INRC Workshop, February 2021

Lava Implementation of Biologically Plausible Deep Learning with Structured Neurons

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Learning with local information

In general:

$$\Delta w = \eta \left(r_{\mathrm{tgt}} - r_{\mathrm{nrn}} \right) r_{\mathrm{in}}$$

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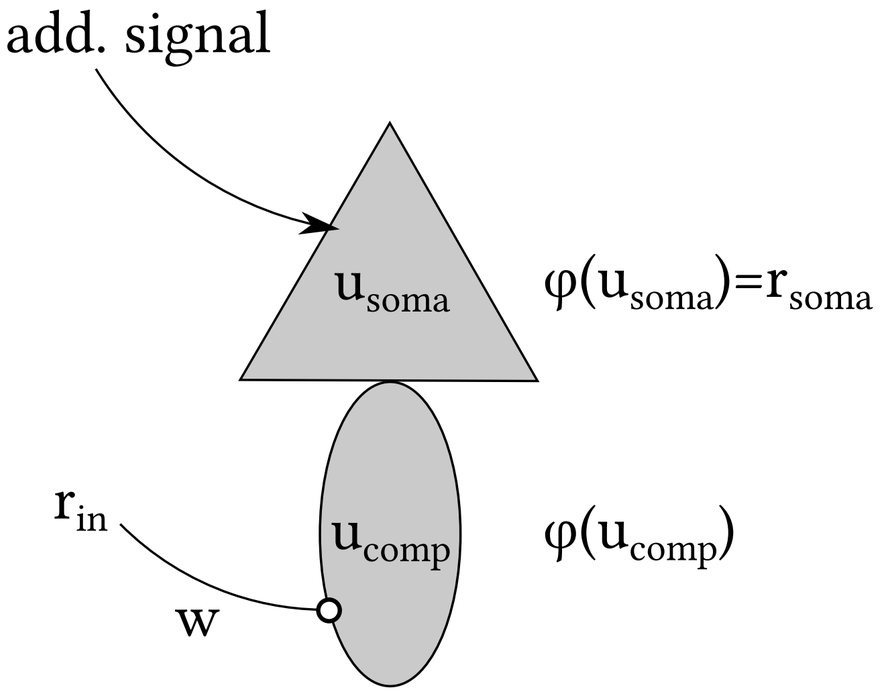
For multicompartment-neurons:

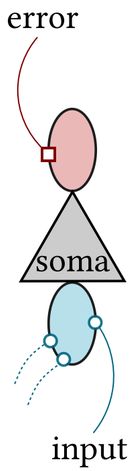
$$r_{\text{tgt}} = r_{\text{soma}}$$

$$r_{\text{nrn}} = \varphi(u_{\text{comp}})$$



(Urbanczik, Senn 2014)

Microcircuits perform error backpropagation



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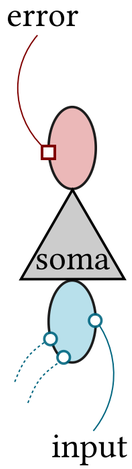

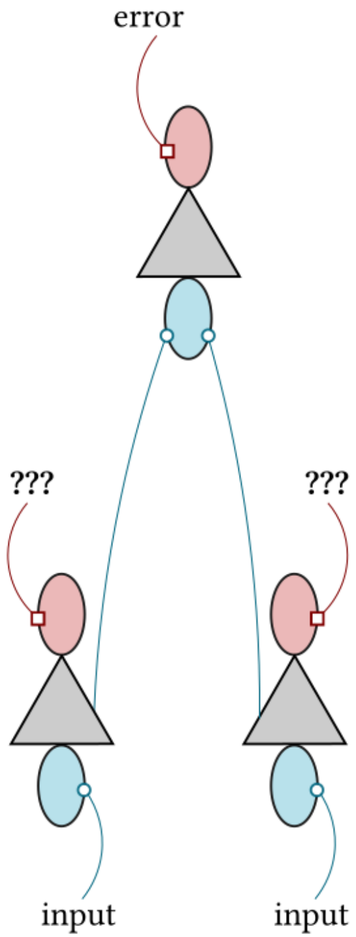

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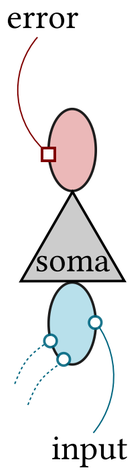

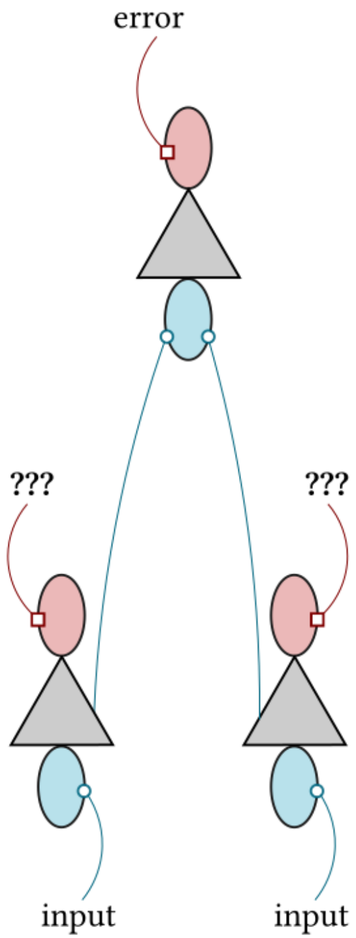

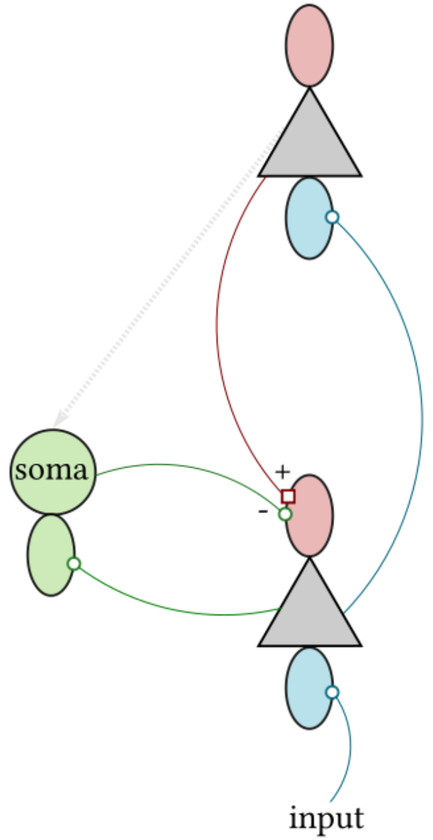

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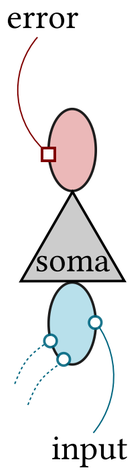
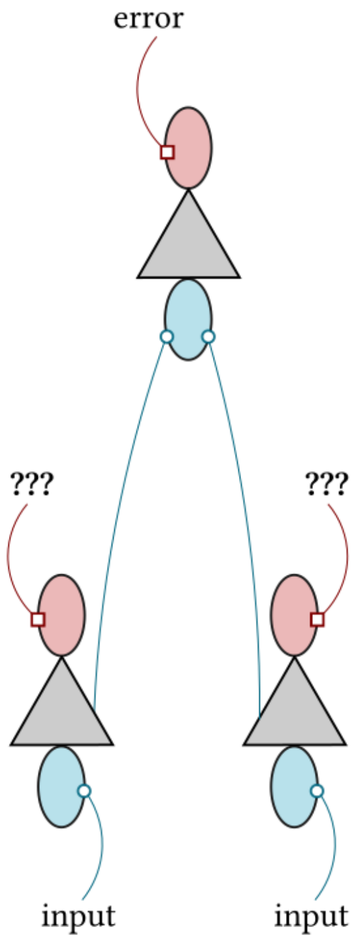
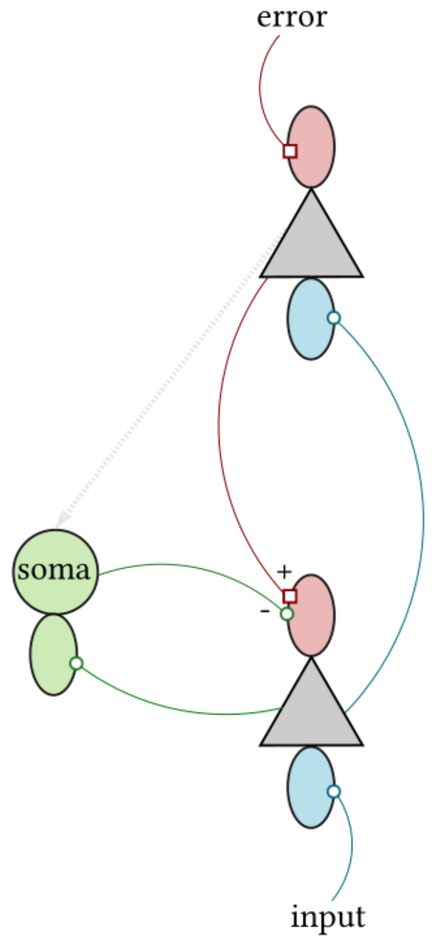
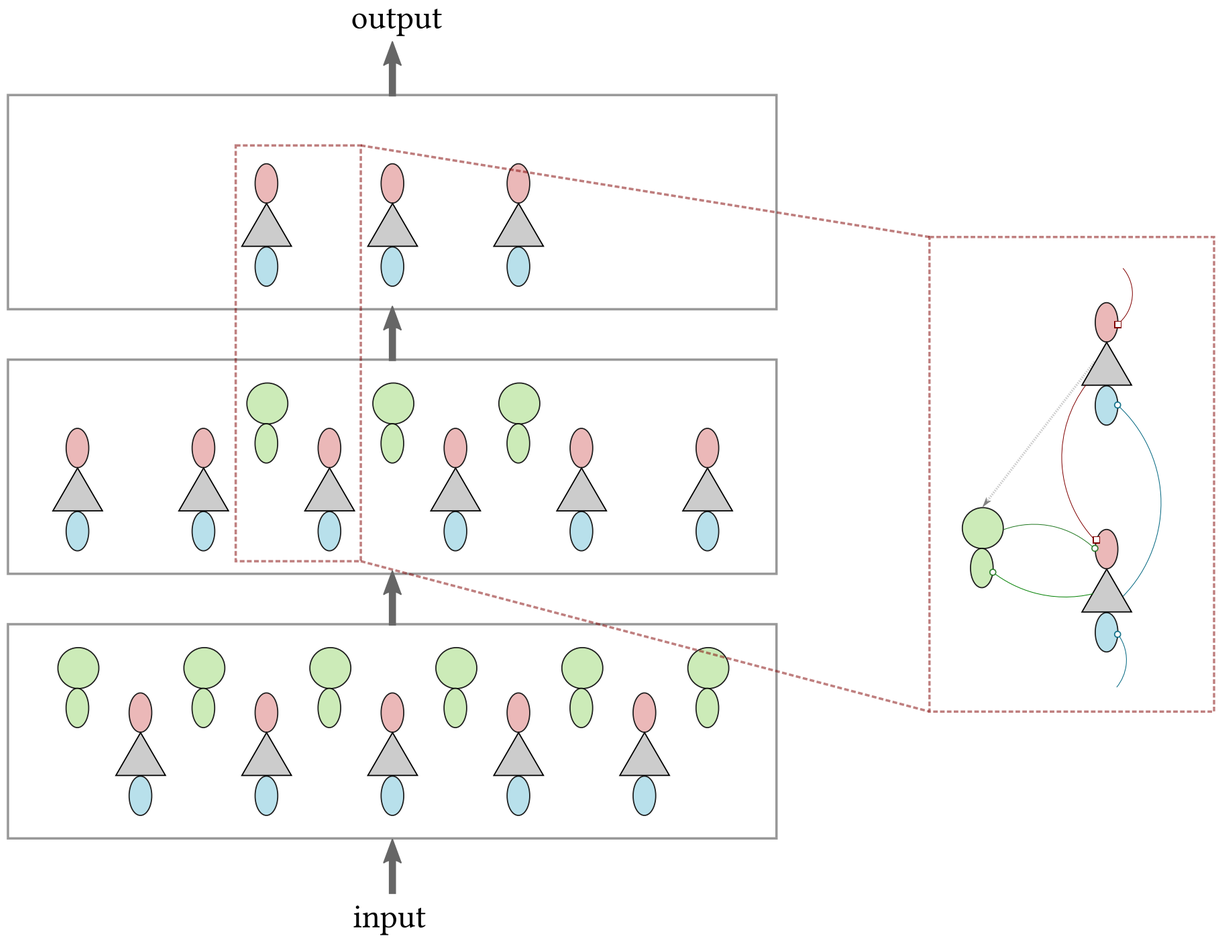
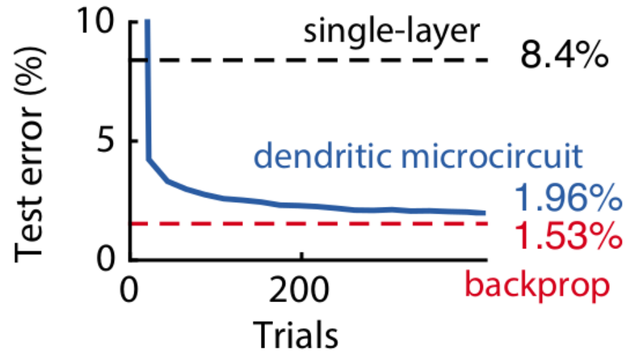


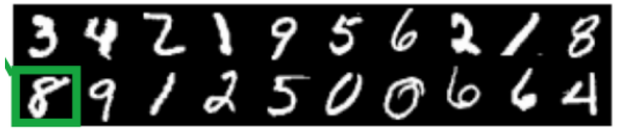




Deep network built out of microcircuits (Sacramento 2018)







MNIST handwritten digit images

Challenges for implementation on neuromorphic hardware

- **Neuron model:** multicompartment-neurons

- **Synaptic plasticity:** using multiple post-synaptic variables

- **Communication:** rate-based

➔ **Increased flexibility of new generation Loihi chips necessary**

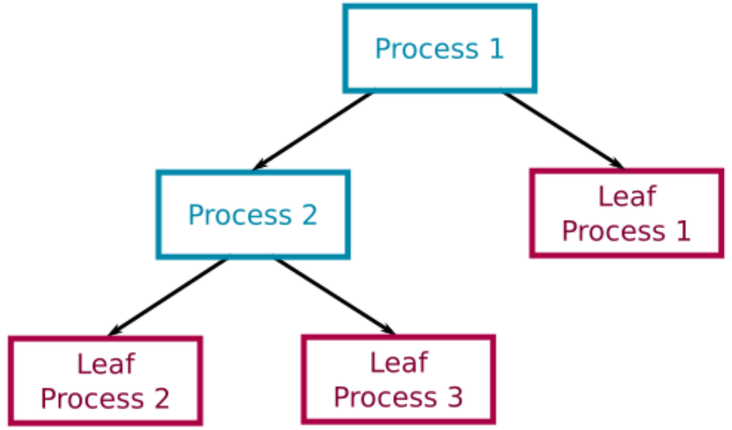
Recap: What you need to know about Lava

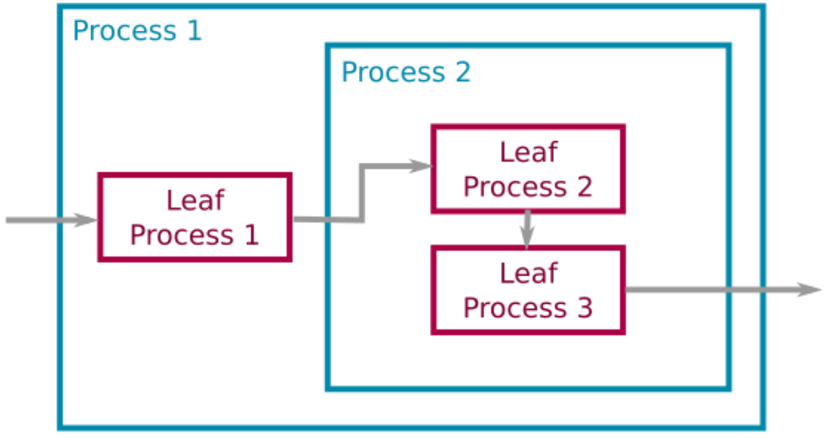
- Everything is a process

- Hierarchical structure of processes

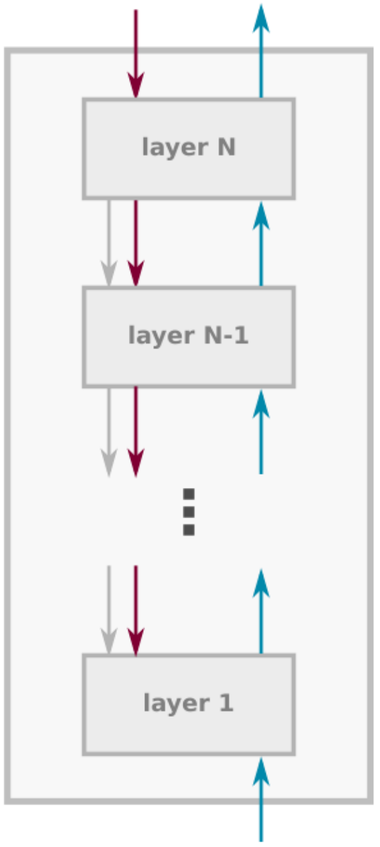
- Leaf processes compute dynamics

- Other processes connect leaf processes





Hierarchical network of microcircuits in Lava



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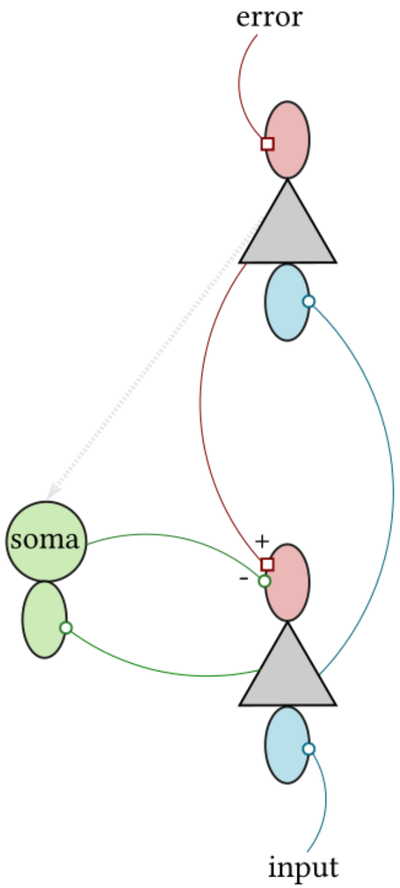
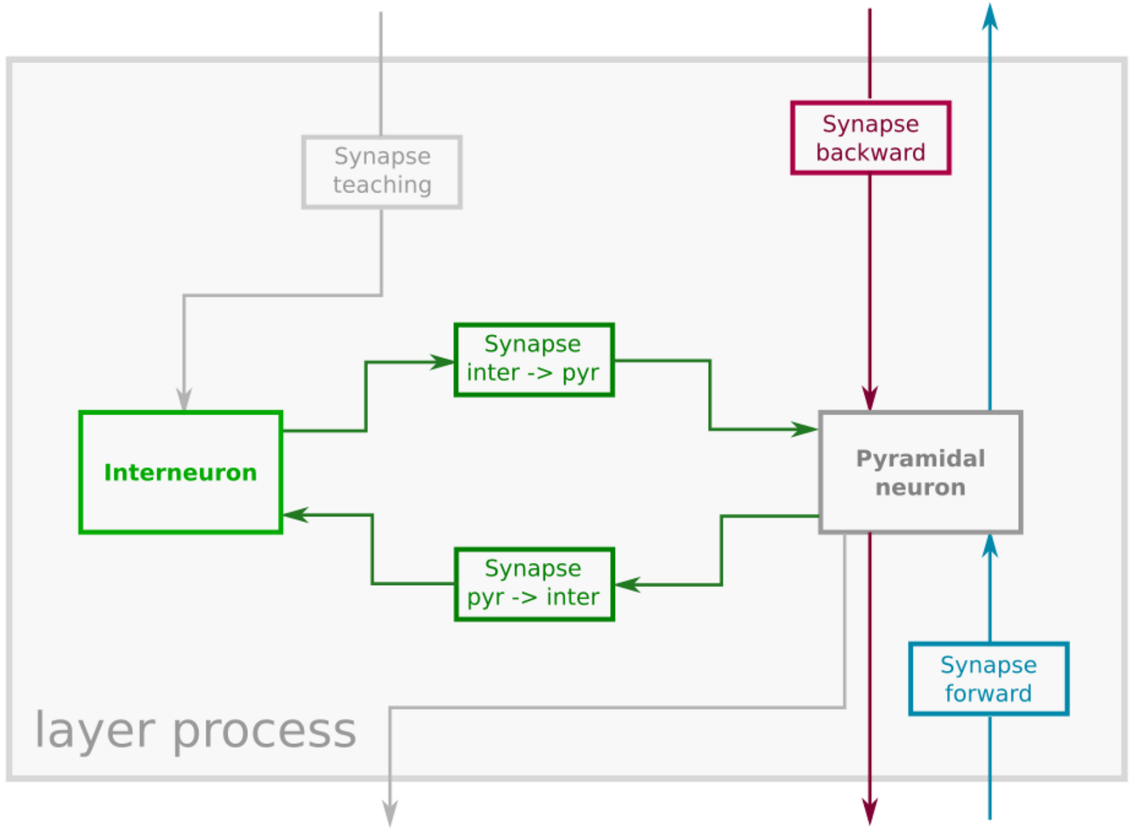
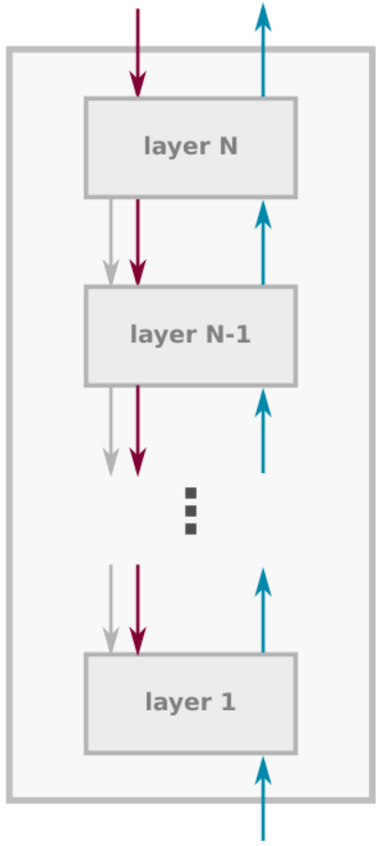




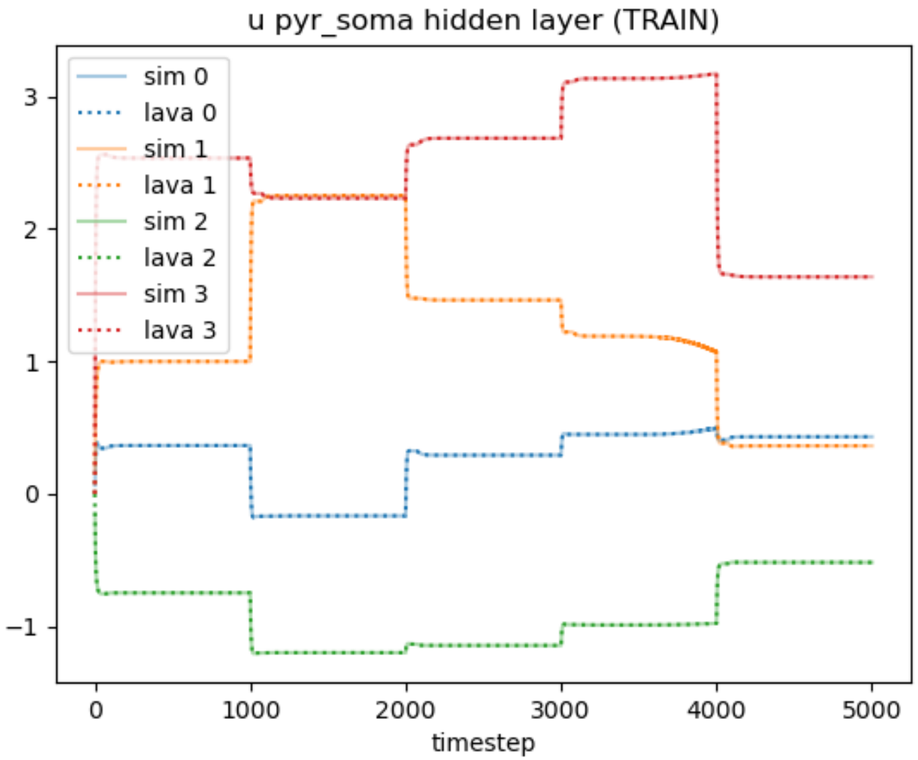


Baseline implementation: first results

- On simulation backend

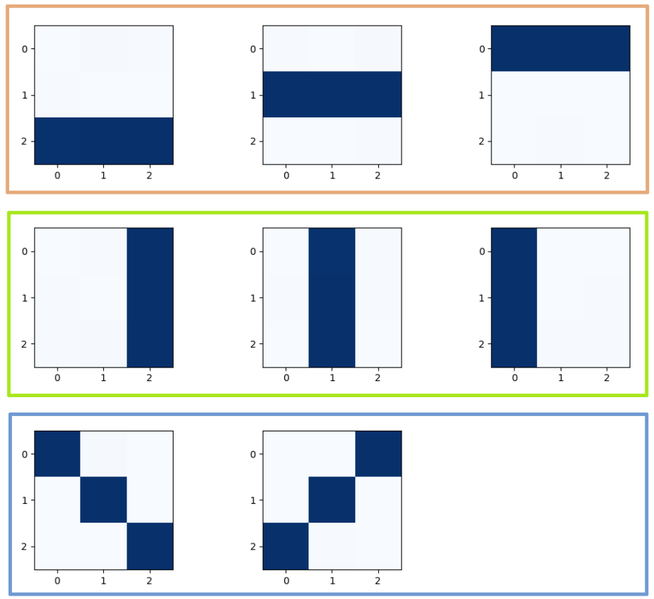
- Removes several restrictions of chip: e.g. floating-point variables, parameter ranges, ...

- Starting point for systematic adaptation to chip spec

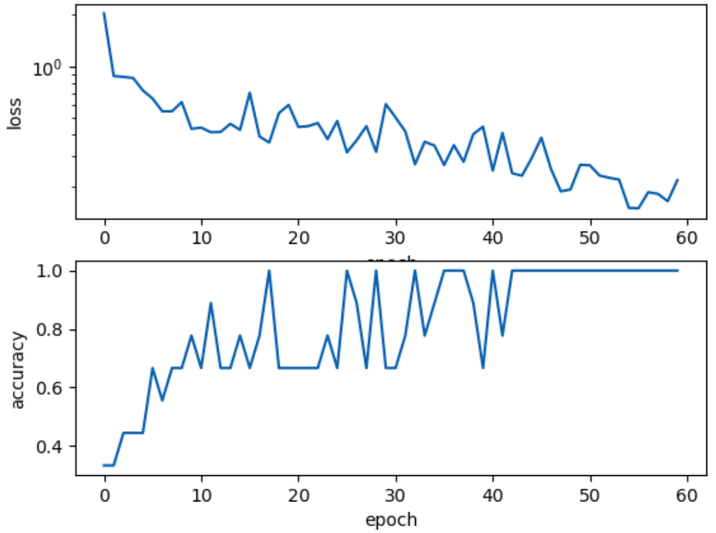


Comparison between numpy simulation and lava implementation

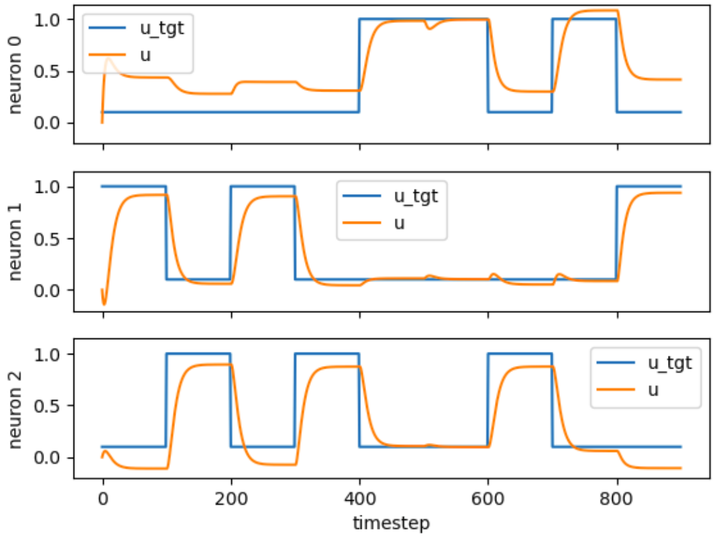
Baseline implementation: small classification task



Dataset with 3 classes:
horizontal, vertical, diagonal



Validation loss and accuracy
during training



One-hot encoding
in ouptut layer

Adapting to the neuromorphic substrate

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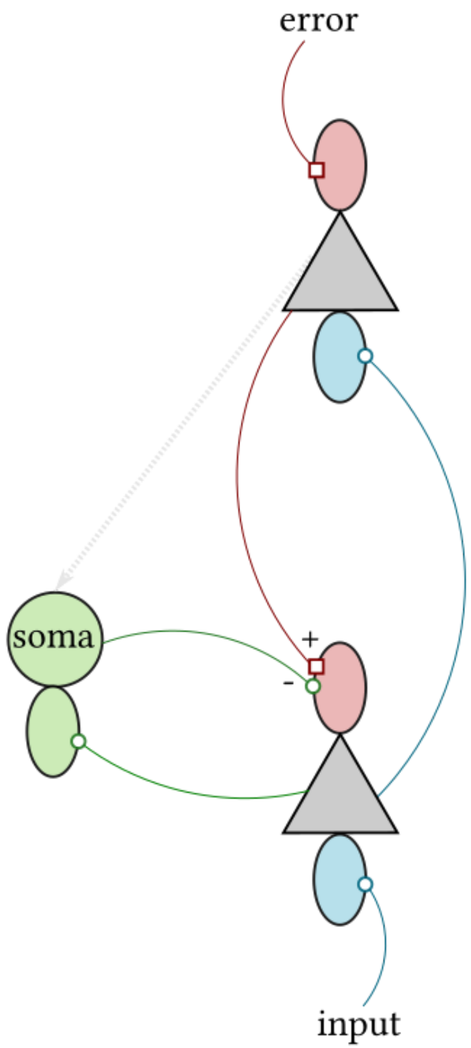
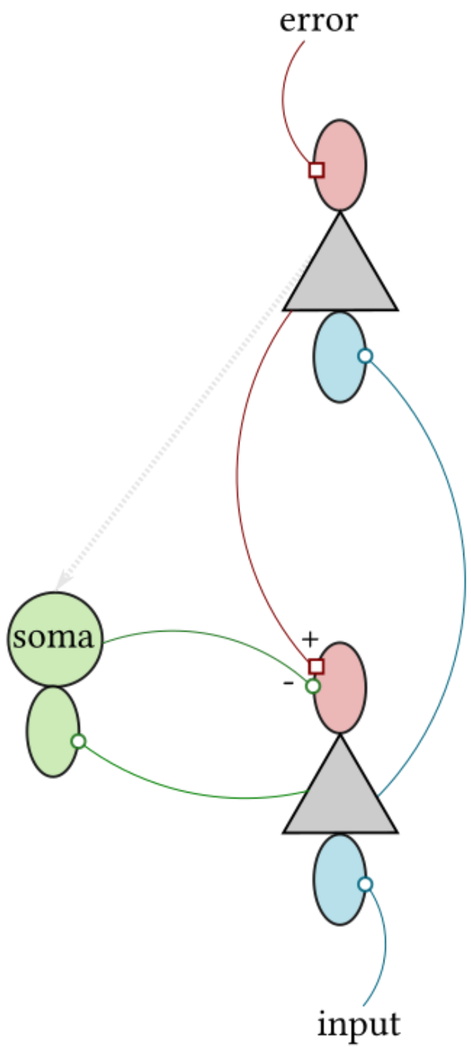
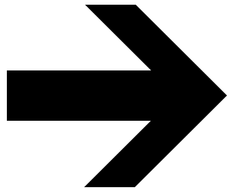
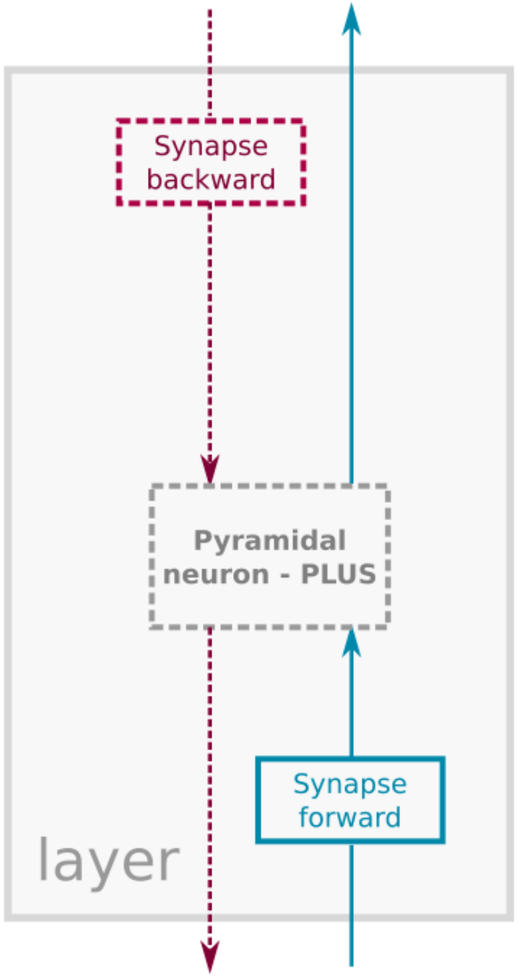


Adapting to the neuromorphic substrate







Summary:

- Dendritic microcircuits implements bio-plausible backprop

- New generation of Loihi chips will better support microcircuits

- Formulation of microcircuits within the Lava framework

Outlook:

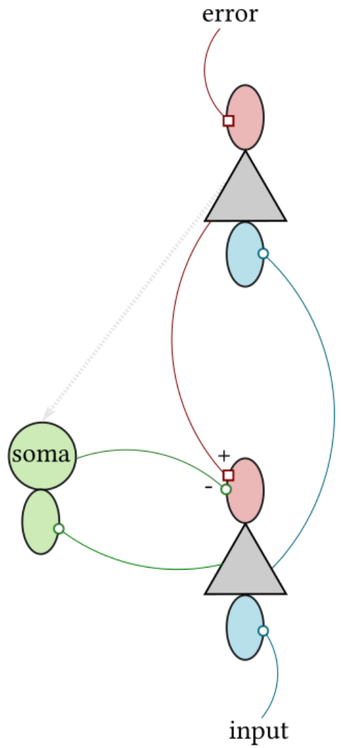
- Adapt model to neuromorphic substrate

- Optimize model for performance on neuromorphic substrate

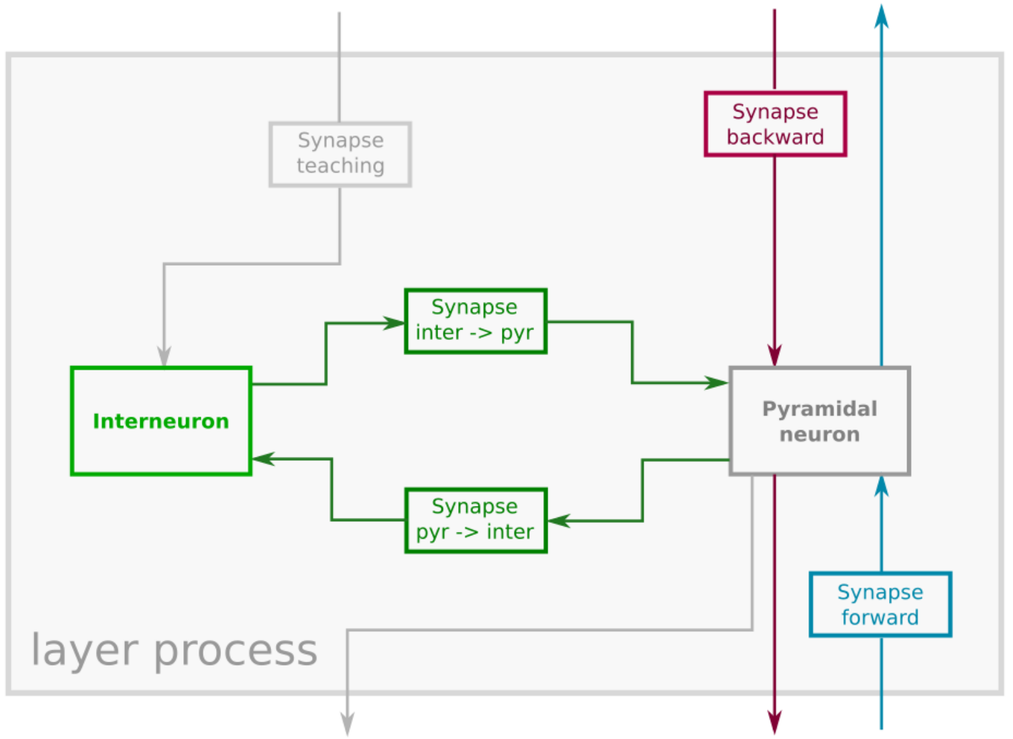
Q&A at the end of live-session

Feb. 10th: 11:45-12:30

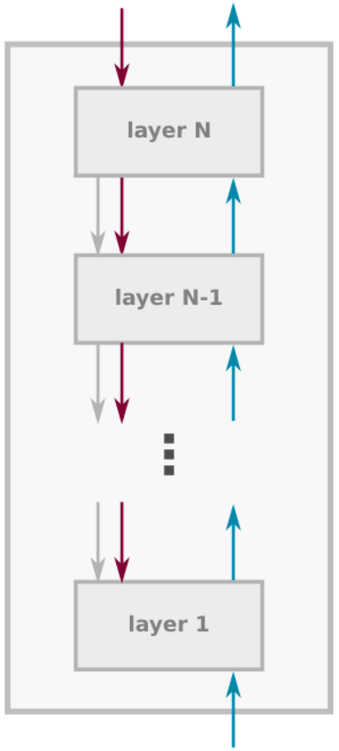
Bio-Plausible Deep Learning with Structured Neurons in Lava



Microcircuit model



Layer process



Network process