Calculating Gradients In Quantum Neural Network

Group 13
陳奕安
林昆佑
矯其臻
葉宇晟

Outline

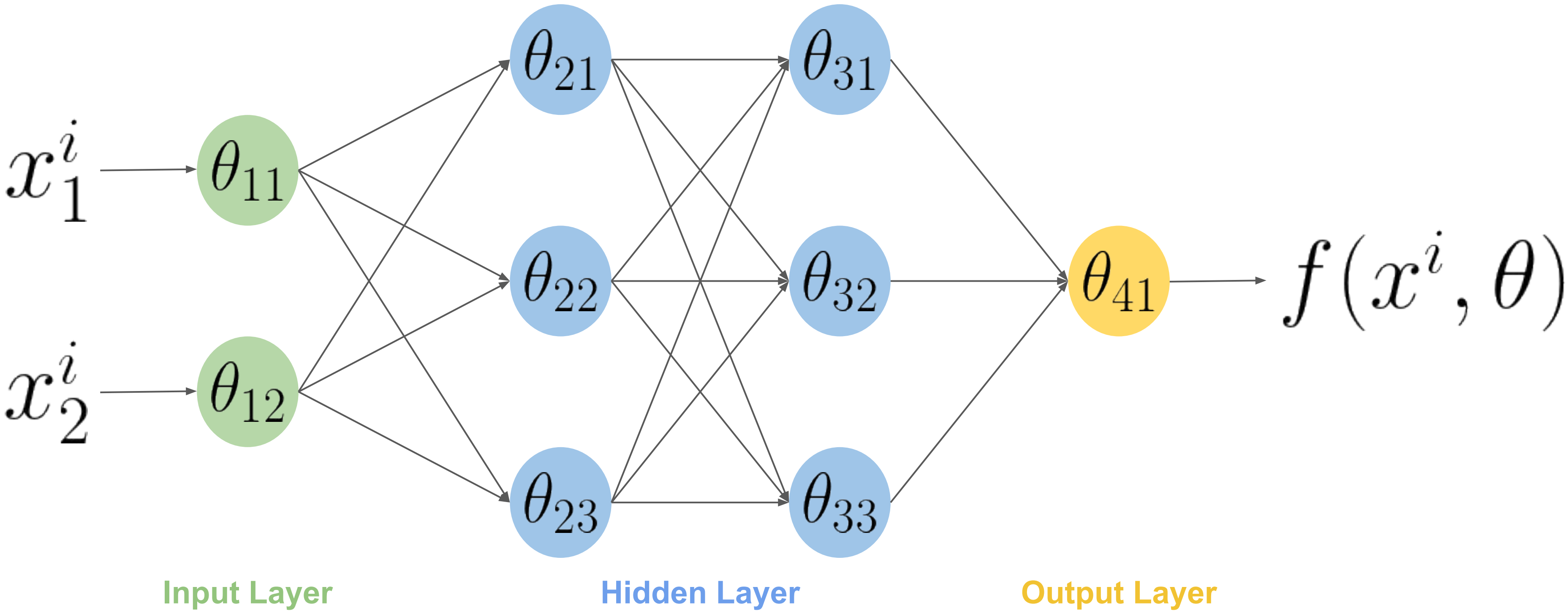
- Review of Classical Neural Network
- Introduction to Quantum Neural Network
- Result of Simulation and Experiment
- Reference

Task Distribution

- 陳奕安 (Simulation, Theory, Slide & Presentation)
- 林昆佑 (Simulation, Ideal Model)
- 矯其臻 (Simulation, Noise Model)
- 葉宇晟 (Simulation, IBMQ)
- github : https://github.com/r08222011/Qiskit_Parameter_Shift

Review of Classical Neural Network

Review of Classical Neural Network



Gradient Descent Method

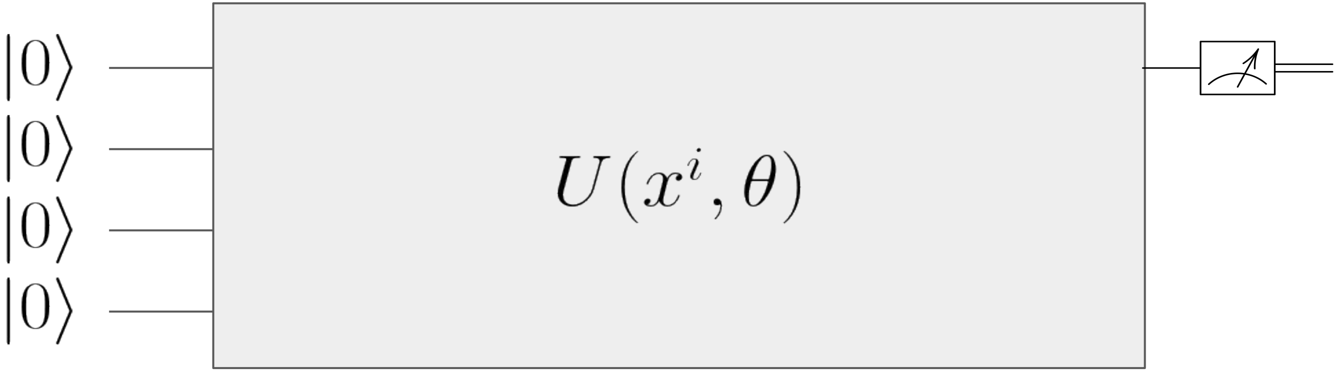
- Define Loss function as $L(\theta) = \sum_{i=1}^{N} (f(x^i, \theta) - y^i)^2$
- To optimize the parameters, substitute $\theta \rightarrow \theta - \lambda \nabla L(\theta)$
- The gradient of the Loss function is simply $\boxed{\frac{\partial L}{\partial \theta} = \sum_{i=1}^{N} 2(f(x^i, \theta) - y^i) \frac{\partial f}{\partial \theta}}$
- After some iterations of optimization, we can reduce the Loss function

Introduction to Quantum Neural Network

Quantum Neural Network

- Design the neural network using quantum circuit

- Define our output value depending on measurement, e.g. $f = \langle 0 | U^\dagger Z_1 U | 0 \rangle$



Gradient for QNN

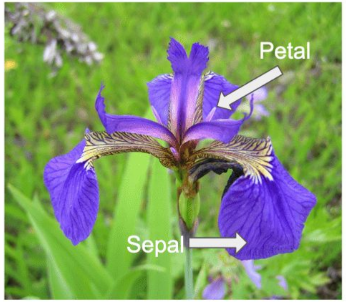
- Can't calculate the gradient $\frac{\partial f}{\partial \theta}$ using classical methods, e.g. finite difference
- In some special cases, we may calculate the gradient using quantum circuit
- Define $R_\sigma(\theta) = e^{-\frac{i}{2}\theta\sigma}$
- Let's say we want to calculate the gradient of $f(\theta) = \langle\psi|R_\sigma(\theta)^\dagger A R_\sigma(\theta)|\psi\rangle$
- Surprisingly, the gradient turns out to be $\boxed{\frac{\partial f}{\partial \theta} = \frac{1}{2}[f(\theta + \frac{\pi}{2}) - f(\theta - \frac{\pi}{2})]}$

Result of Simulation and Experiment

Problem Setup

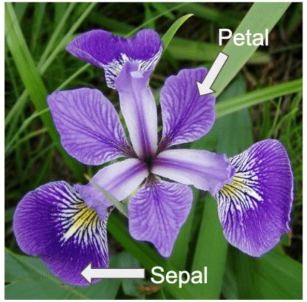
- Classification with Iris data with 4 features (select only 2 types of Iris data)
- Reduce features from 4 to 2 using Principal Component Analysis (PCA)
- Using only 2 qubits and measure the first qubit as the output value

Iris setosa



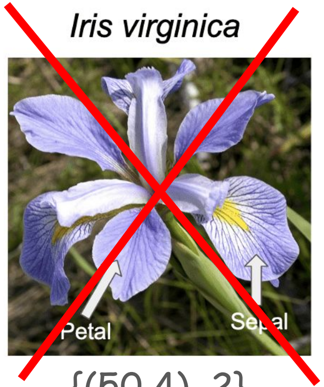
{(50,4), 0}

Iris versicolor

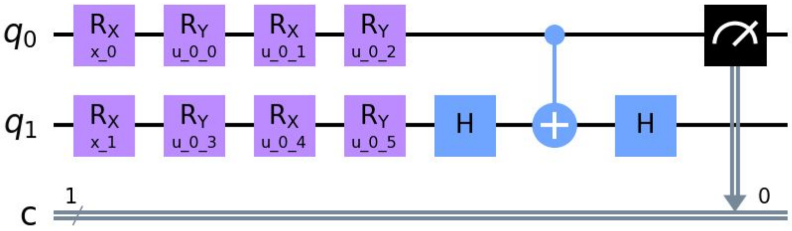


{(50,4), 1}

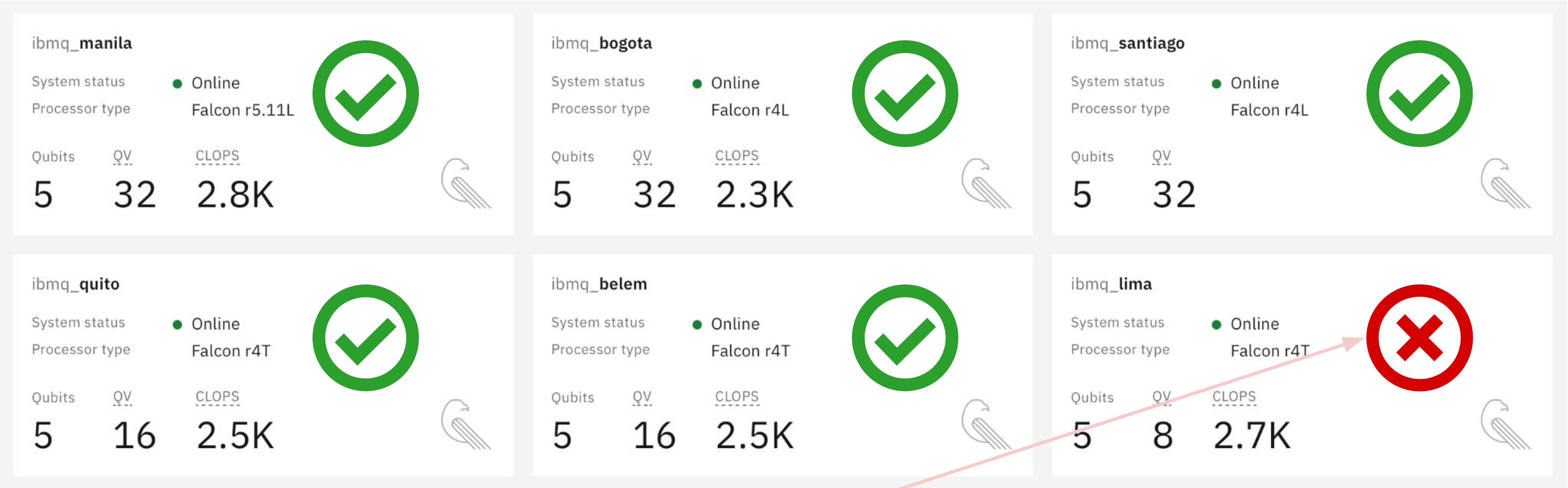
~~*Iris virginica*~~



{(50,4), 2}

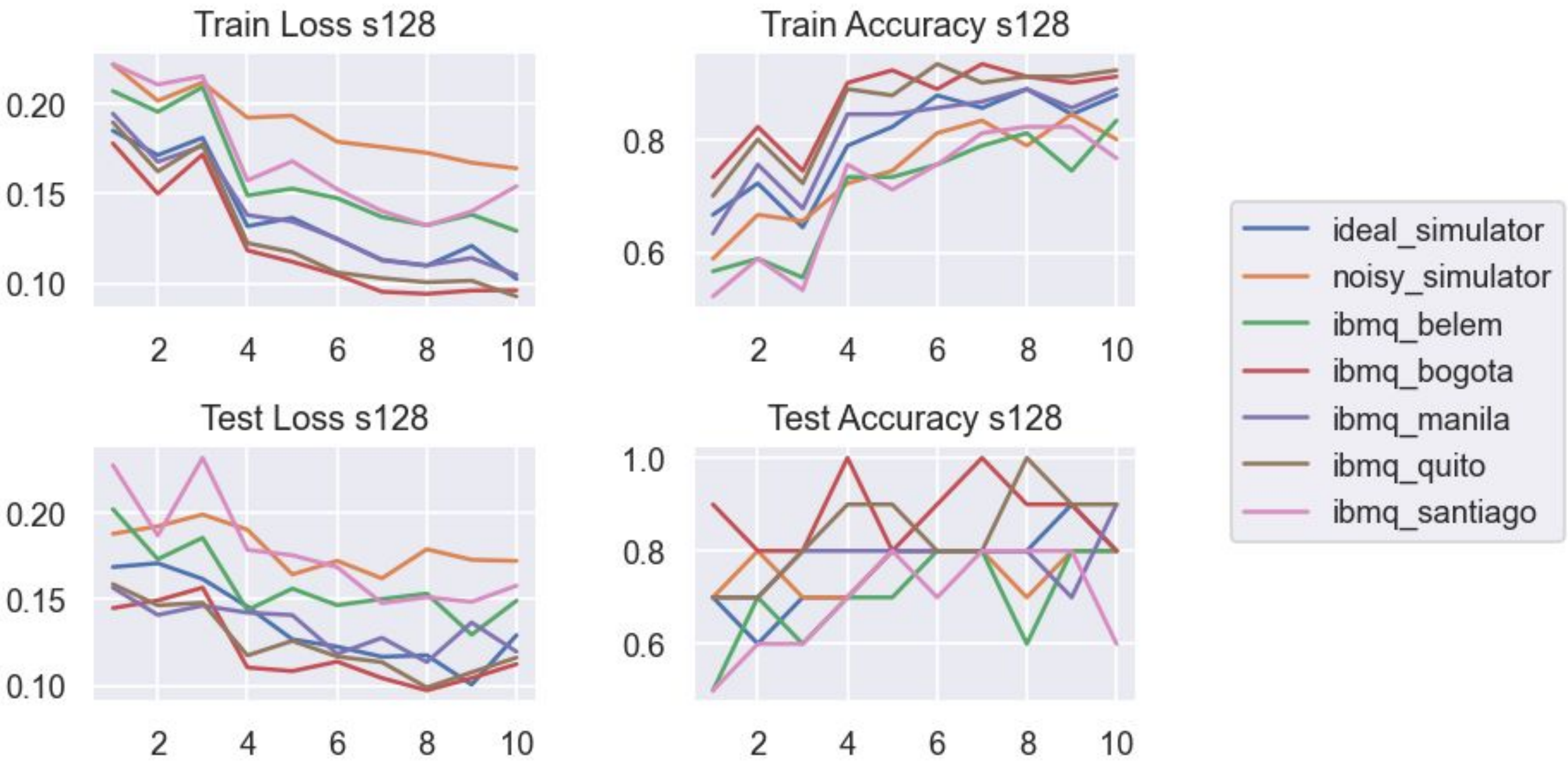


Select IBM Quantum Computer



Too many queues for "ibmq_lima" ...

Result with shots=128



Result with shots=1024

Reference

- *Gradients of parameterized quantum gates using the parameter-shift rule and gate decomposition* by Gavin E. Crooks (arXiv 1905.13311)