Quantum Parameter Study for Quantum Inspired Machine Learning

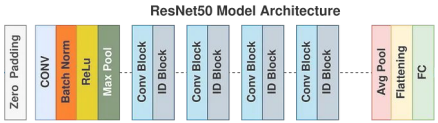

Figure 1a: ResNet50 Neural Network
23M Non-Trainable Parameters [1]

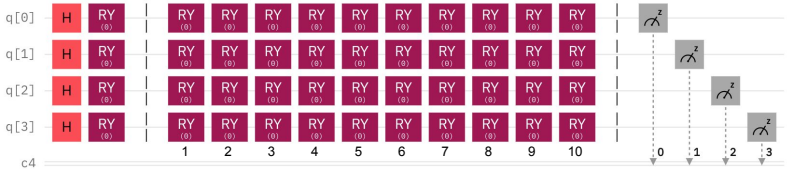

Figure 1b: Quantum Circuit. Left: Embedding Layer [2]
Middle: Up to 40 Trainable Parameters, Right: Measurements

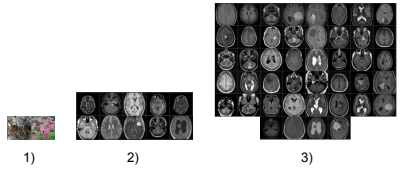

Figure 1c: Datasets. 1) 2-Class Hymenoptera
2) 10-Class Tumor MRI, 3) 44-Class Tumor MRI

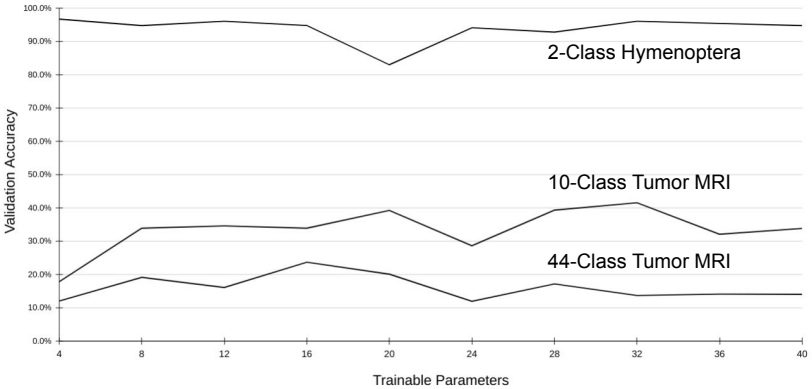

Figure 1d: Validation Accuracies for Different Trainable Parameters with 3 Datasets

Synopsis: A ResNet50 Neural Network without trainable parameters is assisted classifying images with a 4-qubit Quantum Circuit with trainable parameters for the analysis of Accuracy, Loss, and Runtime metrics for three different sized datasets.

Table 1: 2-Class Hymenoptera Dataset 398 Images

Trainable Parameters	Validation Accuracy	Validation Loss	Runtime (sec)	Layers
4	96.7%	0.241	57	1
8	94.8%	0.282	70	2
12	96.1%	0.273	82	3
16	94.8%	0.282	95	4
20	83.0%	0.639	105	5
24	94.1%	0.502	116	6
28	92.8%	0.249	129	7
32	96.1%	0.275	143	8
36	95.4%	0.305	155	9
40	94.8%	0.317	167	10

Table 2: 10-Class Tumor MRI Dataset 3507 Images

Trainable Parameters	Validation Accuracy	Validation Loss	Runtime (sec)	Layers
4	17.8%	2.252	435	1
8	33.9%	1.808	538	2
12	34.6%	1.737	646	3
16	33.9%	1.790	746	4
20	39.3%	1.688	856	5
24	28.7%	2.001	956	6
28	39.3%	1.602	1056	7
32	41.6%	1.691	1164	8
36	32.1%	1.862	1271	9
40	33.8%	1.782	1375	10

Table 3: 44-Class Tumor MRI Dataset 4478 Images

Trainable Parameters	Validation Accuracy	Validation Loss	Runtime (sec)	Layers
4	12.0%	3.377	552	1
8	19.2%	3.106	686	2
12	16.1%	3.278	820	3
16	23.7%	3.058	958	4
20	20.1%	3.153	1094	5
24	12.0%	3.398	1233	6
28	17.2%	3.146	1377	7
32	13.7%	3.286	1510	8
36	14.1%	3.316	1634	9
40	14.1%	3.249	1788	10

Default.qubit [13], 5 Epochs, NVIDIA V100 16 GB [14]
ResNet50: (2048, n_qubits), Classes: (n_qubits, 44) or 10 or 2

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K. Kawchak, CEO ChemicalQDevice

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"For a given architecture, the values of the parameters determine how accurately the model performs the task."
DeepLearning.AI, AI Notes

Introduction: Classical deep neural networks must contain the correct number and configurations of trainable "weights and biases" ie. parameters to achieve the best accuracies. In an analogous way, quantum machine learning trainable parameters through the optimization of qubit rotations can be performed with gates such as Ry, Rx, and Rz. In this study, different numbers of trainable Ry layers were implemented in a 'Quantum transfer learning' model in order to study the effect increasing circuit parameters has on a single dataset, as well as any observable trends between datasets. [3]

A) Effect Increasing Parameters has on Validation Accuracy [4] [5] [6]
1) 2-Class Hymenoptera as a Standard did not experience improvements in accuracy with more trainable quantum parameters
2) 10-Class Tumor MRI dataset experienced the largest increase in accuracies as the number of parameters were increased
3) 44-Class Tumor MRI dataset had small improvements in accuracy for lower number of trainable parameters

B) Parameter Trends Across Different Datasets on Validation Accuracy
Although the Hymenoptera dataset did not appear to exhibit a positive response to additional trainable parameters, the 10-Class and 44-Class datasets both generally increased in accuracy for the first 20 trainable parameters. With less total number of tumor classes and a greater number of images per class, the 10-Class dataset yielded the best accuracy increases for the highest number of parameters.

Discussion: Differences between training and validation losses were the lowest for the 10-class set for 40 parameters, which may indicate less concerns of overfitting. As quantum inspired methods and devices will likely be able to optimize large numbers of parameters, a productive approach will likely be to find the minimum number of parameters needed to assist classical deep learning. This study provided insight into parameter selection when best quality datasets are used. This study builds from prior algorithm prototypings, benchmarking, and cost/efficiency studies. [7] [8] [9] [10] The larger tumor datasets were also independently analyzed w/ larger circuits in separate studies. [11] [12]

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