BrainScaleS-2 Software
Use Cases, Access and Integration into EBRAINS

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BrainScaleS-2

- Physical model, mixed-signal implementation
- AdEx neurons, short-term plasticity
- Structured neurons & nonlinear effects of dendrites
- Accelerated model dynamics ($\sim 10^3$)
- Support for online updates of neuron parameters, synapses (and network topology)
- Programmable plasticity
- Non-spiking operation mode (analog MAC)
BrainScaleS-2 Systems

- **Setup types**
  - “Lab” — local and remote usage
  - Mobile — embedded operation
  - Multi-chip / “Frankenstein Wafer”

  → (Network-attached) Accelerators

- **Software stack providing varying abstraction levels**
  - PyNN, hxtorch.snn, ...
  - hardware abstraction layers
    (configuration and control)
  - communication

  → APIs for modeling, commissioning and development
Experiments? Configuration & “Protocol”

- Synapses, Neurons
- I/O (On-chip/off-chip)
- Observables, Controllables
- Controllers:
  - Host computer
  - FPGA
  - Embedded processors
Experiments? Configuration & “Protocol”

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Configuration & Protocol

- Experiment Description → Initial Configuration
  - Topology
    - Placement & Routing
  - Cell Parameterization
    - Parameter Translation (Calibration)
  - Plasticity Kernels

- Experiment Description → Experiment Protocol
  - Off-chip I/O (input/stimulus, output/recording)
  - On-chip I/O (Poisson spike sources, …)
  - Other dynamics (e.g., via embedded processors)
Experiment “Execution”

- Initial Configuration
- Execution of the ‘Experiment Protocol’
- Host-centric view here but multiple controllers do co-exist
Time Sharing — Experiment Scheduling

Regular scheduling via SLURM:
Exp. 1
Exp. 2
Exp. 3

Hardware idle despite work

Micro-Scheduling via quiggeldy:
Exp. 1
Exp. 2
Exp. 3
quiggeldy (hardware setup)

Commissioner’s View on Structured Neurons

```python
coord = halco.AtomicNeuronOnLogicalNeuron  # relative coordinate
row = halco.NeuronRowOnLogicalNeuron  # 0, 1
column = halco.NeuronColumnOnLogicalNeuron  # 0, 1, ..., 127

morphology = lola.Morphology()
# create compartments: main branch
morphology.create_compartment([coord(0, 0), coord(1, 0)])
morphology.create_compartment([coord(2, 0), coord(3, 0), coord(3, 1)])
# create compartments: sub branches
for row_coord in [0, 1]:
    for column_coord in [4, 6]:
        morphology.create_compartment([coord(column_coord, row_coord),
                                       coord(column_coord + 1, row_coord)])

# enable conductance to shared line
morphology.connect_resistor_to_soma(coord(1, 0))
for row_coord in [0, 1]:
    for column_coord in [3, 5]:
        morphology.connect_resistor_to_soma(coord(column_coord, row_coord))

# direct connection to shared line
morphology.connect_to_soma(coord(2, 0))
for row_coord in [0, 1]:
    for column_coord in [4, 6]:
        morphology.connect_to_soma(coord(column_coord, row_coord))

# connect somatic shared line
morphology.connect_soma_line(start=column(1), end=column(2), row=row(0))
for row_coord in [row(0), row(1)]:
    morphology.connect_soma_line(column(3), column(4), row_coordinate)
morphology.connect_soma_line(column(5), column(6), row_coordinate)

neuron_coordinate, logical_neuron = morphology.done()
```

A

B

C

[Work by Raphael Stock and Jakob Kaiser (2021, 2022)]
class HomeostaticSynapse(pynn.PlasticityRule,
    pynn.standardmodels.synapses.StaticSynapse):
    # ...
    def generate_kernel(self) -> str:
        return textwrap.dedent(""
            // C++ ...
            template <size_t N>
            void PLASTICITY_RULE_KERNEL(
                std::array<SynapseArrayViewHandle, N>& synapses,
                std::array<PPUOnDLS, N> synrams) {
                /* embedded processors have access to a set of
                * observables and controllables ... */
            }
            ")"".format(...)

    # ...
    synapse_type = HomeostaticSynapse(timer=timer, target=60, weight=0)
    pynn.Projection(pop_input, nrn, pynn.AllToAllConnector(),
        synapse_type=synapse_type)

    # ...

[Work by Philipp Spilger (2021, 2022)]
from hxtorch import snn

class Model(torch.nn.Module):
    def __init__(...):
        # Create Instance
        instance = snn.Instance(mock=mock)
        # Add HXModules
        self.linear_h = snn.HXSynapse(
            in_features, out_features, instance=self.instance, ...)
        self.lif_h = snn.HXNeuron(
            hidden_size, instance=self.instance, ...)
        self.linear_o = snn.HXSynapse(
            hidden_size, output_size, instance=self.instance, ...)
        self.li_readout = snn.HXReadoutNeuron(
            output_size, instance=self.instance, ...)

    def forward(self, input):
        current_i = self.linear_h(input)
        spikes_h = self.lif_h(current_i)
        current_o = self.linear(spikes_h)
        membrane_out = self.li_readout(current_o)
        # Run on Hardware
        snn.run(self.instance, runtime=...)
        return membrane_out

    # Execute
    model = Model(...)
    inputs = snn.HXTensorHandle(spikes)
    membrane = model(inputs)

- PyTorch-like description of SNNs
- Handles for tensors (i.e. not using XLA Tensors)
- Same API for software simulation & hardware emulation
- Maintains auto-differentiation functionality
- Flexibility in backward pass by assigning autograd functions to hardware operations
- Future: Integration into Norse?
Platform Access & Operation

- We leverage **EBRAINS** central services!
  - AAA, WebIDE hosting (JupyterLab), storage, quota/job reporting, …, user support
- Access to BrainScaleS via EBRAINS
  (+ SpiNNaker, as well as many other software packages)
- Dedicated BrainScaleS-2 Experiment Service for interactive experimenting
  ($O(10 \text{ Hz})$, limited by specifics of the experiment and I/O)
BSS-2 software now integrated into the EBRAINS Software Distribution…

…enables a native and “natural” integration of BrainScaleS-2 into EBRAINS ‘Collabs’

- We convinced EBRAINS to adopt spack as a package manager :o)
- Future: Deployments on EBRAINS HPC sites → multi-site workflows
Disclaimer

- Our software deployment on EBRAINS is somewhat ‘stable’… we expect more recent software in a couple of weeks (and more frequent releases afterwards).
- In addition, there will be a ‘testing’ deployment providing a continuous stream of newer software versions (approx. weekly).
- Many features presented here are still work in progress (MC neurons, programmable plasticity, SNN support in hxtorch), will require some more time to stabilize and materialize in a release.
Conclusion

- We work towards multiple goals:
  - Commissioning of recent BSS-2 hardware features, e.g., structured neurons and multi-chip systems
  - Programmable plasticity (code generation for the embedded processors)
  - Providing ML-friendly interfaces
  - Efficiency (fast reconfiguration) in high-level use cases
  - Parameter Translation (SI hardware & bio units) and integration of ‘Calibration’
  - We continue to improve system robustness
  ⇒ Transition towards a flatter learning curve for users (deployment, operation & usage)

- Executable Documentation incl. Examples
- Now: BrainScaleS-2 interactive tutorial → PyNN.brainscales2
  - Link to ‘Collab’ should have been sent via mail
  - https://wiki.ebrains.eu/bin/view/Collabs/nmc-test-SOMEUSERNAME/
A scalable approach to modeling on accelerated neuromorphic hardware

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