1 Main Page

GeNN is a software package to enable neuronal network simulations on NVIDIA GPUs by code generation. Models are defined in a simple C-style API and the code for running them on either GPU or CPU hardware is generated by GeNN. GeNN can also be used through external interfaces. Currently there are prototype interfaces for Spine↩ Creator and SpineML and for Brian2.

GeNN is currently developed and maintained by

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Note

This documentation is under construction. If you cannot find what you are looking for, please contact the project developers.

2 Installation

You can download GeNN either as a zip file of a stable release or a snapshot of the most recent stable version or the unstable development version using the Git version control system.

2.1 Downloading a release

Point your browser to https://github.com/genn-team/genn/releases and download a release from the list by clicking the relevant source code button. Note that GeNN is only distributed in the form of source code due to its code generation design. Binary distributions would not make sense in this framework and are not provided. After downloading continue to install GeNN as described in the install section below.

2.2 Obtaining a Git snapshot

If it is not yet installed on your system, download and install Git (http://git-scm.com/). Then clone the GeNN repository from Github

```
git clone https://github.com/genn-team/genn.git
```

The github url of GeNN in the command above can be copied from the HTTPS clone URL displayed on the GeNN Github page (https://github.com/genn-team/genn).

This will clone the entire repository, including all open branches. By default git will check out the master branch which contains the source version upon which the latest release is based. If you want the most recent (but unstable) development version (which may or may not be fully functional at any given time), checkout the development branch

```
git checkout development
```

There are other branches in the repository that are used for specific development purposes and are opened and closed without warning.

As an alternative to using git you can also download the full content of GeNN sources clicking on the "Download ZIP" button on the bottom right of the GeNN Github page (https://github.com/genn-team/genn).

2.3 Installing GeNN

Installing GeNN comprises a few simple steps to create the GeNN development environment.

(i) If you have downloaded a zip file, unpack GeNN.zip in a convenient location. Otherwise enter the directory where you downloaded the Git repository.

(ii) Define the environment variable "GENN_PATH" to point to the main GeNN directory, e.g. if you extracted/downloaded GeNN to /usr/local/GeNN, then you can add "export GENN_PATH=/usr/local/GeNN" to your login script (e.g. `.profile` or `.bashrc`. If you are using WINDOWS, the path should be a windows path as it will be interpreted by the Visual C++ compiler `cl`, and enciront variables are best set using `setx` in a Windows cmd window. To do so, open a Windows cmd window byt typing `cmd` in the search field of the start menu, followed by the `enter` key. In the `cmd` window type

```
setx GENN_PATH "C:\Users\me\GeNN"
```

where `C:\Users\me\GeNN` is the path to your GeNN directory.

(iii) Add $GENN_PATH/lib/bin to your PATH variable, e.g.

```
export PATH=$PATH:$GENN_PATH/lib/bin
```

in your login script, or in windows,

```
setx PATH=%PATH%;%GENN_PATH%/lib/bin
```

(iv) If you haven't installed CUDA on your machine, obtain a fresh installation of the NVIDIA CUDA toolkit from `https://developer.nvidia.com/cuda-downloads`

(v) Set the `CUDA_PATH` variable if it is not already set by the system, by putting

```
export CUDA_PATH=/usr/local/cuda
```

in your login script (or, if CUDA is installed in a non-standard location, the appropriate path to the main CUDA directory). For most people, this will be done by the CUDA install script and the default value of /usr/local/cuda is fine. In Windows, use `setx` to set this variable,

```
setx CUDA_PATH
```

This normally completes the installation.

Depending on the needs of your own projects, e.g., depencies on other libraries or non-standard installation paths of libraries used by GeNN, you may want to modify Makefile examples under `$GENN_PATH/userproject/xxx_project` and `$GENN_PATH/userproject/xxx_project/model` to add extra linker-, include- and compiler-flags on a per-project basis, or modify global default flags in $GENN_PATH/lib/include/makefile_common.mk.

For all makefiles there are separate makefiles for Unix-style operating systems (GNUmakefile) such as Linux or MacOS and for Windows (WINmakefile).

If you are using GeNN in Windows, you can use make.bat to build examples which will attempt to setup your development environment by executing `vcvarsall.bat` which is part of every Visual Studio distribution. For this to work properly, GeNN must be able to locate the Visual Studio install directory, which should be contained in the `VS_PATH` environment variable. You can set this variable by hand if it is not already set by the Visual C++ installer by typing

```
setx VS_PATH "C:\Program Files (x86)\Microsoft Visual Studio 10.0"
```

Note

- The exact path and name of Visual C++ installations will vary between systems.
- Double quotation marks like in the above example are necessary whenever a path contains spaces.

GeNN also has experimental CYGWIN support. However, with the introduction of native Windows support in GeNN 1.1.3, this is not being developed further and should be considered as deprecated.

2.4 Testing Your Installation

To test your installation, follow the example in the Quickstart section.

3 Quickstart

GeNN is based on the idea of code generation for the involved GPU or CPU simulation code for neuronal network models but leaves a lot of freedom how to use the generated code in the final application. To facilitate the use of Ge↩ NN on the background of this philosophy, it comes with a number of complete examples containing both the model description code that is used by GeNN for code generation and the "user side code" to run the generated model and safe the results. Running these complete examples should be achievable in a few minutes. The necessary steps are described below.

3.1 Running an Example Model in Unix

In order to get a quick start and run a provided model, open a shell, navigate to `GeNN/tools` and type

```
make
```

This will compile additional tools for creating and running example projects. For a first complete test, the system is best used with a full driver program such as in the Insect Olfaction Model example:

```
tools/generate_run <0(CPU)/1(GPU)> <#AL> <#KC> <#LH> <#DN> <gscale> <OUTNAME> <MODEL> <DEBUG> <FTYPE>
       <REUSE>.
```

To compile `generate_run.cc`, navigate to the `userproject/MBody1_project` directory and type

```
make all
```

This will generate an executable that you can invoke with, e.g.,

```
./generate_run 1 100 1000 20 100 0.0025 test1 MBody1 0 FLOAT 0
```

which would generate and simulate a model of the locust olfactory system with 100 projection neurons, 1000 Kenyon cells, 20 lateral horn interneurons and 100 output neurons n the mushroom body lobes.

The tool generate_run will generate connectivity matrices for the model `MBody1` and store them into files, compile and run the model on the GPU using these files as inputs and output the resulting spiking activity. To fix the GPU used, replace the first argument `1` with the device number of the desired GPU plus 2, e.g., `2` for GPU 0. All input and output files will be prefixed with `test1` and will be created in a sub-directory with the name `test1_output`. The third to last parameter `0` will switch the debugging mode off, `1` would switch it on. More about debugging in the debugging section . The parameter `FLOAT` will run the model in float (single precision floating point), using `DOU↩ BLE` would use double precision. The last parameter regulates whether previously generated files for connectivity and input should be reused (1) or files should be generated anew (0).

The MBody1 example is already a highly integrated example that showcases many of the features of GeNN and how to program the user-side code for a GeNN application. More details in the User Manual

3.2 Running an Example Model in Windows

All interaction with GeNN programs are command-line based and hence are executed within a `cmd` window. Open a `cmd` window and navigate to the `userprojects\tools` directory.

```
cd %GENN_PATH%\userprojects\tools
```

Then type

```
make.bat all
```

to compile a number of tools that are used by the example projects to generate connectivity and inputs to model networks.

The navigate to the `MBody1_project` directory.

```
cd ..\MBody1_project
```

By typing

```
make.bat all
```

you can compile the `generate_run` engine that allows to run a Insect Olfaction Model model of the insect mushroom body:

```
tools/generate_run <0(CPU)/1(GPU)> <#AL> <#KC> <#LH> <#DN> <gscale> <OUTNAME> <MODEL> <DEBUG> <FTYPE>
       <REUSE>.
```

To invoke `generate_run.exe` type, e.g.,

```
generate_run.exe 1 100 1000 20 100 0.0025 test1 MBody1 0 FLOAT 0
```

which would generate and simulate a model of the locust olfactory system with 100 projection neurons, 1000 Kenyon cells, 20 lateral horn interneurons and 100 output neurons n the mushroom body lobes.

The tool `generate_run.exe` will generate connectivity matrices for the model `MBody1` and store them into files, compile and run the model on an automatically chosen GPU using these files as inputs and output the resulting spiking activity. To fix the GPU used, replace the first argument `1` with the device number of the desired GPU plus 2, e.g., `2` for GPU 0. All input and output files will be prefixed with `test1` and will be created in a sub-directory with the name `test1_output`. The last parameter `0` will switch the debugging mode off, `1` would switch it on. More about debugging in the debugging section .

The MBody1 example is already a highly integrated example that showcases many of the features of GeNN and how to program the user-side code for a GeNN application. More details in the User Manual

3.3 How to use GeNN for New Projects

Creating and running projects in GeNN involves a few steps ranging from defining the fundamentals of the model, inputs to the model, dteails of the model like specific connectivity matrices or initial values, running the model and analyzing or saving the data.

The most common way to use GeNN is to create or modify a program such as `userproject/MBody1_project/generate_run.cc` that wraps around other programs that are used for each of the necessary steps listed above. In more detail, what `generate_run` and similar programs do is:

1. To use other tools (programs) to generate connectivity matrices and store them into files.
2. To build the source code of a model simulation using GeNN. In the example of the MBody1_project this entails writing neuron numbers into `userproject/include/sizes.h`, and executing

   ```
   buildmodel.sh MBody1 [DEBUG OFF/ON]
   ```

   The `buildmodel.sh` script compiles the installed GeNN code generator in conjunction with the user-provided model description (see below), in this example `model/MBody1.cc`. It then executes the GeNN code generator to generate the complete model simulation code for the MBody1 model.

3. To compile the generated model code, that can be found in `model/MBody1_CODE/` by invoking `make clean && make` in the `model` directory. It is at this stage that GeNN generated model simulation code is combined with user-side run-time code, in this example `classol_sim.cu` (classify-olfaction-simulation) which uses the `map_classol` (map-neuron-based-classifier-olfaction) class.
4. To finally run the resulting stand-alone simulator executable, in the MBody1 example `classol_sim` in the `model` directory.

The `generate_run` tool is only a suggested usage scenario of GeNN. Alternatively, users can manually execute the four steps above or integrate GeNN with development environments of their own choice.

Note

> The usage scenario described was made explicit for Unix environments. In Windows the setup is essentially the same except for the usual operating system dependent syntax differences, e.g. the build script is named buildmodel.bat, compilation of the generated model simulator would be `make.bat clean && make.bat all`, or, `nmake /f WINmakefile clean && nmake /f WINmakefile all`, and the resulting executable would be named `classol_sim.exe`.

GeNN comes with several example projects which showcase how to use its features. The MBody1 example discussed above is one of the many provided examples that are described in more detail in Example projects.

3.4 Defining a New Model in GeNN

According to the workflow outlined above, there are several steps to be completed to define a neuronal network model.

1. The neuronal network of interest is defined in a model definitoin file, e.g. `Example1.cc`.

   Note

   > GeNN follows a convention in which C/C++ files end with `.cc` and the model definition file will only be recognizd by the `buildmodel.sh` or `buildmodel.bat` scripts if it follows this convention and ends on `.cc`.

2. Within the the model definition file `Example1.cc`, the following tasks need to be completed:

   a) The time step `DT` needs to be defined, e.g.

   ```
   #define DT 0.1
   ```

   Note

   > All provided examples and pre-defined model elements in GeNN work with units of mV, ms, nF and muS. However, the choice of units is entirely left to the user if custom model elements are used.

   b) The GeNN files `modelSpec.h` and `modelSpec.cc` need to be included,

   ```
   #include "modelSpec.h"
   #include "modelSpec.cc"
   ```

   c) The values for initial variables and parameters for neuron and synapse populations need to be defined, e.g.

   ```
   float myPOI_p[4]= {
     0.1,        // 0 - firing rate
     2.5,        // 1 - refratory period
     20.0,       // 2 - Vspike
     -60.0       // 3 - Vrest
   };
   ```

   would define the (homogeneous) parameters for a population of Poisson neurons.

Note

The number of required parameters and their meaning is defined by the neuron or synapse type. Refer to the User Manual for details.
If heterogeneous parameter values are needed for any particular population of neurons (synapses), a new neuron (synapse) type needs to be defined in which these parameters are defined as variables rather than parameters. See the User Manual for how to define new neuron (synapse) types.

d) the actual network needs to be defined in the form of a function `modelDefinition`, i.e.

```
void modelDefinition(NNmodel &model);
```

Note

The name `modelDefinition` and its parameter of type `NNmodel&` are fixed and cannot be changed if GeNN is to recognise it as a model definition.

`MBody1.cc` shows a typical example of a model definition function. In its core tt contains calls to `model.addNeuronPopulation` and `model.addSynapsePopulation` to build up the network. For a full range of options for defining a network, refer to the User Manual.

3. The programmer defines her own "user-side" modeling code similar to the code in `userproject/MBody1_project/model/map_classol.*` and `userproject/MBody1_project/model/classol_sim.*`. In this code,

a) she defines the connectivity matrices between neuron groups. (In the MBody1 example those are read from files). Refer to the User Manual for the required format of connectivity matrices for dense or sparse connectivities.

b) she defines input patterns (e.g. for Poisson neurons like in the MBody1 example) or individual initial values for neuron and/or synapse variables.

Note

The initial values given in the `modelDefinition` are automatically applied homogeneously to every individual neuron or synapse in each of the neuron or synapse groups.

c) she uses `stepTimeGPU(...);` to run one time step on the GPU or `stepTimeCPU(...);` to run one on the CPU. (both GPU and CPU versions are always compiled).

Note

However, mixing CPU and GPU execution does not make too much sense. Among pother things, The CPU version uses the same host side memory whereto results from the GPU version are copied, which would lead to collisions between what is calculated on the CPU and on the GPU (see next point). However, in certain circumstances, expert users may want to split the calculation and calculate parts (e.g. neurons) on the GPU and parts (e.g. synapses) on the CPU. In such cases the fundamental kernel and function calls contained in `stepTimeXXX` need to be used and appropriate copies of the data from teh CPU to the GPU and vice versa need to be performed.

d) she uses functions like `copyStateFromDevice()` etc to transfer the results from GPU calculations to the main memory of the host computer for further processing.

e) she analyzes the results. In the most simple case this could just be writing the relevant data to output files.

4 Examples

GeNN comes with a number of complete examples. At the moment, there are seven such example projects provided with GeNN.

4.1 Single compartment Izhikevich neuron(s)

This is a minimal example, with only one neuron population (with more or less neurons depending on the command line, but without any synapses). The neurons are Izhikevich neurons [1] with homogeneous parameters across the neuron population. The model can be used by navigating to the `userproject/OneComp_project` directory and entering a command line

```
./generate_run <CPU/GPU> <n> <OUTNAME> <MODEL> <DEBUG> <FTYPE> <REUSE>.
```

All parameters are mandatory and signify:

- `CPU/GPU`: Choose whether to run the simulation on CPU (`0`) or GPU (`1`).
- `n`: Number of neurons
- `OUTNAME`: The base name of the output location and output files
- `MODEL`: The name of the model to execute, as provided this would be `OneComp`
- `DEBUG`: Whether to start in debug mode (1) or normally (0)
- `FTYPE`: Floating point type `FLOAT` or `DOUBLE`
- `REUSE`: whether to re-use input files

This would create `n` tonic spiking Izhikevich neuron(s) with no connectivity, receiving a constant, identical 4 nA input current.

For example, navigate to the `userproject/OneComp_project` directory and type

```
make all
./generate_run 1 1 Outdir OneComp_sim OneComp 0 FLOAT 0
```

to model a single neuron which output will be saved in the `Outdir_output` directory.

4.2 Izhikevich Network Driven by Poisson Input Spike Trains:

In this example project there is again a pool of non-connected Izhikevich model neurons [1] that are connected to a pool of Poisson input neurons with a fixed probability.

The model can be compiled by navigating to the `userproject\PoissonIzh_project` directory and typing

```
make all
```

Subsequently it can be invoked using the following command line

```
./generate_run <CPU/GPU> <#POISSON> <#IZHIKEVICH> <PCONN> <GSCALE> <OUTNAME> <MODEL> <DEBUG
       OFF/ON> <FTYPE> <REUSE>
```

All parameters are mandatory and signify:

- `CPU/GPU`: Choose whether to run the simulation on CPU (`0`) or GPU (`1`).
- `#POISSON`: Number of Poisson input neurons
- `#IZHIKEVICH`: Number of Izhikevich neurons
- `PCONN`: Probability of connections

- OUTNAME: The base name of the output location and output files
- MODEL: The name of the model to execute, as provided this would be PoissonIzh
- DEBUG: Whether to start in debug mode (1) or normally (0)
- FTYPE: Floating point type FLOAT or DOUBLE
- REUSE: whether to re-use input files

For example, navigate to the userproject/PoissonIzh_project directory and type

```
./generate_run 1 100 10 0.5 2 Outdir PoissonIzh 0 DOUBLE 0
```

This will generate a network of 100 Poisson neurons connected to 10 Izhikevich neurons with a 0.5 probability. The same example network can be used with sparse connectivity (i.e. sparse matrix representations for the connectivity within GeNN) by using the keyword SPARSE in the addSynapsePopulation instead of DENSE in PoissonIzh.cc and by uncommenting the lines following the comment //SPARSE CONNECTIVITY in the file PoissonIzh.cu. In this example the model would be simulated with double precision variables and input files and connectivity would not be reused from earlier runs.

4.3 Pulse-coupled Izhikevich Network

This example model is inspired by simple thalamo-cortical network of Izhikevich [1] with an excitatory and an inhibitory population of spiking neurons that are randomly connected.

The model can be built by navigating to the userproject/Izh_Sparse_project directory and typing

```
make all
```

It can then be used as

```
./generate_run <CPU/GPU> <#N> <#CONN> <GSCALE> <OUTNAME> <MODEL> <DEBUG OFF/ON>
 <FTYPE> <REUSE>
```

All parameters are mandatory and signify:

- CPU/GPU: Choose whether to run the simulation on CPU (0) or GPU (1).
- #N: Number of neurons
- #CONN: Number of connections per neuron
- 'GSCALE': General scaling of synaptic conductances
- OUTNAME: The base name of the output location and output files
- MODEL: The name of the model to execute, as provided this would be Izh_sparse
- DEBUG: Whether to start in debug mode (1) or normally (0)
- FTYPE: Floating point type FLOAT or DOUBLE
- REUSE: whether to re-use input files

The model creates a pulse-coupled network [1] with 80% excitatory 20% inhibitory neurons, each connecting to #CONN neurons using the sparse matrix connectivity methods of GeNN.

For example, typing

```
./tools/generate_izhikevich_network_run 1 10000 1000 1 Outdir Izh_sparse 0 FLOAT 0
```

generates a random network of 8000 excitatory and 2000 inhibitory neurons which each have 1000 outgoing synapses to randomly chosen post-synaptic target neurons. The synapses are of a simple pulse-coupling type. The results of the simulation are saved in the directory `Outdir_output`, debugging is switched off, and the connectivity is generated afresh (rather than being read from existing files).

Note

If connectivity were to be read from files, the connectivity files would have to be in the `inputfiles` subdirectory and be named according to the names of the synapse populations involved, e.g., `gIzh_sparse↩ _ee` (<variable name>="">=`g` <model name>="">=`Izh_sparse` `_`<synapse population>=`_ee`). These name conventions are not part of the core GeNN definitions and it is the privilege (or burden) of the user to find their own in their own versions of `generate_XXX_run`.

4.4 Izhikevich network with delayed synapses

This example project demonstrates the feature of synaptic delays in GeNN. It creates a network of three Izhikevich neuron groups, connected all-to-all with short, medium and long delay synapse groups. Neurons in the output group only spike if they are simultaneously innervated by the input neurons, via synapses with long delay, and the interneurons, via synapses with shorter delay.

To run this example project, navigate to `userproject/SynDelay_project` and type, e.g.,

```
buildmodel SynDelay
make clean && make
./bin/release/syn_delay 1 output
```

4.5 Insect Olfaction Model

This project implements the insect olfaction model by Nowotny et al. [2] that demonstrates self-organized clustering of odours in a simulation of the insect antennal lobe and mushroom body. As provided the model works with conductance based Hodgkin-Huxley neurons [4] and several different synapse types, conductance based (but pulse-coupled) excitatory synapses, graded inhibitory synapses and synapses with a type of STDP rule.

To explore the model navigate to `userproject/MBody1_project/` and type

```
make all
./generate_run
```

This will show you the command line parameters that are needed,

```
tools/generate_run <CPU/GPU> <#AL> <#KC> <#LHI> <#DN> <GSCALE> <OUTNAME> <MODEL> <DEBUG> <FTYPE> <
      REUSE>
```

All parameters are mandatory and signify:

- `CPU/GPU`: Choose whether to run the simulation on CPU (`0`) or GPU (`1`).
- `#AL`: Number of neurons in the antennal lobe (AL), the input neurons to this model
- `#KC`: Number of Kenyon cells (KC) in the "hidden layer"

- #LH: Number of lateral horn interneurons, implementing gain control
- #DN: Number of decision neurons (DN) in the output layer
- GSCALE: A general rescaling factor for snaptic strength
- OUTNAME: The base name of the output location and output files
- MODEL: The name of the model to execute, as provided this would be MBody1
- DEBUG: Whether to start in debug mode (1) or normally (0)
- FTYPE: Floating point type FLOAT or DOUBLE
- REUSE: whether to re-use input files

The tool generate_run will generate connectivity files for the model MBody1, compile this model for the CPU and GPU and execute it. The command line parameters are the numbers of neurons in the different neuropils of the model and an overall synaptic strength scaling factor. A typical call would be, e.g.,

```
../../tools/generate_run 1 100 1000 20 100 0.0025 test1 MBody1 0 FLOAT 0
```

which would generate a model, and run it on the GPU (first parameter), with 100 antennal lobe neurons, 1000 mushroom body Kenyon cells, 20 lateral horn interneurons and 100 mushroom body output neurons. All output files will be prefixed with test1 and stored in test1_output. The model that is run is defined in model/↩ MBody1.cc, debugging is switched off, the model would be simulated using float (single precision floating point) variables and parameters and the connectivity and input would be generated afresh for this run.

As provided, the model outputs a file test1.out.st that contains the spiking activity observed in the simulation, where there are two columns in this ASCII file, the first one containing the time of a spike and the second one the ID of the neuron that spiked. Users of matlab can use the scripts in the matlab directory to plot the results of a simulation. For more about the model itself and the scientific insights gained from it see [2].

4.6 Insect Olfaction Model with User-Defined Types

This examples recapitulates the exact same model as Insect Olfaction Model above but with user-defined model types for neurons and synapses throughout. It is run the same way as Insect Olfaction Model, e.g.

```
../../tools/generate_run 1 100 1000 20 100 0.0025 test1 MBody_userdef 0 FLOAT 0
```

But the way user-defined types are used should be very instructive to advanced users wishing to do the same with their models.

5 Release Notes for GeNN v2.0

Version 2.0 of GeNN comes with a lot of improvements and added features, some of which have necessitated some changes to the structure of parameter arrays among others.

5.1 User Side Changes

1. Users are now required to call "initGeNN()" in the model definition function before adding any populations to the neuronal network model.
2. glbscnt is now call glbSpkCnt for consistency with glbSpkEvntCnt.

3. There is no longer a privileged parameter `Epre`. Spike type events are now defined by a code string `spkEvntThreshold`, the same way proper spikes are. The only difference is that Spike type events are specific to a synapse type rather than a neuron type.

4. The function setSynapseG has been deprecated. In a `GLOBALG` scenario, the variables of a synapse group are set to the initial values provided in modeldefinition.

5. Due to the split of synaptic models into weightUpdateModel and postSynModel, the parameter arrays used during model definition need to be carefully split as well so that each side gets the right parameters. For example, previously

```
float myPNKC_p[3]= {
  0.0,          // 0 - Erev: Reversal potential
  -20.0,        // 1 - Epre: Presynaptic threshold potential
  1.0           // 2 - tau_S: decay time constant for S [ms]
};
```

would define the parameter array of three parameters, `Erev`, `Epre`, and `tau_S` for a synapse of type `NSYNAPSE`. This now needs to be "split" into

```
float *myPNKC_p= NULL;
float postExpPNKC[2]={
  1.0,           // 0 - tau_S: decay time constant for S [ms]
  0.0            // 1 - Erev: Reversal potential
};
```

i.e. parameters `Erev` and `tau_S` are moved to the post-synaptic model and its parameter array of two parameters. `Epre` is discontinued as a parameter for `NSYNAPSE`. As a consequence the weightupdate model of `NSYNAPSE` has no parameters and one can pass `NULL` for the parameter array in `addSynapsePopulation`.
The correct parameter lists for all defined neuron and synapse model types are listed in the User Manual.

Note

If the parameters are not redefined appropriately this will lead to uncontrolled behaviour of models and likely to sgementation faults and crashes.

6. Advanced users can now define variables as type "scalar" when introducing new neuron or synapse types. This will at the code generation stage be translated to the model's floating point type (ftype), `float` or `double`. This works for defining variables as well as in all code snippets. Users can also use the expressions "SCALAR_MAX" and "SCALAR_MIN" for "FLT_MIN", "FLT_MAX", "DBL_MIN" and "DBL_MAX", respectively. Corresponding definitions of `scalar`, `SCALAR_MIN` and `SCALAR_MAX` are also available for user-side code whenever the code-generated file `runner.cc` has been included.

7. The example projects have been re-organized so that wrapper scripts of the `generate_run` type are now all located together with the models they run instead of in a common `tools` directory. Generally the structure now is that each example project contains the wrapper script `generate_run` and a `model` subdirectory which contains the model description file and the user side code complete with Makefiles for Unix and Windows operating systems. The generated code will be deposited in the `model` subdirectory in its own `modelname_CODE` folder. Simulation results will always be deposited in a new sub-folder of the main project directory.

8. The `addSynapsePopulation(...)` function has now more mandatory parameters relating to the introduction of separate weightupdate models (pre-synaptic models) and postynaptic models. The correct syntax for the `addSynapsePopulation(...)` can be found with detailed explanations in teh User Manual.

9. We have introduced a simple performance profiling method that users can employ to get an overview over the differential use of time by different kernels. To enable the timers in GeNN generated code, one needs to declare

```
networkmodel.setTiming(TRUE);
```

This will make available and operate GPU-side cudeEvent based timers whose cumulative value can be found in the double precision variables `neuron_tme`, `synapse_tme` and `learning_tme`. They measure the accumulated time that has been spent calculating the neuron kernel, synapse kernel and learning kernel, respectively. CPU-side timers for the simulation functions are also available and their cumulative values can be obtained through

```
float x= sdkGetTimerValue(&neuron_timer);
float y= sdkGetTimerValue(&synapse_timer);
float z= sdkGetTimerValue(&learning_timer);
```

The Insect Olfaction Model example shows how these can be used in the user-side code. To enable timing profiling in this example, simply enable it for GeNN:

```
model.setTiming(TRUE);
```

in `MBody1.cc`'s `modelDefinition` function and define the macro `TIMING` in `classol_sim.h`

```
#define TIMING
```

This will have the effect that timing information is output into `OUTNAME_output/OUTNAME.timingprofile`.

5.2 Developer Side Changes

1. `allocateSparseArrays()` has been changed to take the number of connections, connN, as an argument rather than expecting it to have been set in the Connetion struct before the function is called as was the arrangement previously.
2. For the case of sparse connectivity, there is now a reverse mapping implemented with revers index arrays and a remap array that points to the original positions of variable values in teh forward array. By this mechanism, revers lookups from post to pre synaptic indices are possible but value changes in the sparse array values do only need to be done once.
3. SpkEvnt code is no longer generated whenever it is not actually used. That is also true on a somewhat finer granularity where variable queues for synapse delays are only maintained if the corresponding variables are used in synaptic code. True spikes on the other hand are always detected in case the user is interested in them.

6 User Manual

6.1 Contents

6.2 Introduction

GeNN is a software library for facilitating the simulation of neuronal network models on NVIDIA CUDA enabled GPU hardware. It was designed with computational neuroscience models in mind rather than artificial neural networks. The main philosophy of GeNN is two-fold:

1. GeNN relies heavily on code generation to make it very flexible and to allow adjusting simulation code to the model of interest and the GPU hardware that is detected at compile time.

2. GeNN is lightweight in that it provides code for running models of neuronal networks on GPU hardware but it leaves it to the user to write a final simulation engine. It so allows maximal flexibility to the user who can use any of the provided code but can fully choose, inspect, extend or otherwise modify the generated code. She can also introduce her own optimisations and in particular control the data flow from and to the GPU in any desired granularity.

This manual gives an overview of how to use GeNN for a novice user and tries to lead the user to more expert use later on. With this we jump right in.

6.3 Defining a network model

A network model is defined by the user by providing the function

```
void modelDefinition(NNmodel &model)
```

in a separate file with name `name.cc`, where `name` is the name of the model network under consideration. In this function, the following tasks must be completed:

1. The name of the model must be defined:

   ```
   model.setName("MyModel");
   ```

2. Neuron populations (at least one) must be added (see Defining neuron populations). The user may add as many neuron populations as she wishes. If resources run out, there will not be a warning but GeNN will fail. However, before this breaking point is reached, GeNN will make all necessary efforts in terms of block size optimisation to accommodate the defined models. All populations should have a unique name.
3. Synapse populations (zero or more) can be added (see Defining synapse populations). Again, the number of synaptic connection populations is unlimited other than by resources.

Note

GeNN uses the convention where C/C++ files end in `.cc`. If this is not adhered to the build script `buildmodel.sh` will not recognise the model definition file.

6.3.1 Defining neuron populations

Neuron populations are added using the function

```
model.addNeuronPopulation(name, n, TYPE, para, ini);
```

where the arguments are:

- `const char* name`: Name of the neuron population
- `int n`: number of neurons in the population
- `int TYPE`: Type of the neurons, refers to either a standard type (see Neuron models) or user-defined type
- `double *para`: Parameters of this neuron type
- `double *ini`: Initial values for variables of this neuron type

The user may add as many neuron populations as the model necessitates. They should all have unique names. The possible values for the arguments, predefined models and their parameters and initial values are detailed Neuron models below.

6.3.2 Defining synapse populations

Synapse populations are added with the command

```
model.addSynapsePopulation("name", sType, sConn, gType, delay, postSyn, "preName", "
      postName", sIni, sParam, postSynIni, postSynParam);
```

where the arguments are

- `const char*` name: The name of the synapse population
- `int sType`: The type of synapse to be added. See Built-in Models below for the available predefined synapse types.
- `int sConn`: The type of synaptic connectivity. the options currently are "ALLTOALL", "DENSE", "SPARSE" (see Connectivity types)
- `int gType`: The way how the synaptic conductivity g will be defined. Options are "INDIVIDUALG", "GL↩ OBALG", "INDIVIDUALID". For their meaning, see subsect33 below.
- `int delay`: Synaptic delay (in multiples of the simulation time step `DT`).
- `int postSyn`: Postsynaptic integration method. See sect_postsyn for predefined types.
- `char* preName`: Name of the (existing!) pre-synaptic neuron population.
- `char* postName`: Name of the (existing!) post-synaptic neuron population.
- `double *sIni`: A C-array of doubles containing initial values for the (pre-) synaptic variables.
- `double *sParam`: A C-array of double precision that contains parameter values (common to all synapses of the population) which will be used for the defined synapses. The array must contain the right number of parameters in the right order for the chosen synapse type. If too few, segmentation faults will occur, if too many, excess will be ignored. For pre-defined synapse types the required parameters and their meaning are listed in NSYNAPSE (No Learning) below.
- `double * psIni`: A C-array of double precision numbers containing initial values for the post-synaptic model variables
- `double * psPara`: A C-array of double precision numbers containing parameters fo the post-snaptic model.

  Note

  > If the synapse conductance definition type is "GLOBALG" then the global value of the synapse conductances is taken from the initial value provided in `sINI`. (The function setSynapseG() from earlier versions of GeNN has been deprecated).

  Synaptic updates can occur per "true" spike (i.e at one point per spike, e.g. after a threshold was crossed) or for all "spike type events" (e.g. all points above a given threshold). This is defined within each given synapse type.

6.4 Neuron models

There is a number of predefined models which can be chosen in the `addNeuronGroup(...)` function by their unique cardinal number, starting from 0. For convenience, C variables with readable names are predefined

- 0: MAPNEURON
- 1: POISSONNEURON

- 2: TRAUBMILES
- 3: IZHIKEVICH
- 4: IZHIKEVICH_V

Note

Ist is best practice to not depend on the unique cardinal numbers but use predefined names. While it is not intended that the numbers will change the unique names are guaranteed to work in all future versions of GeNN.

6.4.1 MAPNEURON (Map Neurons)

The MAPNEURON type is a map based neuron model based on [3] but in the 1-dimensional map form used in [2] :

$$V(t+\Delta t) = \begin{cases} V_{\rm spike}\left(\frac{\alpha V_{\rm spike}}{V_{\rm spike}-V(t)\beta I_{\rm syn}}+y\right) & V(t) \leq 0 \\ V_{\rm spike}\left(\alpha+y\right) & V(t) \leq V_{\rm spike}\left(\alpha+y\right) \;\&\; V(t-\Delta t) \leq 0 \\ -V_{\rm spike} & \text{otherwise} \end{cases}$$

Note

The `MAPNEURON` type only works as intended for the single time step size of `DT`= 0.5.

The `MAPNEURON` type has 2 variables:

- `V` - the membrane potential
- `preV` - the membrane potential at the previous time step

and it has 4 parameters:

- `Vspike` - determines the amplitude of spikes, typically -60mV
- `alpha` - determines the shape of the iteration function, typically α= 3
- `y` - "shift / excitation" parameter, also determines the iteration function,originally, y= -2.468
- `beta` - roughly speaking equivalent to the input resistance, i.e. it regulates the scale of the input into the neuron, typically β= 2.64 $\mathrm{M}\Omega$.

Note

The initial values array for the `MAPNEURON` type needs two entries for `V` and `Vpre` and the parameter array needs four entries for `Vspike`, `alpha`, `y` and `beta`, *in that order.*

6.4.2 POISSONNEURON (Poisson Neurons)

Poisson neurons have constant membrane potential (`Vrest`) unless they are activated randomly to the `Vspike` value if (t- `SpikeTime`) > `trefract`.

It has 3 variables:

- `V` - Membrane potential
- `Seed` - Seed for random number generation
- `SpikeTime` - Time at which the neuron spiked for the last time

and 4 parameters:

- `therate` - Firing rate
- `trefract` - Refractory period
- `Vspike` - Membrane potential at spike (mV)
- `Vrest` - Membrane potential at rest (mV)

Note

The initial values array for the `POISSONNEURON` type needs three entries for `V`, `Seed` and `SpikeTime` and the parameter array needs four entries for `therate`, `trefract`, `Vspike` and `Vrest`, *in that order*. Internally, GeNN uses a linear approximation for the probability of firing a spike in a given time step of size `DT`, i.e. the probability of firing is `therate` times `DT`: $p = \lambda \Delta t$. This approximation is usually very good, especially for typical, quite small time steps and moderate firing rates. However, it is worth noting that the approximation becomes poor for very high firing rates and large time steps. An unrelated problem may occur with very low firing rates and small time steps. In that case it can occur that the firing probability is so small that the granularity of the 64 bit integer based random number generator begins to show. The effect manifests itself in that small changes in the firing rate do not seem to have an effect on the behaviour of the Poisson neurons because the numbers are so small that only if the random number is identical 0 a spike will be triggered.

6.4.3 TRAUBMILES (Hodgkin-Huxley neurons with Traub & Miles algorithm)

This conductance based model has been taken from Traub1991 and can be described by the equations:

$$\begin{aligned}
C\frac{dV}{dt} &= -I_{\mathrm{Na}} - I_K - I_{\mathrm{leak}} - I_M - I_{i,DC} - I_{i,\mathrm{syn}} - I_i, \\
I_{\mathrm{Na}}(t) &= g_{\mathrm{Na}} m_i(t)^3 h_i(t)(V_i(t) - E_{\mathrm{Na}}) \\
I_{\mathrm{K}}(t) &= g_{\mathrm{K}} n_i(t)^4 (V_i(t) - E_{\mathrm{K}}) \\
\frac{dy(t)}{dt} &= \alpha_y(V(t))(1 - y(t)) - \beta_y(V(t))y(t),
\end{aligned}$$

where $y_i = m, h, n$, and

$$\begin{aligned}
\alpha_n &= 0.032(-50 - V)/\big(\exp((-50 - V)/5) - 1\big) \\
\beta_n &= 0.5\exp((-55 - V)/40) \\
\alpha_m &= 0.32(-52 - V)/\big(\exp((-52 - V)/4) - 1\big) \\
\beta_m &= 0.28(25 + V)/\big(\exp((25 + V)/5) - 1\big) \\
\alpha_h &= 0.128\exp((-48 - V)/18) \\
\beta_h &= 4/\big(\exp((-25 - V)/5) + 1\big).
\end{aligned}$$

and typical parameters are $C = 0.143$ nF, $g_{\mathrm{leak}} = 0.02672\ \mu$S, $E_{\mathrm{leak}} = -63.563$ mV, $g_{\mathrm{Na}} = 7.15\ \mu$S, $E_{\mathrm{Na}} = 50$ mV, $g_{\mathrm{K}} = 1.43\ \mu$S, $E_{\mathrm{K}} = -95$ mV.

It has 4 variables:

- `V` - membrane potential E
- `m` - probability for Na channel activation m
- `h` - probability for not Na channel blocking h
- `n` - probability for K channel activation n

and 7 parameters:

- `gNa` - Na conductance in 1/(mOhms * cm^2)

- ENa - Na equi potential in mV
- gK - K conductance in 1/(mOhms $*$ cm^2)
- EK - K equi potential in mV
- gl - Leak conductance in 1/(mOhms $*$ cm^2)
- El - Leak equi potential in mV
- Cmem - Membrane capacity density in muF/cm^2

Note

Internally, the ordinary differential equations defining the model are integrated with a linear Euler algorithm and GeNN integrates 25 internal time steps for each neuron for each network time step. I.e., if the network is simulated at DT= 0.1 ms, then the neurons are integrated with a linear Euler algorithm with lDT= 0.004 ms.

6.4.4 IZHIKEVICH (Izhikevich neurons with fixed parameters)

This is the Izhikevich model with fixed parameters [1]. It is usually described as

$$\begin{aligned}\frac{dV}{dt} &= 0.04V^2 + 5V + 140 - U + I, \\ \frac{dU}{dt} &= a(bV - U),\end{aligned}$$

I is an external input current and the voltage V is reset to parameter c and U incremented by parameter d, whenever V $>=$ 30 mV. This is paired with a particular integration procedure of two 0.5 ms Euler time steps for the V equation followed by one 1 ms time step of the U equation. Because of its popularity we provide this model in this form here event though due to the details of the usual implementation it is strictly speaking inconsistent with the displayed equations.

Variables are:

- V - Membrane potential
- U - Membrane recovery variable

Parameters are:

- a - time scale of U
- b - sensitivity of U
- c - after-spike reset value of V
- d - after-spike reset value of U

6.4.5 IZHIKEVICH_V (Izhikevich neurons with variable parameters)

This is the same model as IZHIKEVICH (Izhikevich neurons with fixed parameters) IZHIKEVICH but parameters are defined as "variables" in order to allow users to provide individual values for each individual neuron instead of fixed values for all neurons across the population.

Accordingly, the model has the Variables:

- V - Membrane potential
- U - Membrane recovery variable

- a - time scale of U
- b - sensitivity of U
- c - after-spike reset value of V
- d - after-spike reset value of U

and no parameters.

6.4.6 Defining your own neuron type

In order to define a new neuron type for use in a GeNN application, it is necessary to populate an object of class neuronModel and append it to the global vector nModels. The neuronModel class has several data members that make up the full description of the neuron model:

- simCode of type string: This needs to be assigned a C++ string that contains the code for executing the integration of the model for one time step. Within this code string, variables need to be referred to by , where NAME is the name of the variable as defined in the vector varNames. The code may refer to the predefined primitives DT for the time step size and Isyn for the total incoming synaptic current.
  Example:

  ```
  neuronModel model;
  model.simCode=String("$(V)+= (-$(a)$(V)+$(Isyn))*DT;");
  ```

  would implement a leaky integrator $\frac{dV}{dt} = -aV + I_{\mathrm{syn}}$.

- varNames of type vector<string>: This vector needs to be filled with the names of variables that make up the neuron state. The variables defined here as NAME can then be used in the syntax in the code string.
  Example:

  ```
  model.varNames.push_back(String("V"));
  ```

  would add the variable V as needed by the code string in the example above.

- varTypes of type vector<string>: This vector needs to be filled with the variable type (e.g. "float", "double", etc) for the variables defined in varNames. Types and variables are matched to each other by position in the respective vectors.
  Example:

  ```
  model.varTypes.push_back(String("float"));
  ```

  would designate the variable V to be of type float.

  Note

  Variable names and variable types are matched by their position in the corresponding arrays var↩ Names and varTypes, i.e. the 0th entry of varNames will have the type stored in the 0th entry of varTypes and so on.

- pNames of type vector<string>: This vector will contain the names of parameters relevant to the model. If defined as NAME here, they can then be referenced as in the code string. The length of this vector determines the expected number of parameters in the initialisation of the neuron model. Parameters are currently assumed to be always of type double.

  ```
  model.pNames.push_back(String("a"));
  ```

  stores the parameter a needed in the code example above.

- `dpNames` of type `vector<string>`: Names of "dependent parameters". Dependent parameters are a mechanism for enhanced efficiency when running neuron models. If parameters with model-side meaning, such as time constants or conductances always appear in a certain combination in the model, then it is more efficient to pre-compute this combination and define it as a dependent parameter. This vector contains the names of such dependent parameters.

- `thresholdConditionCode` of type `vector<string>` (if applicable): Condition for true spike detection.

For example, if in the example above the original model had been $\frac{dV}{dt} = -g/CV + I_{\rm syn}$. Then one could define the code string and parameters as

```
model.simCode=String("$(V)+= (-$(a)$(V)+$(Isyn))*DT;");
model.varNames.push_back(String("V"));
model.varTypes.push_back(String("float"));
model.pNames.push_back(String("g"));
model.pNames.push_back(String("C"));
model.dpNames.push_back(String("a"));
```

- `dps` of type `dpclass*`: The dependent parameter class, i.e. an implementation of `dpclass` which would return the value for dependent parameters when queried for them. E.g. in the example above it would return `a` when queried for dependent parameter 0 through `dpclass::calculateDerivedParameter()`. Examples how this is done can be found in the pre-defined classes, e.g. expDecayDp, pwSTDP, rulkovdp etc.

- `tmpVarNames` of type `vector<string>`: This vector can be used to request additional variables that are not part of the state of the neuron but used only as temporary storage during evaluation of the integration time step.
  For example, one could define

  ```
  model.tmpVarNames.push_back(String("a"));
  model.tmpVarNames.push_back(String("float"));
  model.simCode= String("$(a)= $(g)/$(C); \n\
  $(V)+= -$(a)*$(V);\n\");
  ```

  which would be equivalent to

  ```
  model.simCode= String("float $(a)= $(g)/$(C); \n\
  $(V)+= -$(a)*$(V);\n\");
  ```

- `tmpVarTypes` of type `vector<string>`: This vector will contain the variable types of the temporary variables, matched up by position as usual.

Once the completed `neuronModel` object is appended to the `nModels` vector,

```
nModels.push_back(model);
```

it can be used in network descriptions by referring to its cardinal number in the nModels vector. I.e., if the model is added as the 4th entry, it would be model "3" (counting starts at 0 in usual C convention). The information of the cardinal number of a new model can be obtained by referring to `nModels.size()` right before appending the new model, i.e. a typical use case would be.

```
int myModel= nModels.size();
nModels.push_back(model);
```

. Then one can use the model as

```
networkModel.addNeuronPopulation(..., myModel, ...);
```

6.4.7 Explicit current input to neurons

The user can decide whether a neuron group receives external input current or not in addition to the synaptic input that it receives from the network. External input to a neuron group is activated by calling `activateDirectInput` function. It receives two arguments: The first argument is the name of the neuron group to receive input current. The second parameter defines the type of input. Current options are:

- 0: NOINP: Neuron group receives no input. This is the value by default when the explicit input is not activated.
- 1: CONSTINP: All the neurons receive a constant input value. This value may also be defined as a variable, i.e. be time-dependent.
- 2: MATINP: The input is read from a file containing the input matrix.
- 3: INPRULE: The input is defined as a rule. It differs from CONSTINP in the way that the input is injected: CONSTINP creates a value which is modified in real time, hence complex instructions are limited. INPRULE creates an input array which will be copied into the device memory.

6.5 Synapse models

A synapse model is a weightUpdateModel object which consists of variables, parameters, and string objects which will be substituted in the code. The three strings that will be substituted in the code for synapse update are:

- `simCode`: Simulation code that is used when a true spike is detected. Update is done for only one time step after threshold condition detection, which is provided by `thresholdConditionCode` in the neuron model corresponding to the presynaptic neuron population.

What will be integrated in the postsynaptic neuron should be provided by the $(addtoinsyn) snippet. When a spike is detected in the presynaptic neuron population, first the simCode is called by replacing the variables and parameters with their corresponding values. In order to define how presynaptic variables contribute to the update of the postsynaptic neuron, $(addtoinSyn) variable should first be updated accordingly, and then $(updatelinsyn) should be called in order to define where previous conductance values should be integrated before updating the conductances. For an example, see NSYNAPSE (No Learning) for a simple synapse update model and LEARN1SYNAPSE (Learning Synapse with a Primitive Role) for a more complicated model that uses STDP.

- `simCodeEvnt`: Simulation code that is used for spike events, where update is done fo all the instances where event threshold evntThreshold is met. evntThresholdshould also be provided as a string. For an example, see NGRADSYNAPSE (Graded Synapse).
- `simLearnPost`: Simulation code which is used in the learnSynapsesPost kernel/function, where post-synaptic neuron spikes before the presynaptic neuron in the STDP window. Usually this is simply the conductance update rule defined by the other simCode elements above, with negative timing and without post-synaptic update. This code needs to be provided separately as simCode and simCodeEnvt are used after spanning the presynaptic spikes, where it is not possible to detect where a postsynaptic neuron fired before the presynaptic neuron. For an example, see LEARN1SYNAPSE (Learning Synapse with a Primitive Role).

These codes would include update functions for adding up conductances for that neuron model and for changes in conductances for the next time step (learning).

6.5.1 Built-in Models

Currently 3 predefined synapse models are available:

- NSYNAPSE
- NGRADSYNAPSE
- LEARN1SYNAPSE

These are defined in user.h. MBody_userdef example also includes a modified version of these models in as new user-defined models.

6.5.2 NSYNAPSE (No Learning)

If this model is selected, no learning rule is applied to the synapse and presynaptic conductances are are simply added to the postsynaptic input. The model has 1 variable:

- `g` - conductance of `scalar` type

and no other parameters.

`simCode` is:

```
" $(addtoinSyn) = $(g);\n\
  $(updatelinsyn);\n"
```

6.5.3 NGRADSYNAPSE (Graded Synapse)

In a graded synapse, the conductance is updated gradually with the rule:

$$gSyn = g * tanh((E - E_{pre})/V_{slope}$$

The model has 1 variable:

- `g:` conductance of `scalar` type

The parameters are:

- `Epre:` Presynaptic threshold potential
- `Vslope:` Activation slope of graded release

`simCodeEvnt` is:

```
" $(addtoinSyn) = $(g)* tanh(($(V_pre)-($(Epre)))*DT*2/$(Vslope));\n\
  $(updatelinsyn);\n"
```

`evntThreshold` is:

```
" $(V_pre) > $(Epre)"
```

6.5.4 LEARN1SYNAPSE (Learning Synapse with a Primitive Role)

This is a simple STDP rule including a time delay for the finite transmission speed of the synapse, defined as a piecewise function.

The model has 2 variables:

- `g:` conductance of `scalar` type
- `gRaw:` raw conductance of `scalar` type

Parameters are:

- `Epre:` Presynaptic threshold potential
- `tLrn:` Time scale of learning changes

- `tChng`: Width of learning window
- `tDecay`: Time scale of synaptic strength decay
- `tPunish10`: Time window of suppression in response to 1/0
- `tPunish01`: Time window of suppression in response to 0/1
- `gMax`: Maximal conductance achievable
- `gMid`: Midpoint of sigmoid g filter curve
- `gSlope`: Slope of sigmoid g filter curve
- `tauShift`: Shift of learning curve
- `gSyn0`: Value of syn conductance g decays to

For more details about these built-in synapse models, see [2].

6.5.5 LEARN1SYNAPSE (Learning Synapse with a Primitive Role)

If users want to define their own models, they can add a new weightUpdateModel that includes the variables, parameters, and update codes as desired, and then push this object in the weightUpdateModels vector. The model can be used by referring to iths index in the weightUpdateModels vector while adding a new population by calling addSynapsePopulation.

6.5.6 Conductance definition methods

The available options work as follows:

- `INDIVIDUALG`: When this option is chosen in the `addSynapsePopulation` command, GeNN reserves an array of size n_pre x n_post float for individual conductance values for each combination of pre and postsynaptic neuron. The actual values of the conductances are passed at runtime from the user side code, using the `copyGToDevice` function.
- `GLOBALG`: When this option is chosen, the `addSynapsePopulation` command must be followed within the `modelDefinition` function by a call to `setSynapseG` for this synapse population. This option can only be sensibly combined with connectivity type ALLTOALL.
- `INDIVIDUALID`: When this option is chosen, GeNN expects to use the same maximal conductance for all existing synaptic connections but which synapses exist will be defined at runtime from the user side code, provided as a binary array (see Insect Olfaction Model).

6.5.7 Connectivity types

If `INDIVIDUALG` is used with `ALLTOALL` connectivity, synapse variables are stored in an array of size npre $*$ npost .

If connectivity is of SPARSE type, connectivity indices are stored in a struct named SparseProjection in order to occupy minimum memory needed. The struct SparseProjection contains following members: 1: unsigned int connN: number of connections in the population. This value is needed for allocation of arrays. The indices that correspond to these values are defined in a pre-to-post basis by the following arrays: 2: unsigned int ind, of size connN: Indices of corresponding postsynaptic neurons concatenated for each presynaptic neuron. 3: unsigned int $*$indInG, of size model.neuronN[model.synapseSource[synInd]]+1: This array defines from which index in the synapse variable array the indices in ind would correspond to the presynaptic neuron that corresponds to the index of the indInG array, with the number of connections being the size of ind. More specifically, indIng[n+1]-indIng[n] would give the number of postsynaptic connections for neuron n.

For example, consider a network of two presynaptic neurons connected to three postsynaptic neurons: 0th presynaptic neuron connected to 1st and 2nd postsynaptic neurons, the 1st presynaptic neuron connected to 0th and 2nd neurons. The struct SparseProjection should have these members, with indexing from 0:

```
ConnN = 4

ind= [1 2 0 2]

indIng= [0 2 4]
```

A synapse variable of a sparsely connected synapse will be kept in an array using this conductance for indexing. For example, a variable caled `g` will be kept in an array such as: g= [g_Pre0-Post1 g_pre0-post2 g_pre1-post0 g_pre1-post2] If there are no connections for a presynaptic neuron, then g[indIng[n]]=gp[indIng[n]+1].

See tools/gen_syns_sparse_IzhModel used in Izh_sparse project to see a working example.

6.5.8 Postsynaptic integration methods

The way that everything comes from the presynaptic inputs are updated by the postsynaptic neuron can be defined by either using a predefined method or by adding a new postSynModel object.

A postSynModel object consists of variables, parameters, derived parameters and two strings that explain how the method works:

- string `postSynDecay`: This code explains what should be done with the sum of the presynaptic input arriving at the postsynaptic neuron. This usually consists of a decay function.
- string `postSyntoCurrent`: This code explains how the postsynaptic inputs are added up to the input current (Isyn) to the postsynaptic neuron.

There are currently 2 built-in postsynaptic integration methods:

EXPDECAY: Exponential decay. Decay time constant and reversal potential parameters are needed for this postsynaptic mechanism.

This model has no variables and two parameters:

- `tau` : Decay time constant
- `E` : Reversal potential

`tau` is used by the derived parameter `expdecay` which returns expf(-dt/tau).

IZHIKEVICH_PS: Empty postsynaptic rule to be used with Izhikevich neurons.

7 Tutorial 1

In this tutorial we will go through step by step instructions ow to create and a GeNN simulation starting from scratch. Normally, we recommend users to use one of the example projects as a starting point but it can be very instructive to go through the necessary steps one by one once to appreciate what parts make a GeNN simulation.

7.1 The Model Definition

In this tutorial we will use a pre-defined neuron model type (TRAUBMILES) and create a simulation of ten Hodgkin-Huxley neurons [4] without any synaptic connections. We will run this simulation on a GPU and save the results to stdout.

The first step is to write a model definition function in a model definition file. Create a new empty file `tenHHModel.cc` with your favourite editor, e.g.

```
>> emacs tenHHModel.cc &
```

Note

The ">>" in the example code snippets refers to a shell prompt in a unix shell, do not enter them as part of your shell commands.

The model definition file contains the definition of the network model we want to simulate. First, we need to define the simulation step size `DT` and include the GeNN model specification codes `modelSpec.h` and modelSpec.cc<tt>. Then the model definition takes the form of a function namedmodelDefinition`that takes one argument, passed by reference, of type`NNmodel`.  Type in your`tenHHModel.cc' file:

```
// Model definintion file tenHHModel.cc

#define DT 0.1
#include "modelSpec.h"
#include "modelSpec.cc"

void modelDefinition(NNmodel &model)
{
  // definition of tenHHModel
}
```

With this we have fixed the integration time step to `0.1` in the usual time units. The tyoical units in GeNN are `ms`, `mV`, `nF`, and `\form#10S`. Therefore, this defines `DT= 0.1 ms`. Now we need t fill the actual model definition.

Two standard elements to the 'modelDefinition function are initialising GeNN and setting the name of the model:

```
initGeNN();
model.setName("tenHHModel");
```

Note

The name of the model given in the setName method does not need to match the file name of the model definition file. However, we strongly recommend it and if conflicting the file name of the model definition file will prevail.

Making the actual model definition makes use of the `addNeuronPopulation` and 'addSynapsePopulation`member functions of the NNmodel object.  The arguments to a call to`addNeuronPopulations are

- `string name`: the name of the population
- `int N`: The number of neurons in the population
- `int type`: The type of neurons in the population
- `double *p`: An array of parameter values for teh neurons in the population
- `double *ini`: An array of initial values for neuron variables

We first create the parameter and initial variable arrays,

```
// definition of tenHHModel
double p[7]= {
  7.15,          // 0 - gNa: Na conductance in muS
  50.0,          // 1 - ENa: Na equi potential in mV
  1.43,          // 2 - gK: K conductance in muS
 -95.0,          // 3 - EK: K equi potential in mV
  0.02672,       // 4 - gl: leak conductance in muS
  -63.563,       // 5 - El: leak equi potential in mV
  0.143          // 6 - Cmem: membr. capacity density in nF
};

double ini[4]= {
  -60.0,         // 0 - membrane potential V
  0.0529324,     // 1 - prob. for Na channel activation m
  0.3176767,     // 2 - prob. for not Na channel blocking h
  0.5961207      // 3 - prob. for K channel activation n
};
```

Note

The comments are obviously only for clarity, they can in principle be omitted. To avoid any confusion about the meaning of parameters and variables, however, we recommend to always include comments of this type.

Having defined the parameter values and initial values we can now create the neuron population,

```
model.addNeuronPopulation("Pop1", 10, TRAUBMILES, p, ini);
```

Note

`TRAUBMILES` is a variable defined in the GeNN model specification that contains the index number of the pre-defined Traub & Miles model [4].

This completes the model definition in this example. The complete `tenHHModel.cc` file now should look like this:

```
// Model definintion file tenHHModel.cc

#define DT 0.1
#include "modelSpec.h"
#include "modelSpec.cc"

void modelDefinition(NNmodel &model)
{
  // definition of tenHHModel
  initGeNN();
  model.setName("tenHHModel");
  double p[7]= {
    7.15,          // 0 - gNa: Na conductance in muS
    50.0,          // 1 - ENa: Na equi potential in mV
    1.43,          // 2 - gK: K conductance in muS
   -95.0,          // 3 - EK: K equi potential in mV
    0.02672,       // 4 - gl: leak conductance in muS
    -63.563,       // 5 - El: leak equi potential in mV
    0.143          // 6 - Cmem: membr. capacity density in nF
  };

  double ini[4]= {
    -60.0,         // 0 - membrane potential V
    0.0529324,     // 1 - prob. for Na channel activation m
    0.3176767,     // 2 - prob. for not Na channel blocking h
    0.5961207      // 3 - prob. for K channel activation n
  };
  model.addNeuronPopulation("Pop1", 10, TRAUBMILES, p, ini);
}
```

This model definition suffices to generate code for simulating the ten Hodgkin-Huxley neurons on the a GPU or CPU. The second part of a GeNN simulation is the user code that sets up the simulation, does the data handling for input and output and generally defines the numerical experiment to be run.

7.2 User Code

For the purposes of this tutorial we will initially simply run the model for one simulated second and record the final neuron variables into a file. GeNN provides the code for simulating the model in a function called `stepTimeCPU()` (execution on CPU only) or `stepTimeGPU()` (execution on a GPU). To make use of this code we need to define a minimal C/C++ main function. Open a new empty function `tenHHSimulation.cc` in an editor and type

```
// tenHHModel simulation code
#include "tenHHModel.cc"
#include "tenHHModel_CODE/runner.cc"

int main()
{
  allocateMem();
  initialize();

  return 0;
}
```

This boiler plate code includes the relevant model definition file we completed earlier and the entry point to the generated code `runner.cc` in the subdirectory `tenHHModel_CODE` where GeNN deposits all generated code.

Calling `allocateMem()` allocates the memry structures for all neuron variables and `initialize()` sets the initial values and copies values to the GPU.

Now we can use the generated code to execute the integration of the neuron equations provided by GeNN. To do so, we add after `initialize();`

```
stepTimeGPU(1000.0);
```

and we need to copy the result, and output it to stdout,

```
pullPop1fromDevice();
for (int i= 0; i < 10; i++) {
  cout << VPop1[i] << " ";
  cout << mPop1[i] << " ";
  cout << hPop1[i] << " ";
  cout << nPop1[i] << endl;
}
```

`pullPop1fromDevice()` copies all relevant state variables of the ‘Pop1∼ neuron group from the GPU to the CPU main memory. The we can output the results to stdout by looping through all 10 neurons an outputting the state variables VPopo1, mPop1, hPop1, nPop1.

Note

> The naming convention for variables in GeNN is the variable name defined by the neuron type, here TRAUBMILES defining V, m, h, and n, followed by the population name, here `Pop1`.

This completes the user code. The complete `tenHHSimulation.cu` file shoul now look like

```
// tenHHModel simulation code
#include "tenHHModel.cc"
#include "tenHHModel_CODE/runner.cc"

int main()
{
  allocateMem();
  initialize();
  stepTimeGPU(1000.0);
  pullPop1fromDevice();
  for (int i= 0; i < 10; i++) {
    cout << VPop1[i] << " ";
    cout << mPop1[i] << " ";
    cout << hPop1[i] << " ";
    cout << nPop1[i] << endl;
  }
  return 0;
}
```

7.3 Makefile

A GeNN simulation is build with a simple Makefile. On Unix systems we typically name it `GNUmakefile`. Create this file and enter

```
EXECUTABLE      :=tenHHSimulation
SOURCES         :=tenHHSimulation.cu

include $(GENN_PATH)/userproject/include/makefile_common_gnu.mk
```

This defines that the final executable of this simulation is named tenHHSimulation and the simulation code is given in the file `tenHHSimulation.cu` that we completed above.

Now we are ready to compile and run the simulation

7.4 Making and Running the Simulation

To build the model and generate the GeNN code, type in a terminal where you are in the directory containing your `tenHHModel.cc` file,

```
>> buildmodel.sh tenHHModel
```

If your environment variables `GENN_PATH` and `CUDA_PATH` are correctly configured, you should see some compile output ending in `Model build complete ...`. Now type

```
make
```

This should compile your `tenHHSimulation` executable and you can execute it with

```
./tenHHSimulation
```

The output yuo obtain should look like

```
-63.7838 0.0350042 0.336314 0.563243
-63.7838 0.0350042 0.336314 0.563243
-63.7838 0.0350042 0.336314 0.563243
-63.7838 0.0350042 0.336314 0.563243
-63.7838 0.0350042 0.336314 0.563243
-63.7838 0.0350042 0.336314 0.563243
-63.7838 0.0350042 0.336314 0.563243
-63.7838 0.0350042 0.336314 0.563243
-63.7838 0.0350042 0.336314 0.563243
-63.7838 0.0350042 0.336314 0.563243
```

This completes this tutorial. You have created a GeNN model and simulated it successfully!

7.5 Adding External Input

In the example we have created so far, the neurons are not connected and do not receive input. As the TRAUB←MILES model is silent in such conditions, the ten neurons simply will simply rest at their resting potential. To make things more interesting, let us add a constant input to all neurons, add to the end of the `modelDefinition` function

```
model.activateDirectInput("Pop1", CONSTINP);
model.setConstInp("Pop1", 0.1);
```

This will add a constant input of 0.1 nA to all ten neurons. When run with this addition you should observe the output

```
-63.1468 0.0211871 0.987233 0.0423695
-63.1468 0.0211871 0.987233 0.0423695
-63.1468 0.0211871 0.987233 0.0423695
-63.1468 0.0211871 0.987233 0.0423695
-63.1468 0.0211871 0.987233 0.0423695
-63.1468 0.0211871 0.987233 0.0423695
-63.1468 0.0211871 0.987233 0.0423695
-63.1468 0.0211871 0.987233 0.0423695
-63.1468 0.0211871 0.987233 0.0423695
-63.1468 0.0211871 0.987233 0.0423695
```

This is still not particularly interesting as we are just observing the final value of the membrane potentials. To see what is going on in the meantime, we need to copy intermediate values from the device and best save them into a file. This can be done in many ways but one sensible way of doing this is to replace the line

```
stepTimeGPU(1000.0);
```

in `tenHHSimulation.cu` to something like this:

```
ofstream os("tenHH_output.V.dat");
double t= 0.0;
for (int i= 0; i < 5000; i++) {
  stepTimeGPU(0.2);
  pullPop1fromDevice();
  os << t << " ";
  for (int j= 0; j < 10; j++) {
    os << VPop1[j] << " ";
  }
  os << endl;
  t+= 0.2;
}
os.close();
```

After building, making and executing,

```
builmodel.sh tenHHModel
make clean all
./tenHHSimulation
```

there should a file `tenHH_output.V.dat` in the same directory. If you plot column one (time) against column two (voltage of neuron 0), you should observe dynamics like this:

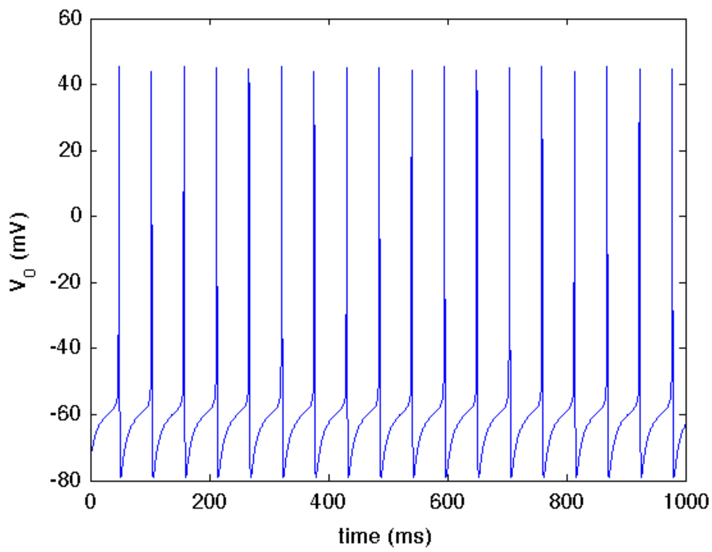


Figure 1: width=10cm

The completed files from this tutorial can be found in `userproject/tenHH_project`.

8 Tutorial 2

In this tutorial we will learn to add synapsePopulations to connect neurons in neuron groups to each other with synatic models. We will as an example connect the ten Hodgkin-Huxley neurons from tutorial 1 in a ring of excitatory synapses.

First, copy the files from Tutorial 1 into a new directory and rename them to new names, e.g.

```
>> cp -r tenHH_project tenHHRing_project
>> cd tenHHRing_project
>> mv tenHHModel.cc tenHHRingModel.cc
>> mv tenHHSimulation.cu tenHHRingSimulation.cu
```

Now, we need to add a synapse group to the model that allows to connect neurons from the Pop1 group to connect to other neurons of this group. Open `tenHHRingModel.cc`, change the model name inside,

```
model.setName("tenHHRing");
```

8.1 Adding Synaptic connections

Now we need additional initial values and parameters for the synapse and post-synaptic models. We will use the standard NSYNAPSE weightu[adte model and EXPDECAY post-synaptic model. They need intial variables and parameters as follows:

```
double s_ini[1] = {
  0.0      // 0 - g: the synaptic conductance value
};
double *s_p= NULL;
double *ps_ini= NULL;
double ps_p[2]= {
  1.0,      // 0 - tau_S: decay time constant for S [ms]
  -80.0     // 1 - Erev: Reversal potential
};
```

If an array is not needed we pass in a NULL pointer. Here there are for example no synaptic parameters and no initial values for the post-synaptic mechanism. We can then add a synapse population at the end of the `modelDefinition(...)` function,

```
model.addSynapsePopulation("Pop1self", NSYNAPSE,
      DENSE, INDIVIDUALG, NO_DELAY, EXPDECAY, "Pop1", "Pop1", s_ini, s_p, ps_ini,
       ps_p);
```

The addSynapsePopulation parameters are

- `const char *name`: The name of the synapse population, here "Pop1self"
- `int sType`: The type of synapse to be added, we here use the predefined typse `NSYNAPSE`. See Built-in Models for all available predefined synapse types.
- `int sConn`: The type of synaptic connectivity, here `DENSE` which means we will provide a full connectivity mtrix later.
- `int gType`: The way how the synaptic conductivity g will be defined. With `GLOBALG` we indicate that all conductance are of the same conductance value, which will be the value given in `sPara`.
- `int delay`: `NO_DELAY` means that there wil be no delays for synaptic signal propagation.
- `int postSyn`: Postsynaptic integration method, we are here using the standard model of an exponential decay of synaptic excitation.
- `char *preName`: Name of the pre-synaptic neuron population, here the `Pop1` population.
- `char *postName`: Name of the post-synaptic neuron population, here also `Pop1`.
- `double *sIni`: A C-array of doubles containing initial values for the synaptic variables.
- `double *sParam`: A C-array of double precision that contains parameter values (common to all synapses of the population)
- `double *psIni`: A C-array of double precision numbers containing initial values for the post-synaptic model variables
- `double *psPara`: A C-array of double precision numbers containing parameters fo the post-snaptic model.

Adding the addSynapsePopulation command to the model definition informs GeNN that there will be synapses between the named neuron populations, here between population `Pop1` and itself. The detailed conenctivity as defined by the variables `g`, we have still to define in the setup of our simulation. At this point our model definition file `tenHHRingModel.cc` should look like this

```
// Model definintion file tenHHModel.cc

#define DT 0.1
#include "modelSpec.h"
#include "modelSpec.cc"

void modelDefinition(NNmodel &model)
{
  // definition of tenHHModel
  initGeNN();
  model.setName("tenHHRingModel");
  double p[7]= {
    7.15,          // 0 - gNa: Na conductance in muS
    50.0,          // 1 - ENa: Na equi potential in mV
    1.43,          // 2 - gK: K conductance in muS
   -95.0,          // 3 - EK: K equi potential in mV
    0.02672,       // 4 - gl: leak conductance in muS
    -63.563,       // 5 - El: leak equi potential in mV
    0.143          // 6 - Cmem: membr. capacity density in nF
  };

  double ini[4]= {
    -60.0,         // 0 - membrane potential V
    0.0529324,     // 1 - prob. for Na channel activation m
    0.3176767,     // 2 - prob. for not Na channel blocking h
    0.5961207      // 3 - prob. for K channel activation n
  };
  model.addNeuronPopulation("Pop1", 10, TRAUBMILES, p, ini);
  model.activateDirectInput("Pop1", CONSTINP);
  model.setConstInp("Pop1", 0.1);
  double s_ini[1] = {
    0.0       // 0 - g: the synaptic conductance value
  };
  double *s_p= NULL;
  double *ps_ini= NULL;
  double ps_p[2]= {
    1.0,      // 0 - tau_S: decay time constant for S [ms]
    -80.0     // 1 - Erev: Reversal potential
  };
  model.addSynapsePopulation("Pop1self", NSYNAPSE,
      DENSE, INDIVIDUALG, NO_DELAY, EXPDECAY, "Pop1", "Pop1", s_ini, s_p, ps_ini,
       ps_p);
}
```

8.2 Defining the Detailed Synaptic Connections

Open the `tenHHRingSimulation.cu` file and update the file names of includes:

```
// tenHHRingModel simulation code
#include "tenHHRingModel.cc"
#include "tenHHRingModel_CODE/runner.cc"
```

Now we need to add code to generate the desired ring connectivity.

```
allocateMem();
initialize();
// define the connectivity
int pre, post;
for (int i= 0; i < 10; i++) {
  pre= i;
  post= (i+1)%10;
  gPop1self[pre*10+post]= 0.01;
}
pushPop1selftoDevice();
```

After memory allocation and initialization `gPop1self` will contain only zeros. We then assign in the loop a non-zero conductivity of 0.01 μS to all synapses from neuron `i` to `i+1` (and `9` to `8` to close the ring).

After adjusting the GNUmakefile to read

```
EXECUTABLE      :=tenHHRingSimulation
SOURCES         :=tenHHRingSimulation.cu

include $(GENN_PATH)/userproject/include/makefile_common_gnu.mk
```

we can build the model

```
>> buildmodel.sh tenHHRingModel
```

and make it

```
>> make clean all
```

After this there should be an exectable `tenHHRingSimulation`, which can be executed,

```
>> ./tenHHRingSimulation
```

which should again result in

```
-64.9054 0.0147837 0.981337 0.030886
-64.9054 0.0147837 0.981337 0.030886
-64.9054 0.0147837 0.981337 0.030886
-64.9054 0.0147837 0.981337 0.030886
-64.9054 0.0147837 0.981337 0.030886
-64.9054 0.0147837 0.981337 0.030886
-64.9054 0.0147837 0.981337 0.030886
-64.9054 0.0147837 0.981337 0.030886
-64.9054 0.0147837 0.981337 0.030886
-64.9054 0.0147837 0.981337 0.030886
```

If we plot the content of columns one and two of `tenHHexample.V.dat` it looks very similar as in Tutorial 1

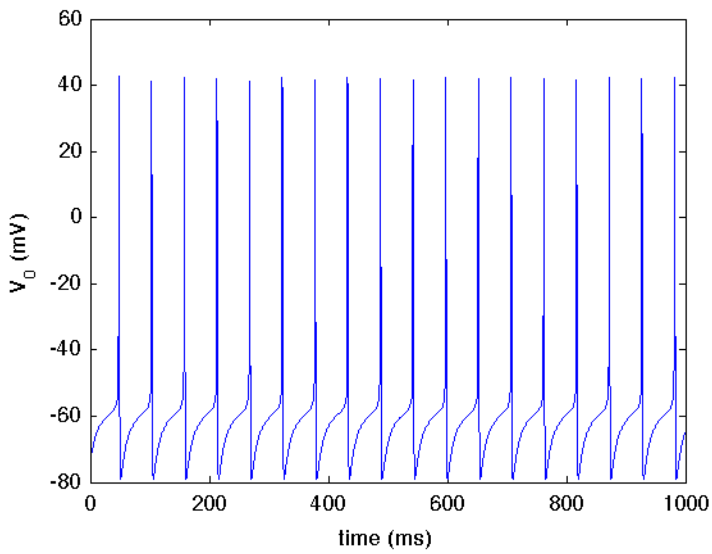


Figure 2: width=10cm

This is because the inhibitory synapses we created were all triggered at the same time so that they act during a post-synaptic spike which makes their effect all but invisible.

8.3 Setting Heterogeneous Initial Conditions

If we define different initial conditions for each of the ten neurons, add after `initialize()`,

```
// set initial variables
for (int i= 0; i < 10; i++) {
  VPop1[i]= -60.0+i;
}
pushPop1toDevice();
```

then we observe different final values for each neuron,

```
-57.3412 0.06223 0.981374 0.104417
-53.3189 0.442962 0.0664687 0.764513
-73.1413 0.00253709 0.927251 0.0277236
-67.1179 0.00927304 0.986692 0.0206106
-63.5878 0.01938 0.991071 0.0387962
-62.2114 0.0255295 0.990933 0.0504799
-61.404 0.0298902 0.990949 0.0586459
-60.6691 0.034405 0.990225 0.0668015
-59.8977 0.0397467 0.988701 0.0758159
-58.9727 0.0470178 0.98615 0.0866963
```

and zooming in on the first 200 ms, the voltage of the first neuron now looks like this

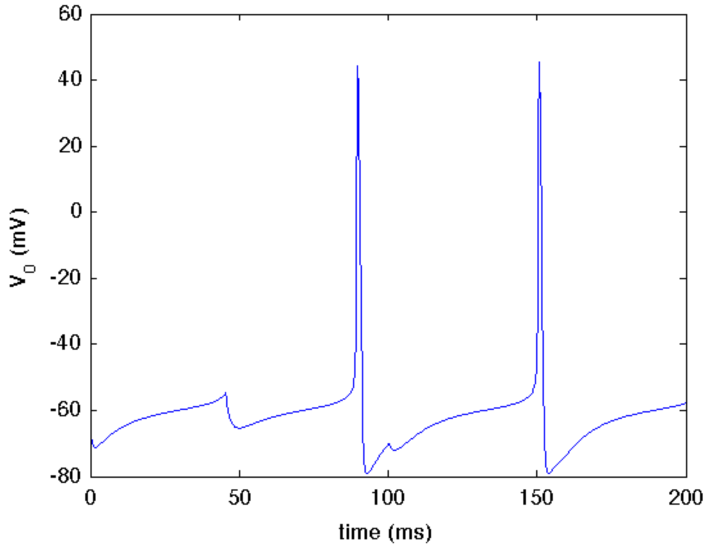


Figure 3: width=10cm

The complete codes for this tutorial are in `userproject\tenHHRing_project`.

9 Suggestions for users

GeNN generates code according to the network model defined by the user, but lets users use generated code the way they want. Here we explain how to setup GeNN and how to use generated functions. We recommend users to take a look at the Examples, and to follow the tutorials Tutorial 1 and Tutorial 2.

9.1 Creating and simulating a network model

The user is first expected to create an object of class NNmodel by creating the function modelDefinition() which includes calls to following methods in correct order:

- initGeNN();
- NNmodel::setName();

Then add neuron populations by:

- NNmodel::addNeuronPopulation();

for each neuron population. Add synapse populations by:

- NNmodel::addSynapsePopulation();

for each synapse population.

Other optional functions are explained in NNmodel class reference. At the end the function should look like this:

```
void modelDefinition(NNModel &model) {
  initGeNN();
  model.setName("YourModelName");
  model.addNeuronPopulation(...);
  ...
  model.addSynapsePopulation(...);
  ...
}
```

modelSpec.h and modelSpec.cc should be included in the file where this function is defined.

This function will be called by generateALL.cc to create corresponding CPU and GPU simulation codes under the <YourModelName>_CODE directory.

These functions can then be used in a .cu file which runs the simulation. This file should include <YourModelName>_CODE/runner.cc. Generated code differ from one model to the other, but core functions are the same and they should be called in correct order. First, following variables should be defined and initialized:

- NNmodel model // initialized by calling modelDefinition(model)
- Array containing current input (if any)

Following are declared by GeNN but should be initialized by the user:

- Poisson neuron offset and rates (if any)
- Connectivity matrices (if sparse)
- Neuron and synapse variables (if not initialising to same value)

Core functions generated by GeNN to be included in the user code include:

- allocateMem()
- deviceMemAllocate()
- allocate<synapse name>(unsigned int SparseProjection.connN) //for sparse connectivity only
- initialize()
- initializeAllSparseArrays()
- convertProbabilityToRandomNumberThreshold()
- copyStateToDevice()
- push<neuron or synapse name>toDevice()
- pull<neuron or synapse name>fromDevice()
- copyStateFromDevice()
- copySpikeNFromDevice()
- copySpikesFromDevice()
- stepTimeCPU() //arguments depend on model
- stepTimeGPU() //arguments depend on model
- freeMem()
- freeDeviceMem()

Copying elements from GPU to host memory is very costly in terms of performance and should only be done when needed.

9.2 Floating point precision

Double precision floating point numbers are supported by devices with compute capability 1.3 or higher. If you have an older GPU, you need to use single precision floating point in your models and simulation.

GPUs are designed to work better with single precision while double precision is the standard for CPUs. This difference should be kept in mind while compaing performance.

While setting up the network for GeNN, double precision floating point numbers are used as this part is done on the CPU. For the simulation, GeNN lets users choose between single or double precision. Overall, new variables in the generated code are defined with the precision specified by NNmodel::setPrecision(unsigned int), providing FLOAT or DOUBLE as argument. FLOAT is the default value. Keyword `scalar` can be used in the user-defined model codes for an interchangeable precision. This keyword is detected at code generation and substituted with "float" or "double" according to the precision set by NNmodel::setPrecision(unsigned int).

There may be ambiguities in arithmetic operations using explicit numbers. Standard C compilers presume that any number defined as "X" is an integer and any number defined as "X.Y" is a double. Make sure to use same precision in your operations in order to avoid performance loss.

9.3 Working with variables in GeNN

9.3.1 Model variables

User-defined model variables originate from core units such as neuronModel, weightUpdateModel or postSynModel object. The name of the variable is defined when the model type is introduced, i.e. with a statement such as

```
neuronModel model;
model.varNames.push_back(String"x"));
model.varTypes.push_back(String("double"));
...
int myModel= nModels.size();
nModels.push_back(model);
```

This declares that whenever the defined model type of cardinal number `myModel` is used, there will be a variable of core name `x`. varType can be of `scalar` type (see Floating point precision). The full GeNN name of this variable is obtained by directly concatenating the core name with the name of the neuron population in which the model type has been used, i.e. after a definition

```
networkModel.addNeuronPopulation("EN", n, myModel, ...);
```

there will be a variable `xEN` of type `double*` available in the global namespace of the simulation program. GeNN will pre-allocated this C array to the correct size of elements corresponding to the size of the neuron population, `n` in the example above. GeNN will also free these variables when the provided function `freeMem()` is called. Users can otherwise manipulate these variable arrays as they wish. For convenience, GeNN provides functions `pullXXfromDevice()` and `pushXXtoDevice()` to copy the variables associated to a neuron population `XX` from the device into host memory and vice versa. E.g.

```
pullENfromDevice();
```

would copy the C array xEN from device memory into host memory (and any other variables that the neuron type of the population EN may have).

The user can also directly use CUDA memory copy commands independent of the provided convenience function. The relevant device pointers for all variables that exist in host memory have the same name prefixed with `d_`. For example, the copy command that would be contained in `pullENfromDevice()` might look like

```
unsigned int size;
size = sizeof(double) * nEN;
cudaMemcpy(xEN, d_xEN, size, cudaMemcpyDeviceToHost);
```

where `n` is an integer containing the population size of the EN neuron population.

The same convention as for neuron variables applies for the variables of synapse groups, both for those originating from weightupdate models and from post-synaptic models, e.g. the variables in type NSYNAPSE contain the variable g of type float. Then, after

```
networkModel.addSynapsePopulation("ENIN", NSYNAPSE, ...);
```

there will be a global variable of type `float*` with the name `gENIN` that is pre-allocated to the right size. There will also be a matching device pointer with the name `d_gENIN`.

Note

The content of `gENIN` needs to be interpreted differently for DENSE connectivity and sparse matrix based SPARSE connectivity representations. For DENSE connectivity `gENIN` would contain "n_pre" times "n_post" elements, ordered along the pre-synaptic neuronsas the major dimension, i.e. the value of `gENIN` for the ith pre-synaptic neuron and the jth post-synaptic neuron would be `gENIN[i*n_post+j]`. The arrangement of values in the SPARSE representation is explained in section Connectivity types

9.3.2 Built-in Variables in GeNN

With GeNN 2.0, there are no more explicitly hard-coded variables. Users are free to call the variable of their models as they want. However, there are some reserved variables that are used for intermediary calculations and communication between different parts of the generated code. They can be used in the user defined code but no other variables should be defined with these names.

- `addtoinSyn` : This variable is used by weightUpdateModel for updating synaptic input. The way it is modified is defined in weightUpdateModel.simCode or weightUpdateModel.simCodeEvnt, therefore if a user defines her own model she should update this variable to contain the input to the post-synaptic model.
- `updatelinsyn` : At the end of the synaptic update by `addtoinSyn`, final values are copied back to the d_inSyn<synapsePopulation> variables which will be used in the next step of the neuron update to provide the input to the postsynaptic neurons.
- `inSyn` : This is an intermediary synapse variable which contains everything is transferred from a presynaptic neuron (by using `addtoinSyn` variable) to a postsynaptic neuron.
- `Isyn` : This is a local variable which defines the (summed) input current to a neuron. It is typically the sum of any explicit current input and all synaptic inputs. The way its value is calculated during the update of the postsynaptic neuron is defined by the code provided in the postSynModel. For example, the standard `EXP_DECAY` postsynaptic model defines ps.postSyntoCurrent= String("$(inSyn)*($(E)-$(V))"); which implements a conductance based synapse in which the postsynaptic current is given by $I_{\text{syn}} = g * s * (V_{\text{rev}} - V_{\text{post}})$.

  Note

  The `addtoinSyn` variables from all incoming synapses are automatically summed and added to the current value of `inSyn`.

  The value resulting from the `postSyntoCurrent` code is assigned to `Isyn` and can then be used in neuron simCode like so:

  ```
  $(V)+= (-$(V)+$(Isyn))*DT
  ```

- `sT` : As a neuron variable, this is the last spike time in a neuron and is automatically generated for pre and postsynaptic neuron groups of a synapse group i that follows a spike based learning rule (indicated by usesPostLearning[i]= TRUE for the ith synapse population).
- `sT_pre` : Spike time of the presynaptic neuron population.
- `sT_post` : Spike time of the postsynaptic neuron population.

9.4 Debugging suggestions

In Linux, users can use cuda-gdb to debug GPU. Example projects in userproject and lib/bin/buildmodel.sh come with a flag to enable debugging. If you are using a project with debugging, the code will be compiled with -g -G flags. In CPU mode the executable will be run in gdb, and in GPU mode it will be run in cuda-gdb in tui mode.

10 Credits

GeNN was created by Thomas Nowotny.

Addition of Izhikevich model, debugging modes and sparse connectivity by Esin Yavuz.

Block size optimisations and delayed synapses by James Turner.

Automatic brackets and dense to sparse network conversion by Alan Diamond.

User-defined synaptic and postsynaptic methods by Alex Cope and Esin Yavuz.

11 Hierarchical Index

11.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

12 Class Index

12.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

13 File Index

13.1 File List

Here is a list of all files with brief descriptions:

14 Class Documentation

14.1 classIzh Class Reference

```
#include <Izh_sparse_model.h>
```

Public Member Functions

- classIzh ()
- ∼classIzh ()
- void init (unsigned int)
- void allocate_device_mem_patterns ()
- void allocate_device_mem_input ()
- void copy_device_mem_input ()
- void read_sparsesyns_par (int, struct SparseProjection, FILE ∗, FILE ∗, FILE ∗, scalar ∗)
- void gen_alltoall_syns (scalar ∗, unsigned int, unsigned int, scalar)
- void free_device_mem ()
- void write_input_to_file (FILE ∗)
- void read_input_values (FILE ∗)
- void create_input_values ()
- void run (double, unsigned int)
- void getSpikesFromGPU ()

    Method for copying all spikes of the last time step from the GPU.
- void getSpikeNumbersFromGPU ()

    Method for copying the number of spikes in all neuron populations that have occurred during the last time step.
- void output_state (FILE ∗, unsigned int)
- void output_spikes (FILE ∗, unsigned int)
- void output_params (FILE ∗, FILE ∗)
- void sum_spikes ()
- void setInput (unsigned int)
- void randomizeVar (scalar ∗, scalar, unsigned int)
- void randomizeVarSq (scalar ∗, scalar, unsigned int)
- void initializeAllVars (unsigned int)

Public Attributes

- NNmodel model
- scalar ∗ input1
- scalar ∗ input2
- scalar ∗ d_input1
- scalar ∗ d_input2
- unsigned int sumPExc
- unsigned int sumPInh

14.1.1 Constructor & Destructor Documentation

14.1.1.1 classIzh::classIzh ( )

14.1.1.2 classIzh::∼classIzh ( )

14.1.2 Member Function Documentation

14.1.2.1 void classIzh::allocate_device_mem_input ( )

14.1.2.2 void classIzh::allocate_device_mem_patterns ( )

14.1.2.3 void classIzh::copy_device_mem_input ( )

14.1.2.4 void classIzh::create_input_values ( )

14.1.2.5 void classIzh::free_device_mem ( )

14.1.2.6 void classIzh::gen_alltoall_syns (scalar ∗ *g*, unsigned int *nPre*, unsigned int *nPost*, scalar *gscale*)

Parameters

gscale	Generate random conductivity values for an all to all network

14.1.2.7 void classIzh::getSpikeNumbersFromGPU ( )

Method for copying the number of spikes in all neuron populations that have occurred during the last time step.

This method is a simple wrapper for the convenience function copySpikeNFromDevice() provided by GeNN.

14.1.2.8 void classIzh::getSpikesFromGPU ( )

Method for copying all spikes of the last time step from the GPU.

This is a simple wrapper for the convenience function copySpikesFromDevice() which is provided by GeNN.

14.1.2.9 void classIzh::init (unsigned int *which*)

14.1.2.10 void classIzh::initializeAllVars (unsigned int *which*)

14.1.2.11 void classIzh::output_params (FILE ∗ *f*, FILE ∗ *f2*)

14.1.2.12 void classIzh::output_spikes (FILE ∗ *f*, unsigned int *which*)

14.1.2.13 void classIzh::output_state (FILE ∗ *f*, unsigned int *which*)

14.1.2.14 void classIzh::randomizeVar (scalar ∗ *Var*, scalar *strength*, unsigned int *neuronGrp*)

14.1.2.15 void classIzh::randomizeVarSq (scalar ∗ *Var*, scalar *strength*, unsigned int *neuronGrp*)

14.1.2.16 void classIzh::read_input_values (FILE ∗)

14.1.2.17 void classIzh::read_sparsesyns_par (int *synInd*, struct SparseProjection *C*, FILE ∗ *f_ind*, FILE ∗ *f_indInG*, FILE ∗ *f_g*, scalar ∗ *g*)

Parameters

g	File handle for a file containing sparse conductivity values

14.1.2.18 void classIzh::run (double *runtime*, unsigned int *which*)

14.1.2.19 void classIzh::setInput (unsigned int *which*)

14.1.2.20 void classIzh::sum_spikes ( )

14.1.2.21 void classIzh::write_input_to_file (FILE ∗ *f*)

14.1.3 Member Data Documentation

14.1.3.1 scalar∗ classIzh::d_input1

14.1.3.2 scalar ∗ classIzh::d_input2

14.1.3.3 scalar∗ classIzh::input1

14.1.3.4 scalar ∗ classIzh::input2

14.1.3.5 NNmodel classIzh::model

14.1.3.6 unsigned int classIzh::sumPExc

14.1.3.7 unsigned int classIzh::sumPInh

The documentation for this class was generated from the following files:

- Izh_sparse_model.h
- Izh_sparse_model.cc

14.2 classol Class Reference

This class cpontains the methods for running the MBody1 example model.

`#include <map_classol.h>`

Public Member Functions

- classol ()
- ∼classol ()
- void init (unsigned int)

  Method for initialising variables.
- void allocate_device_mem_patterns ()

  Method for allocating memory on the GPU device to hold the input patterns.
- void free_device_mem ()

  Methods for unallocating the memory for input patterns on the GPU device.
- void read_pnkcsyns (FILE ∗)

  Method for reading the connectivity between PNs and KCs from a file.
- void read_sparsesyns_par (int, struct SparseProjection, scalar ∗, FILE ∗, FILE ∗, FILE ∗)
- void write_pnkcsyns (FILE ∗)

  Method for writing the conenctivity between PNs and KCs back into file.
- void read_pnlhisyns (FILE ∗)

  Method for reading the connectivity between PNs and LHIs from a file.
- void write_pnlhisyns (FILE ∗)

  Method for writing the connectivity between PNs and LHIs to a file.
- void read_kcdnsyns (FILE ∗)

  Method for reading the connectivity between KCs and DNs (detector neurons) from a file.
- void write_kcdnsyns (FILE ∗)

  Method to write the connectivity between KCs and DNs (detector neurons) to a file.
- void read_input_patterns (FILE ∗)

  Method for reading the input patterns from a file.
- void generate_baserates ()

  Method for calculating the baseline rates of the Poisson input neurons.
- void runGPU (scalar)

  Method for simulating the model for a given period of time on the GPU.
- void runCPU (scalar)

  Method for simulating the model for a given period of time on the CPU.

- void output_state (FILE ∗, unsigned int)

    Method for copying from device and writing out to file of the entire state of the model.
- void getSpikesFromGPU ()

    Method for copying all spikes of the last time step from the GPU.
- void getSpikeNumbersFromGPU ()

    Method for copying the number of spikes in all neuron populations that have occurred during the last time step.
- void output_spikes (FILE ∗, unsigned int)

    Method for writing the spikes occurred in the last time step to a file.
- void sum_spikes ()

    Method for summing up spike numbers.
- void get_kcdnsyns ()

    Method for copying the synaptic conductances of the learning synapses between KCs and DNs (detector neurons) back to the CPU memory.
- classol ()
- ∼classol ()
- void init (unsigned int)
- void allocate_device_mem_patterns ()
- void free_device_mem ()
- void read_pnkcsyns (FILE ∗)
- void read_sparsesyns_par (int, struct SparseProjection, scalar ∗, FILE ∗, FILE ∗, FILE ∗)
- void write_pnkcsyns (FILE ∗)
- void read_pnlhisyns (FILE ∗)
- void write_pnlhisyns (FILE ∗)
- void read_kcdnsyns (FILE ∗)
- void write_kcdnsyns (FILE ∗)
- void read_input_patterns (FILE ∗)
- void generate_baserates ()
- void run (scalar, unsigned int)

    Method for simulating the model for a given period of time.
- void output_state (FILE ∗, unsigned int)
- void getSpikesFromGPU ()
- void getSpikeNumbersFromGPU ()
- void output_spikes (FILE ∗, unsigned int)
- void sum_spikes ()
- void get_kcdnsyns ()
- classol ()
- ∼classol ()
- void init (unsigned int)
- void allocate_device_mem_patterns ()
- void free_device_mem ()
- void read_pnkcsyns (FILE ∗)
- void read_sparsesyns_par (int, struct SparseProjection, scalar ∗, FILE ∗, FILE ∗, FILE ∗)
- void write_pnkcsyns (FILE ∗)
- void read_pnlhisyns (FILE ∗)
- void write_pnlhisyns (FILE ∗)
- void read_kcdnsyns (FILE ∗)
- void write_kcdnsyns (FILE ∗)
- void read_input_patterns (FILE ∗)
- void generate_baserates ()
- void run (scalar, unsigned int)
- void output_state (FILE ∗, unsigned int)
- void getSpikesFromGPU ()
- void getSpikeNumbersFromGPU ()
- void output_spikes (FILE ∗, unsigned int)

- void sum_spikes ()
- void get_kcdnsyns ()
- classol ()
- ∼classol ()
- void init (unsigned int)
- void allocate_device_mem_patterns ()
- void free_device_mem ()
- void read_pnkcsyns (FILE ∗)
- template<class DATATYPE >
  void read_sparsesyns_par (DATATYPE ∗, int, struct SparseProjection, FILE ∗, FILE ∗, FILE ∗)
- void write_pnkcsyns (FILE ∗)
- void read_pnlhisyns (FILE ∗)
- void write_pnlhisyns (FILE ∗)
- void read_kcdnsyns (FILE ∗)
- void write_kcdnsyns (FILE ∗)
- void read_input_patterns (FILE ∗)
- void generate_baserates ()
- void runGPU (scalar)
- void runCPU (scalar)
- void output_state (FILE ∗, unsigned int)
- void getSpikesFromGPU ()
- void getSpikeNumbersFromGPU ()
- void output_spikes (FILE ∗, unsigned int)
- void sum_spikes ()
- void get_kcdnsyns ()
- classol ()
- ∼classol ()
- void init (unsigned int)
- void allocate_device_mem_input ()
- void free_device_mem ()
- void read_PNIzh1syns (scalar ∗, FILE ∗)
- void read_sparsesyns_par (int, struct SparseProjection, FILE ∗, FILE ∗, FILE ∗, double ∗)
- void generate_baserates ()
- void run (float, unsigned int)
- void output_state (FILE ∗, unsigned int)
- void getSpikesFromGPU ()
- void getSpikeNumbersFromGPU ()
- void output_spikes (FILE ∗, unsigned int)
- void sum_spikes ()

Public Attributes

- NNmodel model
- unsigned int offset
- uint64_t ∗ theRates
- scalar ∗ p_pattern
- uint64_t ∗ pattern
- uint64_t ∗ baserates
- uint64_t ∗ d_pattern
- uint64_t ∗ d_baserates
- unsigned int sumPN
- unsigned int sumKC
- unsigned int sumLHI
- unsigned int sumDN
- unsigned int size_g
- unsigned int sumIzh1

14.2.1 Detailed Description

This class cpontains the methods for running the MBody1 example model.

This class cpontains the methods for running the MBody_delayedSyn example model.

14.2.2 Constructor & Destructor Documentation

14.2.2.1 classol::classol ( )

14.2.2.2 classol::∼classol ( )

14.2.2.3 classol::classol ( )

14.2.2.4 classol::∼classol ( )

14.2.2.5 classol::classol ( )

14.2.2.6 classol::∼classol ( )

14.2.2.7 classol::classol ( )

14.2.2.8 classol::∼classol ( )

14.2.2.9 classol::classol ( )

14.2.2.10 classol::∼classol ( )

14.2.3 Member Function Documentation

14.2.3.1 void classol::allocate_device_mem_input ( )

14.2.3.2 void classol::allocate_device_mem_patterns ( )

Method for allocating memory on the GPU device to hold the input patterns.

14.2.3.3 void classol::allocate_device_mem_patterns ( )

14.2.3.4 void classol::allocate_device_mem_patterns ( )

14.2.3.5 void classol::allocate_device_mem_patterns ( )

14.2.3.6 void classol::free_device_mem ( )

14.2.3.7 void classol::free_device_mem ( )

14.2.3.8 void classol::free_device_mem ( )

14.2.3.9 void classol::free_device_mem ( )

Methods for unallocating the memory for input patterns on the GPU device.

14.2.3.10 void classol::free_device_mem ( )

14.2.3.11 void classol::generate_baserates ( )

14.2.3.12 void classol::generate_baserates ( )

14.2.3.13 void classol::generate_baserates ( )

Method for calculating the baseline rates of the Poisson input neurons.

14.2.3.14 void classol::generate_baserates ( )

14.2.3.15 void classol::generate_baserates ( )

14.2.3.16 void classol::get_kcdnsyns ( )

14.2.3.17 void classol::get_kcdnsyns ( )

14.2.3.18 void classol::get_kcdnsyns ( )

Method for copying the synaptic conductances of the learning synapses between KCs and DNs (detector neurons) back to the CPU memory.

14.2.3.19 void classol::get_kcdnsyns ( )

14.2.3.20 void classol::getSpikeNumbersFromGPU ( )

14.2.3.21 void classol::getSpikeNumbersFromGPU ( )

14.2.3.22 void classol::getSpikeNumbersFromGPU ( )

14.2.3.23 void classol::getSpikeNumbersFromGPU ( )

Method for copying the number of spikes in all neuron populations that have occurred during the last time step.

This method is a simple wrapper for the convenience function copySpikeNFromDevice() provided by GeNN.

14.2.3.24 void classol::getSpikeNumbersFromGPU ( )

14.2.3.25 void classol::getSpikesFromGPU ( )

14.2.3.26 void classol::getSpikesFromGPU ( )

14.2.3.27 void classol::getSpikesFromGPU ( )

14.2.3.28 void classol::getSpikesFromGPU ( )

Method for copying all spikes of the last time step from the GPU.

This is a simple wrapper for the convenience function copySpikesFromDevice() which is provided by GeNN.

14.2.3.29 void classol::getSpikesFromGPU ( )

14.2.3.30 void classol::init (unsigned *int*)

14.2.3.31 void classol::init (unsigned int *which*)

Method for initialising variables.

Parameters

which	Flag defining whether GPU or CPU only version is run

14.2.3.32 void classol::init (unsigned *int*)

14.2.3.33 void classol::init (unsigned *int*)

14.2.3.34 void classol::init (unsigned *int*)

14.2.3.35 void classol::output_spikes (FILE ∗ , unsigned *int*)

14.2.3.36 void classol::output_spikes (FILE ∗ , unsigned *int*)

14.2.3.37 void classol::output_spikes (FILE ∗ , unsigned *int*)

14.2.3.38 void classol::output_spikes (FILE ∗ *f*, unsigned int *which*)

Method for writing the spikes occurred in the last time step to a file.

Parameters

f	File handle for a file to write spike times to
which	Flag determining whether using GPU or CPU only

14.2.3.39 void classol::output_spikes (FILE ∗ , unsigned *int*)

14.2.3.40 void classol::output_state (FILE ∗ , unsigned *int*)

14.2.3.41 void classol::output_state (FILE ∗ , unsigned *int*)

14.2.3.42 void classol::output_state (FILE ∗ , unsigned *int*)

14.2.3.43 void classol::output_state (FILE ∗ *f*, unsigned int *which*)

Method for copying from device and writing out to file of the entire state of the model.

Parameters

f	File handle for a file to write the model state to
which	Flag determining whether using GPU or CPU only

14.2.3.44 void classol::output_state (FILE ∗ , unsigned *int*)

14.2.3.45 void classol::read_input_patterns (FILE ∗ *f*)

Method for reading the input patterns from a file.

Parameters

f	File handle for a file containing input patterns

14.2.3.46 void classol::read_input_patterns (FILE ∗)

14.2.3.47 void classol::read_input_patterns (FILE ∗)

14.2.3.48 void classol::read_input_patterns (FILE ∗)

14.2.3.49 void classol::read_kcdnsyns (FILE ∗ *f*)

Method for reading the connectivity between KCs and DNs (detector neurons) from a file.

Parameters

f	File handle for a file containing KC to DN (detector neuron) conductivity values

14.2.3.50 void classol::read_kcdnsyns (FILE ∗)

14.2.3.51 void classol::read_kcdnsyns (FILE ∗)

14.2.3.52 void classol::read_kcdnsyns (FILE ∗)

14.2.3.53 void classol::read_PNIzh1syns (scalar ∗ *gp*, FILE ∗ *f*)

14.2.3.54 void classol::read_pnkcsyns (FILE ∗)

14.2.3.55 void classol::read_pnkcsyns (FILE * f)

Method for reading the connectivity between PNs and KCs from a file.

Parameters

f	File handle for a file containing PN to KC conductivity values

14.2.3.56 void classol::read_pnkcsyns (FILE ∗)

14.2.3.57 void classol::read_pnkcsyns (FILE ∗)

14.2.3.58 void classol::read_pnlhisyns (FILE ∗ *f*)

Method for reading the connectivity between PNs and LHIs from a file.

Parameters

f	File handle for a file containing PN to LHI conductivity values

14.2.3.59 void classol::read_pnlhisyns (FILE ∗)

14.2.3.60 void classol::read_pnlhisyns (FILE ∗)

14.2.3.61 void classol::read_pnlhisyns (FILE ∗)

14.2.3.62 void classol::read_sparsesyns_par (int *synInd,* struct SparseProjection *C,* FILE ∗ *f_ind,* FILE ∗ *f_indInG,* FILE ∗ *f_g,* double ∗ *g*)

Parameters

g	File handle for a file containing sparse conductivity values

14.2.3.63 void classol::read_sparsesyns_par (int *synInd,* struct SparseProjection *C,* scalar ∗ *g,* FILE ∗ *f_ind,* FILE ∗ *f_indInG,* FILE ∗ *f_g*)

Parameters

f_g	File handle for a file containing sparse connectivity values

14.2.3.64 void classol::read_sparsesyns_par (int , struct SparseProjection , scalar ∗ , FILE ∗ , FILE ∗ , FILE ∗)

14.2.3.65 void classol::read_sparsesyns_par (int , struct SparseProjection , scalar ∗ , FILE ∗ , FILE ∗ , FILE ∗)

14.2.3.66 template<class DATATYPE > void classol::read_sparsesyns_par (DATATYPE ∗ *wuvar,* int *synInd,* struct SparseProjection *C,* FILE ∗ *f_ind,* FILE ∗ *f_indInG,* FILE ∗ *f_g*)

Parameters

f_g	File handle for a file containing sparse conductivity values

14.2.3.67 void classol::run (float *runtime,* unsigned int *which*)

14.2.3.68 void classol::run (scalar *runtime,* unsigned int *which*)

Method for simulating the model for a given period of time.

Parameters

runtime	Duration of time to run the model for

which	Flag determining whether to run on GPU or CPU only

14.2.3.69 void classol::run (scalar , unsigned *int*)

14.2.3.70 void classol::runCPU (scalar *runtime*)

Method for simulating the model for a given period of time on the CPU.

Method for simulating the model for a given period of time on th CPU.

Parameters

runtime	Duration of time to run the model for

14.2.3.71 void classol::runCPU (scalar)

14.2.3.72 void classol::runGPU (scalar *runtime*)

Method for simulating the model for a given period of time on the GPU.

Method for simulating the model for a given period of time on th GPU.

Parameters

runtime	Duration of time to run the model for

14.2.3.73 void classol::runGPU (scalar)

14.2.3.74 void classol::sum_spikes ( )

14.2.3.75 void classol::sum_spikes ( )

14.2.3.76 void classol::sum_spikes ( )

14.2.3.77 void classol::sum_spikes ( )

Method for summing up spike numbers.

14.2.3.78 void classol::sum_spikes ( )

14.2.3.79 void classol::write_kcdnsyns (FILE ∗ *f*)

Method to write the connectivity between KCs and DNs (detector neurons) to a file.

Parameters

f	File handle for a file to write KC to DN (detectore neuron) conductivity values to

14.2.3.80 void classol::write_kcdnsyns (FILE ∗)

14.2.3.81 void classol::write_kcdnsyns (FILE ∗)

14.2.3.82 void classol::write_kcdnsyns (FILE ∗)

14.2.3.83 void classol::write_pnkcsyns (FILE ∗)

14.2.3.84 void classol::write_pnkcsyns (FILE ∗)

14.2.3.85 void classol::write_pnkcsyns (FILE ∗ *f*)

Method for writing the conenctivity between PNs and KCs back into file.

Parameters

f	File handle for a file to write PN to KC conductivity values to

14.2.3.86 void classol::write_pnkcsyns (FILE *)

14.2.3.87 void classol::write_pnlhisyns (FILE *)

14.2.3.88 void classol::write_pnlhisyns (FILE * *f*)

Method for writing the connectivity between PNs and LHIs to a file.

Parameters

f	File handle for a file to write PN to LHI conductivity values to

14.2.3.89 void classol::write_pnlhisyns (FILE *)

14.2.3.90 void classol::write_pnlhisyns (FILE *)

14.2.4 Member Data Documentation

14.2.4.1 uint64_t * classol::baserates

14.2.4.2 uint64_t * classol::d_baserates

14.2.4.3 uint64_t * classol::d_pattern

14.2.4.4 NNmodel classol::model

14.2.4.5 unsigned int classol::offset

14.2.4.6 scalar * classol::p_pattern

14.2.4.7 uint64_t * classol::pattern

14.2.4.8 unsigned int classol::size_g

14.2.4.9 unsigned int classol::sumDN

14.2.4.10 unsigned int classol::sumIzh1

14.2.4.11 unsigned int classol::sumKC

14.2.4.12 unsigned int classol::sumLHI

14.2.4.13 unsigned int classol::sumPN

14.2.4.14 uint64_t * classol::theRates

The documentation for this class was generated from the following files:

- MBody1_project/model/map_classol.h
- PoissonIzh-model.h
- MBody1_project/model/map_classol.cc
- PoissonIzh-model.cc

14.3 CodeHelper Class Reference

Public Member Functions

- CodeHelper ()
- void setVerbose (bool isVerbose)
- string openBrace (unsigned int level)
- string closeBrace (unsigned int level)
- string endl ()

Public Attributes

- vector< unsigned int > braces
- bool verbose

14.3.1 Constructor & Destructor Documentation

14.3.1.1 CodeHelper::CodeHelper ( ) [inline]

14.3.2 Member Function Documentation

14.3.2.1 string CodeHelper::closeBrace (unsigned int *level*) [inline]

14.3.2.2 string CodeHelper::endl ( ) [inline]

14.3.2.3 string CodeHelper::openBrace (unsigned int *level*) [inline]

14.3.2.4 void CodeHelper::setVerbose (bool *isVerbose*) [inline]

14.3.3 Member Data Documentation

14.3.3.1 vector<unsigned int> CodeHelper::braces

14.3.3.2 bool CodeHelper::verbose

The documentation for this class was generated from the following file:

- CodeHelper.cc

14.4 CStopWatch Class Reference

```
#include <hr_time.h>
```

Public Member Functions

- CStopWatch ()
- void startTimer ()

  This method starts the timer.
- void stopTimer ()

  This method stops the timer.
- double getElapsedTime ()

  This method returns the time elapsed between start and stop of the timer in seconds.

14.4.1 Constructor & Destructor Documentation

14.4.1.1 CStopWatch::CStopWatch ( ) [inline]

14.4.2 Member Function Documentation

14.4.2.1 double CStopWatch::getElapsedTime ( )

This method returns the time elapsed between start and stop of the timer in seconds.

14.4.2.2 void CStopWatch::startTimer ( )

This method starts the timer.

14.4.2.3 void CStopWatch::stopTimer ( )

This method stops the timer.

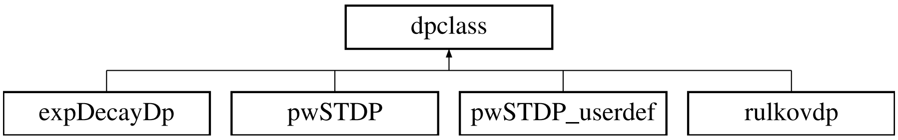
The documentation for this class was generated from the following files:

- hr_time.h
- hr_time.cpp

14.5 dpclass Class Reference

`#include <modelSpec.h>`

Inheritance diagram for dpclass:



Public Member Functions

- dpclass ()
- virtual double calculateDerivedParameter (int index, vector< double > pars, double dt=1.0)

14.5.1 Constructor & Destructor Documentation

14.5.1.1 dpclass::dpclass ( ) [inline]

14.5.2 Member Function Documentation

14.5.2.1 virtual double dpclass::calculateDerivedParameter (int *index*, vector< double > *pars*, double *dt* = 1.0) [inline], [virtual]

Reimplemented in expDecayDp, rulkovdp, pwSTDP_userdef, and pwSTDP.

The documentation for this class was generated from the following file:

- modelSpec.h

14.6 errTupel Struct Reference

Public Attributes

- unsigned int id
- double err

14.6.1 Member Data Documentation

14.6.1.1 double errTupel::err

14.6.1.2 unsigned int errTupel::id

The documentation for this struct was generated from the following file:

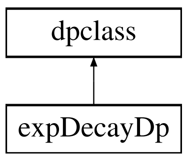
- GA.cc

14.7 expDecayDp Class Reference

Class defining the dependent parameter for exponential decay.

`#include <utils.h>`

Inheritance diagram for expDecayDp:



Public Member Functions

- double calculateDerivedParameter (int index, vector< double > pars, double dt=1.0)
- double expDecay (vector< double > pars, double dt)

14.7.1 Detailed Description

Class defining the dependent parameter for exponential decay.

14.7.2 Member Function Documentation

14.7.2.1 double expDecayDp::calculateDerivedParameter (int *index*, vector< double > *pars*, double *dt* = `1.0`) `[inline]`, `[virtual]`

Reimplemented from dpclass.

14.7.2.2 double expDecayDp::expDecay (vector< double > *pars*, double *dt*) `[inline]`

The documentation for this class was generated from the following file:

- utils.h

14.8 inputSpec Struct Reference

```
#include <helper.h>
```

Public Attributes

- double t
- double baseV
- int N
- vector< double > st
- vector< double > V

14.8.1 Member Data Documentation

14.8.1.1 double inputSpec::baseV

14.8.1.2 int inputSpec::N

14.8.1.3 vector<double> inputSpec::st

14.8.1.4 double inputSpec::t

14.8.1.5 vector<double> inputSpec::V

The documentation for this struct was generated from the following file:

- helper.h

14.9 neuronModel Struct Reference

class (struct) for specifying a neuron model.

```
#include <modelSpec.h>
```

Public Attributes

- string simCode

  Code that defines the execution of one timestep of integration of the neuron model.
- string thresholdConditionCode

  Code evaluating to a bool (e.g. "V > 20") that defines the condition for a true spike in the described neuron model.
- string resetCode

  Code that defines the reset action taken after a spike occurred. This can be empty.
- vector< string > varNames

  Names of the variables in the neuron model.
- vector< string > tmpVarNames

  never used
- vector< string > varTypes

  Types of the variable named above, e.g. "float". Names and types are matched by their order of occurrence in the vector.
- vector< string > tmpVarTypes

  never used
- vector< string > pNames

  Names of (independent) parameters of the model.
- vector< string > dpNames

Names of dependent parameters of the model.
- vector$<$ string $>$ extraGlobalNeuronKernelParameters

  Additional parameter in the neuron kernel; it is translated to a population specific name but otherwise assumed to be one parameter per population rather than per neuron.
- vector$<$ string $>$ extraGlobalNeuronKernelParameterTypes

  Additional parameters in the neuron kernel; they are translated to a population specific name but otherwise assumed to be one parameter per population rather than per neuron.
- dpclass $*$ dps

  Derived parameters.
- bool needPreSt

  Whether presynaptic spike times are needed or not.
- bool needPostSt

  Whether postsynaptic spike times are needed or not.

14.9.1 Detailed Description

class (struct) for specifying a neuron model.

14.9.2 Member Data Documentation

14.9.2.1 vector$<$string$>$ neuronModel::dpNames

Names of dependent parameters of the model.

The dependent parameters are functions of independent parameters that enter into the neuron model. To avoid unecessary computational overhead, these parameters are calculated at compile time and inserted as explicit values into the generated code. See method NNmodel::initDerivedNeuronPara for how this is done.

14.9.2.2 dpclass$*$ neuronModel::dps

Derived parameters.

14.9.2.3 vector$<$string$>$ neuronModel::extraGlobalNeuronKernelParameters

Additional parameter in the neuron kernel; it is translated to a population specific name but otherwise assumed to be one parameter per population rather than per neuron.

14.9.2.4 vector$<$string$>$ neuronModel::extraGlobalNeuronKernelParameterTypes

Additional parameters in the neuron kernel; they are translated to a population specific name but otherwise assumed to be one parameter per population rather than per neuron.

14.9.2.5 bool neuronModel::needPostSt

Whether postsynaptic spike times are needed or not.

14.9.2.6 bool neuronModel::needPreSt

Whether presynaptic spike times are needed or not.

14.9.2.7 vector$<$string$>$ neuronModel::pNames

Names of (independent) parameters of the model.

14.9.2.8 string neuronModel::resetCode

Code that defines the reset action taken after a spike occurred. This can be empty.

14.9.2.9 string neuronModel::simCode

Code that defines the execution of one timestep of integration of the neuron model.

The code will refer to for the value of the variable with name "NN". It needs to refer to the predefined variable "ISYN", i.e. contain , if it is to receive input.

14.9.2.10 string neuronModel::thresholdConditionCode

Code evaluating to a bool (e.g. "V > 20") that defines the condition for a true spike in the described neuron model.

14.9.2.11 vector<string> neuronModel::tmpVarNames

never used

14.9.2.12 vector<string> neuronModel::tmpVarTypes

never used

14.9.2.13 vector<string> neuronModel::varNames

Names of the variables in the neuron model.

14.9.2.14 vector<string> neuronModel::varTypes

Types of the variable named above, e.g. "float". Names and types are matched by their order of occurrence in the vector.

The documentation for this struct was generated from the following file:

- modelSpec.h

14.10 neuronpop Class Reference

```
#include <OneComp_model.h>
```

Public Member Functions

- neuronpop ()
- ∼neuronpop ()
- void init (unsigned int)
- void allocate_device_mem_patterns ()
- void allocate_device_mem_input ()
- void copy_device_mem_input ()
- void write_input_to_file (FILE ∗)
- void read_input_values (FILE ∗)
- void create_input_values (float t)
- void run (float, unsigned int)
- void getSpikesFromGPU ()

  Method for copying all spikes of the last time step from the GPU.
- void getSpikeNumbersFromGPU ()

  Method for copying the number of spikes in all neuron populations that have occurred during the last time step.
- void output_state (FILE ∗, unsigned int)
- void output_spikes (FILE ∗, unsigned int)
- void sum_spikes ()

Public Attributes

- NNmodel model
- float ∗ input1
- float ∗ d_input1
- unsigned int sumIzh1

14.10.1 Constructor & Destructor Documentation

14.10.1.1 neuronpop::neuronpop ( )

14.10.1.2 neuronpop::∼neuronpop ( )

14.10.2 Member Function Documentation

14.10.2.1 void neuronpop::allocate_device_mem_input ( )

14.10.2.2 void neuronpop::allocate_device_mem_patterns ( )

14.10.2.3 void neuronpop::copy_device_mem_input ( )

14.10.2.4 void neuronpop::create_input_values (float *t*)

14.10.2.5 void neuronpop::getSpikeNumbersFromGPU ( )

Method for copying the number of spikes in all neuron populations that have occurred during the last time step.

This method is a simple wrapper for the convenience function copySpikeNFromDevice() provided by GeNN.

14.10.2.6 void neuronpop::getSpikesFromGPU ( )

Method for copying all spikes of the last time step from the GPU.

This is a simple wrapper for the convenience function copySpikesFromDevice() which is provided by GeNN.

14.10.2.7 void neuronpop::init (unsigned int *which*)

14.10.2.8 void neuronpop::output_spikes (FILE ∗ *f*, unsigned int *which*)

14.10.2.9 void neuronpop::output_state (FILE ∗ *f*, unsigned int *which*)

14.10.2.10 void neuronpop::read_input_values (FILE ∗ *f*)

14.10.2.11 void neuronpop::run (float *runtime*, unsigned int *which*)

14.10.2.12 void neuronpop::sum_spikes ( )

14.10.2.13 void neuronpop::write_input_to_file (FILE ∗ *f*)

14.10.3 Member Data Documentation

14.10.3.1 float∗ neuronpop::d_input1

14.10.3.2 float∗ neuronpop::input1

14.10.3.3 NNmodel neuronpop::model

14.10.3.4 unsigned int neuronpop::sumIzh1

The documentation for this class was generated from the following files:

- OneComp_model.h

- OneComp_model.cc

14.11 NNmodel Class Reference

Structure to hold the information that defines synapse dynamics (a model of how synapse variables change over time, independent of or in addition to changes when spikes occur).

```
#include <modelSpec.h>
```

Public Member Functions

- NNmodel ()
- ∼NNmodel ()
- void setName (const string)

  Method to set the neuronal network model name.
- void setPrecision (unsigned int)

  Set numerical precision for floating point.
- void setTiming (bool)

  Set whether timers and timing commands are to be included.
- void setSeed (unsigned int)

  Set the random seed (disables automatic seeding if argument not 0).
- void checkSizes (unsigned int ∗, unsigned int ∗, unsigned int ∗)
- void resetPaddedSums ()

  Re-calculates the block-size-padded sum of threads needed to compute the groups of neurons and synapses assigned to each device. Must be called after changing the hostID:deviceID of any group.
- void setGPUDevice (int)

  Method to choose the GPU to be used for the model. If "AUTODEVICE' (-1), GeNN will choose the device based on a heuristic rule.
- void addNeuronPopulation (const char ∗, unsigned int, unsigned int, double ∗, double ∗)

  Method for adding a neuron population to a neuronal network model, using C style character array for the name of the population.
- void addNeuronPopulation (const string, unsigned int, unsigned int, double ∗, double ∗)

  Method for adding a neuron population to a neuronal network model, using C++ string for the name of the population.
- void addNeuronPopulation (const string, unsigned int, unsigned int, vector< double >, vector< double >)

  Method for adding a neuron population to a neuronal network model, using C++ string for the name of the population.
- void activateDirectInput (const string, unsigned int)

  Method for activating explicit current input.
- void setConstInp (const string, double)

  Method for setting the global input value for a neuron population if CONSTINP.
- void setNeuronClusterIndex (const string neuronGroup, int hostID, int deviceID)

  Function for setting which host and which device a neuron group will be simulated on.
- void addSynapsePopulation (const string name, unsigned int syntype, unsigned int conntype, unsigned int gtype, const string src, const string trg, double ∗p)

  Overload of method for backwards compatibility.
- void addSynapsePopulation (const char ∗, unsigned int, unsigned int, unsigned int, unsigned int, unsigned int, const char ∗, const char ∗, double ∗, double ∗, double ∗)

  Method for adding a synapse population to a neuronal network model, using C style character array for the name of the population.
- void addSynapsePopulation (const string, unsigned int, unsigned int, unsigned int, unsigned int, unsigned int, const string, const string, double ∗, double ∗, double ∗)

  Overloaded version without initial variables for synapses.
- void addSynapsePopulation (const string, unsigned int, unsigned int, unsigned int, unsigned int, unsigned int, const string, const string, double ∗, double ∗, double ∗, double ∗)

Method for adding a synapse population to a neuronal network model, using C++ string for the name of the population.

- void addSynapsePopulation (const string, unsigned int, unsigned int, unsigned int, unsigned int, unsigned int, const string, const string, vector< double >, vector< double >, vector< double >, vector< double >)

  Method for adding a synapse population to a neuronal network model, using C++ string for the name of the population.
- void setSynapseG (const string, double)

  Method for setting the conductance (g) value for a synapse population with "GLOBALG" charactertistic.
- void setMaxConn (const string, unsigned int)

  This function defines the maximum number of connections for a neuron in the population.
- void setSynapseClusterIndex (const string synapseGroup, int hostID, int deviceID)

  Function for setting which host and which device a synapse group will be simulated on.
- void initLearnGrps ()

Public Attributes

- string name

  Name of the neuronal newtwork model.
- string ftype

  Type of floating point variables (float, double, ...; default: float)
- string RNtype

  Underlying type for random number generation (default: long)
- int valid

  Flag for whether the model has been validated (unused?)
- unsigned int needSt

  Whether last spike times are needed at all in this network model (related to STDP)
- unsigned int needSynapseDelay

  Whether delayed synapse conductance is required in the network.
- int chooseGPUDevice
- bool timing
- unsigned int seed
- unsigned int neuronGrpN

  Number of neuron groups.
- vector< string > neuronName

  Names of neuron groups.
- vector< unsigned int > neuronN

  Number of neurons in group.
- vector< unsigned int > sumNeuronN

  Summed neuron numbers.
- vector< unsigned int > padSumNeuronN

  Padded summed neuron numbers.
- vector< unsigned int > neuronPostSyn
- vector< unsigned int > neuronType

  Postsynaptic methods to the neuron.
- vector< vector< double > > neuronPara

  Parameters of neurons.
- vector< vector< double > > dnp

  Derived neuron parameters.
- vector< vector< double > > neuronIni

  Initial values of neurons.
- vector< vector< unsigned int > > inSyn

  The ids of the incoming synapse groups.
- vector< vector< unsigned int > > outSyn

The ids of the outgoing synapse groups.
- vector< unsigned int > receivesInputCurrent

  flags whether neurons of a population receive explicit input currents
- vector< bool > neuronNeedSt

  Whether last spike time needs to be saved for a group.
- vector< bool > neuronNeedTrueSpk

  Whether spike-like events from a group are required.
- vector< bool > neuronNeedSpkEvnt

  Whether spike-like events from a group are required.
- vector< vector< bool > > neuronVarNeedQueue

  Whether a neuron variable needs queueing for syn code.
- vector< string > neuronSpkEvntCondition

  Will contain the spike event condition code when spike events are used.
- vector< unsigned int > neuronDelaySlots

  The number of slots needed in the synapse delay queues of a neuron group.
- vector< int > neuronHostID

  The ID of the cluster node which the neuron groups are computed on.
- vector< int > neuronDeviceID

  The ID of the CUDA device which the neuron groups are comnputed on.
- vector< vector< bool > > neuronVarNeedSpkEvnt

  indicates whether spkEnt values (or delay queues) need to be stored for this variable
- vector< vector< bool > > neuronVarNeedSpk

  indicates whether spk values (or delay queues) need to be stored for this variable
- unsigned int synapseGrpN

  Number of synapse groups.
- vector< string > synapseName

  Names of synapse groups.
- vector< unsigned int > sumSynapseTrgN

  Summed number of target neurons.
- vector< unsigned int > padSumSynapseTrgN

  "Padded" summed target neuron numbers
- vector< unsigned int > maxConn

  Padded summed maximum number of connections for a neuron in the neuron groups.
- vector< unsigned int > padSumSynapseKrnl
- vector< unsigned int > synapseType

  Types of synapses.
- vector< unsigned int > synapseConnType

  Connectivity type of synapses.
- vector< unsigned int > synapseGType

  Type of specification method for synaptic conductance.
- vector< unsigned int > synapseSource

  Presynaptic neuron groups.
- vector< unsigned int > synapseTarget

  Postsynaptic neuron groups.
- vector< unsigned int > synapseInSynNo

  IDs of the target neurons' incoming synapse variables for each synapse group.
- vector< unsigned int > synapseOutSynNo

  The target neurons' outgoing synapse for each synapse group.
- vector< bool > synapseUsesTrueSpikes

  Defines if synapse update is done after detection of real spikes (only one point after threshold)
- vector< bool > synapseUsesSpikeEvents

Defines if synapse update is done after detection of spike events (every point above threshold)

- vector< bool > synapseUsesPostLearning

  Defines if anything is done in case of postsynaptic neuron spiking before presynaptic neuron (punishment in STDP etc.)
- vector< vector< string > > synapseSpkEvntVars

  Defines variable names that are needed in the SpkEvnt condition and that are pre-fetched for that purpose into shared memory.
- vector< vector< double > > synapsePara

  parameters of synapses
- vector< vector< double > > synapseIni

  Initial values of synapse variables.
- vector< vector< double > > dsp_w

  Derived synapse parameters (weightUpdateModel only)
- vector< unsigned int > postSynapseType

  Types of post-synaptic model.
- vector< vector< double > > postSynapsePara

  parameters of postsynapses
- vector< vector< double > > postSynIni

  Initial values of postsynaptic variables.
- vector< vector< double > > dpsp

  Derived postsynapse parameters.
- vector< double > globalInp

  Global explicit input if CONSTINP is chosen.
- unsigned int lrnGroups

  Number of synapse groups with learning.
- vector< unsigned int > padSumLearnN

  Padded summed neuron numbers of learn group source populations.
- vector< unsigned int > lrnSynGrp

  Enumeration of the IDs of synapse groups that learn.
- vector< unsigned int > synapseDelay

  Global synaptic conductance delay for the group (in time steps)
- vector< int > synapseHostID

  The ID of the cluster node which the synapse groups are computed on.
- vector< int > synapseDeviceID

  The ID of the CUDA device which the synapse groups are comnputed on.

14.11.1 Detailed Description

Structure to hold the information that defines synapse dynamics (a model of how synapse variables change over time, independent of or in addition to changes when spikes occur).

14.11.2 Constructor & Destructor Documentation

14.11.2.1 NNmodel::NNmodel ( )

14.11.2.2 NNmodel::∼NNmodel ( )

14.11.3 Member Function Documentation

14.11.3.1 void NNmodel::activateDirectInput (const string *name*, unsigned int *type*)

Method for activating explicit current input.

This function defines the type of the explicit input to the neuron model. Current options are common constant input to all neurons, input from a file and input defines as a rule.

Parameters

name	Name of the neuron population
type	Type of input: 1 if common input, 2 if custom input from file, 3 if custom input as a rule

14.11.3.2 void NNmodel::addNeuronPopulation (const char ∗ *name*, unsigned int *nNo*, unsigned int *type*, double ∗ *p*, double ∗ *ini*)

Method for adding a neuron population to a neuronal network model, using C style character array for the name of the population.

Parameters

name	Name of the neuron population
nNo	Number of neurons in the population
type	Type of the neurons, refers to either a standard type or user-defined type
p	Parameters of this neuron type
ini	Initial values for variables of this neuron type

14.11.3.3 void NNmodel::addNeuronPopulation (const string *name*, unsigned int *nNo*, unsigned int *type*, double ∗ *p*, double ∗ *ini*)

Method for adding a neuron population to a neuronal network model, using C++ string for the name of the population.

Parameters

name	The name of the neuron population
nNo	Number of neurons in the population
type	Type of the neurons, refers to either a standard type or user-defined type
p	Parameters of this neuron type
ini	Initial values for variables of this neuron type

14.11.3.4 void NNmodel::addNeuronPopulation (const string *name*, unsigned int *nNo*, unsigned int *type*, vector< double > *p*, vector< double > *ini*)

Method for adding a neuron population to a neuronal network model, using C++ string for the name of the population.

This function adds a neuron population to a neuronal network models, assigning the name, the number of neurons in the group, the neuron type, parameters and initial values. The latter two defined as STL vectors of double.

Parameters

name	The name of the neuron population
nNo	Number of neurons in the population
type	Type of the neurons, refers to either a standard type or user-defined type
p	Parameters of this neuron type
ini	Initial values for variables of this neuron type

14.11.3.5 void NNmodel::addSynapsePopulation (const string *name*, unsigned int *syntype*, unsigned int *conntype*, unsigned int *gtype*, const string *src*, const string *target*, double ∗ *params*)

Overload of method for backwards compatibility.

Parameters

name	The name of the synapse population
syntype	The type of synapse to be added (i.e. learning mode)

conntype	The type of synaptic connectivity
gtype	The way how the synaptic conductivity g will be defined
src	Name of the (existing!) pre-synaptic neuron population
target	Name of the (existing!) post-synaptic neuron population
params	A C-type array of doubles that contains synapse parameter values (common to all synapses of the population) which will be used for the defined synapses. The array must contain the right number of parameters in the right order for the chosen synapse type. If too few, segmentation faults will occur, if too many, excess will be ignored.

14.11.3.6 void NNmodel::addSynapsePopulation (const char ∗ *name,* unsigned int *syntype,* unsigned int *conntype,* unsigned int *gtype,* unsigned int *delaySteps,* unsigned int *postsyn,* const char ∗ *src,* const char ∗ *trg,* double ∗ *p,* double ∗ *PSVini,* double ∗ *ps*)

Method for adding a synapse population to a neuronal network model, using C style character array for the name of the population.

Parameters

name	The name of the synapse population
syntype	The type of synapse to be added (i.e. learning mode)
conntype	The type of synaptic connectivity
gtype	The way how the synaptic conductivity g will be defined
delaySteps	Number of delay slots
postsyn	Postsynaptic integration method
src	Name of the (existing!) pre-synaptic neuron population
trg	Name of the (existing!) post-synaptic neuron population
p	A C-type array of doubles that contains synapse parameter values (common to all synapses of the population) which will be used for the defined synapses. The array must contain the right number of parameters in the right order for the chosen synapse type. If too few, segmentation faults will occur, if too many, excess will be ignored.
PSVini	A C-type array of doubles that contains the initial values for postsynaptic mechanism variables (common to all synapses of the population) which will be used for the defined synapses. The array must contain the right number of parameters in the right order for the chosen synapse type. If too few, segmentation faults will occur, if too many, excess will be ignored.
ps	A C-type array of doubles that contains postsynaptic mechanism parameter values (common to all synapses of the population) which will be used for the defined synapses. The array must contain the right number of parameters in the right order for the chosen synapse type. If too few, segmentation faults will occur, if too many, excess will be ignored.

14.11.3.7 void NNmodel::addSynapsePopulation (const string *name,* unsigned int *syntype,* unsigned int *conntype,* unsigned int *gtype,* unsigned int *delaySteps,* unsigned int *postsyn,* const string *src,* const string *trg,* double ∗ *p,* double ∗ *PSVini,* double ∗ *ps*)

Overloaded version without initial variables for synapses.

Overloaded old version.

Parameters

name	The name of the synapse population
syntype	The type of synapse to be added (i.e. learning mode)
conntype	The type of synaptic connectivity
gtype	The way how the synaptic conductivity g will be defined
delaySteps	Number of delay slots

postsyn	Postsynaptic integration method
src	Name of the (existing!) pre-synaptic neuron population
trg	Name of the (existing!) post-synaptic neuron population
p	A C-type array of doubles that contains synapse parameter values (common to all synapses of the population) which will be used for the defined synapses. The array must contain the right number of parameters in the right order for the chosen synapse type. If too few, segmentation faults will occur, if too many, excess will be ignored.
PSVini	A C-type array of doubles that contains the initial values for postsynaptic mechanism variables (common to all synapses of the population) which will be used for the defined synapses. The array must contain the right number of parameters in the right order for the chosen synapse type. If too few, segmentation faults will occur, if too many, excess will be ignored.
ps	A C-type array of doubles that contains postsynaptic mechanism parameter values (common to all synapses of the population) which will be used for the defined synapses. The array must contain the right number of parameters in the right order for the chosen synapse type. If too few, segmentation faults will occur, if too many, excess will be ignored.

14.11.3.8 void NNmodel::addSynapsePopulation (const string *name*, unsigned int *syntype*, unsigned int *conntype*, unsigned int *gtype*, unsigned int *delaySteps*, unsigned int *postsyn*, const string *src*, const string *trg*, double ∗ *synini*, double ∗ *p*, double ∗ *PSVini*, double ∗ *ps*)

Method for adding a synapse population to a neuronal network model, using C++ string for the name of the population.

This function adds a synapse population to a neuronal network model, assigning the name, the synapse type, the connectivity type, the type of conductance specification, the source and destination neuron populations, and the synaptic parameters.

Parameters

name	The name of the synapse population
syntype	The type of synapse to be added (i.e. learning mode)
conntype	The type of synaptic connectivity
gtype	The way how the synaptic conductivity g will be defined
delaySteps	Number of delay slots
postsyn	Postsynaptic integration method
src	Name of the (existing!) pre-synaptic neuron population
trg	Name of the (existing!) post-synaptic neuron population
synini	A C-type array of doubles that contains the initial values for synapse variables (common to all synapses of the population) which will be used for the defined synapses. The array must contain the right number of parameters in the right order for the chosen synapse type. If too few, segmentation faults will occur, if too many, excess will be ignored.
p	A C-type array of doubles that contains synapse parameter values (common to all synapses of the population) which will be used for the defined synapses. The array must contain the right number of parameters in the right order for the chosen synapse type. If too few, segmentation faults will occur, if too many, excess will be ignored.
PSVini	A C-type array of doubles that contains the initial values for postsynaptic mechanism variables (common to all synapses of the population) which will be used for the defined synapses. The array must contain the right number of parameters in the right order for the chosen synapse type. If too few, segmentation faults will occur, if too many, excess will be ignored.

ps	A C-type array of doubles that contains postsynaptic mechanism parameter values (common to all synapses of the population) which will be used for the defined synapses. The array must contain the right number of parameters in the right order for the chosen synapse type. If too few, segmentation faults will occur, if too many, excess will be ignored.

14.11.3.9 void NNmodel::addSynapsePopulation (const string *name*, unsigned int *syntype*, unsigned int *conntype*, unsigned int *gtype*, unsigned int *delaySteps*, unsigned int *postsyn*, const string *src*, const string *trg*, vector$<$ double $>$ *synini*, vector$<$ double $>$ *p*, vector$<$ double $>$ *PSVini*, vector$<$ double $>$ *ps*)

Method for adding a synapse population to a neuronal network model, using C++ string for the name of the population.

This function adds a synapse population to a neuronal network model, assigning the name, the synapse type, the connectivity type, the type of conductance specification, the source and destination neuron populations, and the synaptic parameters.

Parameters

name	The name of the synapse population
syntype	The type of synapse to be added (i.e. learning mode)
conntype	The type of synaptic connectivity
gtype	The way how the synaptic conductivity g will be defined
delaySteps	Number of delay slots
postsyn	Postsynaptic integration method
src	Name of the (existing!) pre-synaptic neuron population
trg	Name of the (existing!) post-synaptic neuron population
synini	A C-type array of doubles that contains the initial values for synapse variables (common to all synapses of the population) which will be used for the defined synapses. The array must contain the right number of parameters in the right order for the chosen synapse type. If too few, segmentation faults will occur, if too many, excess will be ignored.
p	A C-type array of doubles that contains synapse parameter values (common to all synapses of the population) which will be used for the defined synapses. The array must contain the right number of parameters in the right order for the chosen synapse type. If too few, segmentation faults will occur, if too many, excess will be ignored.
PSVini	A C-type array of doubles that contains the initial values for postsynaptic mechanism variables (common to all synapses of the population) which will be used for the defined synapses. The array must contain the right number of parameters in the right order for the chosen synapse type. If too few, segmentation faults will occur, if too many, excess will be ignored.
ps	A C-type array of doubles that contains postsynaptic mechanism parameter values (common to all synapses of the population) which will be used for the defined synapses. The array must contain the right number of parameters in the right order for the chosen synapse type. If too few, segmentation faults will occur, if too many, excess will be ignored.

14.11.3.10 void NNmodel::checkSizes (unsigned int $*$, unsigned int $*$, unsigned int $*$)

14.11.3.11 void NNmodel::initLearnGrps ( )

14.11.3.12 void NNmodel::resetPaddedSums ( )

Re-calculates the block-size-padded sum of threads needed to compute the groups of neurons and synapses assigned to each device. Must be called after changing the hostID:deviceID of any group.

This function re-calculates the block-size-padded sum of threads needed to compute the groups of neurons and synapses assigned to each device. Must be called after changing the hostID:deviceID of any neuron or synapse group.

14.11.3.13 void NNmodel::setConstInp (const string *sName*, double *globalInp0*)

Method for setting the global input value for a neuron population if CONSTINP.

This function sets a global input value to the specified neuron group.

14.11.3.14 void NNmodel::setGPUDevice (int *device*)

Method to choose the GPU to be used for the model. If "AUTODEVICE' (-1), GeNN will choose the device based on a heuristic rule.

This function defines the way how the GPU is chosen. If "AUTODEVICE" (-1) is given as the argument, GeNN will use internal heuristics to choose the device. Otherwise the argument is the device number and the indicated device will be used.

14.11.3.15 void NNmodel::setMaxConn (const string *sname,* unsigned int *maxConnP*)

This function defines the maximum number of connections for a neuron in the population.

14.11.3.16 void NNmodel::setName (const string *inname*)

Method to set the neuronal network model name.

14.11.3.17 void NNmodel::setNeuronClusterIndex (const string *neuronGroup,* int *hostID,* int *deviceID*)

Function for setting which host and which device a neuron group will be simulated on.

This function is for setting which host and which device a neuron group will be simulated on.

Parameters

neuronGroup	Name of the neuron population
hostID	ID of the host
deviceID	ID of the device

14.11.3.18 void NNmodel::setPrecision (unsigned int *floattype*)

Set numerical precision for floating point.

This function sets the numerical precision of floating type variables. By default, it is FLOAT.

14.11.3.19 void NNmodel::setSeed (unsigned int *inseed*)

Set the random seed (disables automatic seeding if argument not 0).

This function sets the random seed. If the passed argument is >0, automatic seeding is disabled. If the argument is 0, the underlying seed is obtained from the time() function.

Parameters

inseed	the new seed

14.11.3.20 void NNmodel::setSynapseClusterIndex (const string *synapseGroup,* int *hostID,* int *deviceID*)

Function for setting which host and which device a synapse group will be simulated on.

This function is for setting which host and which device a synapse group will be simulated on.

Parameters

synapseGroup	Name of the synapse population
hostID	ID of the host
deviceID	ID of the device

14.11.3.21 void NNmodel::setSynapseG (const string *sName,* double *g*)

Method for setting the conductance (g) value for a synapse population with "GLOBALG" charactertistic.

This functions sets the global value of the maximal synaptic conductance for a synapse population that was idfenti-fied as conductance specifcation method "GLOBALG".

14.11.3.22 void NNmodel::setTiming (bool *theTiming*)

Set whether timers and timing commands are to be included.

This function sets a flag to determine whether timers and timing commands are to be included in generated code.

14.11.4 Member Data Documentation

14.11.4.1 int NNmodel::chooseGPUDevice

14.11.4.2 vector<vector<double> > NNmodel::dnp

Derived neuron parameters.

14.11.4.3 vector<vector<double> > NNmodel::dpsp

Derived postsynapse parameters.

14.11.4.4 vector<vector<double> > NNmodel::dsp_w

Derived synapse parameters (weightUpdateModel only)

14.11.4.5 string NNmodel::ftype

Type of floating point variables (float, double, ...; default: float)

14.11.4.6 vector<double> NNmodel::globalInp

Global explicit input if CONSTINP is chosen.

14.11.4.7 vector<vector<unsigned int> > NNmodel::inSyn

The ids of the incoming synapse groups.

14.11.4.8 unsigned int NNmodel::lrnGroups

Number of synapse groups with learning.

14.11.4.9 vector<unsigned int> NNmodel::lrnSynGrp

Enumeration of the IDs of synapse groups that learn.

14.11.4.10 vector<unsigned int> NNmodel::maxConn

Padded summed maximum number of connections for a neuron in the neuron groups.

14.11.4.11 string NNmodel::name

Name of the neuronal newtwork model.

14.11.4.12 unsigned int NNmodel::needSt

Whether last spike times are needed at all in this network model (related to STDP)

14.11.4.13 unsigned int NNmodel::needSynapseDelay

Whether delayed synapse conductance is required in the network.

14.11.4.14 vector<unsigned int> NNmodel::neuronDelaySlots

The number of slots needed in the synapse delay queues of a neuron group.

14.11.4.15 vector<int> NNmodel::neuronDeviceID

The ID of the CUDA device which the neuron groups are comnputed on.

14.11.4.16 unsigned int NNmodel::neuronGrpN

Number of neuron groups.

14.11.4.17 vector<int> NNmodel::neuronHostID

The ID of the cluster node which the neuron groups are computed on.

14.11.4.18 vector<vector<double> > NNmodel::neuronIni

Initial values of neurons.

14.11.4.19 vector<unsigned int> NNmodel::neuronN

Number of neurons in group.

14.11.4.20 vector<string> NNmodel::neuronName

Names of neuron groups.

14.11.4.21 vector<bool> NNmodel::neuronNeedSpkEvnt

Whether spike-like events from a group are required.

14.11.4.22 vector<bool> NNmodel::neuronNeedSt

Whether last spike time needs to be saved for a group.

14.11.4.23 vector<bool> NNmodel::neuronNeedTrueSpk

Whether spike-like events from a group are required.

14.11.4.24 vector<vector<double> > NNmodel::neuronPara

Parameters of neurons.

14.11.4.25 vector<unsigned int> NNmodel::neuronPostSyn

14.11.4.26 vector<string> NNmodel::neuronSpkEvntCondition

Will contain the spike event condition code when spike events are used.

14.11.4.27 vector<unsigned int> NNmodel::neuronType

Postsynaptic methods to the neuron.
Types of neurons

14.11.4.28 vector<vector<bool> > NNmodel::neuronVarNeedQueue

Whether a neuron variable needs queueing for syn code.

14.11.4.29 vector<vector<bool > > NNmodel::neuronVarNeedSpk

indicates whether spk values (or delay queues) need to be stored for this variable

14.11.4.30 vector<vector<bool > > NNmodel::neuronVarNeedSpkEvnt

indicates whether spkEnt values (or delay queues) need to be stored for this variable

14.11.4.31 vector<vector<unsigned int> > NNmodel::outSyn

The ids of the outgoing synapse groups.

14.11.4.32 vector<unsigned int> NNmodel::padSumLearnN

Padded summed neuron numbers of learn group source populations.

14.11.4.33 vector<unsigned int> NNmodel::padSumNeuronN

Padded summed neuron numbers.

14.11.4.34 vector<unsigned int> NNmodel::padSumSynapseKrnl

14.11.4.35 vector<unsigned int> NNmodel::padSumSynapseTrgN

"Padded" summed target neuron numbers

14.11.4.36 vector<vector<double> > NNmodel::postSynapsePara

parameters of postsynapses

14.11.4.37 vector<unsigned int> NNmodel::postSynapseType

Types of post-synaptic model.

14.11.4.38 vector<vector<double> > NNmodel::postSynIni

Initial values of postsynaptic variables.

14.11.4.39 vector<unsigned int> NNmodel::receivesInputCurrent

flags whether neurons of a population receive explicit input currents

14.11.4.40 string NNmodel::RNtype

Underlying type for random number generation (default: long)

14.11.4.41 unsigned int NNmodel::seed

14.11.4.42 vector<unsigned int> NNmodel::sumNeuronN

Summed neuron numbers.

14.11.4.43 vector<unsigned int> NNmodel::sumSynapseTrgN

Summed number of target neurons.

14.11.4.44 vector<unsigned int> NNmodel::synapseConnType

Connectivity type of synapses.

14.11.4.45 vector<unsigned int> NNmodel::synapseDelay

Global synaptic conductance delay for the group (in time steps)

14.11.4.46 vector<int> NNmodel::synapseDeviceID

The ID of the CUDA device which the synapse groups are comnputed on.

14.11.4.47 unsigned int NNmodel::synapseGrpN

Number of synapse groups.

14.11.4.48 vector<unsigned int> NNmodel::synapseGType

Type of specification method for synaptic conductance.

14.11.4.49 vector<int> NNmodel::synapseHostID

The ID of the cluster node which the synapse groups are computed on.

14.11.4.50 vector<vector<double> > NNmodel::synapseIni

Initial values of synapse variables.

14.11.4.51 vector<unsigned int> NNmodel::synapseInSynNo

IDs of the target neurons' incoming synapse variables for each synapse group.

14.11.4.52 vector<string> NNmodel::synapseName

Names of synapse groups.

14.11.4.53 vector<unsigned int> NNmodel::synapseOutSynNo

The target neurons' outgoing synapse for each synapse group.

14.11.4.54 vector<vector<double> > NNmodel::synapsePara

parameters of synapses

14.11.4.55 vector<unsigned int> NNmodel::synapseSource

Presynaptic neuron groups.

14.11.4.56 vector<vector<string> > NNmodel::synapseSpkEvntVars

Defines variable names that are needed in the SpkEvnt condition and that are pre-fetched for that purpose into shared memory.

14.11.4.57 vector<unsigned int> NNmodel::synapseTarget

Postsynaptic neuron groups.

14.11.4.58 vector<unsigned int> NNmodel::synapseType

Types of synapses.

14.11.4.59 vector<bool> NNmodel::synapseUsesPostLearning

Defines if anything is done in case of postsynaptic neuron spiking before presynaptic neuron (punishment in STDP etc.)

14.11.4.60 vector<bool> NNmodel::synapseUsesSpikeEvents

Defines if synapse update is done after detection of spike events (every point above threshold)

14.11.4.61 vector<bool> NNmodel::synapseUsesTrueSpikes

Defines if synapse update is done after detection of real spikes (only one point after threshold)

14.11.4.62 bool NNmodel::timing

14.11.4.63 int NNmodel::valid

Flag for whether the model has been validated (unused?)

The documentation for this class was generated from the following files:

- modelSpec.h
- modelSpec.cc

14.12 postSynModel Struct Reference

Structure to hold the information that defines a post-synaptic model (a model of how synapses affect post-synaptic neuron variables, classically in the form of a synaptic current). It also allows to define an equation for the dynamics that can be applied to the summed synaptic input variable "insyn".

```
#include <modelSpec.h>
```

Public Attributes

- string postSyntoCurrent

  Code that defines how postsynaptic update is translated to current.
- string postSynDecay

  Code that defines how postsynaptic current decays.
- vector< string > varNames

  Names of the variables in the postsynaptic model.
- vector< string > varTypes

  Types of the variable named above, e.g. "float". Names and types are matched by their order of occurrence in the vector.
- vector< string > pNames

  Names of (independent) parameters of the model.
- vector< string > dpNames

  Names of dependent parameters of the model.
- dpclass * dps

  Derived parameters.

14.12.1 Detailed Description

Structure to hold the information that defines a post-synaptic model (a model of how synapses affect post-synaptic neuron variables, classically in the form of a synaptic current). It also allows to define an equation for the dynamics that can be applied to the summed synaptic input variable "insyn".

14.12.2 Member Data Documentation

14.12.2.1 vector<string> postSynModel::dpNames

Names of dependent parameters of the model.

14.12.2.2 dpclass* postSynModel::dps

Derived parameters.

14.12.2.3 vector<string> postSynModel::pNames

Names of (independent) parameters of the model.

14.12.2.4 string postSynModel::postSynDecay

Code that defines how postsynaptic current decays.

14.12.2.5 string postSynModel::postSyntoCurrent

Code that defines how postsynaptic update is translated to current.

14.12.2.6 vector<string> postSynModel::varNames

Names of the variables in the postsynaptic model.

14.12.2.7 vector<string> postSynModel::varTypes

Types of the variable named above, e.g. "float". Names and types are matched by their order of occurrence in the vector.

The documentation for this struct was generated from the following file:

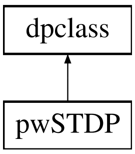
- modelSpec.h

14.13 pwSTDP Class Reference

TODO This class definition may be code-generated in a future release.

```
#include <utils.h>
```

Inheritance diagram for pwSTDP:



Public Member Functions

- double calculateDerivedParameter (int index, vector< double > pars, double dt)
- double lim0 (vector< double > pars, double dt)
- double lim1 (vector< double > pars, double dt)
- double slope0 (vector< double > pars, double dt)
- double slope1 (vector< double > pars, double dt)
- double off0 (vector< double > pars, double dt)
- double off1 (vector< double > pars, double dt)
- double off2 (vector< double > pars, double dt)

14.13.1 Detailed Description

TODO This class definition may be code-generated in a future release.

This class defines derived parameters for the learn1synapse standard weightupdate model

14.13.2 Member Function Documentation

14.13.2.1 double pwSTDP::calculateDerivedParameter (int *index*, vector< double > *pars*, double *dt*) [inline], [virtual]

Reimplemented from dpclass.

14.13.2.2 double pwSTDP::lim0 (vector< double > *pars*, double *dt*) [inline]

14.13.2.3 double pwSTDP::lim1 (vector< double > *pars*, double *dt*) [inline]

14.13.2.4 double pwSTDP::off0 (vector< double > *pars*, double *dt*) [inline]

14.13.2.5 double pwSTDP::off1 (vector< double > *pars*, double *dt*) [inline]

14.13.2.6 double pwSTDP::off2 (vector< double > *pars*, double *dt*) [inline]

14.13.2.7 double pwSTDP::slope0 (vector< double > *pars*, double *dt*) [inline]

14.13.2.8 double pwSTDP::slope1 (vector< double > *pars*, double *dt*) [inline]

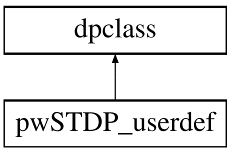
The documentation for this class was generated from the following file:

- utils.h

14.14 pwSTDP_userdef Class Reference

TODO This class definition may be code-generated in a future release.

Inheritance diagram for pwSTDP_userdef:



Public Member Functions

- double calculateDerivedParameter (int index, vector< double > pars, double dt=DT)
- double lim0 (vector< double > pars, double dt)
- double lim1 (vector< double > pars, double dt)
- double slope0 (vector< double > pars, double dt)
- double slope1 (vector< double > pars, double dt)
- double off0 (vector< double > pars, double dt)
- double off1 (vector< double > pars, double dt)
- double off2 (vector< double > pars, double dt)

14.14.1 Detailed Description

TODO This class definition may be code-generated in a future release.

14.14.2 Member Function Documentation

14.14.2.1 double pwSTDP_userdef::calculateDerivedParameter (int *index*, vector< double > *pars*, double *dt* = DT) [inline], [virtual]

Reimplemented from dpclass.

14.14.2.2 double pwSTDP_userdef::lim0 (vector< double > *pars*, double *dt*) [inline]

14.14.2.3 double pwSTDP_userdef::lim1 (vector< double > *pars*, double *dt*) [inline]

14.14.2.4 double pwSTDP_userdef::off0 (vector< double > *pars*, double *dt*) [inline]

14.14.2.5 double pwSTDP_userdef::off1 (vector< double > *pars*, double *dt*) [inline]

14.14.2.6 double pwSTDP_userdef::off2 (vector< double > *pars*, double *dt*) [inline]

14.14.2.7 double pwSTDP_userdef::slope0 (vector< double > *pars*, double *dt*) [inline]

14.14.2.8 double pwSTDP_userdef::slope1 (vector< double > *pars*, double *dt*) [inline]

The documentation for this class was generated from the following file:

- MBody_userdef.cc

14.15 randomGauss Class Reference

Class random Gauss encapsulates the methods for generating random neumbers with Gaussian distribution.

`#include <gauss.h>`

Public Member Functions

- randomGauss ()
  Constructor for the Gaussian random number generator class without giving explicit seeds.
- randomGauss (unsigned long, unsigned long, unsigned long)
  Constructor for the Gaussian random number generator class when seeds are provided explicitly.
- ∼randomGauss ()
- double n ()
  Method for obtaining a random number with Gaussian distribution.

14.15.1 Detailed Description

Class random Gauss encapsulates the methods for generating random neumbers with Gaussian distribution.

A random number from a Gaussian distribution of mean 0 and standard deviation 1 is obtained by calling the method randomGauss::n().

14.15.2 Constructor & Destructor Documentation

14.15.2.1 randomGauss::randomGauss ( ) [explicit]

Constructor for the Gaussian random number generator class without giving explicit seeds.

The seeds for random number generation are generated from the internal clock of the computer during execution.

14.15.2.2 randomGauss::randomGauss (unsigned long *seed1*, unsigned long *seed2*, unsigned long *seed3*)

Constructor for the Gaussian random number generator class when seeds are provided explicitly.

The seeds are three arbitrary unsigned long integers.

14.15.2.3 randomGauss::∼randomGauss ( ) [inline]

14.15.3 Member Function Documentation

14.15.3.1 double randomGauss::n ( )

Method for obtaining a random number with Gaussian distribution.

Function for generating a pseudo random number from a Gaussian distribution.

The documentation for this class was generated from the following files:

- gauss.h
- gauss.cc

14.16 randomGen Class Reference

Class randomGen which implements the ISAAC random number generator for uniformely distributed random numbers.

`#include <randomGen.h>`

Public Member Functions

- randomGen ()

  Constructor for the ISAAC random number generator class without giving explicit seeds.
- randomGen (unsigned long, unsigned long, unsigned long)

  Constructor for the Gaussian random number generator class when seeds are provided explicitly.
- ∼randomGen ()
- double n ()

  Method to obtain a random number from a uniform ditribution on [0,1].

14.16.1 Detailed Description

Class randomGen which implements the ISAAC random number generator for uniformely distributed random numbers.

The random number generator initializes with system timea or explicit seeds and returns a random number according to a uniform distribution on [0,1]; making use of the ISAAC random number generator; C++ Implementation by Quinn Tyler Jackson of the RG invented by Bob Jenkins Jr.

14.16.2 Constructor & Destructor Documentation

14.16.2.1 randomGen::randomGen ( ) [explicit]

Constructor for the ISAAC random number generator class without giving explicit seeds.

The seeds for random number generation are generated from the internal clock of the computer during execution.

14.16.2.2 randomGen::randomGen (unsigned long *seed1*, unsigned long *seed2*, unsigned long *seed3*)

Constructor for the Gaussian random number generator class when seeds are provided explicitly.

The seeds are three arbitrary unsigned long integers.

14.16.2.3 randomGen::~randomGen ( ) [inline]

14.16.3 Member Function Documentation

14.16.3.1 double randomGen::n ( )

Method to obtain a random number from a uniform ditribution on [0,1].

Function for generating a pseudo random number from a uniform distribution on the interval [0,1].

The documentation for this class was generated from the following files:

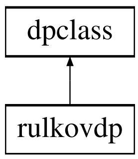
- randomGen.h
- randomGen.cc

14.17 rulkovdp Class Reference

Class defining the dependent parameters of teh Rulkov map neuron.

```
#include <utils.h>
```

Inheritance diagram for rulkovdp:



Public Member Functions

- double calculateDerivedParameter (int index, vector< double > pars, double dt=1.0)
- double ip0 (vector< double > pars)
- double ip1 (vector< double > pars)
- double ip2 (vector< double > pars)

14.17.1 Detailed Description

Class defining the dependent parameters of teh Rulkov map neuron.

14.17.2 Member Function Documentation

14.17.2.1 double rulkovdp::calculateDerivedParameter (int *index*, vector< double > *pars*, double *dt* = 1.0) [inline], [virtual]

Reimplemented from dpclass.

14.17.2.2 double rulkovdp::ip0 (vector< double > *pars*) [inline]

14.17.2.3 double rulkovdp::ip1 (vector< double > *pars*) [inline]

14.17.2.4 double rulkovdp::ip2 (vector< double > *pars*) [inline]

The documentation for this class was generated from the following file:

- utils.h

14.18 stdRG Class Reference

`#include <randomGen.h>`

Public Member Functions

- stdRG ()

  Constructor of the standard random number generator class without explicit seed.
- stdRG (unsigned int)

  Constructor of the standard random number generator class with explicit seed.
- ∼stdRG ()
- double n ()

  Method to generate a uniform random number.
- unsigned long nlong ()

14.18.1 Constructor & Destructor Documentation

14.18.1.1 stdRG::stdRG ( ) `[explicit]`

Constructor of the standard random number generator class without explicit seed.

The seed is taken from teh internal clock of the computer.

14.18.1.2 stdRG::stdRG (unsigned int *seed*)

Constructor of the standard random number generator class with explicit seed.

The seed is an arbitrary unsigned int

14.18.1.3 stdRG::∼stdRG ( ) `[inline]`

14.18.2 Member Function Documentation

14.18.2.1 double stdRG::n ( )

Method to generate a uniform random number.

The moethod is a wrapper for the C function rand() and returns a pseudo random number in the interval [0,1[

14.18.2.2 unsigned long stdRG::nlong ( )

The documentation for this class was generated from the following files:

- randomGen.h
- randomGen.cc

14.19 stopWatch Struct Reference

`#include <hr_time.h>`

Public Attributes

- timeval start
- timeval stop

14.19.1 Member Data Documentation

14.19.1.1 timeval stopWatch::start

14.19.1.2 timeval stopWatch::stop

The documentation for this struct was generated from the following file:

- hr_time.h

14.20 SynDelay Class Reference

`#include <SynDelaySim.h>`

Public Member Functions

- SynDelay (bool usingGPU)
- ∼SynDelay ()
- void run (float t)

14.20.1 Constructor & Destructor Documentation

14.20.1.1 SynDelay::SynDelay (bool *usingGPU*)

14.20.1.2 SynDelay::∼SynDelay ( )

14.20.2 Member Function Documentation

14.20.2.1 void SynDelay::run (float *t*)

The documentation for this class was generated from the following files:

- SynDelaySim.h
- SynDelaySim.cu

14.21 weightUpdateModel Class Reference

Structure to hold the information that defines a weightupdate model (a model of how spikes affect synaptic (and/or) (mostly) post-synaptic neuron variables. It also allows to define changes in response to post-synaptic spikes/spike-like events.

`#include <modelSpec.h>`

Public Member Functions

- weightUpdateModel ()

Public Attributes

- string simCode

  Simulation code that is used for true spikes (only one time step after spike detection)
- string simCodeEvnt

  Simulation code that is used for spike events (all the instances where event threshold condition is met)
- string simLearnPost

Simulation code which is used in the learnSynapsesPost kernel/function, where postsynaptic neuron spikes before the presynaptic neuron in the STDP window.

- string evntThreshold

  Simulation code for spike event detection.
- string synapseDynamics

  Simulation code for synapse dynamics independent of spike detection.
- vector< string > varNames

  Names of the variables in the postsynaptic model.
- vector< string > varTypes

  Types of the variable named above, e.g. "float". Names and types are matched by their order of occurrence in the vector.
- vector< string > pNames

  Names of (independent) parameters of the model.
- vector< string > dpNames

  Names of dependent parameters of the model.
- vector< string > extraGlobalSynapseKernelParameters

  Additional parameter in the neuron kernel; it is translated to a population specific name but otherwise assumed to be one parameter per population rather than per synapse.
- vector< string > extraGlobalSynapseKernelParameterTypes

  Additional parameters in the neuron kernel; they are translated to a population specific name but otherwise assumed to be one parameter per population rather than per synapse.
- dpclass * dps
- bool needPreSt

  Whether presynaptic spike times are needed or not.
- bool needPostSt

  Whether postsynaptic spike times are needed or not.

14.21.1 Detailed Description

Structure to hold the information that defines a weightupdate model (a model of how spikes affect synaptic (and/or) (mostly) post-synaptic neuron variables. It also allows to define changes in response to post-synaptic spikes/spike-like events.

14.21.2 Constructor & Destructor Documentation

14.21.2.1 weightUpdateModel::weightUpdateModel ( ) [inline]

14.21.3 Member Data Documentation

14.21.3.1 vector<string> weightUpdateModel::dpNames

Names of dependent parameters of the model.

14.21.3.2 dpclass* weightUpdateModel::dps

14.21.3.3 string weightUpdateModel::evntThreshold

Simulation code for spike event detection.

14.21.3.4 vector<string> weightUpdateModel::extraGlobalSynapseKernelParameters

Additional parameter in the neuron kernel; it is translated to a population specific name but otherwise assumed to be one parameter per population rather than per synapse.

14.21.3.5 vector<string> weightUpdateModel::extraGlobalSynapseKernelParameterTypes

Additional parameters in the neuron kernel; they are translated to a population specific name but otherwise assumed to be one parameter per population rather than per synapse.

14.21.3.6 bool weightUpdateModel::needPostSt

Whether postsynaptic spike times are needed or not.

14.21.3.7 bool weightUpdateModel::needPreSt

Whether presynaptic spike times are needed or not.

14.21.3.8 vector<string> weightUpdateModel::pNames

Names of (independent) parameters of the model.

14.21.3.9 string weightUpdateModel::simCode

Simulation code that is used for true spikes (only one time step after spike detection)

14.21.3.10 string weightUpdateModel::simCodeEvnt

Simulation code that is used for spike events (all the instances where event threshold condition is met)

14.21.3.11 string weightUpdateModel::simLearnPost

Simulation code which is used in the learnSynapsesPost kernel/function, where postsynaptic neuron spikes before the presynaptic neuron in the STDP window.

14.21.3.12 string weightUpdateModel::synapseDynamics

Simulation code for synapse dynamics independent of spike detection.

14.21.3.13 vector<string> weightUpdateModel::varNames

Names of the variables in the postsynaptic model.

14.21.3.14 vector<string> weightUpdateModel::varTypes

Types of the variable named above, e.g. "float". Names and types are matched by their order of occurrence in the vector.

The documentation for this class was generated from the following file:

- modelSpec.h

15 File Documentation

15.1 00_MainPage.dox File Reference

15.2 01_Installation.dox File Reference

15.3 02_Quickstart.dox File Reference

15.4 03_Examples.dox File Reference

15.5 09_ReleaseNotes_v2.dox File Reference

15.6 10_UserManual.dox File Reference

15.7 11_Tutorial.dox File Reference

15.8 12_Tutorial.dox File Reference

15.9 13_UserGuide.dox File Reference

15.10 14_Credits.dox File Reference

15.11 classol_sim.cu File Reference

```
#include "classol_sim.h"
```

Functions

- int main (int argc, char ∗argv[])
  This function is the entry point for running the simulation of the MBody1 model network.

15.11.1 Function Documentation

15.11.1.1 int main (int *argc,* char ∗ *argv[]*)

This function is the entry point for running the simulation of the MBody1 model network.

15.12 classol_sim.cu File Reference

```
#include "classol_sim.h"
```

Functions

- int main (int argc, char ∗argv[])
  This function is the entry point for running the simulation of the MBody_delayedSyn model network.

15.12.1 Function Documentation

15.12.1.1 int main (int *argc,* char ∗ *argv[]*)

This function is the entry point for running the simulation of the MBody_delayedSyn model network.

15.13 classol_sim.cu File Reference

```
#include "classol_sim.h"
```

Functions

- int main (int argc, char ∗argv[])
  This function is the entry point for running the simulation of the MBody1 model network.

15.13.1 Function Documentation

15.13.1.1 int main (int *argc*, char ∗ *argv[]*)

This function is the entry point for running the simulation of the MBody1 model network.

15.14 classol_sim.cu File Reference

```
#include "classol_sim.h"
```

Functions

- int main (int argc, char ∗argv[])

  This function is the entry point for running the simulation of the MBody1 model network.

15.14.1 Function Documentation

15.14.1.1 int main (int *argc*, char ∗ *argv[]*)

This function is the entry point for running the simulation of the MBody1 model network.

15.15 classol_sim.h File Reference

```
#include <cassert>
#include "hr_time.cpp"
#include "utils.h"
#include <cuda_runtime.h>
#include "MBody1.cc"
#include "map_classol.cc"
```

Macros

- #define MYRAND(Y, X) Y = Y ∗ 1103515245 +12345; X= (Y >> 16);
- #define DBG_SIZE 10000
- #define PATTERNNO 100
- #define T_REPORT_TME 10000.0
- #define SYN_OUT_TME 20000.0
- #define PAT_TIME 100.0
- #define PATFTIME 1.5
- #define TOTAL_TME 5000.0

Variables

- scalar t = 0.0f
- unsigned int iT = 0
- scalar InputBaseRate = 2e-04
- int patSetTime
- int patFireTime
- CStopWatch timer

15.15.1 Macro Definition Documentation

15.15.1.1 #define DBG_SIZE 10000

15.15.1.2 #define MYRAND(Y, X) Y = Y * 1103515245 +12345; X= (Y >> 16);

15.15.1.3 #define PAT_TIME 100.0

15.15.1.4 #define PATFTIME 1.5

15.15.1.5 #define PATTERNNO 100

15.15.1.6 #define SYN_OUT_TME 20000.0

15.15.1.7 #define T_REPORT_TME 10000.0

15.15.1.8 #define TOTAL_TME 5000.0

15.15.2 Variable Documentation

15.15.2.1 scalar InputBaseRate = 2e-04

15.15.2.2 unsigned int iT = 0

15.15.2.3 int patFireTime

15.15.2.4 int patSetTime

15.15.2.5 scalar t = 0.0f

15.15.2.6 CStopWatch timer

15.16 classol_sim.h File Reference

```
#include <cassert>
#include "hr_time.cpp"
#include "utils.h"
#include <cuda_runtime.h>
#include "MBody_delayedSyn.cc"
#include "map_classol.cc"
```

Macros

- #define MYRAND(Y, X) Y = Y * 1103515245 +12345; X= (Y >> 16);
- #define DBG_SIZE 10000
- #define PATTERNNO 100
- #define T_REPORT_TME 10000.0
- #define SYN_OUT_TME 20000.0
- #define PAT_TIME 100.0
- #define PATFTIME 1.5
- #define TOTAL_TME 1000.0

Variables

- scalar t = 0.0f
- unsigned int iT = 0
- scalar InputBaseRate = 2e-04

- int patSetTime
- int patFireTime
- CStopWatch timer

15.16.1 Macro Definition Documentation

15.16.1.1 #define DBG_SIZE 10000

15.16.1.2 #define MYRAND(Y, X) Y = Y ∗ 1103515245 +12345; X= (Y >> 16);

15.16.1.3 #define PAT_TIME 100.0

15.16.1.4 #define PATFTIME 1.5

15.16.1.5 #define PATTERNNO 100

15.16.1.6 #define SYN_OUT_TME 20000.0

15.16.1.7 #define T_REPORT_TME 10000.0

15.16.1.8 #define TOTAL_TME 1000.0

15.16.2 Variable Documentation

15.16.2.1 scalar InputBaseRate = 2e-04

15.16.2.2 unsigned int iT = 0

15.16.2.3 int patFireTime

15.16.2.4 int patSetTime

15.16.2.5 scalar t = 0.0f

15.16.2.6 CStopWatch timer

15.17 classol_sim.h File Reference

```
#include <cassert>
#include "hr_time.cpp"
#include "utils.h"
#include <cuda_runtime.h>
#include "MBody_individualID.cc"
#include "map_classol.cc"
```

Macros

- #define MYRAND(Y, X) Y = Y ∗ 1103515245 +12345; X= (Y >> 16);
- #define DBG_SIZE 10000
- #define PATTERNNO 100
- #define T_REPORT_TME 10000.0
- #define SYN_OUT_TME 20000.0
- #define PAT_TIME 100.0
- #define PATFTIME 1.5
- #define TOTAL_TME 1000.0

Variables

- scalar t = 0.0f
- unsigned int iT = 0
- scalar InputBaseRate = 2e-04
- int patSetTime
- int patFireTime
- CStopWatch timer

15.17.1 Macro Definition Documentation

15.17.1.1 #define DBG_SIZE 10000

15.17.1.2 #define MYRAND(*Y*, *X*) Y = Y ∗ 1103515245 +12345; X= (Y >> 16);

15.17.1.3 #define PAT_TIME 100.0

15.17.1.4 #define PATFTIME 1.5

15.17.1.5 #define PATTERNNO 100

15.17.1.6 #define SYN_OUT_TME 20000.0

15.17.1.7 #define T_REPORT_TME 10000.0

15.17.1.8 #define TOTAL_TME 1000.0

15.17.2 Variable Documentation

15.17.2.1 scalar InputBaseRate = 2e-04

15.17.2.2 unsigned int iT = 0

15.17.2.3 int patFireTime

15.17.2.4 int patSetTime

15.17.2.5 scalar t = 0.0f

15.17.2.6 CStopWatch timer

15.18 classol_sim.h File Reference

```
#include <cassert>
#include "hr_time.cpp"
#include "utils.h"
#include <cuda_runtime.h>
#include <cfloat>
#include "MBody_userdef.cc"
#include "map_classol.cc"
```

Macros

- #define MYRAND(Y, X) Y = Y ∗ 1103515245 +12345; X= (Y >> 16);
- #define DBG_SIZE 10000
- #define PATTERNNO 100
- #define T_REPORT_TME 10000.0

- #define SYN_OUT_TME 20000.0
- #define PAT_TIME 100.0
- #define PATFTIME 1.5
- #define TOTAL_TME 5000.0

Variables

- scalar t = 0.0f
- unsigned int iT = 0
- scalar InputBaseRate = 2e-04
- int patSetTime
- int patFireTime
- CStopWatch timer

15.18.1 Macro Definition Documentation

15.18.1.1 #define DBG_SIZE 10000

15.18.1.2 #define MYRAND(*Y*, *X*) Y = Y * 1103515245 +12345; X= (Y >> 16);

15.18.1.3 #define PAT_TIME 100.0

15.18.1.4 #define PATFTIME 1.5

15.18.1.5 #define PATTERNNO 100

15.18.1.6 #define SYN_OUT_TME 20000.0

15.18.1.7 #define T_REPORT_TME 10000.0

15.18.1.8 #define TOTAL_TME 5000.0

15.18.2 Variable Documentation

15.18.2.1 scalar InputBaseRate = 2e-04

15.18.2.2 unsigned int iT = 0

15.18.2.3 int patFireTime

15.18.2.4 int patSetTime

15.18.2.5 scalar t = 0.0f

15.18.2.6 CStopWatch timer

15.19 CodeHelper.cc File Reference

```
#include <iostream>
#include <cstring>
#include <string>
#include <sstream>
#include <vector>
```

Classes

- class CodeHelper

Macros

- #define __CODE_HELPER_CC
- #define SAVEP(X) "(" << X << ")"
- #define OB(X) hlp.openBrace(X)
- #define CB(X) hlp.closeBrace(X)
- #define ENDL hlp.endl()

15.19.1 Macro Definition Documentation

15.19.1.1 #define __CODE_HELPER_CC

15.19.1.2 #define CB(*X*) hlp.closeBrace(X)

15.19.1.3 #define ENDL hlp.endl()

15.19.1.4 #define OB(*X*) hlp.openBrace(X)

15.19.1.5 #define SAVEP(*X*) "(" << X << ")"

15.20 ensureFtype.h File Reference

```
#include <string>
```

Functions

- void doFinal (string &code, unsigned int i, string type, unsigned int &state)
- string ensureFtype (string oldcode, string type)

Variables

- string digits = string("0123456789")

  Function for converting code to contain only explicit single precision (float) constants.
- string op = string("+-∗/(<>= ,;")+string("\n")+string("\t")

15.20.1 Function Documentation

15.20.1.1 void doFinal (string & *code,* unsigned int *i,* string *type,* unsigned int & *state*)

15.20.1.2 string ensureFtype (string *oldcode,* string *type*)

15.20.2 Variable Documentation

15.20.2.1 string digits = string("0123456789")

Function for converting code to contain only explicit single precision (float) constants.

15.20.2.2 string op = string("+-∗/(<>= ,;")+string("\n")+string("\t")

15.21 extra_neurons.h File Reference

Functions

- n varNames clear ()
- n varNames push_back (tS("V"))

- n varTypes push_back (tS("float"))
- n varNames push_back (tS("V_NB"))
- n varNames push_back (tS("tSpike_NB"))
- n varNames push_back (tS("__regime_val"))
- n varTypes push_back (tS("int"))
- n pNames push_back (tS("VReset_NB"))
- n pNames push_back (tS("VThresh_NB"))
- n pNames push_back (tS("tRefrac_NB"))
- n pNames push_back (tS("VRest_NB"))
- n pNames push_back (tS("TAUm_NB"))
- n pNames push_back (tS("Cm_NB"))
- nModels push_back (n)
- n varNames push_back (tS("count_t_NB"))
- n pNames push_back (tS("max_t_NB"))

Variables

- n simCode

15.21.1 Function Documentation

15.21.1.1 ps dpNames clear ( )

15.21.1.2 n varNames push_back (tS("V"))

15.21.1.3 ps varTypes push_back (tS("float"))

15.21.1.4 n varNames push_back (tS("V_NB"))

15.21.1.5 n varNames push_back (tS("tSpike_NB"))

15.21.1.6 n varNames push_back (tS("__regime_val"))

15.21.1.7 n varTypes push_back (tS("int"))

15.21.1.8 n pNames push_back (tS("VReset_NB"))

15.21.1.9 n pNames push_back (tS("VThresh_NB"))

15.21.1.10 n pNames push_back (tS("tRefrac_NB"))

15.21.1.11 n pNames push_back (tS("VRest_NB"))

15.21.1.12 n pNames push_back (tS("TAUm_NB"))

15.21.1.13 n pNames push_back (tS("Cm_NB"))

15.21.1.14 nModels push_back (n)

15.21.1.15 n varNames push_back (tS("count_t_NB"))

15.21.1.16 n pNames push_back (tS("max_t_NB"))

15.21.2 Variable Documentation

15.21.2.1 n simCode

Initial value:

```
= tS(" \
          $(V) = -1000000; \
          if ($(__regime_val)==1) { \n \
$(V_NB) += (Isyn_NB/$(Cm_NB)+($(VRest_NB)-$(V_NB))/$(TAUm_NB))*DT; \n \
                  if ($(V_NB)>$(VThresh_NB)) { \n \
$(V_NB) = $(VReset_NB); \n \
$(tSpike_NB) = t; \n \
                  $(V) = 100000; \
$(__regime_val) = 2; \n \
} \n \
} \n \
if ($(__regime_val)==2) { \n \
if (t-$(tSpike_NB) > $(tRefrac_NB)) { \n \
$(__regime_val) = 1; \n \
} \n \
} \n \
")
```

15.22 extra_postsynapses.h File Reference

Functions

- ps varNames clear ()
- ps varNames push_back (tS("g_PS"))
- ps varTypes push_back (tS("float"))
- ps pNames push_back (tS("tau_syn_PS"))
- ps pNames push_back (tS("E_PS"))
- postSynModels push_back (ps)

Variables

- ps postSyntoCurrent
- ps postSynDecay

15.22.1 Function Documentation

15.22.1.1 ps varNames clear ( )

15.22.1.2 ps varNames push_back (tS("g_PS"))

15.22.1.3 ps varTypes push_back (tS("float"))

15.22.1.4 ps pNames push_back (tS("tau_syn_PS"))

15.22.1.5 ps pNames push_back (tS("E_PS"))

15.22.1.6 postSynModels push_back (ps)

15.22.2 Variable Documentation

15.22.2.1 ps postSynDecay

Initial value:

```
= tS(" \
          $(g_PS) += (-$(g_PS)/$(tau_syn_PS))*DT; \n \
                           $(inSyn) = 0; \
         ")
```

15.22.2.2 ps postSyntoCurrent

Initial value:

```
= tS(" \
  0; \n \
        float Isyn_NB = 0; \n \
         { \n \
        float v_PS = lV_NB; \n \
         float g_in_PS = $(inSyn); \
$(g_PS) = $(g_PS)+g_in_PS; \n \
Isyn_NB += ($(g_PS)*($(E_PS)-v_PS)); \n \
          } \n \
")
```

15.23 extra_postsynapses.h File Reference

Functions

- ps varNames clear ()
- postSynModels push_back (ps)
- ps varNames push_back (tS("g_PS"))
- ps varTypes push_back (tS("float"))
- ps pNames push_back (tS("tau_syn_PS"))
- ps pNames push_back (tS("E_PS"))

Variables

- postSynModel ps
- ps postSyntoCurrent
- ps postSynDecay

15.23.1 Function Documentation

15.23.1.1 ps varNames clear ( )

15.23.1.2 postSynModels push_back (ps)

15.23.1.3 ps varNames push_back (tS("g_PS"))

15.23.1.4 ps varTypes push_back (tS("float"))

15.23.1.5 ps pNames push_back (tS("tau_syn_PS"))

15.23.1.6 ps pNames push_back (tS("E_PS"))

15.23.2 Variable Documentation

15.23.2.1 ps postSynDecay

Initial value:

```
= tS(" \
             $(inSyn) = 0; \
        ")
```

15.23.2.2 ps postSyntoCurrent

Initial value:

```
= tS(" \
  0; \n \
        float I_sum_NB = 0; \n \
         { \n \
        float in_PS = $(inSyn); \n \
        I_sum_NB += (in_PS); \n \
          } \n \
")
```

15.23.2.3 postSynModel ps

15.24 extra_weightupdates.h File Reference

15.25 GA.cc File Reference

`#include <algorithm>`

Classes

- struct errTupel

Functions

- int compareErrTupel (const void ∗x, const void ∗y)
- void procreatePop (FILE ∗osb)

15.25.1 Function Documentation

15.25.1.1 int compareErrTupel (const void ∗ *x*, const void ∗ *y*)

15.25.1.2 void procreatePop (FILE ∗ *osb*)

15.26 gauss.cc File Reference

Contains the implementation of the Gaussian random number generator class randomGauss.

`#include "gauss.h"`

Macros

- #define GAUSS_CC

    macro for avoiding multiple inclusion during compilation

15.26.1 Detailed Description

Contains the implementation of the Gaussian random number generator class randomGauss.

15.26.2 Macro Definition Documentation

15.26.2.1 #define GAUSS_CC

macro for avoiding multiple inclusion during compilation

15.27 gauss.h File Reference

Random number generator for Gaussian random variable with mean 0 and standard deviation 1.

```
#include <cmath>
#include "randomGen.h"
#include "randomGen.cc"
#include "gauss.cc"
```

Classes

- class randomGauss

    Class random Gauss encapsulates the methods for generating random neumbers with Gaussian distribution.

Macros

- #define GAUSS_H

    macro for avoiding multiple inclusion during compilation

15.27.1 Detailed Description

Random number generator for Gaussian random variable with mean 0 and standard deviation 1.

This random number generator is based on the ratio of uniforms method by A.J. Kinderman and J.F. Monahan and improved with quadratic boundind curves by J.L. Leva. Taken from Algorithm 712 ACM Trans. Math. Softw. 18 p. 454. (the necessary uniform random variables are obtained from the ISAAC random number generator; C++ Implementation by Quinn Tyler Jackson of the RG invented by Bob Jenkins Jr.).

15.27.2 Macro Definition Documentation

15.27.2.1 #define GAUSS_H

macro for avoiding multiple inclusion during compilation

15.28 gen_input_structured.cc File Reference

```
#include <iostream>
#include <fstream>
#include <stdlib.h>
#include "randomGen.h"
#include "randomGen.cc"
```

Functions

- int main (int argc, char *argv[])

Variables

- randomGen R

15.28.1 Function Documentation

15.28.1.1 int main (int *argc*, char ∗ *argv[]*)

15.28.2 Variable Documentation

15.28.2.1 randomGen R

15.29 gen_kcdn_syns.cc File Reference

This file is part of a tool chain for running the classol/MBody1 example model.

```
#include <iostream>
#include <fstream>
#include <stdlib.h>
#include "randomGen.h"
#include "gauss.h"
#include "randomGen.cc"
```

Functions

- int main (int argc, char ∗argv[])

Variables

- randomGen R
- randomGauss RG

15.29.1 Detailed Description

This file is part of a tool chain for running the classol/MBody1 example model.

This file compiles to a tool to generate appropriate connectivity patterns between KCs and DNs (detector neurons) in the model. The connectivity is saved to file and can then be read by the classol method for reading this connectivity.

15.29.2 Function Documentation

15.29.2.1 int main (int *argc*, char ∗ *argv[]*)

15.29.3 Variable Documentation

15.29.3.1 randomGen R

15.29.3.2 randomGauss RG

15.30 gen_pnkc_syns.cc File Reference

This file is part of a tool chain for running the classol/MBody1 example model.

```
#include <iostream>
#include <fstream>
#include <stdlib.h>
#include "randomGen.h"
#include "gauss.h"
#include "randomGen.cc"
```

Functions

- int main (int argc, char *argv[])

Variables

- randomGen R
- randomGauss RG

15.30.1 Detailed Description

This file is part of a tool chain for running the classol/MBody1 example model.

This file compiles to a tool to generate appropriate connectivity patterns between PNs and KCs in the model. The connectivity is saved to file and can then be read by the classol method for reading this connectivity.

15.30.2 Function Documentation

15.30.2.1 int main (int *argc*, char * *argv[]*)

15.30.3 Variable Documentation

15.30.3.1 randomGen R

15.30.3.2 randomGauss RG

15.31 gen_pnkc_syns_indivID.cc File Reference

This file is part of a tool chain for running the classol/MBody1 example model.

```
#include <iostream>
#include <fstream>
#include <stdlib.h>
#include <cstdint>
#include "randomGen.h"
#include "gauss.h"
#include "simpleBit.h"
#include "randomGen.cc"
```

Functions

- int main (int argc, char *argv[])

Variables

- randomGen R
- randomGauss RG

15.31.1 Detailed Description

This file is part of a tool chain for running the classol/MBody1 example model.

This file compiles to a tool to generate appropriate connectivity patterns between PNs and KCs in the model. In contrast to the gen_pnkc_syns.cc tool, here the output is in a format that is suited for the "INDIVIDUALID" method for specifying connectivity. The connectivity is saved to file and can then be read by the classol method for reading this connectivity.

15.31.2 Function Documentation

15.31.2.1 int main (int *argc*, char ∗ *argv[]*)

15.31.3 Variable Documentation

15.31.3.1 randomGen R

15.31.3.2 randomGauss RG

15.32 gen_pnlhi_syns.cc File Reference

This file is part of a tool chain for running the classol/MBody1 example model.

```
#include <iostream>
#include <fstream>
#include <stdlib.h>
```

Functions

- int main (int argc, char ∗argv[])

15.32.1 Detailed Description

This file is part of a tool chain for running the classol/MBody1 example model.

This file compiles to a tool to generate appropriate connectivity patterns between PNs and LHIs (lateral horn interneurons) in the model. The connectivity is saved to file and can then be read by the classol method for reading this connectivity.

15.32.2 Function Documentation

15.32.2.1 int main (int *argc*, char ∗ *argv[]*)

15.33 gen_syns_sparse.cc File Reference

This file generates the arrays needed for sparse connectivity. The connectivity is saved to a file for each variable and can then be read to fill the struct of connectivity.

```
#include <iostream>
#include <fstream>
#include <string.h>
#include "randomGen.h"
#include "gauss.h"
#include <vector>
```

Functions

- int main (int argc, char ∗argv[])

Variables

- randomGen R
- randomGauss RG

15.33.1 Detailed Description

This file generates the arrays needed for sparse connectivity. The connectivity is saved to a file for each variable and can then be read to fill the struct of connectivity.

15.33.2 Function Documentation

15.33.2.1 int main (int *argc*, char ∗ *argv[]*)

15.33.3 Variable Documentation

15.33.3.1 randomGen R

15.33.3.2 randomGauss RG

15.34 gen_syns_sparse_izhModel.cc File Reference

This file is part of a tool chain for running the Izhikevich network model.

```
#include <iostream>
#include <fstream>
#include <stdlib.h>
#include <string.h>
#include <vector>
#include "randomGen.h"
#include "randomGen.cc"
```

Functions

- int printVector (vector< unsigned int > &)
- int printVector (vector< double > &)
- int main (int argc, char ∗argv[])

Variables

- randomGen R
- randomGen Rind
- double gsyn
- double ∗ garray
- unsigned int ∗ ind
- double ∗ garray_ee
- std::vector< double > g_ee
- std::vector< unsigned int > indInG_ee
- std::vector< unsigned int > ind_ee
- double ∗ garray_ei

- std::vector< double > g_ei
- std::vector< unsigned int > indInG_ei
- std::vector< unsigned int > ind_ei
- double * garray_ie
- std::vector< double > g_ie
- std::vector< unsigned int > indInG_ie
- std::vector< unsigned int > ind_ie
- double * garray_ii
- std::vector< double > g_ii
- std::vector< unsigned int > indInG_ii
- std::vector< unsigned int > ind_ii

15.34.1 Detailed Description

This file is part of a tool chain for running the Izhikevich network model.

15.34.2 Function Documentation

15.34.2.1 int main (int *argc*, char * *argv[]*)

15.34.2.2 int printVector (vector< unsigned int > & *v*)

15.34.2.3 int printVector (vector< double > & *v*)

15.34.3 Variable Documentation

15.34.3.1 std::vector<double> g_ee

15.34.3.2 std::vector<double> g_ei

15.34.3.3 std::vector<double> g_ie

15.34.3.4 std::vector<double> g_ii

15.34.3.5 double* garray

15.34.3.6 double* garray_ee

15.34.3.7 double* garray_ei

15.34.3.8 double* garray_ie

15.34.3.9 double* garray_ii

15.34.3.10 double gsyn

15.34.3.11 unsigned int* ind

15.34.3.12 std::vector<unsigned int> ind_ee

15.34.3.13 std::vector<unsigned int> ind_ei

15.34.3.14 std::vector<unsigned int> ind_ie

15.34.3.15 std::vector<unsigned int> ind_ii

15.34.3.16 std::vector<unsigned int> indInG_ee

15.34.3.17 std::vector<unsigned int> indInG_ei

15.34.3.18 std::vector<unsigned int> indInG_ie

15.34.3.19 std::vector<unsigned int> indInG_ii

15.34.3.20 randomGen R

15.34.3.21 randomGen Rind

15.35 generate_run.cc File Reference

```
#include <iostream>
#include <fstream>
#include <string>
#include <sstream>
#include <cstdlib>
#include <cmath>
#include "toString.h"
#include <sys/stat.h>
```

Functions

- int main (int argc, char *argv[])

  Main entry point for generate_run.

15.35.1 Function Documentation

15.35.1.1 int main (int *argc*, char * *argv[]*)

Main entry point for generate_run.

15.36 generate_run.cc File Reference

```
#include <iostream>
#include <fstream>
#include <string>
#include <sstream>
#include <cstdlib>
#include <cmath>
#include <locale>
#include <sys/stat.h>
```

Macros

- #define tS(X) toString(X)

  Macro providing the abbreviated syntax tS() instead of toString().

Functions

- template<typename T >
  std::string toString (T t)

  Template function for string conversion.

- string toUpper (string s)
- string toLower (string s)
- unsigned int openFileGetMax (unsigned int ∗array, unsigned int size, string name)
- int main (int argc, char ∗argv[])

    Main entry point for generate_run.

15.36.1 Macro Definition Documentation

15.36.1.1 #define tS(*X*) toString(X)

Macro providing the abbreviated syntax tS() instead of toString().

15.36.2 Function Documentation

15.36.2.1 int main (int *argc,* char ∗ *argv[ ]*)

Main entry point for generate_run.

15.36.2.2 unsigned int openFileGetMax (unsigned int ∗ *array,* unsigned int *size,* string *name*)

15.36.2.3 string toLower (string *s*)

15.36.2.4 template<typename T > std::string toString (T *t*)

Template function for string conversion.

15.36.2.5 string toUpper (string *s*)

15.37 generate_run.cc File Reference

```
#include <iostream>
#include <fstream>
#include <string>
#include <sstream>
#include <cstdlib>
#include <cmath>
#include <cfloat>
#include <locale>
#include <sys/stat.h>
```

Macros

- #define tS(X) toString(X)

    Macro providing the abbreviated syntax tS() instead of toString().

Functions

- template<typename T >
  std::string toString (T t)

    template function for string conversion from const char∗ to C++ string
- string toUpper (string s)
- string toLower (string s)
- int main (int argc, char ∗argv[])

    Main entry point for generate_run.

15.37.1 Macro Definition Documentation

15.37.1.1 #define tS(*X*) toString(X)

Macro providing the abbreviated syntax tS() instead of toString().

15.37.2 Function Documentation

15.37.2.1 int main (int *argc*, char ∗ *argv[]*)

Main entry point for generate_run.

15.37.2.2 string toLower (string *s*)

15.37.2.3 template<typename T > std::string toString (T *t*)

template function for string conversion from const char∗ to C++ string

15.37.2.4 string toUpper (string *s*)

15.38 generate_run.cc File Reference

```
#include <iostream>
#include <fstream>
#include <string>
#include <sstream>
#include <cstdlib>
#include <cmath>
#include <cfloat>
#include <locale>
#include <sys/stat.h>
```

Macros

- #define tS(X) toString(X)

    Macro providing the abbreviated syntax tS() instead of toString().

Functions

- template<typename T >
  std::string toString (T t)

    template function for string conversion from const char∗ to C++ string
- string toUpper (string s)
- string toLower (string s)
- int main (int argc, char ∗argv[])

    Main entry point for generate_run.

15.38.1 Macro Definition Documentation

15.38.1.1 #define tS(*X*) toString(X)

Macro providing the abbreviated syntax tS() instead of toString().

15.38.2 Function Documentation

15.38.2.1 int main (int *argc*, char ∗ *argv[]*)

Main entry point for generate_run.

15.38.2.2 string toLower (string *s*)

15.38.2.3 template<typename T > std::string toString (T *t*)

template function for string conversion from const char∗ to C++ string

15.38.2.4 string toUpper (string *s*)

15.39 generate_run.cc File Reference

```
#include <iostream>
#include <fstream>
#include <string>
#include <sstream>
#include <cstdlib>
#include <cmath>
#include <cfloat>
#include <locale>
#include <sys/stat.h>
```

Macros

- #define tS(X) toString(X)

  Macro providing the abbreviated syntax tS() instead of toString().

Functions

- template<typename T >
  std::string toString (T t)

  template function for string conversion from const char∗ to C++ string
- string toUpper (string s)
- string toLower (string s)
- int main (int argc, char ∗argv[])

  Main entry point for generate_run.

15.39.1 Macro Definition Documentation

15.39.1.1 #define tS(*X*) toString(X)

Macro providing the abbreviated syntax tS() instead of toString().

15.39.2 Function Documentation

15.39.2.1 int main (int *argc*, char ∗ *argv[]*)

Main entry point for generate_run.

15.39.2.2 string toLower (string *s*)

15.39.2.3 template<typename T > std::string toString (T *t*)

template function for string conversion from const char∗ to C++ string

15.39.2.4 string toUpper (string *s*)

15.40 generate_run.cc File Reference

```
#include <iostream>
#include <fstream>
#include <string>
#include <sstream>
#include <cstdlib>
#include <cmath>
#include <locale>
#include <sys/stat.h>
```

Macros

- #define tS(X) toString(X)

    Macro providing the abbreviated syntax tS() instead of toString().

Functions

- template<typename T >
  std::string toString (T t)

    Template function for string conversion.

- string toUpper (string s)
- string toLower (string s)
- int main (int argc, char ∗argv[])

    Main entry point for generate_run.

15.40.1 Macro Definition Documentation

15.40.1.1 #define tS(*X*) toString(X)

Macro providing the abbreviated syntax tS() instead of toString().

15.40.2 Function Documentation

15.40.2.1 int main (int *argc,* char ∗ *argv[]*)

Main entry point for generate_run.

15.40.2.2 string toLower (string *s*)

15.40.2.3 template<typename T > std::string toString (T *t*)

Template function for string conversion.

15.40.2.4 string toUpper (string *s*)

15.41 generate_run.cc File Reference

```
#include <iostream>
#include <fstream>
#include <string>
#include <sstream>
#include <cstdlib>
#include <cmath>
#include <sys/stat.h>
```

Functions

- template<typename T >
  std::string toString (T t)

  Template function for string conversion.
- int main (int argc, char ∗argv[])

  Main entry point for generate_run.

15.41.1 Function Documentation

15.41.1.1 int main (int *argc,* char ∗ *argv[]*)

Main entry point for generate_run.

15.41.1.2 template<typename T > std::string toString (T *t*)

Template function for string conversion.

15.42 generate_run.cc File Reference

```
#include <iostream>
#include <fstream>
#include <string>
#include <sstream>
#include <cstdlib>
#include <cmath>
#include <sys/stat.h>
```

Functions

- template<typename T >
  std::string toString (T t)

  Template function for string conversion.
- int main (int argc, char ∗argv[])

  Main entry point for generate_run.

15.42.1 Function Documentation

15.42.1.1 int main (int *argc,* char ∗ *argv[]*)

Main entry point for generate_run.

15.42.1.2 template<typename T > std::string toString (T *t*)

Template function for string conversion.

15.43 generateALL.cc File Reference

Main file combining the code for code generation. Part of the code generation section.

```
#include "global.h"
#include "modelSpec.h"
#include "modelSpec.cc"
#include "generateKernels.cc"
#include "generateRunner.cc"
#include "generateCPU.cc"
#include <sys/stat.h>
```

Functions

- void generate_model_runner (NNmodel &model, string path)

  This function will call the necessary sub-functions to generate the code for simulating a model.
- int chooseDevice (ostream &mos, NNmodel ∗&model, string path)

  Helper function that prepares data structures and detects the hardware properties to enable the code generation code that follows.
- int main (int argc, char ∗argv[])

  Main entry point for the generateALL executable that generates the code for GPU and CPU.

15.43.1 Detailed Description

Main file combining the code for code generation. Part of the code generation section.

The file includes separate files for generating kernels (generateKernels.cc), generating the CPU side code for running simulations on either the CPU or GPU (generateRunner.cc) and for CPU-only simulation code (generateCP↩ U.cc).

15.43.2 Function Documentation

15.43.2.1 int chooseDevice (ostream & *mos,* NNmodel ∗& *model,* string *path*)

Helper function that prepares data structures and detects the hardware properties to enable the code generation code that follows.

The main tasks in this function are the detection and characterization of the GPU device present (if any), choosing which GPU device to use, finding and appropriate block size, taking note of the major and minor version of the C↩ UDA enabled device chosen for use, and populating the list of standard neuron models. The chosen device number is returned.

Parameters

mos	output stream for messages
model	the nn model we are generating code for
path	path the generated code will be deposited

15.43.2.2 void generate_model_runner (NNmodel & *model,* string *path*)

This function will call the necessary sub-functions to generate the code for simulating a model.

Parameters

model	Model description
path	Path where the generated code will be deposited

15.43.2.3 int main (int *argc*, char ∗ *argv[]*)

Main entry point for the generateALL executable that generates the code for GPU and CPU.

The main function is the entry point for the code generation engine. It prepares the system and then invokes generate_model_runner to inititate the different parts of actual code generation.

Parameters

argc	number of arguments; expected to be 2
argv	Arguments; expected to contain the target directory for code generation.

15.44 generateCPU.cc File Reference

Functions for generating code that will run the neuron and synapse simulations on the CPU. Part of the code generation section.

```
#include <string>
#include "CodeHelper.cc"
#include <cfloat>
```

Functions

- void genNeuronFunction (NNmodel &model, string &path, ostream &mos)

  Function that generates the code of the function the will simulate all neurons on the CPU.
- void generate_process_presynaptic_events_code_CPU (ostream &os, NNmodel &model, unsigned int src, unsigned int trg, int i, string &localID, unsigned int inSynNo, string postfix)

  Function for generating the CUDA synapse kernel code that handles presynaptic spikes or spike type events.
- void genSynapseFunction (NNmodel &model, string &path, ostream &mos)

  Function that generates code that will simulate all synapses of the model on the CPU.

15.44.1 Detailed Description

Functions for generating code that will run the neuron and synapse simulations on the CPU. Part of the code generation section.

15.44.2 Function Documentation

15.44.2.1 void generate_process_presynaptic_events_code_CPU (ostream & *os*, NNmodel & *model*, unsigned int *src*, unsigned int *trg*, int *i*, string & *localID*, unsigned int *inSynNo*, string *postfix*)

Function for generating the CUDA synapse kernel code that handles presynaptic spikes or spike type events.

Parameters

os	output stream for code

model	the neuronal network model to generate code for
src	the number of the src neuron population
trg	the number of the target neuron population
i	the index of the synapse group being processed
localID	the variable name of the local ID of the thread within the synapse group
inSynNo	the ID number of the current synapse population as the incoming population to the target neuron population
postfix	whether to generate code for true spikes or spike type events

15.44.2.2 void genNeuronFunction (NNmodel & *model*, string & *path*, ostream & *mos*)

Function that generates the code of the function the will simulate all neurons on the CPU.

Parameters

model	Model description
path	output stream for code
mos	output stream for messages

15.44.2.3 void genSynapseFunction (NNmodel & *model*, string & *path*, ostream & *mos*)

Function that generates code that will simulate all synapses of the model on the CPU.

Parameters

model	Model description
path	Path for code generation
mos	output stream for messages

15.45 generateKernels.cc File Reference

Contains functions that generate code for CUDA kernels. Part of the code generation section.

```
#include <string>
#include "CodeHelper.cc"
#include "global.h"
```

Functions

- void genNeuronKernel (NNmodel &model, string &path, ostream &mos)

  Function for generating the CUDA kernel that simulates all neurons in the model.
- void generate_process_presynaptic_events_code (ostream &os, NNmodel &model, unsigned int src, unsigned int trg, int i, string &localID, unsigned int inSynNo, string postfix)

  Function for generating the CUDA synapse kernel code that handles presynaptic spikes or spike type events.
- void genSynapseKernel (NNmodel &model, string &path, ostream &mos)

  Function for generating a CUDA kernel for simulating all synapses.

Variables

- short * isGrpVarNeeded
- CodeHelper hlp

15.45.1 Detailed Description

Contains functions that generate code for CUDA kernels. Part of the code generation section.

15.45.2 Function Documentation

15.45.2.1 void generate_process_presynaptic_events_code (ostream & *os*, NNmodel & *model*, unsigned int *src*, unsigned int *trg*, int *i*, string & *localID*, unsigned int *inSynNo*, string *postfix*)

Function for generating the CUDA synapse kernel code that handles presynaptic spikes or spike type events.

Parameters

os	output stream for code
model	the neuronal network model to generate code for
src	the number of the src neuron population
trg	the number of the target neuron population
i	the index of the synapse group being processed
localID	the variable name of the local ID of the thread within the synapse group
inSynNo	the ID number of the current synapse population as the incoming population to the target neuron population
postfix	whether to generate code for true spikes or spike type events

15.45.2.2 void genNeuronKernel (NNmodel & *model*, string & *path*, ostream & *mos*)

Function for generating the CUDA kernel that simulates all neurons in the model.

The code generated upon execution of this function is for defining GPU side global variables that will hold model state in the GPU global memory and for the actual kernel function for simulating the neurons for one time step. Binary flag for the sparse synapses to use atomic operations when the number of connections is bigger than the block size, and shared variables otherwise

Parameters

model	Model description
path	path for code output
mos	output stream for messages

15.45.2.3 void genSynapseKernel (NNmodel & *model*, string & *path*, ostream & *mos*)

Function for generating a CUDA kernel for simulating all synapses.

This functions generates code for global variables on the GPU side that are synapse-related and the actual CUDA kernel for simulating one time step of the synapses. $<$ "id" if first synapse group, else "lid". lid =(thread index- last thread of the last synapse group)

Parameters

model	Model description
path	Path for code output
mos	output stream for messages

15.45.3 Variable Documentation

15.45.3.1 CodeHelper hlp

15.45.3.2 short* isGrpVarNeeded

15.46 generateRunner.cc File Reference

Contains functions to generate code for running the simulation on the GPU, and for I/O convenience functions between GPU and CPU space. Part of the code generation section.

```
#include <cfloat>
```

Functions

- void genRunner (NNmodel &model, string path, ostream &mos)

    A function that generates predominantly host-side code.
- void genRunnerGPU (NNmodel &model, string &path, ostream &mos)

    A function to generate the code that simulates the model on the GPU.

15.46.1 Detailed Description

Contains functions to generate code for running the simulation on the GPU, and for I/O convenience functions between GPU and CPU space. Part of the code generation section.

15.46.2 Function Documentation

15.46.2.1 void genRunner (NNmodel & *model,* string *path,* ostream & *mos*)

A function that generates predominantly host-side code.

In this function host-side functions and other code are generated, including: Global host variables, "allocatedMem()" function for allocating memories, "freeMem" function for freeing the allocated memories, "initialize" for initializing host variables, "gFunc" and "initGRaw()" for use with plastic synapses if such synapses exist in the model.

Parameters

model	Model description
path	path for code generation
mos	output stream for messages

15.46.2.2 void genRunnerGPU (NNmodel & *model,* string & *path,* ostream & *mos*)

A function to generate the code that simulates the model on the GPU.

The function generates functions that will spawn kernel grids onto the GPU (but not the actual kernel code which is generated in "genNeuronKernel()" and "genSynpaseKernel()"). Generated functions include "copyGToDevice()", "copyGFromDevice()", "copyStateToDevice()", "copyStateFromDevice()", "copySpikesFromDevice()", "copySpike←NFromDevice()" and "stepTimeGPU()". The last mentioned function is the function that will initialize the execution on the GPU in the generated simulation engine. All other generated functions are "convenience functions" to handle data transfer from and to the GPU.

Parameters

model	Model description
path	path for code generation
mos	output stream for messages

15.47 GeNNHelperKrnls.cu File Reference

```
#include <curand_kernel.h>
```

Macros

- #define BlkSz 256

Functions

- __global__ void setup_kernel (curandState ∗state, unsigned long seed, int sizeofResult)
- template<class T >
  __global__ void generate_random_gpuInput_xorwow (curandState ∗state, T ∗result, int sizeofResult, T Rstrength, T Rshift)
- void xorwow_setup (curandState ∗devStates, long int sampleSize)

15.47.1 Macro Definition Documentation

15.47.1.1 #define BlkSz 256

15.47.2 Function Documentation

15.47.2.1 template<class T > __global__ void generate_random_gpuInput_xorwow (curandState ∗ *state*, T ∗ *result*, int *sizeofResult*, T *Rstrength*, T *Rshift*)

15.47.2.2 __global__ void setup_kernel (curandState ∗ *state*, unsigned long *seed*, int *sizeofResult*)

15.47.2.3 void xorwow_setup (curandState ∗ *devStates*, long int *sampleSize*)

15.48 global.h File Reference

Global header file containing a few global variables. Part of the code generation section.

```
#include <iostream>
#include <cstring>
#include <string>
#include <sstream>
#include <vector>
#include <cmath>
#include <cuda_runtime.h>
#include "toString.h"
#include <stdint.h>
```

Macros

- #define _GLOBAL_H_

  macro for avoiding multiple inclusion during compilation

Variables

- int neuronBlkSz
- int synapseBlkSz
- int learnBlkSz
- cudaDeviceProp ∗ deviceProp
- int theDev
- int hostCount

  Global variable containing the number of hosts within the local compute cluster.
- int deviceCount

Global variable containing the number of CUDA devices found on this host.
- int optimiseBlockSize = 1

  Flag for signalling whether or not block size optimisation should be performed.
- int UIntSz = sizeof(unsigned int) ∗ 8

  size of the unsigned int variable type on the local architecture
- int logUIntSz = (int) (logf((float) UIntSz) / logf(2.0f) + 1e-5f)

  logarithm of the size of the unsigned int variable type on the local architecture

15.48.1 Detailed Description

Global header file containing a few global variables. Part of the code generation section.

This global header file also takes care of including some generally used cuda support header files.

15.48.2 Macro Definition Documentation

15.48.2.1 #define _GLOBAL_H_

macro for avoiding multiple inclusion during compilation

15.48.3 Variable Documentation

15.48.3.1 int deviceCount

Global variable containing the number of CUDA devices found on this host.

15.48.3.2 cudaDeviceProp∗ deviceProp

15.48.3.3 int hostCount

Global variable containing the number of hosts within the local compute cluster.

15.48.3.4 int learnBlkSz

15.48.3.5 int logUIntSz = (int) (logf((float) UIntSz) / logf(2.0f) + 1e-5f)

logarithm of the size of the unsigned int variable type on the local architecture

15.48.3.6 int neuronBlkSz

15.48.3.7 int optimiseBlockSize = 1

Flag for signalling whether or not block size optimisation should be performed.

15.48.3.8 int synapseBlkSz

15.48.3.9 int theDev

15.48.3.10 int UIntSz = sizeof(unsigned int) ∗ 8

size of the unsigned int variable type on the local architecture

15.49 helper.h File Reference

```
#include <vector>
```

Classes

- struct inputSpec

Functions

- ostream & operator<< (ostream &os, inputSpec &I)
- void write_para ()
- void single_var_reinit (int n, double fac)
- void copy_var (int src, int trg)
- void var_reinit (double fac)
- void truevar_init ()
- void initexpHH ()
- void truevar_initexpHH ()
- void runexpHH (float t)
- void initI (inputSpec &I)

Variables

- double sigGNa = 0.1
- double sigENa = 10.0
- double sigGK = 0.1
- double sigEK = 10.0
- double sigGl = 0.1
- double sigEl = 10.0
- double sigC = 0.1
- double Vexp
- double mexp
- double hexp
- double nexp
- double gNaexp
- double ENaexp
- double gKexp
- double EKexp
- double glexp
- double Elexp
- double Cexp

15.49.1 Function Documentation

15.49.1.1 void copy_var (int *src*, int *trg*)

15.49.1.2 void initexpHH ( )

15.49.1.3 void initI (inputSpec & *I*)

15.49.1.4 ostream& operator<< (ostream & *os*, inputSpec & *I*)

15.49.1.5 void runexpHH (float *t*)

15.49.1.6 void single_var_reinit (int *n*, double *fac*)

15.49.1.7 void truevar_init ( )

15.49.1.8 void truevar_initexpHH ( )

15.49.1.9 void var_reinit (double *fac*)

15.49.1.10 void write_para ( )

15.49.2 Variable Documentation

15.49.2.1 double Cexp

15.49.2.2 double EKexp

15.49.2.3 double Elexp

15.49.2.4 double ENaexp

15.49.2.5 double gKexp

15.49.2.6 double glexp

15.49.2.7 double gNaexp

15.49.2.8 double hexp

15.49.2.9 double mexp

15.49.2.10 double nexp

15.49.2.11 double sigC = 0.1

15.49.2.12 double sigEK = 10.0

15.49.2.13 double sigEl = 10.0

15.49.2.14 double sigENa = 10.0

15.49.2.15 double sigGK = 0.1

15.49.2.16 double sigGl = 0.1

15.49.2.17 double sigGNa = 0.1

15.49.2.18 double Vexp

15.50 HHVClamp.cc File Reference

This file contains the model definition of HHVClamp model. It is used in both the GeNN code generation and the user side simulation code. The HHVClamp model implements a population of unconnected Hodgkin-Huxley neurons that evolve to mimick a model run on the CPU, using genetic algorithm techniques.

```
#include "modelSpec.h"
#include "modelSpec.cc"
#include "HHVClampParameters.h"
```

Macros

- #define DT 0.5

  This defines the global time step at which the simulation will run.

Functions

- void modelDefinition (NNmodel &model)

    This function defines the HH model with variable parameters.

Variables

- double myHH_ini [11]
- double ∗ myHH_p = NULL

15.50.1 Detailed Description

This file contains the model definition of HHVClamp model. It is used in both the GeNN code generation and the user side simulation code. The HHVClamp model implements a population of unconnected Hodgkin-Huxley neurons that evolve to mimick a model run on the CPU, using genetic algorithm techniques.

15.50.2 Macro Definition Documentation

15.50.2.1 #define DT 0.5

This defines the global time step at which the simulation will run.

15.50.3 Function Documentation

15.50.3.1 void modelDefinition (NNmodel & *model*)

This function defines the HH model with variable parameters.

15.50.4 Variable Documentation

15.50.4.1 double myHH_ini[11]

Initial value:

```
= {
  -60.0,
  0.0529324,
  0.3176767,
  0.5961207,
  120.0,
  55.0,
  36.0,
  -72.0,
  0.3,
  -50.0,
  1.0
}
```

15.50.4.2 double∗ myHH_p = NULL

15.51 hr_time.cpp File Reference

This file contains the implementation of the CStopWatch class that provides a simple timing tool based on the system clock.

```
#include <cstdio>
#include "hr_time.h"
```

15.51.1 Detailed Description

This file contains the implementation of the CStopWatch class that provides a simple timing tool based on the system clock.

15.52 hr_time.h File Reference

This header file contains the definition of the CStopWatch class that implements a simple timing tool using the system clock.

```
#include <sys/time.h>
```

Classes

- struct stopWatch
- class CStopWatch

15.52.1 Detailed Description

This header file contains the definition of the CStopWatch class that implements a simple timing tool using the system clock.

15.53 Izh_sim_sparse.cu File Reference

```
#include <iostream>
#include <fstream>
#include "Izh_sparse_sim.h"
#include "../GeNNHelperKrnls.cu"
```

Functions

- int main (int argc, char *argv[])

15.53.1 Function Documentation

15.53.1.1 int main (int *argc*, char * *argv[]*)

15.54 Izh_sparse.cc File Reference

```
#include "modelSpec.h"
#include "modelSpec.cc"
#include <vector>
#include "sizes.h"
```

Macros

- #define DT 1.0

Functions

- void modelDefinition (NNmodel &model)

Variables

- std::vector< unsigned int > neuronPSize
- std::vector< unsigned int > neuronVSize
- std::vector< unsigned int > synapsePSize
- double ∗ exclzh_p = NULL
- double ∗ inhIzh_p = NULL
- double IzhExc_ini [6]
- double IzhInh_ini [6]
- double ∗ SynIzh_p = NULL
- double postExpP [2]
- double ∗ postSynV = NULL
- double SynIzh_ini [1]

15.54.1 Macro Definition Documentation

15.54.1.1 #define DT 1.0

15.54.2 Function Documentation

15.54.2.1 void modelDefinition (NNmodel & *model*)

15.54.3 Variable Documentation

15.54.3.1 double∗ exclzh_p = NULL

15.54.3.2 double∗ inhIzh_p = NULL

15.54.3.3 double IzhExc_ini[6]

Initial value:

```
={

        -65.0,
         0.0,
         0.02,
        0.2,
        -65.0,
         8.0
}
```

15.54.3.4 double IzhInh_ini[6]

Initial value:

```
={

        -65,
         0.0,
         0.02,
        0.25,
        -65.0,
         2.0
}
```

15.54.3.5 std::vector<unsigned int> neuronPSize

15.54.3.6 std::vector<unsigned int> neuronVSize

15.54.3.7 double postExpP[2]

Initial value:

```
={
  0.0,
  0.0
}
```

15.54.3.8 double∗ postSynV = NULL

15.54.3.9 std::vector<unsigned int> synapsePSize

15.54.3.10 double SynIzh_ini[1]

Initial value:

```
= {
    0.0
}
```

15.54.3.11 double∗ SynIzh_p = NULL

15.55 Izh_sparse_model.cc File Reference

```
#include "Izh_sparse_CODE/runner.cc"
#include "../../lib/include/numlib/randomGen.h"
#include "../../lib/include/numlib/gauss.h"
#include "Izh_sparse_model.h"
```

Macros

- #define _IZH_SPARSE_MODEL_CC_

Variables

- randomGauss RG
- randomGen R

15.55.1 Macro Definition Documentation

15.55.1.1 #define _IZH_SPARSE_MODEL_CC_

15.55.2 Variable Documentation

15.55.2.1 randomGen R

15.55.2.2 randomGauss RG

15.56 Izh_sparse_model.h File Reference

Classes

- class classIzh

15.57 Izh_sparse_sim.h File Reference

```
#include <cassert>
#include "hr_time.cpp"
#include "utils.h"
#include <cuda_runtime.h>
#include "Izh_sparse.cc"
#include "Izh_sparse_model.cc"
```

Macros

- #define DBG_SIZE 5000
- #define T_REPORT_TME 5000.0
- #define TOTAL_TME 5000.0

Variables

- float t = 0.0f
- unsigned int iT = 0
- CStopWatch timer

15.57.1 Macro Definition Documentation

15.57.1.1 #define DBG_SIZE 5000

15.57.1.2 #define T_REPORT_TME 5000.0

15.57.1.3 #define TOTAL_TME 5000.0

15.57.2 Variable Documentation

15.57.2.1 unsigned int iT = 0

15.57.2.2 float t = 0.0f

15.57.2.3 CStopWatch timer

15.58 map_classol.cc File Reference

```
#include "map_classol.h"
#include "MBody1_CODE/runner.cc"
```

Macros

- #define _MAP_CLASSOL_CC_

  macro for avoiding multiple inclusion during compilation

15.58.1 Macro Definition Documentation

15.58.1.1 #define _MAP_CLASSOL_CC_

macro for avoiding multiple inclusion during compilation

15.59 map_classol.cc File Reference

```
#include "map_classol.h"
#include "MBody_delayedSyn_CODE/runner.cc"
```

Macros

- #define _MAP_CLASSOL_CC_

    macro for avoiding multiple inclusion during compilation

15.59.1 Macro Definition Documentation

15.59.1.1 #define _MAP_CLASSOL_CC_

macro for avoiding multiple inclusion during compilation

15.60 map_classol.cc File Reference

```
#include "map_classol.h"
#include "MBody_individualID_CODE/runner.cc"
```

Macros

- #define _MAP_CLASSOL_CC_

    macro for avoiding multiple inclusion during compilation

15.60.1 Macro Definition Documentation

15.60.1.1 #define _MAP_CLASSOL_CC_

macro for avoiding multiple inclusion during compilation

15.61 map_classol.cc File Reference

```
#include "MBody_userdef_CODE/runner.cc"
#include "sparseUtils.cc"
#include "map_classol.h"
```

Macros

- #define _MAP_CLASSOL_CC_

    macro for avoiding multiple inclusion during compilation

15.61.1 Macro Definition Documentation

15.61.1.1 #define _MAP_CLASSOL_CC_

macro for avoiding multiple inclusion during compilation

15.62 map_classol.h File Reference

Classes

- class classol

  This class cpontains the methods for running the MBody1 example model.

15.63 map_classol.h File Reference

Classes

- class classol

  This class cpontains the methods for running the MBody1 example model.

15.64 map_classol.h File Reference

Classes

- class classol

  This class cpontains the methods for running the MBody1 example model.

15.65 map_classol.h File Reference

Classes

- class classol

  This class cpontains the methods for running the MBody1 example model.

15.66 MBody1.cc File Reference

```
#include "modelSpec.h"
#include "modelSpec.cc"
#include "../../userproject/include/sizes.h"
```

Macros

- #define DT 0.1

  This defines the global time step at which the simulation will run.

Functions

- void modelDefinition (NNmodel &model)

  This function defines the MBody1 model, and it is a good example of how networks should be defined.

Variables

- double myPOI_p [4]
- double myPOI_ini [4]
- double stdTM_p [7]
- double stdTM_ini [4]

- double myPNKC_p [3]
- double postExpPNKC [2]
- double myPNLHI_p [3]
- double postExpPNLHI [2]
- double myLHIKC_p [4]
- double gLHIKC = 0.006
- double postExpLHIKC [2]
- double myKCDN_p [13]
- double postExpKCDN [2]
- double myDNDN_p [4]
- double gDNDN = 0.01
- double postExpDNDN [2]
- double ∗ postSynV = NULL

15.66.1 Macro Definition Documentation

15.66.1.1 #define DT 0.1

This defines the global time step at which the simulation will run.

15.66.2 Function Documentation

15.66.2.1 void modelDefinition (NNmodel & *model*)

This function defines the MBody1 model, and it is a good example of how networks should be defined.

15.66.3 Variable Documentation

15.66.3.1 double gDNDN = 0.01

15.66.3.2 double gLHIKC = 0.006

15.66.3.3 double myDNDN_p[4]

Initial value:

```
= {
  -92.0,
  -30.0,
  8.0,
  50.0
}
```

15.66.3.4 double myKCDN_p[13]

Initial value:

```
= {
  0.0,
  -20.0,
  5.0,
  25.0,
  100.0,
  50000.0,
  100000.0,
  100.0,
  0.06,
  0.03,
  33.33,
  10.0,

  0.00006
}
```

15.66.3.5 double myLHIKC_p[4]

Initial value:

```
= {
  -92.0,
  -40.0,
  3.0,
  50.0
}
```

15.66.3.6 double myPNKC_p[3]

Initial value:

```
= {
  0.0,
  -20.0,
  1.0
}
```

15.66.3.7 double myPNLHI_p[3]

Initial value:

```
= {
  0.0,
  -20.0,
  1.0
}
```

15.66.3.8 double myPOI_ini[4]

Initial value:

```
= {
 -60.0,
  0,
  -10.0,
}
```

15.66.3.9 double myPOI_p[4]

Initial value:

```
= {
  0.1,
  2.5,
  20.0,
  -60.0
}
```

15.66.3.10 double postExpDNDN[2]

Initial value:

```
={
  8.0,
  -92.0
}
```

15.66.3.11 double postExpKCDN[2]

Initial value:

```
={
  5.0,
  0.0
}
```

15.66.3.12 double postExpLHIKC[2]

Initial value:

```
={
  3.0,
  -92.0
}
```

15.66.3.13 double postExpPNKC[2]

Initial value:

```
={
  1.0,
  0.0
}
```

15.66.3.14 double postExpPNLHI[2]

Initial value:

```
={
  1.0,
  0.0
}
```

15.66.3.15 double∗ postSynV = NULL

15.66.3.16 double stdTM_ini[4]

Initial value:

```
= {
  -60.0,
  0.0529324,
  0.3176767,
  0.5961207
}
```

15.66.3.17 double stdTM_p[7]

Initial value:

```
= {
  7.15,
  50.0,
  1.43,
  -95.0,
  0.02672,
  -63.563,
  0.143
}
```

15.67 MBody1.cc File Reference

```
#include "modelSpec.h"
#include "modelSpec.cc"
#include "sizes.h"
```

Macros

- #define DT 0.1

  This defines the global time step at which the simulation will run.

Functions

- void modelDefinition (NNmodel &model)

  This function defines the MBody1 model, and it is a good example of how networks should be defined.

Variables

- int nGPU = 0
- double myPOI_p [4]
- double myPOI_ini [3]
- double stdTM_p [7]
- double stdTM_ini [4]
- double ∗ myPNKC_p = NULL
- double myPNKC_ini [1]
- double postExpPNKC [2]
- double ∗ myPNLHI_p = NULL
- double myPNLHI_ini [1]
- double postExpPNLHI [2]
- double myLHIKC_p [2]
- double myLHIKC_ini [1]
- double postExpLHIKC [2]
- double myKCDN_p [11]
- double myKCDN_ini [2]
- double postExpKCDN [2]
- double myDNDN_p [2]
- double myDNDN_ini [1]
- double postExpDNDN [2]
- double ∗ postSynV = NULL

15.67.1 Macro Definition Documentation

15.67.1.1 #define DT 0.1

This defines the global time step at which the simulation will run.

15.67.2 Function Documentation

15.67.2.1 void modelDefinition (NNmodel & *model*)

This function defines the MBody1 model, and it is a good example of how networks should be defined.

15.67.3 Variable Documentation

15.67.3.1 double myDNDN_ini[1]

Initial value:

```
={
    5.0/_NLB
}
```

15.67.3.2 double myDNDN_p[2]

Initial value:

```
= {
  -30.0,
  50.0
}
```

15.67.3.3 double myKCDN_ini[2]

Initial value:

```
={
  0.01,
  0.01,
}
```

15.67.3.4 double myKCDN_p[11]

Initial value:

```
= {
  -20.0,
  50.0,
  50.0,
  50000.0,
  100000.0,
  200.0,
  0.015,
  0.0075,
  33.33,
  10.0,
  0.00006
}
```

15.67.3.5 double myLHIKC_ini[1]

Initial value:

```
= {
    0.35/_NLHI
}
```

15.67.3.6 double myLHIKC_p[2]

Initial value:

```
= {
  -40.0,
  50.0
}
```

15.67.3.7 double myPNKC_ini[1]

Initial value:

```
= {
  0.01
}
```

15.67.3.8 double∗ myPNKC_p = NULL

15.67.3.9 double myPNLHI_ini[1]

Initial value:

```
= {
    0.0
}
```

15.67.3.10 double∗ myPNLHI_p = NULL

15.67.3.11 double myPOI_ini[3]

Initial value:

```
= {
 -60.0,
  0,
  -10.0
}
```

15.67.3.12 double myPOI_p[4]

Initial value:

```
= {
  0.1,
  2.5,
  20.0,
  -60.0
}
```

15.67.3.13 int nGPU = 0

15.67.3.14 double postExpDNDN[2]

Initial value:

```
={
  8.0,
  -92.0
}
```

15.67.3.15 double postExpKCDN[2]

Initial value:

```
={
  5.0,
  0.0
}
```

15.67.3.16 double postExpLHIKC[2]

Initial value:

```
={
    1.5,
  -92.0
}
```

15.67.3.17 double postExpPNKC[2]

Initial value:

```
={
  1.0,
  0.0
}
```

15.67.3.18 double postExpPNLHI[2]

Initial value:

```
={
  1.0,
  0.0
}
```

15.67.3.19 double* postSynV = NULL

15.67.3.20 double stdTM_ini[4]

Initial value:

```
= {
  -60.0,
  0.0529324,
  0.3176767,
  0.5961207
}
```

15.67.3.21 double stdTM_p[7]

Initial value:

```
= {
  7.15,
  50.0,
  1.43,
  -95.0,
  0.02672,
  -63.563,
  0.143
}
```

15.68 MBody_delayedSyn.cc File Reference

This file contains the model definition of the mushroom body "MBody_delayedSyn" model. It is used in both the GeNN code generation and the user side simulation code (class classol, file classol_sim).

```
#include "modelSpec.h"
#include "modelSpec.cc"
#include "sizes.h"
```

Macros

- #define DT 0.1

  This defines the global time step at which the simulation will run.

Functions

- void modelDefinition (NNmodel &model)

  This function defines the MBody_delayedSyn model, and it is a good example of how networks should be defined.

Variables

- int nGPU = 0
- double myPOI_p [4]
- double myPOI_ini [3]
- double stdTM_p [7]
- double stdTM_ini [4]
- double ∗ myPNKC_p = NULL
- double myPNKC_ini [1]
- double postExpPNKC [2]
- double ∗ myPNLHI_p = NULL
- double myPNLHI_ini [1]
- double postExpPNLHI [2]
- double myLHIKC_p [2]
- double myLHIKC_ini [1]
- double postExpLHIKC [2]
- double myKCDN_p [11]
- double myKCDN_ini [2]
- double postExpKCDN [2]
- double myDNDN_p [2]
- double myDNDN_ini [1]
- double postExpDNDN [2]
- double ∗ postSynV = NULL

15.68.1 Detailed Description

This file contains the model definition of the mushroom body "MBody_delayedSyn" model. It is used in both the GeNN code generation and the user side simulation code (class classol, file classol_sim).

15.68.2 Macro Definition Documentation

15.68.2.1 #define DT 0.1

This defines the global time step at which the simulation will run.

15.68.3 Function Documentation

15.68.3.1 void modelDefinition (NNmodel & *model*)

This function defines the MBody_delayedSyn model, and it is a good example of how networks should be defined.

15.68.4 Variable Documentation

15.68.4.1 double myDNDN_ini[1]

Initial value:

```
={
    5.0/_NLB
}
```

15.68.4.2 double myDNDN_p[2]

Initial value:

```
= {
  -30.0,
  50.0
}
```

15.68.4.3 double myKCDN_ini[2]

Initial value:

```
={
  0.01,
  0.01,
}
```

15.68.4.4 double myKCDN_p[11]

Initial value:

```
= {
  -20.0,
  50.0,
  50.0,
  50000.0,
  100000.0,
  200.0,
  0.015,
  0.0075,
  33.33,
  10.0,
  0.00006
}
```

15.68.4.5 double myLHIKC_ini[1]

Initial value:

```
= {
    0.35/_NLHI
}
```

15.68.4.6 double myLHIKC_p[2]

Initial value:

```
= {
  -40.0,
  50.0
}
```

15.68.4.7 double myPNKC_ini[1]

Initial value:

```
= {
  0.01
}
```

15.68.4.8 double∗ myPNKC_p = NULL

15.68.4.9 double myPNLHI_ini[1]

Initial value:

```
= {
    0.0
}
```

15.68.4.10 double∗ myPNLHI_p = NULL

15.68.4.11 double myPOI_ini[3]

Initial value:

```
= {
 -60.0,
  0,
  -10.0
}
```

15.68.4.12 double myPOI_p[4]

Initial value:

```
= {
  0.1,
  2.5,
  20.0,
  -60.0
}
```

15.68.4.13 int nGPU = 0

15.68.4.14 double postExpDNDN[2]

Initial value:

```
={
  8.0,
  -92.0
}
```

15.68.4.15 double postExpKCDN[2]

Initial value:

```
={
  5.0,
  0.0
}
```

15.68.4.16 double postExpLHIKC[2]

Initial value:

```
={
    1.5,
  -92.0
}
```

15.68.4.17 double postExpPNKC[2]

Initial value:

```
={
  1.0,
  0.0
}
```

15.68.4.18 double postExpPNLHI[2]

Initial value:

```
={
  1.0,
  0.0
}
```

15.68.4.19 double∗ postSynV = NULL

15.68.4.20 double stdTM_ini[4]

Initial value:

```
= {
  -60.0,
  0.0529324,
  0.3176767,
  0.5961207
}
```

15.68.4.21 double stdTM_p[7]

Initial value:

```
= {
  7.15,
  50.0,
  1.43,
  -95.0,
  0.02672,
  -63.563,
  0.143
}
```

15.69 MBody_individualID.cc File Reference

This file contains the model definition of the mushroom body "MBody_incividualID" model. It is used in both the GeNN code generation and the user side simulation code (class classol, file classol_sim). It uses INDIVIDUALID for the connections from AL to MB allowing quite large numbers of PN and KC.

```
#include "modelSpec.h"
#include "modelSpec.cc"
#include "sizes.h"
```

Macros

- #define DT 0.1

  This defines the global time step at which the simulation will run.

Functions

- void modelDefinition (NNmodel &model)
  This function defines the MBody1 model, and it is a good example of how networks should be defined.

Variables

- int nGPU = 0
- double myPOI_p [4]
- double myPOI_ini [3]
- double stdTM_p [7]
- double stdTM_ini [4]
- double ∗ myPNKC_p = NULL
- double myPNKC_ini [1]
- double postExpPNKC [2]
- double ∗ myPNLHI_p = NULL
- double myPNLHI_ini [1]
- double postExpPNLHI [2]
- double myLHIKC_p [2]
- double myLHIKC_ini [1]
- double postExpLHIKC [2]
- double myKCDN_p [11]
- double myKCDN_ini [2]
- double postExpKCDN [2]
- double myDNDN_p [2]
- double myDNDN_ini [1]
- double postExpDNDN [2]
- double ∗ postSynV = NULL

15.69.1 Detailed Description

This file contains the model definition of the mushroom body "MBody_incividualID" model. It is used in both the GeNN code generation and the user side simulation code (class classol, file classol_sim). It uses INDIVIDUALID for the connections from AL to MB allowing quite large numbers of PN and KC.

15.69.2 Macro Definition Documentation

15.69.2.1 #define DT 0.1

This defines the global time step at which the simulation will run.

15.69.3 Function Documentation

15.69.3.1 void modelDefinition (NNmodel & *model*)

This function defines the MBody1 model, and it is a good example of how networks should be defined.

15.69.4 Variable Documentation

15.69.4.1 double myDNDN_ini[1]

Initial value:

```
={
    5.0/_NLB
}
```

15.69.4.2 double myDNDN_p[2]

Initial value:

```
= {
  -30.0,
  50.0
}
```

15.69.4.3 double myKCDN_ini[2]

Initial value:

```
={
  0.01,
  0.01,
}
```

15.69.4.4 double myKCDN_p[11]

Initial value:

```
= {
  -20.0,
  50.0,
  50.0,
  50000.0,
  100000.0,
  200.0,
  0.015,
  0.0075,
  33.33,
  10.0,
  0.00006
}
```

15.69.4.5 double myLHIKC_ini[1]

Initial value:

```
= {
    0.35/_NLHI
}
```

15.69.4.6 double myLHIKC_p[2]

Initial value:

```
= {
  -40.0,
  50.0
}
```

15.69.4.7 double myPNKC_ini[1]

Initial value:

```
= {
  gPNKC_GLOBAL
}
```

15.69.4.8 double* myPNKC_p = NULL

15.69.4.9 double myPNLHI_ini[1]

Initial value:

```
= {
    0.0
}
```

15.69.4.10 double* myPNLHI_p = NULL

15.69.4.11 double myPOI_ini[3]

Initial value:

```
= {
 -60.0,
  0,
  -10.0
}
```

15.69.4.12 double myPOI_p[4]

Initial value:

```
= {
  0.1,
  2.5,
  20.0,
  -60.0
}
```

15.69.4.13 int nGPU = 0

15.69.4.14 double postExpDNDN[2]

Initial value:

```
={
  8.0,
  -92.0
}
```

15.69.4.15 double postExpKCDN[2]

Initial value:

```
={
  5.0,
  0.0
}
```

15.69.4.16 double postExpLHIKC[2]

Initial value:

```
={
    1.5,
  -92.0
}
```

15.69.4.17 double postExpPNKC[2]

Initial value:

```
={
  1.0,
  0.0
}
```

15.69.4.18 double postExpPNLHI[2]

Initial value:

```
={
  1.0,
  0.0
}
```

15.69.4.19 double∗ postSynV = NULL

15.69.4.20 double stdTM_ini[4]

Initial value:

```
= {
  -60.0,
  0.0529324,
  0.3176767,
  0.5961207
}
```

15.69.4.21 double stdTM_p[7]

Initial value:

```
= {
  7.15,
  50.0,
  1.43,
  -95.0,
  0.02672,
  -63.563,
  0.143
}
```

15.70 MBody_userdef.cc File Reference

This file contains the model definition of the mushroom body model. It is used in both the GeNN code generation and the user side simulation code (class classol, file classol_sim). It uses user-defined models for everything.

```
#include "modelSpec.h"
#include "modelSpec.cc"
#include "sizes.h"
```

Classes

- class pwSTDP_userdef

  TODO This class definition may be code-generated in a future release.

Macros

- #define DT 0.1

  This defines the global time step at which the simulation will run.

Functions

- void modelDefinition (NNmodel &model)

  This function defines the MBody1 model with user defined synapses.

Variables

- int nGPU = 0
- double myPOI_p [4]
- double myPOI_ini [3]
- double stdTM_p [7]
- double stdTM_ini [4]
- double ∗ myPNKC_p = NULL
- double myPNKC_ini [1]
- double postExpPNKC [2]
- double ∗ myPNLHI_p = NULL
- double myPNLHI_ini [1]
- double postExpPNLHI [2]
- double myLHIKC_p [2]
- double myLHIKC_ini [1]
- double postExpLHIKC [2]
- double myKCDN_p [11]
- double myKCDN_ini [2]
- double postExpKCDN [2]
- double myDNDN_p [4]
- double myDNDN_ini [1]
- double postExpDNDN [2]
- double ∗ postSynV = NULL
- double postSynV_EXPDECAY_EVAR [1]
- scalar ∗ gpPNKC = new scalar[_NAL∗_NMB]
- scalar ∗ gpKCDN = new scalar[_NMB∗_NLB]

15.70.1 Detailed Description

This file contains the model definition of the mushroom body model. It is used in both the GeNN code generation and the user side simulation code (class classol, file classol_sim). It uses user-defined models for everything.

15.70.2 Macro Definition Documentation

15.70.2.1 #define DT 0.1

This defines the global time step at which the simulation will run.

15.70.3 Function Documentation

15.70.3.1 void modelDefinition (NNmodel & *model*)

This function defines the MBody1 model with user defined synapses.

15.70.4 Variable Documentation

15.70.4.1 scalar* gpKCDN = new scalar[_NMB*_NLB]

15.70.4.2 scalar* gpPNKC = new scalar[_NAL*_NMB]

15.70.4.3 double myDNDN_ini[1]

Initial value:

```
={
    5.0/_NLB
}
```

15.70.4.4 double myDNDN_p[4]

Initial value:

```
= {
  -30.0,
  50.0
}
```

15.70.4.5 double myKCDN_ini[2]

Initial value:

```
={
  0.01,
  0.01,
}
```

15.70.4.6 double myKCDN_p[11]

Initial value:

```
= {
  -20.0,
  50.0,
  50.0,
  50000.0,
  100000.0,
  200.0,
  0.015,
  0.0075,
  33.33,
  10.0,
  0.00006
}
```

15.70.4.7 double myLHIKC_ini[1]

Initial value:

```
= {
    0.35/_NLHI
}
```

15.70.4.8 double myLHIKC_p[2]

Initial value:

```
= {
  -40.0,
  50.0
}
```

15.70.4.9 double myPNKC_ini[1]

Initial value:

```
= {
  0.01
}
```

15.70.4.10 double∗ myPNKC_p = NULL

15.70.4.11 double myPNLHI_ini[1]

Initial value:

```
= {
    0.0
}
```

15.70.4.12 double∗ myPNLHI_p = NULL

15.70.4.13 double myPOI_ini[3]

Initial value:

```
= {
 -60.0,
  0,
  -10.0
}
```

15.70.4.14 double myPOI_p[4]

Initial value:

```
= {
  0.1,
  2.5,
  20.0,
  -60.0
}
```

15.70.4.15 int nGPU = 0

15.70.4.16 double postExpDNDN[2]

Initial value:

```
={
  8.0,
  -92.0
}
```

15.70.4.17 double postExpKCDN[2]

Initial value:

```
={
  5.0,
  0.0
}
```

15.70.4.18 double postExpLHIKC[2]

Initial value:

```
={
  1.5,
  -92.0
}
```

15.70.4.19 double postExpPNKC[2]

Initial value:

```
={
  1.0,
  0.0
}
```

15.70.4.20 double postExpPNLHI[2]

Initial value:

```
={
  1.0,
  0.0
}
```

15.70.4.21 double* postSynV = NULL

15.70.4.22 double postSynV_EXPDECAY_EVAR[1]

Initial value:

```
= {
0
}
```

15.70.4.23 double stdTM_ini[4]

Initial value:

```
= {
  -60.0,
  0.0529324,
  0.3176767,
  0.5961207
}
```

15.70.4.24 double stdTM_p[7]

Initial value:

```
= {
  7.15,
  50.0,
  1.43,
  -95.0,
  0.02672,
  -63.563,
  0.143
}
```

15.71 modelSpec.cc File Reference

```
#include "utils.h"
```

Macros

- #define _MODELSPEC_CC_

    macro for avoiding multiple inclusion during compilation

Functions

- void initGeNN ()

    Method for GeNN initialisation (by preparing standard models)

15.71.1 Macro Definition Documentation

15.71.1.1 #define _MODELSPEC_CC_

macro for avoiding multiple inclusion during compilation

15.71.2 Function Documentation

15.71.2.1 void initGeNN ( )

Method for GeNN initialisation (by preparing standard models)

15.72 modelSpec.h File Reference

Header file that contains the class (struct) definition of neuronModel for defining a neuron model and the class definition of NNmodel for defining a neuronal network model. Part of the code generation and generated code sections.

```
#include <vector>
#include "global.h"
```

Classes

- class dpclass
- struct neuronModel

    class (struct) for specifying a neuron model.
- struct postSynModel

    Structure to hold the information that defines a post-synaptic model (a model of how synapses affect post-synaptic neuron variables, classically in the form of a synaptic current). It also allows to define an equation for the dynamics that can be applied to the summed synaptic input variable "insyn".
- class weightUpdateModel

    Structure to hold the information that defines a weightupdate model (a model of how spikes affect synaptic (and/or) (mostly) post-synaptic neuron variables. It also allows to define changes in response to post-synaptic spikes/spike-like events.
- class NNmodel

    Structure to hold the information that defines synapse dynamics (a model of how synapse variables change over time, independent of or in addition to changes when spikes occur).

Macros

- #define _MODELSPEC_H_

    macro for avoiding multiple inclusion during compilation

- #define MAXNRN 6
- #define SYNTYPENO 4
- #define NOINP 0

  Macro attaching the name NOINP (no input) to 0.
- #define CONSTINP 1

  Macro attaching the name CONSTINP (constant input) to 1.
- #define MATINP 2

  Macro attaching the name MATINP (explicit input defined as a matrix) to 2.
- #define INPRULE 3

  Macro attaching the name INPRULE (explicit dynamic input defined as a rule) to 3.
- #define RANDNINP 4

  Macro attaching the name RANDNINP (Random input with Gaussian distribution, calculated real time on the device by the generated code) to 4 (TODO, not implemented yet)
- #define ALLTOALL 0

  Macro attaching the label "ALLTOALL" to connectivity type 0.
- #define DENSE 1

  Macro attaching the label "DENSE" to connectivity type 1.
- #define SPARSE 2

  Macro attaching the label "SPARSE" to connectivity type 2.
- #define INDIVIDUALG 0

  Macro attaching the label "INDIVIDUALG" to method 0 for the definition of synaptic conductances.
- #define GLOBALG 1

  Macro attaching the label "GLOBALG" to method 1 for the definition of synaptic conductances.
- #define INDIVIDUALID 2

  Macro attaching the label "INDIVIDUALID" to method 2 for the definition of synaptic conductances.
- #define NO_DELAY 1

  Macro used to indicate no synapse delay for the group (only one queue slot will be generated)
- #define NOLEARNING 0

  Macro attaching the label "NOLEARNING" to flag 0.
- #define LEARNING 1

  Macro attaching the label "LEARNING" to flag 1.
- #define EXITSYN 0

  Macro attaching the label "EXITSYN" to flag 0 (excitatory synapse)
- #define INHIBSYN 1

  Macro attaching the label "INHIBSYN" to flag 1 (inhibitory synapse)
- #define TRUE 1

  Macro attaching the label "TRUE" to value 1.
- #define FALSE 0

  Macro attaching the label "FALSE" to value 0.
- #define CPU 0

  Macro attaching the label "CPU" to flag 0.
- #define GPU 1

  Macro attaching the label "GPU" to flag 1.
- #define FLOAT 0

  Macro attaching the label "FLOAT" to flag 0. Used by NNModel::setPrecision()
- #define DOUBLE 1

  Macro attaching the label "DOUBLE" to flag 1. Used by NNModel::setPrecision()
- #define AUTODEVICE -1

  Macro attaching the label AUTODEVICE to flag -1. Used by setGPUDevice.
- #define SPK_THRESH_STDP 0.0f

  Macro defining the spiking threshold for the purposes of STDP.
- #define MAXPOSTSYN 2

Functions

- void initGeNN ()

  Method for GeNN initialisation (by preparing standard models)

Variables

- unsigned int GeNNReady = 0
- unsigned int MAPNEURON

  variable attaching the name "MAPNEURON"
- unsigned int POISSONNEURON

  variable attaching the name "POISSONNEURON"
- unsigned int TRAUBMILES_FAST

  varianle attaching the name "TRAUBMILES_FAST"
- unsigned int TRAUBMILES_ALTERNATIVE

  varianle attaching the name "TRAUBMILES_ALTERNATIVE"
- unsigned int TRAUBMILES_SAFE

  varianle attaching the name "TRAUBMILES_SAFE"
- unsigned int TRAUBMILES

  varianle attaching the name "TRAUBMILES"
- unsigned int IZHIKEVICH

  variable attaching the name "IZHIKEVICH"
- unsigned int IZHIKEVICH_V

  variable attaching the name "IZHIKEVICH_V"
- unsigned int NSYNAPSE

  Variable attaching the name NSYNAPSE to predefined synapse type 0, which is a non-learning synapse.
- unsigned int NGRADSYNAPSE

  Variable attaching the name NGRADSYNAPSE to predefined synapse type 1 which is a graded synapse wrt the presynaptic voltage.
- unsigned int LEARN1SYNAPSE

  Variable attaching the name LEARN1SYNAPSE to the predefined synapse type 2 which is a learning using spike timing; uses a primitive STDP rule for learning.
- unsigned int EXPDECAY
- unsigned int IZHIKEVICH_PS

15.72.1 Detailed Description

Header file that contains the class (struct) definition of neuronModel for defining a neuron model and the class definition of NNmodel for defining a neuronal network model. Part of the code generation and generated code sections.

15.72.2 Macro Definition Documentation

15.72.2.1 #define _MODELSPEC_H_

macro for avoiding multiple inclusion during compilation

15.72.2.2 #define ALLTOALL 0

Macro attaching the label "ALLTOALL" to connectivity type 0.

15.72.2.3 #define AUTODEVICE -1

Macro attaching the label AUTODEVICE to flag -1. Used by setGPUDevice.

15.72.2.4 #define CONSTINP 1

Macro attaching the name CONSTINP (constant input) to 1.

15.72.2.5 #define CPU 0

Macro attaching the label "CPU" to flag 0.

15.72.2.6 #define DENSE 1

Macro attaching the label "DENSE" to connectivity type 1.

15.72.2.7 #define DOUBLE 1

Macro attaching the label "DOUBLE" to flag 1. Used by NNModel::setPrecision()

15.72.2.8 #define EXITSYN 0

Macro attaching the label "EXITSYN" to flag 0 (excitatory synapse)

15.72.2.9 #define FALSE 0

Macro attaching the label "FALSE" to value 0.

15.72.2.10 #define FLOAT 0

Macro attaching the label "FLOAT" to flag 0. Used by NNModel::setPrecision()

15.72.2.11 #define GLOBALG 1

Macro attaching the label "GLOBALG" to method 1 for the definition of synaptic conductances.

15.72.2.12 #define GPU 1

Macro attaching the label "GPU" to flag 1.

15.72.2.13 #define INDIVIDUALG 0

Macro attaching the label "INDIVIDUALG" to method 0 for the definition of synaptic conductances.

15.72.2.14 #define INDIVIDUALID 2

Macro attaching the label "INDIVIDUALID" to method 2 for the definition of synaptic conductances.

15.72.2.15 #define INHIBSYN 1

Macro attaching the label "INHIBSYN" to flag 1 (inhibitory synapse)

15.72.2.16 #define INPRULE 3

Macro attaching the name INPRULE (explicit dynamic input defined as a rule) to 3.

15.72.2.17 #define LEARNING 1

Macro attaching the label "LEARNING" to flag 1.

15.72.2.18 #define MATINP 2

Macro attaching the name MATINP (explicit input defined as a matrix) to 2.

15.72.2.19 #define MAXNRN 6

15.72.2.20 #define MAXPOSTSYN 2

15.72.2.21 #define NO_DELAY 1

Macro used to indicate no synapse delay for the group (only one queue slot will be generated)

15.72.2.22 #define NOINP 0

Macro attaching the name NOINP (no input) to 0.

15.72.2.23 #define NOLEARNING 0

Macro attaching the label "NOLEARNING" to flag 0.

15.72.2.24 #define RANDNINP 4

Macro attaching the name RANDNINP (Random input with Gaussian distribution, calculated real time on the device by the generated code) to 4 (TODO, not implemented yet)

15.72.2.25 #define SPARSE 2

Macro attaching the label "SPARSE" to connectivity type 2.

15.72.2.26 #define SPK_THRESH_STDP 0.0f

Macro defining the spiking threshold for the purposes of STDP.

15.72.2.27 #define SYNTYPENO 4

15.72.2.28 #define TRUE 1

Macro attaching the label "TRUE" to value 1.

15.72.3 Function Documentation

15.72.3.1 void initGeNN ( )

Method for GeNN initialisation (by preparing standard models)

15.72.4 Variable Documentation

15.72.4.1 unsigned int EXPDECAY

15.72.4.2 unsigned int GeNNReady = 0

15.72.4.3 unsigned int IZHIKEVICH

variable attaching the name "IZHIKEVICH"

15.72.4.4 unsigned int IZHIKEVICH_PS

15.72.4.5 unsigned int IZHIKEVICH_V

variable attaching the name "IZHIKEVICH_V"

15.72.4.6 unsigned int LEARN1SYNAPSE

Variable attaching the name LEARN1SYNAPSE to the predefined synapse type 2 which is a learning using spike timing; uses a primitive STDP rule for learning.

15.72.4.7 unsigned int MAPNEURON

variable attaching the name "MAPNEURON"

15.72.4.8 unsigned int NGRADSYNAPSE

Variable attaching the name NGRADSYNAPSE to predefined synapse type 1 which is a graded synapse wrt the presynaptic voltage.

15.72.4.9 unsigned int NSYNAPSE

Variable attaching the name NSYNAPSE to predefined synapse type 0, which is a non-learning synapse.

15.72.4.10 unsigned int POISSONNEURON

variable attaching the name "POISSONNEURON"

15.72.4.11 unsigned int TRAUBMILES

varianle attaching the name "TRAUBMILES"

15.72.4.12 unsigned int TRAUBMILES_ALTERNATIVE

varianle attaching the name "TRAUBMILES_ALTERNATIVE"

15.72.4.13 unsigned int TRAUBMILES_FAST

varianle attaching the name "TRAUBMILES_FAST"

15.72.4.14 unsigned int TRAUBMILES_SAFE

varianle attaching the name "TRAUBMILES_SAFE"

15.73 OneComp.cc File Reference

```
#include "modelSpec.h"
#include "modelSpec.cc"
#include "../../userproject/include/sizes.h"
```

Macros

- #define DT 1.0

Functions

- void modelDefinition (NNmodel &model)

Variables

- double exIzh_p [4]
- double exIzh_ini [2]
- double mySyn_p [3]
- double postExp [2]
- double ∗ postSynV = NULL
- float inpIzh1 = 4.0

15.73.1 Macro Definition Documentation

15.73.1.1 #define DT 1.0

15.73.2 Function Documentation

15.73.2.1 void modelDefinition (NNmodel & *model*)

15.73.3 Variable Documentation

15.73.3.1 double exIzh_ini[2]

Initial value:

```
={
        -65,
        -20
}
```

15.73.3.2 double exIzh_p[4]

Initial value:

```
={
        0.02,
        0.2,
        -65,
        6
}
```

15.73.3.3 float inpIzh1 = 4.0

15.73.3.4 double mySyn_p[3]

Initial value:

```
= {
  0.0,
  -20.0,
  1.0
}
```

15.73.3.5 double postExp[2]

Initial value:

```
={
  1.0,
  0.0
}
```

15.73.3.6 double* postSynV = NULL

15.74 OneComp_model.cc File Reference

```
#include "OneComp_CODE/runner.cc"
```

Macros

- #define _ONECOMP_MODEL_CC_

15.74.1 Macro Definition Documentation

15.74.1.1 #define _ONECOMP_MODEL_CC_

15.75 OneComp_model.h File Reference

```
#include "OneComp.cc"
```

Classes

- class neuronpop

15.76 OneComp_sim.cu File Reference

```
#include "OneComp_sim.h"
```

Functions

- int main (int argc, char ∗argv[])

15.76.1 Function Documentation

15.76.1.1 int main (int *argc*, char ∗ *argv[]*)

15.77 OneComp_sim.h File Reference

```
#include <cassert>
#include "hr_time.cpp"
#include "utils.h"
#include <cuda_runtime.h>
#include "OneComp_model.h"
#include "OneComp_model.cc"
```

Macros

- #define DBG_SIZE 10000
- #define T_REPORT_TME 100.0
- #define TOTAL_TME 5000

Variables

- float t = 0.0f
- unsigned int iT = 0
- CStopWatch timer

15.77.1 Macro Definition Documentation

15.77.1.1 #define DBG_SIZE 10000

15.77.1.2 #define T_REPORT_TME 100.0

15.77.1.3 #define TOTAL_TME 5000

15.77.2 Variable Documentation

15.77.2.1 unsigned int iT = 0

15.77.2.2 float t = 0.0f

15.77.2.3 CStopWatch timer

15.78 PoissonIzh-model.cc File Reference

```
#include "PoissonIzh-model.h"
#include "PoissonIzh_CODE/runner.cc"
#include "modelSpec.h"
#include "modelSpec.cc"
```

Macros

- #define _POISSONIZHMODEL_CC_

15.78.1 Macro Definition Documentation

15.78.1.1 #define _POISSONIZHMODEL_CC_

15.79 PoissonIzh-model.h File Reference

Classes

- class classol

  This class cpontains the methods for running the MBody1 example model.

15.80 PoissonIzh.cc File Reference

```
#include "modelSpec.h"
#include "modelSpec.cc"
#include "../../userproject/include/sizes.h"
```

Macros

- #define DT 1.0
- #define _FTYPE FLOAT
- #define scalar float
- #define SCALAR_MIN (float)FLT_MIN
- #define SCALAR_MAX (float)FLT_MAX

Functions

- void modelDefinition (NNmodel &model)

Variables

- double myPOI_p [4]
- double myPOI_ini [4]
- double exIzh_p [4]
- double exIzh_ini [2]
- double mySyn_p [3]
- double mySyn_ini [1]
- double postExp [2]
- double ∗ postSynV = NULL

15.80.1 Macro Definition Documentation

15.80.1.1 #define _FTYPE FLOAT

15.80.1.2 #define DT 1.0

15.80.1.3 #define scalar float

15.80.1.4 #define SCALAR_MAX (float)FLT_MAX

15.80.1.5 #define SCALAR_MIN (float)FLT_MIN

15.80.2 Function Documentation

15.80.2.1 void modelDefinition (NNmodel & *model*)

15.80.3 Variable Documentation

15.80.3.1 double exIzh_ini[2]

Initial value:

```
={

        -65,
        -20
}
```

15.80.3.2 double exIzh_p[4]

Initial value:

```
={

        0.02,
        0.2,
        -65,
        6
}
```

15.80.3.3 double myPOI_ini[4]

Initial value:

```
= {
 -60.0,
  0,
  -10.0
}
```

15.80.3.4 double myPOI_p[4]

Initial value:

```
= {

  1,
  2.5,
  20.0,
  -60.0
}
```

15.80.3.5 double mySyn_ini[1]

Initial value:

```
={
  0.0
}
```

15.80.3.6 double mySyn_p[3]

Initial value:

```
= {
  0.0,
  -20.0,
  1.0
}
```

15.80.3.7 double postExp[2]

Initial value:

```
={
  1.0,
  0.0
}
```

15.80.3.8 double∗ postSynV = NULL

15.81 PoissonIzh_sim.cu File Reference

```
#include "PoissonIzh_sim.h"
```

Functions

- int main (int argc, char ∗argv[ ])

15.81.1 Function Documentation

15.81.1.1 int main (int *argc*, char ∗ *argv[ ]*)

15.82 PoissonIzh_sim.h File Reference

```
#include <cassert>
#include "hr_time.cpp"
#include "utils.h"
#include <cuda_runtime.h>
#include "PoissonIzh.cc"
#include "PoissonIzh-model.h"
#include "PoissonIzh-model.cc"
```

Macros

- #define MYRAND(Y, X) Y = Y $*$ 1103515245 +12345; X= (Y $>>$ 16);
- #define INJECTCURRENT 0
- #define DBG_SIZE 1000
- #define PATTERNNO 100
- #define T_REPORT_TME 1000.0
- #define SYN_OUT_TME 2000.0
- #define TOTAL_TME 5000

Variables

- float t = 0.0f
- unsigned int iT = 0
- scalar InputBaseRate = 2e-02
- CStopWatch timer

15.82.1 Macro Definition Documentation

15.82.1.1 #define DBG_SIZE 1000

15.82.1.2 #define INJECTCURRENT 0

15.82.1.3 #define MYRAND(*Y*, *X*) Y = Y $*$ 1103515245 +12345; X= (Y $>>$ 16);

15.82.1.4 #define PATTERNNO 100

15.82.1.5 #define SYN_OUT_TME 2000.0

15.82.1.6 #define T_REPORT_TME 1000.0

15.82.1.7 #define TOTAL_TME 5000

15.82.2 Variable Documentation

15.82.2.1 scalar InputBaseRate = 2e-02

15.82.2.2 unsigned int iT = 0

15.82.2.3 float t = 0.0f

15.82.2.4 CStopWatch timer

15.83 randomGen.cc File Reference

Contains the implementation of the ISAAC random number generator class for uniformly distributed random numbers and for a standard random number generator based on the C function rand().

```
#include "randomGen.h"
```

Macros

- #define RANDOMGEN_CC

  macro for avoiding multiple inclusion during compilation

15.83.1 Detailed Description

Contains the implementation of the ISAAC random number generator class for uniformly distributed random numbers and for a standard random number generator based on the C function rand().

15.83.2 Macro Definition Documentation

15.83.2.1 #define RANDOMGEN_CC

macro for avoiding multiple inclusion during compilation

15.84 randomGen.h File Reference

header file containing the class definition for a uniform random generator based on the ISAAC random number generator

```
#include <time.h>
#include <limits.h>
#include <stdlib.h>
#include "isaac.hpp"
#include <assert.h>
```

Classes

- class randomGen

  Class randomGen which implements the ISAAC random number generator for uniformely distributed random numbers.
- class stdRG

Macros

- #define RANDOMGEN_H

  macro for avoiding multiple inclusion during compilation

15.84.1 Detailed Description

header file containing the class definition for a uniform random generator based on the ISAAC random number generator

15.84.2 Macro Definition Documentation

15.84.2.1 #define RANDOMGEN_H

macro for avoiding multiple inclusion during compilation

15.85 simpleBit.h File Reference

Contains three macros that allow simple bit manipulations on an (presumably unsigned) 32 bit integer.

```
#include <cassert>
#include <cmath>
```

Macros

- #define SIMPLEBIT_H

    macro for avoiding multiple inclusion during compilation
- #define B(x, i) ((x) & (0x80000000 >> (i)))

    Extract the bit at the specified position i from x.
- #define setB(x, i) x= ((x) | (0x80000000 >> (i)))

    Set the bit at the specified position i in x to 1.
- #define delB(x, i) x= ((x) & (∼(0x80000000 >> (i))))

    Set the bit at the specified position i in x to 0.

15.85.1 Detailed Description

Contains three macros that allow simple bit manipulations on an (presumably unsigned) 32 bit integer.

15.85.2 Macro Definition Documentation

15.85.2.1 #define B(*x*, *i*) ((x) & (0x80000000 >> (i)))

Extract the bit at the specified position i from x.

15.85.2.2 #define delB(*x*, *i*) x= ((x) & (∼(0x80000000 >> (i))))

Set the bit at the specified position i in x to 0.

15.85.2.3 #define setB(*x*, *i*) x= ((x) | (0x80000000 >> (i)))

Set the bit at the specified position i in x to 1.

15.85.2.4 #define SIMPLEBIT_H

macro for avoiding multiple inclusion during compilation

15.86 sparseUtils.cc File Reference

```
#include <cstdio>
#include <cmath>
```

Macros

- #define sparse_utils_cc

Functions

- template<class DATATYPE >
  unsigned int countEntriesAbove (DATATYPE ∗Array, int sz, DATATYPE includeAbove)
- template<class DATATYPE >
  DATATYPE getG (DATATYPE ∗wuvar, SparseProjection ∗sparseStruct, int x, int y)
- template<class DATATYPE >
  float getSparseVar (DATATYPE ∗wuvar, SparseProjection ∗sparseStruct, int x, int y)
- template<class DATATYPE >
  void setSparseConnectivityFromDense (DATATYPE ∗wuvar, int preN, int postN, DATATYPE ∗tmp_gRNPN, SparseProjection ∗sparseStruct)

- template<class DATATYPE >
void createSparseConnectivityFromDense (DATATYPE ∗wuvar, int preN, int postN, DATATYPE ∗tmp_gR↩NPN, SparseProjection ∗sparseStruct, bool runTest)
- void createPosttoPreArray (unsigned int preN, unsigned int postN, SparseProjection ∗sparseStruct)
- void strsearch (string &s, const string trg)

    !!!!find var to check if a string is used in a code (atm it is used to create post-to-pre arrays)

15.86.1 Macro Definition Documentation

15.86.1.1 #define sparse_utils_cc

15.86.2 Function Documentation

15.86.2.1 template<class DATATYPE > unsigned int countEntriesAbove (DATATYPE ∗ *Array,* int *sz,* DATATYPE *includeAbove*)

15.86.2.2 void createPosttoPreArray (unsigned int *preN,* unsigned int *postN,* SparseProjection ∗ *sparseStruct*)

15.86.2.3 template<class DATATYPE > void createSparseConnectivityFromDense (DATATYPE ∗ *wuvar,* int *preN,* int *postN,* DATATYPE ∗ *tmp_gRNPN,* SparseProjection ∗ *sparseStruct,* bool *runTest*)

15.86.2.4 template<class DATATYPE > DATATYPE getG (DATATYPE ∗ *wuvar,* SparseProjection ∗ *sparseStruct,* int *x,* int *y*)

15.86.2.5 template<class DATATYPE > float getSparseVar (DATATYPE ∗ *wuvar,* SparseProjection ∗ *sparseStruct,* int *x,* int *y*)

15.86.2.6 template<class DATATYPE > void setSparseConnectivityFromDense (DATATYPE ∗ *wuvar,* int *preN,* int *postN,* DATATYPE ∗ *tmp_gRNPN,* SparseProjection ∗ *sparseStruct*)

15.86.2.7 void strsearch (string & *s,* const string *trg*)

!!!!find var to check if a string is used in a code (atm it is used to create post-to-pre arrays)

15.87 stringutils.h File Reference

```
#include <string>
```

Macros

- #define __mathFN 56

Functions

- void substitute (string &s, const string trg, const string rep)

    Tool for substituting strings in the neuron code strings or other templates.
- void name_substitutions (string &code, string prefix, vector< string > &names, string postfix=string(""))

    This function performs a list of name substitutions for variables in code snippets.
- void value_substitutions (string &code, vector< string > &names, vector< double > &values)

    This function performs a list of value substitutions for parameters in code snippets.
- void extended_name_substitutions (string &code, string prefix, vector< string > &names, string ext, string postfix=string(""))

    This function performs a list of name substitutions for variables in code snippets where the variables have a prefix/postfix in their names.

- void extended_value_substitutions (string &code, vector< string > &names, string ext, vector< double > &values)

  This function performs a list of value substitutions for parameters in code snippets where the parameters have a prefix/postfix in their names.
- void ensureMathFunctionFtype (string &code, string type)

  This function converts code to contain only explicit single precision (float) function calls (C99 standard)
- void doFinal (string &code, unsigned int i, string type, unsigned int &state)

  This function is part of the parser that converts any floating point constant in a code snippet to a floating point constant with an explicit precision (by appending "f" or removing it).
- string ensureFtype (string oldcode, string type)

  This function implements a parser that converts any floating point constant in a code snippet to a floating point constant with an explicit precision (by appending "f" or removing it).

Variables

- string digits = string("0123456789")
- string op = string("+-∗/(<>= ,;")+string("\n")+string("\t")
- const char ∗ __dnames [__mathFN]
- const char ∗ __fnames [__mathFN]

15.87.1 Macro Definition Documentation

15.87.1.1 #define __mathFN 56

15.87.2 Function Documentation

15.87.2.1 void doFinal (string & *code*, unsigned int *i*, string *type*, unsigned int & *state*)

This function is part of the parser that converts any floating point constant in a code snippet to a floating point constant with an explicit precision (by appending "f" or removing it).

15.87.2.2 string ensureFtype (string *oldcode*, string *type*)

This function implements a parser that converts any floating point constant in a code snippet to a floating point constant with an explicit precision (by appending "f" or removing it).

15.87.2.3 void ensureMathFunctionFtype (string & *code*, string *type*)

This function converts code to contain only explicit single precision (float) function calls (C99 standard)

15.87.2.4 void extended_name_substitutions (string & *code*, string *prefix*, vector< string > & *names*, string *ext*, string *postfix* = `string("")`)

This function performs a list of name substitutions for variables in code snippets where the variables have a prefix/postfix in their names.

15.87.2.5 void extended_value_substitutions (string & *code*, vector< string > & *names*, string *ext*, vector< double > & *values*)

This function performs a list of value substitutions for parameters in code snippets where the parameters have a prefix/postfix in their names.

15.87.2.6 void name_substitutions (string & *code*, string *prefix*, vector< string > & *names*, string *postfix* = `string("")`)

This function performs a list of name substitutions for variables in code snippets.

15.87.2.7 void substitute (string & *s*, const string *trg*, const string *rep*)

Tool for substituting strings in the neuron code strings or other templates.

15.87.2.8 void value_substitutions (string & *code*, vector< string > & *names*, vector< double > & *values*)

This function performs a list of value substitutions for parameters in code snippets.

15.87.3 Variable Documentation

15.87.3.1 const char* __dnames[__mathFN]

15.87.3.2 const char* __fnames[__mathFN]

15.87.3.3 string digits = string("0123456789")

15.87.3.4 string op = string("+-*/(<>= ,;")+string("\n")+string("\t")

15.88 SynDelay.cc File Reference

```
#include "modelSpec.h"
#include "modelSpec.cc"
```

Macros

- #define DT 1.0f

Functions

- void modelDefinition (NNmodel &model)

Variables

- double input_p [4]
- double input_ini [2]
- double postExpInp [2]
- double inter_p [4]
- double inter_ini [2]
- double postExpInt [2]
- double output_p [4]
- double output_ini [2]
- double postExpOut [2]
- double synapses_p [3]
- double inputInter_ini [1]
- double inputOutput_ini [1]
- double interOutput_ini [1]
- double * postSynV = NULL
- double constInput = 4.0

15.88.1 Macro Definition Documentation

15.88.1.1 #define DT 1.0f

15.88.2 Function Documentation

15.88.2.1 void modelDefinition (NNmodel & *model*)

15.88.3 Variable Documentation

15.88.3.1 double constInput = 4.0

15.88.3.2 double input_ini[2]

Initial value:

```
= {
  -65,
  -20
}
```

15.88.3.3 double input_p[4]

Initial value:

```
= {
  0.02,
  0.2,
  -65,
  6
}
```

15.88.3.4 double inputInter_ini[1]

Initial value:

```
= {
  0.06
}
```

15.88.3.5 double inputOutput_ini[1]

Initial value:

```
= {
  0.03
}
```

15.88.3.6 double inter_ini[2]

Initial value:

```
= {
  -65,
  -20
}
```

15.88.3.7 double inter_p[4]

Initial value:

```
= {
  0.02,
  0.2,
  -65,
  6
}
```

15.88.3.8 double interOutput_ini[1]

Initial value:

```
= {
  0.03
}
```

15.88.3.9 double output_ini[2]

Initial value:

```
= {
  -65,
  -20
}
```

15.88.3.10 double output_p[4]

Initial value:

```
= {
  0.02,
  0.2,
  -65,
  6
}
```

15.88.3.11 double postExpInp[2]

Initial value:

```
= {
  1.0,
  0.0
}
```

15.88.3.12 double postExpInt[2]

Initial value:

```
= {
  1.0,
  0.0
}
```

15.88.3.13 double postExpOut[2]

Initial value:

```
= {
  1.0,
  0.0
}
```

15.88.3.14 double∗ postSynV = NULL

15.88.3.15 double synapses_p[3]

Initial value:

```
= {
  0.0,
  -30.0,
  1.0
}
```

15.89 SynDelaySim.cu File Reference

```
#include <cstdlib>
#include <iostream>
#include <fstream>
#include "hr_time.cpp"
#include "utils.h"
#include "SynDelaySim.h"
#include "SynDelay_CODE/runner.cc"
```

Macros

- #define SYNDELAYSIM_CU

Functions

- int main (int argc, char ∗argv[])

15.89.1 Macro Definition Documentation

15.89.1.1 #define SYNDELAYSIM_CU

15.89.2 Function Documentation

15.89.2.1 int main (int *argc,* char ∗ *argv[]*)

15.90 SynDelaySim.h File Reference

Classes

- class SynDelay

Macros

- #define DT 1.0f
- #define TOTAL_TIME 5000.0f
- #define REPORT_TIME 1000.0f

15.90.1 Macro Definition Documentation

15.90.1.1 #define DT 1.0f

15.90.1.2 #define REPORT_TIME 1000.0f

15.90.1.3 #define TOTAL_TIME 5000.0f

15.91 toString.h File Reference

Contains a template function for string conversion from const char∗ to C++ string.

```
#include <string>
#include <sstream>
```

Macros

- #define _TOSTRING_H_

    macro for avoiding multiple inclusion during compilation

- #define tS(X) toString(X)

    Macro providing the abbreviated syntax tS() instead of toString().

Functions

- template<class T >
  std::string toString (T t)

    template function for string conversion from const char∗ to C++ string

- template<>
  std::string toString (float t)
- template<>
  std::string toString (double t)

15.91.1 Detailed Description

Contains a template function for string conversion from const char∗ to C++ string.

15.91.2 Macro Definition Documentation

15.91.2.1 #define _TOSTRING_H_

macro for avoiding multiple inclusion during compilation

15.91.2.2 #define tS(*X*) toString(X)

Macro providing the abbreviated syntax tS() instead of toString().

15.91.3 Function Documentation

15.91.3.1 template<class T > std::string toString (T *t*)

template function for string conversion from const char∗ to C++ string

15.91.3.2 template<> std::string toString (float *t*)

15.91.3.3 template<> std::string toString (double *t*)

15.92 utils.h File Reference

This file contains standard utility functions provide within the NVIDIA CUDA software development toolkit (SDK). The remainder of the file contains a function that defines the standard neuron models.

```
#include <cstdlib>
#include <iostream>
#include <string>
#include <vector>
#include <map>
#include <memory>
#include <fstream>
#include <cmath>
#include <cuda_runtime.h>
#include "modelSpec.h"
#include "toString.h"
#include "stringutils.h"
#include "extra_neurons.h"
#include "extra_postsynapses.h"
#include "extra_weightupdates.h"
#include "numlib/simpleBit.h"
```

Classes

- class rulkovdp

  Class defining the dependent parameters of teh Rulkov map neuron.
- class expDecayDp

  Class defining the dependent parameter for exponential decay.
- class pwSTDP

  TODO This class definition may be code-generated in a future release.

Macros

- #define _UTILS_H_

  macro for avoiding multiple inclusion during compilation
- #define CHECK_CUDA_ERRORS(call)

  Macro for wrapping cuda runtime function calls and catching any errors that may be thrown.

Functions

- void gennError (string error)

  Function called upon the detection of an error. Outputs an error message and then exits.
- void writeHeader (ostream &os)

  Function to write the comment header denoting file authorship and contact details into the generated code.
- unsigned int theSize (string type)

  Tool for determining the size of variable types on the current architecture.
- void prepareStandardModels ()

  Function that defines standard neuron models.
- void preparePostSynModels ()

  Function that prepares the standard post-synaptic models, including their variables, parameters, dependent parameters and code strings.
- void prepareWeightUpdateModels ()

  Function that prepares the standard (pre) synaptic models, including their variables, parameters, dependent parameters and code strings.

Variables

- vector< neuronModel > nModels

  Global C++ vector containing all neuron model descriptions.
- vector< postSynModel > postSynModels

  Global C++ vector containing all post-synaptic update model descriptions.
- vector< weightUpdateModel > weightUpdateModels

  Global C++ vector containing all weightupdate model descriptions.

15.92.1 Detailed Description

This file contains standard utility functions provide within the NVIDIA CUDA software development toolkit (SDK). The remainder of the file contains a function that defines the standard neuron models.

15.92.2 Macro Definition Documentation

15.92.2.1 #define _UTILS_H_

macro for avoiding multiple inclusion during compilation

15.92.2.2 #define CHECK_CUDA_ERRORS(*call*)

Value:

```
{                                                                         \
  cudaError_t error = call;                                               \
  if (error != cudaSuccess)                                               \
  {                                                                       \
    fprintf(stderr, "%s: %i: cuda error %i: %s\n",                        \
            __FILE__, __LINE__, (int)error, cudaGetErrorString(error));   \
    exit(EXIT_FAILURE);                                                   \
  }                                                                       \
}
```

Macro for wrapping cuda runtime function calls and catching any errors that may be thrown.

15.92.3 Function Documentation

15.92.3.1 void gennError (string *error*)

Function called upon the detection of an error. Outputs an error message and then exits.

15.92.3.2 void preparePostSynModels ( )

Function that prepares the standard post-synaptic models, including their variables, parameters, dependent parameters and code strings.

15.92.3.3 void prepareStandardModels ( )

Function that defines standard neuron models.

The neuron models are defined and added to the C++ vector nModels that is holding all neuron model descriptions. User defined neuron models can be appended to this vector later in (a) separate function(s).

15.92.3.4 void prepareWeightUpdateModels ( )

Function that prepares the standard (pre) synaptic models, including their variables, parameters, dependent parameters and code strings.

15.92.3.5 unsigned int theSize (string *type*)

Tool for determining the size of variable types on the current architecture.

15.92.3.6 void writeHeader (ostream & *os*)

Function to write the comment header denoting file authorship and contact details into the generated code.

15.92.4 Variable Documentation

15.92.4.1 vector<neuronModel> nModels

Global C++ vector containing all neuron model descriptions.

15.92.4.2 vector<postSynModel> postSynModels

Global C++ vector containing all post-synaptic update model descriptions.

15.92.4.3 vector<weightUpdateModel> weightUpdateModels

Global C++ vector containing all weightupdate model descriptions.

15.93 VClampGA.cu File Reference

Main entry point for the GeNN project demonstrating realtime fitting of a neuron with a GA running mostly on the GPU.

```
#include "VClampGA.h"
```

Functions

- int main (int argc, char *argv[])

  This function is the entry point for running the project.

15.93.1 Detailed Description

Main entry point for the GeNN project demonstrating realtime fitting of a neuron with a GA running mostly on the GPU.

15.93.2 Function Documentation

15.93.2.1 int main (int *argc,* char * *argv[]*)

This function is the entry point for running the project.

15.94 VClampGA.h File Reference

```
#include <cassert>
#include "hr_time.cpp"
#include "utils.h"
#include <cuda_runtime.h>
#include "HHVClamp.cc"
#include "HHVClamp_CODE/runner.cc"
#include "../../../lib/include/numlib/randomGen.h"
#include "../../../lib/include/numlib/gauss.h"
#include "helper.h"
#include "GA.cc"
```

Macros

- #define RAND(Y, X) Y = Y $*$ 1103515245 +12345;X= (unsigned int)(Y $>>$ 16) & 32767

Variables

- randomGen R
- randomGauss RG
- double t = 0.0f
- unsigned int iT = 0
- CStopWatch timer

15.94.1 Macro Definition Documentation

15.94.1.1 #define RAND(*Y*, *X*) Y = Y $*$ 1103515245 +12345;X= (unsigned int)(Y $>>$ 16) & 32767

15.94.2 Variable Documentation

15.94.2.1 unsigned int iT = 0

15.94.2.2 randomGen R

15.94.2.3 randomGauss RG

15.94.2.4 double t = 0.0f

15.94.2.5 CStopWatch timer

References

[1] Eugene M Izhikevich. Simple model of spiking neurons. *IEEE Transactions on neural networks*, 14(6):1569–1572, 2003. 7, 8, 17

[2] Thomas Nowotny, Ramón Huerta, Henry DI Abarbanel, and Mikhail I Rabinovich. Self-organization in the olfactory system: one shot odor recognition in insects. *Biological cybernetics*, 93(6):436–446, 2005. 9, 10, 15, 22

[3] Nikolai F Rulkov. Modeling of spiking-bursting neural behavior using two-dimensional map. *Physical Review E*, 65(4):041922, 2002. 15

[4] R. D. Traub and R. Miles. *Neural Networks of the Hippocampus*. Cambridge University Press, New York, 1991. 9, 23, 25

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