Bartlomiej Borzyszkowski
CERN OpenLab (CMS Experiment), Intel AI Products Group

bartek_borzyszkowski@wp.pl
github.com/borzyszkowski/SNN-CMS

15 August 2019
Neuromorphic Computing
In High Energy Physics
Artificial Neural Networks

- spectacular successes of AI in recent years
- only marginal similarities between brain-like computation
- neurons operate on a common clock cycle
Spiking Neural Networks

• inspired by information processing in biology
• asynchronous binary signals depending on time
• low power consumption, fast inference, event-driven processing

Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5090003/
Intel Loihi

- Dedicated neuromorphic hardware
- Supports training and inference of SNNs
- Efficient asynchronous computing

state-of-the-art in neuromorphic hardware

Presented by Intel Labs in 2018

Selected Benchmarks (the keywords spotting task)

Loihi vs. Intel Movidius Speed

Power Consumption

Results
Utilization of SNNs at CERN

• data processing at the High-Luminosity LHC
• signal-to-noise discrimination
• characterization of particles based on the records

Increased precision of upgraded detectors

Source: http://hilumihc.web.cern.ch/
MNIST classification

- **SNN Simulation:**
  2.79% error
  (Nengo-DL simulation with synapse)

- **SNN Loihi - hardware:**
  2.00% error
  (deployed on the chip)

Trained with Nengo, optimized with synaptic filters.

Source: [https://www.nengo.ai/nengo-loihi/examples/mnist_convnet.html](https://www.nengo.ai/nengo-loihi/examples/mnist_convnet.html)
Jet Tagging – HLS4ML at CMS Experiment

• 16 features (detector input)
• 5 particles (classes):
  - gluon (g)
  - quark (q)
  - W boson (w)
  - Z boson (z)
  - top quark (t)

Current results with DNNs:

Jet Tagging – Spiking Neural Networks

DNN model used:

- 16 inputs
- 64 nodes
  - activation: ReLU
- 32 nodes
  - activation: ReLU
- 32 nodes
  - activation: ReLU
- 5 outputs
  - activation: SoftMax

DNN accuracy:

75.20%

SNN accuracy:

57.43%

Trainend with Nengo-DL

70.98%

After optimizing with synaptic filters in Nengo-DL.

Previously simulated in SNNToolbox with Brian2 and INISim.

github.com/borzyszkowski/SNN-CMS
Opportunities

• Triggering systems at CERN
• Event-based sensors
• Anomaly detection in time series
• Exploration of Spiking Autoencoders
• ...

Thank you for your attention!

Project supervised by:

• Maurizio Pierini
• Jean-Roch Vlimant

CMS Experiment