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github.com/borzyszkowski/SNN-CMS

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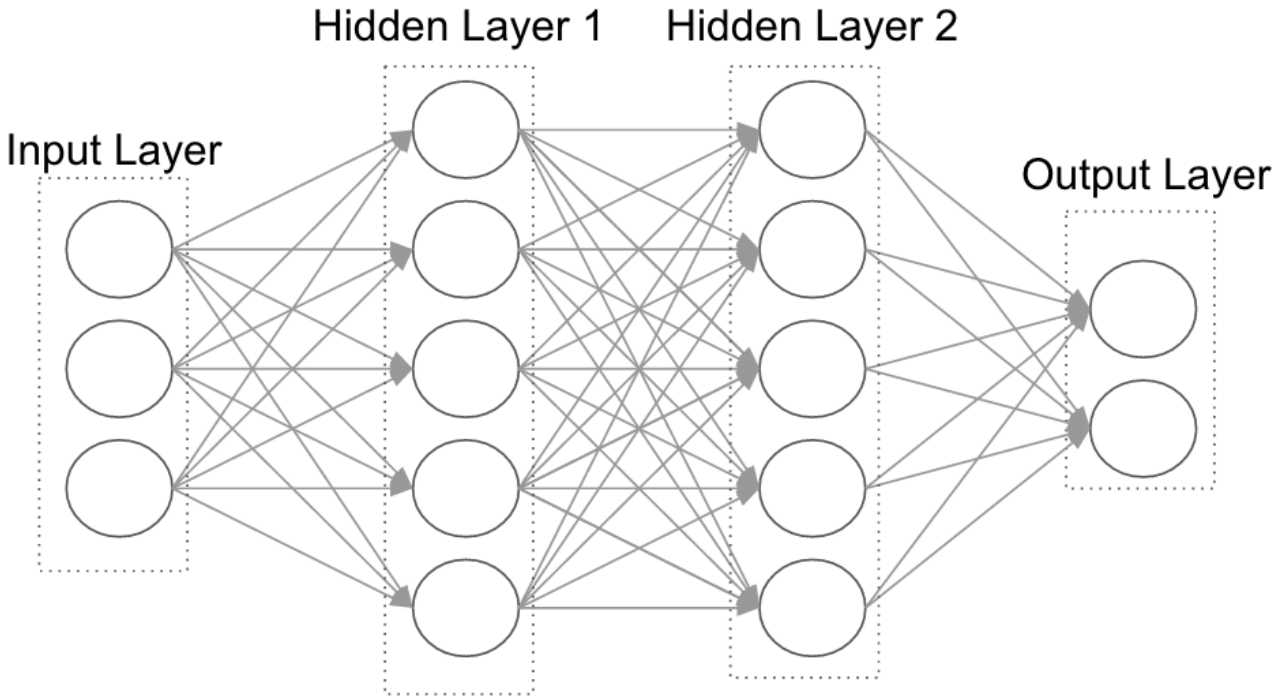
Neuromorphic Computing

In High Energy Physics

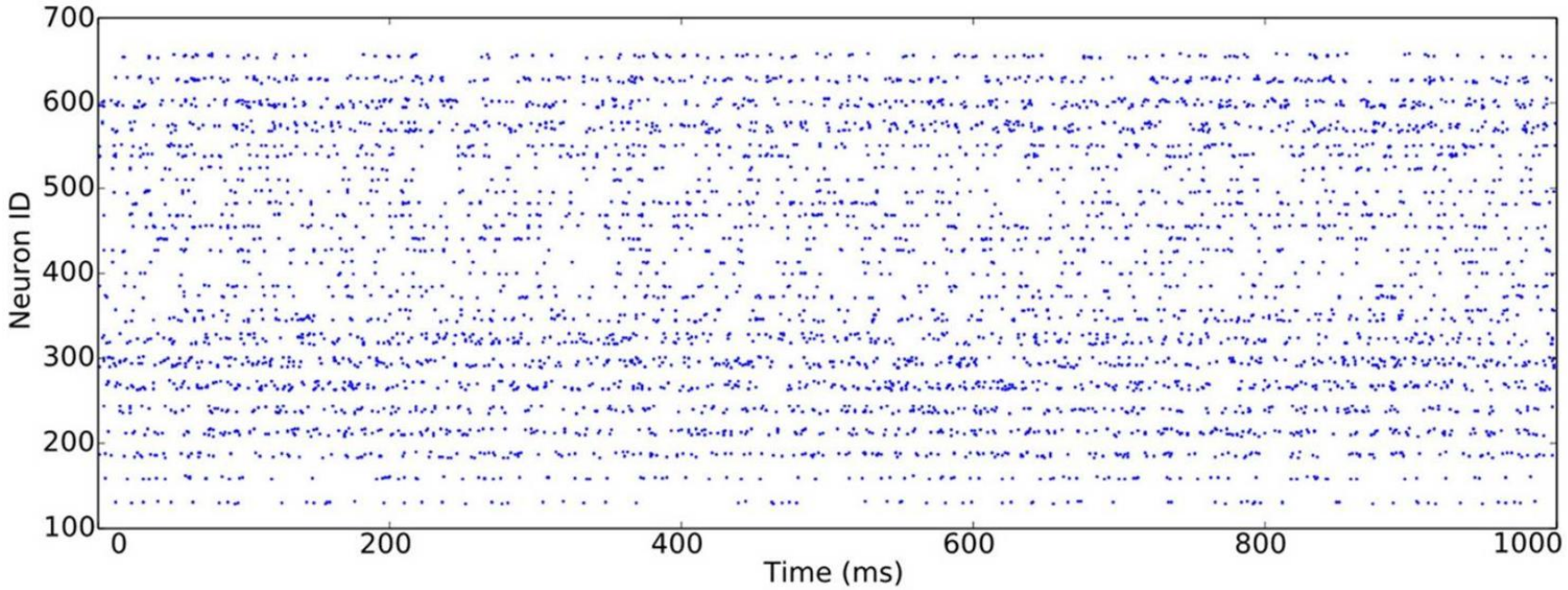
Artificial Neural Networks

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



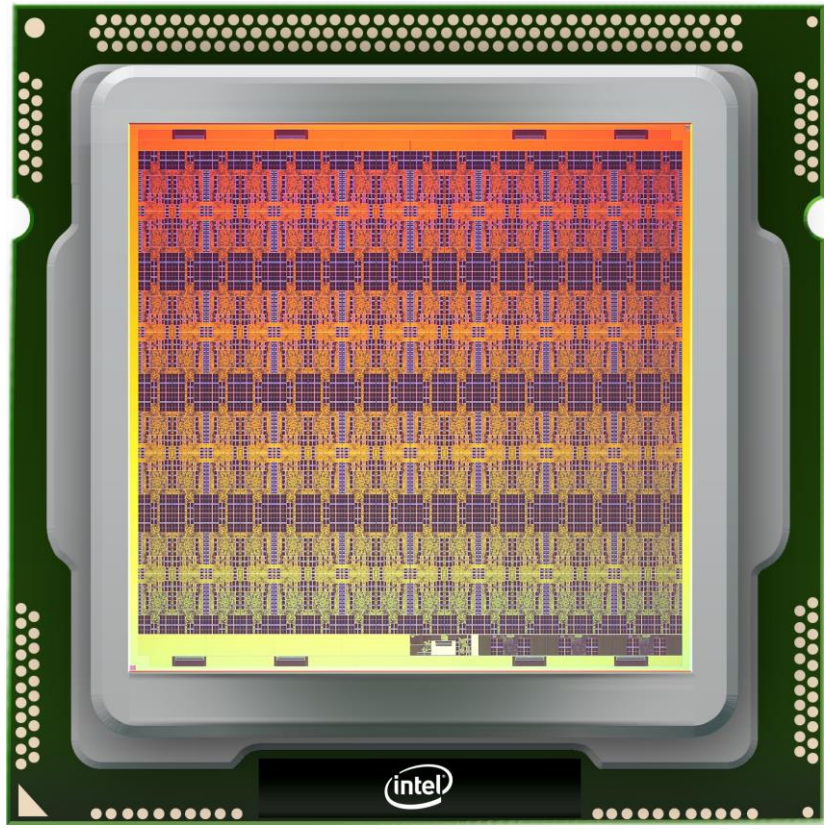
Spiking Neural Networks

- 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/PMC5090001/

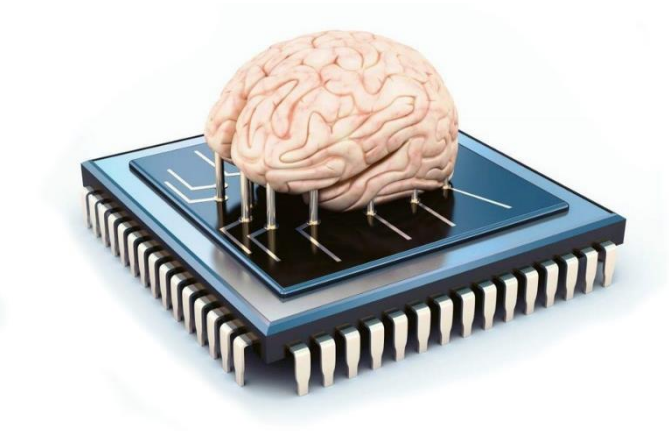
Intel Loihi



Presented by Intel Labs in 2018

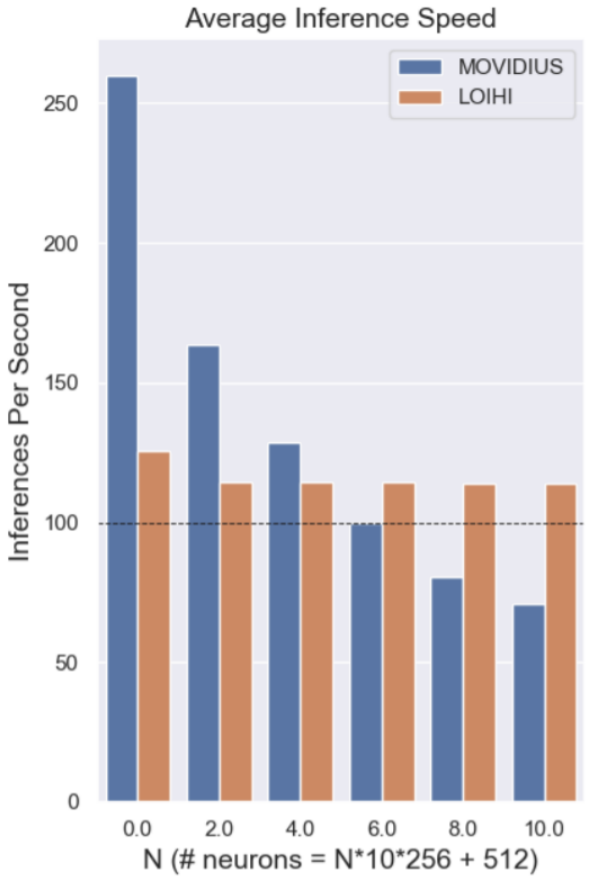
- Dedicated neuromorphic hardware
- Supports training and inference of SNNs
- Efficient asynchronous computing

state-of-the-art in neuromorphic hardware

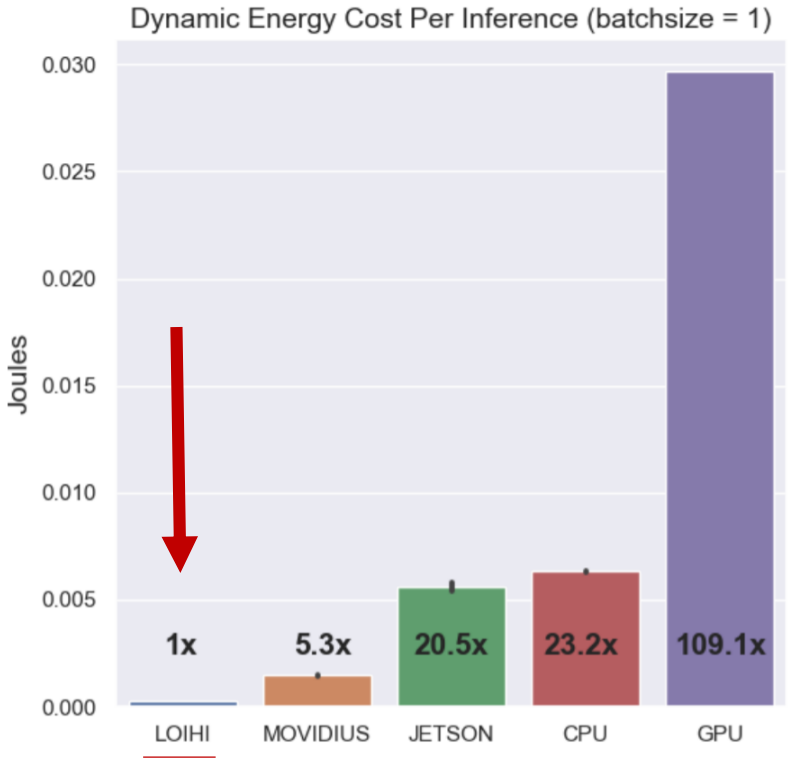


Source: https://www.intel.com/content/www/us/en/research/neuromorphic-computing.html, https://www.forbes.com/sites/cognitiveworld/2019/02/21/the-rise-of-the-silicon-brain/#499bef356957

Selected Benchmarks (the keywords spotting task)



Loihi vs. Intel Movidius Speed



Power Consumption

Source: https://arxiv.org/abs/1812.01739, arXiv:1812.01739, Peter Blouw, Xuan Choo, Eric Hunsberger, Chris Eliasmith - Benchmarking Keyword Spotting Efficiency on Neuromorphic Hardware

Results

Utilization of SNNs at CERN

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

<u>Increased precision of upgraded detectors</u>

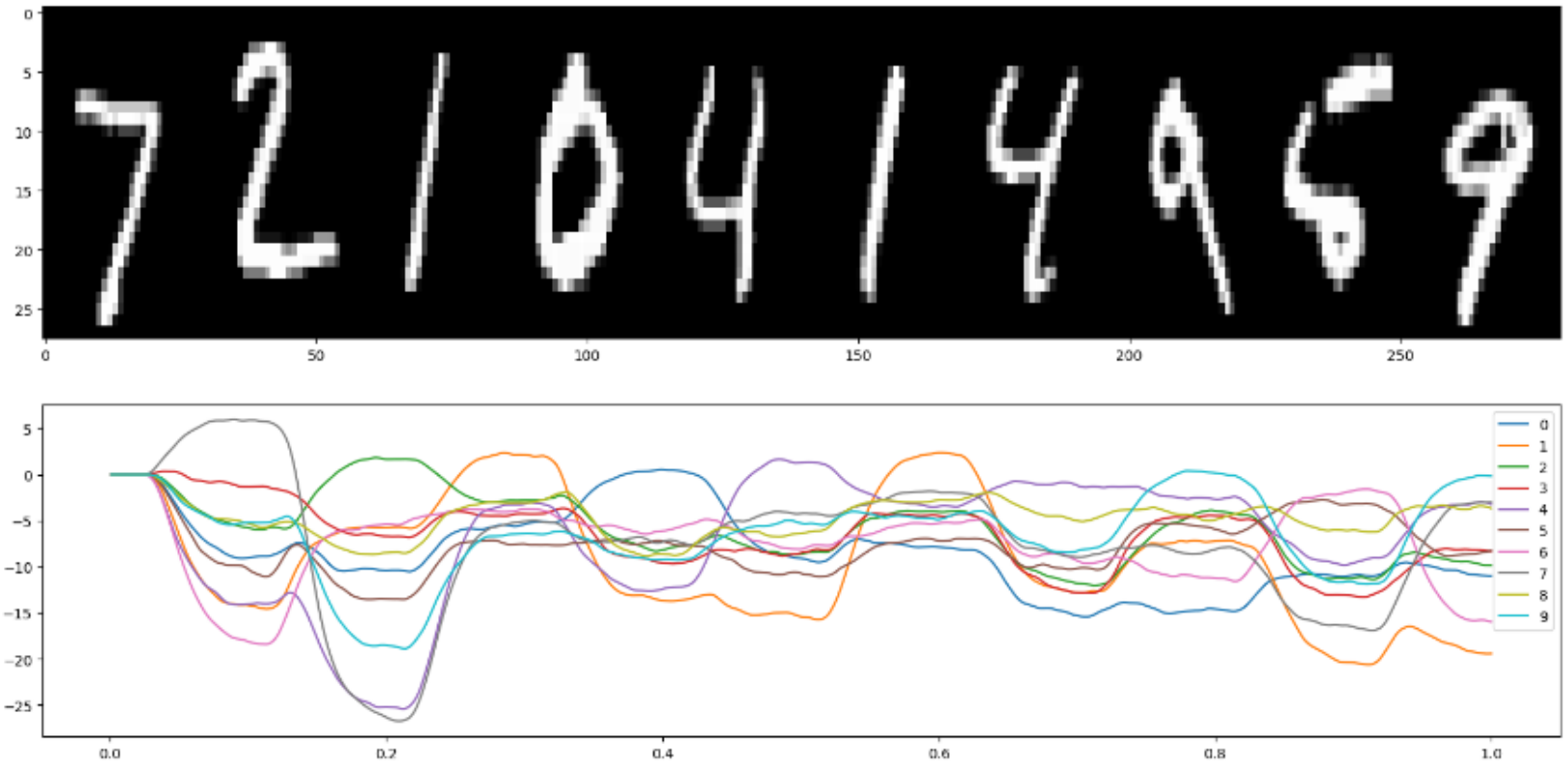
Source: http://hilumilhc.web.cern.ch/

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.



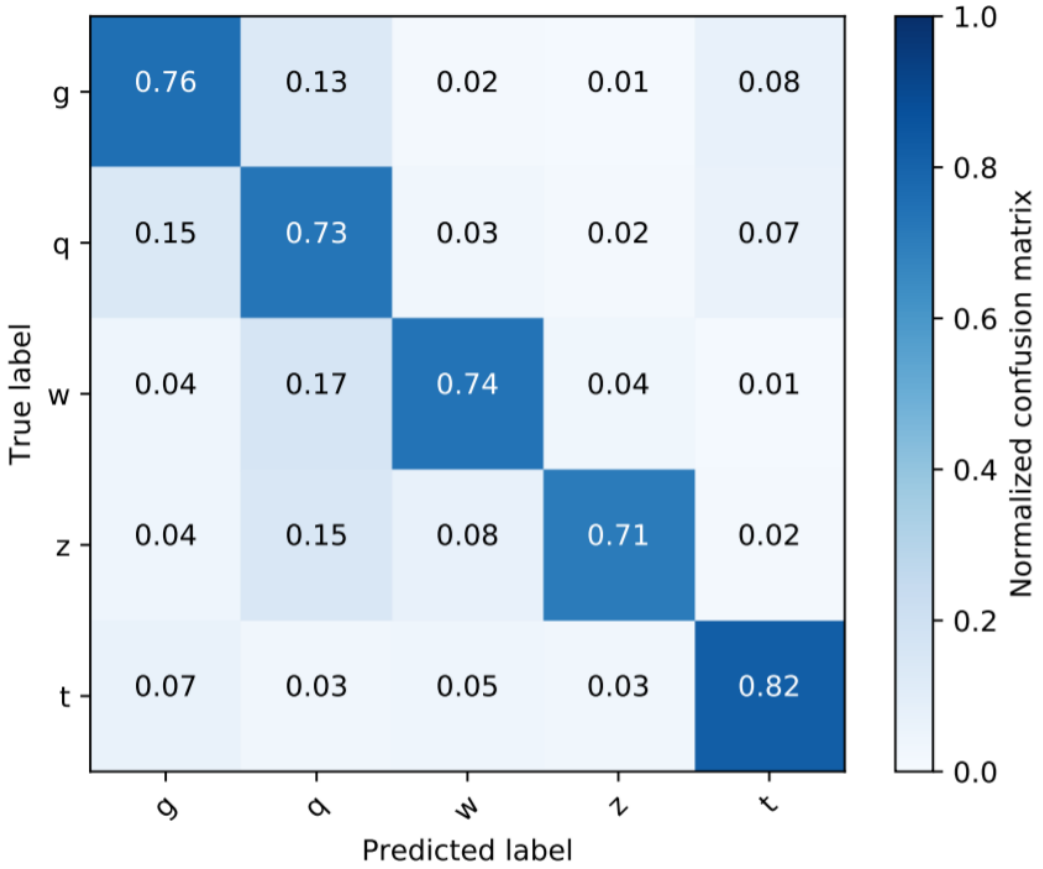
Convolutional Neural Network executed on the Loihi chip

Source: 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**)

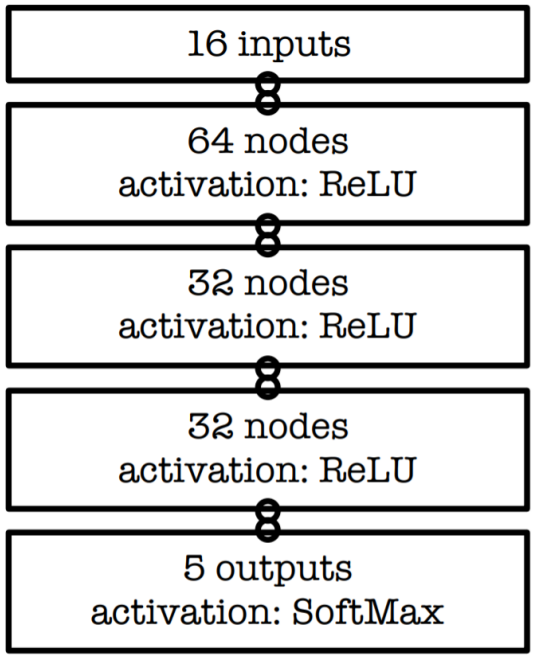
Current results with DNNs:



Source: https://arxiv.org/abs/1804.06913, arXiv:1804.06913, Jennifer Ngadiuba et al. - Fast inference of deep neural networks in FPGAs for particle physics

Jet Tagging – Spiking Neural Networks

DNN model used:



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.

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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