

NEST ROADMAP

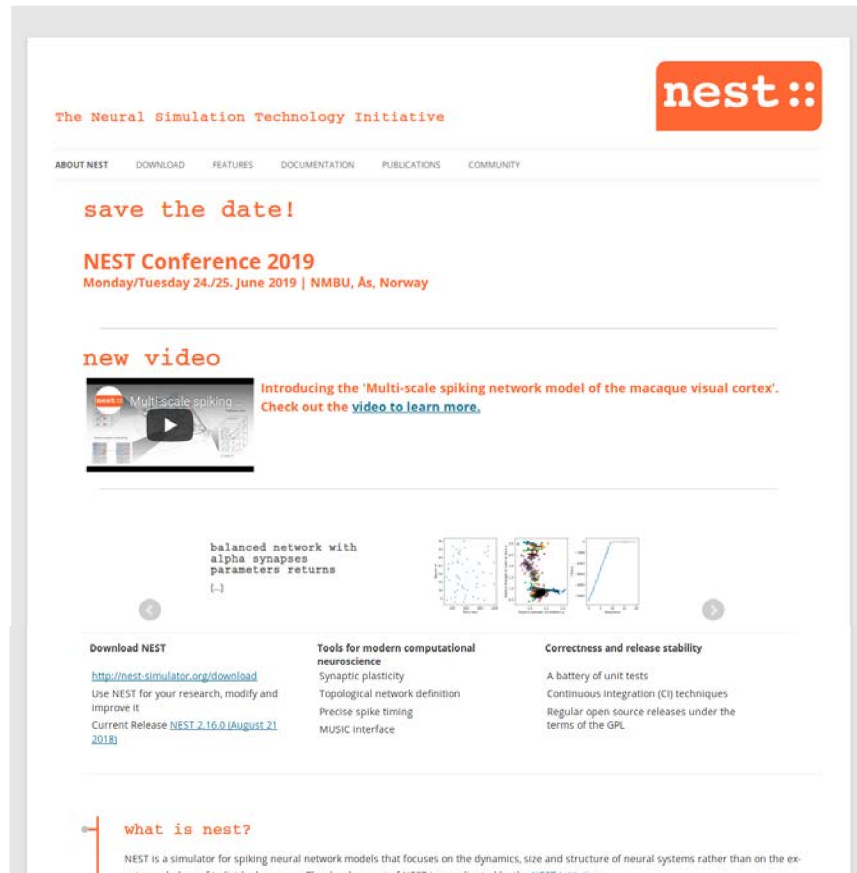
HBP CodeJam #9
Palermo, Italy

nest ::

2018-11-26 | 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

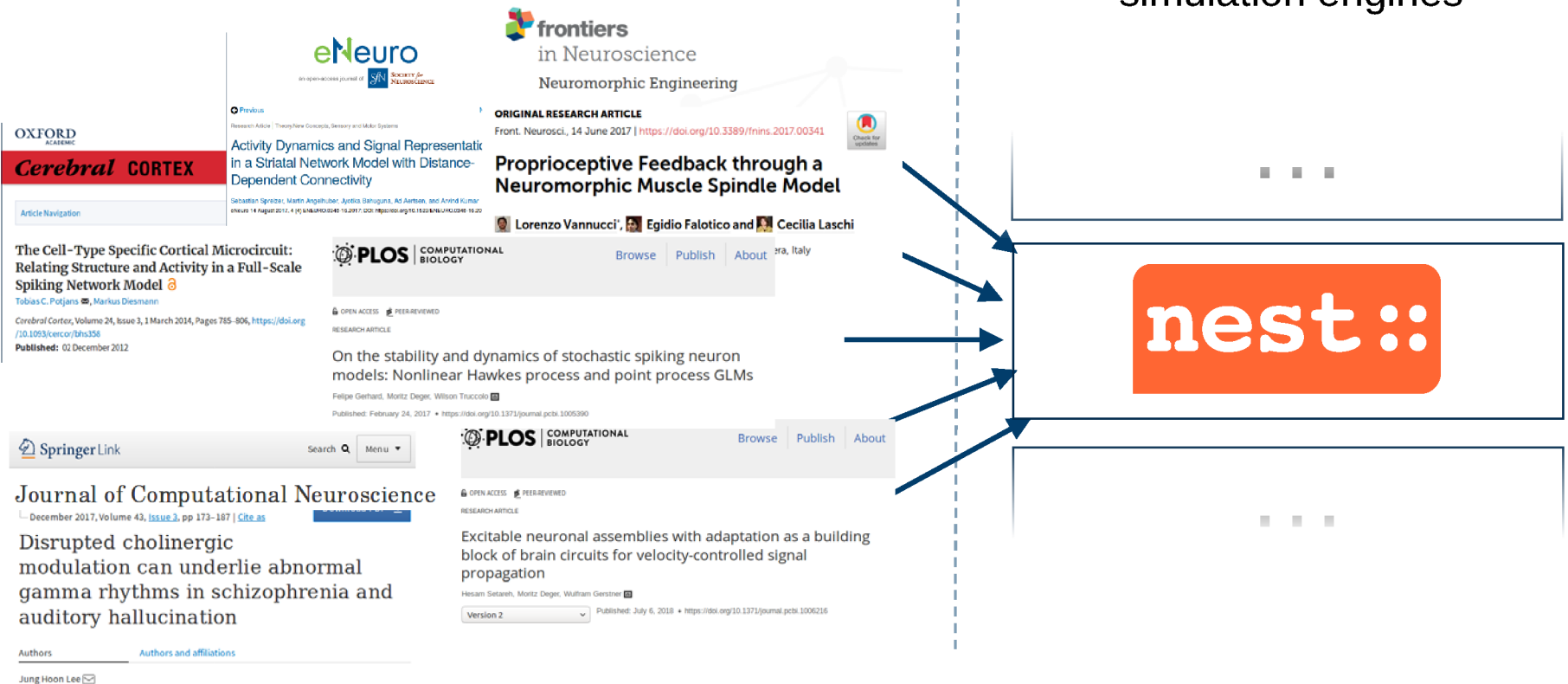
concrete mathematical model

SP7

SP6

SP9

JOINT PLATFORM
simulation engines



- enables use of validated and optimized simulation code



Human Brain Project



26 November 2018
Slide 3

Co-funded by
the European Union

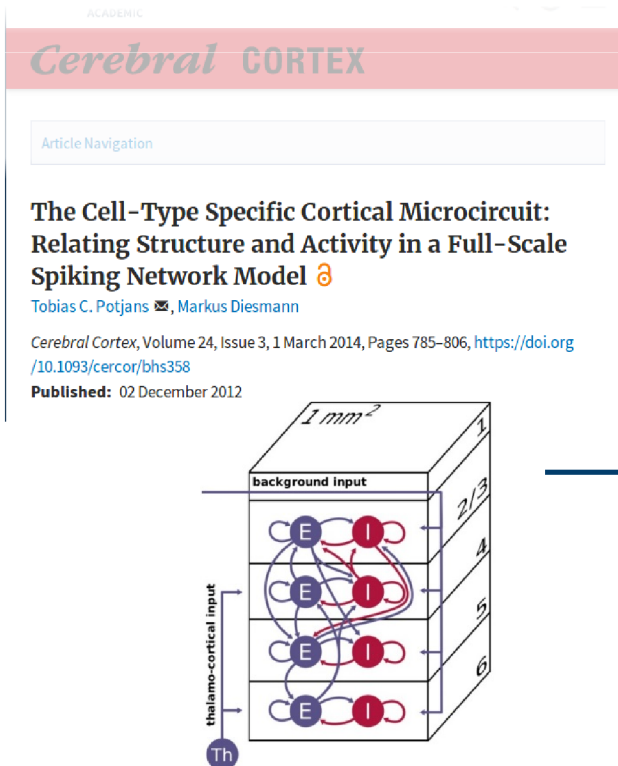


FOR SOME MODELS

– SEVERAL SIMULATION ENGINES

SP4

concrete mathematical model



JOINT PLATFORM
simulation engines

nest ::

SP7

SP6

NEURON

SP6

SpiNNaker

Biologically
Inspired
Massively
Parallel
Architectures

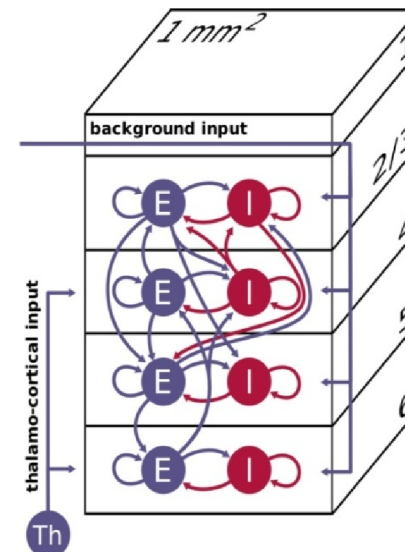
SP9

- enables cross-validation of results at highest level

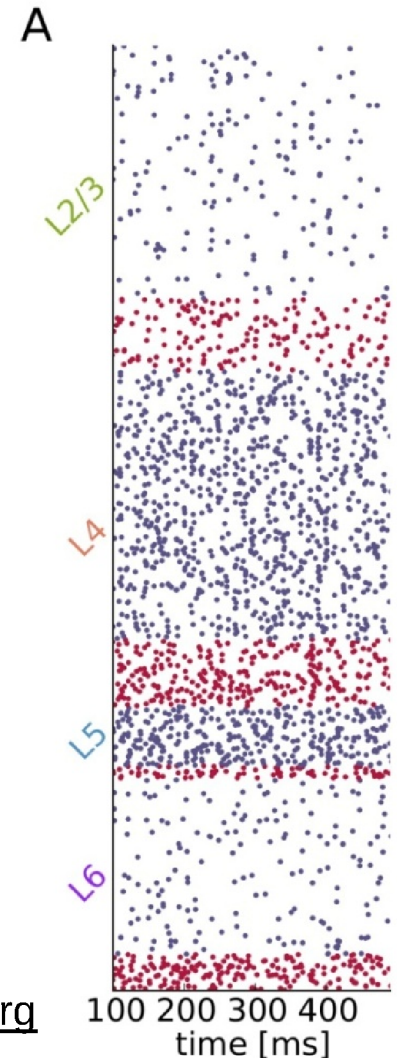
LOCAL CORTICAL MICROCIRCUIT

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



10⁵ neurons
10⁹ 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

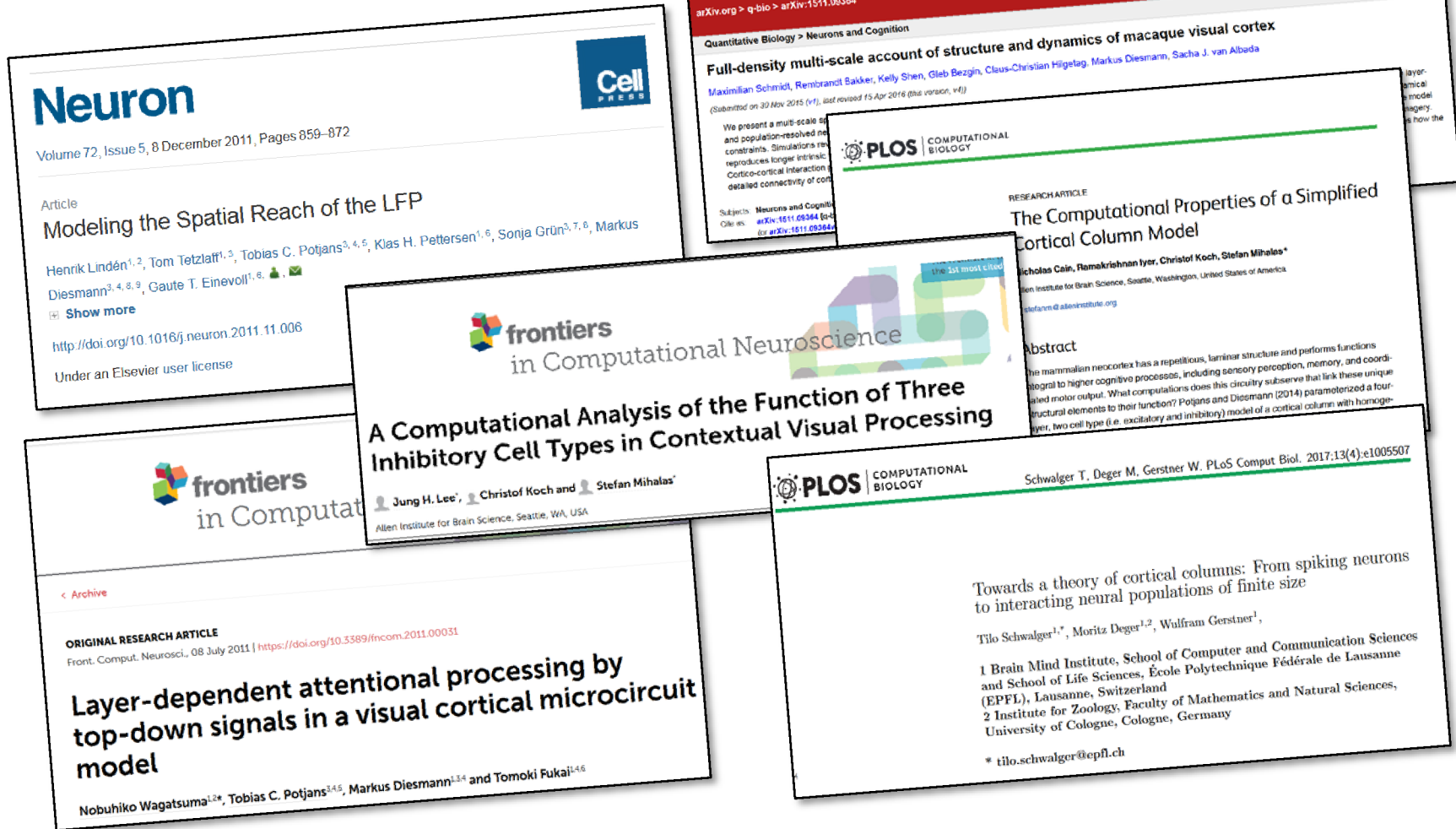
Cerebral Cortex, Volume 24, Issue 3, 1 March 2014, Pages 785–806,
<https://doi.org/10.1093/cercor/bhs358>



available at:
www.opensourcebrain.org

BUILDING BLOCK FOR FURTHER STUDIES

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

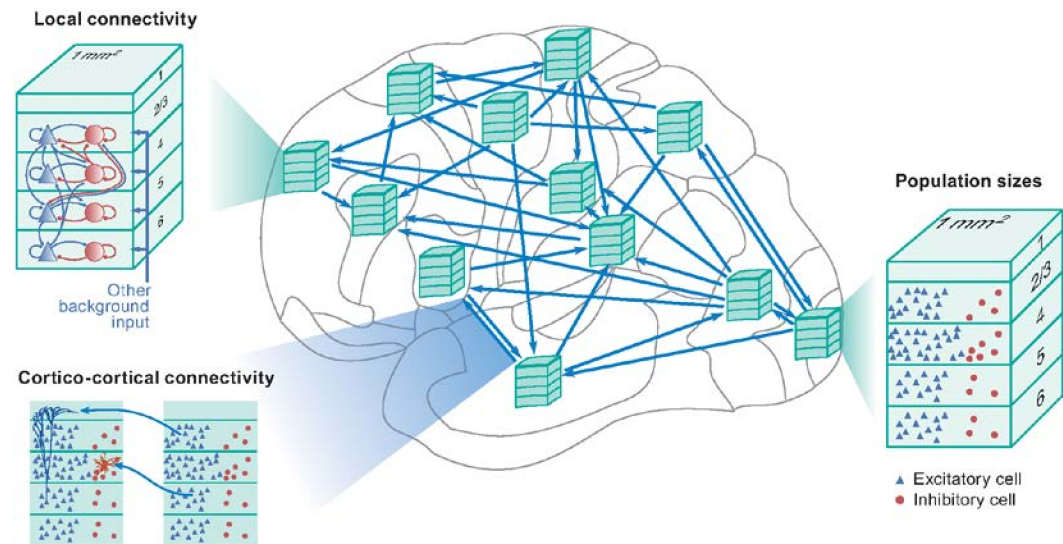


MULTI-AREA MODEL OF MACAQUE VISUAL CORTEX

- 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

CDP
4

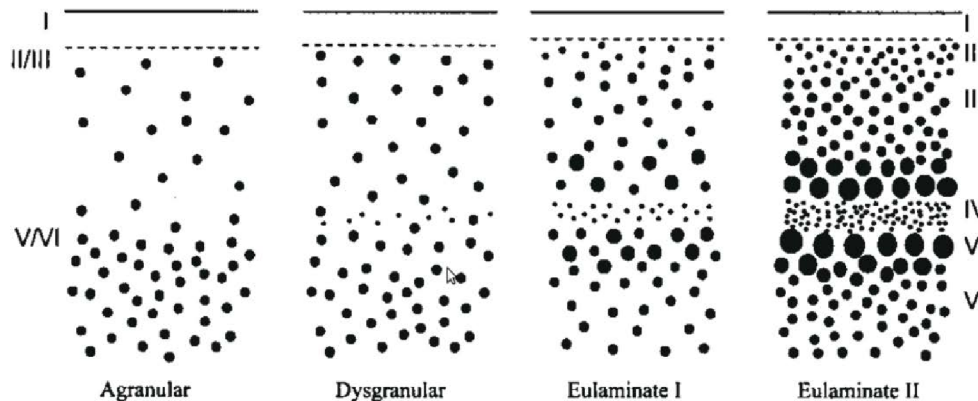
SP4



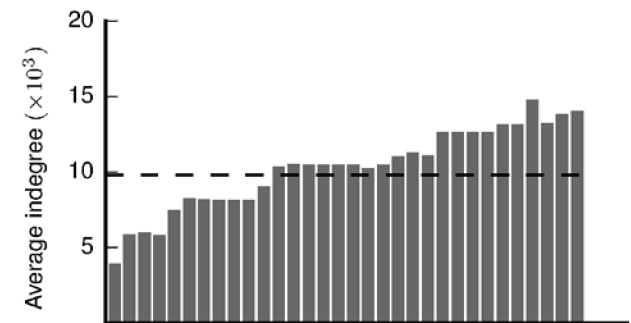
CORTICAL AREAS NOT ALL THE SAME

- 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*

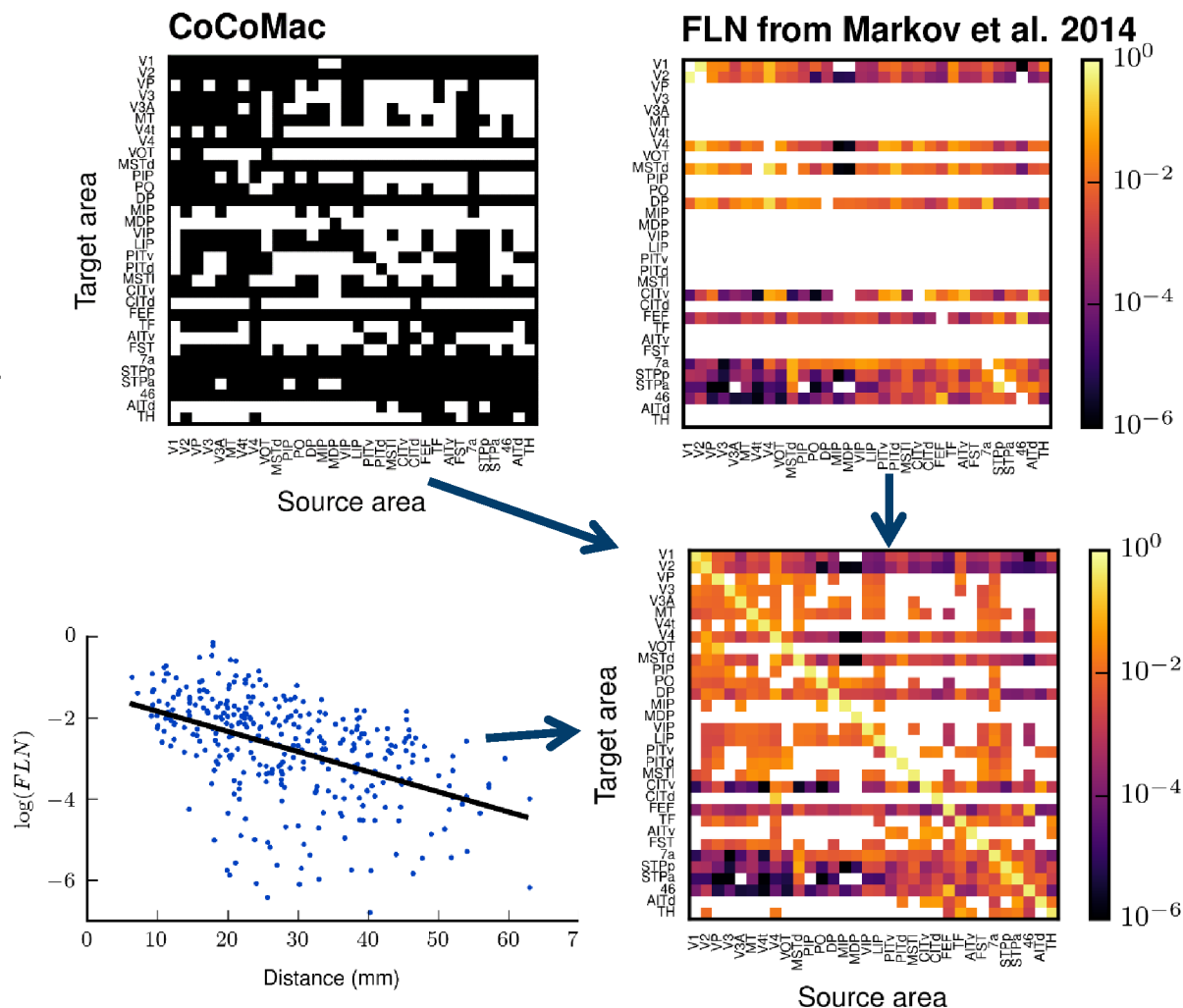


high neuron density → low neuron density

- 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 Schmidt¹ · Rembrandt Bakker^{1,2} · Claus C. Hilgetag^{3,4} · Markus Diesmann^{1,5,6} · Sacha J. van Albada¹

Received: 13 February 2017 / Accepted: 24 October 2017
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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 and Hilgetag et al. (2016, Table 4)
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), Bousquet and Goldman-Rakic (1991), Rockland and Pandya (1999), Angelucci et al. (2003), Rozzi et al. (2006), Eggan et al. (2009), Binzegger et al. (2004)
Ratios of excitatory to inhibitory cell counts	Binzegger et al. (2004)
Surface areas	Computed with Caret (Van Essen et al. 2001) on the F99 cortical surface (Van Essen et al. 2001)
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 Colonnier (1982)

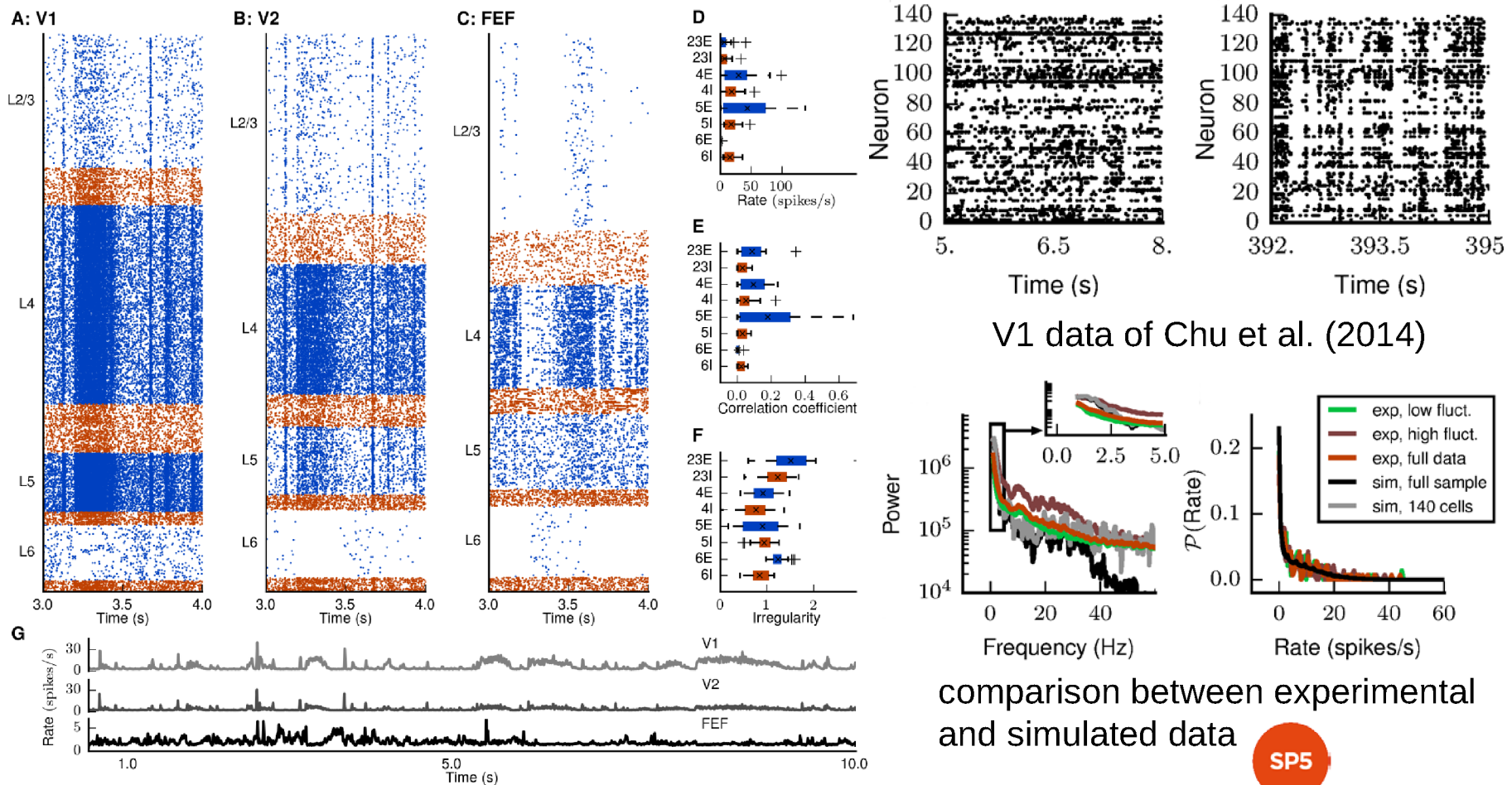


manuscript just describing model construction
<https://doi.org/10.1007/s00429-017-1554-4>

SP4

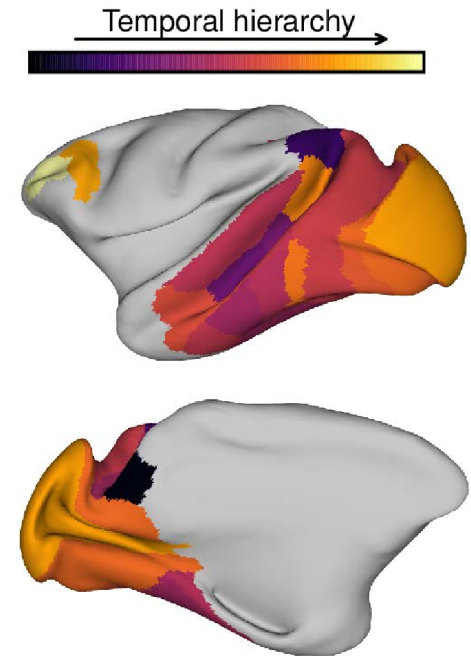
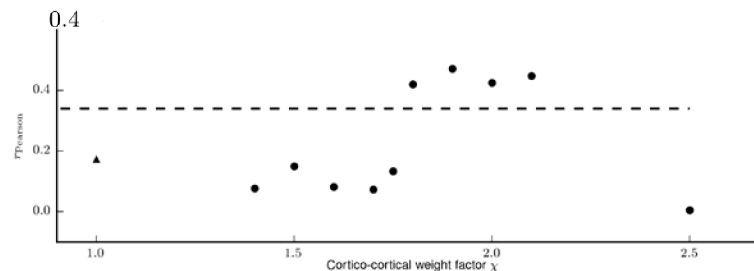
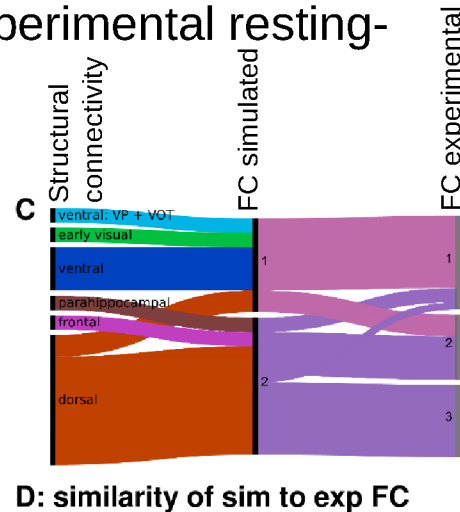
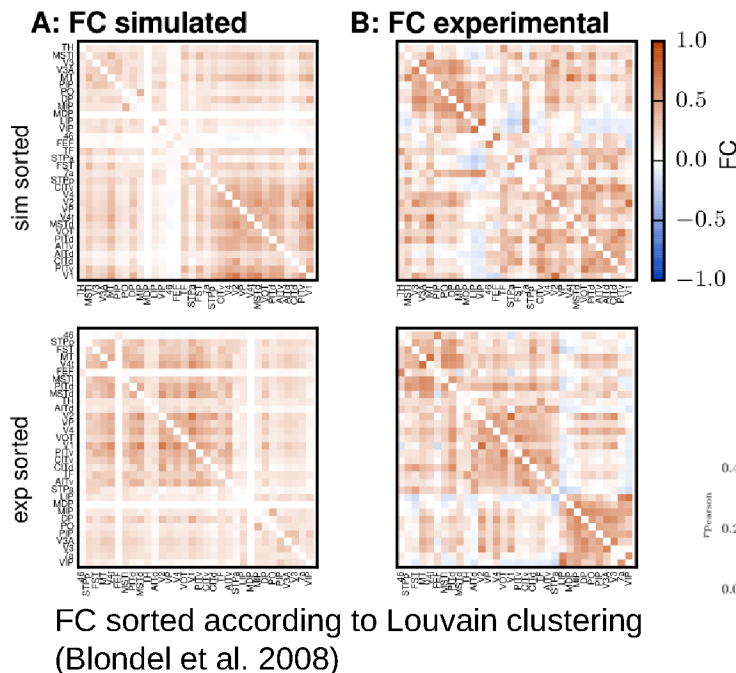
MULTI-AREA MODEL: DYNAMICAL RESULTS

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



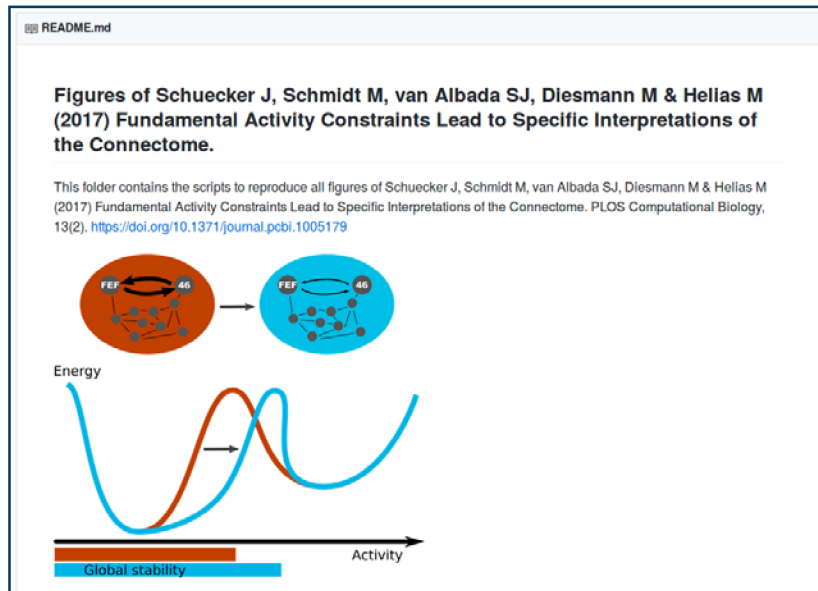
MULTI-AREA MODEL: DYNAMICAL RESULTS

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

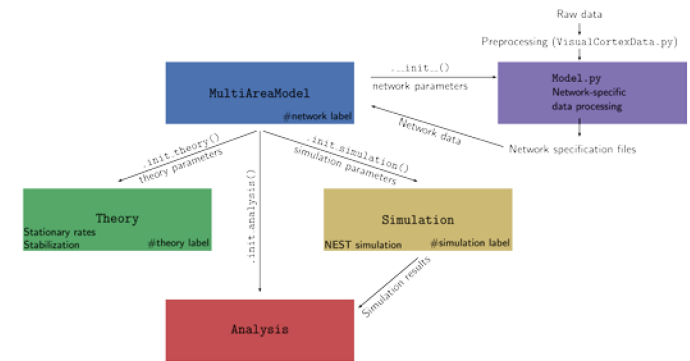


Schmidt M, Bakker R, Shen K, Bezgin G, Hilgetag CC, Diesmann M, van Albada SJ (2016) DOI: <https://doi.org/10.1371/journal.pcbi.1006359>

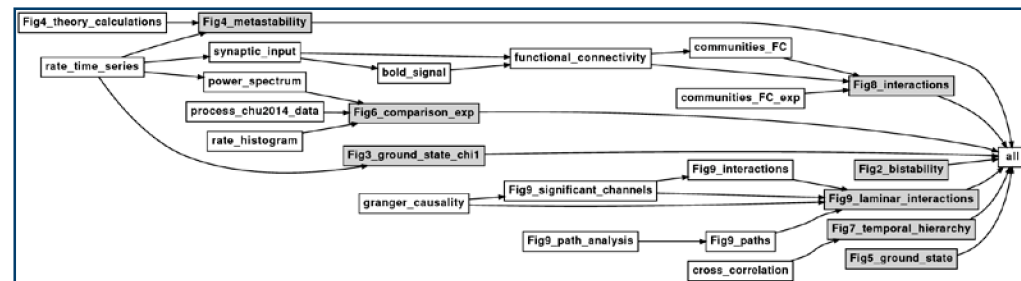
REPRODUCING FIGURES



additional README with specific instructions for each publication



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



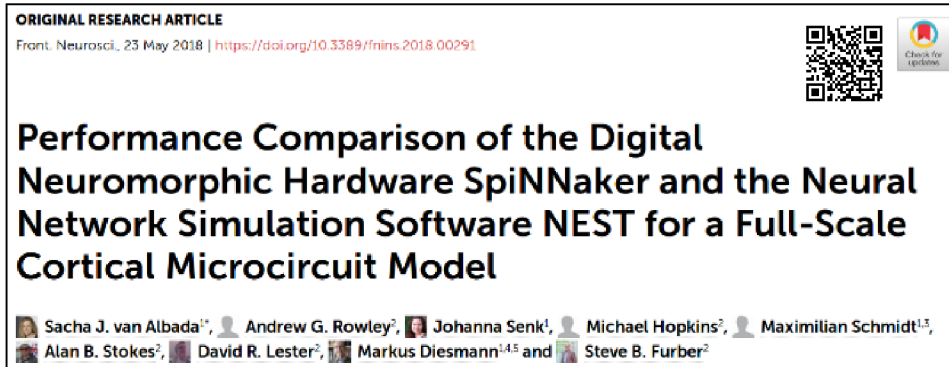
code snippet from the above Snakemake file

```

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

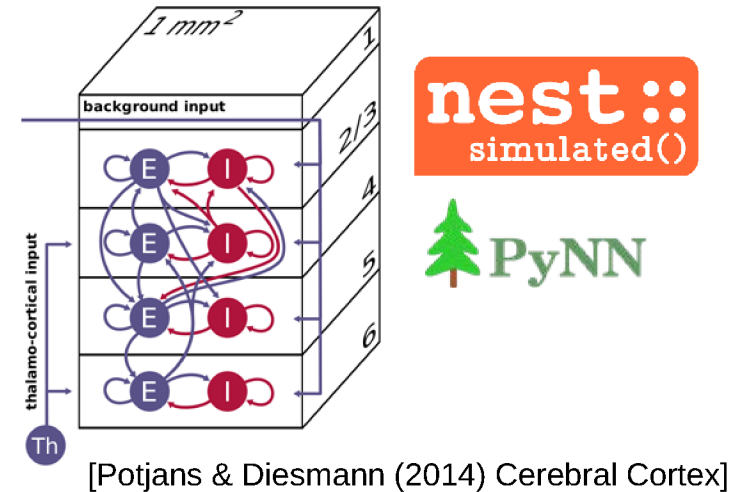


Human Brain Project

SP7

SP9

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



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16,002

TOTAL VIEWS



[2018-11-26]



Human Brain Project



26 November 2018
Slide 14

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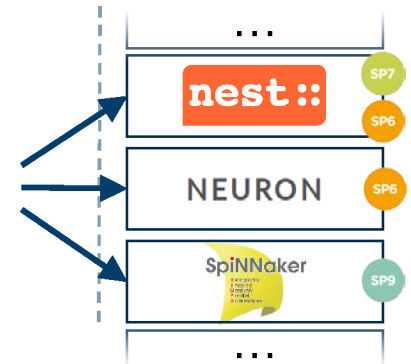


WORK TOWARDS JOINT PLATFORM

- 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)

SP4



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

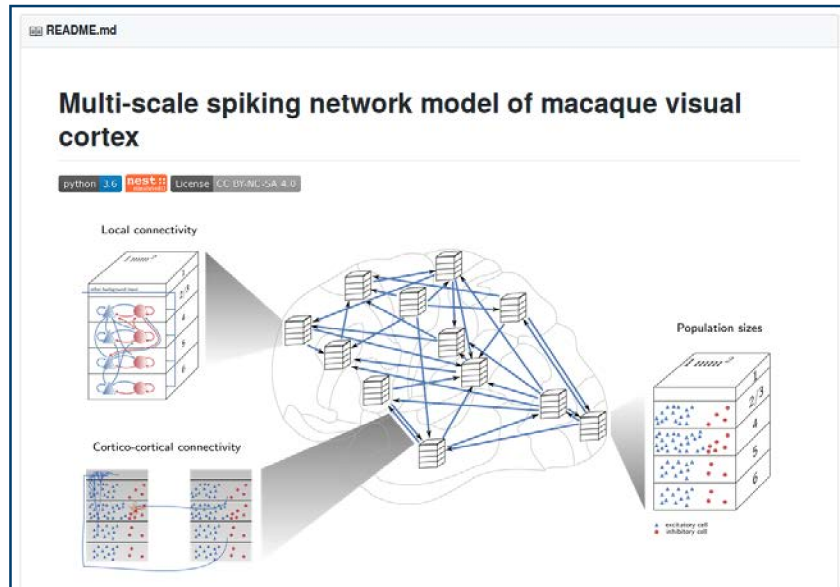
Followed by a Hackathon
during the rest of the week.



Thanks!

DOCUMENTATION

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



README 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/>.