Simple Data Input Output and Visualisation on Spinnaker - Lab Manual

1. Introduction

This manual will introduce you to the basics of live retrieval and injection of data (in the form of spikes) for PyNN scripts that are running on SpiNNaker neuromorphic hardware.

2. Installation

The PyNN 0.7 toolchain for SpiNNaker (sPyNNaker 2016.001), can be installed by following the instructions available from here:
http://spinnakermanchester.github.io/2016.001.Arbitrary/spynnaker/PyNNOnSpinnakerInstall.html

Matplotlib is marked as optional, but you will also need to install this dependency to complete some of the forthcoming exercises. The sPyNNakerExternalDevicesPlugin 2016.001 must also be installed.

To refer on how to configure your sPyNNaker installation to use your SpiNNaker machine, please refer to “Using PyNN with SpiNNaker” section of the “Running PyNN Simulations on SpiNNaker” lab manual.

3. PyNN Support

This section discusses the standard support from |PyNN related to spike injection and retrieval.

3.1 Output

The standard support for data output for a platform such as SpiNNaker, through the PyNN language, is to use the methods record(), record_v(), for declaring the need to record, and get_Spikes(), get_v(), for retrieval of the specific data.

The issue with the get functions are that they are called after run() completes, and therefore are not live, and so not able to interact with an external device running in real-time. In the current implementation of sPyNNaker, all of the data declared to be recorded via record(), record_v(), is stored on the SDRAM of the chips that the corresponding populations were placed on. By writing the data to SDRAM, the data is stored locally and therefore is guaranteed to be read at some point in the future. In the current implementation, if the memory requirements for recording cannot be met, the model will be run for less time, paused whilst the data is extracted, and then resumed. This may be repeated a number of times until the whole simulation has completed.

When used with an external simulation, it is possible to call run a number times, extracting the data between each run and passing it to an external simulation. This mode of operation will not work if the external device or simulation cannot also be paused.

3.2 Input

The standard support for data input for a platform such as SpiNNaker, through the PyNN language, is to use the neural models SpikeSourceArray and SpikeSourcePoisson. The issue with both of these models is that they are either random rate based (the spikeSourcePoisson) or have to be supplied in advance with all the spikes to be sent (SpikeSourceArray). As with the output of spikes, it is possible to change the input spikes of a SpikeSourceArray between successive calls to run(). Again, this will only work if the external device or simulation can be paused.

4. External Device Plugin Support

As stated previously, the issue with this is that PyNN 0.7 expects its **run()** method to block for the entire time of the run, and therefore it is impossible to set up a real time extraction or retrieval of data via this FrontEnd (sPyNNaker), and has no current support for live retrieval or live injection.

It is worth noting that future releases of PyNN may use the MUSIC interface to support live injection and retrieval of spikes, but the current software version of sPyNNaker only supports PyNN 0.7 and therefore there is no built in support.

To compensate for this, the sPyNNakerExternalDevicesPlugin module was created that contains support for live injection and retrieval of spikes from a running PyNN 0.7 simulation during the simulation, whilst still maintaining the real-time operation of the simulation.

4.1 Live Output

To activate live retrieval from a given population, the command

activate_live_output_for(<Population_object>**)**

is used. This informs the sPyNNaker backend to add the supporting utility model (Live packet gatherer) into the graph object (which sPyNNaker uses to represent your PyNN neural models) and an edge between your population and the associate LPG for your ports.

Other parameters for the **activate_live_output_for()** function are defined below:

Parameter	**Description**
port	The port number to receive packets from the SpiNNaker machine.
database_notify_host	The hostname for the database notification protocol; by default the localhost is used, but any external host could act as a receiver, provided it can read the file system that the database is written to.
database_notify_port_num	The port number for the database notification protocol; by default database notifications are sent to port 19998. However

	this can be changed if there is more than one listener, or a separate listener for each population.
database_ack_port_num	The port number that the database notification protocol will listen to, to receive the acknowledgement packet that the database has been read. By default this is 19999. It is unlikely that this needs to be changed.

4.2 Live Injection

To activate the live injection functionality, you need to instantiate a new neural model (called a SpikeInjector) which is located in **spynnaker_external_devices_plugin.pyNN.SpikeInjector**

The **SpikeInjector** is considered as any other neural model in PyNN, so you can build a population with a number of neurons etc in the normal way, as shown below:

```
injector_forward = Frontend.Population(
       5, ExternalDevices.SpikeInjector, [‘port’: 12367],
       label='spike_injector_forward')
```

The key parameters of the **SpikeInjector** are as follows:

Parameter	**Description**
port	The port that packets are going to be sent to on the SpiNNaker system - must be one per injector, but any port other than 17893 or 54321 can be used (these are reserved for SpiNNaker operations).
virtual_key	The base routing key that the spike injector is going to use for routing. **This parameter is optional.**

4.3 Python Live reciever

The following block of code creates a live packet receiver to receive spikes from a live simulation:

```
1   # declare python code when received spikes for a timer tick
2   def receive_spikes(label, time, neuron_ids):
3       for neuron_id in neuron_ids:
4       print “Received spike at time {} from {}-{}”.format(
5           time, label, neuron_id)
6
7   # import python live spike connection
8   from spynnaker_external_devices_plugin.pyNN.connections.\
9       spynnaker_live_spikes_connection import SpynnakerLiveSpikesConnection
10
11  # set up python live spike connection
```

```
12  live_spikes_connection = SpynnakerLiveSpikesConnection(
13      receive_labels=["receiver"])
14
15  # register python receiver with live spike connection
16  live_spikes_connection.add_receive_callback("receiver", receive_spikes)
```

1. Lines 1 to 5 creates a function that takes as its input all the neuron ids that fired at a specific time, from the population with the given label. From here, it generates a print message for each neuron.
2. Lines 7 to 9 imports the python support for live injection/live retrieval. The SpynnakerLiveSpikesConnection handles both live retrieval and live injection.
3. Lines 11 to 13 instantiates the SpynnakerLiveSpikesConnection, and informs the connection that it will receive data under the label "receiver".
4. Lines 15 to 16 informs the connection that any packets being received with the "receiver" label need to be forwarded to the function receive_spikes defined on lines 1 to 5.

This script must be run in advance of the script that sets up the simulation. The SpynnakerLiveSpikesConnection will listen for the simulation script to complete the setup operations and so starts synchronized with the simulation. It is possible to run the reception of spikes within the same script as the simulation; to do this, ensure that the above code is placed before the call to run().

If you need more than one SpynnakerLiveSpikesConnection on the same host, the connection can take an additional parameter specifying the local port to listen on for notifications from the simulation, by specifying the local_port parameter in the constructor e.g.:

```
live_spikes_connection_1 = SpynnakerLiveSpikesConnection(
    receive_labels=["receiver"], local_port=19996)
live_spikes_connection_2 = SpynnakerLiveSpikesConnection(
    receive_labels=["receiver_2"], local_port=19997)
```

Note that you must then also tell the simulation side that these ports are in use. This can be done when calling activate_live_output_for for the population by specifying the database_notify_port_num parameter e.g.

```
activate_live_output_for(receiver, database_notify_port_num=19996)
activate_live_output_for(receiver_2, database_notify_port_num=19997)
```

4.4 Python Live injector

The following block of code creates a live packet injector:

```
1  # create python injector
2  def send_spike(label, sender):
3      sender.send_spike(label, 0, send_full_keys=True)
5
6  # import python injector connection
7  from spynnaker_external_devices_plugin.pyNN.connections.\
8  spynnaker_live_spikes_connection import SpynnakerLiveSpikesConnection
9
```

```
10 # set up python injector connection
11 live_spikes_connection = SpynnakerLiveSpikesConnection(
12     send_labels=["spike_sender"])
13
14 # register python injector with injector connection
15 live_spikes_connection.add_start_callback("spike_sender", send_spike)
```

1. Lines 1 to 3 create a function that will be called when the simulation starts, allowing the synchronized sending of spikes.
2. Lines 6 to 8 imports the python support for live injection/live retrieval. The SpynnakerLiveSpikesConnection handles both live retrieval and live injection.
3. Lines 10 to 12 instantiates the SpynnakerLiveSpikesConnection, and informs the connection it will inject data via the label spike_sender.
4. Lines 14 to 15 informs the connection that when the simulation starts, to call the send_spike function defined on lines 1 to 3.

As with the live reception script, this must be called before the simulation script, or before run() in the simulation script.

4.5 C++ Implementation of SpyNNakerLiveSpikesConnection and Visualiser

The host C++ version of the Python "SpynnakerLiveSpikesConnection" and example visualiser is currently available from the following locations:

https://github.com/SpiNNakerManchester/Visualiser/archive/2016.001.zip
https://github.com/SpiNNakerManchester/Visualiser/archive/2016.001.tar.gz

This source code must be compiled before use, and depends on the pthread and sqlite libraries for the library itself, and the freeglut and opengl libraries for the example visualiser application. A Makefile exists at the top level folder which will make both the spynnaker_external_device_lib library and the example visualiser, but each can be made separately by running make in the appropriate subdirectory.

spynnaker_external_device_lib

The C++ implementation is designed to be similar to the Python implementation. A number of sample applications are provided within the spynnaker_external_device_lib/examples folder which show how the API can be used.

c_based_visualiser_framework

This contains an example visualiser for producing a spike raster plot, and is based on the spynnaker_external_device_lib.

The visualiser application can accept 4 parameters. These are defined below:

Parameter	Description
-colour_map	Path to a file containing the population labels to receive, and their associated colours. This must be specified.

-hand_shake_port	Optional port which the visualiser will listen to for database handshake (default is 19998).
-database	Optional file path to where the database is located, if needed for manual configuration.
-remote_host	Optional remote host address of the SpiNNaker board, which allows port triggering if allowed by your firewall.

7.1 colour_map file format

The colour_map file consists of a collection of lines, where each line contains 4 values separated by tabs. These values, in order are:

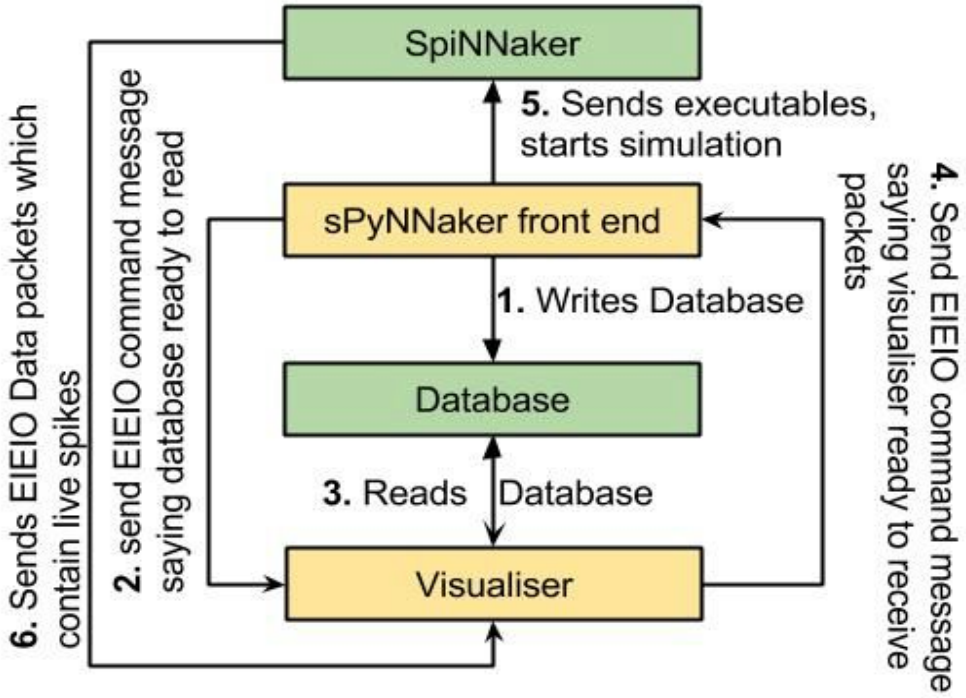
1. The population label.
2. The red colour value.
3. The green colour value.
4. The blue colour value.

An example file is shown below:

```
spike_forward	0	0	255
spike_backwards	0	255	0
```

5. Database Notification protocol

The support built behind all this software is a simple notification protocol on a database that's written during compilation time. The notification protocol is illustrated below:



The steps within the notification protocol are defined below:

1. The sPyNNaker front end writes a database that contains all the data objects generated from sPyNNaker during the compilation process.
2. The notification protocol sends a message to all the notification protocol listeners containing the path to the database to be read. The SpynnakerLiveSpikesConnection Python and C implementations are set up to receive this message.
3. These devices then read the database to determine the information required. This includes the port to listen on to receive live output spikes, the port to send like input spikes to, and the mapping between SpiNNaker routing keys and neuron ids.
4. Once these devices have read the database, they notify the sPyNNaker front end that they are ready for the simulation to start.
5. Once all devices have notified the sPyNNaker front end, the simulation begins. The sPyNNaker front end also notifies the devices when the simulation has actually started, in case it was still loading data when they became ready.
6. The SpiNNaker machine transmits live spike output packets and receives live spike input packets.

6. Caveats

To use the live injection and retrieval functionality only supports the use of the Ethernet connection, which means that there is a limited bandwidth of a maximum of approx 30 MB/s. This bandwidth is shared between both types of functionality, as well as system support for certain types of neural models, such as the SpikeSourceArray.

Furthermore, this functionality depends upon the lossy communication fabric of the SpiNNaker machine. This means that even though a neuron fires a spike you may not see it via the live retrieval functionality. If you need to ensure you receive every packet that has been transmitted, we recommend using the standard PyNN functionality.

By using this functionality, you are making your script non portable between different simulators. The activate_live_output_for(<pop_object>) and SpikeInjector models are not supported by other PyNN backends (such as Nest, Brian etc).

Finally, this functionality uses a number of additional SpiNNaker cores. Therefore a network which would just fit onto your SpiNNaker machine before would likely fail to fit on the machine when these functionalities are added in.

8. Tasks

The following tasks when completed will have hopefully taught you how to use the live injection and live retrieval functionality supported by the sPyNNakerExternalDevicesPlugin 2016.001 module.

We have assumed here that you were able to complete the tasks covered by:
Running PyNN Simulations on SpiNNaker:
http://spinnakermanchester.github.io/2016.001.AnotherFineProductFromTheNonsenseFactory/spynnaker/RunningPyNNSimulationsonSpiNNaker-LabManual.pdf

We will be building upon the result from **task 2.1 Synfire Chain [Moderate].**

Please go back to this lab manual and complete this task before attempting these if you haven't already.

It is recommended to keep each task's solution separate, as some tasks build upon previous solutions, in different ways.

Task 1.1: A simple synfire chain with a injected spike via python injector [EASY]

This task will create a synfire chain which is stimulated from a injector spike generated on host and then injected into the simulation.

1. Remove the spike source array population.
2. Replace it with the SpikeInjector population.
3. Build a python injector function.
4. Import and instantiate an SpynnakerLiveSpikesConnection connection.
5. link a start callback to the python injector function.

Task 1.2: A simple synfire chain with live streaming via the python receiver [EASY]

Go back to the original code produced by **task 2.1 Synfire Chain [Moderate]** from **Running PyNN Simulations on SpiNNaker**, and update it to stream the spikes from the If_cur_exp population.

1. remember to call the activate_live_output_for(<pop_object>)
2. Build a python receiver function that prints out the neuron ids for the population.
3. Import and instantiate an SpynnakerLiveSpikesConnection connection.
4. link a receive callback to the python receiver function.

Task 1.3: A simple synfire chain with live injection and live streaming via the python support [Easy]

Take the code from the previous 2 tasks and integrate them together to produce one that injects and streams the packets back to the terminal.

1. Remember that you can use both the recieve_labels and send_labels of the same SpynnakerLiveSpikesConnection.

Task 1.4: A simple synfire chain with live injection via python and live streaming via the c visualiser [Medium]

Take the code from the previous task and remove the python receiver code (or don't if you feel confident) and activate the visualizer to take the packets the original python receiver code processed.

1. Remember to compile the visualiser
2. Remember to generate the correct colour_map
3. Remember to remove the python receiver code (or don't if you're feeling confident).

Task 1.5: 2 Synfire chains which set each other off using python injectors whilst still using the c visualiser [Very Hard]

Take the code from the previous task and modify it so that there are two synfire populations which are tied to one injector population. Modify the receive function so that it contains some logic that fires the second neuron when the last neuron in the first synfire fires, and does the same when the last neuron for the second synfire sets off some neuron id of the first synfire chain.

1. you will need to change the number of neurons the spike injector contains.
2. You will need to change the connector from the spike injector and each synfire population.
3. You will need to modify the receive function, and add a global variable for the SpynnakerLiveSpikesConnection.
4. You'll need at least 2 SpynnakerLiveSpikesConnection and multiple activate_live_output_for(<pop_objevt>) for each population.
5. Remember that each population can only be tied to one LivePacketGatherer, so to visualise and do closed loop systems require more populations.

6. You will need to modify the c visualiser colour_map to take into account the new synfire population.

Task 1.6: 2 Synfire chains which set each other off using python injectors and live retrieval with 2 visualiser instances [Very Hard/Easy]

This task takes everything you've learnt so far and raises the level. Using the code from the previous task. Create two visualiser instances, each of which only processes one synfire population.

1. Remember all the lessons from the previous tasks.
2. Remember to change the ports on the activate_live_output_for(<pop_object>) accordingly.
3. You will need to create at least 2 SpynnakerLiveSpikesConnection's. But it might be worth starting with 3 and reducing it to two once you've got it working.
4. Remember the different colour_maps

Task 2.1: A simple synfire chain with a injected spike via c injector [EASY]

This task requires that you replace the injector from task 1.1 with a c injector.

1. Remember to import the correct header file.
2. Remember to use c syntax.

Task 2.2: A simple synfire chain with live streaming via the c receiver [EASY]

This task requires that you replace the receiver from task 1.2 with a c receiver.

1. Remember to import the correct header file.
2. Remember to use c syntax.

Task 2.3: A simple synfire chain with live injection and live streaming via the c support [Easy]

This task requires that you replace the injector and receiver from task 1.3 with a c injector and receiver.

1. Remember to import the correct header file.
2. Remember to use c syntax.

Task 2.4: A simple synfire chain with live injection via c and live streaming via the c visualiser [Medium]

This task requires that you replace the injector from task 1.4 with a c injector and to set up the visualiser.

1. Remember to import the correct header file.
2. Remember to use c syntax.
3. Remember to set up the visualiser correctly.

Task 2.5: 2 Synfire chains which set each other off using c injectors [Medium]

This task requires that you replace the injectors and receivers from task 1.5 with c injectors and receivers and to set up the visualiser.

1. Remember to import the correct header file.
2. Remember to use c syntax.

Task 2.6: 2 Synfire chains which set each other off using c injectors and live retrieval with 2 visualiser instances [Hard]

This task requires that you replace the injectors and receivers from task 1.6 with c injectors and receivers and to set up the visualiser.

1. Remember to import the correct header file.
2. Remember to use c syntax.
3. Remember to set up the visualisers correctly.

Task 3: (optional) Create some model which uses all interfaces [Very Hard]

This task is the merging of all the functionalities covered in this lab manual. Take the codes from both task 2.6 and 1.6 and integrate them together so that:

1. One injector is controlled by the c code, whilst another is done via the python interface.
2. Still uses 2 visualisers to stream the results.
3. Uses the python receive interface to count 5 firings of a given neuron id and then changes the neuron stimulated by the python injector.

Hint: remember to keep a global connection object for the python codes.

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Task Solutions:

Task 1.1: A simple synfire chain with a injected spike via python injector [EASY]

```
# imports of both spynnaker and external device plugin.
import spynnaker.pyNN as Frontend
import spynnaker_external_devices_plugin.pyNN as ExternalDevices
from spynnaker_external_devices_plugin.pyNN.connections\
       .spynnaker_live_spikes_connection import SpynnakerLiveSpikesConnection
# plotter in python
import pylab
# initial call to set up the front end (pynn requirement)
Frontend.setup(timestep=1.0, min_delay=1.0, max_delay=144.0)
# neurons per population and the length of runtime in ms for the simulation,
# as well as the expected weight each spike will contain
n_neurons = 100
run_time = 8000
weight_to_spike = 2.0
# neural parameters of the ifcur model used to respond to injected spikes.
# (cell params for a synfire chain)
cell_params_lif = {'cm': 0.25, 'i_offset': 0.0, 'tau_m': 20.0, 'tau_refrac': 2.0,
                       'tau_syn_E': 5.0, 'tau_syn_I': 5.0, 'v_reset': -70.0, 'v_rest':
-65.0,
                   'v_thresh': -50.0}
# create synfire populations (if cur exp)
pop_forward = Frontend.Population(n_neurons, Frontend.IF_curr_exp,
                                  cell_params_lif, label='pop_forward')
# Create injection populations
injector_forward = Frontend.Population(
       n_neurons, ExternalDevices.SpikeInjector,
       {'port':12365}, label='spike_injector_forward')
# Create a connection from the injector into the populations
Frontend.Projection(injector_forward, pop_forward,
                    Frontend.OneToOneConnector(weights=weight_to_spike))
# Synfire chain connections where each neuron is connected to its next neuron
# NOTE: there is no recurrent connection so that each chain stops once it
# reaches the end
loop_forward = list()
loop_backward = list()
```

```
for i in range(0, n_neurons - 1):
       loop_forward.append((i, (i + 1) % n_neurons, weight_to_spike, 3))
Frontend.Projection(pop_forward, pop_forward,
                    Frontend.FromListConnector(loop_forward))
# record spikes from the synfire chains so that we can read off valid results
# in a safe way afterwards, and verify the behavior
pop_forward.record()
# Create a sender of packets for the forward population
def send_input_forward(label, sender):
       print "Sending forward spike for neuron 0"
       sender.send_spike(label, 0)
# Set up the live connection for sending spikes
live_spikes_connection = SpynnakerLiveSpikesConnection(
       receive_labels=None, local_port=19999,
       send_labels=["spike_injector_forward"])
# Set up callbacks to occur at the start of simulation
live_spikes_connection.add_start_callback("spike_injector_forward",
                                          send_input_forward)
# Run the simulation on spiNNaker
Frontend.run(run_time)
# Retrieve spikes from the synfire chain population
spikes_forward = pop_forward.getSpikes()
# If there are spikes, plot using matplotlib
if len(spikes_forward) != 0:
       pylab.figure()
       if len(spikes_forward) != 0:
       pylab.plot([i[1] for i in spikes_forward],
                    [i[0] for i in spikes_forward], "b.")
       pylab.ylabel('neuron id')
       pylab.xlabel('Time/ms')
       pylab.title('spikes')
       pylab.show()
else:
       print "No spikes received"
# Clear data structures on spiNNaker to leave the machine in a clean state for
# future executions
Frontend.end()
```

Task 1.2: A simple synfire chain with live streaming via the python receiver [EASY]

```
# imports of both spynnaker and external device plugin.
import spynnaker.pyNN as Frontend
import spynnaker_external_devices_plugin.pyNN as ExternalDevices
from spynnaker_external_devices_plugin.pyNN.connections\
       .spynnaker_live_spikes_connection import SpynnakerLiveSpikesConnection
# plotter in python
import pylab
# initial call to set up the front end (pynn requirement)
Frontend.setup(timestep=1.0, min_delay=1.0, max_delay=144.0)
# neurons per population and the length of runtime in ms for the simulation,
# as well as the expected weight each spike will contain
n_neurons = 100
run_time = 8000
weight_to_spike = 2.0
# neural parameters of the ifcur model used to respond to injected spikes.
# (cell params for a synfire chain)
cell_params_lif = {'cm': 0.25, 'i_offset': 0.0, 'tau_m': 20.0, 'tau_refrac': 2.0,
                        'tau_syn_E': 5.0, 'tau_syn_I': 5.0, 'v_reset': -70.0, 'v_rest':
-65.0,
                   'v_thresh': -50.0}
# create synfire populations (if cur exp)
pop_forward = Frontend.Population(n_neurons, Frontend.IF_curr_exp,
                                  cell_params_lif, label='pop_forward')
# Create injection populations
injector_forward = Frontend.Population(
       1, Frontend.SpikeSourceArray,
       {'spike_times': [[0]]}, label='spike_playback_forward')
# Create a connection from the injector into the populations
Frontend.Projection(injector_forward, pop_forward,
                    Frontend.FromListConnector([(0, 0, weight_to_spike, 1)]))
# Synfire chain connections where each neuron is connected to its next neuron
# NOTE: there is no recurrent connection so that each chain stops once it
# reaches the end
loop_forward = list()
for i in range(0, n_neurons - 1):
       loop_forward.append((i, (i + 1) % n_neurons, weight_to_spike, 3))
Frontend.Projection(pop_forward, pop_forward,
                    Frontend.FromListConnector(loop_forward))
# record spikes from the synfire chains so that we can read off valid results
# in a safe way afterwards, and verify the behavior
pop_forward.record()
# Activate the sending of live spikes
ExternalDevices.activate_live_output_for(
```

```
        pop_forward, database_notify_host="localhost",
        database_notify_port_num=19996)
# Create a receiver of live spikes
def receive_spikes(label, time, neuron_ids):
        for neuron_id in neuron_ids:
        print "Received spike at time", time, "from", label, "-", neuron_id
# if not using the c visualiser, then a new spynnaker live spikes connection
# is created to define that there are python code which receives the
# outputted spikes.
live_spikes_connection = SpynnakerLiveSpikesConnection(
    receive_labels=["pop_forward"], local_port=19996, send_labels=None)
# Set up callbacks to occur when spikes are received
live_spikes_connection.add_receive_callback("pop_forward", receive_spikes)
# Run the simulation on spiNNaker
Frontend.run(run_time)
# Retrieve spikes from the synfire chain population
spikes_forward = pop_forward.getSpikes()
# If there are spikes, plot using matplotlib
if len(spikes_forward) != 0:
        pylab.figure()
        if len(spikes_forward) != 0:
        pylab.plot([i[1] for i in spikes_forward],
                    [i[0] for i in spikes_forward], "b.")
        pylab.ylabel('neuron id')
        pylab.xlabel('Time/ms')
        pylab.title('spikes')
        pylab.show()
else:
        print "No spikes received"
# Clear data structures on spiNNaker to leave the machine in a clean state for
# future executions
Frontend.end()
```

Task 1.3: A simple synfire chain with live injection and live streaming via the python support [Easy]

```
# imports of both spynnaker and external device plugin.
import spynnaker.pyNN as Frontend
import spynnaker_external_devices_plugin.pyNN as ExternalDevices
from spynnaker_external_devices_plugin.pyNN.connections\
       .spynnaker_live_spikes_connection import SpynnakerLiveSpikesConnection
# plotter in python
import pylab
# initial call to set up the front end (pynn requirement)
Frontend.setup(timestep=1.0, min_delay=1.0, max_delay=144.0)
# neurons per population and the length of runtime in ms for the simulation,
# as well as the expected weight each spike will contain
n_neurons = 100
run_time = 8000
weight_to_spike = 2.0
# neural parameters of the ifcur model used to respond to injected spikes.
# (cell params for a synfire chain)
cell_params_lif = {'cm': 0.25, 'i_offset': 0.0, 'tau_m': 20.0, 'tau_refrac': 2.0,
                        'tau_syn_E': 5.0, 'tau_syn_I': 5.0, 'v_reset': -70.0, 'v_rest':
-65.0,
                   'v_thresh': -50.0}
# create synfire populations (if cur exp)
pop_forward = Frontend.Population(n_neurons, Frontend.IF_curr_exp,
                                  cell_params_lif, label='pop_forward')
# Create injection populations
injector_forward = Frontend.Population(
       n_neurons, ExternalDevices.SpikeInjector,
       {'port':12365}, label='spike_injector_forward')
# Create a connection from the injector into the populations
Frontend.Projection(injector_forward, pop_forward,
                    Frontend.OneToOneConnector(weights=weight_to_spike))
# Synfire chain connections where each neuron is connected to its next neuron
# NOTE: there is no recurrent connection so that each chain stops once it
# reaches the end
loop_forward = list()
loop_backward = list()
for i in range(0, n_neurons - 1):
       loop_forward.append((i, (i + 1) % n_neurons, weight_to_spike, 3))
Frontend.Projection(pop_forward, pop_forward, Frontend.FromListConnector(loop_forward))
# record spikes from the synfire chains so that we can read off valid results
# in a safe way afterwards, and verify the behavior
pop_forward.record()
# Activate the sending of live spikes
```

```
ExternalDevices.activate_live_output_for(
       pop_forward, database_notify_host="localhost",
       database_notify_port_num=19996)
# Create a sender of packets for the forward population
def send_input_forward(label, sender):
    print "Sending forward spike for neuron 0"
    sender.send_spike(label, 0)
# Create a receiver of live spikes
def receive_spikes(label, time, neuron_ids):
    for neuron_id in neuron_ids:
        print "Received spike at time", time, "from", label, "-", neuron_id
# Set up the live connection for sending spikes
live_spikes_connection = SpynnakerLiveSpikesConnection(
       receive_labels=None, local_port=19999, send_labels=["spike_injector_forward"])
# Set up callbacks to occur at the start of simulation
live_spikes_connection.add_start_callback("spike_injector_forward", send_input_forward)
# if not using the c visualiser, then a new spynnaker live spikes connection
# is created to define that there are python code which receives the
# outputted spikes.
live_spikes_connection = SpynnakerLiveSpikesConnection(
       receive_labels=["pop_forward"], local_port=19996, send_labels=None)
# Set up callbacks to occur when spikes are received
live_spikes_connection.add_receive_callback("pop_forward", receive_spikes)
# Run the simulation on spiNNaker
Frontend.run(run_time)
# Retrieve spikes from the synfire chain population
spikes_forward = pop_forward.getSpikes()
# If there are spikes, plot using matplotlib
if len(spikes_forward) != 0:
       pylab.figure()
       if len(spikes_forward) != 0:
       pylab.plot([i[1] for i in spikes_forward],
                    [i[0] for i in spikes_forward], "b.")
       pylab.ylabel('neuron id')
       pylab.xlabel('Time/ms')
       pylab.title('spikes')
       pylab.show()
else:
       print "No spikes received"
# Clear data structures on spiNNaker to leave the machine in a clean state for
# future executions
Frontend.end()
```

Task 1.4: A simple synfire chain with live injection via python and live streaming via the c visualiser [Medium]

```
# imports of both spynnaker and external device plugin.
import spynnaker.pyNN as Frontend
import spynnaker_external_devices_plugin.pyNN as ExternalDevices
from spynnaker_external_devices_plugin.pyNN.connections\
       .spynnaker_live_spikes_connection import SpynnakerLiveSpikesConnection
# plotter in python
import pylab
# initial call to set up the front end (pynn requirement)
Frontend.setup(timestep=1.0, min_delay=1.0, max_delay=144.0)
# neurons per population and the length of runtime in ms for the simulation,
# as well as the expected weight each spike will contain
n_neurons = 100
run_time = 8000
weight_to_spike = 2.0
# neural parameters of the ifcur model used to respond to injected spikes.
# (cell params for a synfire chain)
cell_params_lif = {'cm': 0.25, 'i_offset': 0.0, 'tau_m': 20.0, 'tau_refrac': 2.0,
                        'tau_syn_E': 5.0, 'tau_syn_I': 5.0, 'v_reset': -70.0, 'v_rest':
-65.0,
                   'v_thresh': -50.0}
# create synfire populations (if cur exp)
pop_forward = Frontend.Population(n_neurons, Frontend.IF_curr_exp,
                                  cell_params_lif, label='pop_forward')
# Create injection populations
injector_forward = Frontend.Population(
       n_neurons, ExternalDevices.SpikeInjector,
       {'port':12365}, label='spike_injector_forward')
# Create a connection from the injector into the populations
Frontend.Projection(injector_forward, pop_forward,
                    Frontend.OneToOneConnector(weights=weight_to_spike))
# Synfire chain connections where each neuron is connected to its next neuron
# NOTE: there is no recurrent connection so that each chain stops once it
# reaches the end
loop_forward = list()
for i in range(0, n_neurons - 1):
       loop_forward.append((i, (i + 1) % n_neurons, weight_to_spike, 3))
Frontend.Projection(pop_forward, pop_forward,
                    Frontend.FromListConnector(loop_forward))
# record spikes from the synfire chains so that we can read off valid results
# in a safe way afterwards, and verify the behavior
pop_forward.record()
# Activate the sending of live spikes
ExternalDevices.activate_live_output_for(
```

```
        pop_forward, database_notify_host="localhost",
        database_notify_port_num=19996)
# Create a sender of packets for the forward population
def send_input_forward(label, sender):
    print "Sending forward spike for neuron 0"
    sender.send_spike(label, 0)
# if not using the c visualiser, then a new spynnaker live spikes connection
# is created to define that there are python code which receives the
# outputted spikes.
live_spikes_connection = SpynnakerLiveSpikesConnection(
    receive_labels=["pop_forward"], local_port=19996,
    send_labels=[“spike_injector_forward”])
# Set up callbacks to occur at the start of simulation
live_spikes_connection.add_start_callback("spike_injector_forward", send_input_forward)
# Run the simulation on spiNNaker
Frontend.run(run_time)
# Retrieve spikes from the synfire chain population
spikes_forward = pop_forward.getSpikes()
# If there are spikes, plot using matplotlib
if len(spikes_forward) != 0:
        pylab.figure()
        if len(spikes_forward) != 0:
        pylab.plot([i[1] for i in spikes_forward],
                    [i[0] for i in spikes_forward], "b.")
        pylab.ylabel('neuron id')
        pylab.xlabel('Time/ms')
        pylab.title('spikes')
        pylab.show()
else:
        print "No spikes received"
# Clear data structures on spiNNaker to leave the machine in a clean state for
# future executions
Frontend.end()
```

Visualiser stuff

command line:

```
./vis -colour-map single_synfire
```

colour map (“single_synfire”):

```
pop_forward     0     0     255
```

Task 1.5: 2 Synfire chains which set each other off using python injectors whilst still using the c visualiser [Hard]

```
# imports of both spynnaker and external device plugin.
import spynnaker.pyNN as Frontend
import spynnaker_external_devices_plugin.pyNN as ExternalDevices
from spynnaker_external_devices_plugin.pyNN.connections\
       .spynnaker_live_spikes_connection import SpynnakerLiveSpikesConnection
# plotter in python
import pylab
from threading import Condition
# initial call to set up the front end (pynn requirement)
Frontend.setup(timestep=1.0, min_delay=1.0, max_delay=144.0)
# neurons per population and the length of runtime in ms for the simulation,
# as well as the expected weight each spike will contain
n_neurons = 100
run_time = 8000
weight_to_spike = 2.0
# neural parameters of the ifcur model used to respond to injected spikes.
# (cell params for a synfire chain)
cell_params_lif = {'cm': 0.25, 'i_offset': 0.0, 'tau_m': 20.0, 'tau_refrac': 2.0,
                        'tau_syn_E': 5.0, 'tau_syn_I': 5.0, 'v_reset': -70.0, 'v_rest':
-65.0,
                   'v_thresh': -50.0}
# create synfire populations (if cur exp)
pop_forward = Frontend.Population(n_neurons, Frontend.IF_curr_exp,
                                  cell_params_lif, label='pop_forward')
pop_backward = Frontend.Population(n_neurons, Frontend.IF_curr_exp,
                                  cell_params_lif, label='pop_backward')
# create equiv of parrot populations for closed loop calculation
pop_forward_parrot = Frontend.Population(
       n_neurons, Frontend.IF_curr_exp, cell_params_lif, label='pop_forward_parrot')
pop_backward_parrot = Frontend.Population(
       n_neurons, Frontend.IF_curr_exp, cell_params_lif, label='pop_backward_parrot')
# Create injection populations
injector_forward = Frontend.Population(
       n_neurons, ExternalDevices.SpikeInjector, {"port": 19344},
       label='spike_injector_forward')
# Create a connection from the injector into the populations
Frontend.Projection(injector_forward, pop_forward,
                    Frontend.FromListConnector([0, 0, weight_to_spike, 3]))
Frontend.Projection(injector_forward, pop_backward,
                    Frontend.FromListConnector([1, 99, weight_to_spike, 3]))
# Add links to the parrot populations for closed loop calculations
Frontend.Projection(pop_forward, pop_forward_parrot,
                    Frontend.OneToOneConnector(weight_to_spike, 1))
```

```
Frontend.Projection(pop_backward, pop_backward_parrot,
                    Frontend.OneToOneConnector(weight_to_spike, 1))
# Synfire chain connections where each neuron is connected to its next neuron
# NOTE: there is no recurrent connection so that each chain stops once it
# reaches the end
loop_forward = list()
loop_backward = list()
for i in range(0, n_neurons - 1):
       loop_forward.append((i, (i + 1) % n_neurons, weight_to_spike, 3))
       loop_backward.append(((i + 1) % n_neurons, i, weight_to_spike, 3))
Frontend.Projection(pop_forward, pop_forward,
                    Frontend.FromListConnector(loop_forward))
Frontend.Projection(pop_backward, pop_backward,
                    Frontend.FromListConnector(loop_backward))
# record spikes from the synfire chains so that we can read off valid results
# in a safe way afterwards, and verify the behavior
pop_forward.record()
pop_backward.record()
# Activate the sending of live spikes
ExternalDevices.activate_live_output_for(
       pop_forward, database_notify_host="localhost",
       database_notify_port_num=19996)
ExternalDevices.activate_live_output_for(
       pop_backward, database_notify_host="localhost",
       database_notify_port_num=19996)
# Activate the sending of spikes for the python reciever
ExternalDevices.activate_live_output_for(
       pop_forward, database_notify_host="localhost",
       database_notify_port_num=19995, port=13333)
ExternalDevices.activate_live_output_for(
       pop_backward, database_notify_host="localhost",
       database_notify_port_num=19995, port=13333)
# Create a condition to avoid overlapping prints
print_condition = Condition()
# Create a sender of packets for the forward population
def send_input_forward(label, sender):
    print "Sending forward spike for neuron 0"
    sender.send_spike(label, 0)
# Create a receiver of live spikes
def receive_spikes(label, time, neuron_ids):
       for neuron_id in neuron_ids:
       print_condition.acquire()
       print "Received spike at time", time, "from", label, "-", neuron_id
       print_condition.release()
        if neuron_id == 0 and label== "pop_backward_parrot":
               live_spikes_connection.send_spike("pop_forward", 0)
        elif neuron_id == 99 and label== "pop_forward_parrot":
               live_spikes_connection.send_spike("pop_backward", 1)
```

```
# Set up the live connection for sending spikes
live_spikes_connection = SpynnakerLiveSpikesConnection(
       local_port=19996, send_labels=["spike_injector_forward"])
# Set up the live connection for sending spikes
live_spikes_connection_receiver = SpynnakerLiveSpikesConnection(
       receive_labels=["pop_forward_parrot", "pop_backward_parrot"], local_port=19995)
# Set up callbacks to occur at the start of simulation
live_spikes_connection.add_start_callback("spike_injector_forward",
                                          send_input_forward)
# Set up callbacks to occur when spikes are received
live_spikes_connection_receiver.add_receive_callback(
       "pop_forward_parrot", receive_spikes)
live_spikes_connection_receiver.add_receive_callback(
       "pop_backward_parrot", receive_spikes)
Frontend.run(run_time)

# Retrieve spikes from the synfire chain population
spikes_forward = pop_forward.getSpikes()
spikes_backward = pop_backward.getSpikes()
# If there are spikes, plot using matplotlib
if len(spikes_forward) != 0 or len(spikes_backward) != 0:
       pylab.figure()
       if len(spikes_forward) != 0:
       pylab.plot([i[1] for i in spikes_forward],
                     [i[0] for i in spikes_forward], "b.")
       if len(spikes_backward) != 0:
       pylab.plot([i[1] for i in spikes_backward],
                     [i[0] for i in spikes_backward], "r.")
       pylab.ylabel('neuron id')
       pylab.xlabel('Time/ms')
       pylab.title('spikes')
       pylab.show()
else:
       print "No spikes received"
# Clear data structures on spiNNaker to leave the machine in a clean state for
# future executions
Frontend.end()
```

Visualiser stuff

command line:

```
./vis -colour-map duel_synfire
```

colour_map (“duel_synfire”):

```
pop_forward 0     0     255
pop_backward  0     255    0
```

Task 1.6: 2 Synfire chains which set each other off using python injectors and live retrieval with 2 visualiser instances [Very Hard]

```
# imports of both spynnaker and external device plugin.
import spynnaker.pyNN as Frontend
import spynnaker_external_devices_plugin.pyNN as ExternalDevices
from spynnaker_external_devices_plugin.pyNN.connections\
       .spynnaker_live_spikes_connection import SpynnakerLiveSpikesConnection
# plotter in python
import pylab
from threading import Condition
# initial call to set up the front end (pynn requirement)
Frontend.setup(timestep=1.0, min_delay=1.0, max_delay=144.0)
# neurons per population and the length of runtime in ms for the simulation,
# as well as the expected weight each spike will contain
n_neurons = 100
run_time = 8000
weight_to_spike = 2.0
# neural parameters of the ifcur model used to respond to injected spikes.
# (cell params for a synfire chain)
cell_params_lif = {'cm': 0.25, 'i_offset': 0.0, 'tau_m': 20.0, 'tau_refrac': 2.0,
                        'tau_syn_E': 5.0, 'tau_syn_I': 5.0, 'v_reset': -70.0, 'v_rest':
-65.0,
                   'v_thresh': -50.0}
# create synfire populations (if cur exp)
pop_forward = Frontend.Population(n_neurons, Frontend.IF_curr_exp,
                                  cell_params_lif, label='pop_forward')
pop_backward = Frontend.Population(n_neurons, Frontend.IF_curr_exp,
                                  cell_params_lif, label='pop_backward')
# create equiv of parrot populations for closed loop calculation
pop_forward_parrot = Frontend.Population(
       n_neurons, Frontend.IF_curr_exp, cell_params_lif, label='pop_forward_parrot')
pop_backward_parrot = Frontend.Population(
       n_neurons, Frontend.IF_curr_exp, cell_params_lif, label='pop_backward_parrot')
# Create injection populations
injector_forward = Frontend.Population(
       n_neurons, ExternalDevices.SpikeInjector, {"port": 19344},
       label='spike_injector_forward')
# Create a connection from the injector into the populations
Frontend.Projection(injector_forward, pop_forward,
                    Frontend.FromListConnector([0, 0, weight_to_spike, 3]))
Frontend.Projection(injector_forward, pop_backward,
                    Frontend.FromListConnector([1, 99, weight_to_spike, 3]))
# Add links to the parrot populations for closed loop calculations
Frontend.Projection(pop_forward, pop_forward_parrot,
                    Frontend.OneToOneConnector(weight_to_spike, 1))
```

```
Frontend.Projection(pop_backward, pop_backward_parrot,
                    Frontend.OneToOneConnector(weight_to_spike, 1))
# Synfire chain connections where each neuron is connected to its next neuron
# NOTE: there is no recurrent connection so that each chain stops once it
# reaches the end
loop_forward = list()
loop_backward = list()
for i in range(0, n_neurons - 1):
       loop_forward.append((i, (i + 1) % n_neurons, weight_to_spike, 3))
       loop_backward.append(((i + 1) % n_neurons, i, weight_to_spike, 3))
Frontend.Projection(pop_forward, pop_forward,
                    Frontend.FromListConnector(loop_forward))
Frontend.Projection(pop_backward, pop_backward,
                    Frontend.FromListConnector(loop_backward))
# record spikes from the synfire chains so that we can read off valid results
# in a safe way afterwards, and verify the behavior
pop_forward.record()
pop_backward.record()
# Activate the sending of live spikes
ExternalDevices.activate_live_output_for(
       pop_forward, database_notify_host="localhost",
       database_notify_port_num=19996, port=19234)
ExternalDevices.activate_live_output_for(
       pop_backward, database_notify_host="localhost",
       database_notify_port_num=19994)
# Activate the sending of spikes for the python reciever
ExternalDevices.activate_live_output_for(
       pop_forward, database_notify_host="localhost",
       database_notify_port_num=19995, port=13333)
ExternalDevices.activate_live_output_for(
       pop_backward, database_notify_host="localhost",
       database_notify_port_num=19995, port=13333)
# Create a condition to avoid overlapping prints
print_condition = Condition()
# Create a sender of packets for the forward population
def send_input_forward(label, sender):
    print "Sending forward spike for neuron 0"
    sender.send_spike(label, 0)
# Create a receiver of live spikes
def receive_spikes(label, time, neuron_ids):
       for neuron_id in neuron_ids:
       print_condition.acquire()
       print "Received spike at time", time, "from", label, "-", neuron_id
       print_condition.release()
        if neuron_id == 0 and label== "pop_backward_parrot":
               live_spikes_connection.send_spike("pop_forward", 0)
        elif neuron_id == 99 and label== "pop_forward_parrot":
               live_spikes_connection.send_spike("pop_backward", 1)
```

```
# Set up the live connection for sending spikes
live_spikes_connection = SpynnakerLiveSpikesConnection(
       local_port=19996, send_labels=["spike_injector_forward"])
# Set up the live connection for sending spikes
live_spikes_connection_receiver = SpynnakerLiveSpikesConnection(
       receive_labels=["pop_forward_parrot", "pop_backward_parrot"], local_port=19995)
# Set up callbacks to occur at the start of simulation
live_spikes_connection.add_start_callback("spike_injector_forward",
                                          send_input_forward)
# Set up callbacks to occur when spikes are received
live_spikes_connection_receiver.add_receive_callback(
       "pop_forward_parrot", receive_spikes)
live_spikes_connection_receiver.add_receive_callback(
       "pop_backward_parrot", receive_spikes)
Frontend.run(run_time)

# Retrieve spikes from the synfire chain population
spikes_forward = pop_forward.getSpikes()
spikes_backward = pop_backward.getSpikes()
# If there are spikes, plot using matplotlib
if len(spikes_forward) != 0 or len(spikes_backward) != 0:
       pylab.figure()
       if len(spikes_forward) != 0:
       pylab.plot([i[1] for i in spikes_forward],
                     [i[0] for i in spikes_forward], "b.")
       if len(spikes_backward) != 0:
       pylab.plot([i[1] for i in spikes_backward],
                     [i[0] for i in spikes_backward], "r.")
       pylab.ylabel('neuron id')
       pylab.xlabel('Time/ms')
       pylab.title('spikes')
       pylab.show()
else:
       print "No spikes received"
# Clear data structures on spiNNaker to leave the machine in a clean state for
# future executions
Frontend.end()
```

Visualiser stuff

command line 1:

```
./vis -colour-map first_synfire
```

command line 2:

```
./vis -colour-map second_synfire  -hand_shake_port 19994
```

colour_map ("first_synfire"):

```
pop_forward 0      0      255
```

colour_map ("second_synfire"):

```
pop_backward       0      255    0
```

Task 2.1: A simple synfire chain with a injected spike via c injector [EASY]

[Needs filling in]

Task 2.2: A simple synfire chain with live streaming via the c receiver [EASY]

[Needs filling in]

Task 2.3: A simple synfire chain with live injection and live streaming via the c support [Easy]

[Needs filling in]

Task 2.4: A simple synfire chain with live injection via c and live streaming via the c visualiser [Medium]

[Needs filling in]

Task 2.5: 2 Synfire chains which set each other off using c injectors [Medium]

[Needs filling in]

Task 2.6: 2 Synfire chains which set each other off using c injectors and live retrieval with 2 visualiser instances [Hard]

[Needs filling in]

Task 3: (optional) Create some model which uses all interfaces [Very Hard]

[Needs filling in]