QOSF Mentorship – Screening Task Research Document
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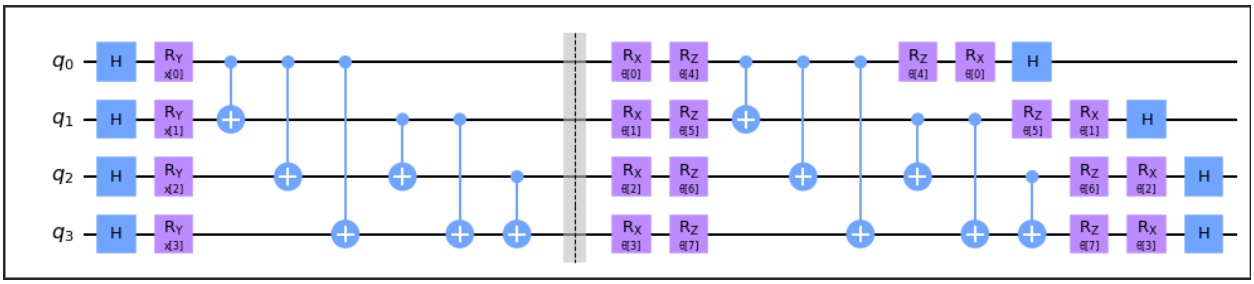
First Ansatz

This is my first attempt at "Task 2 – Encoding and Classifier" from the Cohort 5 Screening Tasks.



1: my first ansatz for Task #2; the barrier separates the data encoding bit from the variational circuit part

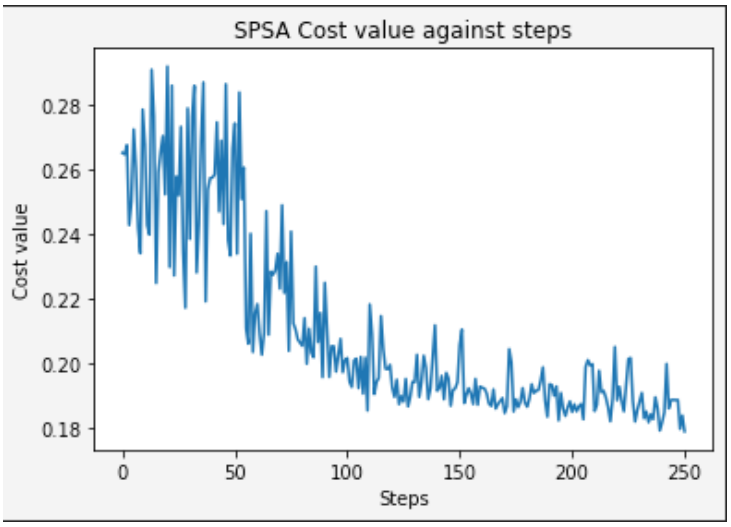
My variational circuit is based off of the quantum variational classifier by Rodney Osodo for a heart attack dataset. I used an angle encoding scheme after normalizing all of the data from columns 0 to 3. It was the easiest to implement as it would map the four features to four qubits. For the variational model, I followed the prompts suggestion and used a layer of CNOT's sandwiched between an Rx and Rz gate. I am using the SPSA optimizer and able to consistently get 100% accuracy on the test data.

Observations and Places to Improve

I want to improve on a couple of aspects. I want to 1) experiment with different encoding schemes and variational circuits to see which would be best for this dataset and 2) somehow make the cost curve smoother and steeper.

I mostly chose the angle encoding scheme because it was the easiest to implement using quantum gates. As I said before, I based the variational circuit on the task prompt. I want to experiment with different variational algorithms, especially the prebuilt ones provided by Qiskit. One question I want to answer is how I can best encode the data.

The cost value seems to jump everywhere while the circuit is optimizing its parameters. Though it eventually finds the optimal parameters and value, I don't really understand why the cost keeps jumping all over the place instead of smoothly decreasing.



2: the cost value shows a downward trend, but is very chaotic

Testing the Data Encoding Scheme and Variational Ansatz

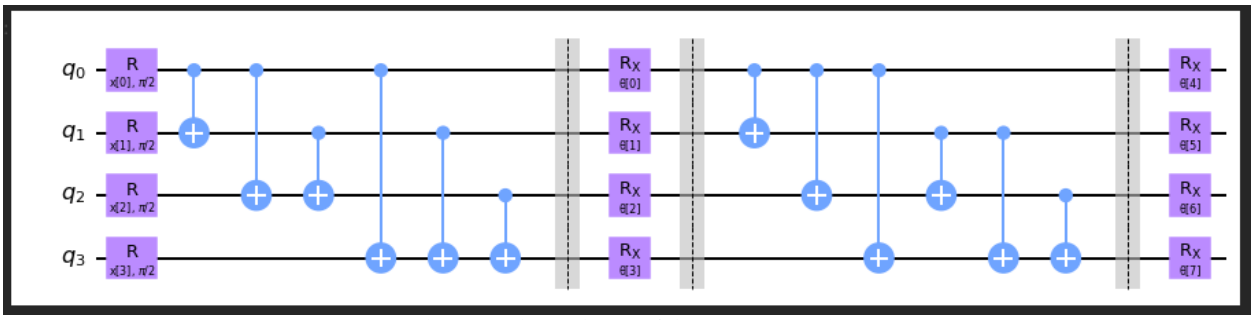
I am going to test different feature map encoding schemes with the Real Amplitudes ansatz. For some reason, I couldn't get any other ansatz, like EfficientSU2, to work. I will test the PauliFeatureMap and the ZZFeatureMap with my original angle encoding scheme.

Feature Map + Variational Circuit	Cost	Accuracy
Original Circuit	0.13612224259323233	100%
PauliFeatureMap	0.17419994312864498	83.33%
ZZFeatureMap	0.15614310722036695	99.17%

My original circuit performed the best. I am not fully sure why, but this could be because RealAmplitudes uses RY gates, which match with my original circuit. The Pauli Feature Map and ZZ Feature Map use unitary, X, and Hadamard gates. To test if the gate that maps the function decreases the cost, I am going to use a TwoLocal ansatz with RX and CX gates, along with full entanglement.

The TwoLocal ansatz is very similar to mine, except mine includes RZ gates before and after the CNOT entangling layer.

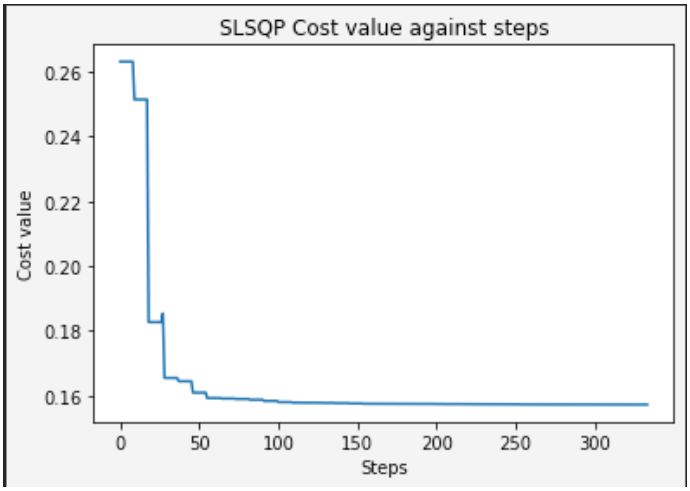
Feature Map + Variational Circuit	Cost	Accuracy
Original Circuit	0.17225285660724407	95%
PauliFeatureMap	0.15986905659960599	96.67%
ZZFeatureMap	0.15765375841371423	95%



3: my data encoding scheme w/ the RX TwoLocal ansatz

I am going to use the ZZFeatureMap with the RealAmplitudes ansatz, like shown in both the Qiskit and Rodney's implementation. I will test some optimizers. I am going to be checking COBYLA, ADAM, SLSQP, and POWELL, and comparing the results with the SPSA optimizer. I believe the reason for the uneven descent of my original variational circuit was due to the randomness inherit in the SPSA optimizer. This will be proven right if the other optimizers show a cleaner descent.

Optimizer	Cost	Accuracy
SPSA	0.15765375841371423	95%
COBYLA	0.16658115543874177	82.5%
ADAM	0.23147974067601282	59.17%
SLSQP	0.15728091581461578	94.17%
POWELL	0.15725962284687664	93.33%



4: SLSQP has a clean descent, converges on parameters faster than SPSA but isn't as accurate

Conclusion

I was really surprised with the difference in accuracy between optimizers. I was right regarding SPSA and the uneven curve; most of the other optimizers showed a smooth convergence. I will be using the ZZFeatureMap, the RealAmplitudes ansatz, and the SPSA optimizer for my second variational circuit.