National Aeronautics and Space Administration

Investigation of Spiking Neural Networks for Modulation Recognition using Spike-Timing-Dependent Plasticity

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Agenda

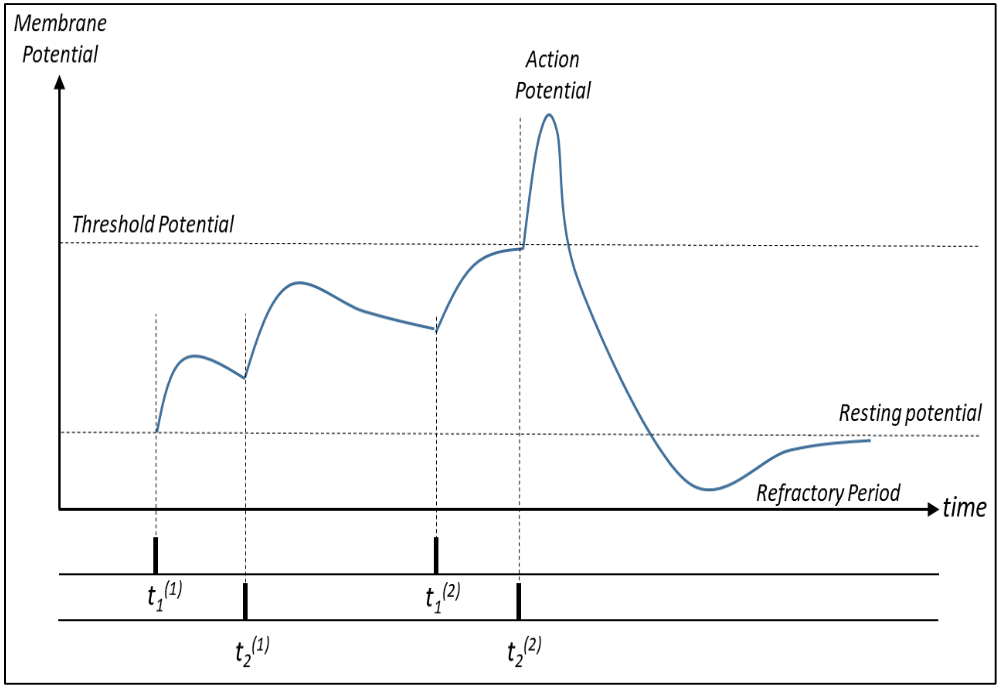
- Motivation and Goals
- Overview of Spiking Neurons
- Spiking Neuron Model
- SNN Architecture
- Learning Algorithm
- Classification Error Performance
- Discussion and Future Work

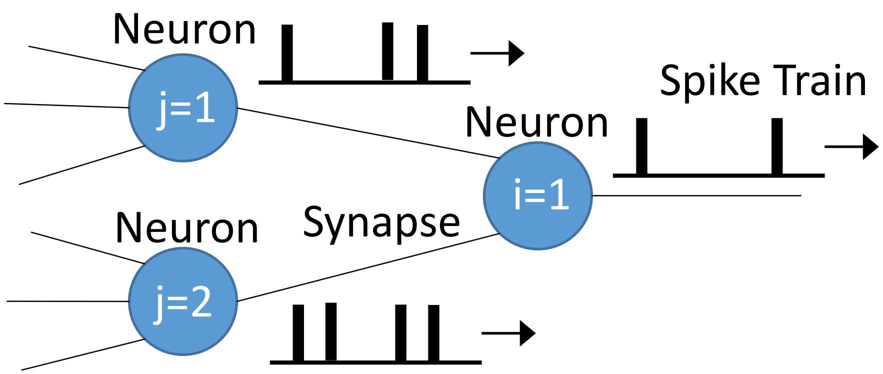
Motivation and Goals

- NASA's infusion of new capabilities
  - Machine learning and artificial intelligence
  - Increased mission science return, enhanced autonomy
- Spiking Neural Networks (SNNs) and neuromorphic hardware
  - Energy efficiency
  - Ideal for resource-constrained platforms
  - CubeSats
- Cognitive functionality
  - Modulation recognition capability (BPSK, QPSK, 8PSK)
  - SNN using STDP
  - Classification error performance

Spiking Neural Networks

- SNNs model biology
- Neurons and connecting synapses
- Neuron membrane potential and threshold
- Action potentials (e.g., spikes)
- Neuronal Refractoriness





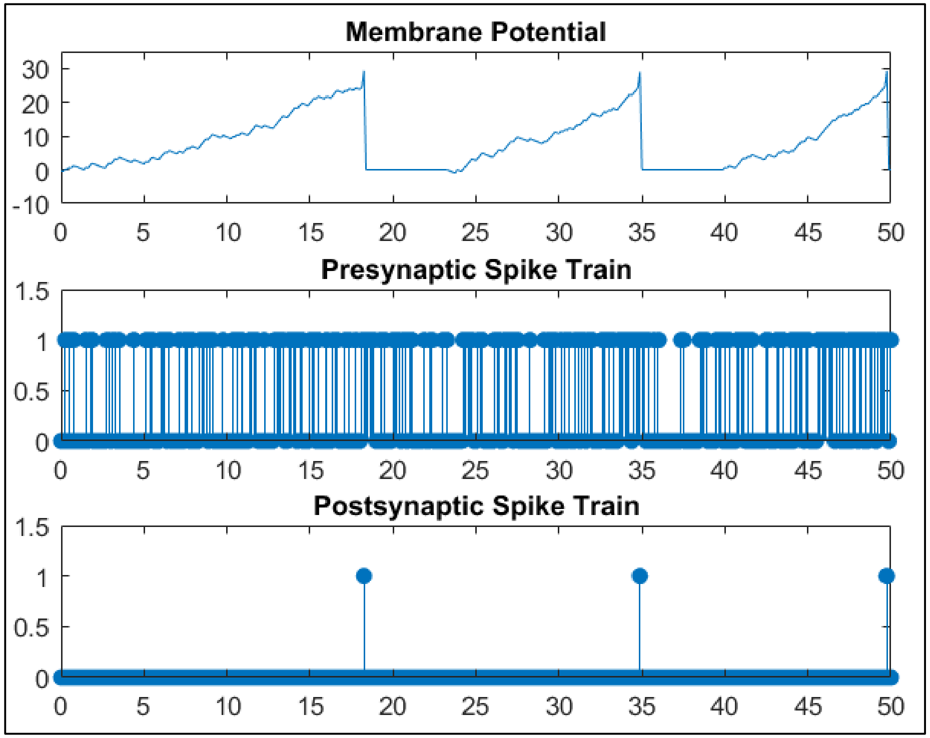
Spiking Neuron Model

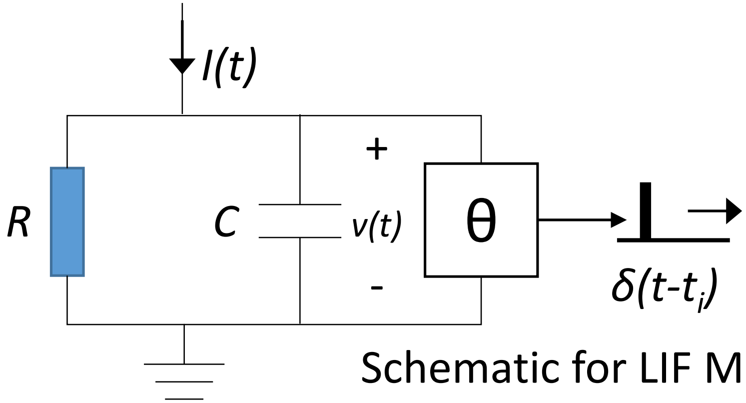
- Leaky Integrate and Fire (LIF) Model

$$\tau\, dv/dt = -v(t) + RI(t)$$

- Simplified Response Model (SRM)

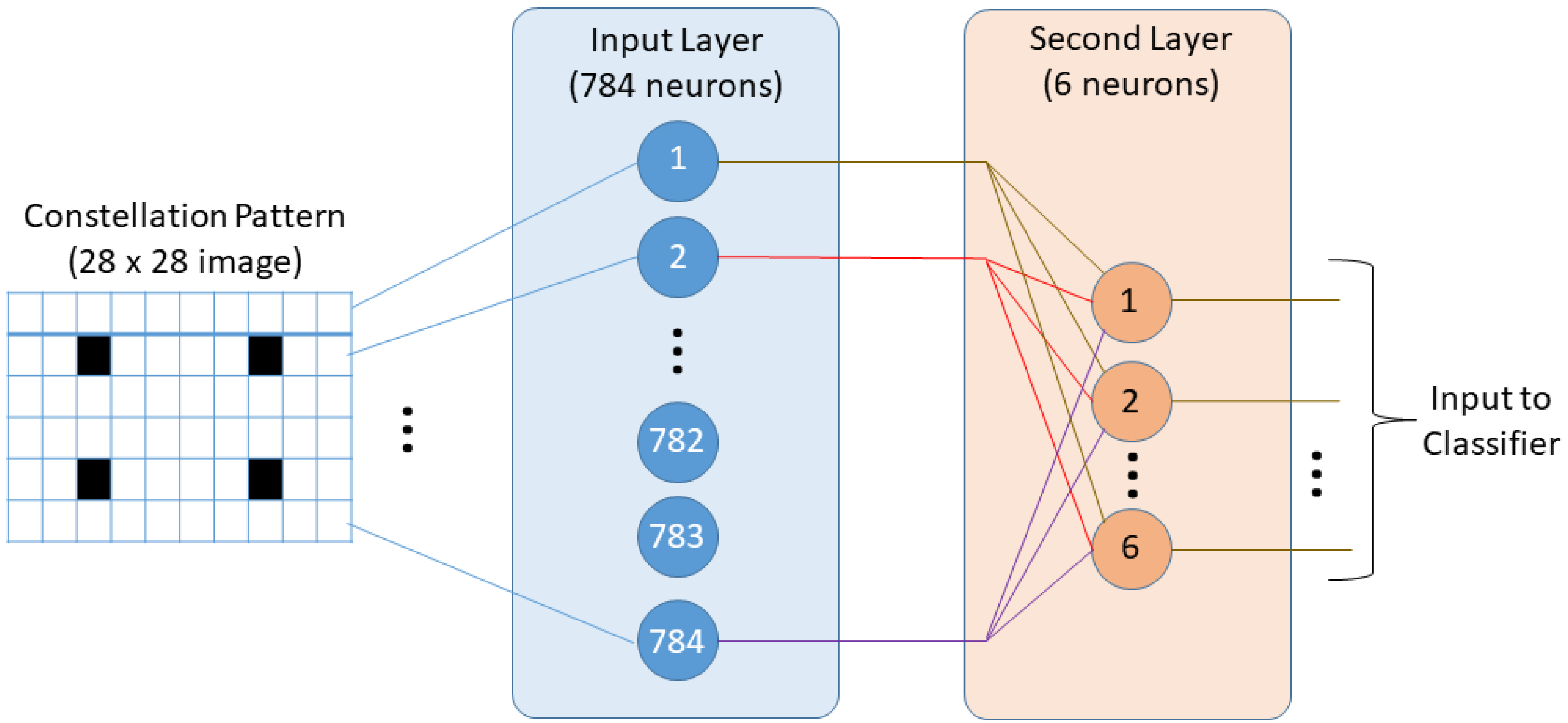
$$v_t = v_{t-1} + \sum_i \omega_i s_{it} - D$$





Schematic for LIF Model
(Derived from Gerstner and Kistler, “Spiking Neuron Models”, 2002)

SNN Architecture

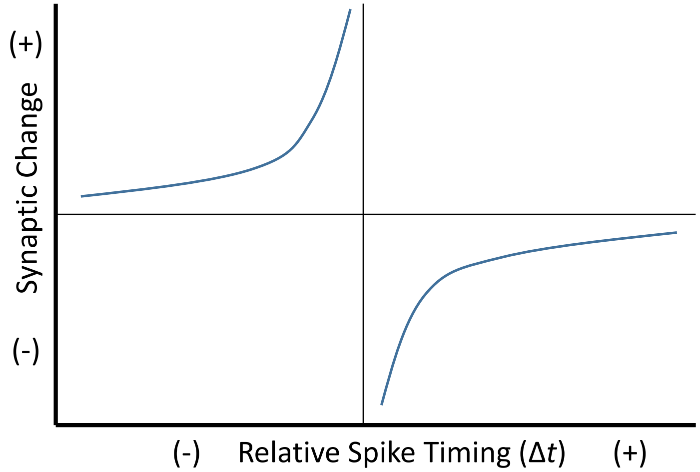


Learning Algorithm

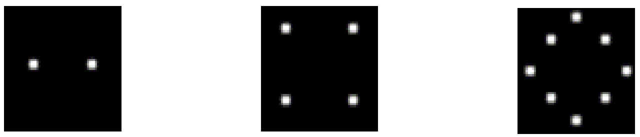
- Unsupervised learning
- Spike-Timing-Dependent Plasticity (STDP)
- Correlation of pre- and postsynaptic spike arrivals

$$\Delta\omega(\Delta t) = \begin{cases} A_{+}\exp\left({}^{\Delta t}/_{\tau_{+}}\right), & \Delta t < 0 \\ A_{-}\exp\left({}^{-\Delta t}/_{\tau_{-}}\right), & \Delta t \geq 0 \end{cases}$$

- Adaptive membrane potential
- Lateral inhibition

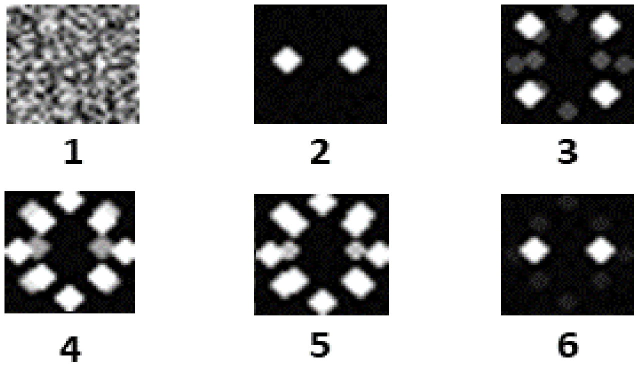


Training Patterns

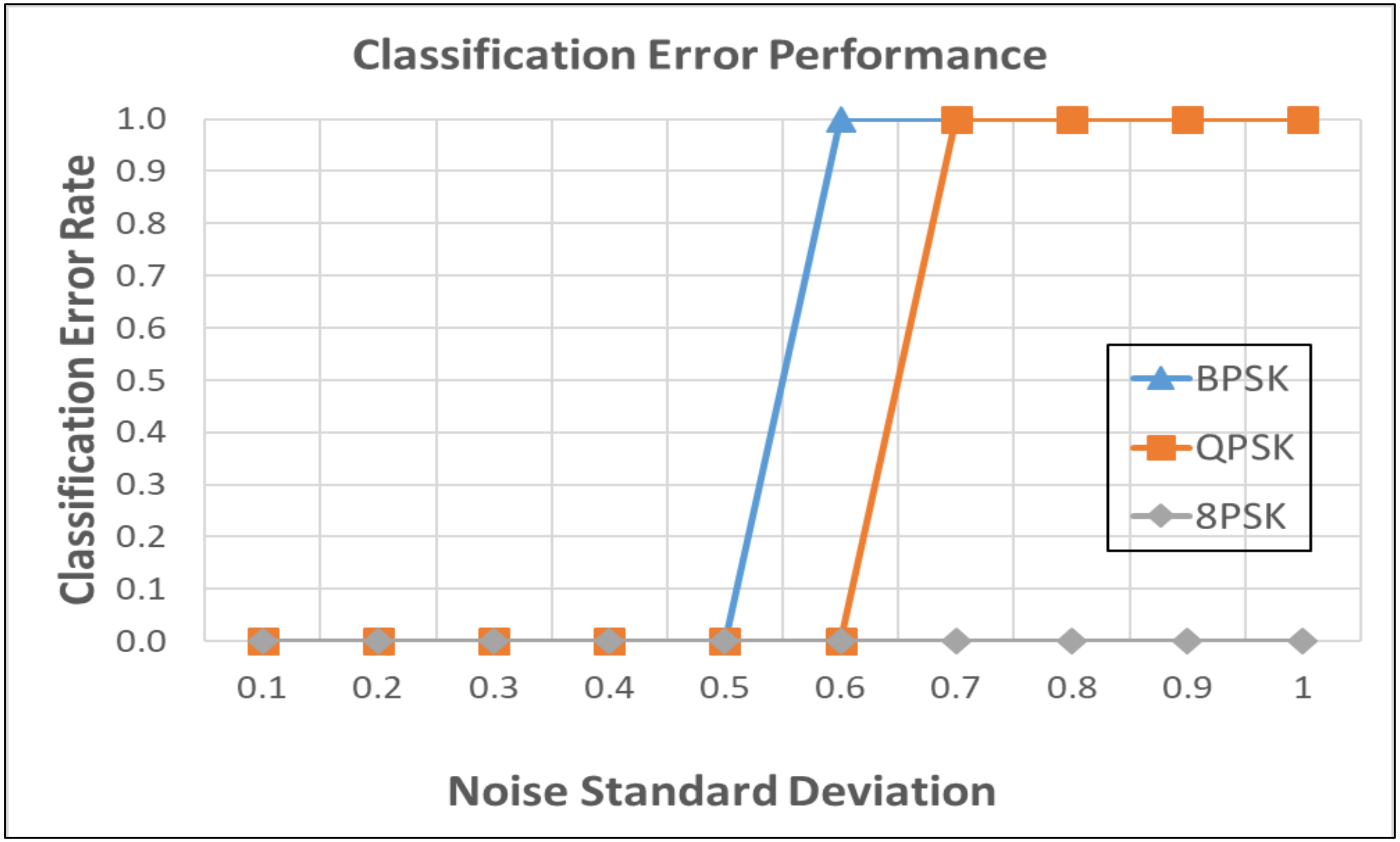


BPSK QPSK 8PSK

Learned Patterns



Classification Error



Discussion and Future Work

- SNN model for modulation recognition
  - Compare with CNN implementation
- Data set
  - More extensive samples with noise
  - Actual sampled I-Q values
- Learning methods
  - Challenges of unsupervised learning
  - Other STDP variants
  - Supervised, reinforcement methods
- Neural network architectures
  - Deep learning
  - Recurrent vs feedforward
- Implementation on neuromorphic hardware

Thank you