BrainScaleS Workshop

4th HBP School

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Introduction

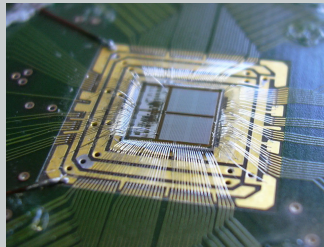# Analog Neuromorphic Hardware

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

Spikey

- single chip system
- 384 LIF neurons

2010

HICANN

- 180 nm CMOS
- 512 AdEx neurons

2015

20 Wafer System

- 4 million neurons
- 0.9 billion synapses

2017

HICANN DLS

- 65 nm CMOS
- PPU: integrated processing unit for advanced plasticity

2022

500 Wafer System

- 500 million neurons
- 130 billion synapses

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.getMinExcWeight()
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()
```
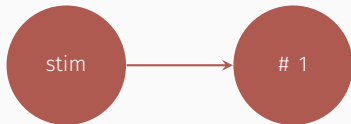
Analog membrane traces:

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

- only *one* analog-to-digital converter (ADC)
- → one can record a single neuron at a time

Tasks

- 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

- 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
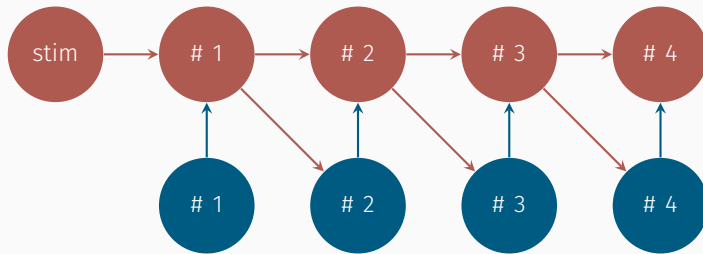2. check that the stimulation is passed to the second neuron

stim → # 1 → # 2

- 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

- Lorem ipsum

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