Quantum Neural Network Benchmarking with MNIST Dataset

SenSIP Algorithms and Devices REU

Matthew Dobson, REU Student, Arizona State University
Graduate Mentor: Glen Uehara, Faculty Advisor: Andreas Spanias
SenSIP Center, School of ECEE, Arizona State University

SenSIP INDUSTRY CONSORTIUM

ABSTRACT

- Leverage inherent parallelization of quantum computers for machine learning applications.
- Compare quantum computer simulations against classical neural networks on the MNIST dataset.

MOTIVATION

Quantum computing is a pillar of future-leaning research in computation. Phenomena from quantum mechanics principles such as superposition and entanglement are leveraged for greater parallel computation power than classical Boolean computing. In theory certain application areas could see computation speed increases in the order of thousands.

PROBLEM STATEMENT

Current hardware is still early, so we test the majority of our quantum algorithms in simulators. These don't yet fully encompass the speed advantages yet, but are able to provide a relatively robust simulation of how the algorithm will operate on actual quantum hardware.

Figure 1: Legacy IBM Quantum Computer

DESIGN: HYBRID QUANTUM NEURAL NETWORK

- Developed hybrid quantum-classical neural network (QNN) framework
- Tested capabilities on 2, 3 and 4 qubit quantum systems
- Designed two separate algorithm architectures for training on 2 classes of MNIST and full 10 class MNIST dataset.

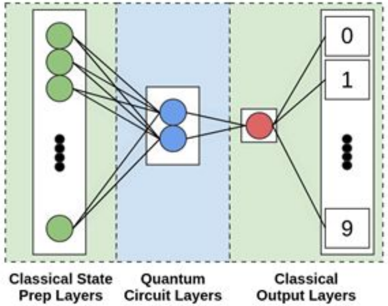

Figure 2: QNN Architecture

FUTURE WORK

- Emphasis on development of modular toolboxes to ease development and testing time of quantum programs
- Refine machine learning study when applied with quantum computers
- Benchmark different quantum hardware systems

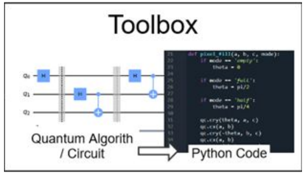

Figure 3: Toolbox architecture concept.

CHALLENGES

- Early nature of quantum computing led to challenges in design
- Prime difficulty in runtime of quantum simulated programs

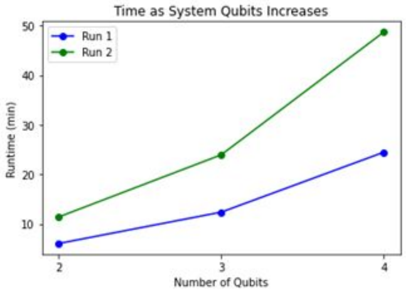

Figure 4: Time cost of increasing number of qubits in design

REFERENCES

[1] A. Baldominos, Y. Saez, P. Isasi, “A Survey of Handwritten Character Recognition with MNIST and EMNIST” Applied Sciences, 3169;doi:10.3390/app9153169, Aug. 2019.U.

[2] S. Shanthamallu, A. Spanias, C. Tepedelenlioglu, M. Stanley, “A Brief Survey of Machine Learning Methods and their Sensor and IoT Applications” SenSIP Center, School of ECEE, Arizona State University, NXP Semiconductors

[3] G. Uehara, “Quantum Machine Learning using Quantum Simulation” School of ECEE, Arizona State University

[4] O. I. Abiodun, A. Jantan, A. E. Omolara, K. V. Dada, N. A. E. Mohamed, H. Arshad, “State-of-the-art in artificial neural network applications: A survey” Heliyon, Volume 4, Issue 11, Nov. 2018, e00938

[5] B. O. Kaziha “A comparison of Quantized Convolutional and LSTM Recurrent Neural Network Models Using MNIST”. International Conference on Electrical and Computing Technologies and Applications, ICECTA 2019 (2019).

[6] A. Palvanov, Y. Choy “Comparisons of deep learning algorithms for MNIST in real-time environment”. International Journal of Fuzzy Logic and Intelligent Systems (2018), 126-134, 18(2)

[7] S. Y. Simard, D. Steinkraus, J. C. Platt “Best Practices for Convolutional Neural Networks Applied to Visual Document Analysis”. IEEE Computer Society, (2003)

[8] D. Pedamonti “Comparisons of non-linear activation functions for deep neural networks on MNIST classification task”. Department of Computer Science, University of Edinburgh, (2018)

[9] V. P. Ngoc, H. Wiklicky “Tunable Quantum Neural Networks for Boolean Functions” Imperial College London. ArXivID: 2003.14122v2

[10] E. Grant, M, Bendetti, S. Cao et al “Heirarchical Quantum Classifiers” Quantum Information, (2018), 1-8, 4(1)

[11] G. Uehara, S. Rao, M. Dobson, C. Tepedelenlioglu, A. Spanias “Quantum Neural Network Parameter Estimation for Photovoltaic Fault Detection” IEEE IISA 2021 Conference, SenSIP Center, School of ECEE, Arizona State University

ACKNOWLEDGEMENT

This project was funded in part by the National Science Foundation, award number 1659871.

ASU Ira A. Fulton Schools *of* Engineering
ARIZONA STATE UNIVERSITY

Sensor Signal and Information Processing Center
http://sensip.asu.edu

This material is based upon work supported by the National Science Foundation under Grant No. CNS 1659871 REU Site: Sensors, Signal and Information Processing Devices and Algorithms.

NATIONAL SCIENCE FOUNDATION