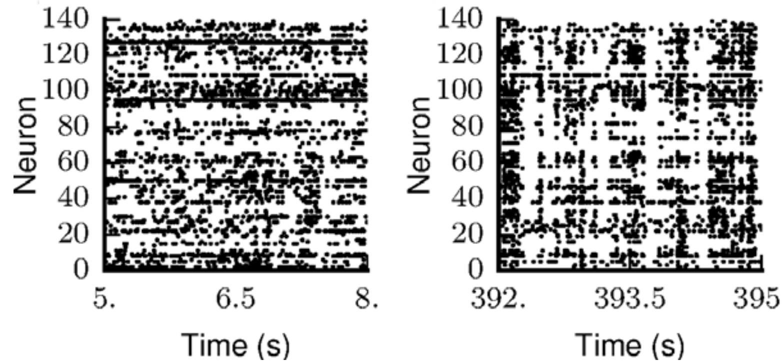
manuscript just describing model construction
https://doi.org/10.1007/s00429-017-1554-4

SP4

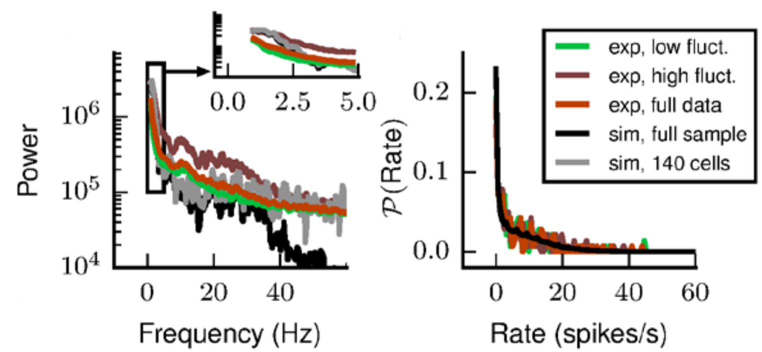
MULTI-AREA MODEL: DYNAMICAL RESULTS

- stable resting state with heterogeneous laminar rate patterns and irregular firing
- cortico-cortical interactions trigger increased spike bursts in higher visual areas





V1 data of Chu et al. (2014)

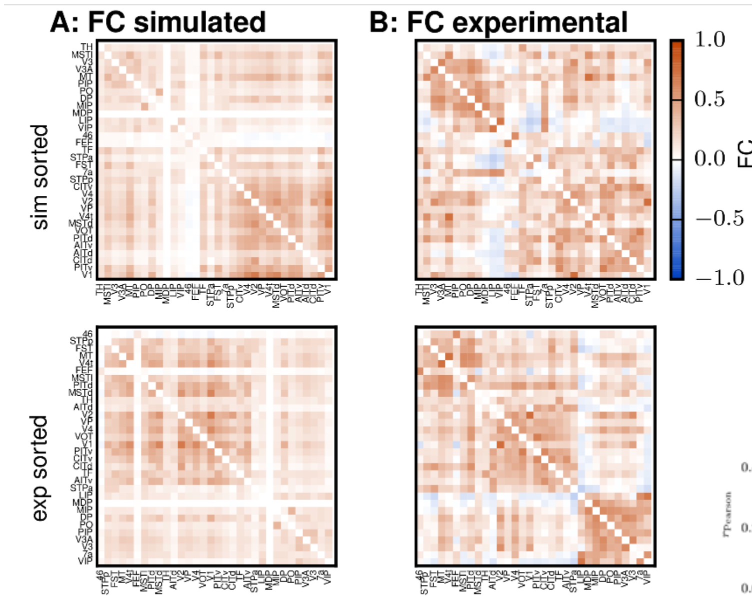


comparison between experimental and simulated data

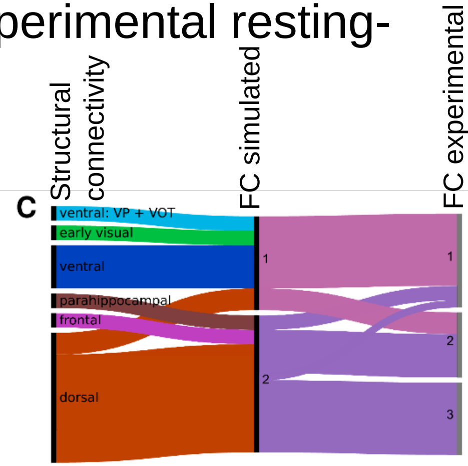
SP5

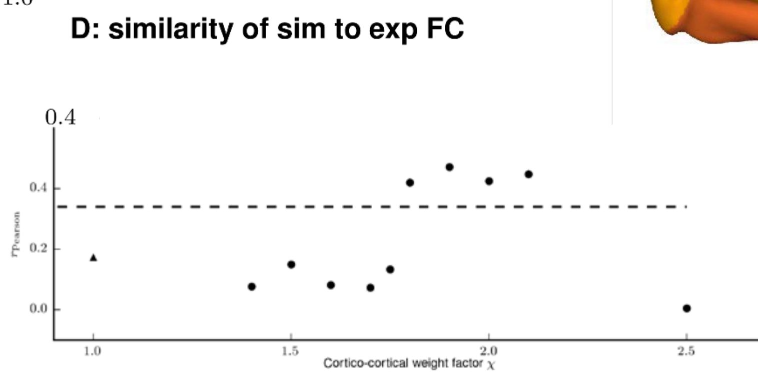
MULTI-AREA MODEL: DYNAMICAL RESULTS

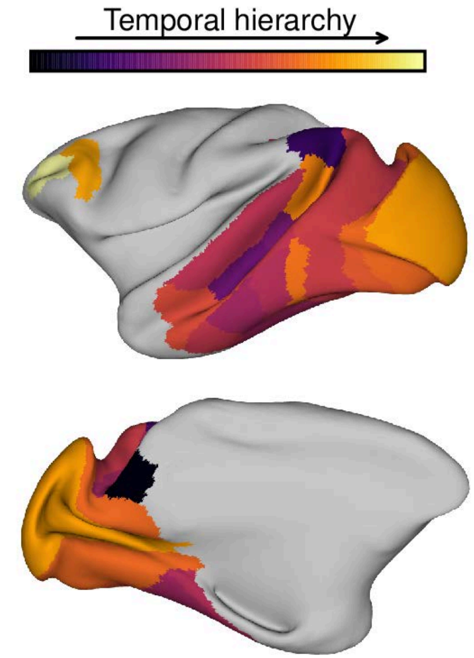
- activity propagates in feedback direction
- inter-area interactions mimic experimental resting-state fMRI



FC sorted according to Louvain clustering (Blondel et al. 2008)

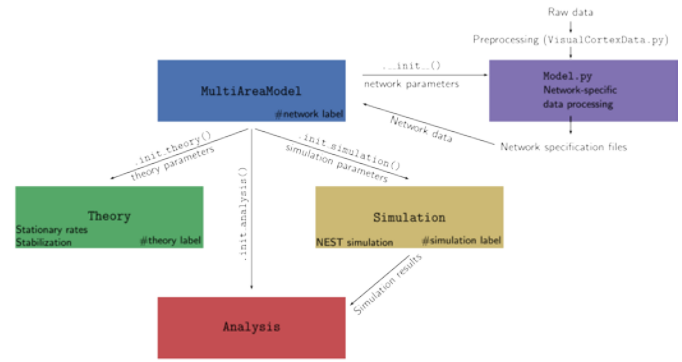






Schmidt M, Bakker R, Shen K, Bezgin G, Hilgetag CC, Diesmann M, van Albada SJ (2016) DOI: https://doi.org/10.1371/journal.pcbi.1006359

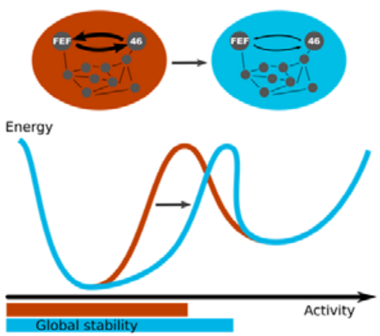
REPRODUCING FIGURES



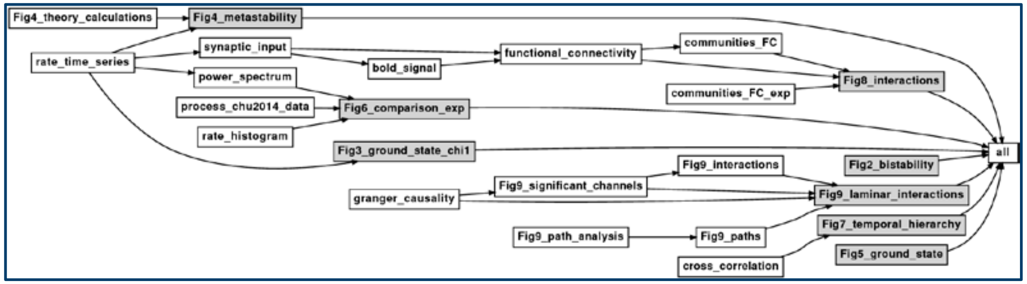
README.md

Figures of Schuecker J, Schmidt M, van Albada SJ, Diesmann M & Helias M (2017) Fundamental Activity Constraints Lead to Specific Interpretations of the Connectome.

This folder contains the scripts to reproduce all figures of Schuecker J, Schmidt M, van Albada SJ, Diesmann M & Helias M (2017) Fundamental Activity Constraints Lead to Specific Interpretations of the Connectome. PLOS Computational Biology, 13(2). https://doi.org/10.1371/journal.pcbi.1005179



Snakemake*-based workflow to reproduce figures of Schmidt et al. (2018) *PLOS CB*



additional README with specific instructions for each publication

code snippet from the above Snakemake file

```
rule Fig4_metastability:
    input:
        expand(os.path.join(DATA_DIR, '{simulation}', 'Analysis', 'rate_time_series_full', 'rate_time_series_full_V1.npy'),
               simulation=SIM_LABELS['Fig4']),
        expand('Fig4_theory_data/results_{cc_weights_factor}.npy',
               cc_weights_factor=[1.0, 1.8, 1.9, 2., 2.1, 2.5])
    output:
        'Fig4_metastability.eps'
    shell:
        'python3 Fig4_metastability.py'
```

*Köster J, Rahmann S (2012) *Bioinformatics*

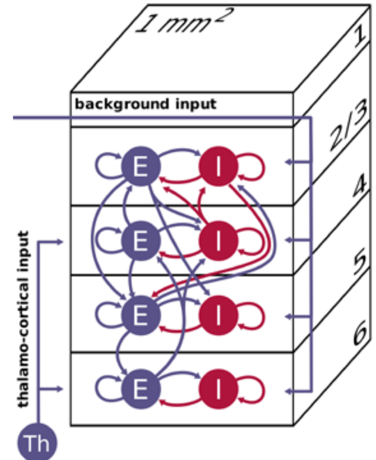
BENCHMARKING OF NEUROMORPHIC SYSTEMS

ORIGINAL RESEARCH ARTICLE
Front. Neurosci., 23 May 2018 | https://doi.org/10.3389/fnins.2018.00291

Performance Comparison of the Digital Neuromorphic Hardware SpiNNaker and the Neural Network Simulation Software NEST for a Full-Scale Cortical Microcircuit Model

Sacha J. van Albada[1*], Andrew G. Rowley[2], Johanna Senk[1], Michael Hopkins[2], Maximilian Schmidt[1,3], Alan B. Stokes[2], David R. Lester[2], Markus Diesmann[1,4,5] and Steve B. Furber[2]

Human Brain Project   SP7   SP9



[Potjans & Diesmann (2014) Cerebral Cortex]

nest :: simulated()

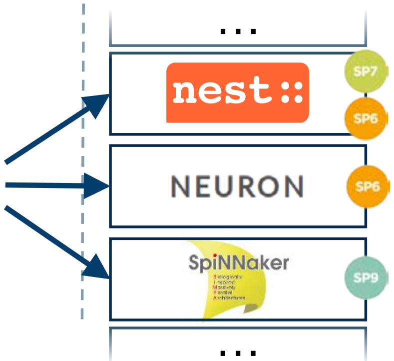
PyNN

- 4 year project
- started in EU BrainScaleS
- close collaboration with Manchester
- aim: full-density model on SpiNNaker

[2018-11-26]

WORK TOWARDS JOINT PLATFORM

- Make models and data reusable
- Work towards interoperable infrastructure elements
- Enable validation between elements



NEST

- Use MAM as next test case for on SpiNNaker
- Use MAM as test case for JP
- Interfaces: NESTIO, NESTML
- Develop common concepts for documentation

USER-LEVEL DOCUMENTATION

EITN Workshop

- Building a common concept for user-level documentation
- Discussed current status, issues and used technologies

(hosted by WP4.2)

Co-funded by the European Union

NEST CONFERENCE 2019
SAVE THE DATE: 24-25 JUNE 2019

The NEST Conference 2019 will be held Monday/Tuesday

24./25. June 2019
at NMBU, Ås, Norway

Followed by a Hackathon during the rest of the week.

Thanks!

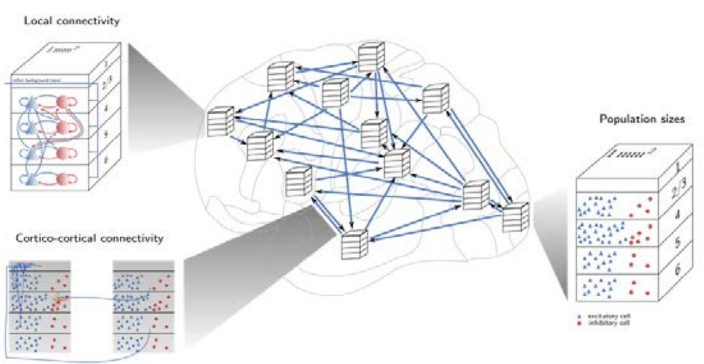
DOCUMENTATION

https://inm-6.github.io/multi-area-model

README.md

Multi-scale spiking network model of macaque visual cortex

python 3.6 | nest | License CC BY-NC-SA 4.0



README provides all technical information needed to instantiate and run the model

instructions for running a simulation

Running a simulation

A simple simulation can be run in the following way:

1. Define custom parameters custom_params = ... custom_simulation_params = ...
2. Instantiate the model class together with a simulation class instance.

```
M = MultiAreaModel(custom_params, simulation=True, sim_spec=custom_simulation_params)
```

3. Start the simulation.

```
M.simulation.simulate()
```

software requirements

Requirements

python_dicthash (https://github.com/INM-6/python-dicthash), correlation_toolbox (https://github.com/INM-6/correlation-toolbox), pandas, numpy, nested_dict, matplotlib (2.1.2), scipy, NEST 2.14.0

Optional: seaborn, Sumatra

To install the required packages with pip, execute:

```
pip install -r requirements.txt
```

Note that NEST needs to be installed separately, see http://www.nest-simulator.org/installation/.