Hybrid Quantum-Classical Neural Network for Semantic Segmentation

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Background

- Semantic segmentation is an important computer vision problem: necessary for tasks such as self-driving cars or augmented reality
- Semantic segmentation is unique from other ML problems such as classification as each pixel needs to be given a class
- Quantum computing is becoming both cheaper and more accessible
- Quantum computing has the advantage of using qubits and quantum physics

Fig 1: Result from VGG-16 Classical Segnet

Literature Review

- Segmentation of surface cracks was done through a hybrid K-means algorithm for segmentation [9]
- Medical data with binary classification for tumors used SHS 256 algorithm as well as 2 bit quantum circuit for classification and traditional segCNN for segmentation[10]
- Classification of X-Rays from COVID-19 patients with a hybrid CNN with a Convolution layer at the start of the neural network [11]

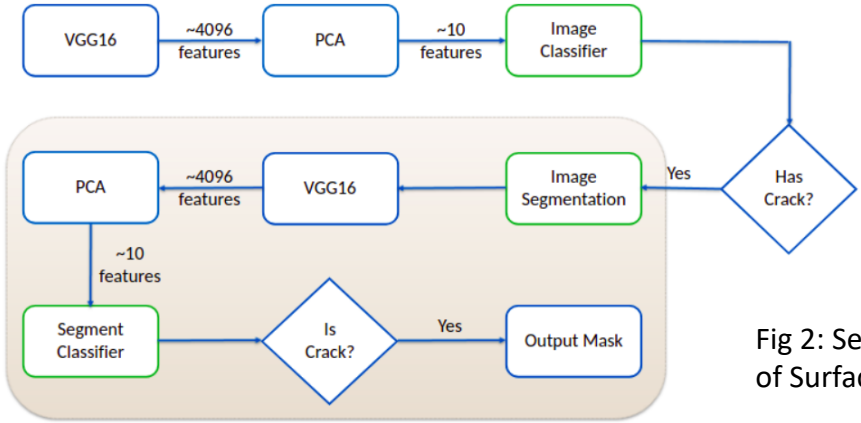


Fig 2: Semantic Segmentation of Surface Cracks

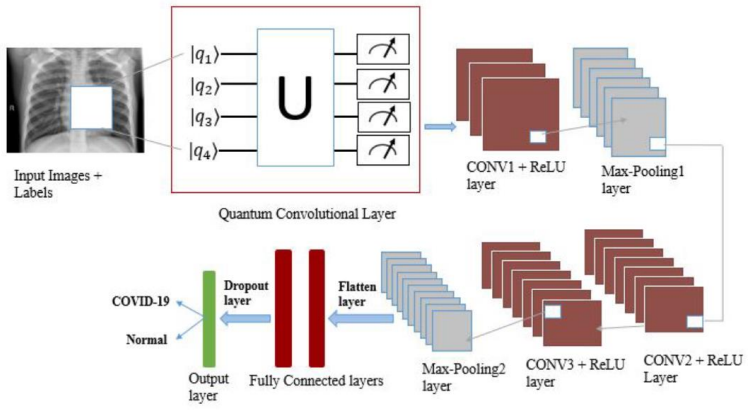


Fig 3: Semantic Segmentation of X-Rays

Objective

Examine the effects of a quantum layer at the end of a Segnet neural network for semantic segmentation

Compare runtime and accuracy of traditional vs hybrid neural network

Test on dataset of footpaths in Bangladesh

Fig 4: Images from dataset (Footpaths in Bangladesh)

Approach

- Reduce image size and set distinct classes for neural network
- Run through a Segnet with a VGG-16 encoder

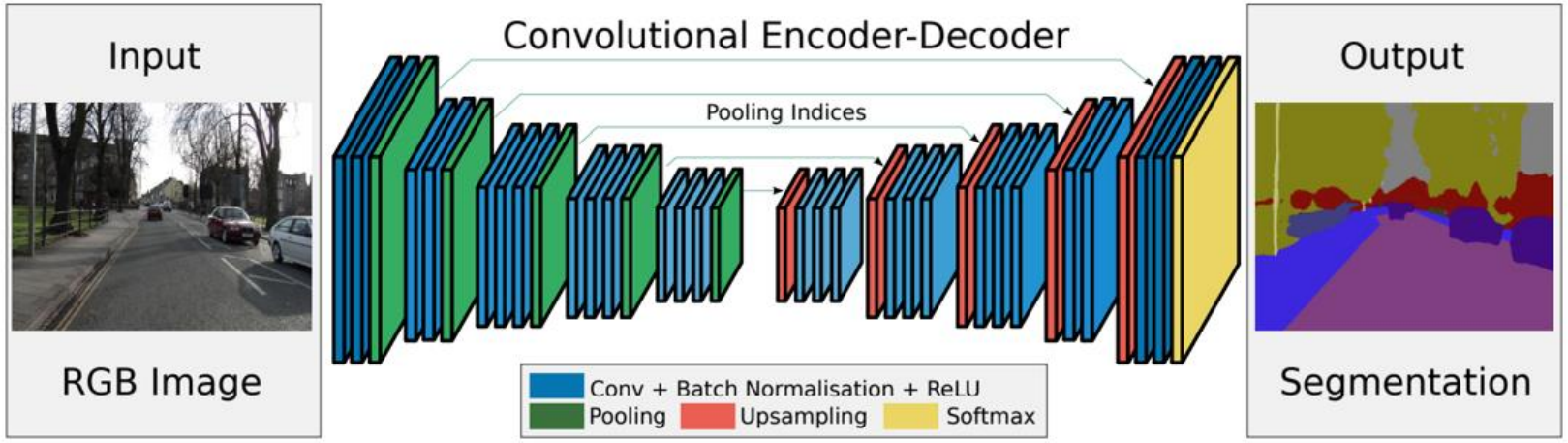


Fig 5: Diagram of Classical Segnet

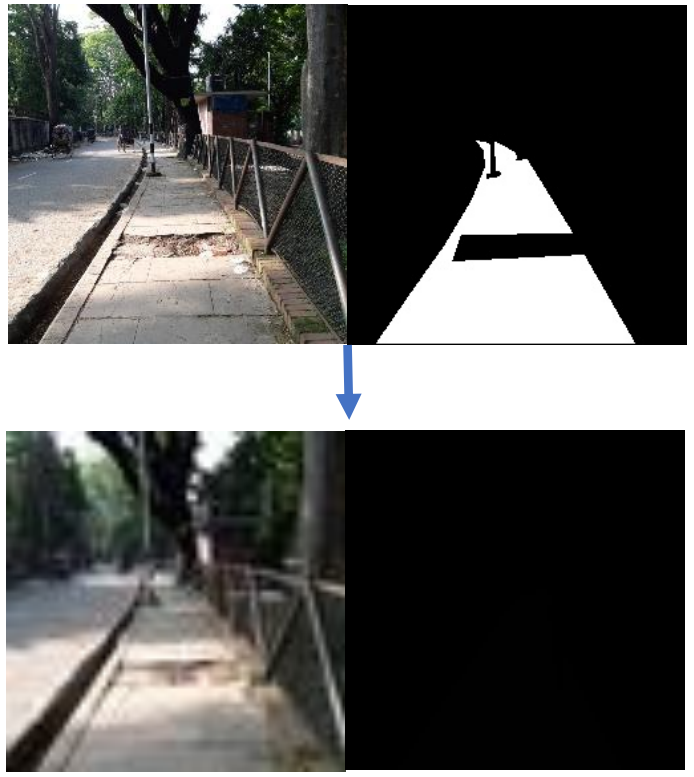


Fig 6: Reduced and Annotated Image

Approach

- Decoder will have either traditional softmax, quantum circuit, or quantum circuit before traditional softmax as final layer.
- Quantum Circuit is an angle embedding for each of the bits followed by a basic entanglement and measurement

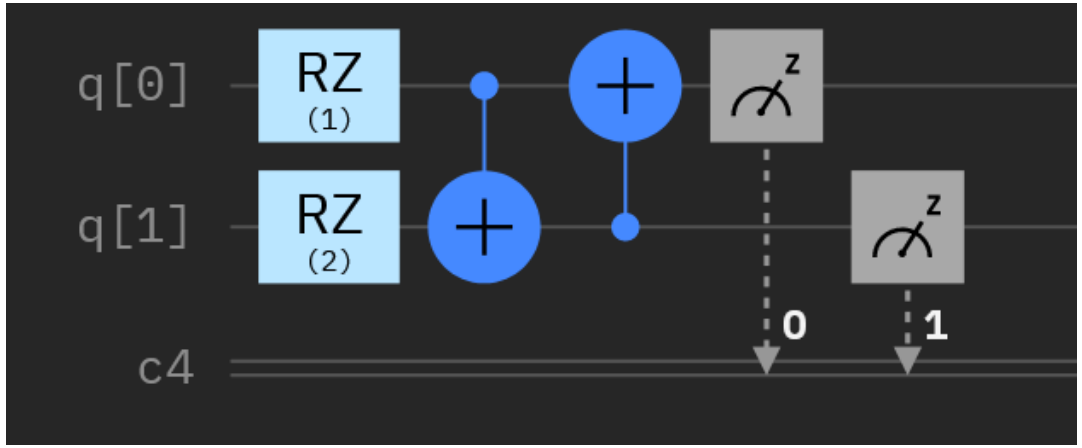


Fig 7: Diagram of Quantum Circuit

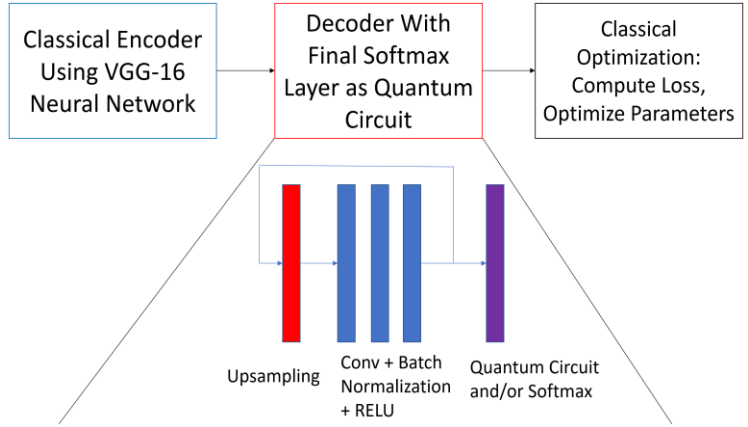
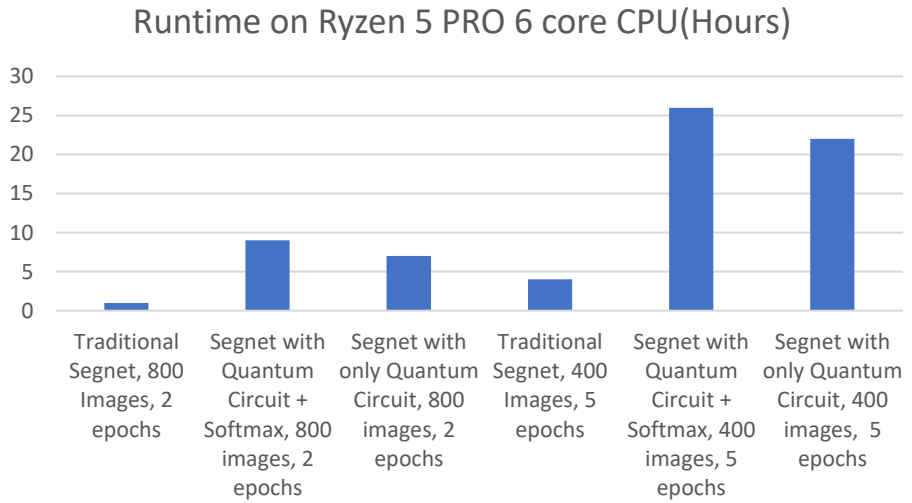
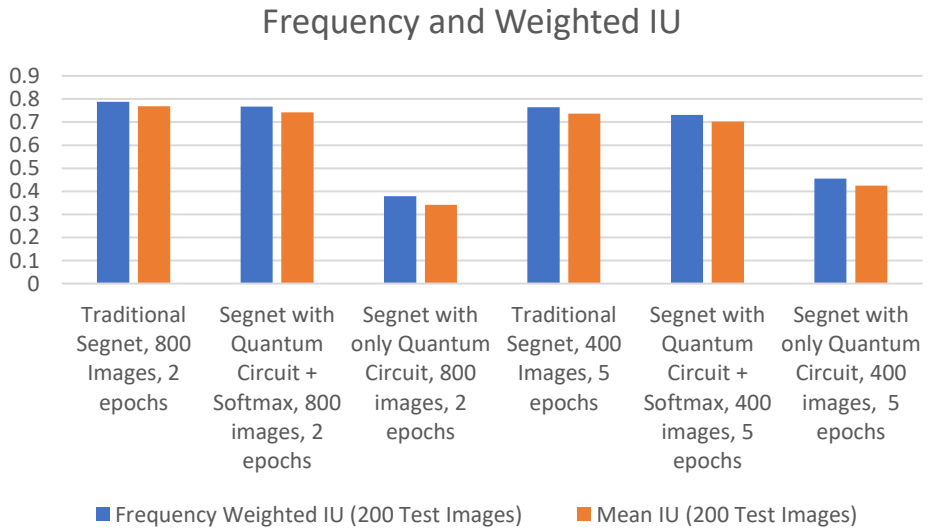


Fig 8: Diagram of Hybrid Segnet

Result

Model	Runtime on Ryzen 5 PRO 6 core CPU(Hours)	Frequency Weighted IU (200 Test Images)	Mean IU (200 Test Images)
Traditional Segnet, 800 Images, 2 epochs	1	0.7884	0.7685
Segnet with Quantum Circuit + Softmax, 800 images, 2 epochs	9	0.7665	0.7421
Segnet with only Quantum Circuit, 800 images, 2 epochs	7	0.3795	0.3417
Traditional Segnet, 400 Images, 5 epochs	4	0.7638	0.7368
Segnet with Quantum Circuit + Softmax, 400 images, 5 epochs	26	0.7312	0.7019
Segnet with only Quantum Circuit, 400 images, 5 epochs	22	0.4554	0.4242





Conclusion

- Quantum computing was significantly slower
- Just softmax was most accurate, however softmax + quantum circuit was very close
- Just quantum circuit as replacement for softmax was not very accurate

Possible Future Work

- Improve quantum circuit
- Adjust traditional neural network for better result

Reflection

- I enjoyed conducting research: working with the models, trying different dataset
- I gained knowledge of both ML and quantum computing as well as combining the two
- Learned about the research process such as writing papers and presentations
- Overall, a great learning experience

References

[1] V. Badrinarayanan, A. Kendall, and R. Cipolla, “Segnet: A deep convolutional encoder-decoder architecture for image segmentation,” IEEE transactions on pattern analysis and machine
intelligence, vol. 39, no. 12, pp. 2481–2495, 2017.
[2] J. Preskill, “Quantum computing in the nisq era and beyond,” Quantum, vol. 2, p. 79, 2018.
[3] D. Rist`e, M. P. Da Silva, C. A. Ryan, A. W. Cross, A. D.C´orcoles, J. A. Smolin, J. M. Gambetta, J. M. Chow, and B. R. Johnson, “Demonstration of quantum advantage in machine learning,” npj Quantum Information, vol. 3, no. 1, pp. 1–5, 2017.
[4] J. Liu, K. H. Lim, K. L. Wood, W. Huang, C. Guo, and H.-L. Huang, “Hybrid quantum-classical convolutional neural networks,” Science China Physics, Mechanics & Astronomy, vol. 64, no. 9, pp. 1–8, 2021.
[5] R. Divya and J. D. Peter, “Quantum machine learning: A comprehensive review on optimization of machine learning algorithms,” in 2021 Fourth International Conference on Microelectronics, Signals & Systems (ICMSS). IEEE, 2021, pp. 1–6.
[6] A. Garcia-Garcia, S. Orts-Escolano, S. Oprea, V. Villena-Martinez, and J. Garcia-Rodriguez, “A review on deep learning techniques applied to semantic segmentation,” arXiv preprint arXiv:1704.06857, 2017.
[7] M. Mamun, A. Al, and I. Kadir, “an-eye,” 2020.
[8] “Hybrid quantum-classical neural networks with py-torch and qiskit,” Apr 2022. [Online]. Available: https://qiskit.org/textbook/ch-machine-learning/machine-learning-qiskit-pytorch.html
[9] S. Pramanik, M. G. Chandra, C. Sridhar, A. Kulkarni, P. Sahoo, V. C. DV, H. Sharma, A. Paliwal, V. Navelkar, S. Poojary et al., “A quantum-classical hybrid method for image classification and segmentation,” arXiv preprint arXiv:2109.14431, 2021.
[10] J. Amin, M. A. Anjum, N. Gul, and M. Sharif, “A secure two-qubit quantum model for segmentation and classification of brain tumor using mri images based on blockchain,” Neural Computing and Applications, pp. 1–14, 2022.
[11] E. H. Houssein, Z. Abohashima, M. Elhoseny, and W. M. Mohamed, “Hybrid quantum-classical convolutional neural network model for covid-19 prediction using chest x-ray images,” Journal of Computational Design and Engineering, vol. 9, no. 2, pp. 343–363, 2022.
[12] J. Fritsch, T. Kuehnl, and A. Geiger, “A new performance measure and evaluation benchmark for road detection algorithms,” in International Conference on Intelligent Transportation Systems (ITSC), 2013.