Sussex, Monday 3 July 2023

# Can we learn from the brain to make AI more energy efficient?

Prof Thomas Nowotny

School of Engineering and Informatics

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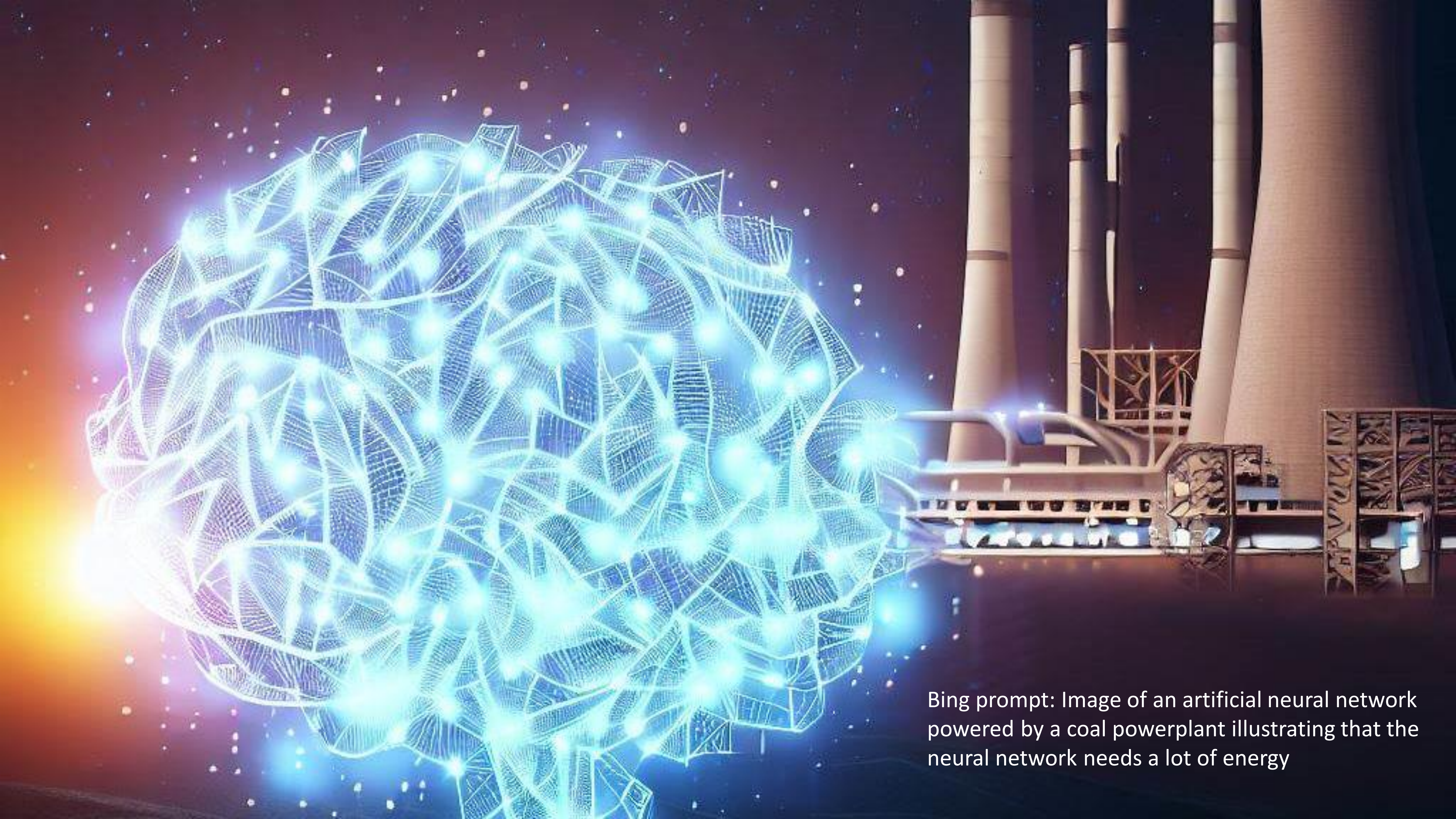
Bing prompt: A Spiking Neural Network



Bing prompt: Image of an artificial neural network powered by a coal powerplant illustrating that the neural network needs a lot of energy

Bing prompt: Car driving to the moon, using a lot of petrol

# Modern AI Resource Trends

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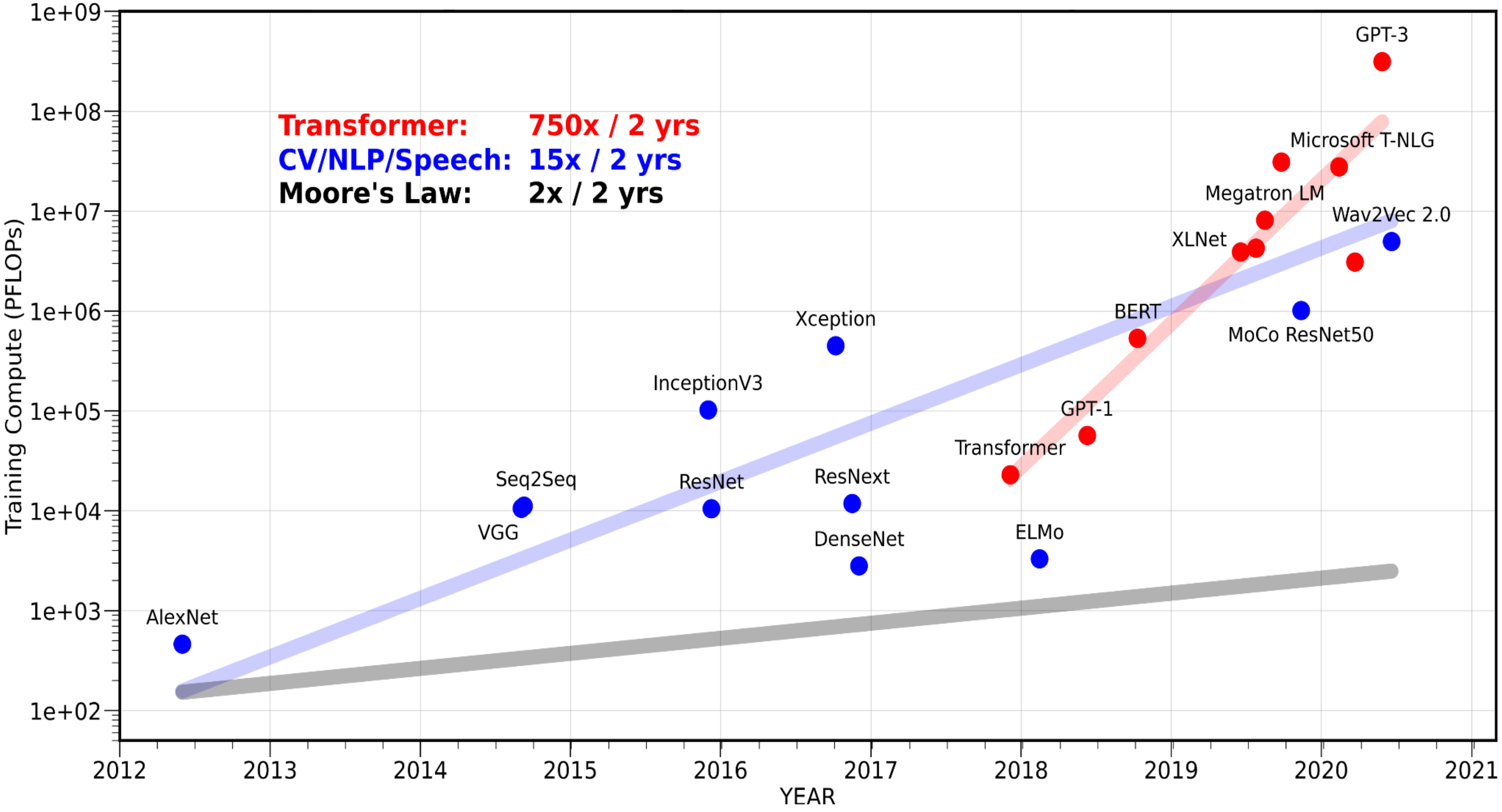


Gholami, A., Yao, Z., Kim, S., Mahoney, M. W., & Keutzer, K. (2021) AI and Memory Wall. *RiseLab Medium* Blog Post, University of Califonia Berkeley, 2021, March 29

# Brain Circuits vs Artificial Neural Networks

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- Electro-chemical “wetware”
- Evolved embodied
- Sparse communication with “spikes”

- Metal-oxide hardware
- Built for machine learning
- Dense communication of floating point numbers

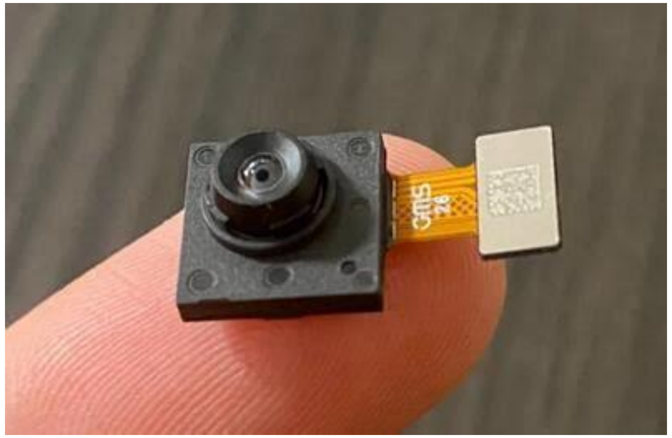
# Neuromorphic computing

SpiNNaker
(Manchester/
Dresden)

BrainScaleS
(Heidelberg)


Intel Loihi
(Intel Corporation)

Synsense
Speck



IBM synapse
(IBM)

# General classification problem

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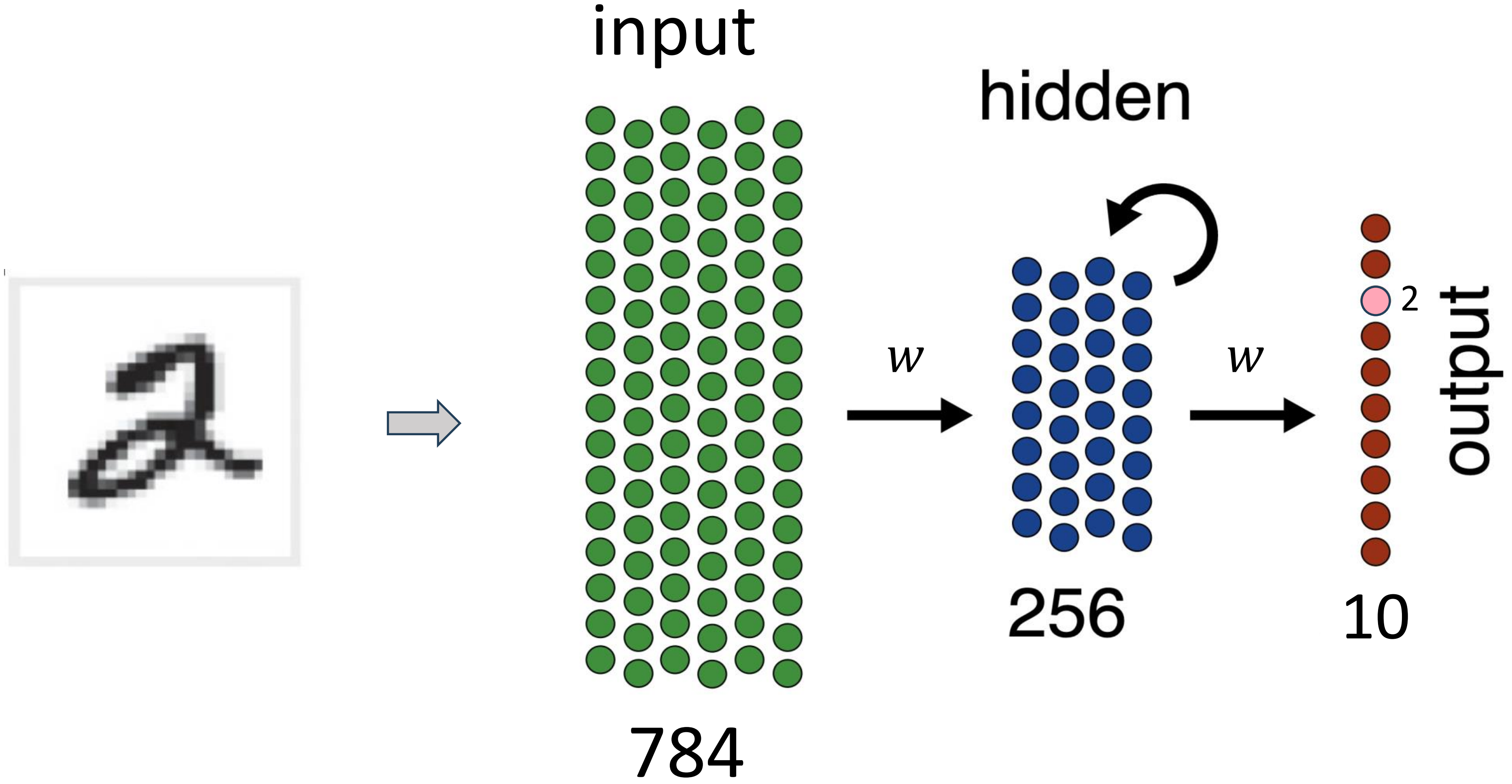

# Training: Gradient descent

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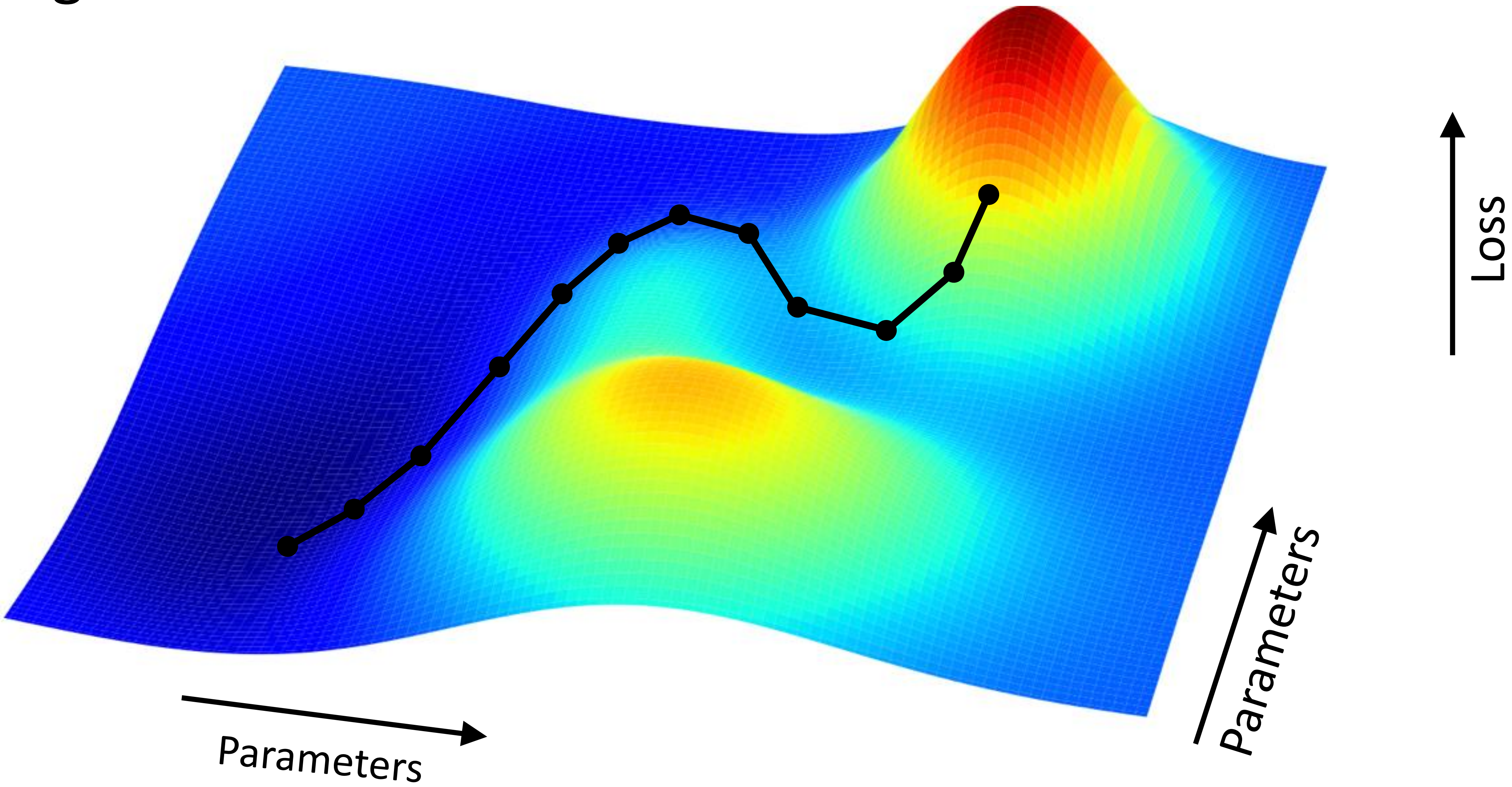

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www.nature.com/scientificreports

frontiers

ORIGINAL RESEARCH

IOP Publishing Neuromorph. Comput. Eng. 2 (2022) 024002 https://doi.org/10.1088/2634-4386/ac5ac5

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Computing and Engineering

CrossMark

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PAPER

# mlGeNN: accelerating SNN inference using GPU-enabled neural networks

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Keywords: machine learning, spiking neural networks, GPU, ANN to SNN conversion, convolutional neural networks, GeNN, Re

# GeNN (**G**PU **e**nhanced **N**eural **N**etworks)

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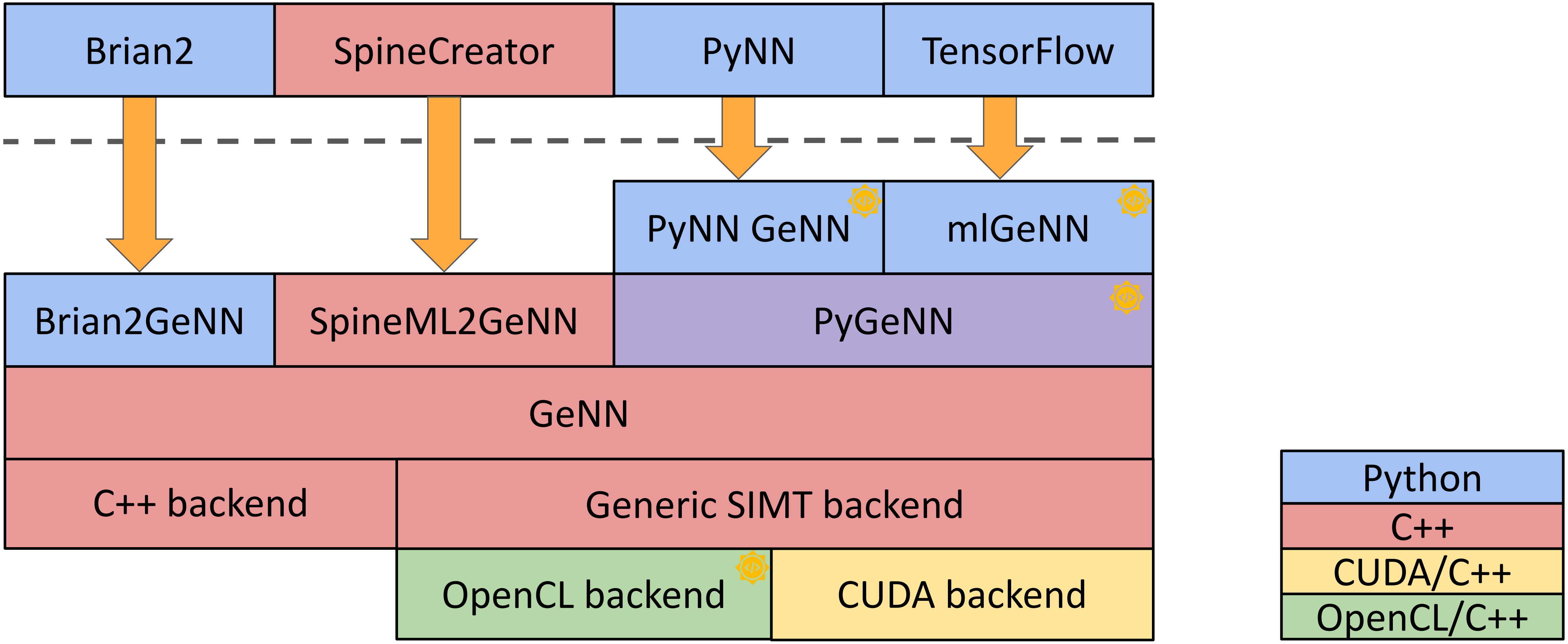
GeNN generates CUDA kernels and data transfer “convenience functions” based on a model definition provided by a user.

(Meta Compiler)

# GeNN ecosystem




https://github.com/genn-team/genn/

# Handwritten digits with EventProp

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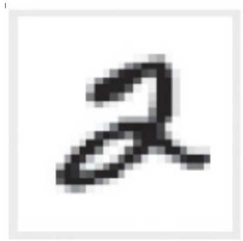

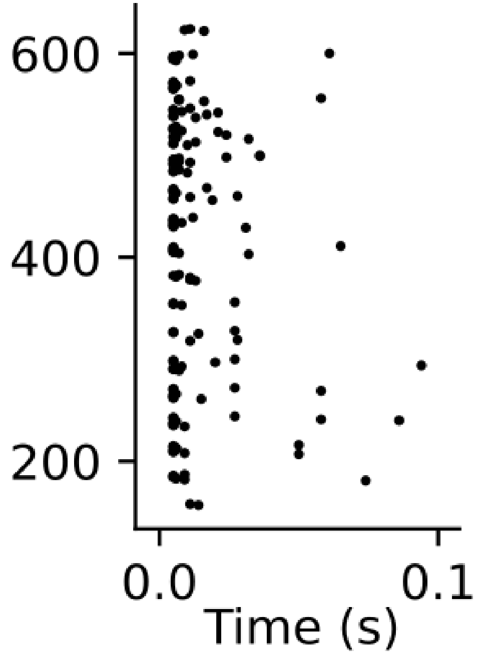


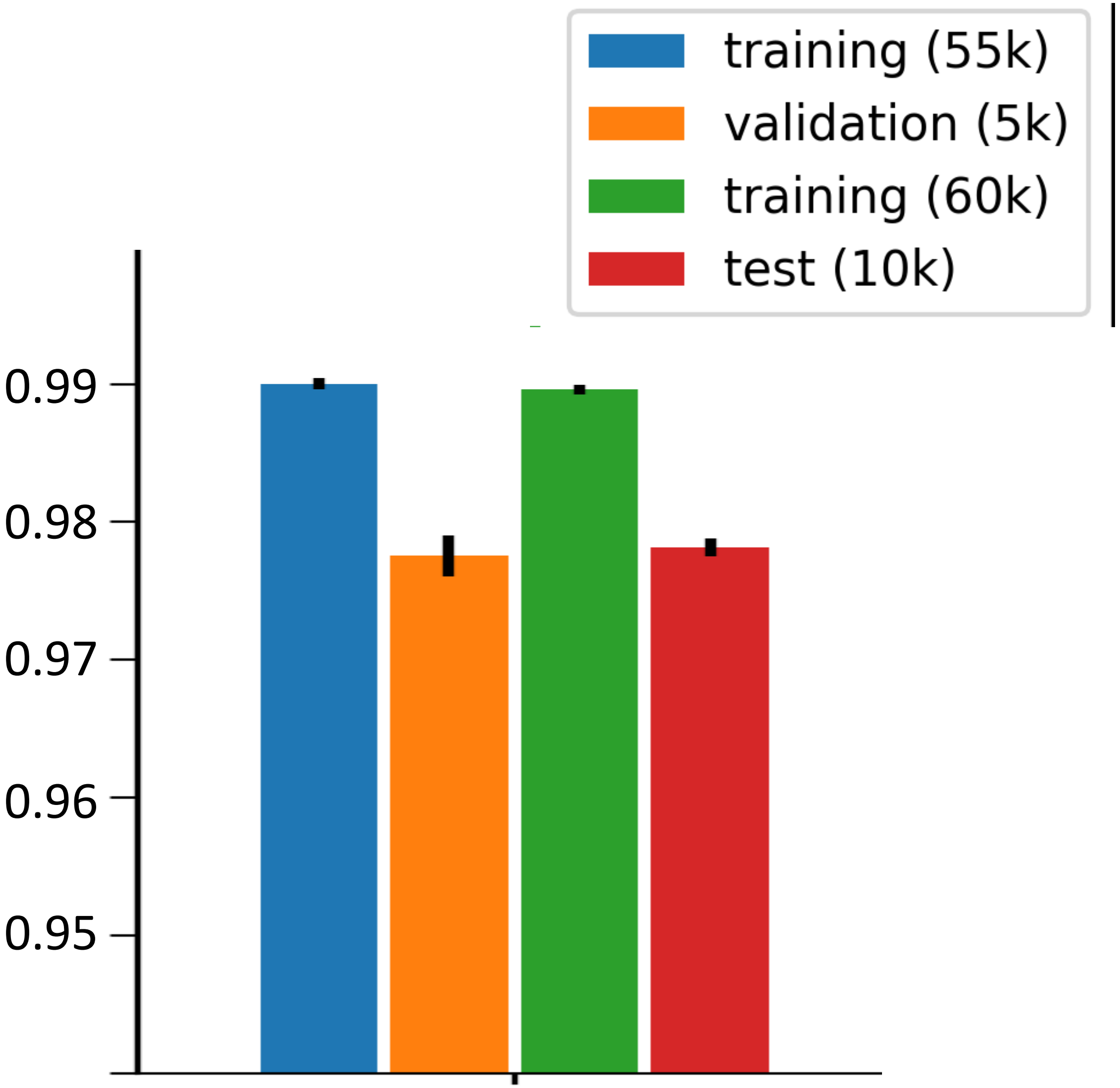


Trains to >97% in 27s on a PC with RTX 3090

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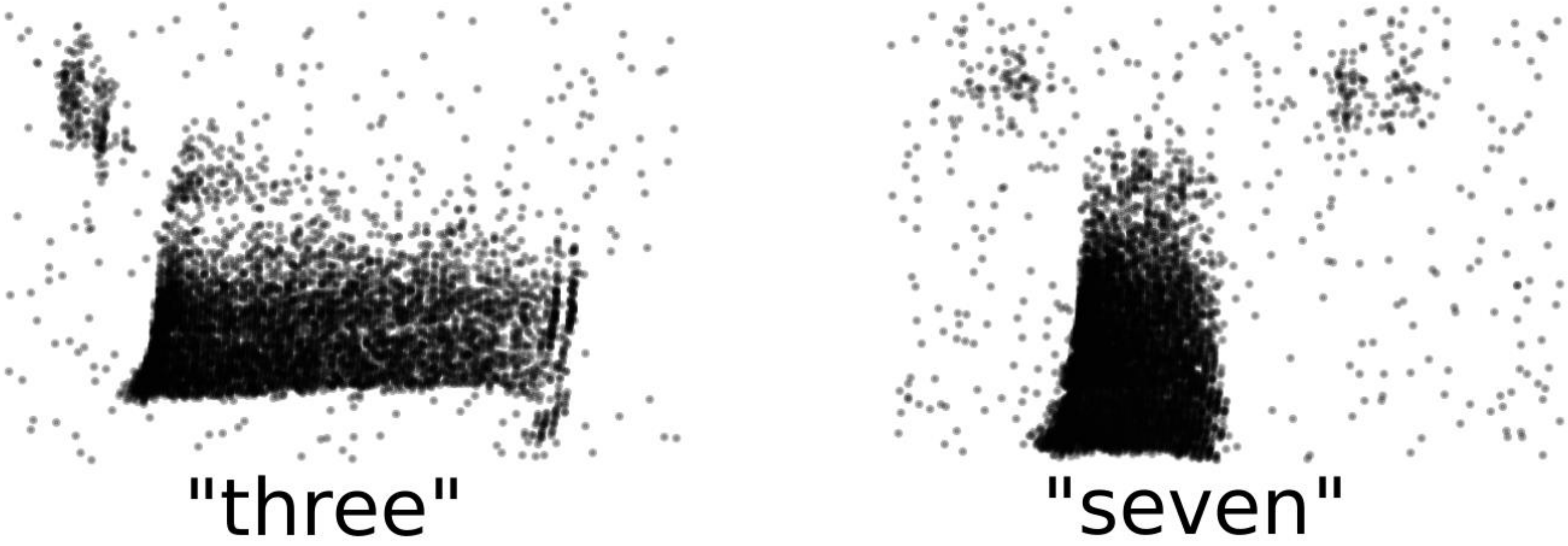
# Spiking Heidelberg Digits




Cramer, B., Stradmann, Y., Schemmel, J., & Zenke, F. (2020). The Heidelberg Spiking Data Sets for the Systematic Evaluation of Spiking Neural Networks. IEEE Transactions on Neural Networks and Learning Systems. https://doi.org/10.1109/TNNLS.2020.3044364

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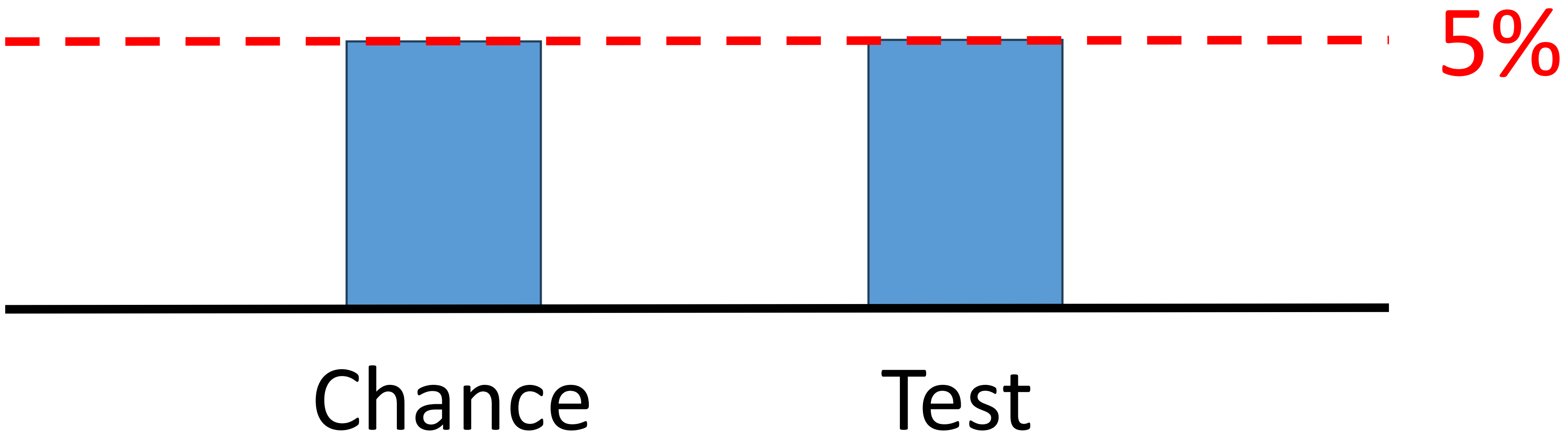
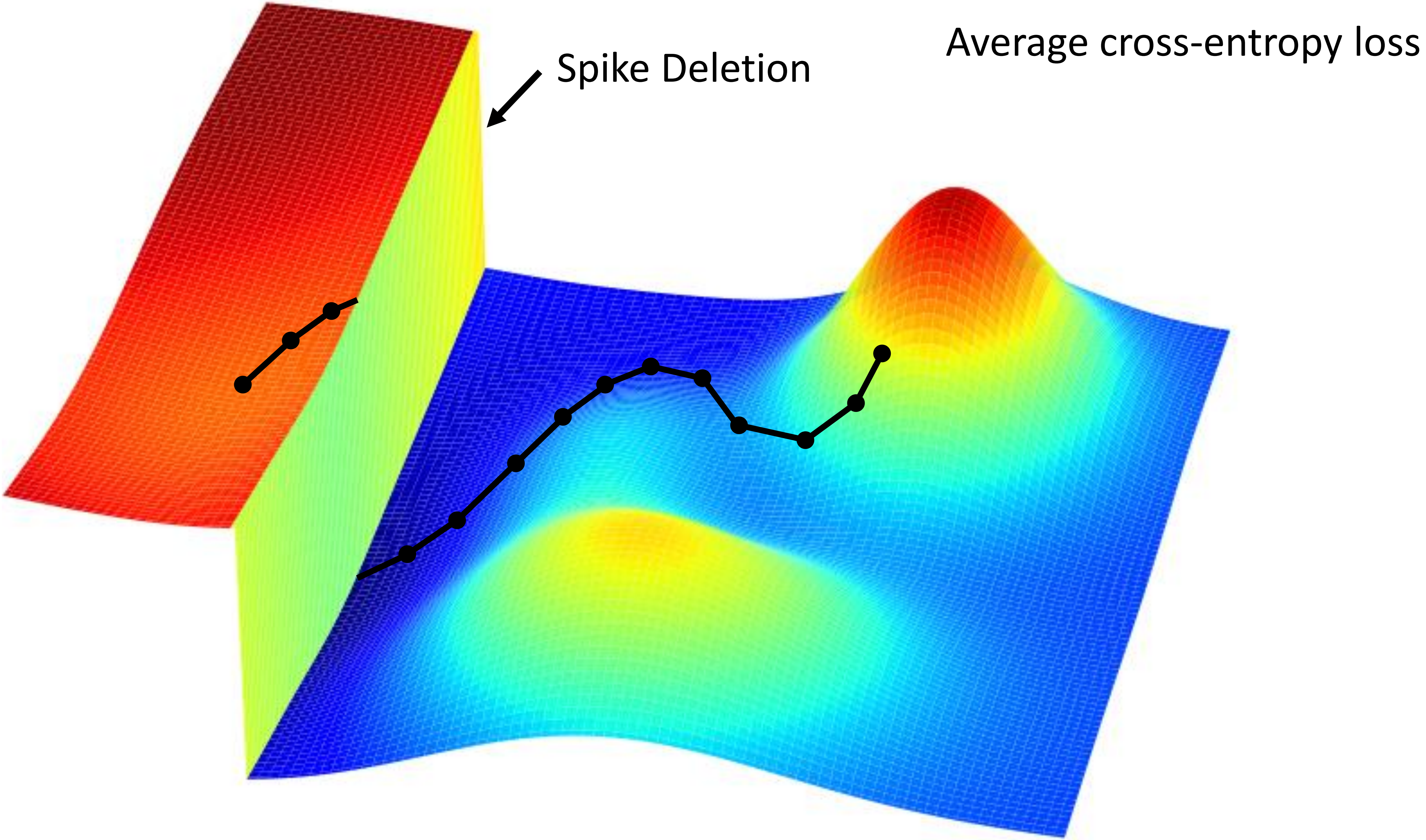
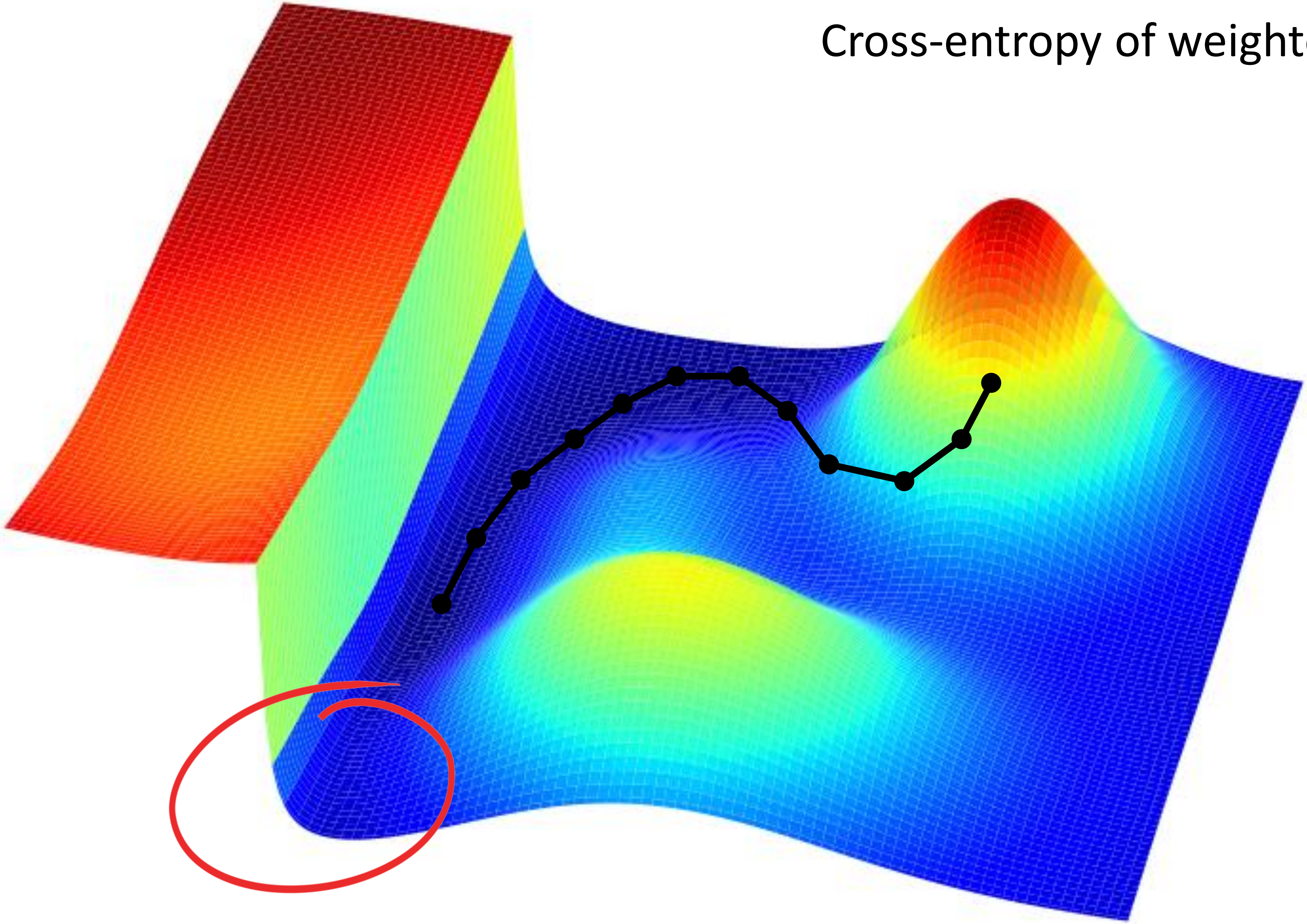
# No learning!




Average cross-entropy loss
Spike Deletion

# Cross-entropy of weighted average loss



# Spiking Heidelberg Digits

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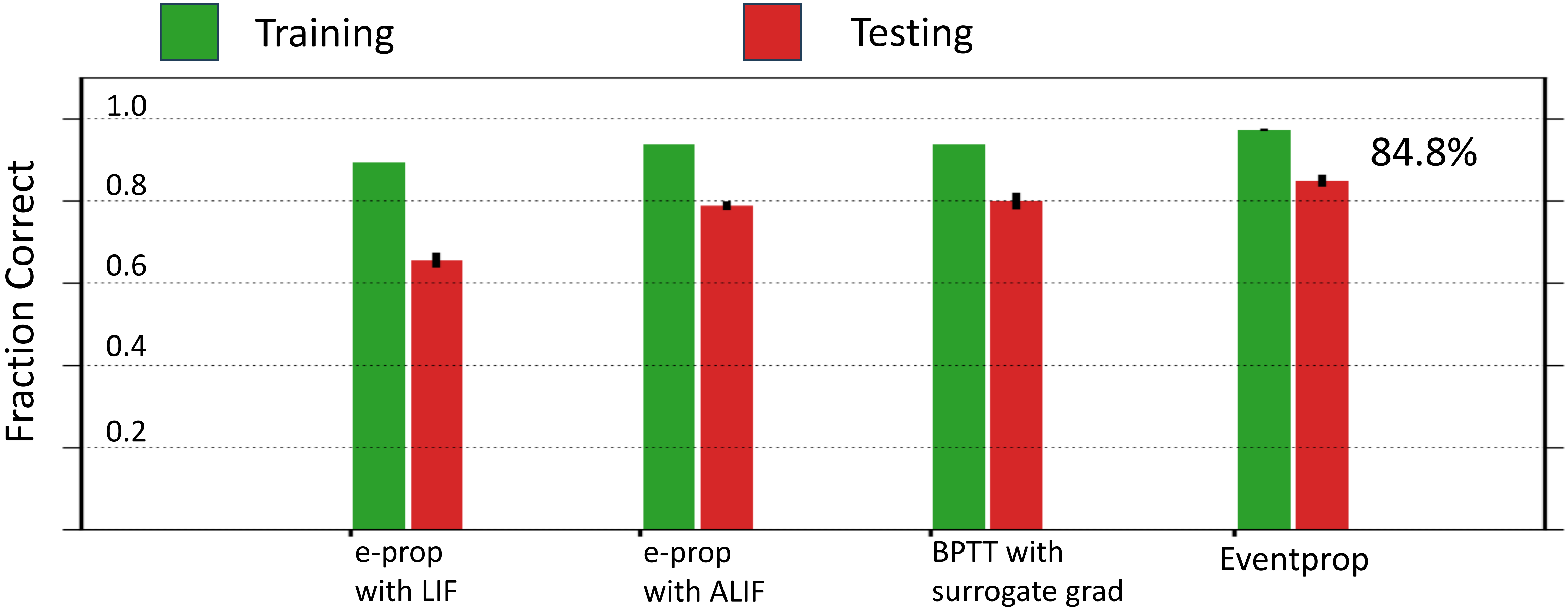



1. Zenke F, Vogels T. The remarkable robustness of surrogate gradient learning for instilling complex function in spiking neural networks. Neural Comput 33:899-925 (2021)
2. J. C Knight, T. Nowotny. Efficient GPU training of LSNNs using eProp. NICE 2022. ACM, 8–10


EventProp
Spiking simulation
Gradient Descent
Augmentation

# Augmentation

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- Augmentation is used to make data sets larger to counter-act over-fitting to few examples
- Augmentation for event-based data is an open field with not much work
- Candidates:
  - Global random channel shift
  - Local random channel swap
  - Random time compression/dilation
  - Blending

# Parameter sweeps

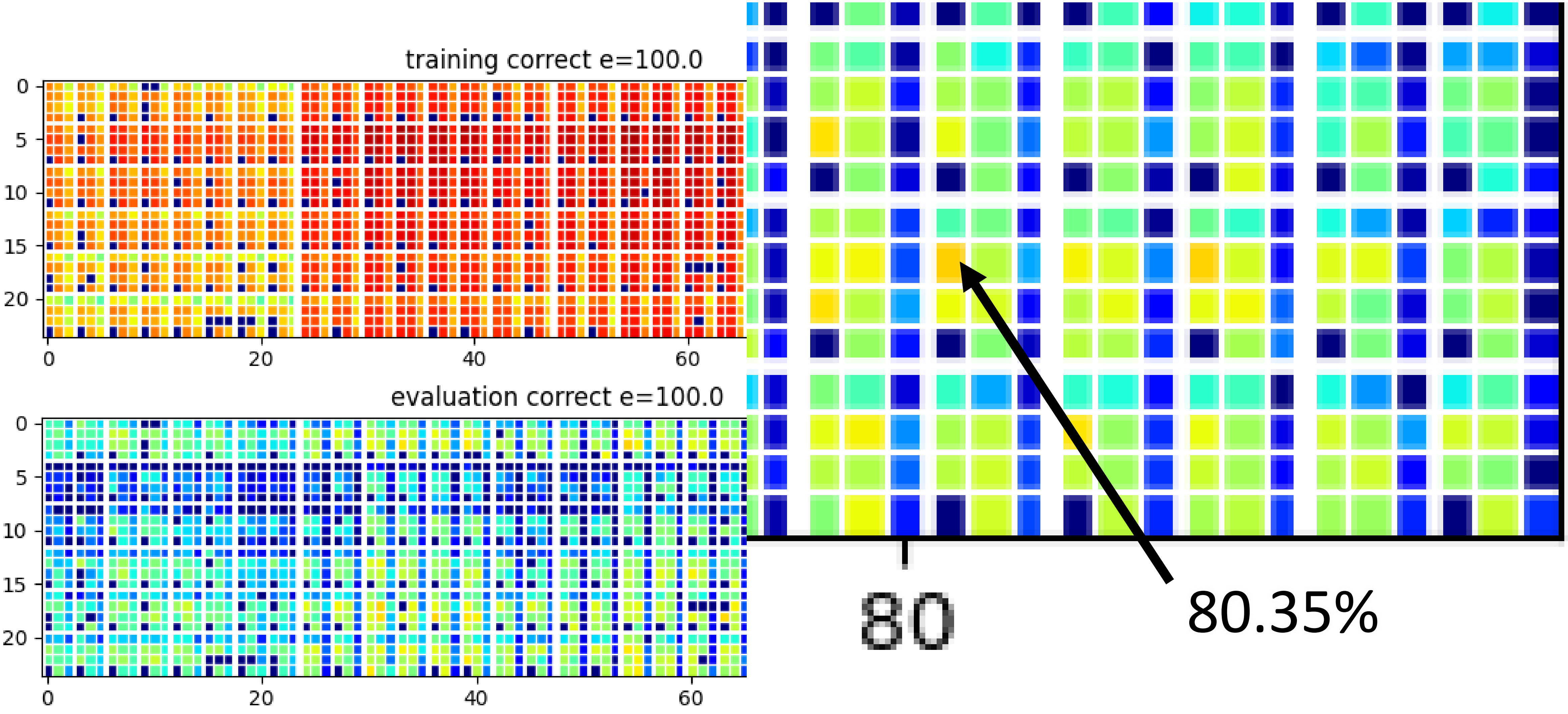
- Try parameters for the network and augmentations
- Best proxy for test set performance is leave-one-speaker-out (loso) cross-validation
- A full 10-fold loso cross-validation with 300 epochs per fold takes about **16 hours on an A100 GPU**

JADE
Tier 2 HPC


ORACLE Cloud
Research

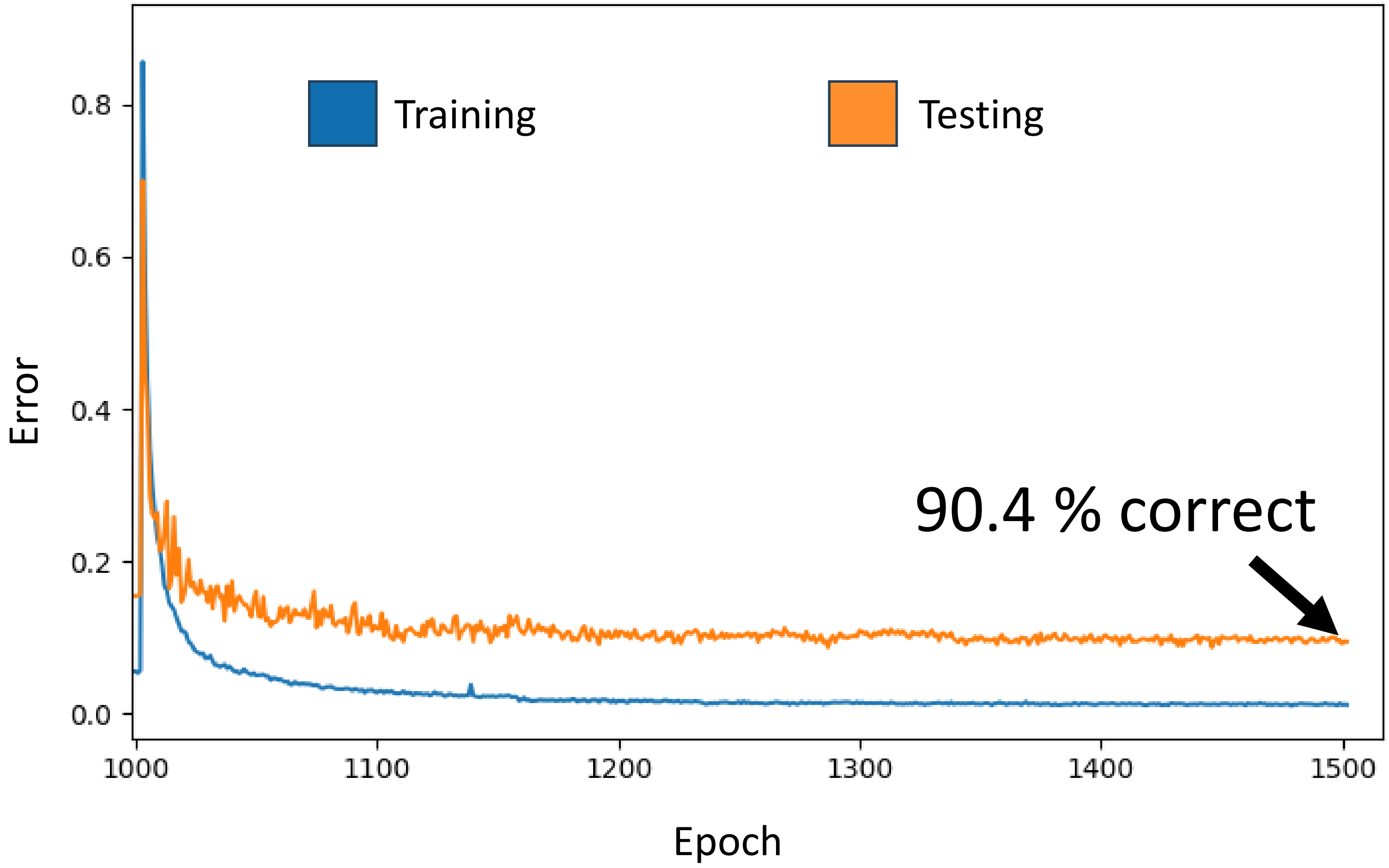
# Example Scan Results





# Test set performance





# Summary

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- JADE 2 (and other GPU clusters) help us investigate event-based neural network solutions competitive against SOTA

| Dataset | Method | Recurrent | Delays | # Params | Top1 Accuracy |
|---|---|---|---|---|---|
| **SHD** | EventProp-GeNN [31] | ✓ | ✗ | N/a | $84.80 \pm 1.5\%$ |
| | Cuba-LIF [7] | ✗ | ✗ | N/a | $87.80 \pm 1.1\%$ |
| | Adaptive SRNN [44] | ✓ | ✗ | N/a | 90.40% |
| | SNN with Delays [2] | ✗ | ✓ | 0.1M | 90.43% |
| | TA-SNN [43] | ✗ | ✗ | N/a | 91.08% |
| | STSC-SNN [46] | ✗ | ✗ | 2.1M | 92.36% |
| | Adaptive Delays [37] | ✗ | ✓ | 0.1M | 92.45% |
| | RadLIF [3] | ✓ | ✗ | 3.9M | 94.62% |
| | **Our work (2 hidden layers)** | ✗ | ✓ | **0.2M** | $\mathbf{95.07 \pm 0.24\%}$ |

← 90.4 % correct (Adaptive SRNN)

} Use test set for validation (RadLIF, Our work)

Hammouamri, I., Khalfaoui-Hassani, I., & Masquelier, T. (2023). Learning Delays in Spiking Neural Networks using Dilated Convolutions with Learnable Spacings. *arXiv preprint arXiv:2306.17670*.

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The Leverhulme Trust

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