IoT Neural Networks:
Linear Integrate & Fire

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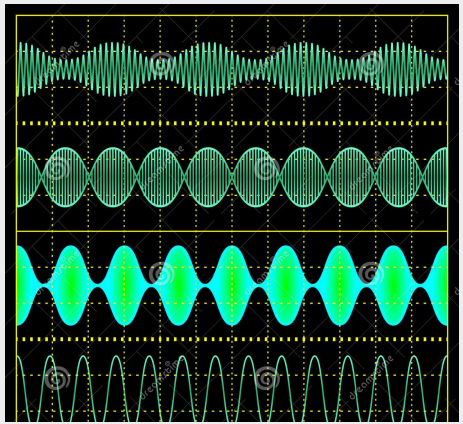
Introduction

“Use Spiking Neural Networks for Modulation Classification”

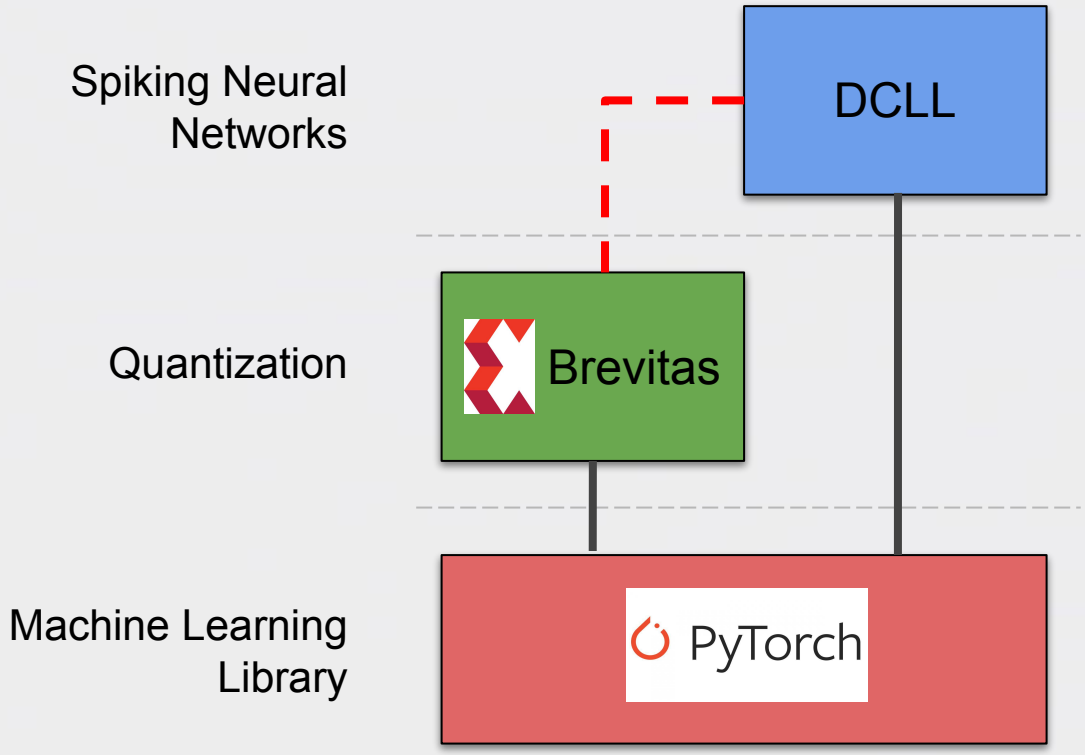
Modulation



Goals

1. Train a Spiking Neural Network Model for RadioML dataset
2. Quantize the Model to save computation power and memory

Overview



1) Used **DCLL** to create and train a Spiking Neural Network (SNN) for RadioML

   Tuned:
   - Hyperparameters
   - Network Architecture

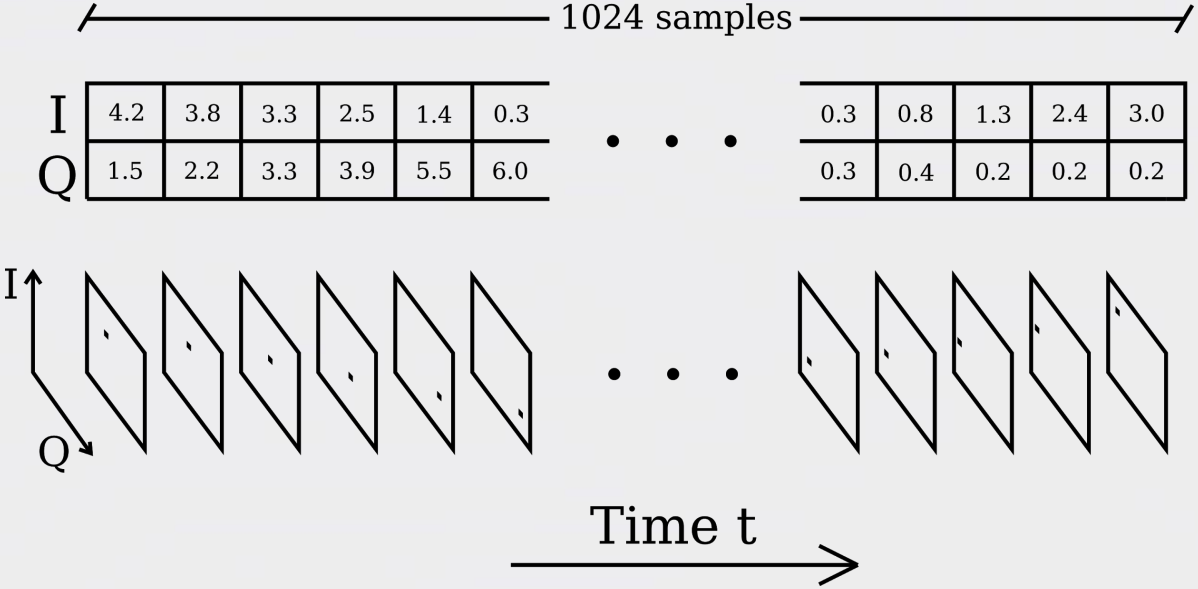
2) Connected **Brevitas** and **DCLL** Library to train quantized SNN

   Experimented with:
   - Bit widths
   - Parameters to quantize

RadioML Dataset

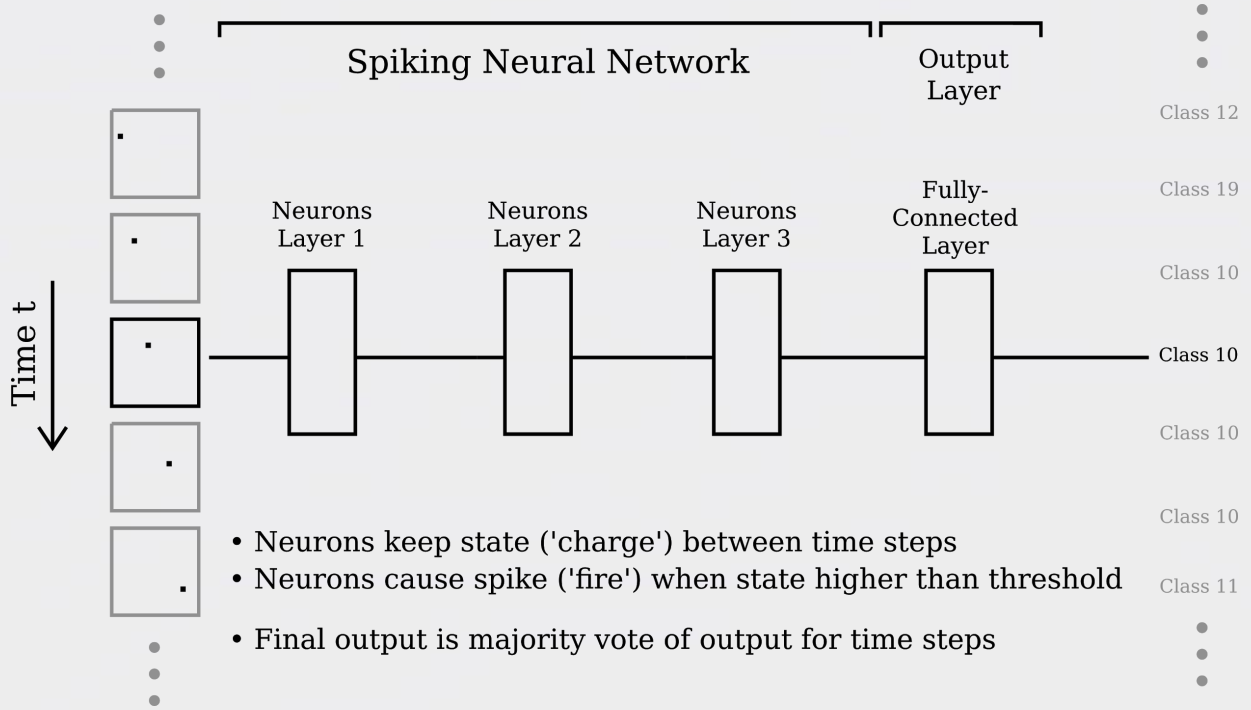
- **RadioML dataset:**
  Radio signal represented as list of **number pairs** (I/Q part of signal)

- **For SNN input:**
  - Create list of 2D images
  - Axes represent I/Q part
  - Number pairs are marked as spikes in images



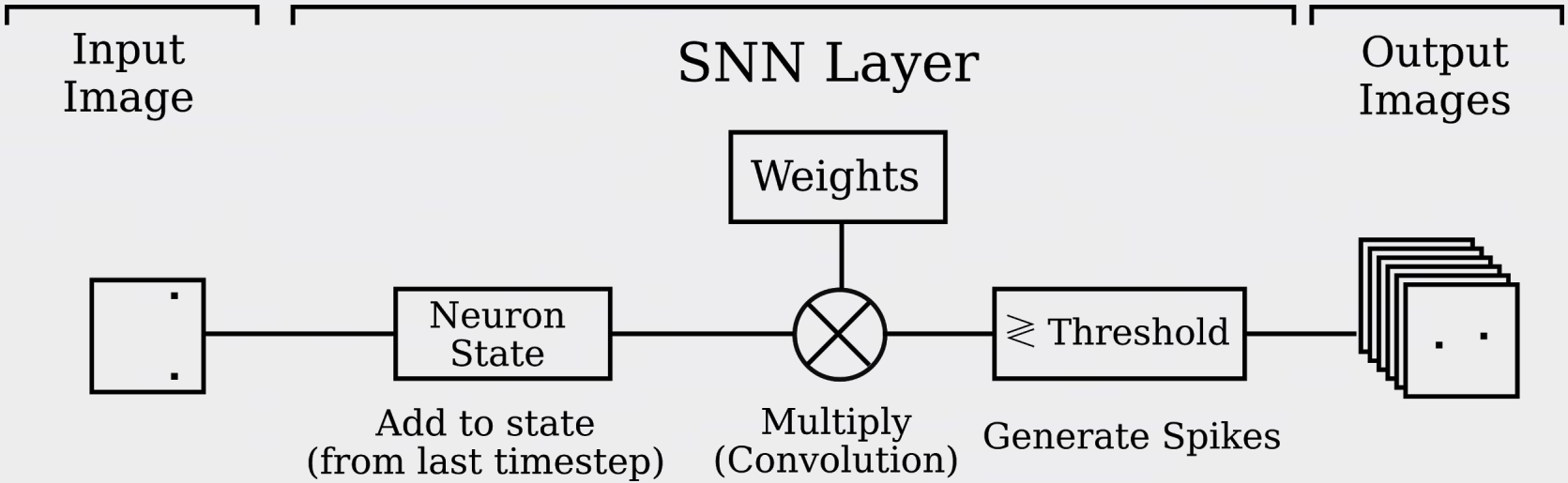
SNN Model Architecture

- **Model architecture:**
  - 3 convolutional SNN layers
  - 1 traditional linear layer
- Compute output for each of **1024 input timesteps**
- **Training:**
  - Problem: spikes not differentiable
  - Use **Deep Continuous Local Learning (DCLL)** which trains local classifier at every layer using approximated gradient



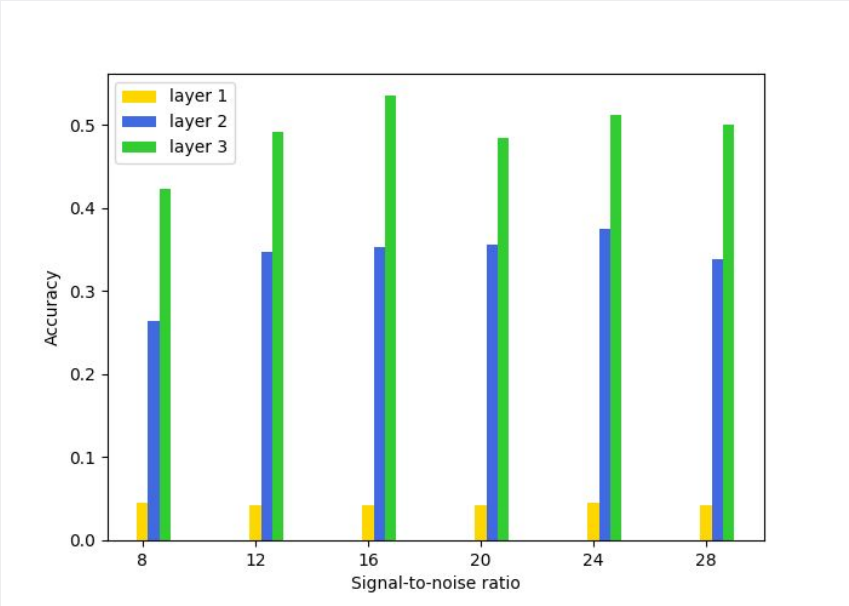
SNN Layer

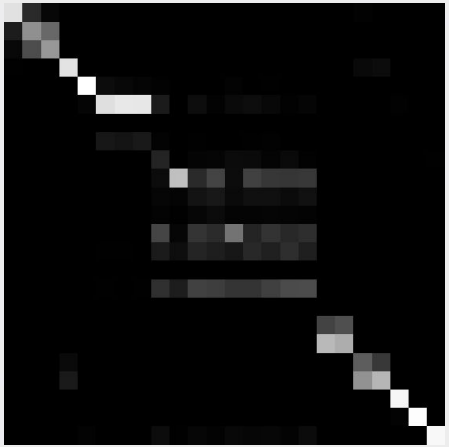
Architecture of SNN layer:



Results

- **50-55% accuracy on higher signal-to-noise ratios**
- **70-75% accuracy with 10 classes instead of 24**

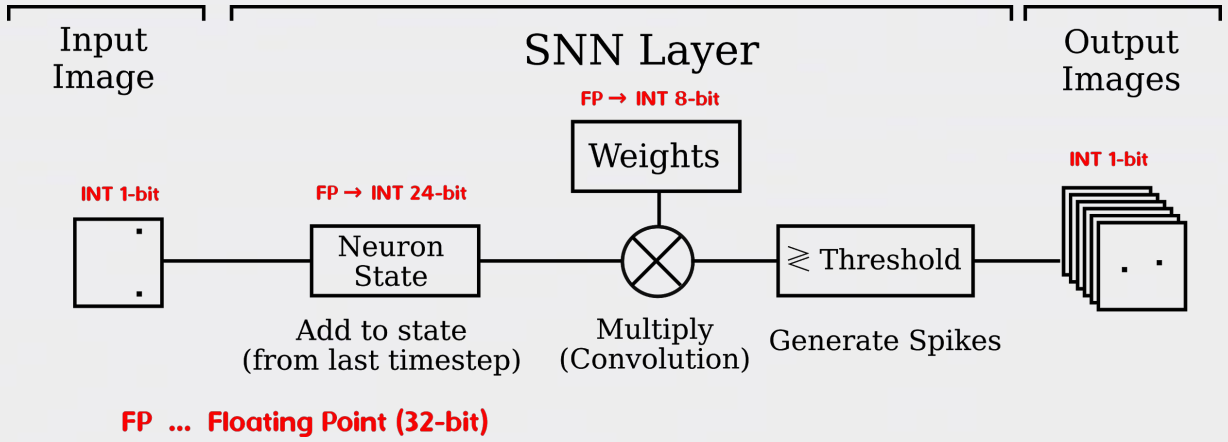




Confusion matrix

Quantization

- **Quantization**
  - Reduce *Number of Bits*
  - To *Save Memory*
  - And *Simplify Computation*
- **Quantize**
  - Weights
  - Neuron State
  - Input (already spike/no spike)
- **DCLL - Brevitas**
  - Create Layer *QuantConv2dDCLL*
  - Substitute for *Conv2dDCLL*

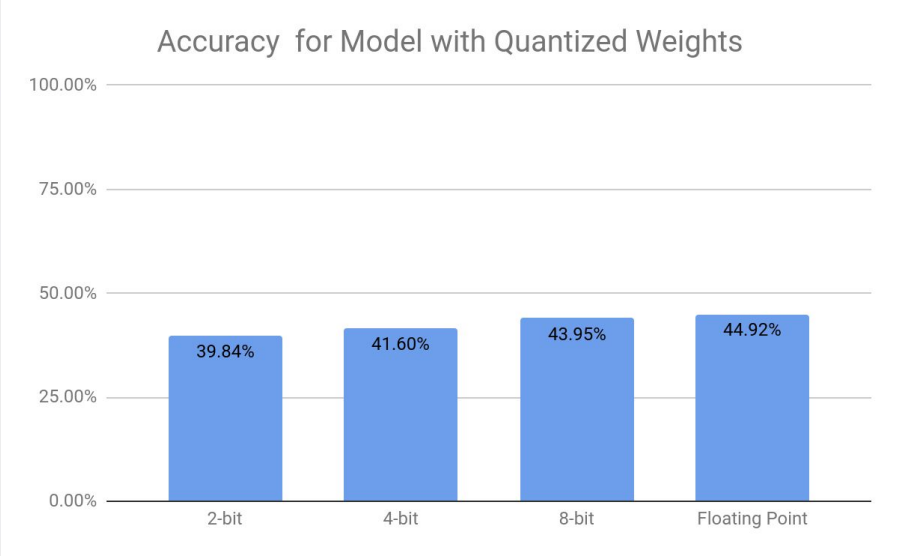


Results Quantization

Quantized Weights

Tradeoff:

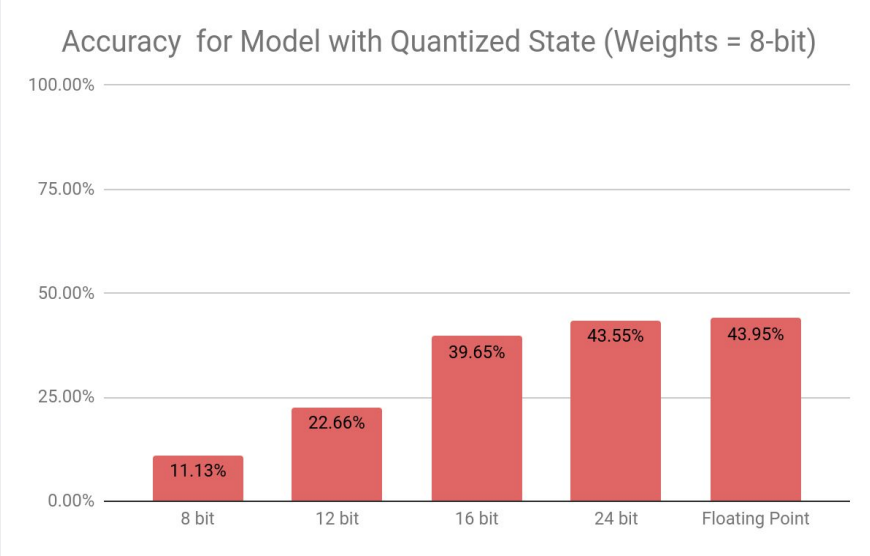
INT 8-bit Weights -1% accuracy -75% Memory (Weights)



Quantized Weights and State

Tradeoff:

INT 24-bit State -0.4% accuracy -25% Memory (State)



Conclusion

Achievements:

- Trained an **SNN model for modulation classification** using RadioML dataset and Deep Continuous Local Learning (DCLL)
- Connected **DCLL** Library with **Brevitas** for Quantization Aware Training
- Proposed **quantized version** of the network for efficient implementation on FPGA

Issues / Future Work:

- Network doesn’t generalize well (low accuracy on test set)
- Explore different training methods (e.g. Genetic Algorithms)