Human Brain Project

5th Annual Human Brain Project Summit

18th - 20th October 2017
Scottish Exhibition Centre (SEC), Glasgow

Hosted by the University of Glasgow
University of Glasgow
Co-funded by the European Union

Tutorial: BrainScaleS Neuromorphic Hardware

HBP Summit 2017

Eric Müller, Andreas Grübl

October 18, 2017

Kirchhoff-Institute for Physics, Heidelberg University

`https://github.com/electronicvisions/SpikeyNUC-workshop`

Introduction

Information

Wifi:

ESSIDs: `DemoBrainScaleS`, `DemoBrainScaleS1`, `DemoBrainScaleS2`

Password: `BrainScaleS`

Jupyter notebook hub:

`http://10.0.0.212`

(Pick a username, password is `BrainScaleS`)

GitHub:

`https://github.com/electronicvisions/SpikeyNUC-workshop`

Spikey school:

`http://10.0.0.212`

Analog Neuromorphic Hardware

1

observations

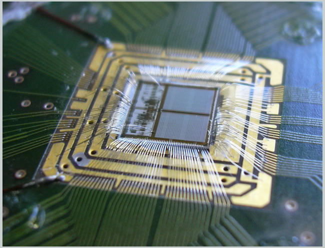
2

mathematical model

$$C\frac{\mathrm{d}V}{\mathrm{d}t} = -g_\mathrm{L}(V - E_\mathrm{L}) + I_\mathrm{syn}(t)$$

3

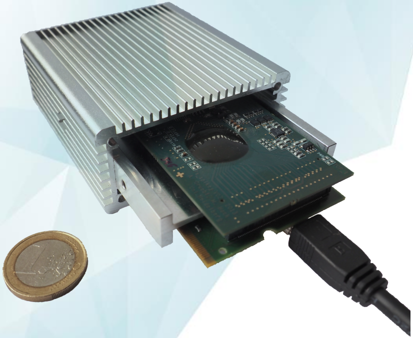
hardware realization



Roadmap

2004	2010	2015	2017	2018	2022
Spikey	**HICANN**	**20 Wafer System**	**HICANN DLS**	**HICANN DLS-SR**	**500 Wafer System**
single chip system	180 nm CMOS	4 million neurons	65 nm CMOS	O(512) neurons	500 million neurons
384 LIF neurons	512 AdEx neurons	0.9 billion synapses	32 neurons		130 billion synapses
			integrated CPU for programmable plasticity		

System overview



host ⟷ FPGA ⟷ Spikey

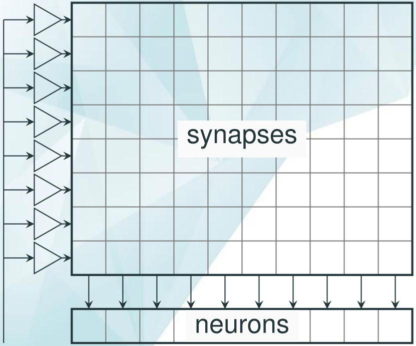
FPGA:

- Field-programmable gate array
- reconfigurable logic gates
- experiment control and communication

Spikey:

- 384 neurons, 384 $\times$ 256 synapses
- speedup of 10^4

The analog core



Synapses:

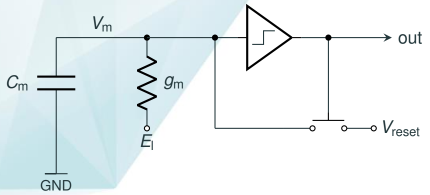
- 4 bit weights (0 . . . 15)
- STDP and STP

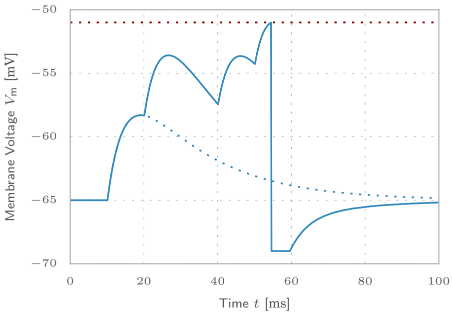
Neurons:

- Leaky-integrate-and-fire model (LIF)
- analog parameters can be configured freely

Leaky-integrate-and-fire neurons

$$C_{\mathrm{m}} \frac{\mathrm{d}\, V_{\mathrm{m}}}{\mathrm{d}\, t} = -g_{\mathrm{l}}(V_{\mathrm{m}} - E_{\mathrm{l}}) + I_{\mathrm{syn}} + I_{\mathrm{ext}}$$





Working with Spikey

PyNN API documentation

https://neuralensemble.org/docs/PyNN/0.7/api/api-0.7.html

Look out for:

- `pynn.Population`
- `pynn.Projection`
- `pynn.*Connector`

Creating (groups of) neurons

Create *populations* of neurons:

```
params = {
    "v_thresh": -60.0
    }
neurons = pynn.Population(42, pynn.IF_facets_hardware1, cellparams=params)
```

Get a list of default neuron parameters:

```
print pynn.IF_facets_hardware1.default_parameters
```

Generating stimuli

Create a stimulus from a spike train:

```
spike_train = np.arange(10.0, 101.0, 10.0)
stimulus = pynn.Population(1, pynn.SpikeSourceArray, {"spike_times": spike_train})
```

There is also a Poisson spike source:

```
poisson_params = {
    "start": 10.0,
    "duration": 100.0,
    "rate": 5.0
    }
stimulus = pynn.Population(1, pynn.SpikeSourcePoisson, poisson_params)
```

Synaptic connections

Connect all pre-synaptic to all post-synaptic neurons:

```
weight = 15 * pynn.minExcWeight()
conn = pynn.AllToAllConnector(weights=weight)
proj = pynn.Projection(pre, post, conn)
```

Specify connections in a list:

```
conn = pynn.FromListConnector([(7, 13, w, d), (42, 0, w, d)])
```

Other connectors (look at specification):

`FixedNumberPreConnector` `FixedNumberPostConnector` `FixedProbabilityConnector`

Recording observables

Spike times:

```
neurons.record()
...
spikes = neurons.getSpikes()
```

Analog membrane traces:

```
pynn.record_v(neurons[0], "")
```

- only *one* analog-to-digital converter (ADC)

→ one can record a single neuron at a time

Tasks

Task 1: a single neuron

- create a spike source
- create a single LIF neuron
- connect these two populations with maximum weight
- record spikes and the membrane trace of the stimulated neuron

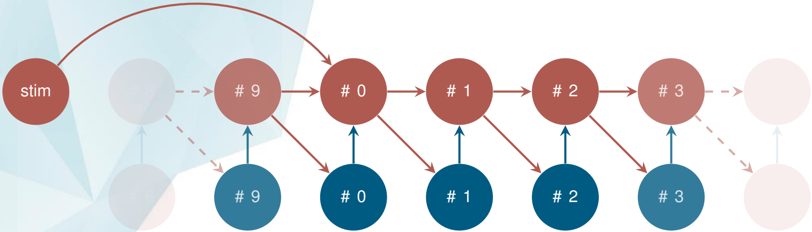
1. vary the synaptic weight and observe the membrane trace
2. play around with the inter-spike interval of the stimulating spike train
3. observe how the PSPs stack up and eventually cause the neuron to fire

Task 2: passing spikes

- extend the network by adding another neuron
- record and plot the spikes of both neurons

1. think about different possibilities of creating and connecting the neurons
2. check that the stimulation is passed to the second neuron

Task 3: a closed synfire chain



- create ten excitatory and ten inhibitory **populations** of neurons and connect them as depicted
- create a transient stimulus to the zeroth excitatory population
- record and plot the spikes of the neurons
- record the membrane potential of a neuron of your choice

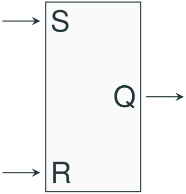
Task 3: a closed synfire chain

1. evaluate the stability of the chain by tweaking the weight parameters
2. what happens if you disconnect the inhibitory neurons?
3. modify the chain length

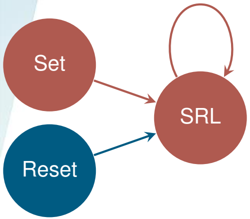
Task 4: a neural SR latch

Think about how to create a simple SR latch (set/reset latch).

S	R	Q
0	0	no change
0	1	Q = 0, reset state
1	0	Q = 1, set state
1	1	undefined



Task 4: a neural SR latch



- create a population of latch neurons and project them onto themselves
- create a transient excitatory and a transient inhibitory stimulus to the latch neurons
- set the stimuli such that the latch is switched on and off consecutively
- record and plot the spikes of the neurons
- record the membrane potential of a latch neuron