EBRAINS

Spiking Simulation Models and Tools

A brief overview over the HBP/EBRAINS tools around spiking neural network simulations with point-neuron resolution

by many contributors and Dennis Terhorst

SfN Global Connectome

2021-01-12

Network Level Spiking Simulations
EBRAINS Context

EBRAINS

neuron models

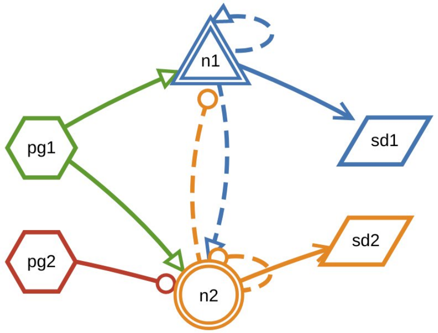
nest::ml

$$C_m \frac{dV}{dt} = -g_L(V - E_L) + g_L \Delta_T \exp\left(\frac{V - V_{th}}{\Delta_T}\right) - g_e(t)(V - E_e)$$
$$-g_i(t)(V - E_i) - w + I_e$$

synapse models

PyNN

connectivity



simulation

SpiNNaker — Biologically Inspired Massively Parallel Architectures

BrainScaleS

nest::

analysis & validation

elephant — ELECTROPHYSIOLOGY ANALYSIS TOOLKIT

NESTML is a **domain-specific modeling language** for the dynamical simulation of

- **point neurons** (spiking and rate-based), as well as
- **synapses** and
- **synaptic plasticity rules** (in alpha version).

- Low on boilerplate; concise yet expressive syntax
- Direct language support for dynamical equations
- Imperative programming style specification of event
- handling and generation

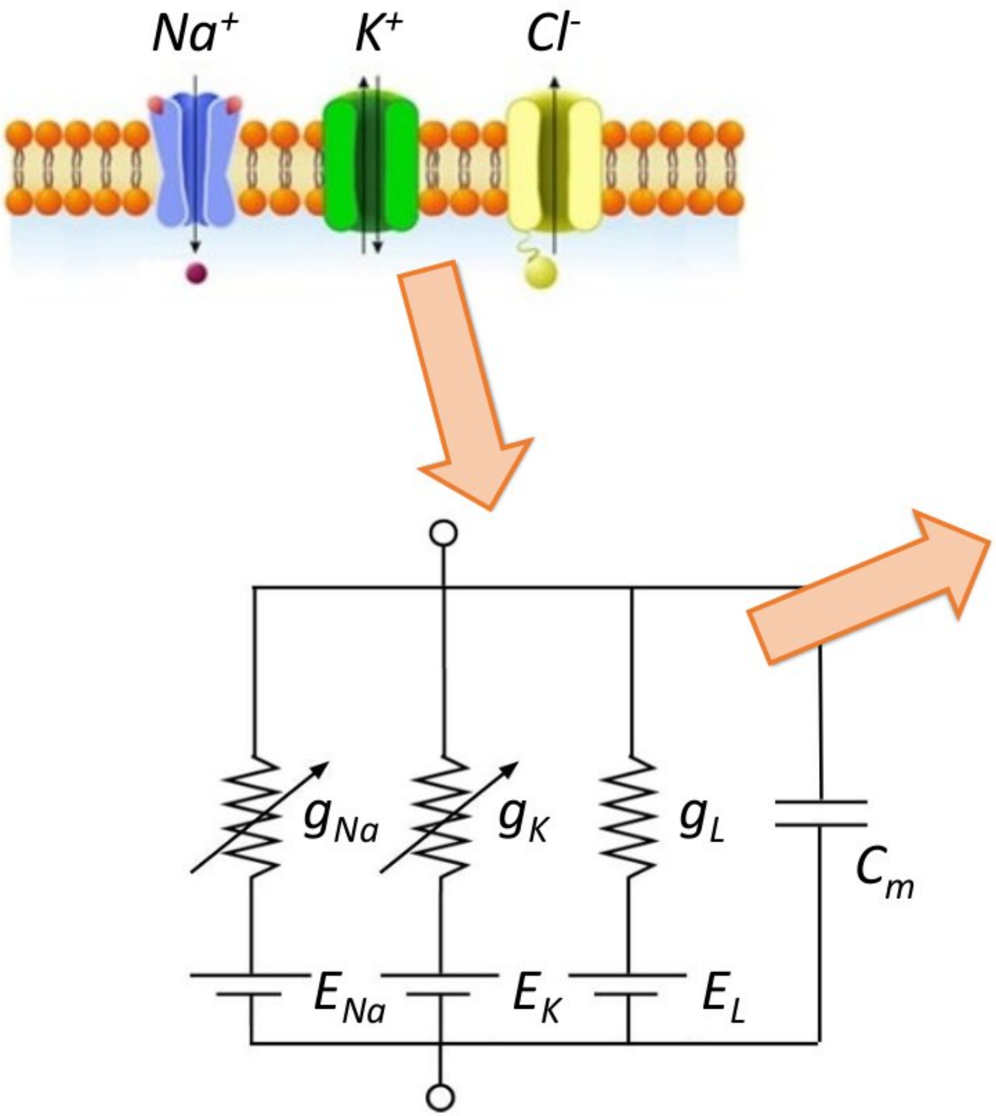


Image credit: Designua / Shutterstock

```
neuron hodgkin_huxley:
  state:
    V_m mV = -65 mV
    Act_m, Act_n, Inact_h ...
  end

  equations:
    shape syn_psc_kernel = exp(-t / tau_syn)
    function I_Na pA = g_Na * Act_m**3 * Inact_h * (V_m - E_Na)
    function I_K pA = ...
    function I_L pA = g_L * (V_m - E_L)
    V_m' = -(I_Na + I_K + I_L) / C_m
           + convolve(syn_psc_kernel, spikes)
    Act_n' = (alpha_n * (1 - Act_n) - beta_n * Act_n) / ms
    Act_m' = ...
    Inact_h' = ...
  end

  parameters:
    C_m pF = 250 pF
    V_threshold mV = 40 mV
    ...
  end

  update:
    integrate_odes()
    if V_m >= V_threshold:
      emit_spike()
    end
  end
end
```

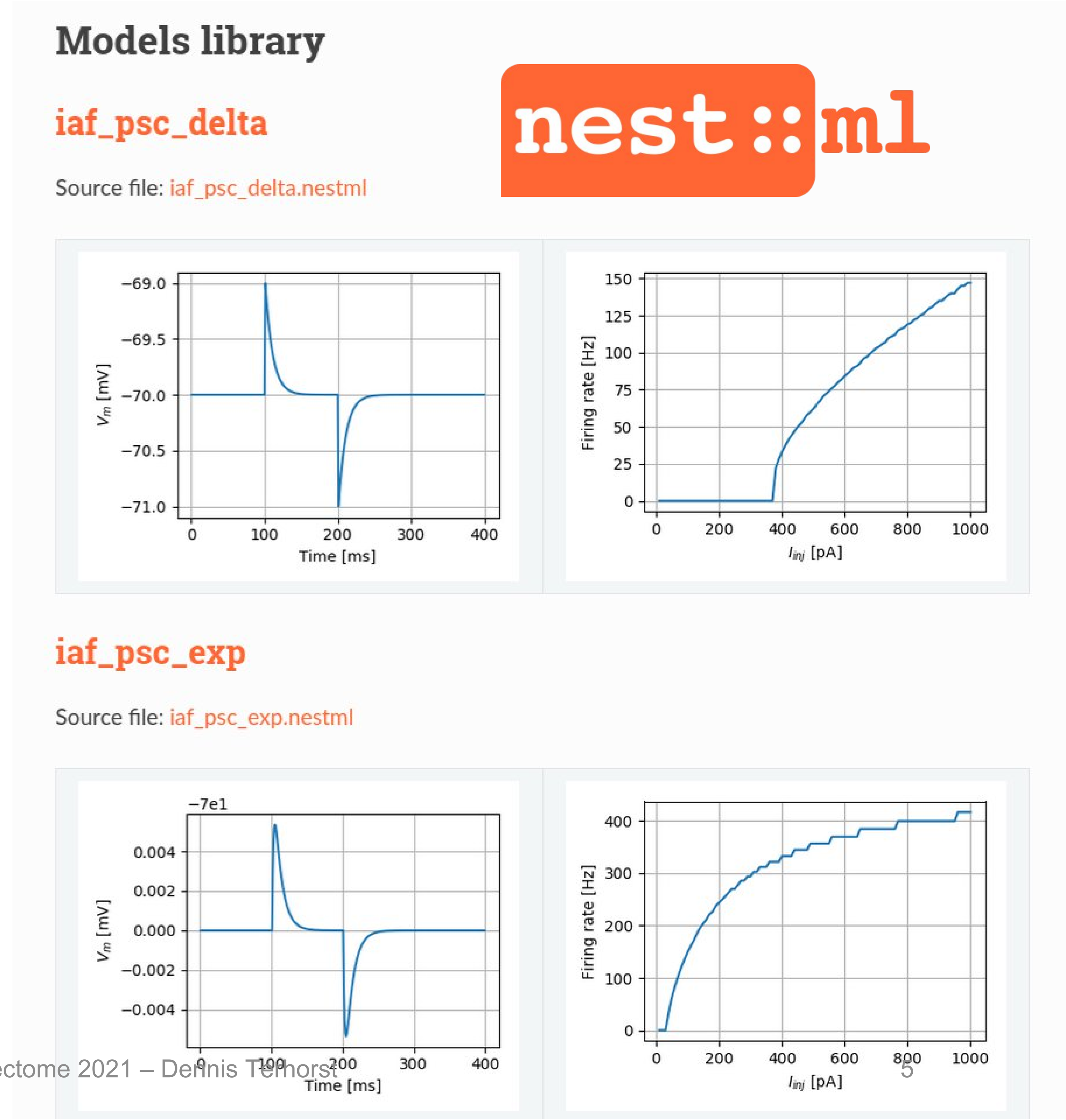
nest::ml

Code generation

nest::

NESTML software development uses best practices in software engineering.

- Unit tests: language feature tests; physical units consistency; etc.
- Integration tests: models are behaviorally validated in one or more simulation runs
- Extensive documentation and automated HTML documentation generation for models: https://nestml.readthedocs.org/
- Open development: https://github.com/nest/nestml
- GNU GPL v2.0 licensed



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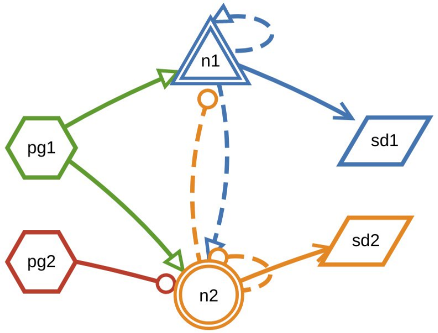

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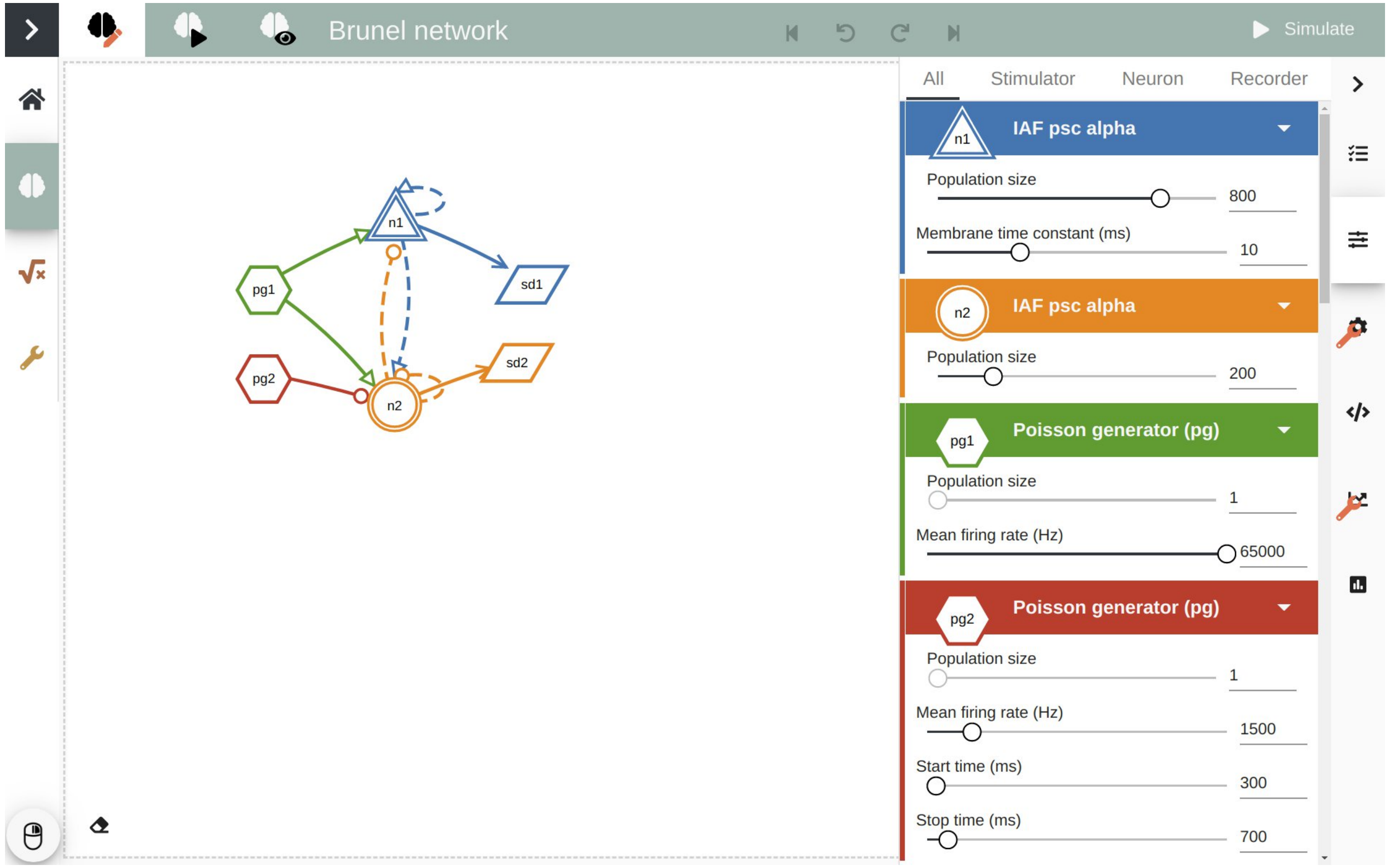
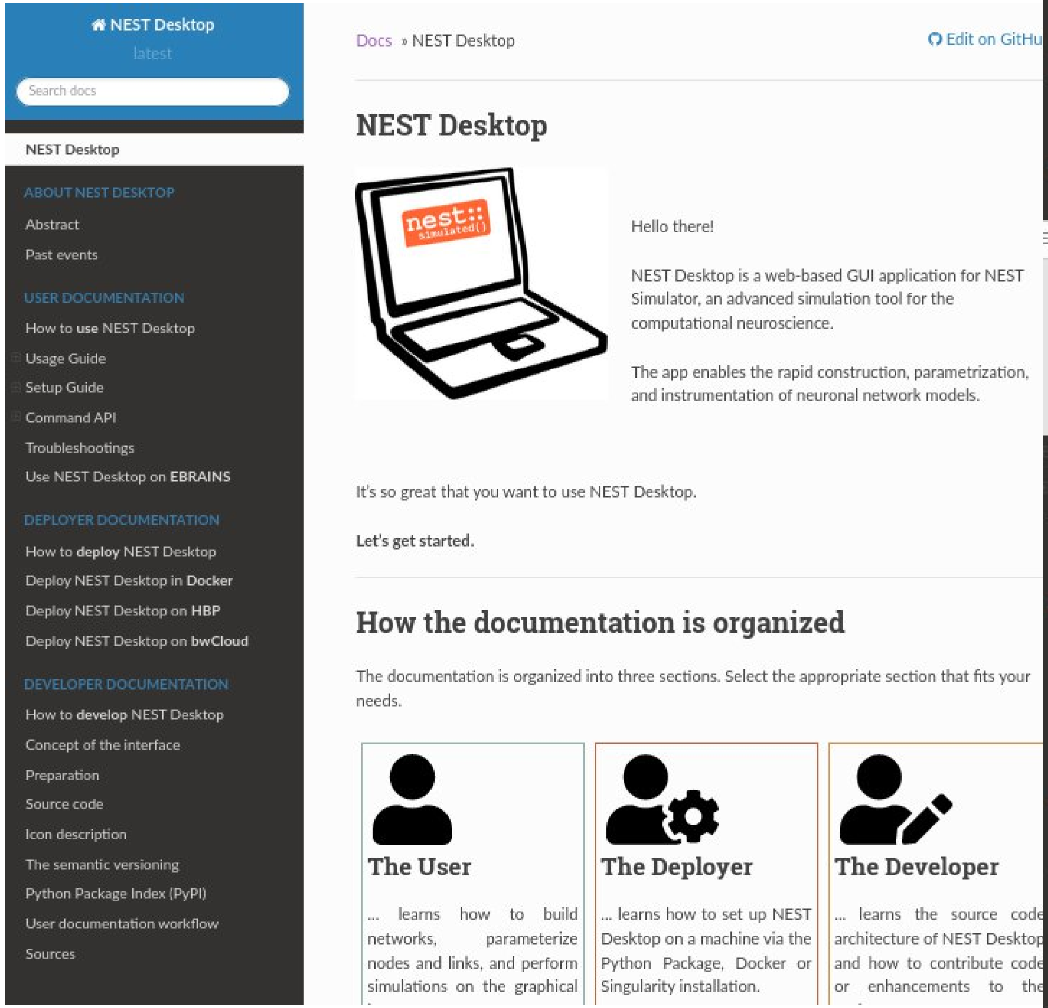
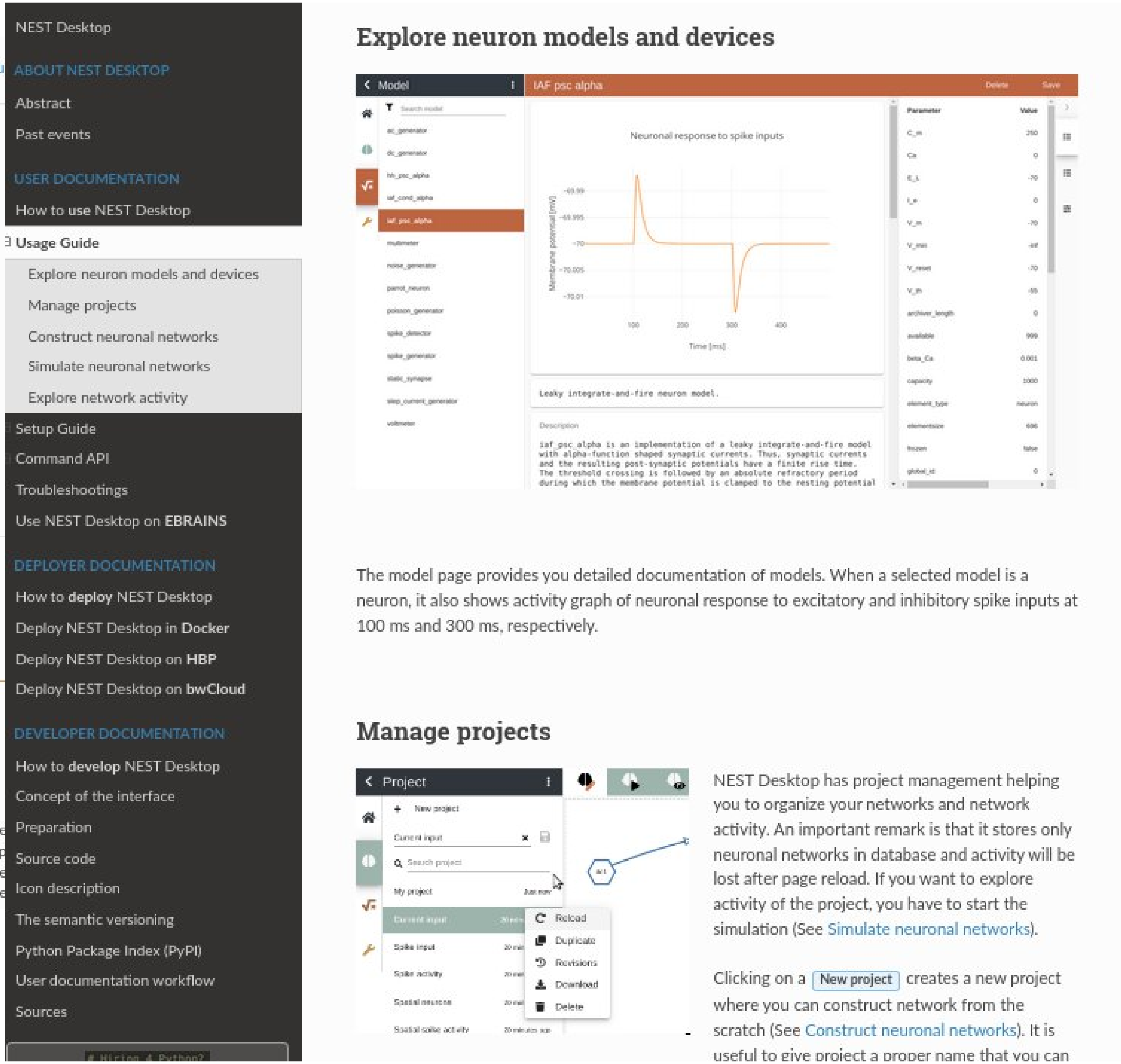
NEST Desktop



NEST Desktop





Check out
https://nest-desktop.readthedocs.org

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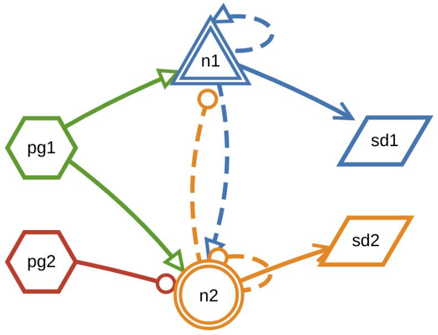

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The Neural Simulation Technology Initiative

ABOUT NEST | DOWNLOAD | FEATURES | DOCUMENTATION | PUBLICATIONS | COMMUNITY

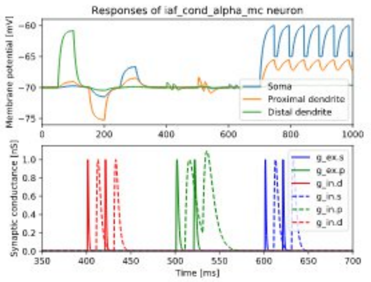
NEST Simulator is a simulator for spiking neural network models that focuses on the

- dynamics,
- size and
- structure of neural systems

rather than on the exact morphology of individual neurons.

multi-compartment neuron example

[...]



Download NEST

https://nest-simulator.org/download

Current Release NEST 2.20.0 (January 31 2020)

Tools for modern computational neuroscience

Synaptic plasticity

Topological network definition

Precise spike timing

MUSIC interface

Correctness and release stability

A battery of unit tests

Continuous integration (CI) techniques

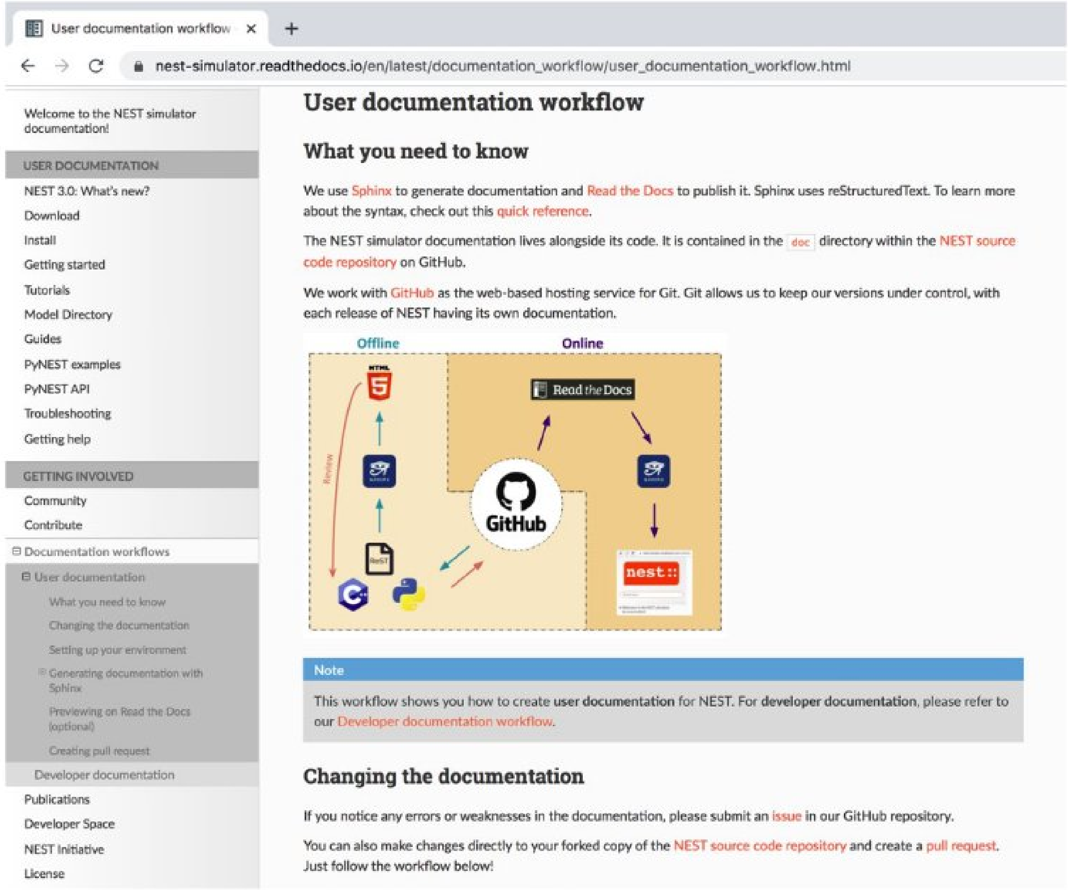
Regular open source releases under the terms of the GPL

nest::initiative

DOCUMENTATION REQUIREMENTS AND CONCEPTS

nest::

- For the community, documentation should be easy to:
  - Find
  - Use
  - Understand
  - Write
  - Maintain



JÜLICH
Forschungszentrum

Search docs

⊟ Welcome to the NEST simulator documentation!

⊞ Introducing NEST 3.0

USER DOCUMENTATION

- NEST 3.0: What's new?
- Download
- Install
- Configure
- Getting started
- Tutorials
- Guides
- PyNEST examples
- Model Directory
- PyNEST API
- Troubleshooting
- Getting help

GETTING INVOLVED

- Community
- Contribute

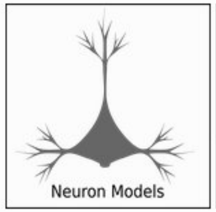
1. Models of information processing e.g., in the visual or auditory cortex of mammals,
2. Models of network activity dynamics, e.g., laminar cortical networks or balanced random networks,
3. Models of learning and plasticity.

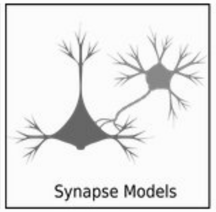
New to NEST?

Start here at our Getting Started page

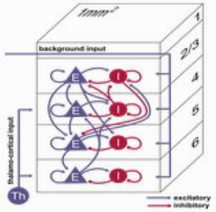
Have an idea of the type of model you need?

Click on one of the images to access our model directory:





Create complex networks using the Microcircuit Model:



Need a different model?

Check out how you can create you own model here.

Have a question or issue with NEST?

See our Getting Help page.

www.nest-simulator.org

Search docs

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⊟ Guides

- NEST 3.0: What's new?
- NEST 3.0: Detailed transition guide
- Connection Management
- Running simulations
- Stimulating the network
- Recording from simulations
- multimeter – Sampling continuous quantities from neurons
- spike_recorder – Collecting spikes from neurons
- weight_recorder – Recording weights from synapses
- Guide to parallel computing

`'azimuth_angle'` entry in the specific mask dictionary for rotation from the x-axis towards the y-axis about the z-axis, or a `'polar_angle'` entry, specifying the rotation angle in degrees from the z-axis about the (possibly rotated) x axis, from the (possibly rotated) y-axis. You can specify both at once of course. If both are specified, we first rotate about the z-axis and then about the new x-axis. NEST currently does not support rotation in all three directions, the rotation from the y-axis about the (possibly rotated) z-axis, from the (possibly rotated) x-axis is missing.

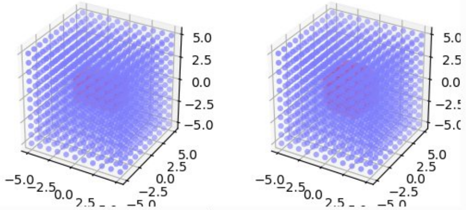

Figure 33 Masks for 3D NodeCollections. For all mask types, the driver node is marked by a wide light-red circle, the selected pool nodes by red dots and the masks are red. From left to right: box and spherical masks centered about the driver node.

Masks for grid-based layers

Grid-based layers can be connected using rectangular *grid masks*. For these, you specify the size of the mask not by lower left and upper right corner coordinates, but give their size in x and y direction, as in this example:

```
conndict = {'rule': 'pairwise_bernoulli',
            'p': 1.0,
            'mask': {'grid': {'shape': [5, 3]}}}
```

The resulting connections are shown in Figure 34. By default the top-left corner of a grid mask, i.e., the grid mask element with grid index $[0, 0]$ [2], is aligned with the driver node. You can change this alignment by specifying an *anchor* for the mask:

```
conndict = {'rule': 'pairwise_bernoulli',
            'p': 1.0,
            'mask': {'grid': {'shape': [5, 3]},
                     'anchor': [2, 1]}}
```

Check out https://nest-simulator.readthedocs.org

References

Visit

https://**nestml**.readthedocs.org

https://**nest-desktop**.readthedocs.org

https://**pynn**.readthedocs.org

https://**nest-simulator**.readthedocs.org

https://**nest-simulator.org**

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Slides (or parts) where provided by Charl Linssen, Sara Konradi, Sebastian Spreitzer, Steffen Graber and others.