

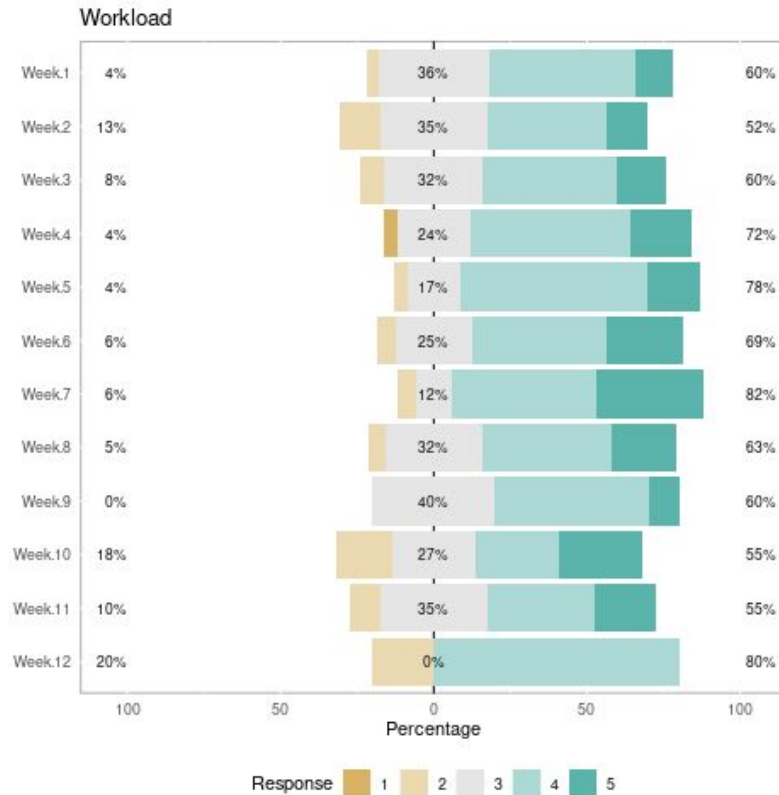
0x18 - Case Study: SNN Accelerator

ENGR 3410: Computer Architecture

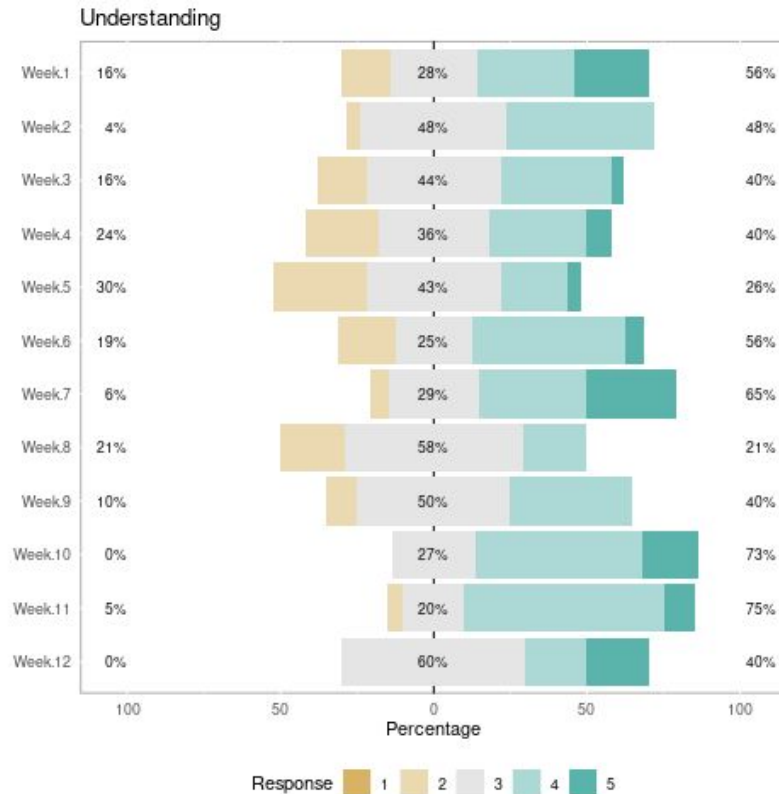
Jon Tse

Fall 2020

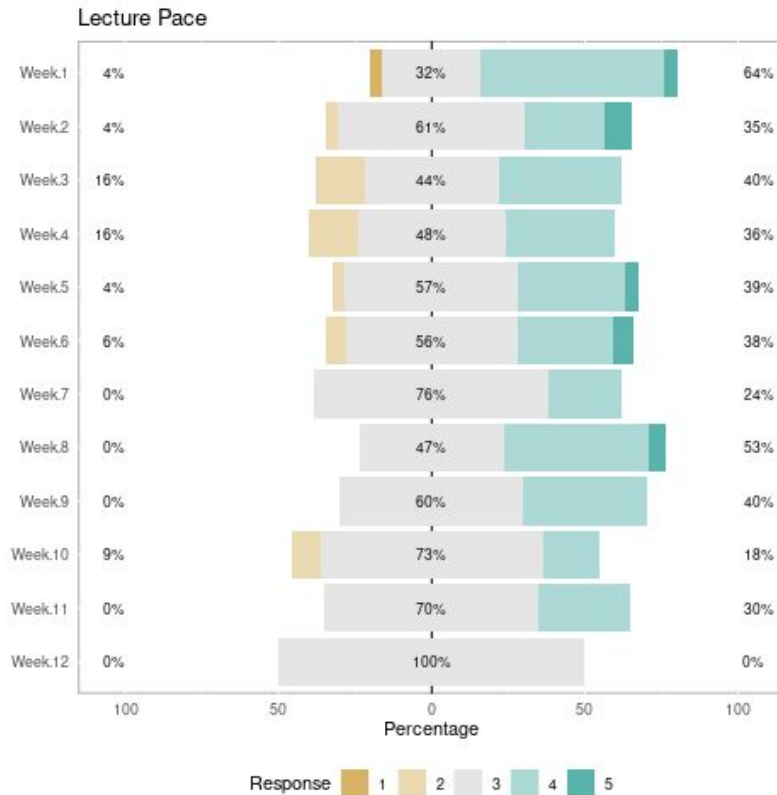
Feedback - Workload



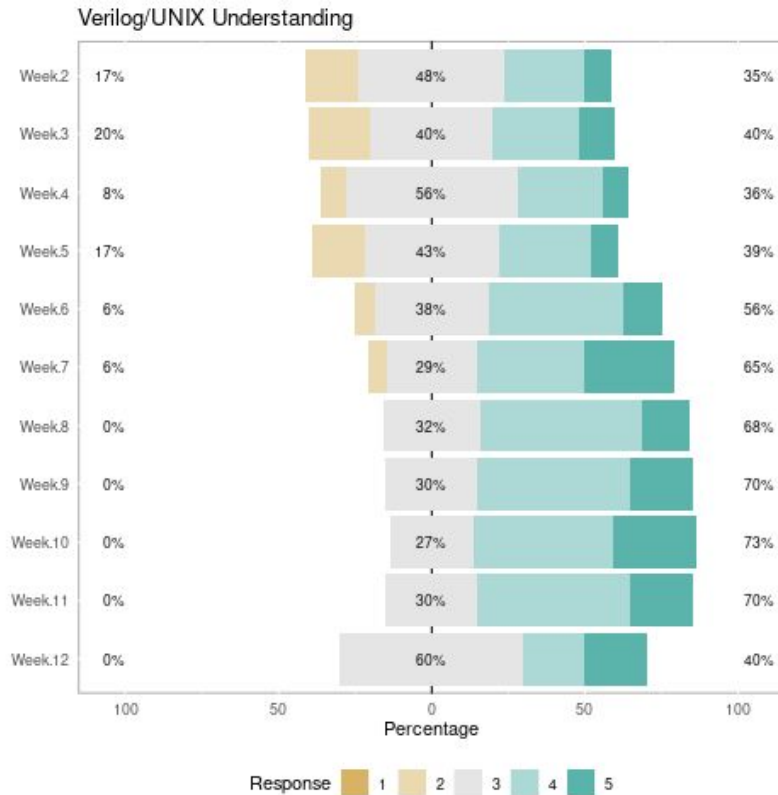
Feedback - Understanding



Feedback - Pace



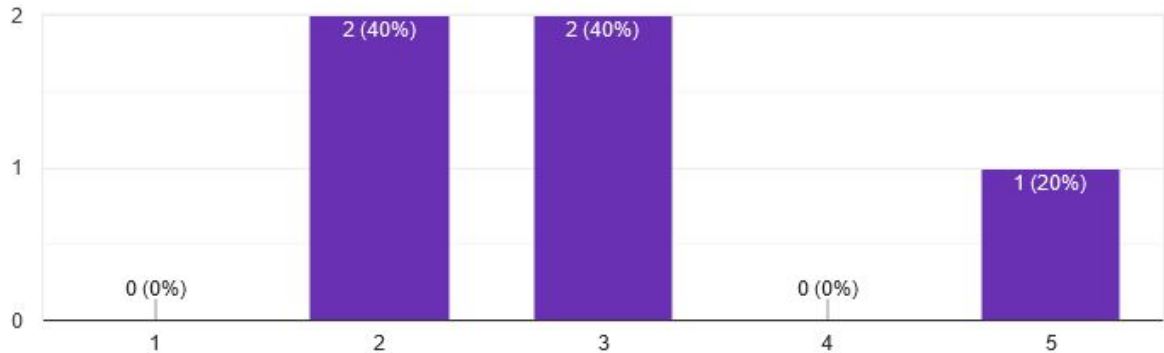
Feedback - Tools



Feedback - Final Project

How is work going on your final project?

5 responses



Feedback - Top of Mind

Anything else on your mind?

2 responses

Happy Thanksgiving!

Final project things are going well! Assembly programs are fun!

Housekeeping

- Write Up Draft due Dec 14, Midnight Eastern
- Presentation Dec 15/17 during “class time”
 - Sign up in the Google Spreadsheet
 - Conflicts/special casing, please email me.
- Final Write Up (if necessary) due Dec 18.
- NINJAs moving to “on call” hours. Use Slack.
- Wrap up and AMA Thursday

Final Projects

GPU History

Conway's Game of Life

MIPS GPU Coprocessor

SPI Coprocessor

CPU/GPU Benchmarking

Multi-core CPU

Encryption

Caches

Extend Lab 4

Minecraft ALU

Snake in Assembly

Oversimplified

Intro to Neuromorphic Computing

- Machine Learning
- Deep Learning
- Spiking Neural Networks

Machine Learning

Explicit Programming

- Most software
- If this, then that!
- Can inspect algorithm
-

Machine Learning

- Current buzzword
- Data and statistics of data foundation
- Algorithm hard to inspect
- Emergent behavior

Examples of Machine Learning

- Classification
 - Labeling data
 - “This is a photo of a cat.”
 - “This email is spam.”
- Clustering
 - Grouping data points
 - Spotify song recommendations.
 - Video recommendations on YouTube.

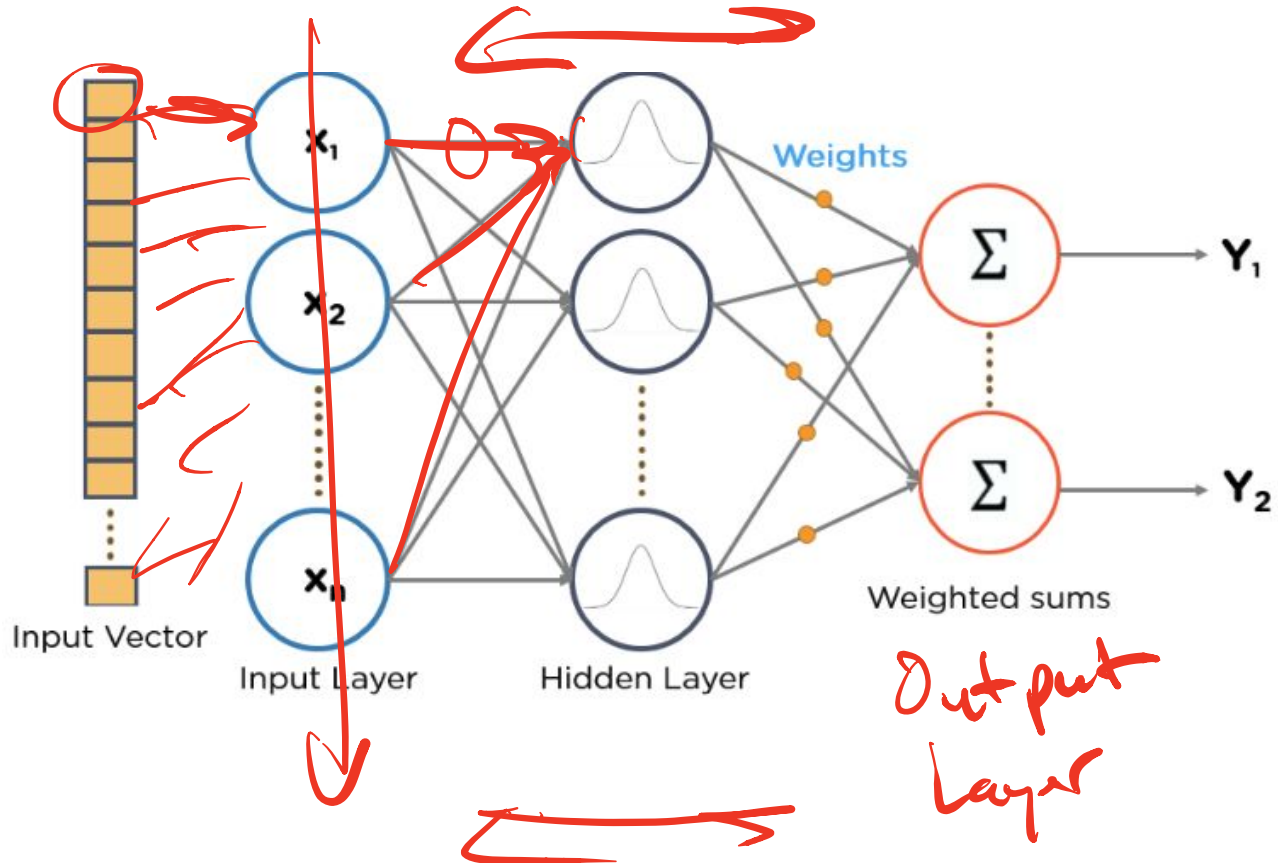
Types of Machine Learning

- Supervised Learning
 - Provide correct examples to learn.
 - ML engine generalizes rules based on examples.
- Unsupervised Learning
 - Provide raw data and maybe some metadata
 - ML engine returns some guesses at patterns.
- Reinforcement Learning
 - Unsupervised learning + some feedback
 - e.g. learning to play a video game

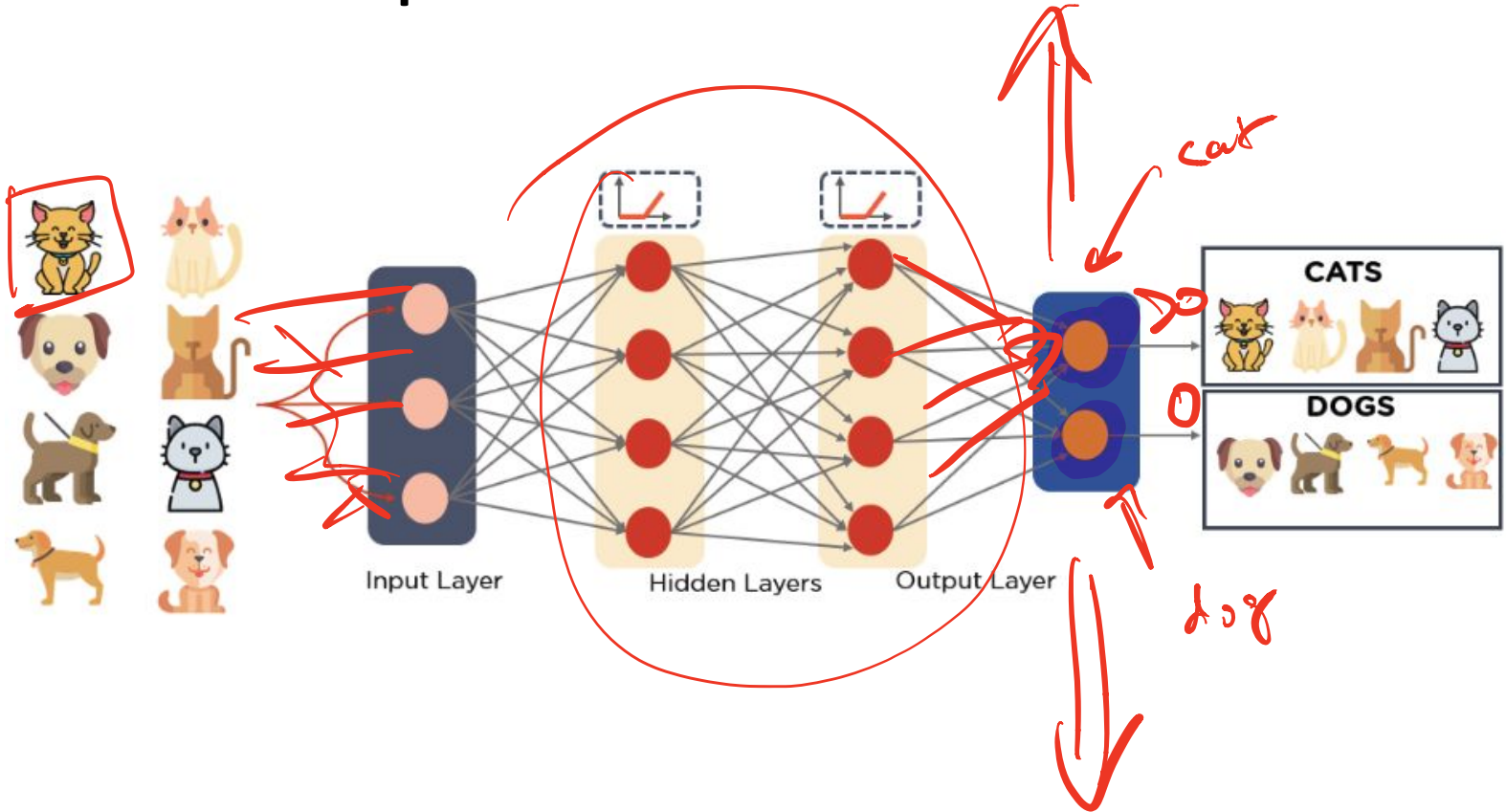
Deep Learning

- One form of Machine Learning
- Bio-inspired
- Uses “Artificial Neural Networks”

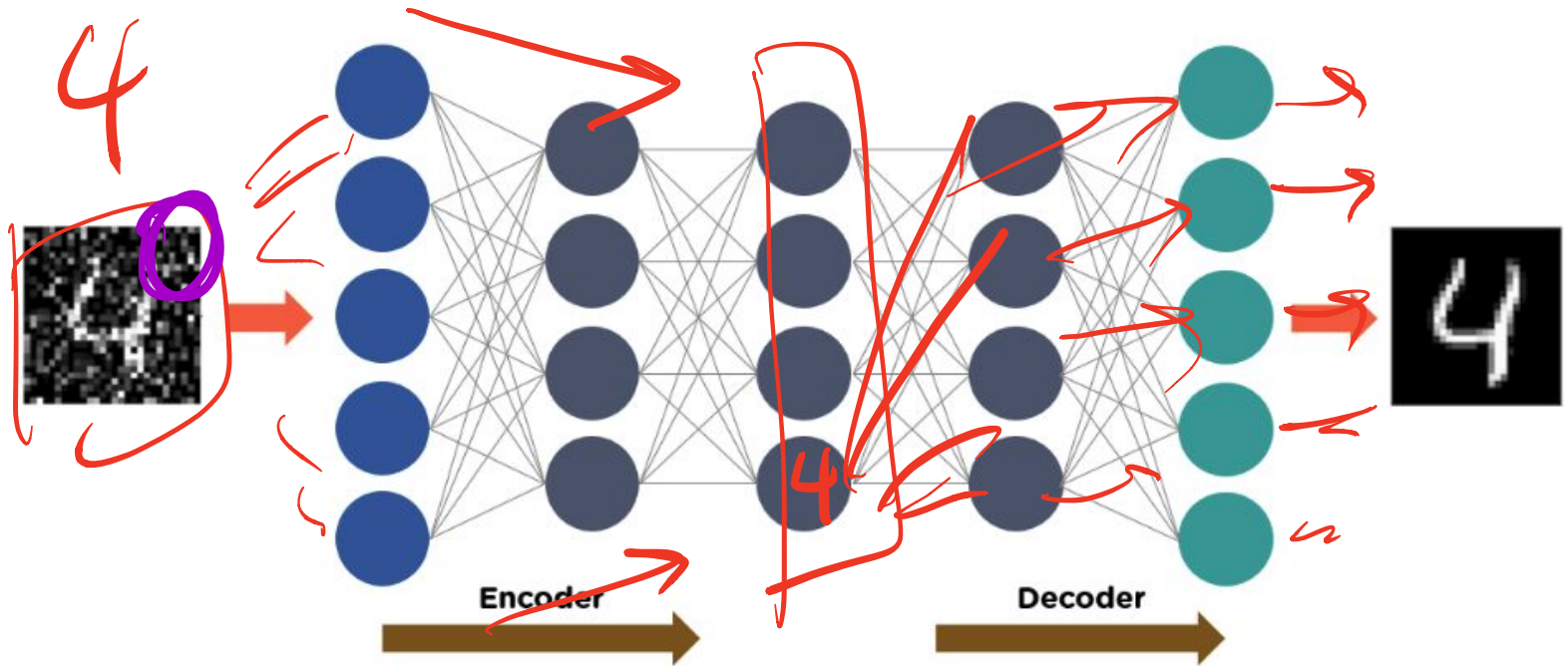
Example of Deep Learning ANN



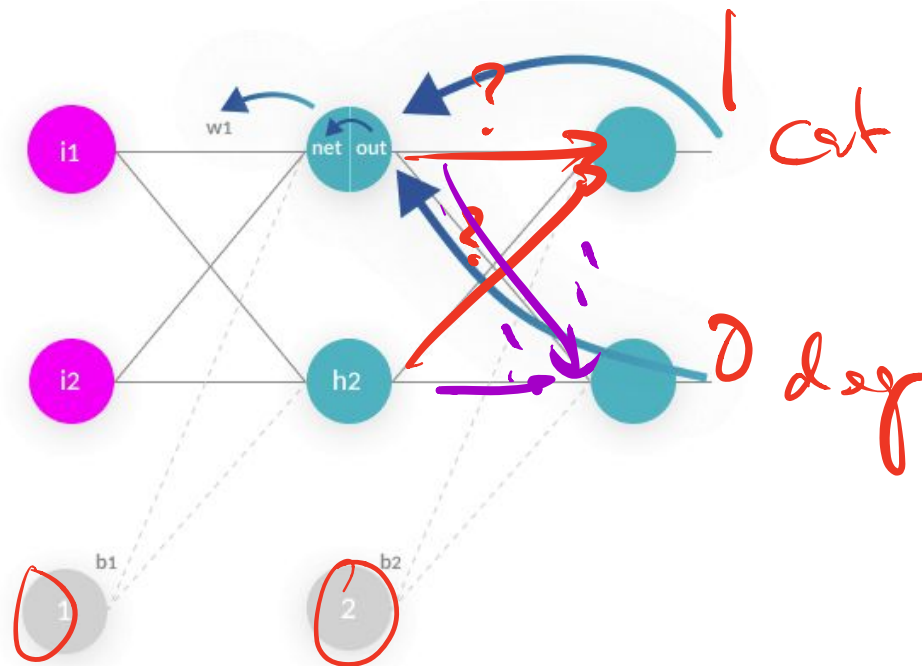
Example - Cat Photo Classifier



Example - Image Denoiser

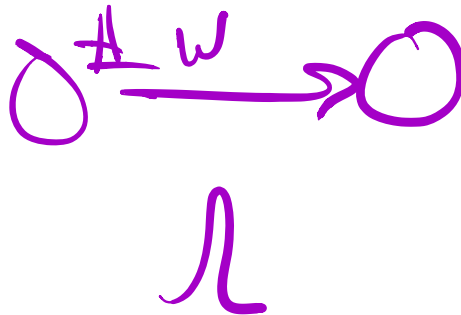


How: Backpropagation

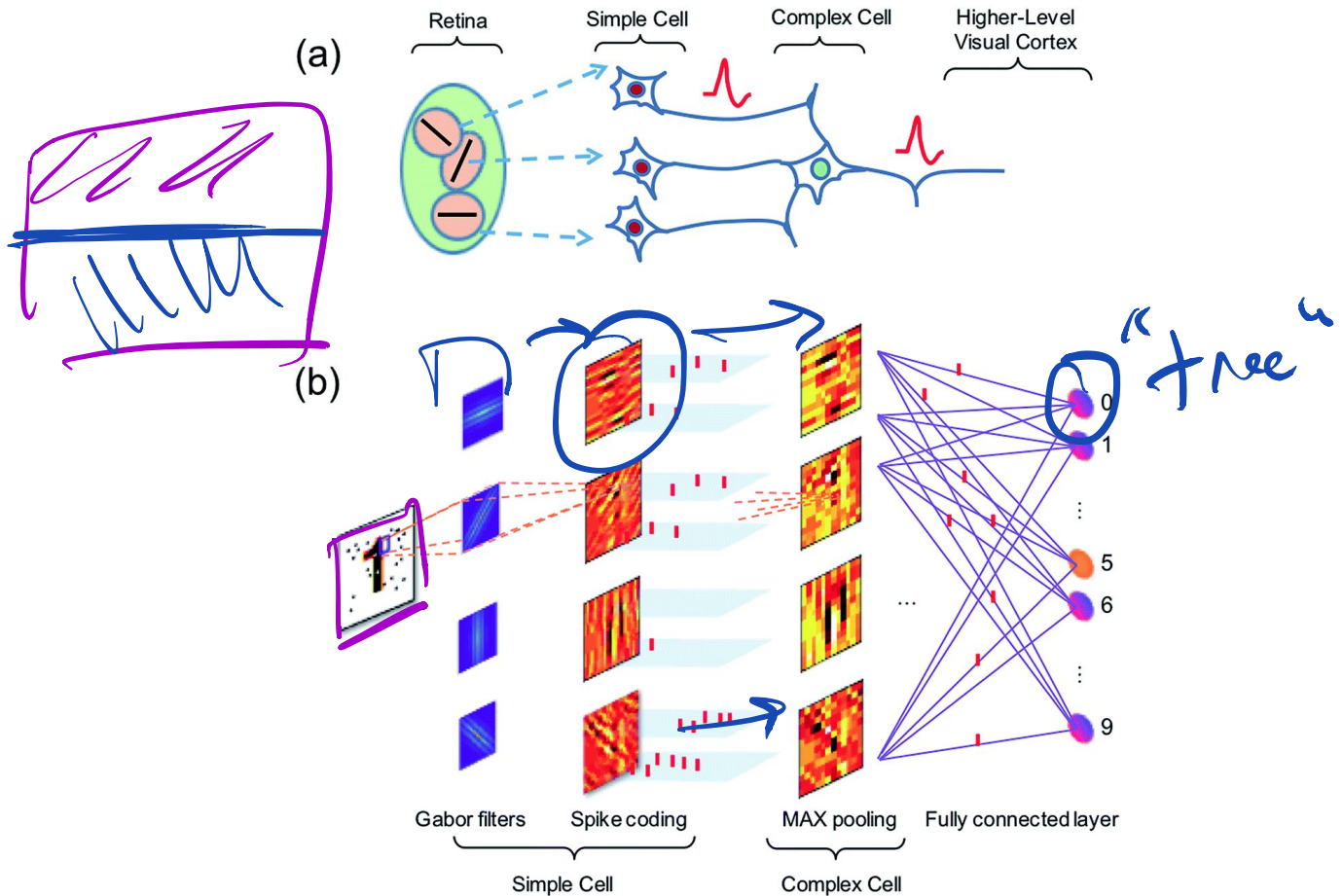


Spiking Neural Networks

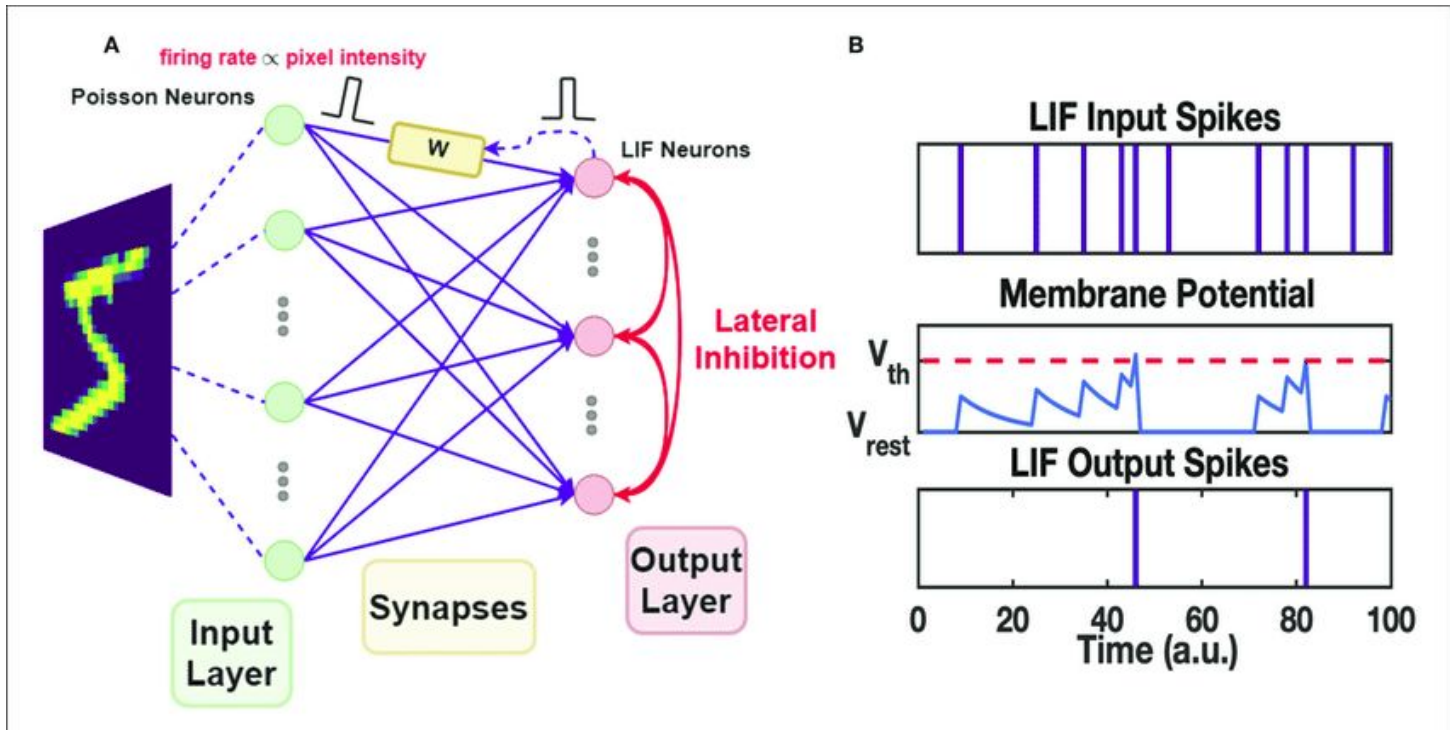
- Another form of Machine Learning
- Bio-*mimetic*
- Uses “Spiking Neural Networks”



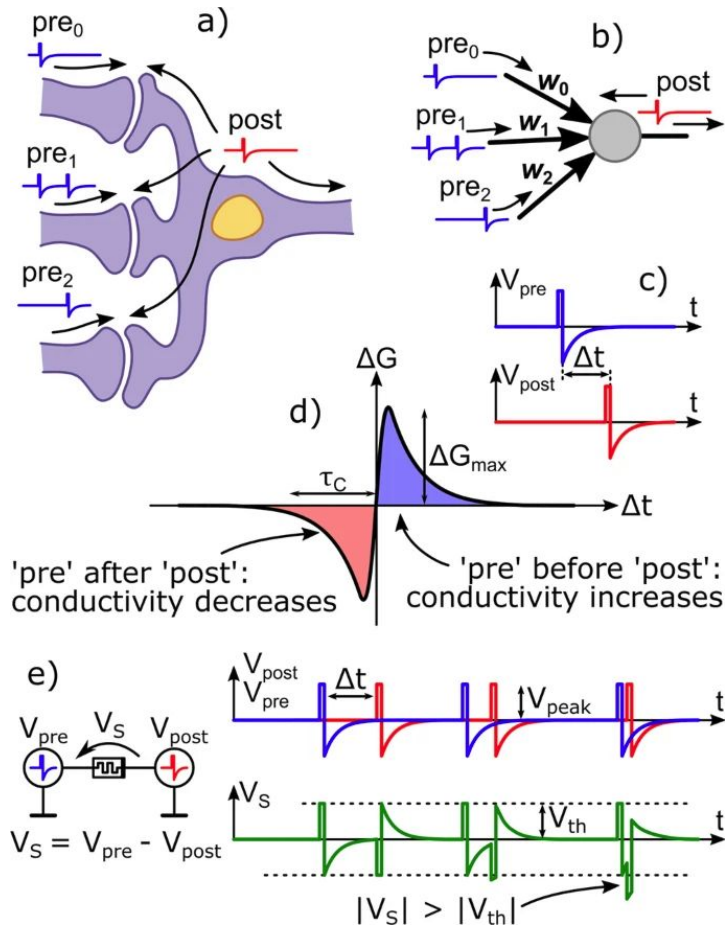
Example - Visual System



Example - Image Classifier



Training



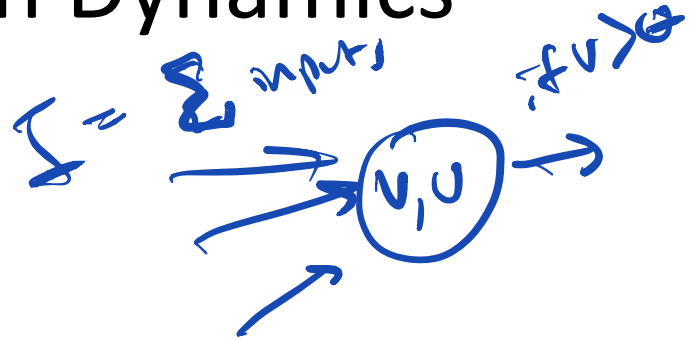
Let's Build One!



- Simulate Neuron Dynamics
- Simulate Synapse (connection) dynamics
- Wire it all up!

Step 1 - Neuron Dynamics

- What model?
 - Hodgkin-Huxley
 - Izhikevich
 - LIF - Leaky Integrate and Fire



two differential equations

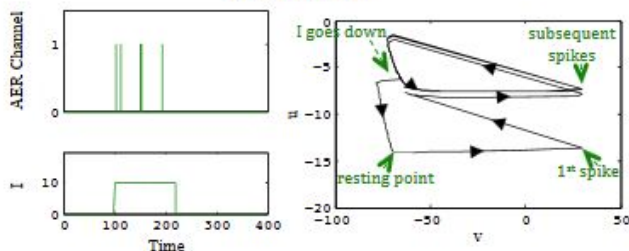
$$\begin{aligned} v' &= ev^2 + fv + g - u + I & (1) \\ u' &= a(bv - u) & (2) \end{aligned}$$

with an after-spike reset.

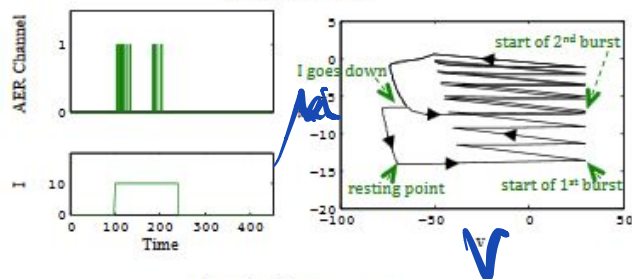
$$\text{if } v > \theta, \text{ then: } v = c \text{ and } u = u + d \quad (3)$$

Step 1 - Neuron Dynamics

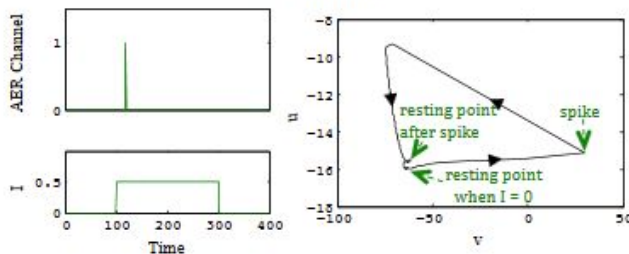
Tonic Spiking



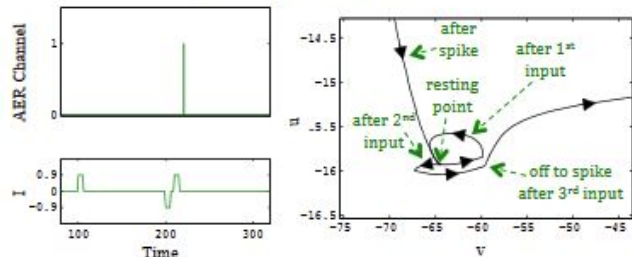
Tonic Bursting



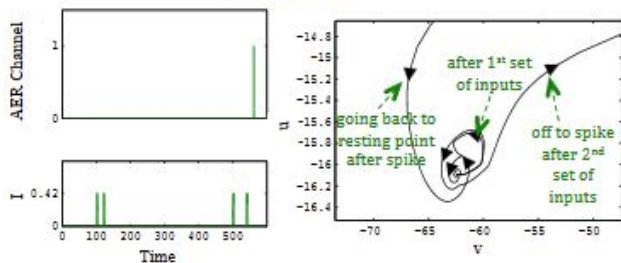
Phasic Spiking



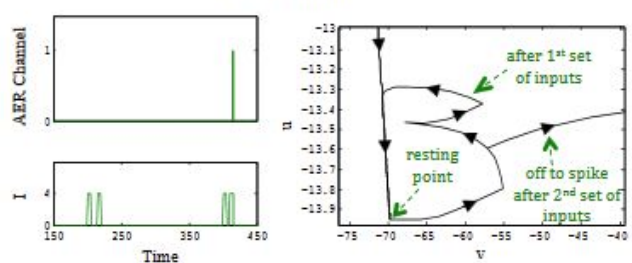
Threshold Variation



Resonator



Integrator

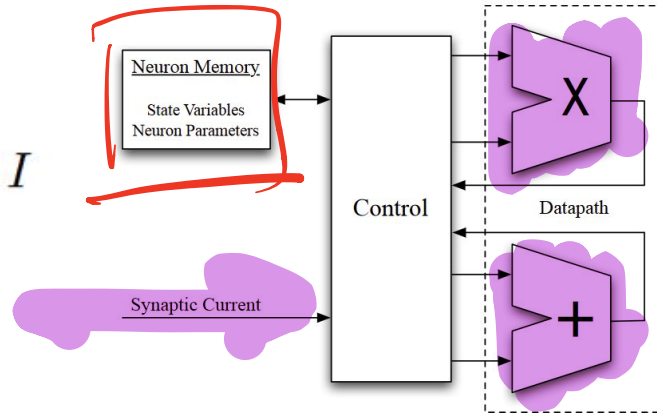


Step 1 - Neuron Dynamics

mult

$$v' = ev^2 + fv + g - u + I$$

$$u' = a(bv - u)$$



Step	Multiplier	Adder
1	ev	$g - u$
2	bv	$ev + f$
3	$v(ev + f)$	$bv - u$
4	$a(bv - u)$	$v(ev + f) + g - u$
5		$v + v(ev + f) + g - u$
6		$u + a(bv - u)$
7		$v + v(ev + f) + g - u + I$

Step 1 - Neuron Dynamics

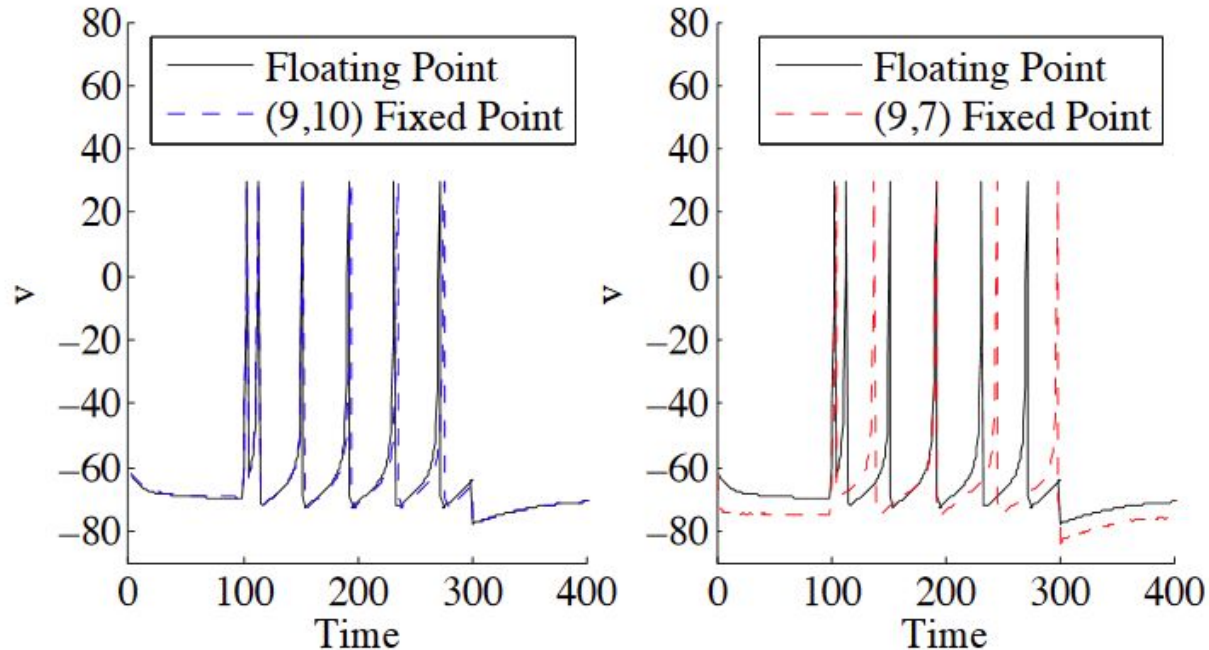
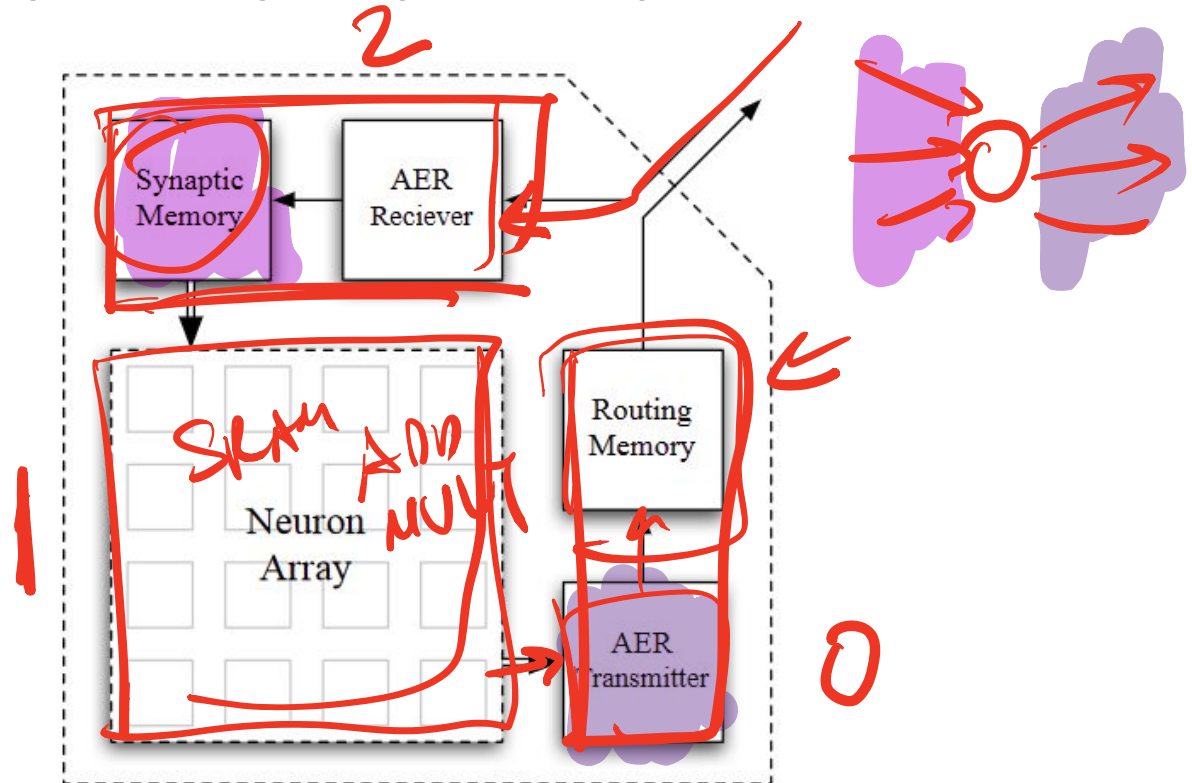


Fig. 7. Fixed- versus floating-point implementations with parameters for tonic spikes. Step current is applied from time 100 to 300. The v and time axes are dimensionless.

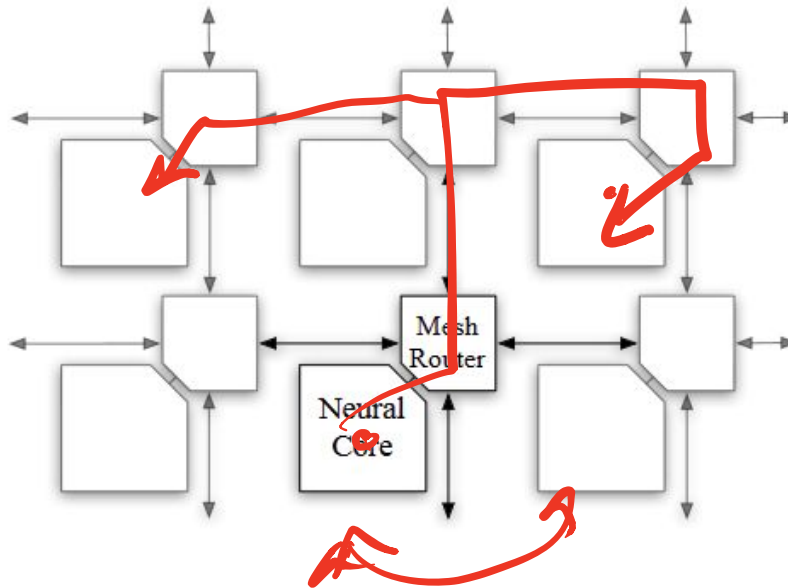
Step 2- Synaptic Dynamics

- Typical Neurons have 10^3 to 10^4 synapses!
- Cannot wire all that up in 2D!
- Solution: Time Domain Multiplex!

Step 2- Synaptic Dynamics



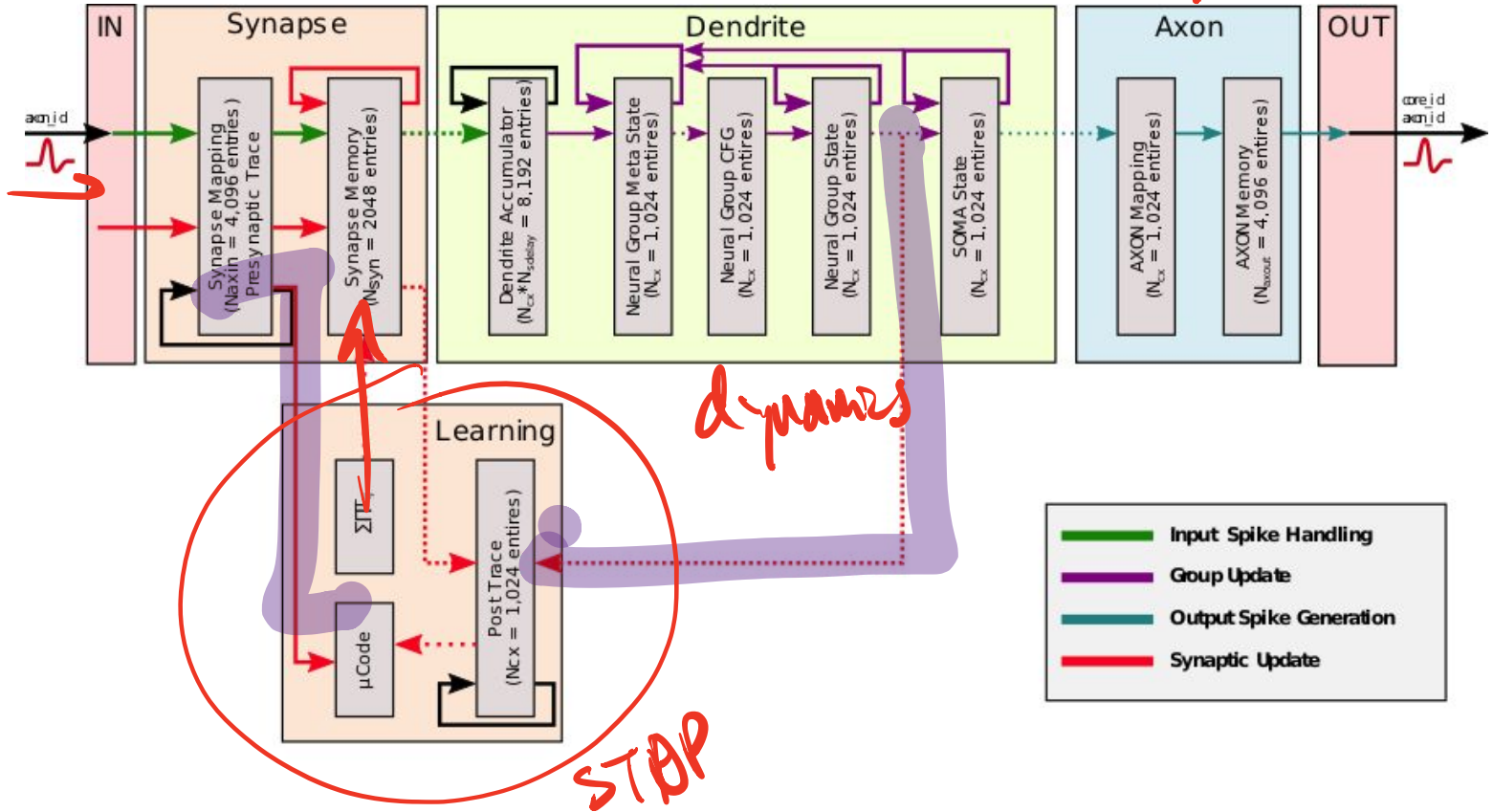
Step 3 - Wire it all up!



Loihi Example

input
control

output
control



Usage Model

- Compute-in-Memory
 - Non von Neumann
 - No virtual memory, so limited capacity
- Compile desired network
 - Place and route, like on an FPGA
 - Stream onto chip
 - Run chip