Dynamic Adaptive Neural Network Arrays: A Neuromorphic Architecture

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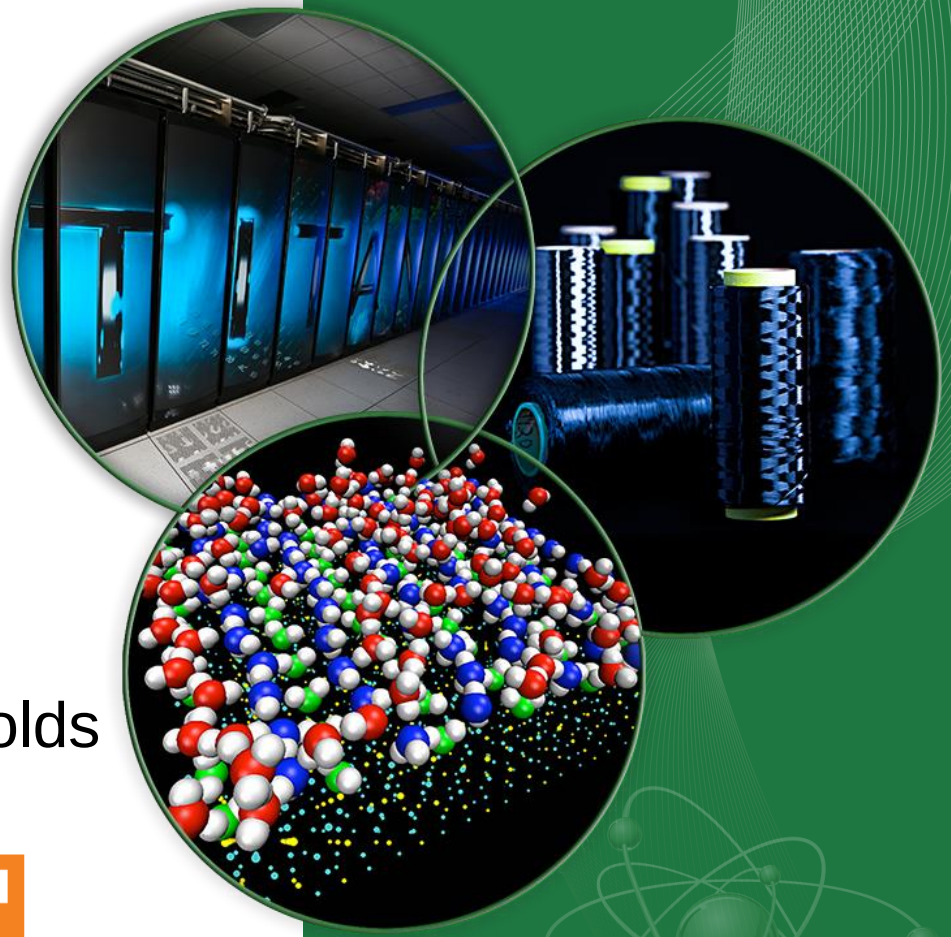

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Neuromorphic Computing

- Neuromorphic computing systems are software/hardware systems that are inspired by biological brains.
  - Neural networks in hardware.
- Goal is to capture some of the important capabilities of the biological brain: real-time processing, generalization of learned information, robustness, adaptability to changes in the environment.
- Neuromorphic hardware: improvements in size/portability, power, computation time and communication costs over neuromorphic simulations.

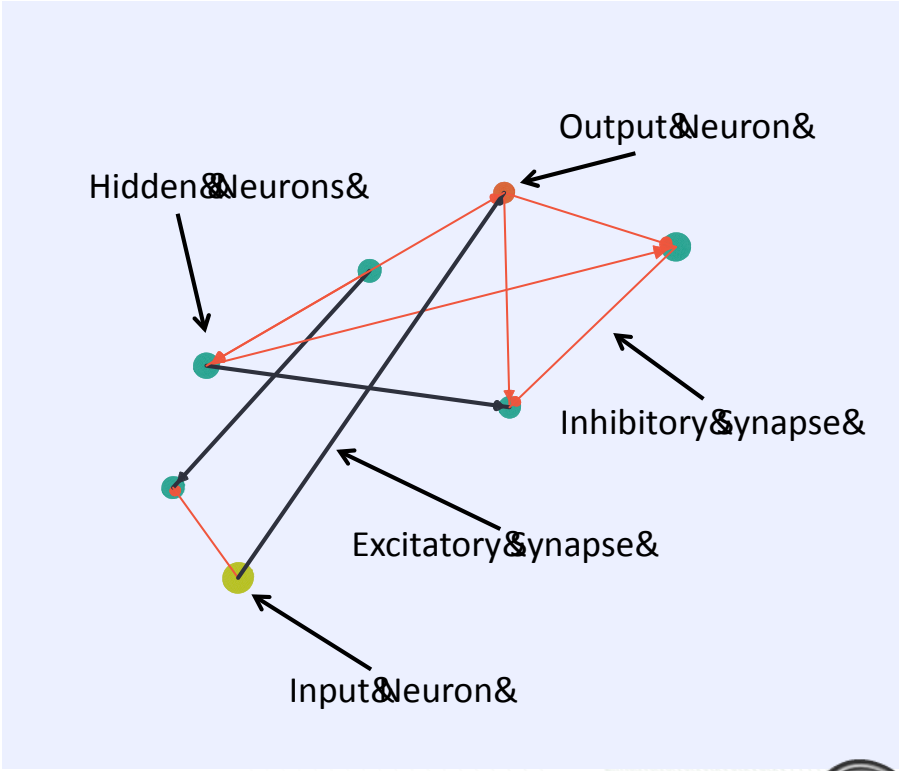
Neuromorphic Computing Projects

Neuromorphic Project	Biology/Computation	Hardware
SpiNNaker[1]	Biology	ARM Boards, Custom Interconnection
BrainScaleS[2]	Biology	Wafer-Scale ASIC
Neurogrid[3]	Biology/Computation	Fabbed using existing processes. Analog components.
TrueNorth[4]	Computation	Fabbed using existing processes.

1. Furber, Steve B., et al. "Overview of the spinnaker system architecture." *Computers, IEEE Transactions on* 62.12 (2013): 2454-2467.
2. Brüderle, Daniel, et al. "A comprehensive workflow for general-purpose neural modeling with highly configurable neuromorphic hardware systems." *Biological cybernetics* 104.4-5 (2011): 263-296.
3. Benjamin, Ben Varkey, et al. "Neurogrid: A mixed-analog-digital multichip system for large-scale neural simulations." *Proceedings of the IEEE* 102.5 (2014): 699-716.
4. Merolla, Paul A., et al. "A million spiking-neuron integrated circuit with a scalable communication network and interf[illegible]" *Science* 345.6197 (2014): 668-673.

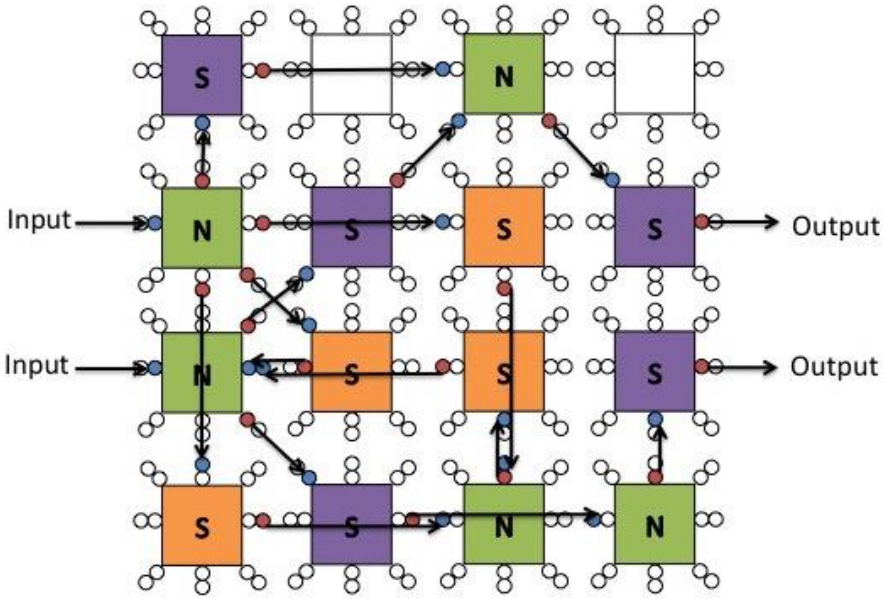
Dynamic Adaptive Neural Network Array (DANNA)

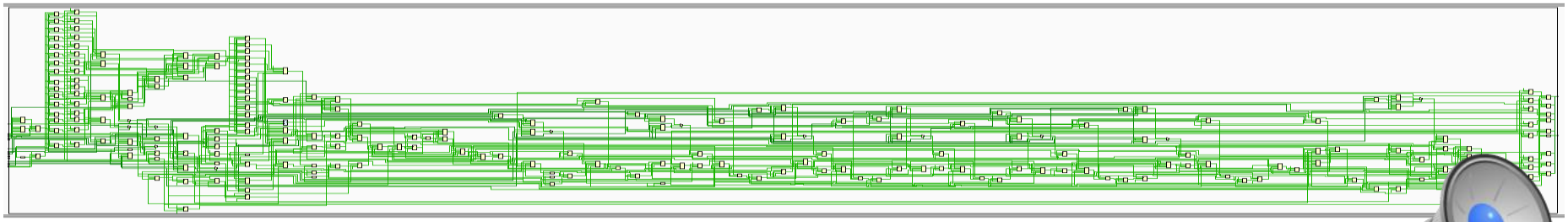
- Implementation of a spiking neural network architecture, Neuroscience-Inspired Dynamic Architecture (NIDA).
- Neuron: threshold and refractory period.
- Synapse: weight, delay, and LTP/LTD.
- Trained/design using evolutionary optimization.



Dynamic Adaptive Neural Network Array (DANNA)

- Array of programmable neuromorphic elements
  - Can be a neuron or a synapse.
- Elements can connect to up to 16 neighbors.
- Current Implementation: FPGA





Comparison

Neuromorphic System	Programmable Structure	Component Complexity (Neuron/Synapse)	On-Chip Learning
DANNA[1]	Neurons and synapses	2 / 2	Yes
TrueNorth[2]	Fixed (Synapses on/off)	10 / 3	No
Neurogrid[3]	Fixed (Synapses on/off)	79 / 8	No
BrainScaleS[4]	Neurons and synapses	Variable	Yes
SpiNNaker[5]	Neurons and synapses	Variable	Yes

1. Dean, Mark E., Catherine D. Schuman, and J. Douglas Birdwell. "Dynamic adaptive neural network array." *Unconventional Computation and Natural Computation*. Springer International Publishing, 2014. 129-141.
2. Merolla, Paul A., et al. "A million spiking-neuron integrated circuit with a scalable communication network and interface." *Science* 345.6197 (2014): 668-673.
3. Benjamin, Ben Varkey, et al. "Neurogrid: A mixed-analog-digital multichip system for large-scale neural simulations." *Proceedings of the IEEE* 102.5 (2014): 699-716.
4. Brüderle, Daniel, et al. "A comprehensive workflow for general-purpose neural modeling with highly configurable neuromorphic hardware systems." *Biological cybernetics* 104.4-5 (2011): 263-296.
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Preliminary Results: Iris

- 150 instances:
  - Four attributes:
    - Sepal length and width.
    - Petal length and width.
  - Three possible classes:
    - Iris Setosa, Iris Virginica, Iris Versicolour.
- Training set and testing set each have 75 instances (25 instances of each type).
- Fitness function: Evaluates the DANNA network on each of the 75 training instances.
- Stopping condition: 96 percent accuracy (72/75 correct).

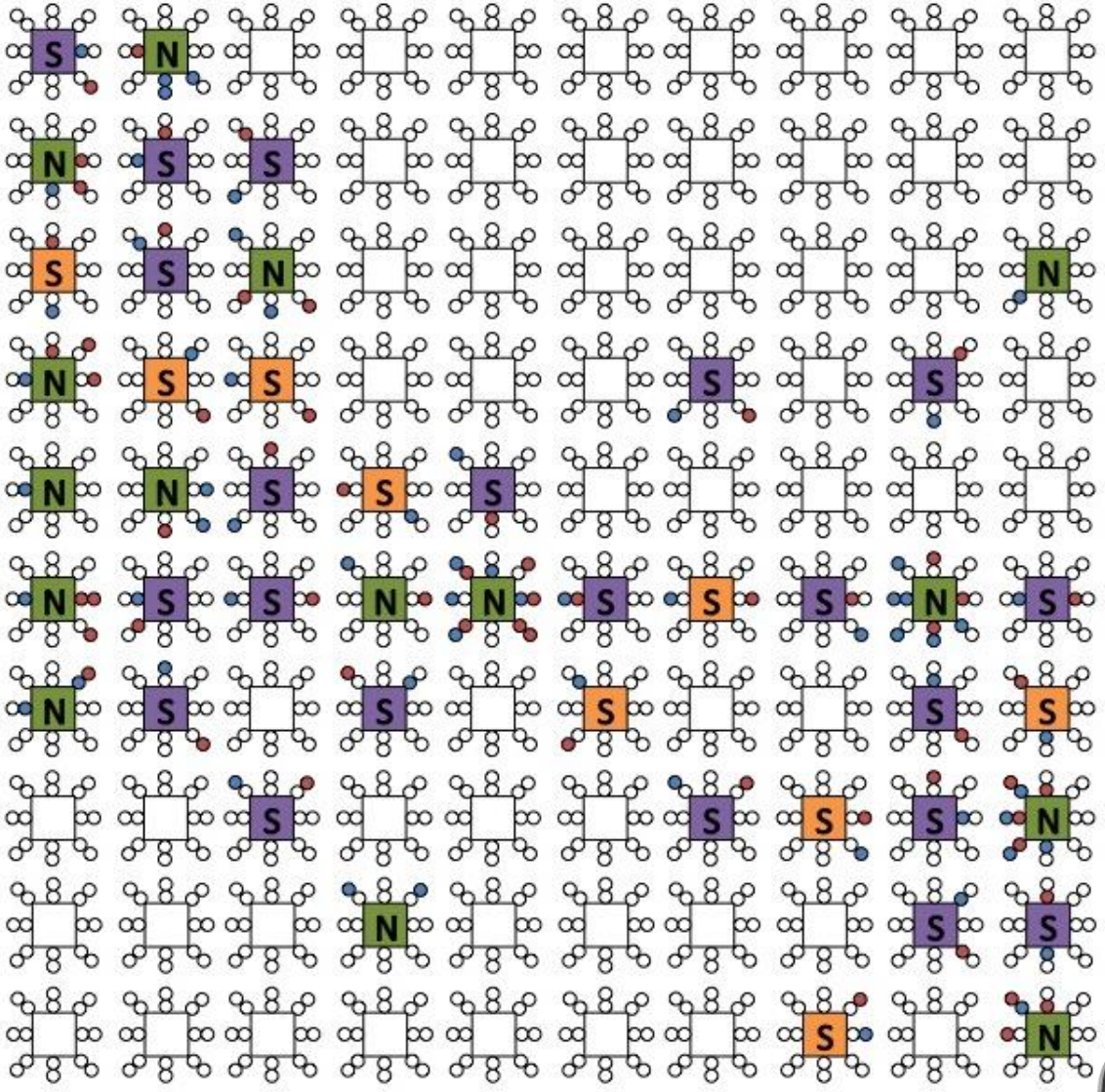
Image and Data Set: https://archive.ics.uci.edu/ml/datasets/Iris

Preliminary Results: Iris

Size:
15 neurons
30 synapses

Training Accuracy:
96 percent
(72/75)

Testing Accuracy:
98.67 percent
(74/75)



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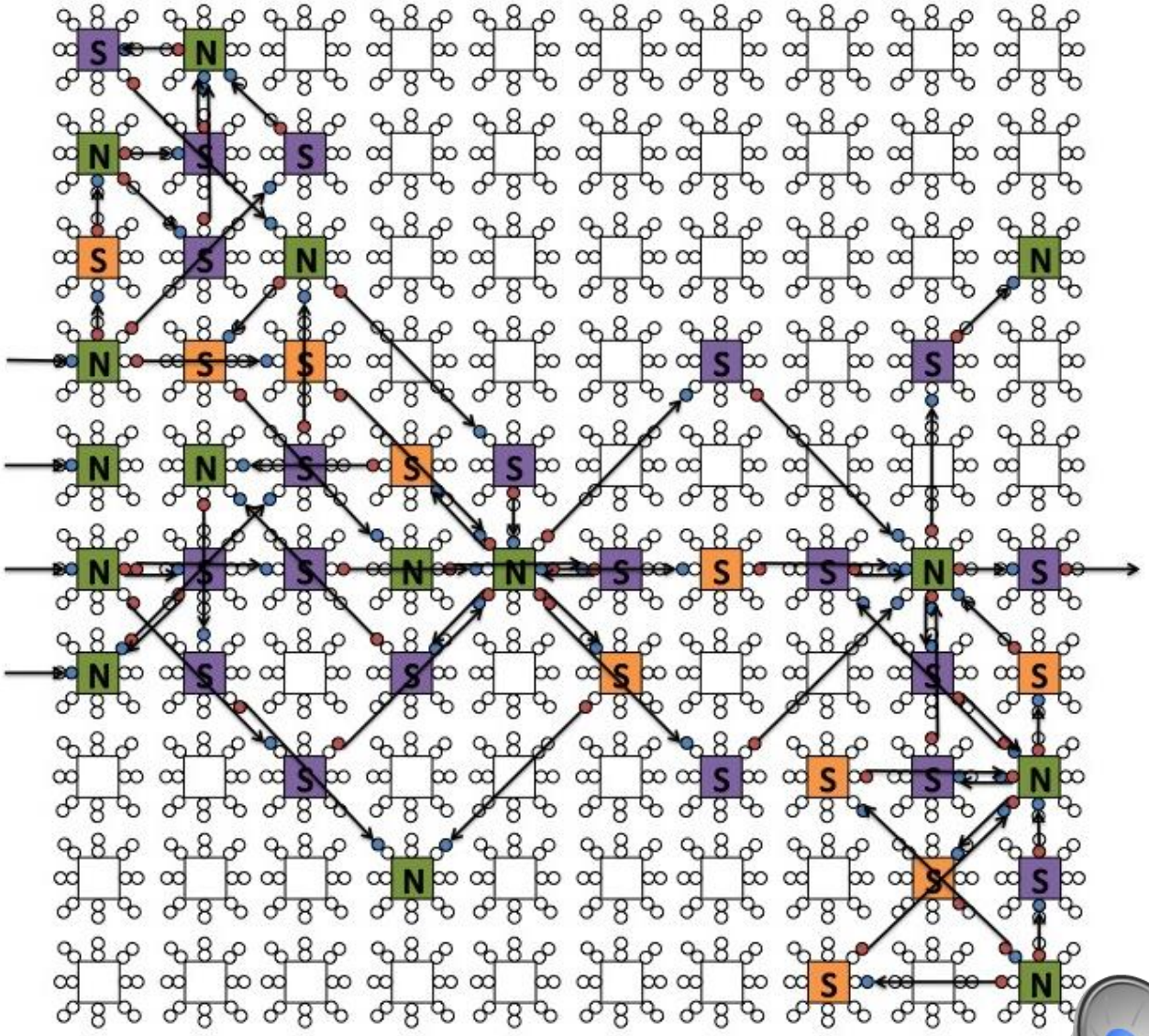
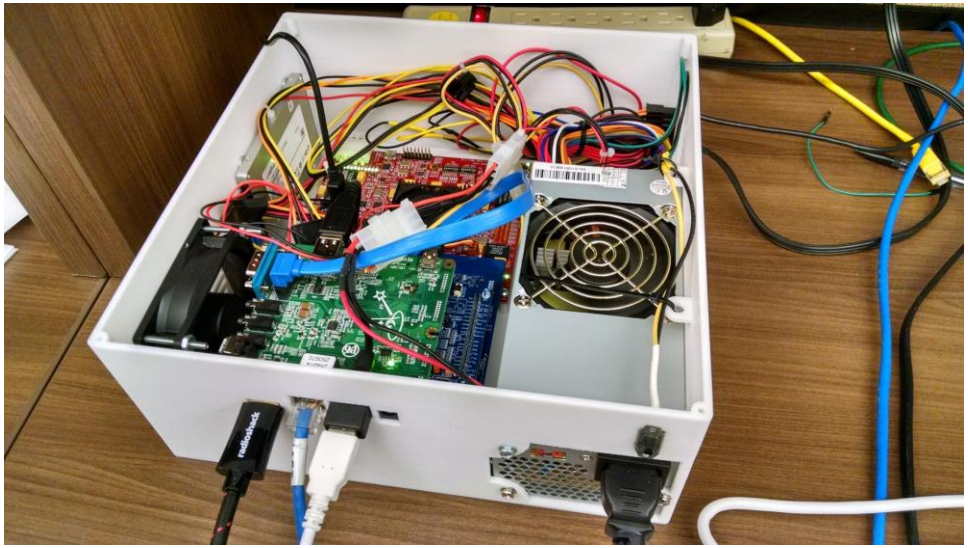


Future Work



- Improved simulation:
  - Event queue instead of clock-based.
  - CPU vector instructions.
  - GPUs.
- Parallelized evolutionary optimization.
  - Parallelization of training for NIDA is already in progress.
- Development, visualization and analysis tools for DANNA hardware kit.
- In Progress Hardware Implementations:
  - VLSI.
  - Memristors.

Contact

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