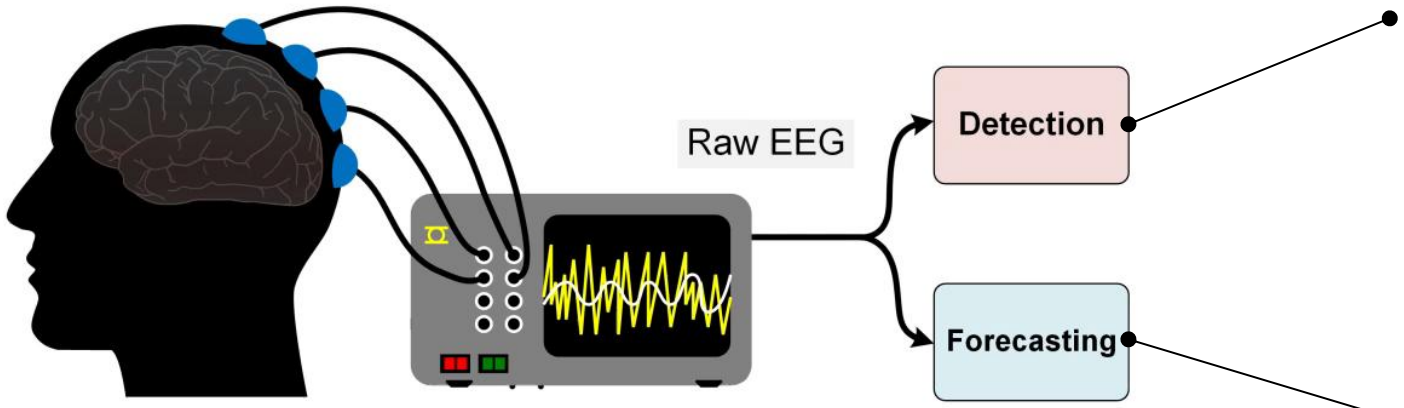
12TH ANNUAL IEEE Engineering Medicine and Biology Society
International Conference on Neural Engineering

Neuromorphic Neuromodulation

Using the Brain to Forecast the Brain

Jason Eshraghian
University of California, Santa Cruz



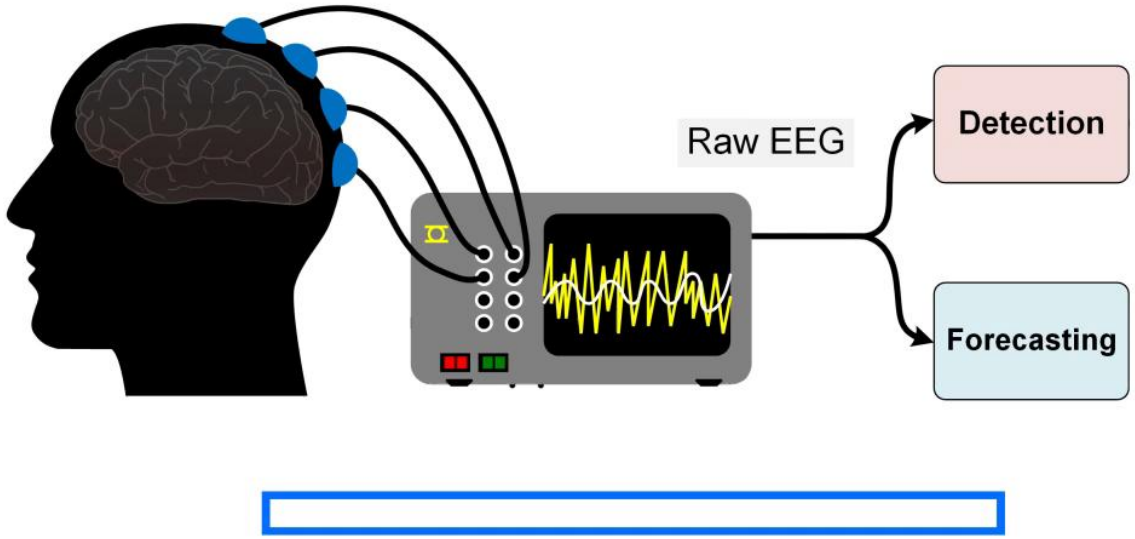
As good as it gets

Enables preventative measures

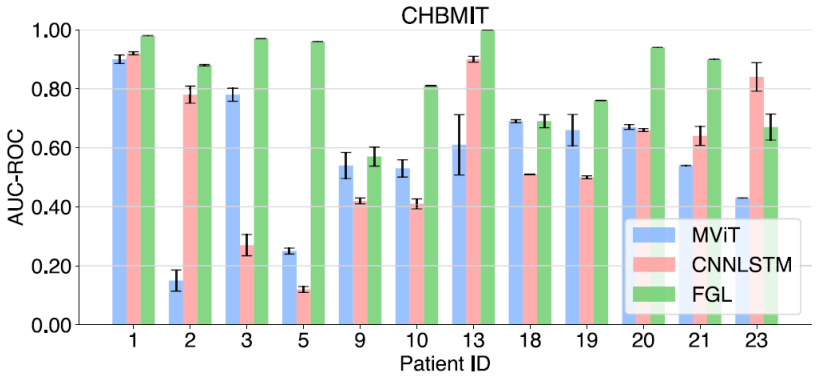
But it’s difficult

S. Gunasekaran, J. K. Eshraghian, Nature Communications, 2025.

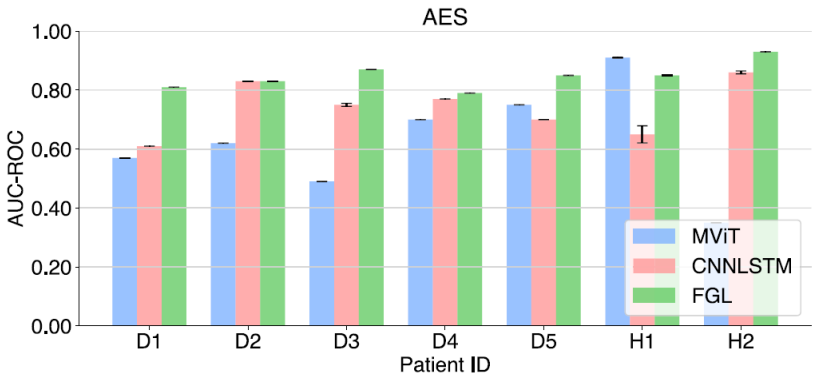
Future-Guided Learning



- No need for manual labels
- Forecasting = patient-specific
- Higher AUC-ROC



(A)



(B)

S. Gunasekaran, J. K. Eshraghian, Nature Communications, 2025.

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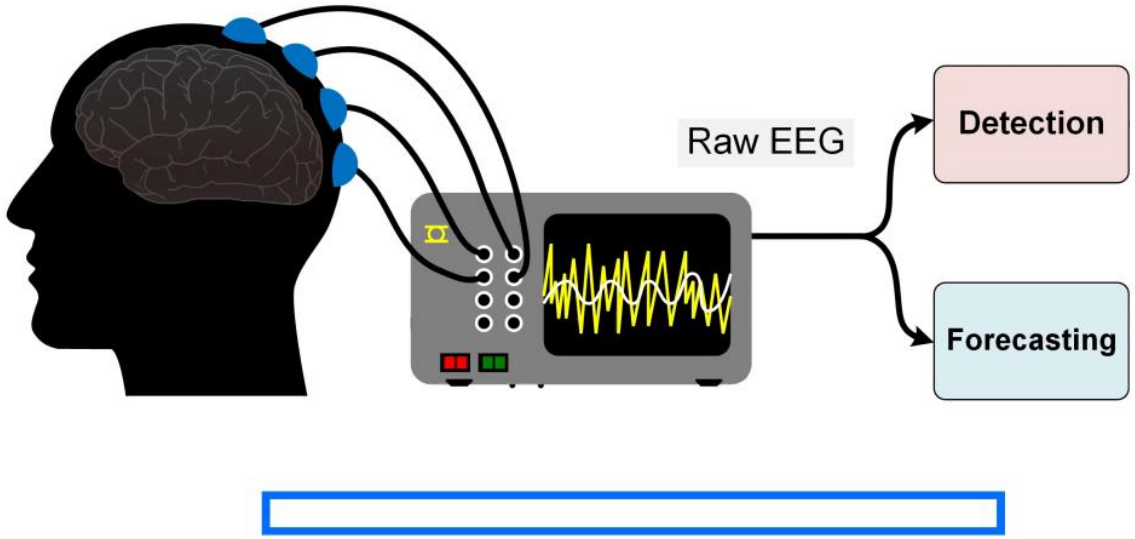

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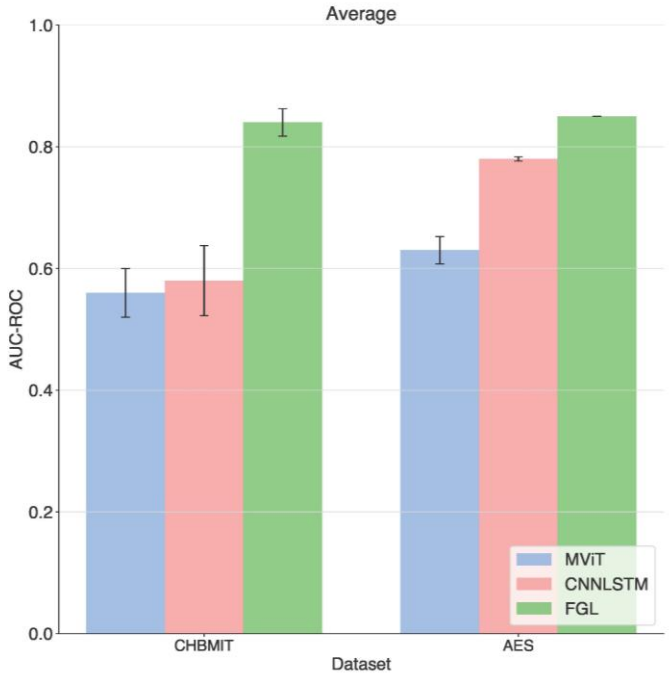

Takeaway: We can minimize surprise by learning from the future

S. Gunasekaran, J. K. Eshraghian, Nature Communications, 2025.

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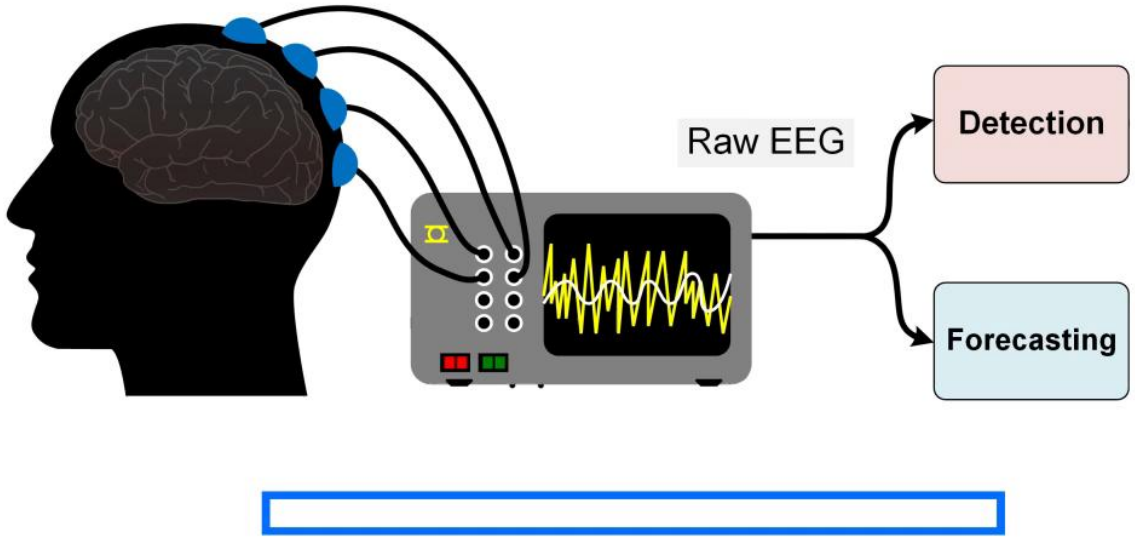


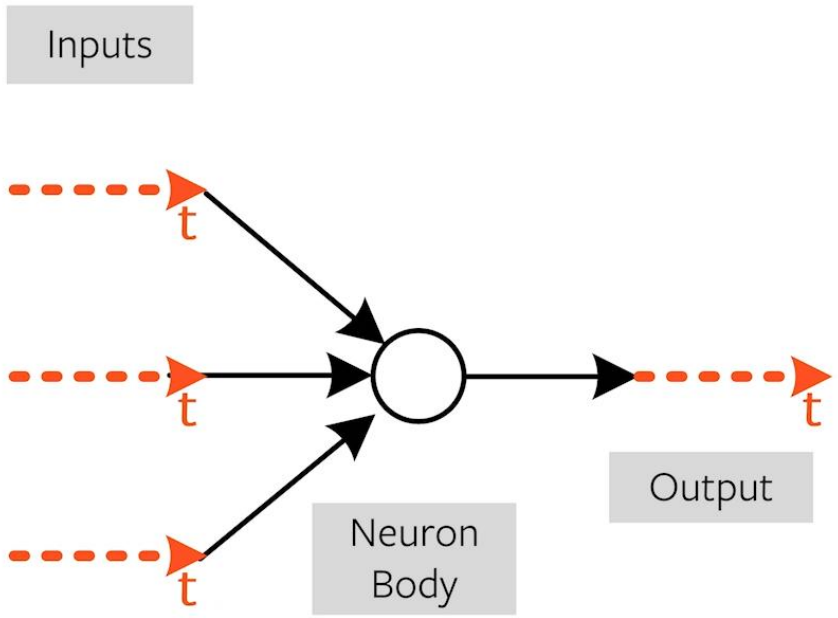
Takeaway: We can minimize surprise by learning from the future

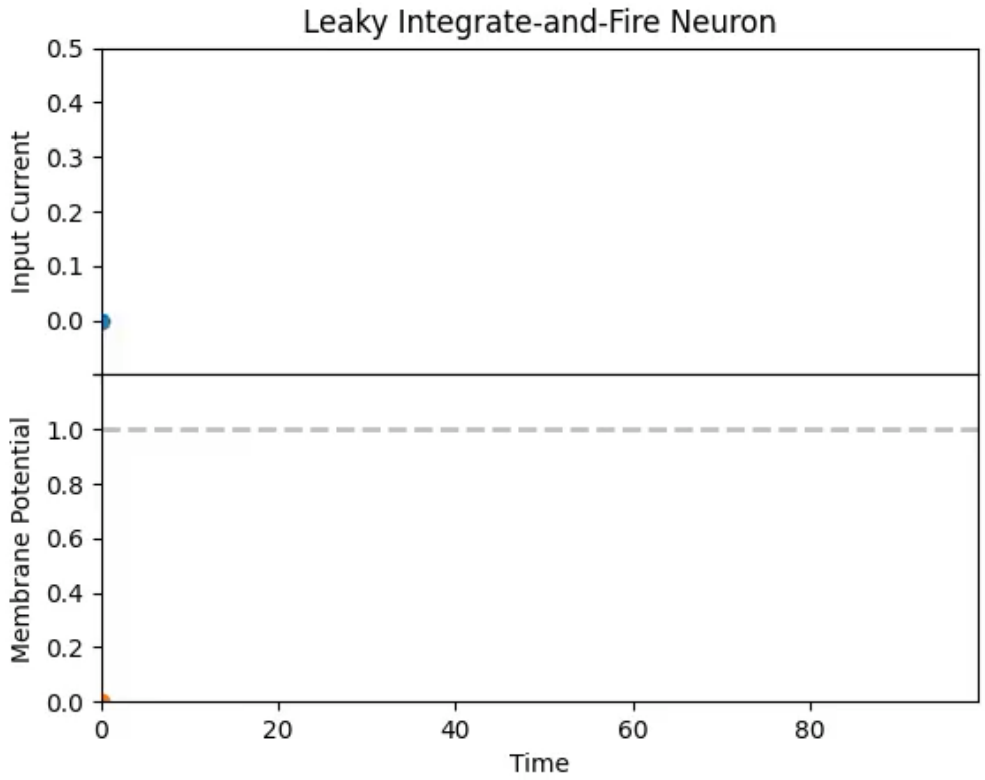
Training Cost?

- Only learning at mismatch ✅
- Multiple model deployment ❌

S. Gunasekaran, J. K. Eshraghian, Nature Communications, 2025.

Spiking Neural Networks



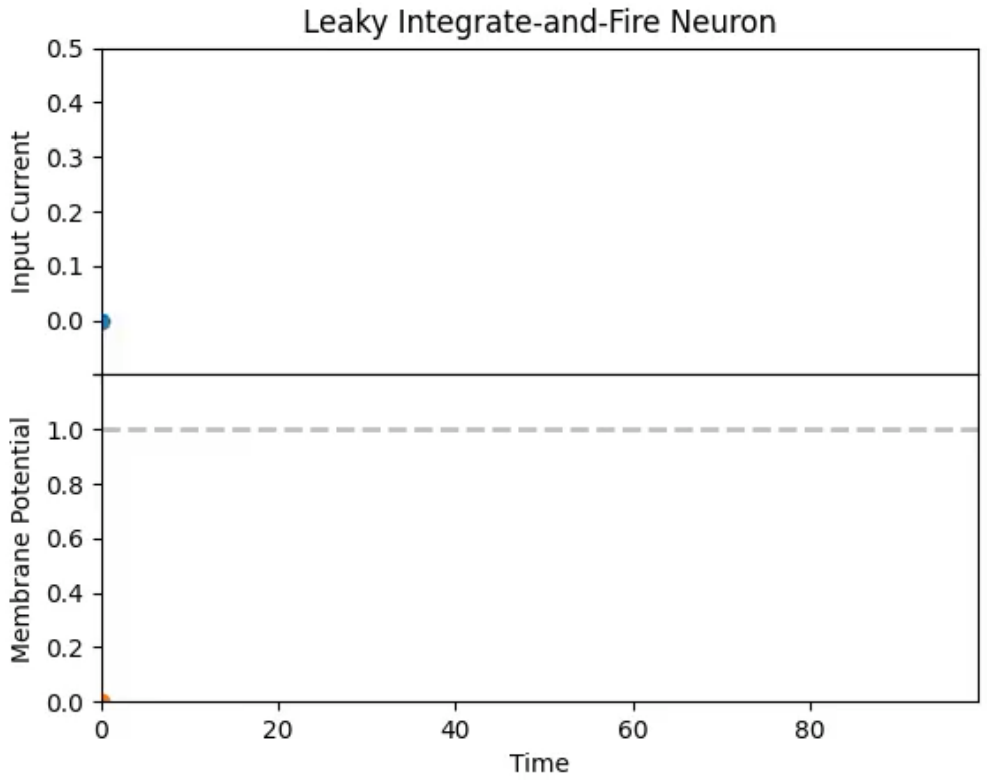


Spiking Neural Networks

Sparsity

Low-precision arithmetic

Compressed information representation



snnTorch

Gradient-based Learning with Spiking Neural Networks

Python package for gradient-based optimization of SNNs

real-time online learning

seamless integration with PyTorch

>350,000 downloads

neuromorphic HW compatible

github.com/jeshraghian/snntorch

Tutorial	Title	Colab Link
Tutorial 1	Spike Encoding with snnTorch	Open in Colab
Tutorial 2	The Leaky Integrate and Fire Neuron	Open in Colab
Tutorial 3	A Feedforward Spiking Neural Network	Open in Colab
Tutorial 4	2nd Order Spiking Neuron Models (Optional)	Open in Colab
Tutorial 5	Training Spiking Neural Networks with snnTorch	Open in Colab
Tutorial 6	Surrogate Gradient Descent in a Convolutional SNN	Open in Colab
Tutorial 7	Neuromorphic Datasets with Tonic + snnTorch	Open in Colab

Advanced Tutorials	Colab Link
Population Coding	Open in Colab
Regression: Part I - Membrane Potential Learning with LIF Neurons	Open in Colab
Regression: Part II - Regression-based Classification with Recurrent LIF Neurons	Open in Colab
Accelerating snnTorch on IPUs	–

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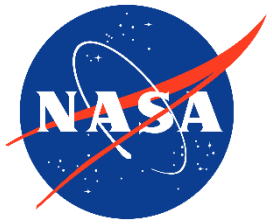

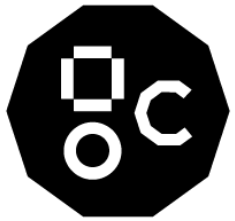

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But does this address the right problem?

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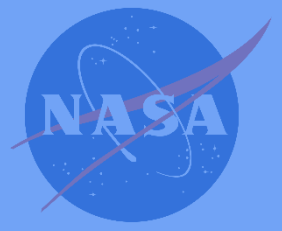

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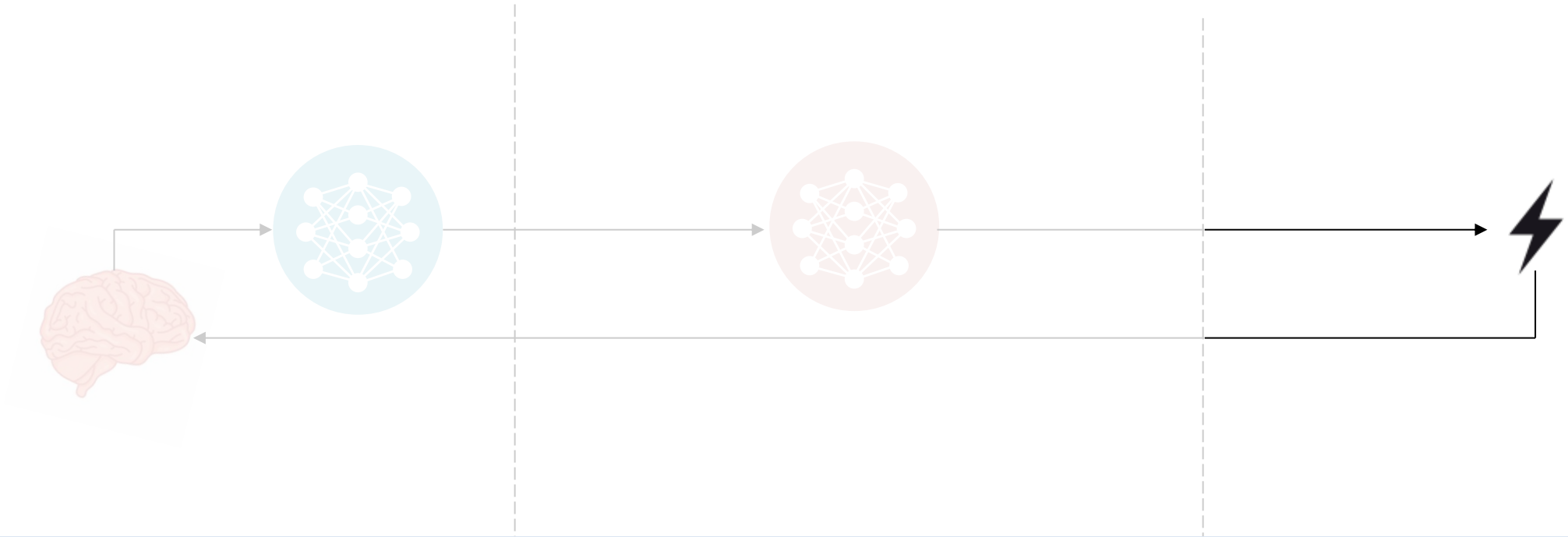
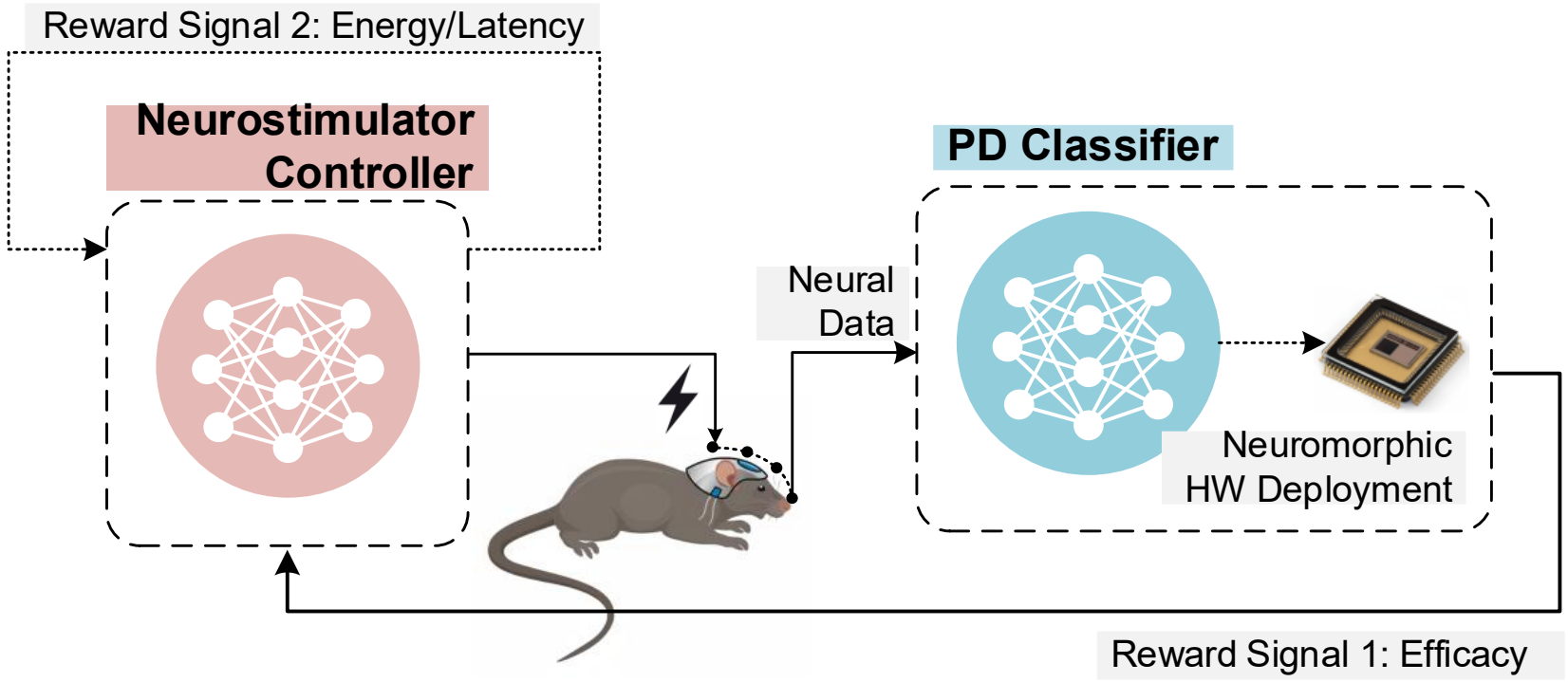
Sensing	Controller	Neurostimulator
		
Bursty – e.g., Epilepsy		
Med-Low drain	Very Low drain	Med drain
Continuous – e.g., Parkinson's		
Med-Very Low drain	Med-Low drain	Very high drain

Energy-Aware Learning

Rewarding your model for <u>total</u> energy usage



B. Nguyen, J. K. Eshraghian, et al. IEEE ISCAS 2025; IEEE NER 2025.

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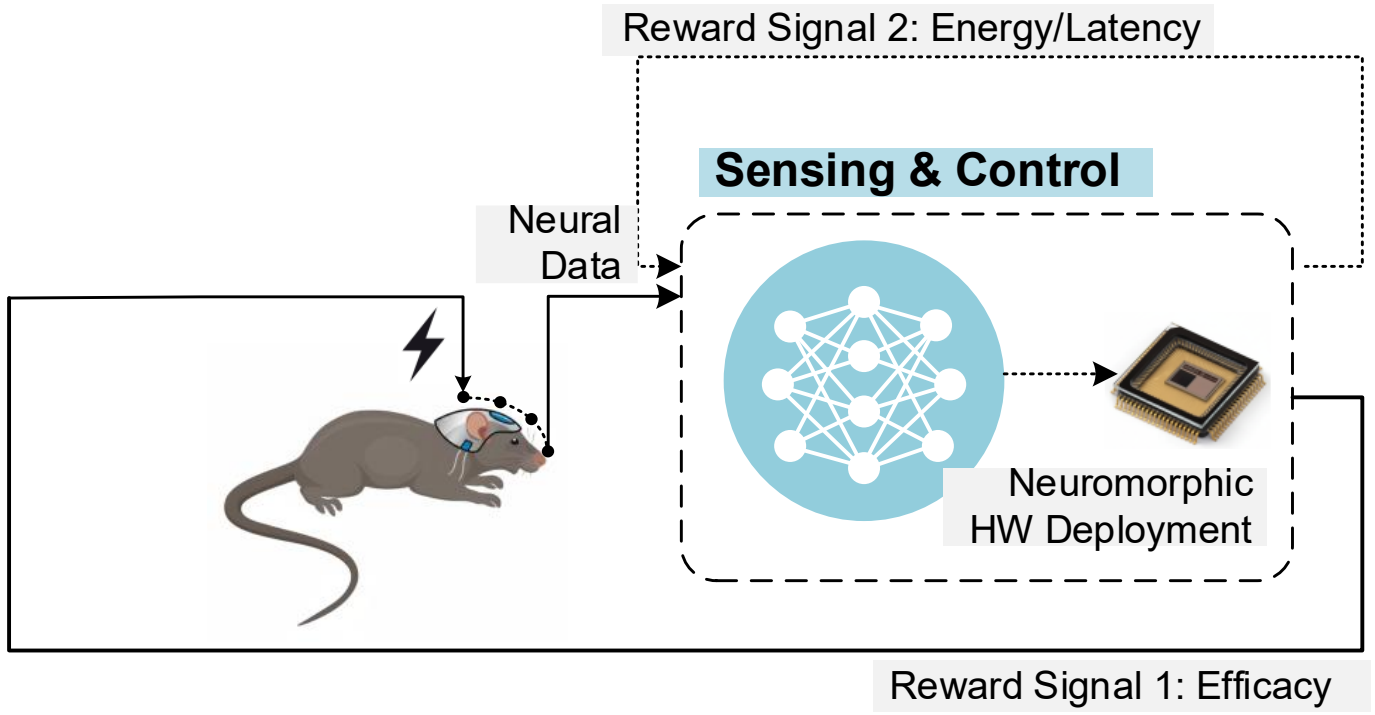

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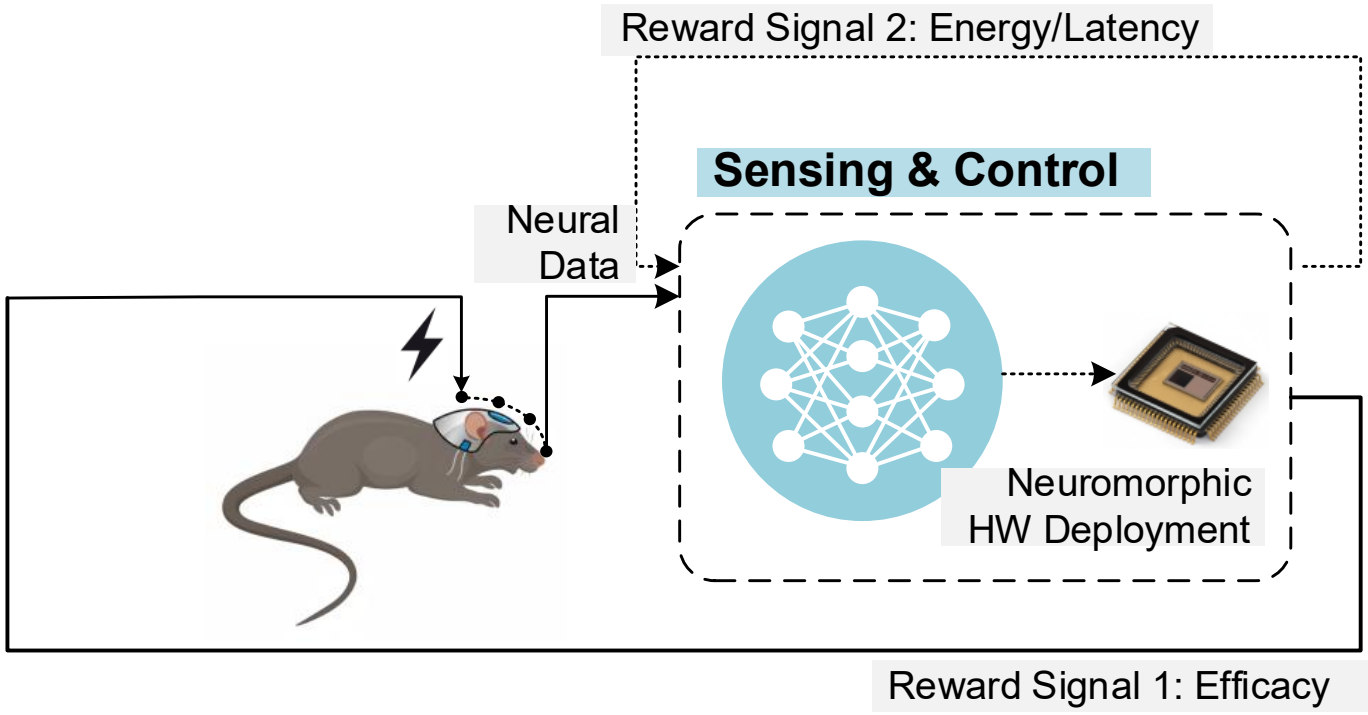

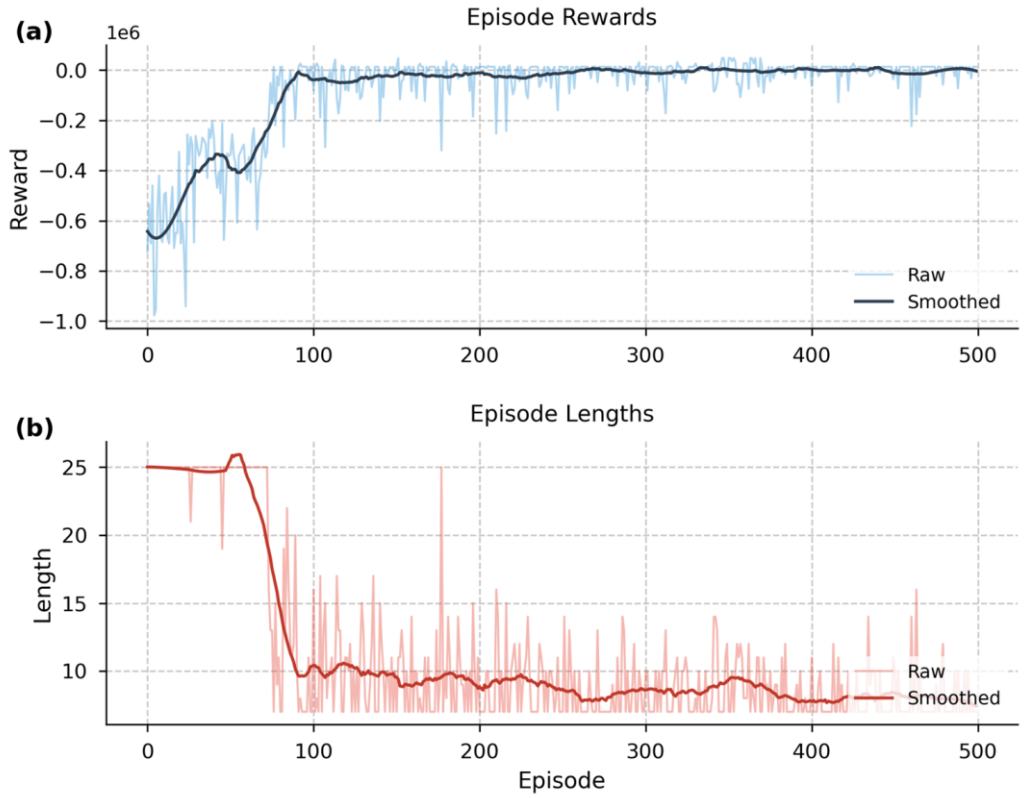

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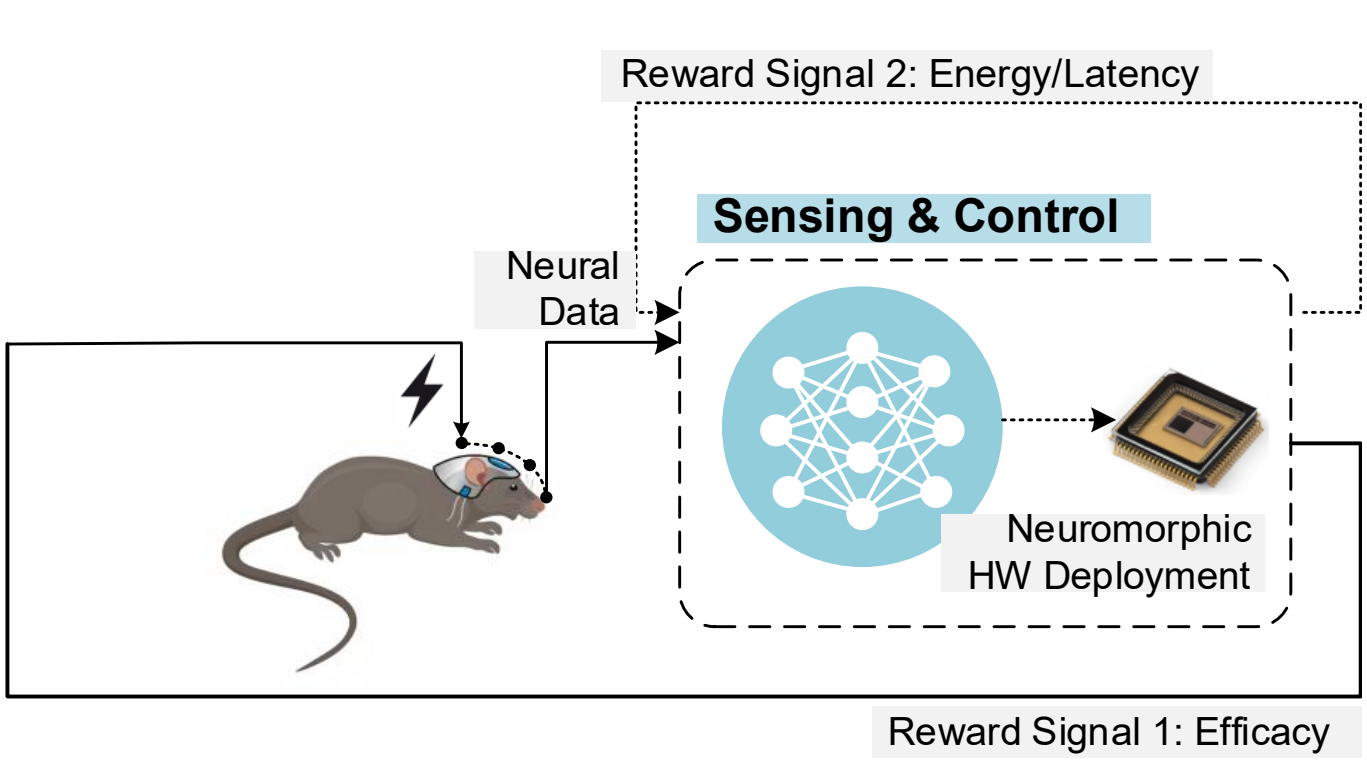

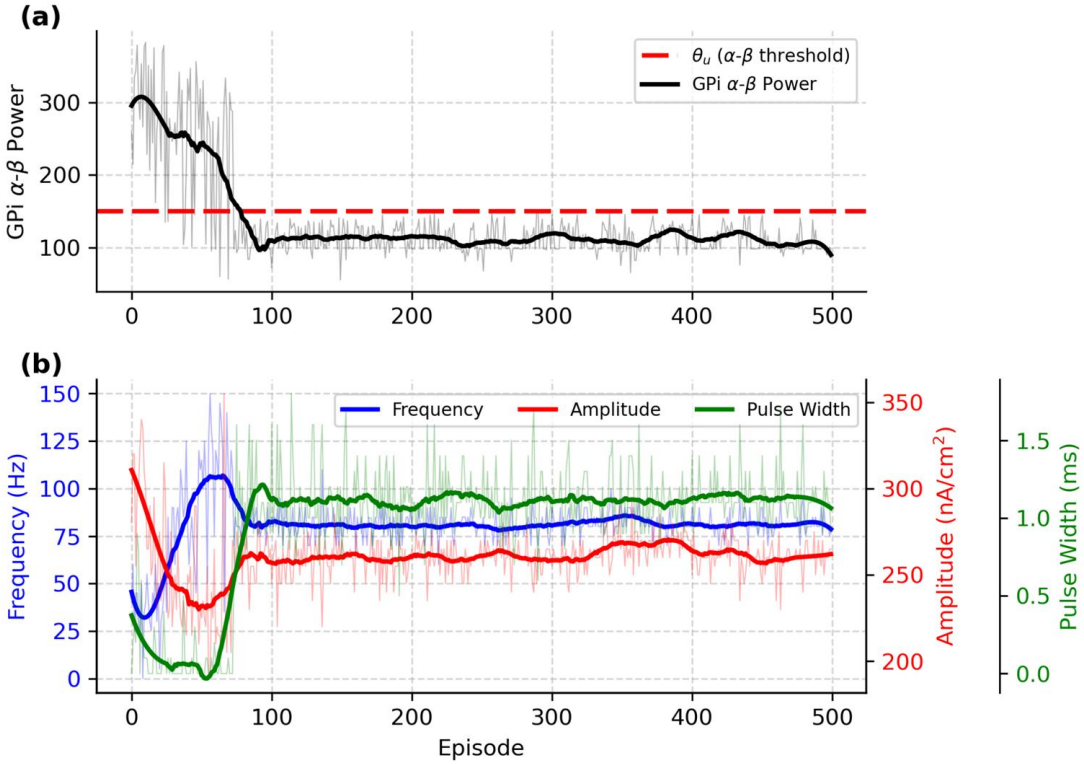

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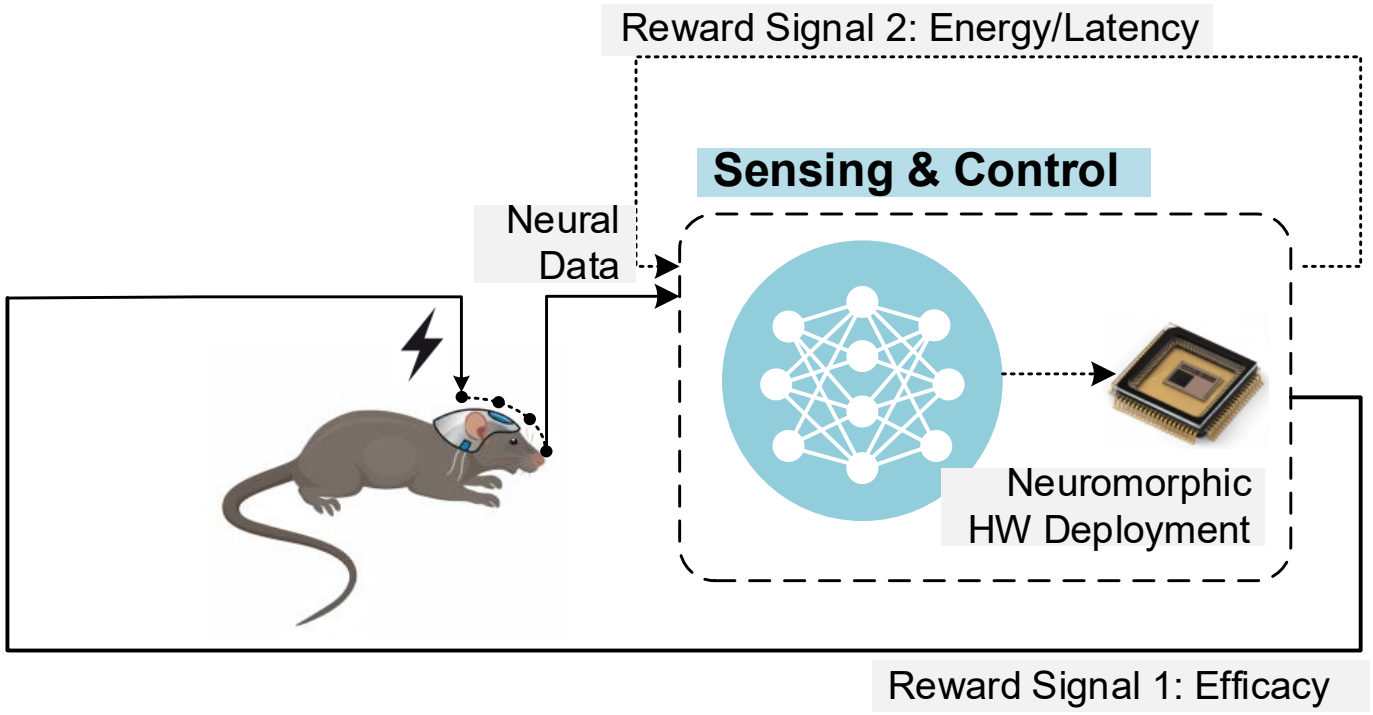

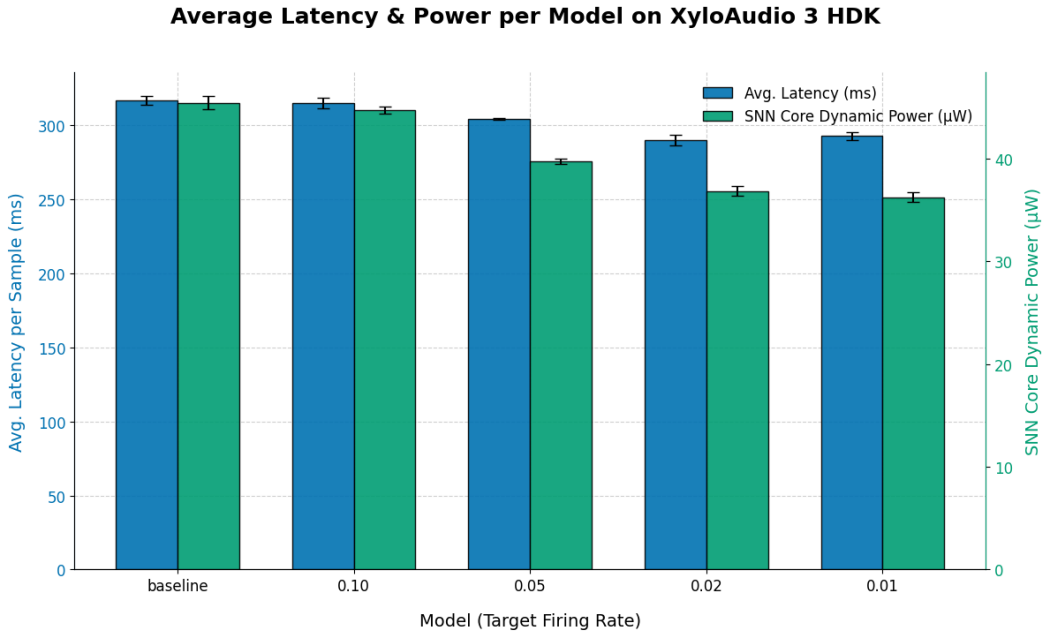

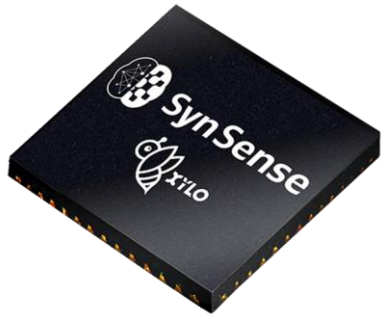

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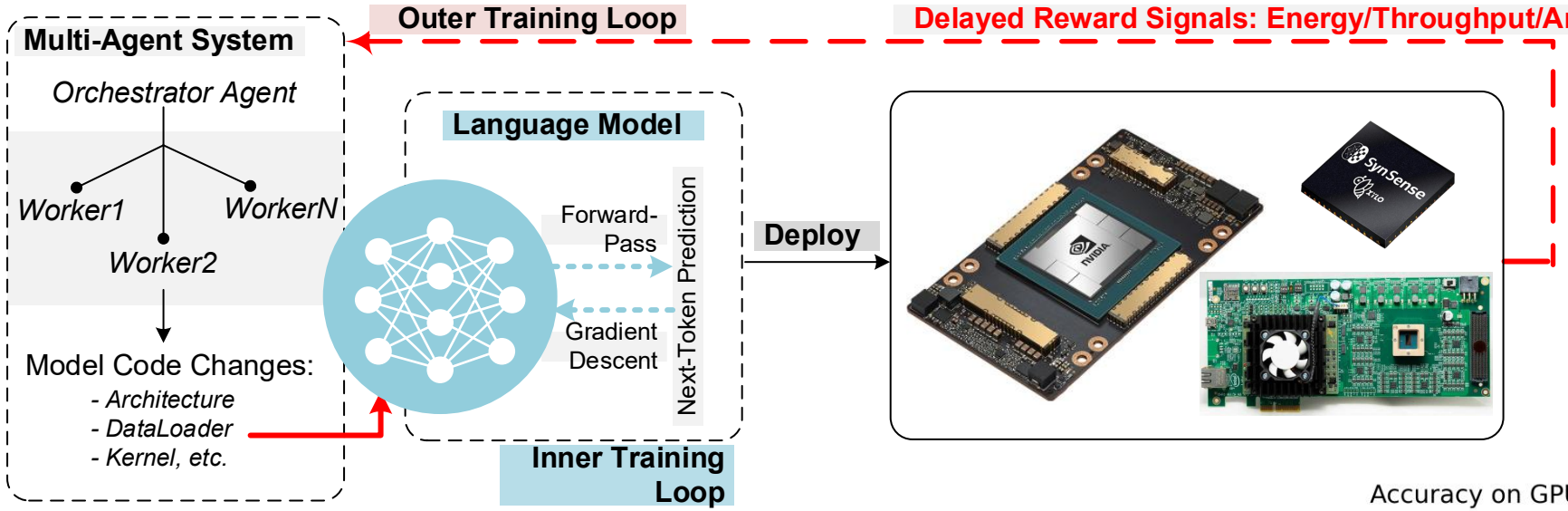
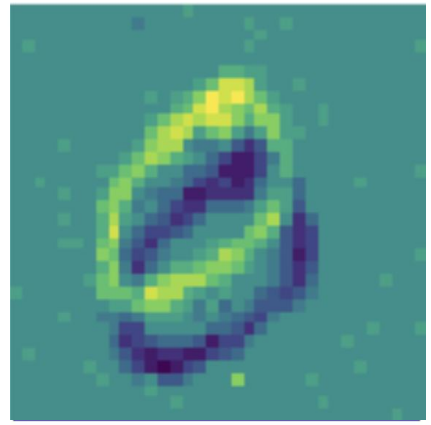
Energy-Aware Learning

Beyond Neurostimulation

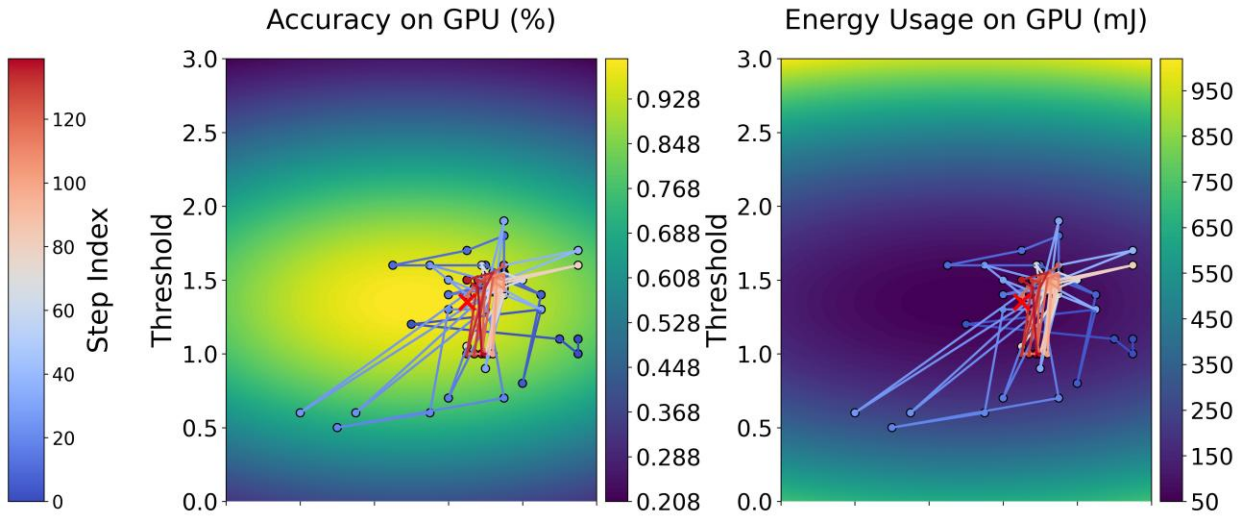




Toy experiments on RTX 4090

This agentic approach to energy-aware learning took a couple of hours to integrate the N-MNIST dataset to <10 time-steps

The neuromorphic community took ~4 years to come to the same realization.



UCSC Neuromorphic Computing Group

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