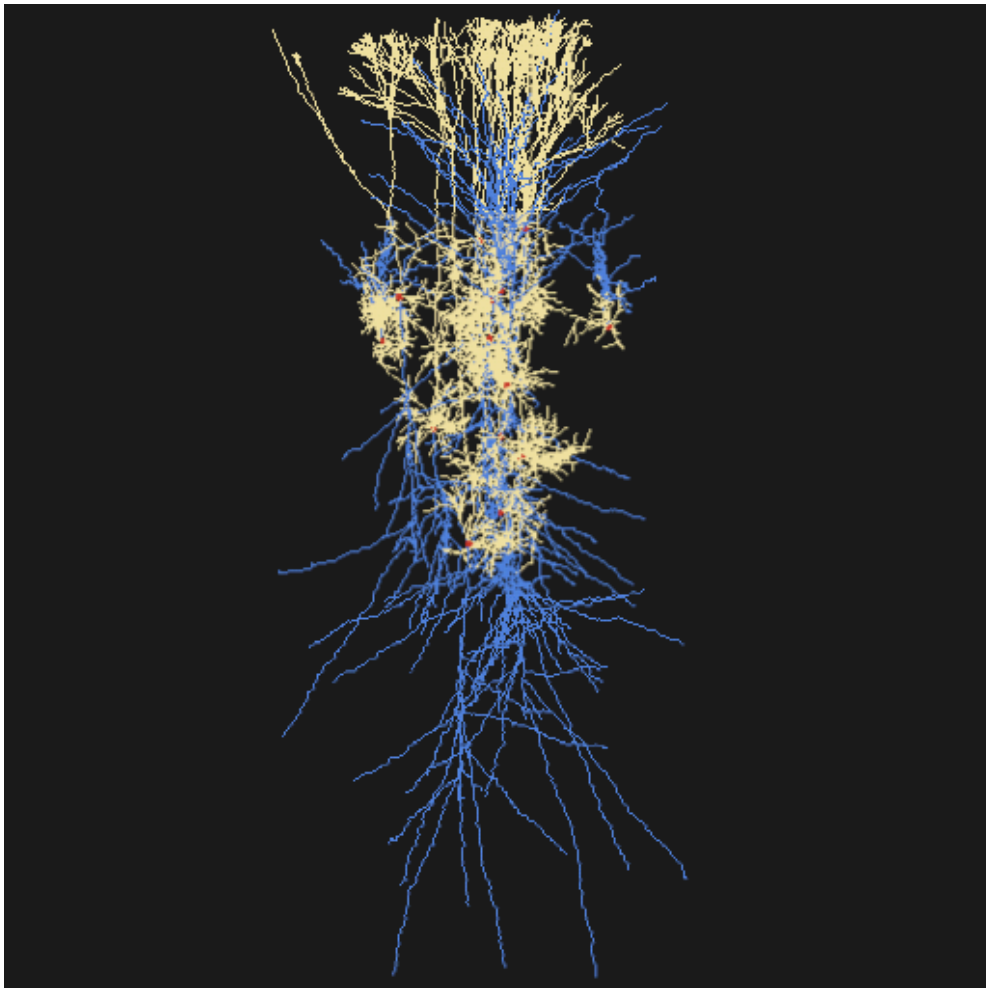
NeuGen

A Generator for Realistic Neurons in 3D



Manual

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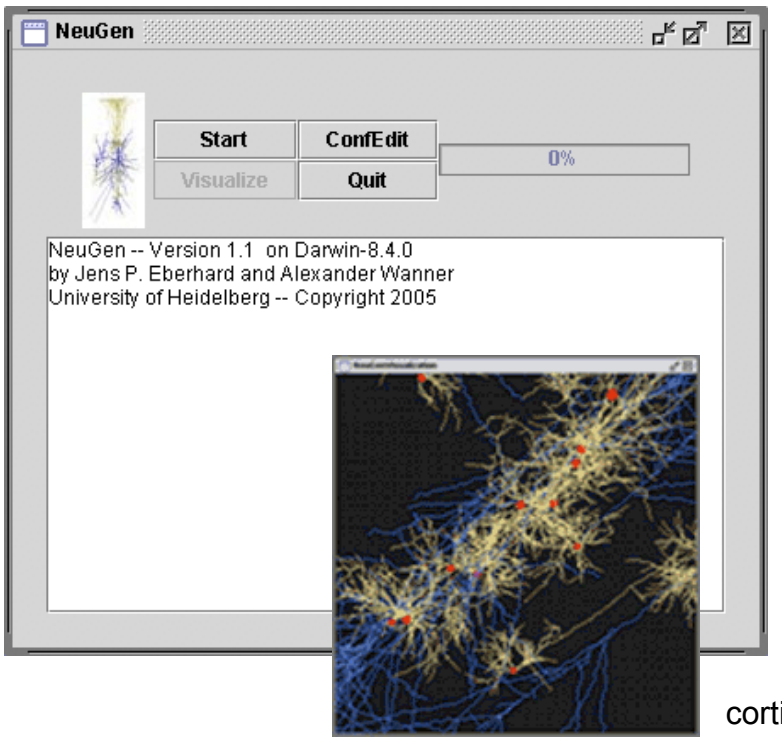
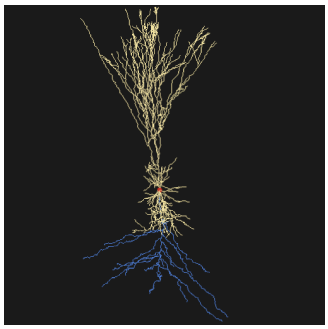
Introduction

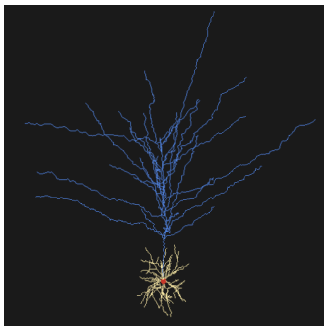


NeuGen is made for the generation of dendritic and axonal morphology of realistic neurons and networks in 3D.

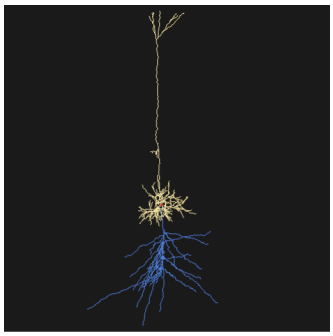
The idea for the development of NeuGen has been to simulate networks of synaptically connected neurons in a cortical column. This project is mainly a result of the fact that experimental data is available nowadays to extract the anatomical fingerprints of the cells for generating synthetic neuron geometries.



L2/3 cell
generated by NeuGen.



L4 cell
generated by NeuGen.



L5A cell
generated by NeuGen.

Dendrites are shown in yellow; the axonal tree is colored blue.

Key Features

NeuGen

- NeuGen is a tool for the efficient generation and description of dendritic and axonal morphology of realistic neurons and neural networks in 3D
- NeuGen builds real neural network geometries
- NeuGen is based on experimental data. The 'in silico' neurons are based on cells of cortical columns in the neocortex

Neurons

- NeuGen generates
  - L4 spiny stellate neurons
  - L2/3 pyramidal cells
  - L5A and L5B pyramidal cells
  - L4 star pyramidal cells

Visualization

- Generated networks can be visualized via the NeuGen GUI
- NeuGen also has an interface to the Open Visualization Data Explorer (OpenDX) for the visualization of single neurons or networks

Synapses and Networks

- NeuGen creates synapses by distributions and/or distance. It uses the NetCon class of NEURON to create an interface to this simulation program.
- The interconnection is made due to realistic connectivity patterns in a cortical column found by experiments.

Simulation

- Output can be generated for NEURON via HOC files.
- Implementation of a multi-compartmental model from the ModelDB to simulate the generated networks directly with NEURON.
  - Model from Mainen & Sejnowski, Nature 382 (1996), with fast active channels in soma and axon, and slow active currents in dendrites. NeuGen generates uniform distributions of channels.

Installation

The software package NeuGen is available for different platforms. Currently we support NeuGen for Windows XP, Linux and MacOS X. The current standard distribution includes all new features and is stable.

Download the NeuGen version for your operating system and save it in a folder of your choice. Unzip the package there. A folder called NEUGEN_v[version number] will be extracted. It contains all necessary files, including test configuration files for NeuGen's parameters.

NeuGen can be started at once.

Starting NeuGen

Starting NeuGen with MS Windows

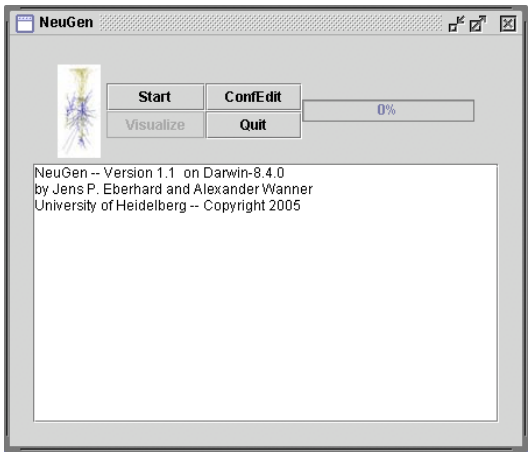
Double mouse click on NeuGenGui.jar (or execute `java -jar NeuGenGui.jar` in the prompt) in the NeuGen folder. The **NeuGen GUI Start Screen** will appear.

Starting NeuGen with MacOs X

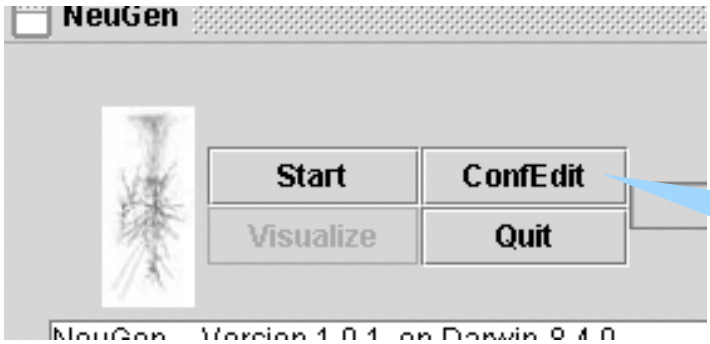
Double mouse click on the NeuGen symbol in the NeuGen folder. The **NeuGen GUI Start Screen** will appear.

Starting NeuGen with Linux

Start a shell, change to the NeuGen directory and type `java -jar NeuGenGui.jar`. The **NeuGen GUI Start Screen** will appear.



Settings

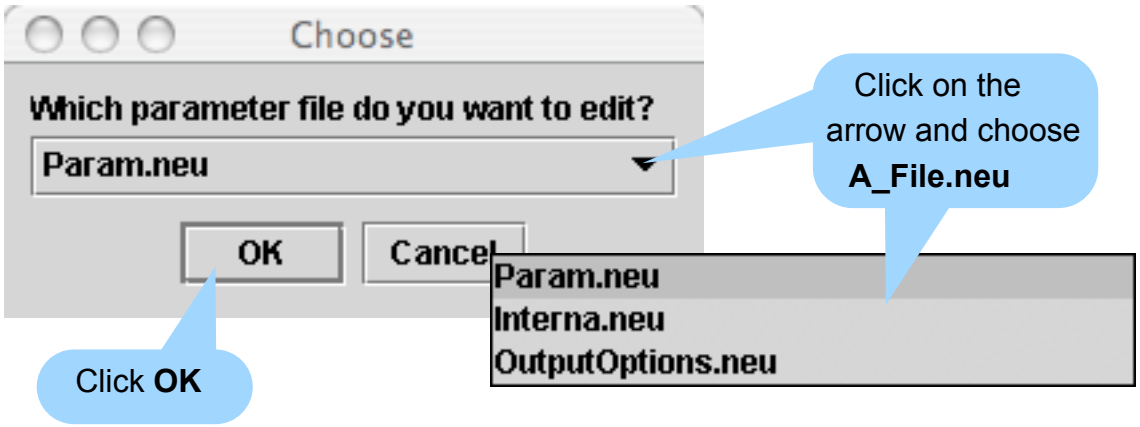


The **Configuration Editor** allows you to change Neugen' s settings.

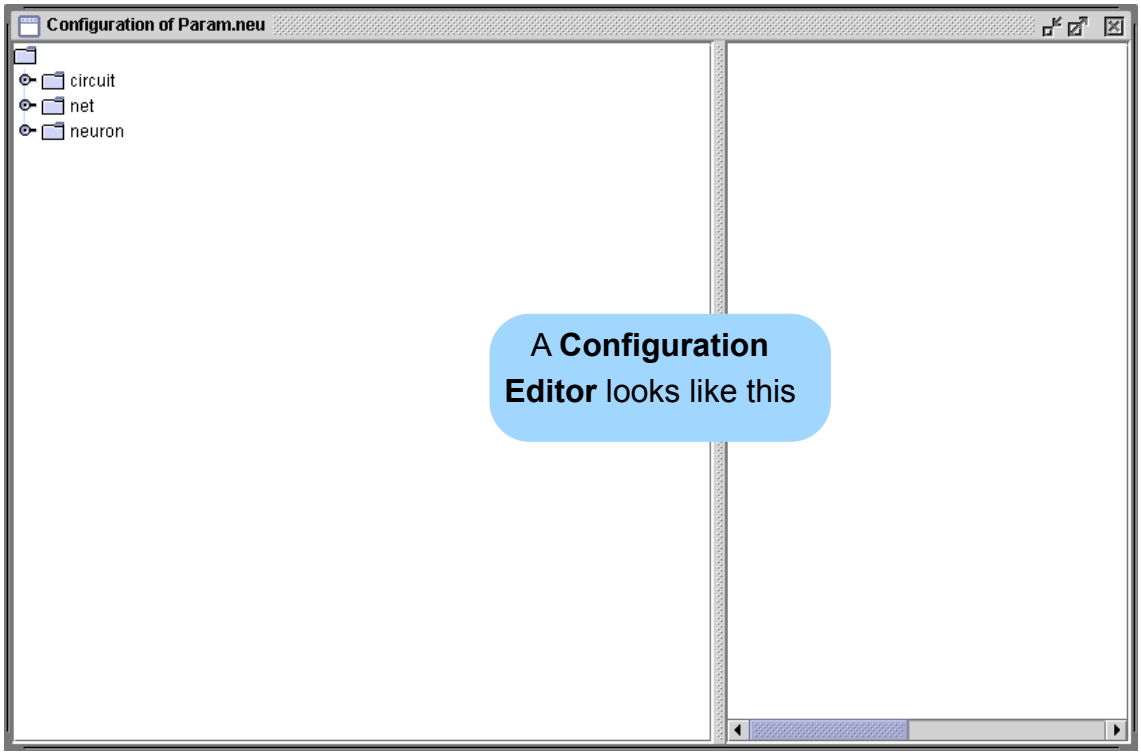
Things you can change include the number and type of cells generated, the names and types of the output files and also special parameters concerning the generation.

To set the configuration values, press the **ConfEdit** button located in the buttons panel at the top of the NeuGen start screen. A file chooser menu will pop up. One out of three configuration files can be chosen: **Param.neu**, which contains the numbers and kinds of cells generated, **OutputOptions.neu**, where the paths to the output files can be set, and **Interna.neu**, which contains the special parameters, that should only be changed by the expert user. In the following we will give explanations on how to set the parameters via the Configuration Editor.

Configuration - Generals

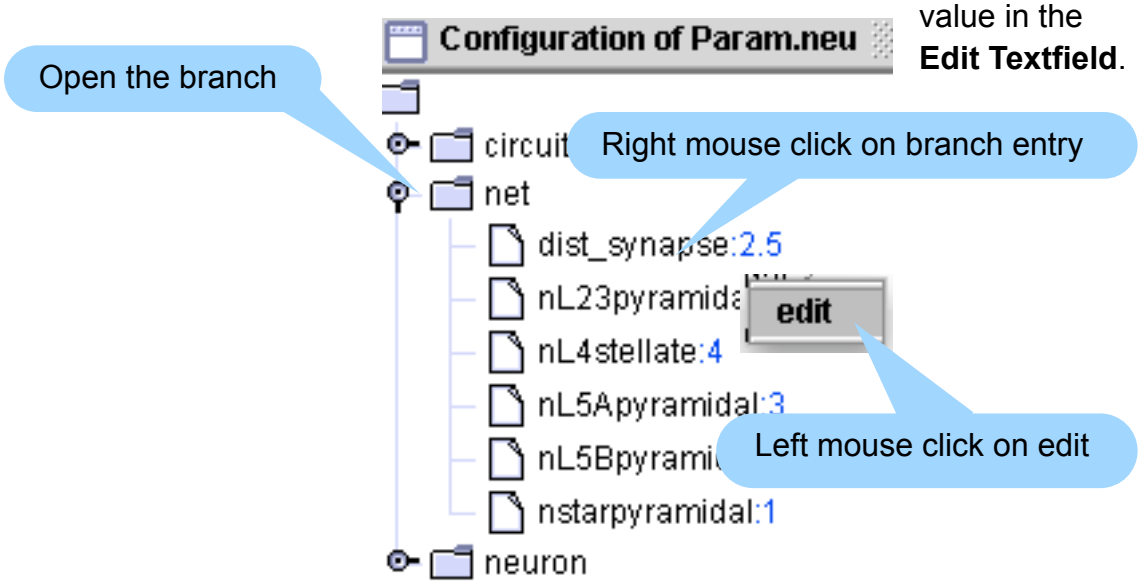


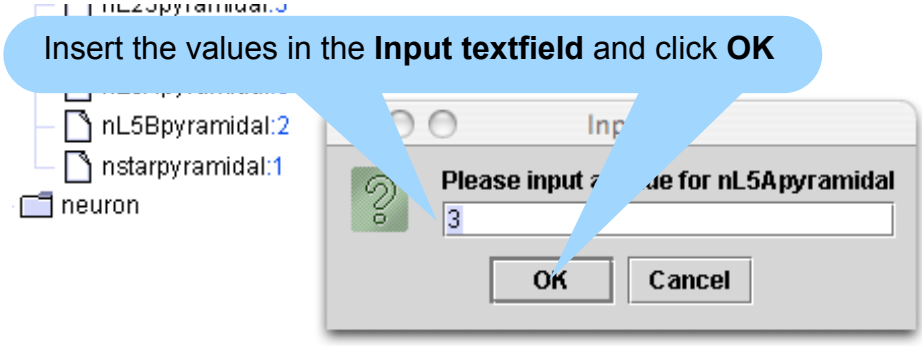
The **Configuration Editor** will appear.



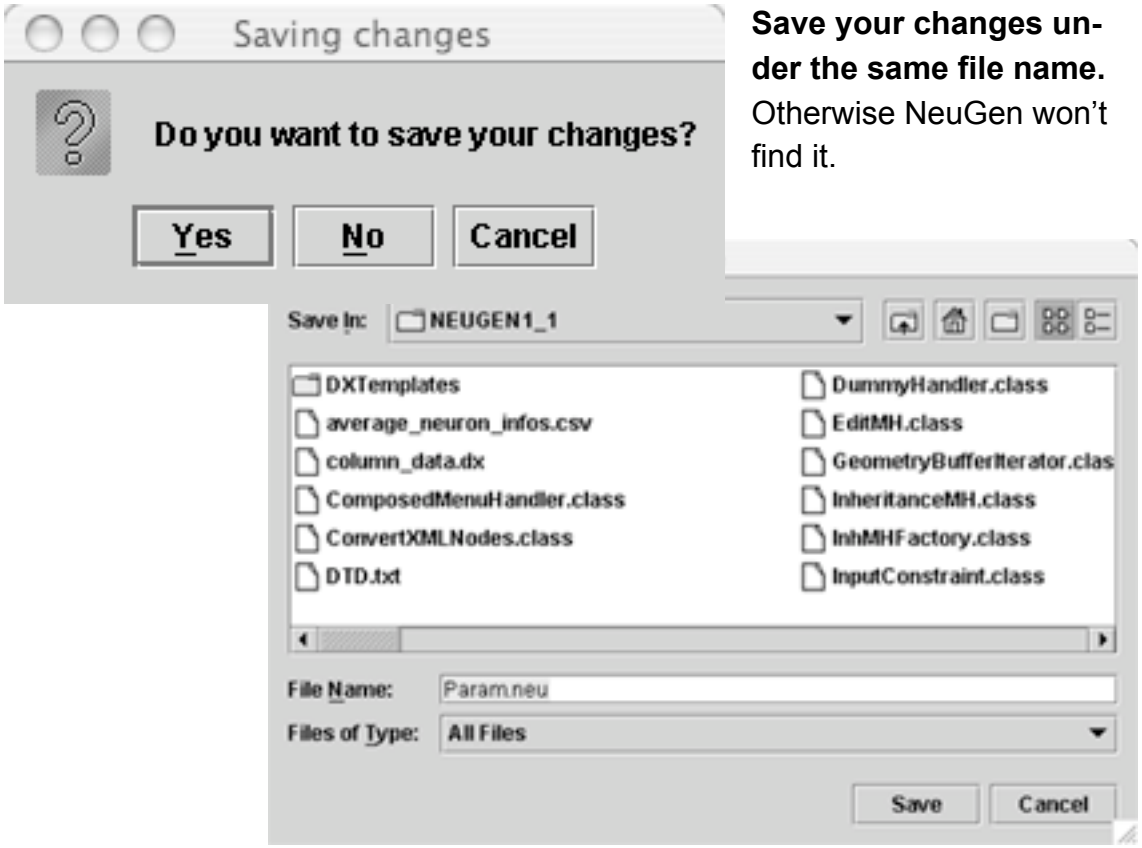
All configuration editors have a tree structure. You can enter the branches by clicking on the  symbol.

To edit the entries, enter the branch, right click on the entry and type the new value in the **Edit Textfield**.





After you have made all the changes, close the Configuration Editor window.

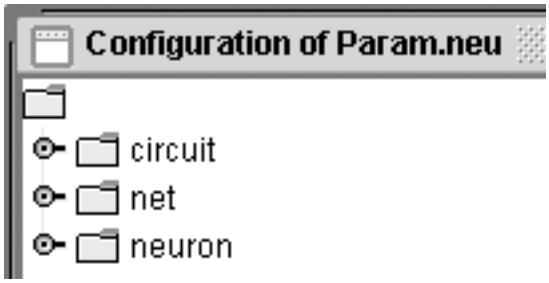


Save your changes under the same file name. Otherwise NeuGen won't find it.

All recommended values are given in brackets in the tables below and are taken from experimental findings. These are also the default values. If you want to keep them for reuse, copy the `.neu` files in backup files.

Configuration parameters - Param.neu

In **Param.neu** you can set, what types of cells and how many of them shall be generated.



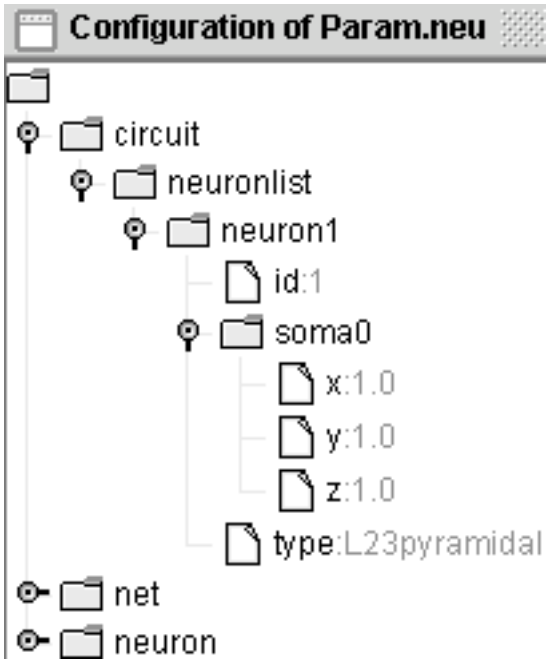
Also you can influence, the number of synapses, that will be generated and change some features of neurons and their parts.

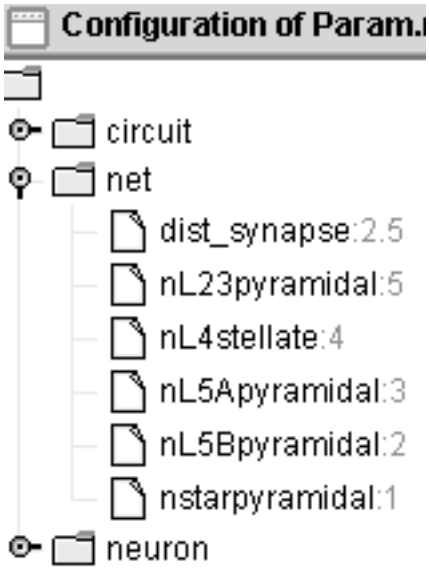
All relevant cell types found in the neocortex can be generated with NeuGen and include L2/3 pyramidal cells, L4 stellate neurons and starpyramidal cells, as well as L5A and L5B pyramidal cells.

Without visualization the total number of neurons generated can be as high as 5000. For the visualization the number is limited to about 250, depending on computer capacities.

The values, which can be set are not all absolute parameters. Except for the numbers of cells, all parameters are scaled with random numbers to provide the possibility of generating realistic networks, which vary in form and size.

At the moment **circuit** is only a place-holder for future implementations.





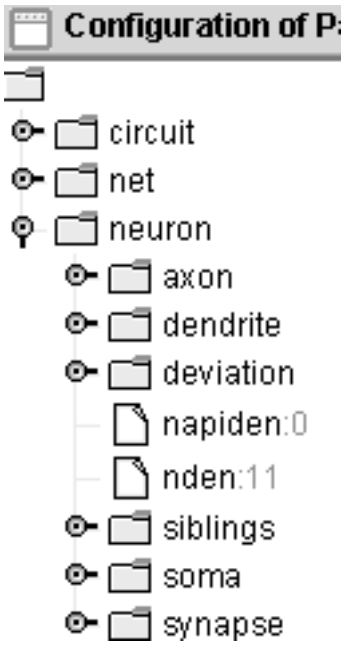
net contains information about the types and numbers of neurons generated, and a parameter to influence the number of synapses.

dist_synapse	below this threshold distance between axons and dendrites synapses will be set
nL23pyramidal	number of L2/3 pyramidal cells in the network
nL4stellate	number of L4 stellate cells in the network
nL5Apyramidal	number of L5A pyramidal cells in the network
nL5Bpyramidal	number of L5B pyramidal cells in the network
nstarpyramidal	number of L4 starpyramidal cells in the network

neuron contains information about the appearance of a single cell.

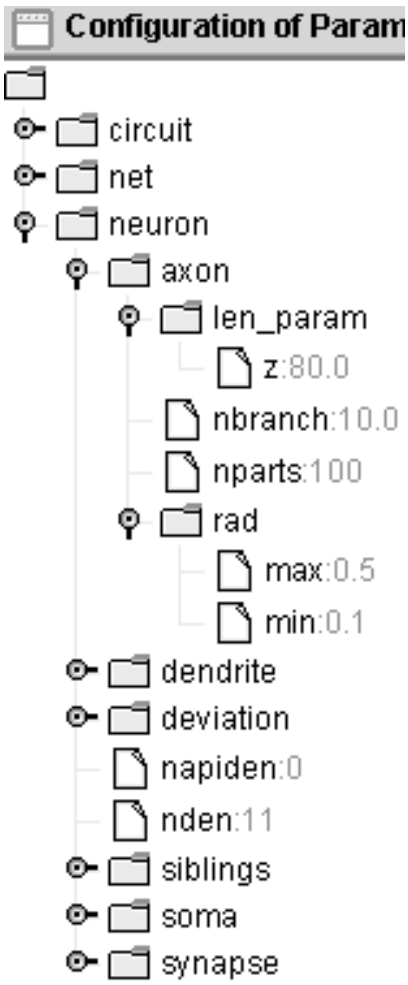
Parameters of all neuron parts, including axon, dendrites, soma and synapses, as well as the deviation from the “abstract base neuron” and the numbers of dendrites can be changed.

For beginners it is recommended to use the default settings.

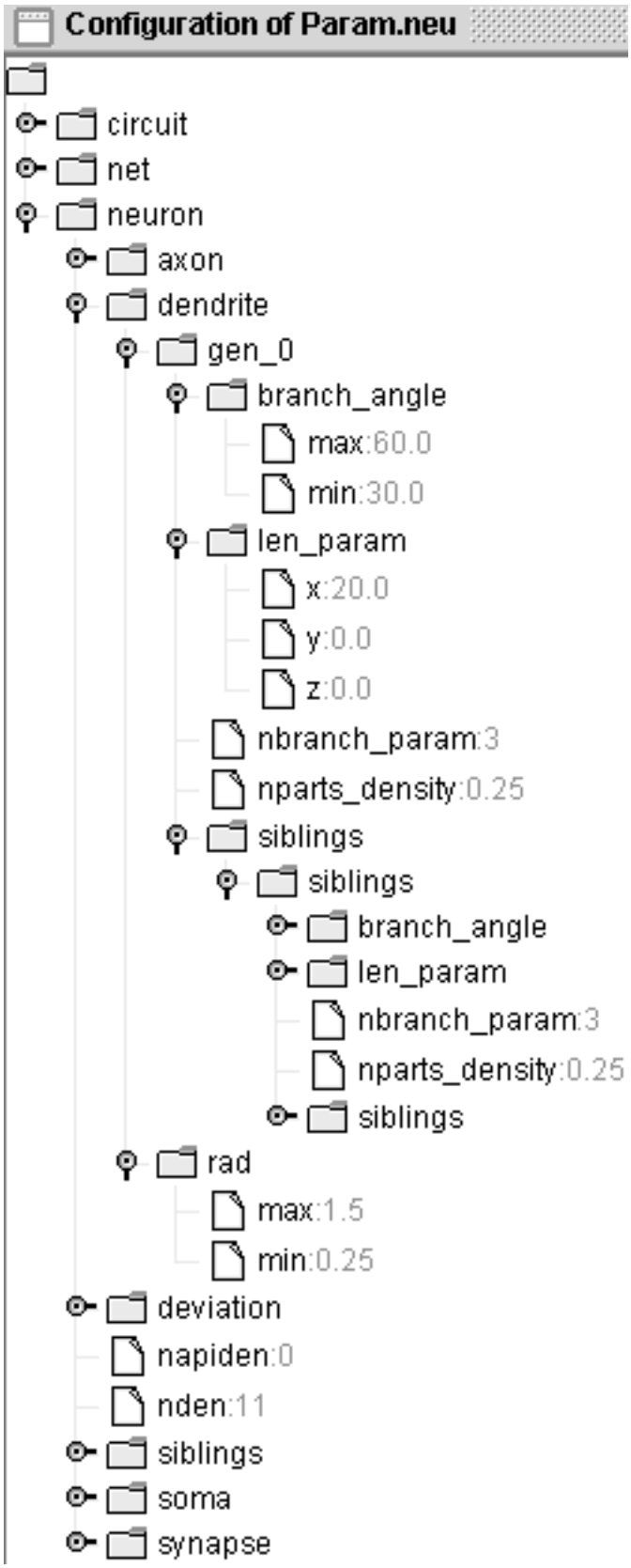


axon	axon parameters
dendrite	dendrite parameters
deviation	deviation parameters
napiden	number of apical dendrites • 0
nden	total number of primary dendrites (basal and apical) • 11
siblings	parameters of subsequent generations of the dendritic tree
soma	soma parameters
synapse	synapse parameters

neuron > axon contains length, radius and branching parameters of the axon.



len_param	length parameter of the axon (multiplied with soma radius)
z	base length in z direction in µm • 375 (L4 stellate) / soma radius • 400 (L2/3 pyramidal, L4 star) / soma radius • 500 (L5 pyramidal) / soma radius
nbranch	number of branches of the axonal tree • 12 (L2/3 pyramidal) • 26 (L4 stellate) • 24 (all other types)
nparts	number of segments for the primary trunk of the axon • 90 (L4 stellate) • 100 (all other types)
rad	base radius (context-sensitive parameter)
max	maximum base radius in µm • 0.5
min	minimum base.radius in µm • 0.1



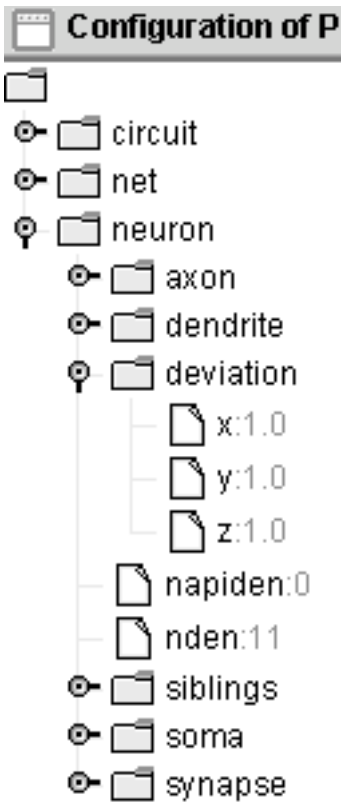
neuron > dendrite contains settings for the dendritic tree.

gen_0	first dendritic generation of the dendritic tree
branch_angle	base angle between two branches at a branching point in degree
max	maximal branching angle • 60
min	minimal branching angle • 30
len_param	geometric length vector in multiples of the soma radius..
x	...in x-direction • 20
y	...in y-direction • 0
z	...in z-direction • 0
nbranch_param	number of branches
nbranch_density	density of compartments (number per µm) • 0.25
siblings	subsequent generations of the dendritic tree ...
siblings > ...	... and their parameters
rad	radius of the dendrite in µm (context-sensitive)

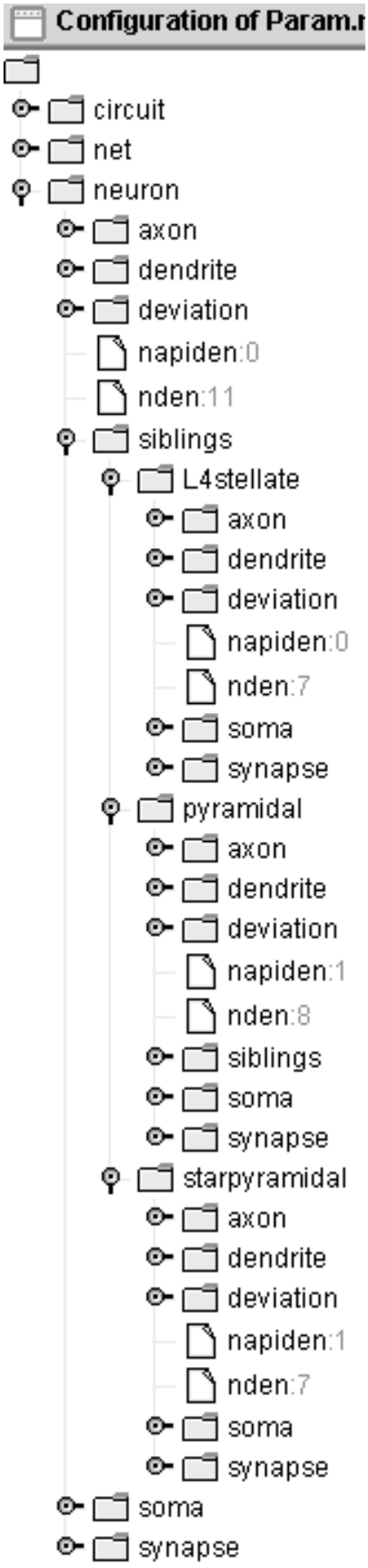
max	maximal radius
	• basal
	  • 0.5 (L4 star)
	  • 1.5 (all other types)
	• apical
	  • 0 (L4 stellate)
	  • 2.5 (L4 star)
	  • 1.5 (all other types)

min	minimal radius
	• basal
	  • 0.5 (L4 stellate)
	  • 0.25 (all other types)
	• apical
	  • 0 (L4 stellate)
	  • 0.5 (L4 star)
	  • 0.25 (all other types)

neuron > deviation contains parameters to control the deviation from the base neuron; i.e. the appearance of the realization of this neuron.

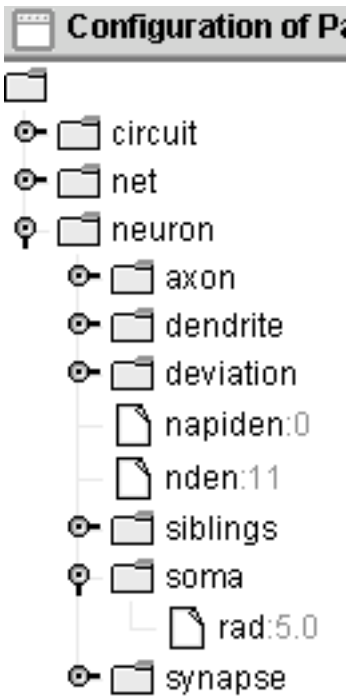


x	deviation in x-direction • 1.0
y	deviation in y-direction • 1.0
z	deviation in z-direction • 1.0

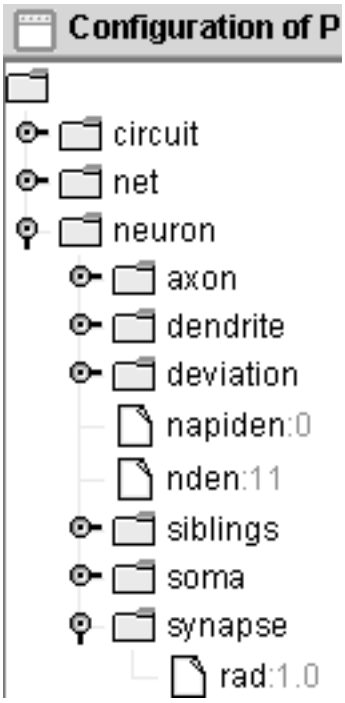


neuron > siblings contains parameters for the cells of the subsequent generartions of this neuron. Sibling cells can be of any of the cell types L4 stellate, pyramidal and starpyramidal.

neuron > soma contains the base radius of the soma.



radius	base radius of the soma in µm • 5.0

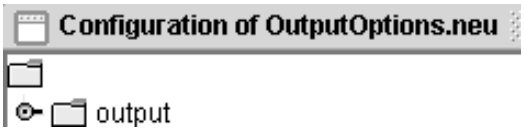


neuron > synapse contains the base radius of the synapses.

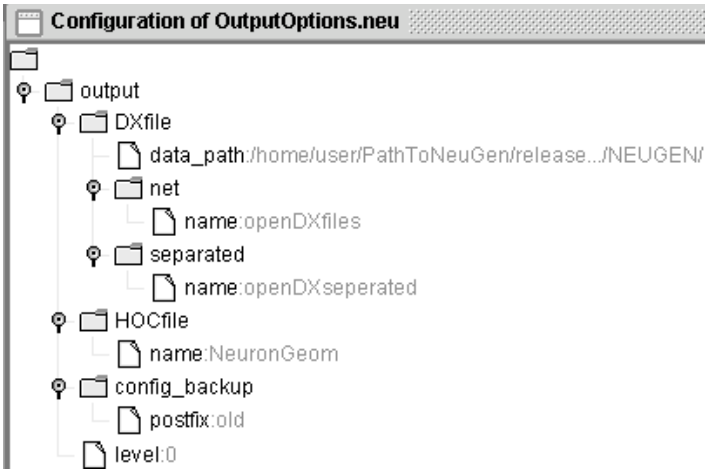
radius	base radius of the synapses in µm • 1.0

Configuration parameters - OutputOptions.neu

In **OutputOptions.neu** you can set paths and file names.This means, you can decide, what kinds of output files NeuGen shall generate.



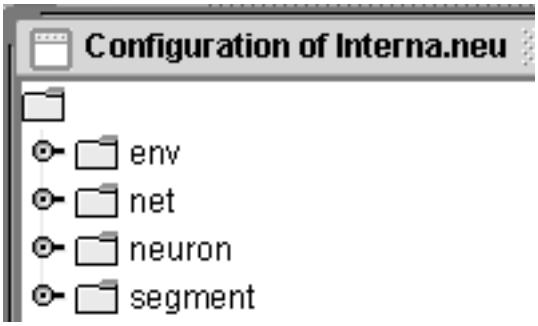
Possible output formats are `.dx` resp. `.net` for data visualization with the OpenDX DataExplorer and .hoc for simulations with the simulation software NEURON.



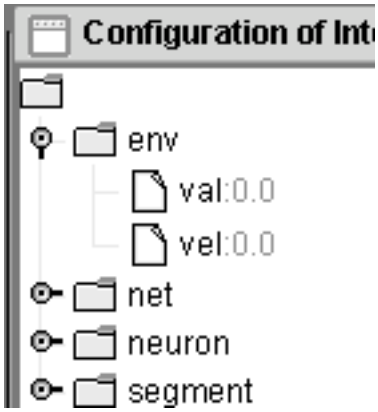
DXfile	output files to be used with the OpenDX Dataexplorer
data_path	path to the NEUGEN directory, into which the DX output will be written. (must be path to NEUGEN)
net	`.net` file, which contains info about the net as a whole
name	base name of the DX files without path
seperated	`.dx` files, which contain infos about the single parts of the net
name	base name of the seperated DX files without path
HOCfile	output files to be used with NEURON
name	base name of `.hoc` file
config_backup	configurations will be backuped, if a postfix is given
postfix	postfix for backup files
level	level of output information • 0 (minimal information) - 2 (maximal information)

Configuration parameters - Interna.neu

In **Interna.neu** internal generation parameters are stored. Changes in this file can result in **severe changes** of the appearance of the cells.



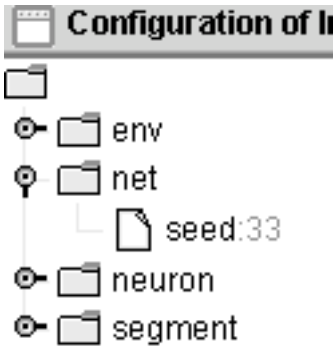
Therefor, the parameters in this file should only be changed by very experienced users, who know, what they are doing.



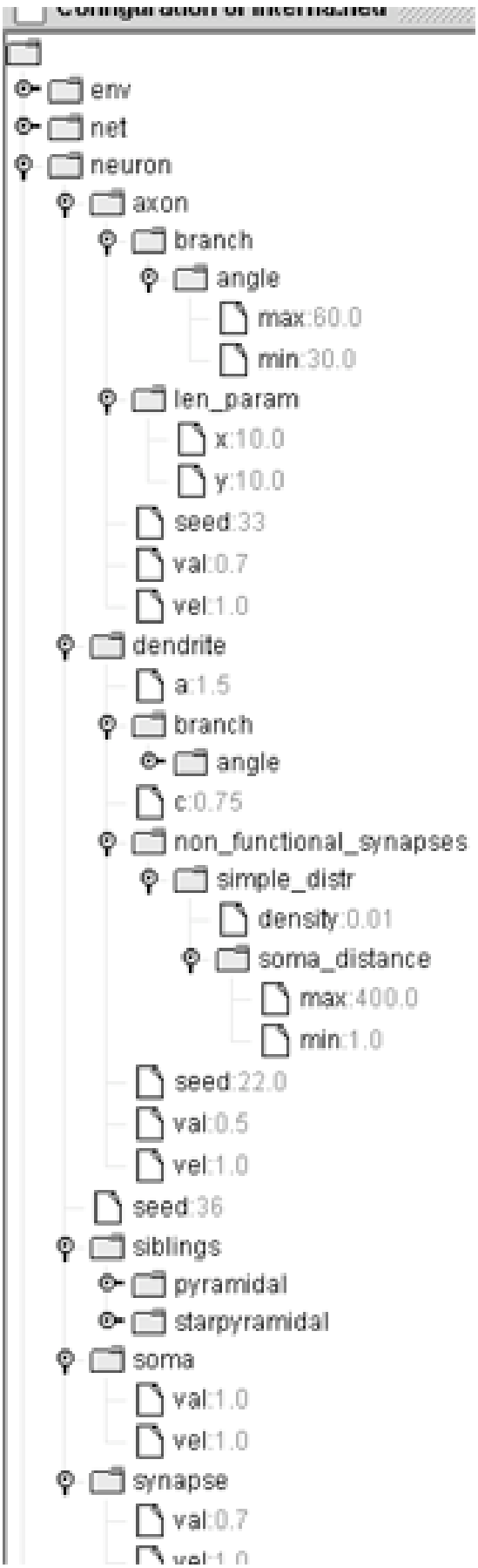
env (deprecated)

val	environment value
vel	environment velocity

net contains the start value for the generator of random numbers used for the construction of the network and its parts.



seed	start value for random number generators • 33



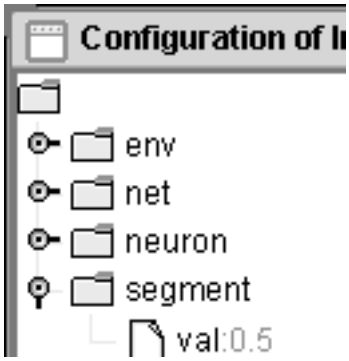
neuron contains additional information of the parameters of neuron parts.

axon	axons of the neurons
branch	branch parameters of the axons
angle	base angle of axon branches
max	maximum base angle of the axon branches • 60.0 degree
min	minimum base angle of the axon branches • 30.0 degree
len_param	lenght parameters of the axons in µm
x	length in x-direction • 10.0 µm
y	length in y-direction • 10.0 µm
seed	start value for random number generator for len • 33
val	(deprecated, 0.7)
vel	(deprecated, 1.0)
dendrite	dendrite parameters
a	value of Rall's power • 1.5
branch	branch parameters of the dendrites
angle	angle parameters of the dendrite
c	threshold for the radius of Rall's power rule • 0.75

non_functional_synapses	parameters for the input synapses
simple_distr	parameters for the distribution of nf_synapses
density	density of non-functional synapses • 0.01
soma_distance	distance of point to soma
max	maximal distance to soma • 400.0 µm
min	minimal distance to soma • 1.0 µm
seed	start value for random number generator • 22.0
val	(deprecated, 0.5)
vel	(deprecated, 1.0)
seed	start value for random number generator • 36
siblings	parameters for subsequent generations
pyramidal	parameters for pyramidal siblings
starpyramidal	parameters for starpyramidal siblings

soma	soma parameters
val	(deprecated, 1.0)
vel	(deprecated, 1.0)
synapse	synapse parameters
val	(deprecated, 0.7)
vel	(deprecated, 1.0)

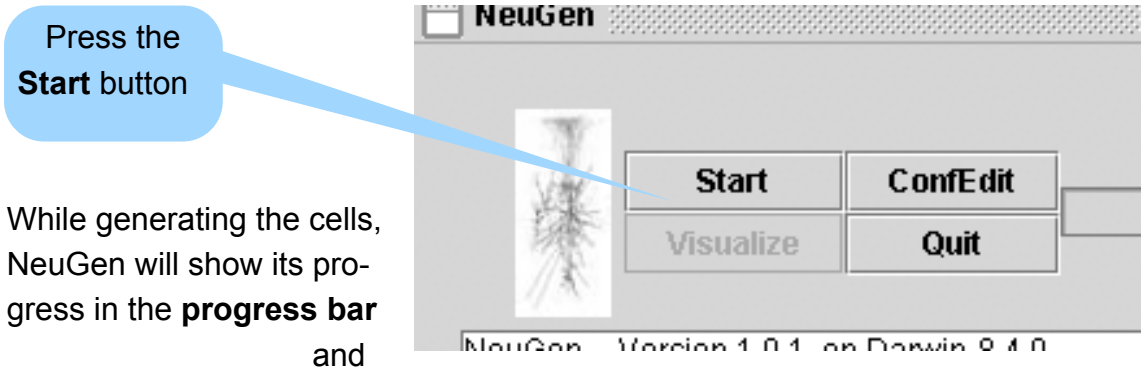
segment



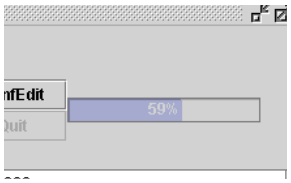
val	(deprecated, 0.5)

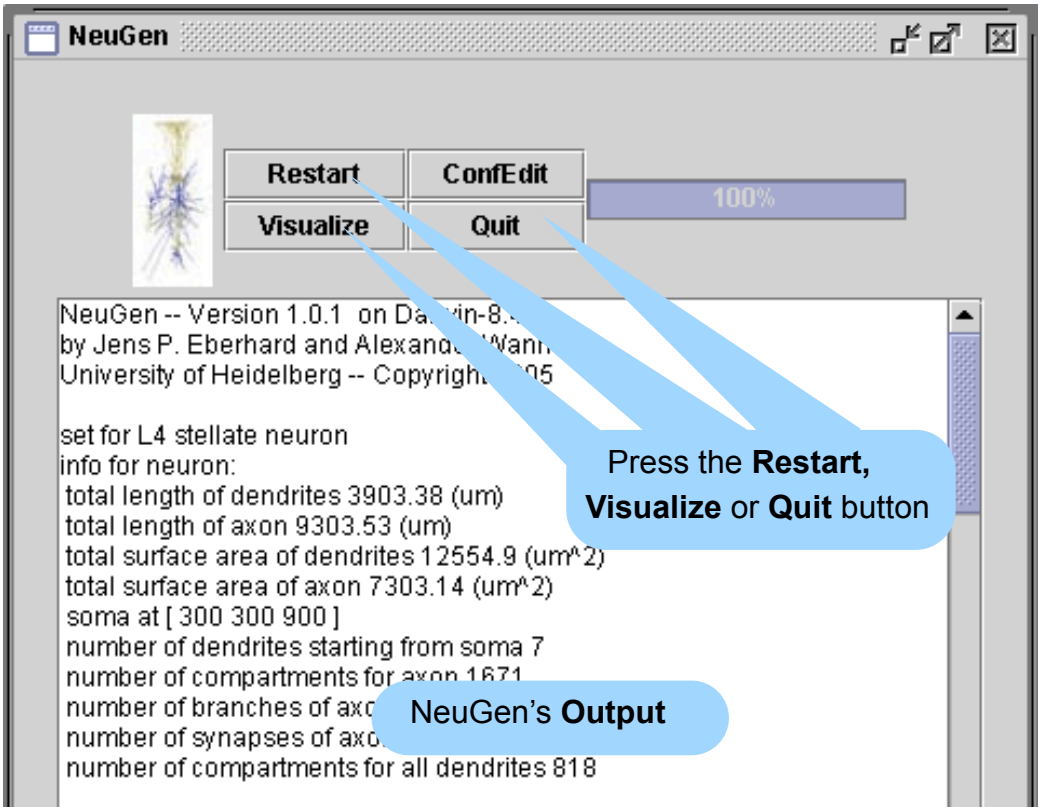
Starting the generation of neurons

After you have made all your changes in the configuration editor, you can start the generation of neurons by left mouse click on **Start** on the NeuGen GUI start screen buttons panel.



While generating the cells, NeuGen will show its progress in the **progress bar** and also will write information in the **output textfield**. After it has finished, you can **visualize** your network, **restart** the generation to get a different realization of the network or **quit** the application.

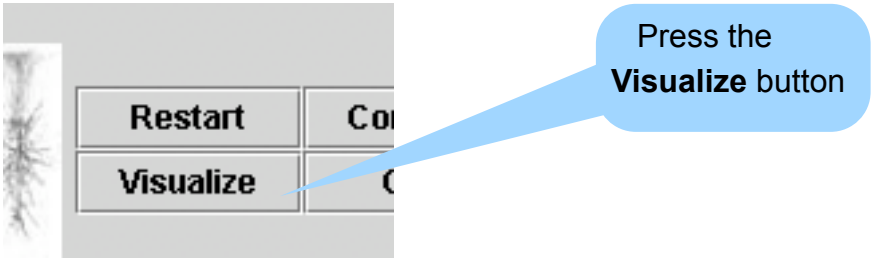


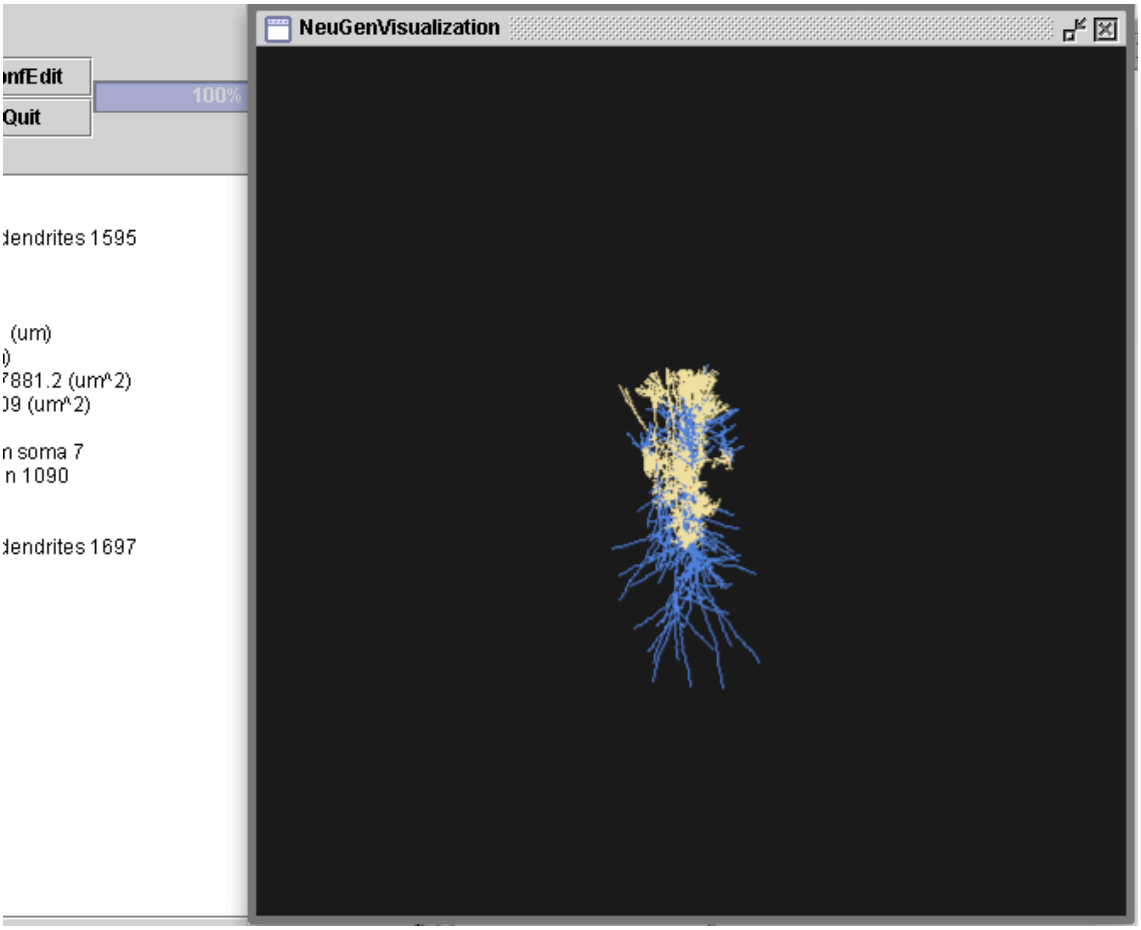


Visualizing the generated net

Since version 1.1 NeuGen has its own visualization window. You can visualize a generated network of up to 250 neurons, depending on computer capacities.

To visualize the neuron or network, press the visualization button on NeuGen's buttons panel.

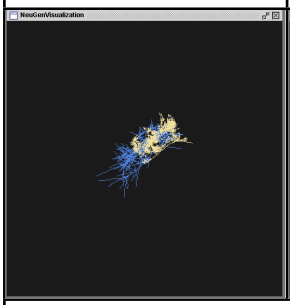
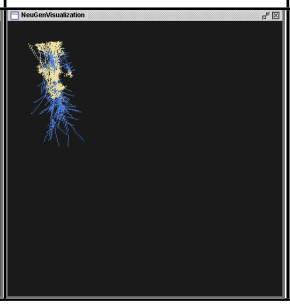
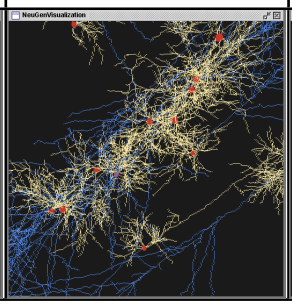
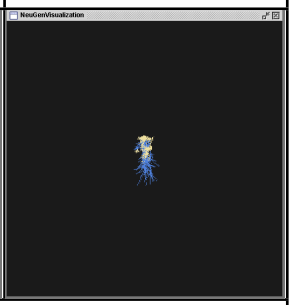




The **NeuGen Visualization Window** will appear.

Orientation

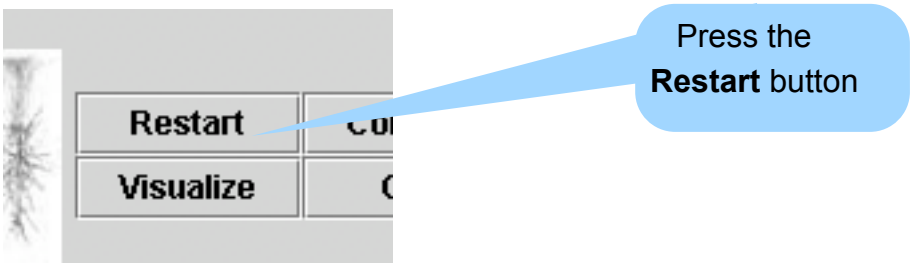
Orientation change as well as zooming into the image can be done with the mouse.

You can ...			
... **rotate** ...	... **move** ...	... **zoom in** ...	... **zoom out of** ...
			
... the image by ...			
... **dragging** it with the **left mouse** button hold.	... **dragging** it with the **right mouse** button hold.	... **dragging it upwards** with the **middle mouse** button hold.	... **dragging it downwards** with the **middle mouse** button hold.

Note: The image cannot be saved, but is lost, if another generation is started. Of course you can make a screen shot with some program.

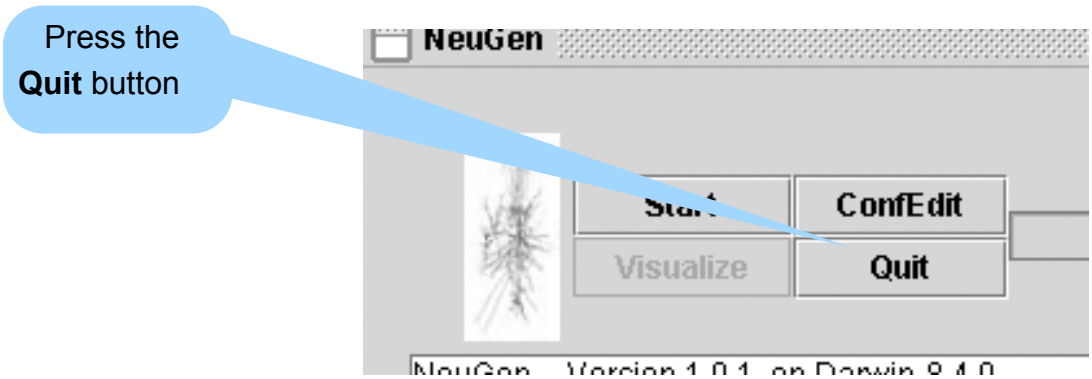
Restarting the generation of neurons

After the first generation of the network, the Start button will be named Restart. If you press it without changing the parameters, you will get a different realization of the network with the same configuration parameters.



Quitting NeuGen

Quit NeuGen by pressing the Quit button. Before quitting you can save the text output by selecting it with the left mouse button, copying it with ctrl+c and inserting it with ctrl+v into a text editor of your choice. It is recommended to do this, so that you can have all the information of the network at one glance, e.g. the number of synapses or the types of cells generated.



Using NeuGen’s output

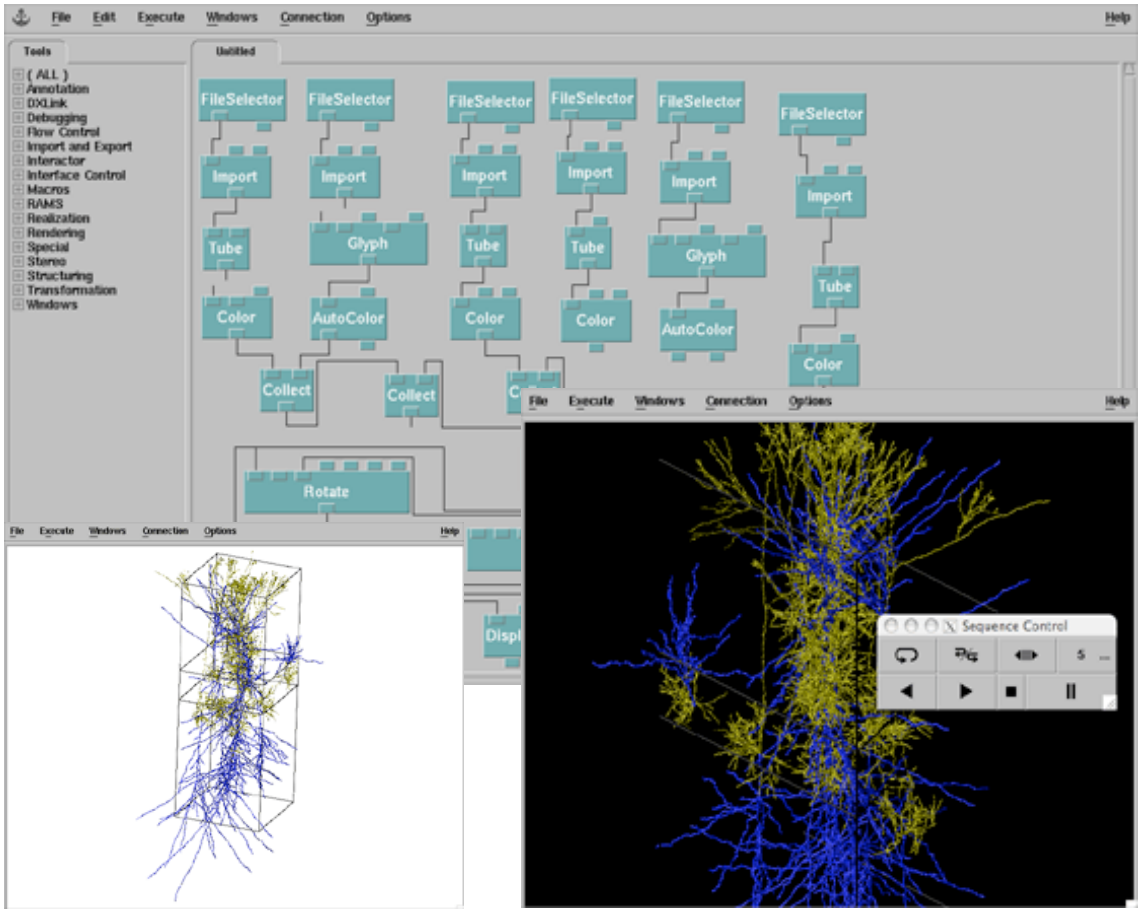
You can use NeuGen’s output `.net` files for visualization with the visualization software OpenDX.

The `.hoc` files can be used for simulations with the NEURON simulation environment

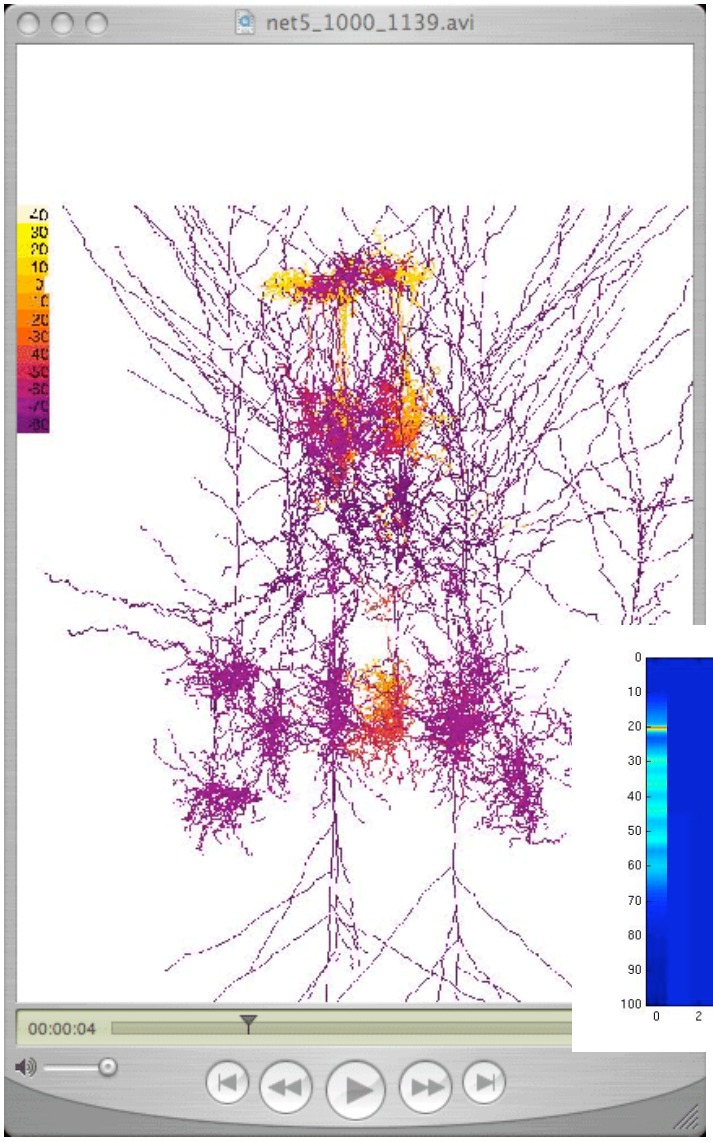
Using NeuGen’s output with OpenDX Dataexplorer

The visualization routines of NeuGen allow to write the necessary files for a three-dimensional rendered display of the neurons.

The visualization of the cells in 3D can be made with the program Open Visualization Data Explorer (OpenDX) running on a variety of operating systems. The input format for the Data Explorer is the native OpenDX file format. The files are written by NeuGen, i.e., all files including the program files for OpenDX are automatically generated by NeuGen using the options in the configuration file OutputOptions.neu. The generated program for OpenDX allows then a rendered interactive display of the neurons and can be run with "Execute".



Using NeuGen's output with NEURON



To use the electrophysiological, compartmental neuron model for simulations with NEURON and with NeuGen, it is necessary to download and install an additional package of the ModelDB called Pyramidal Neuron Deep, Superficial; Aspiny, Stellate: Mainen/ Sejnoski 1996 (pat-demo.tar) for NEURON.