



# Implementation of Dragonfly Interception Model on Neuromorphic Hardware



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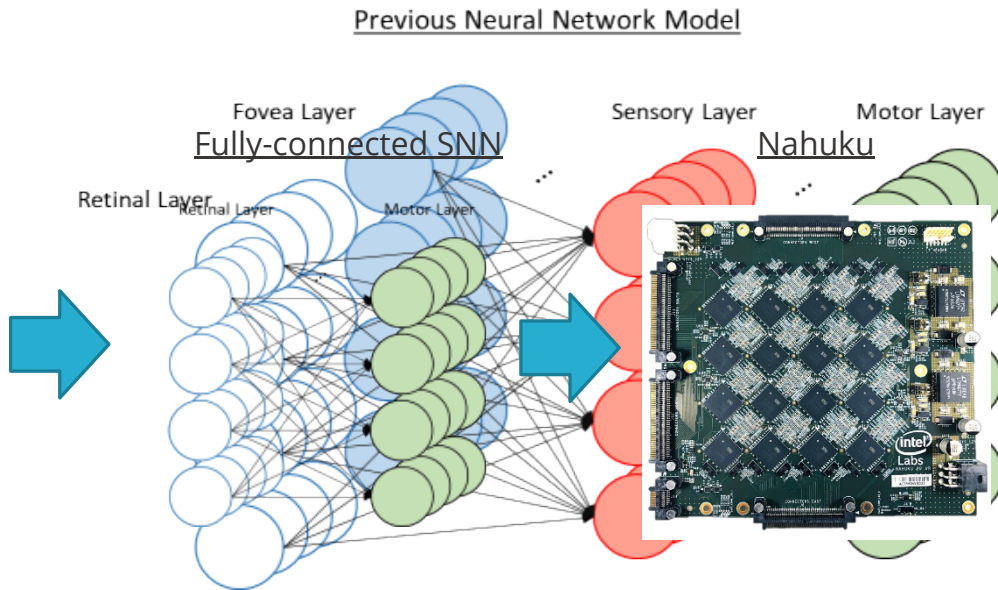


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# Towards Dragonfly Interception using Intel's Loihi



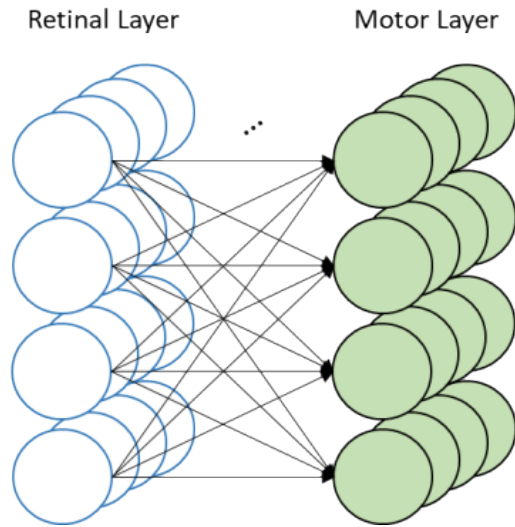
Dragonfly



Previous work<sup>1</sup> has proposed a dragonfly-inspired neural network model that calculates guidance for prey-interception.

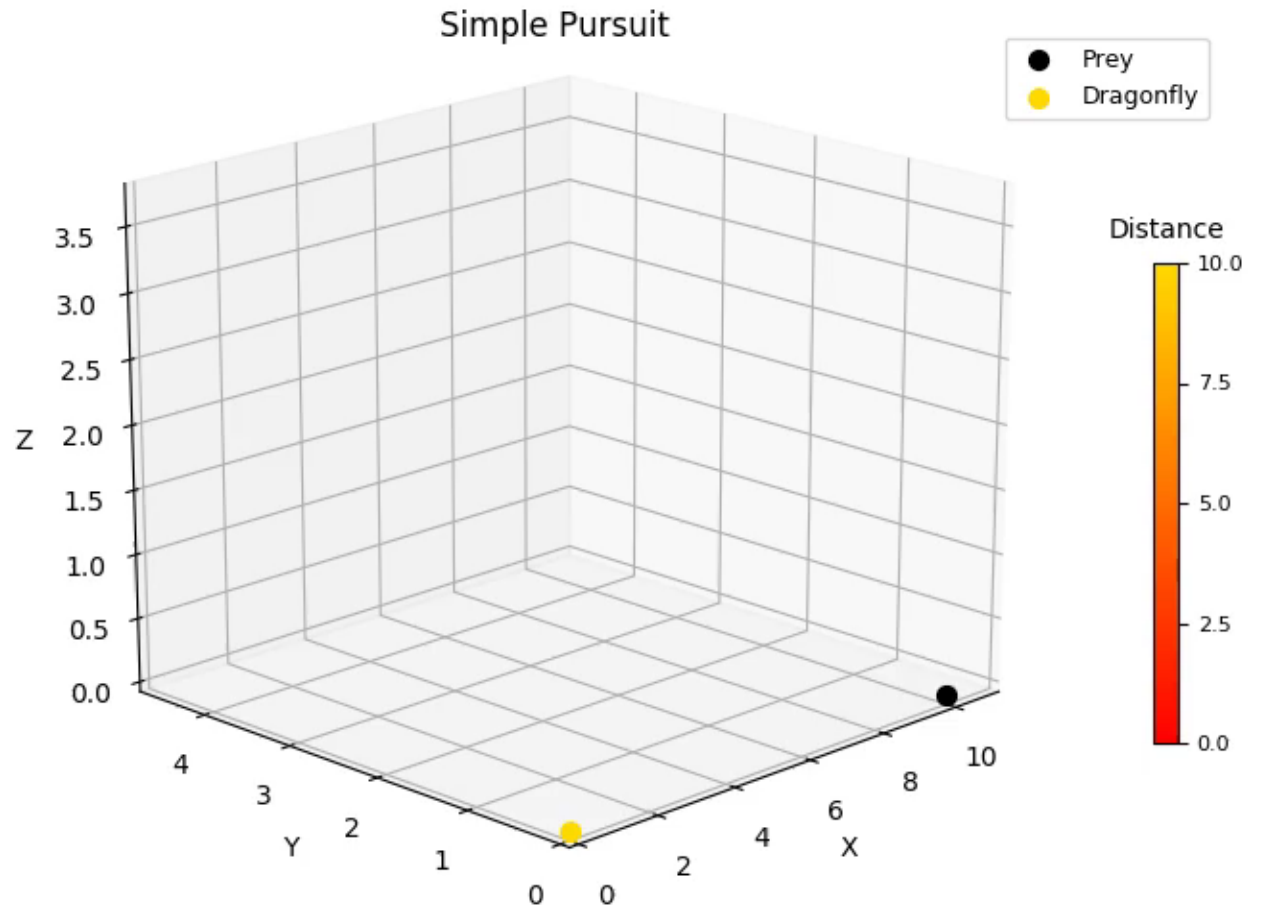
1. Can this bio-inspired model be implemented on a bio-inspired device?
2. What possible platform constraints might limit the model?
3. Would implementation on a neuromorphic device increase the model's computational efficiency?

# Simplified Spiking Neural Network

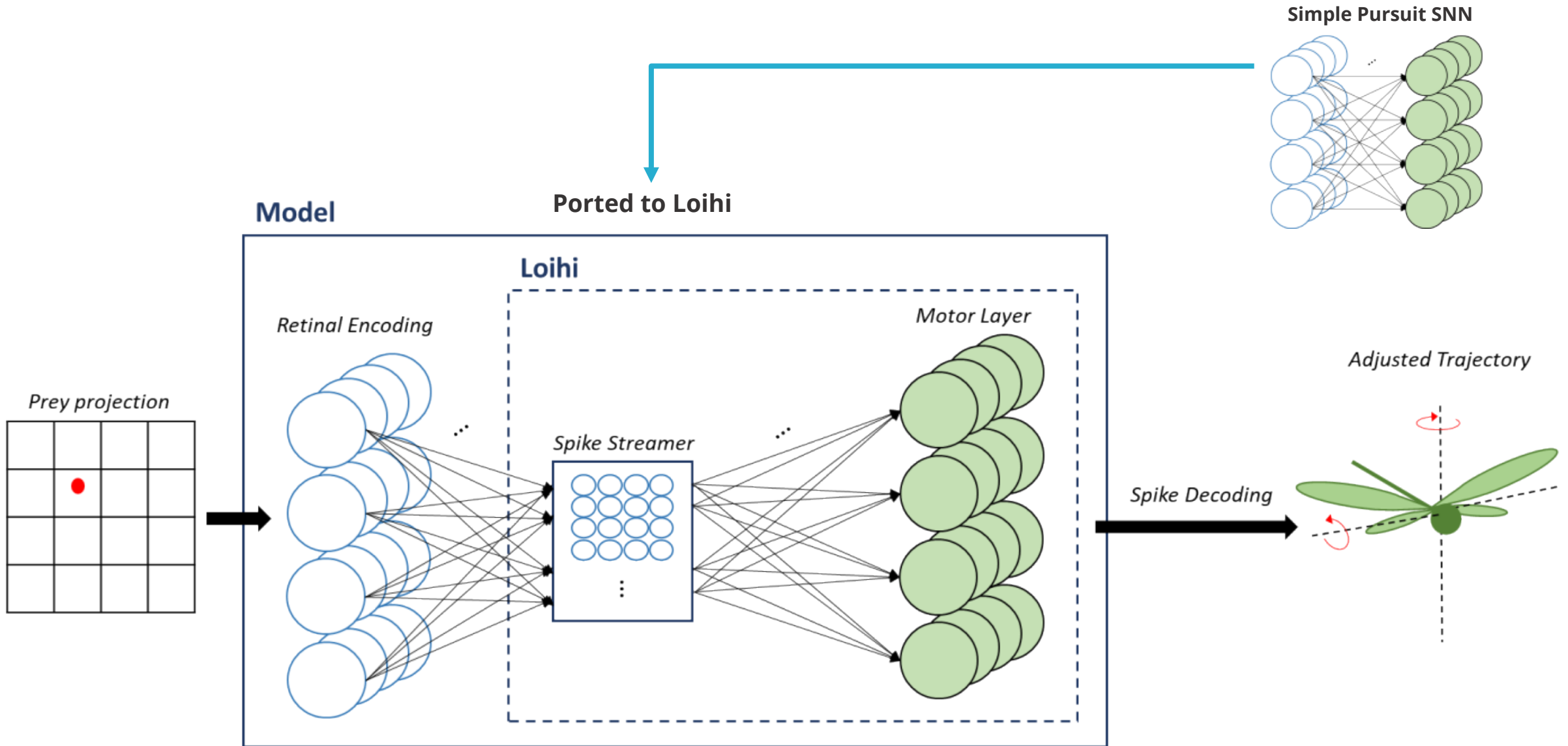


## Simplified SNN Implementation

- Performs simple pursuit
- Retinal layer receives external stimulus encoded in spikes off-network
- Motor layer output is in spiking domain and decoded as continuous values off-network
- Layers of SNN are configured as  $N \times N$  grids



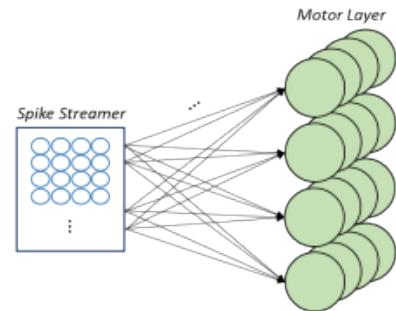
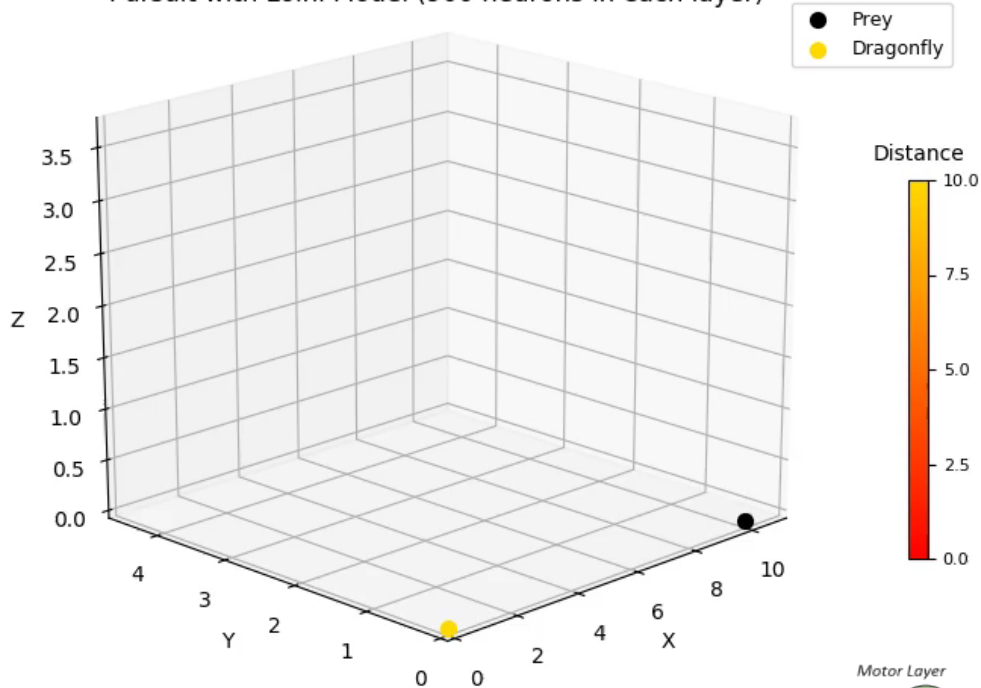
# Experimental Model of Simple Pursuit with Loihi



# Porting the SNN Model to Loihi



Pursuit with Loihi Model (900 neurons in each layer)



*Nahuku, a Loihi development board, is the neuromorphic device used in this project. Our board houses 8 chips, capable of implementing up to 1 million neurons and 1 billion synapses.*

## Using Loihi in the Model

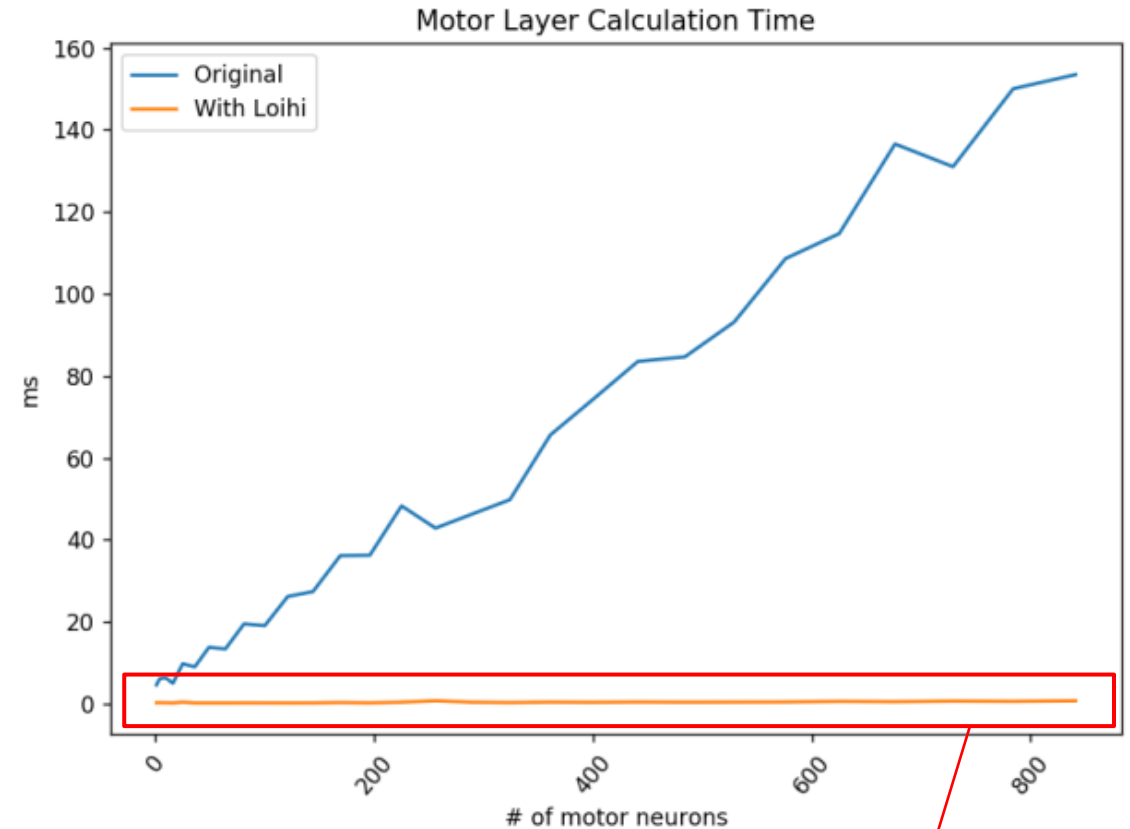
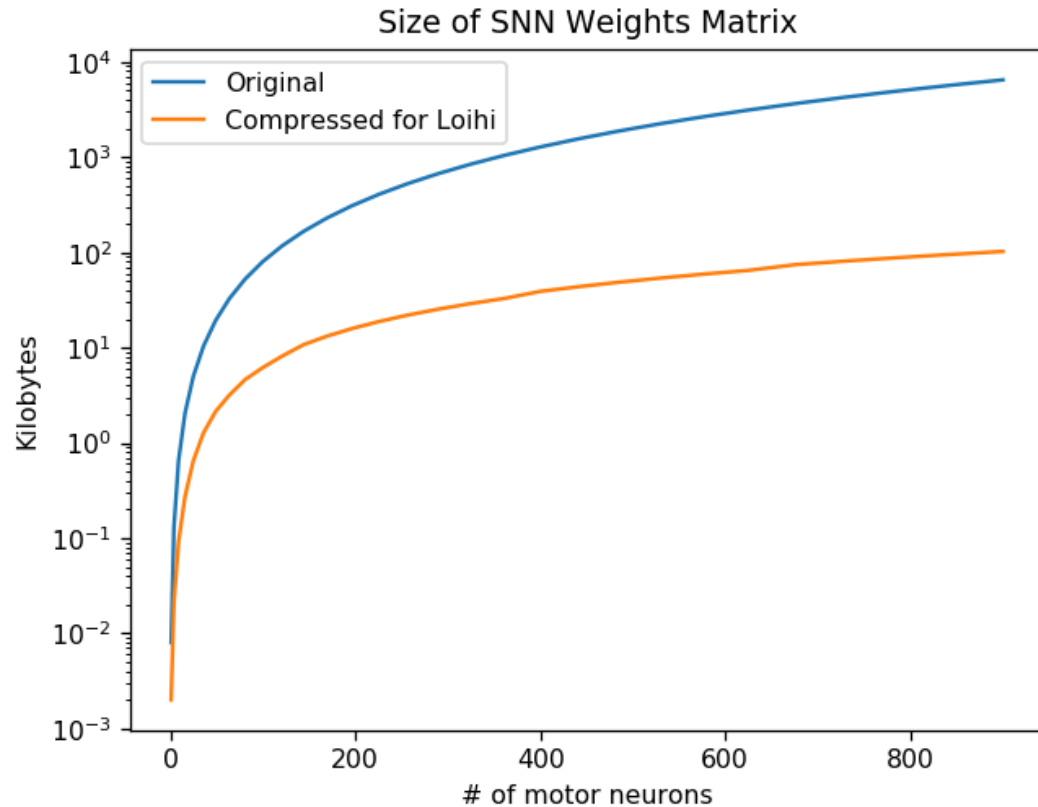
- Only the synapses and motor layer reside on Loihi
- Neurons in motor layer are Integrate-and-Fire neurons, and synaptic input is modulated by the fixed synaptic matrix
- Built-in performance probes are used to evaluate certain metrics on Loihi

## Challenges and Constraints

- Resolving the synchronous simulation environment with Loihi's asynchronous computing mesh.
  - Using the spike streamer allowed the Loihi execution time steps to be fixed to a pre-defined step size (1ms)
- Loihi's synaptic memory block size required that the fixed weight matrix be converted and normalized to 8-bit integer values and compressed with a dense compression algorithm
- Scaling the network beyond a single Loihi core (1024 neurons, 128KB of synaptic memory)

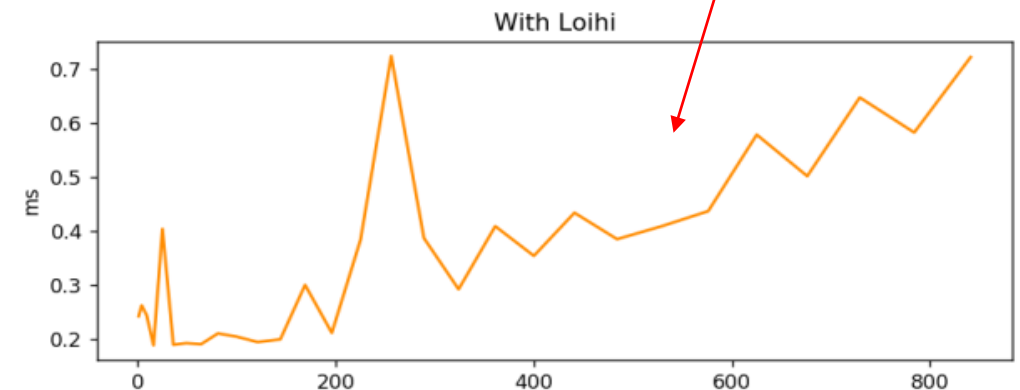
# Performance Evaluation

All Loihi networks were placed across 24 neurocores and utilized 1 embedded CPU



## Key Takeaways:

- Physical size of weight matrix is substantially smaller on Loihi implementation
- Motor Layer calculations are performed much faster in the Loihi motor layer



## Remaining Challenges



- Properly distributing the network on Loihi to see if the previous results hold with larger scale
- The implementation of more complex neuron primitives
- Experiments that compare current retina layer encoding and calculation with the possible substitution of a natively spiking vision sensor, such as a DVS camera
- An investigation of power used by the network in both off- and on-Loihi implementations
- Configuring the Loihi network to provide motor output without needing to be synchronized with the external simulation environment

## Current

**Simplified SNN Implementation**

- Performs simple pursuit
- Assumes input is provided by external device that frontloads preprocessing
- Motor layer output is in spiking domain and decoded as continuous values off-network
- Layers of SNN are configured as  $N \times N$  grids

## Next Steps

**Using a DVS Camera**

- Substitution of the current input generator with an external device that provides spikes to the network, such as a DVS camera

**Full SNN Implementation**

- Extend the Loihi network to its full implementation that accounts for more parameters



THANK YOU



1. Frances S. Chance. 2020. Interception from a Dragonfly Neural Network Model. In International Conference on Neuromorphic Systems 2020 (Oak Ridge, TN, USA) (ICONS 2020). Association for Computing Machinery, New York, NY, USA, Article
2. Mike Davies, Narayan Srinivasa, Tsung-Han Lin, Gautham Chinya, Yongqiang Cao, Sri Harsha Choday, Georgios Dimou, Prasad Joshi, Nabil Imam, Shweta Jain, Yuyun Liao, Chit-Kwan Lin, Andrew Lines, Ruokun Liu, Deepak Mathaikutty, Steven McCoy, Arnab Paul, Jonathan Tse, Guruguhanathan Venkataramanan, Yi-Hsin Weng, Andreas Wild, Yoonseok Yang, and Hong Wang. 2018. Loihi: A Neuromorphic Manycore Processor with On-Chip Learning. *IEEE Micro* 38, 1 (2018), 82–99. <https://doi.org/10.1109/MM.2018.112130359>