Comparing Quantum Encoding Methods in a Hybrid Deep Neural Network

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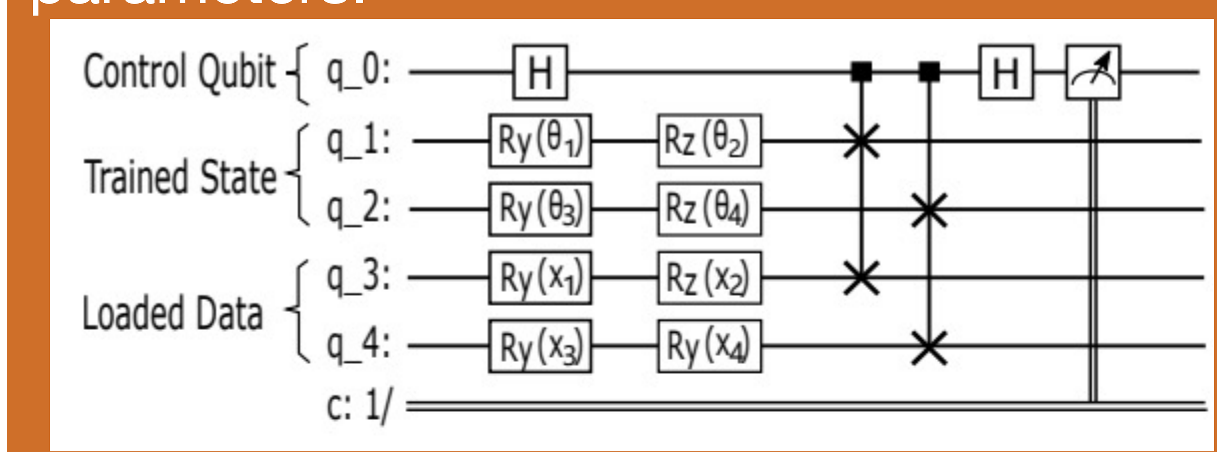
To utilize quantum computing for common tasks (such as machine learning) classical data must be converted into quantum states through **quantum encoding**. This study tests the three main quantum encoding methods on QuClassi, a quantum-classical hybrid neural network.

Methods:

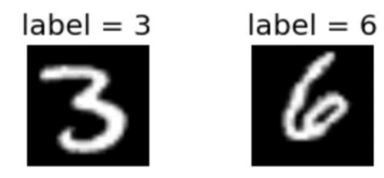
- Implemented the three encoding methods on QuClassi
- Tested different parameters to determine that 5 epochs and 0.01 learning rate are optimal for accuracy and time
- Tested the models (the mean values of three trials displayed in **average accuracy**)
- Trained models on simulator, tested on both simulator and hardware (displayed in **Simulator vs Hardware Accuracy**)
- Calculated Accuracy, loss (MSE), and entropy every epoch (displayed in graphs)

QuClassi:

Uses qubits as "neurons", uses classical gradient optimization to recalculate parameters.



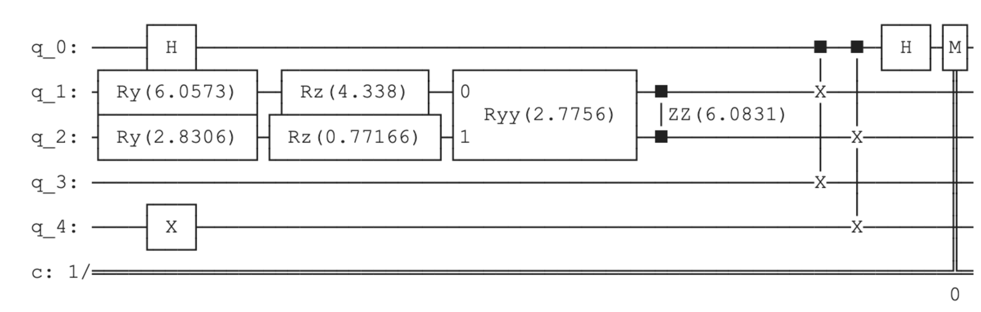
Goal: binary classification between handshapes from MNIST dataset

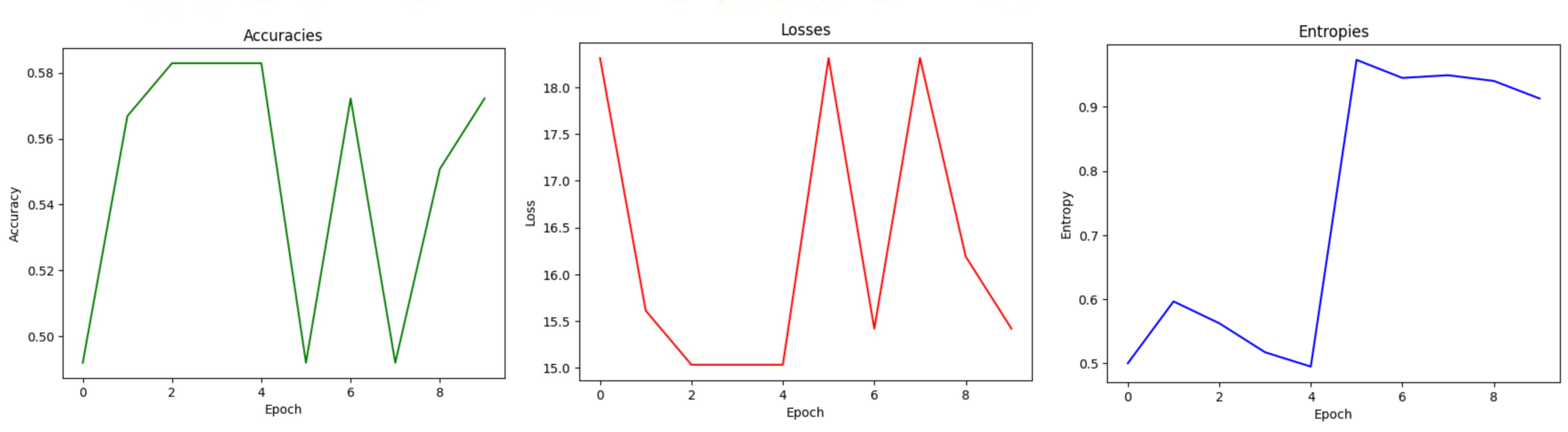


Basis Encoding

n data points of m binary digits encoded into n*m qubits

$$x = b_{n-1}b_{n-2}\dots b_0 \rightarrow |x\rangle = |b_{n-1}b_{n-2}\dots b_0\rangle$$



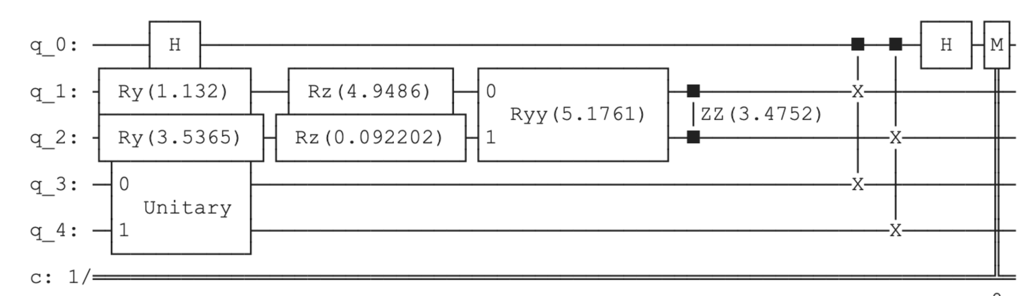


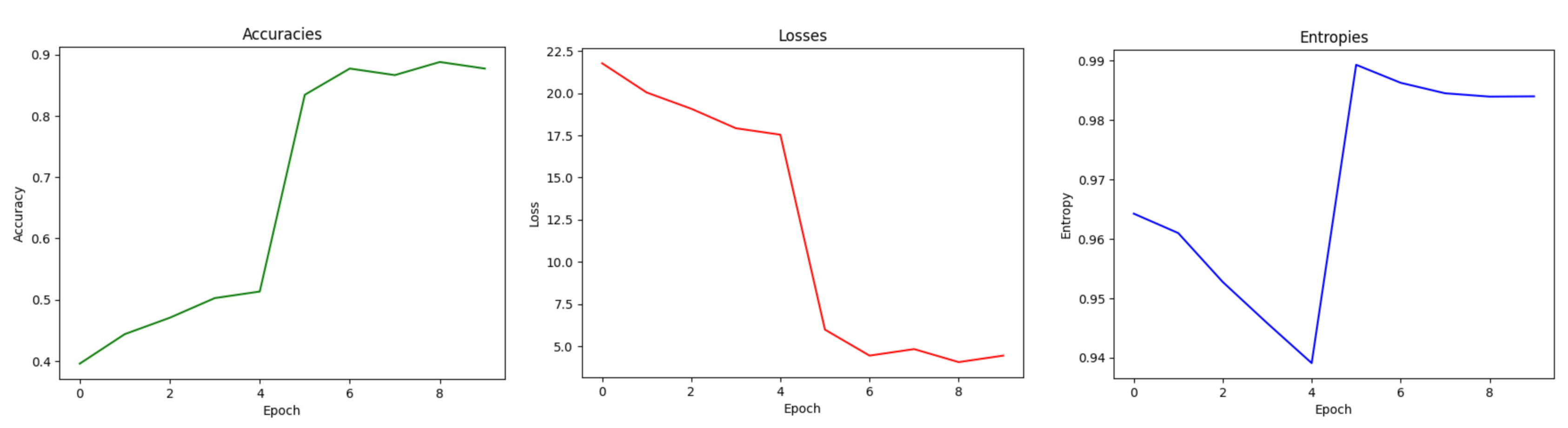
Average Accuracy on Simulator: ***54.36%***
Simulator vs Hardware Accuracy:
56.95% vs 55.61%

Amplitude Encoding

n data points encoded into log(n) qubits

$$X=[1.2,2.7,1.1,0.5]. \quad |\psi\rangle = \frac{1.2}{\sqrt{10.19}}|00\rangle + \frac{2.7}{\sqrt{10.19}}|01\rangle + \frac{1.1}{\sqrt{10.19}}|10\rangle + \frac{0.5}{\sqrt{10.19}}|11\rangle$$



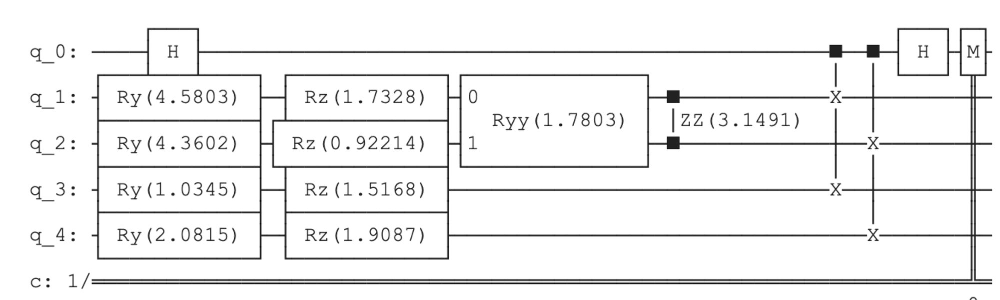


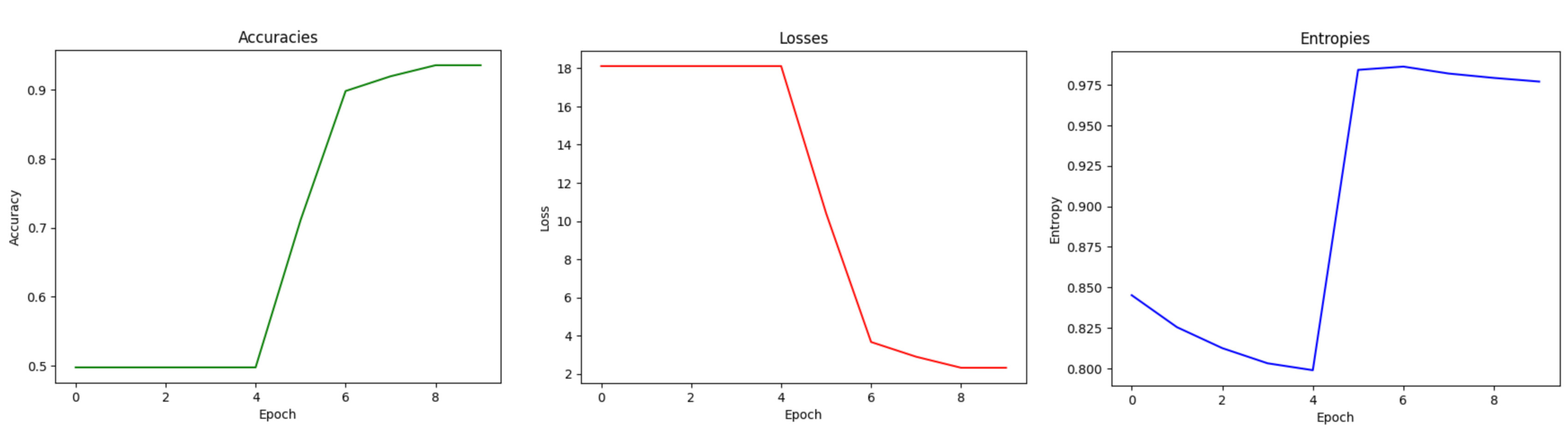
Average Accuracy on Simulator: ***86.45%***
Simulator vs Hardware Accuracy:
88.72% vs 52.94%

Rotation Encoding

n data points encoded into n qubits

$$|\psi(\theta)\rangle = R_y(\theta)\,|0\rangle + e^{i\phi}R_y(\theta)\,|1\rangle$$





Average Accuracy on Simulator: ***85.91%***
Simulator vs Hardware Accuracy:
96.25% vs 54.01%

Future Directions: test other proposed encoding techniques, test on other neural network architectures.

Sources

Stein, S. A., Baheri, B., Chen, D., Mao, Y., Guan, Q., Li, A., Xu, S., & Ding, C. (2022). *QuClassi: A Hybrid Deep Neural Network Architecture based on Quantum State Fidelity*. arXiv preprint arXiv:2103.11307. Retrieved from https://arxiv.org/abs/2103.11307

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