Qiskit

Elements for building a quantum future

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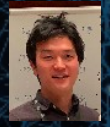

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Basic Quantum Neural Network

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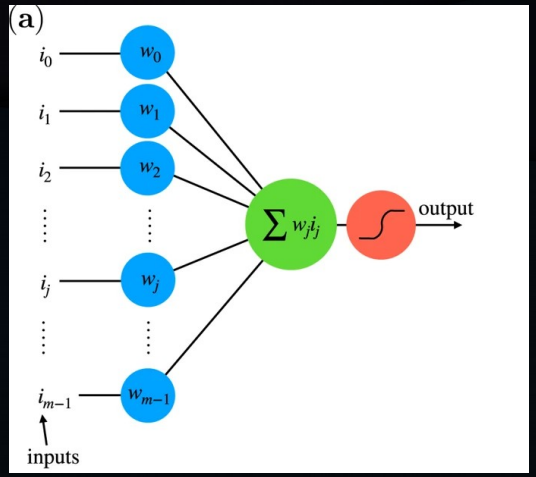
Introduction

- Neural Network models are widely used for Classification problem in Machine Learning [1]
- Training the data in Neural Network for Big Data problem
- Representation of the Qubit for Neuron (Quantum Neuron), with the input and weight
- Optimization of the parameters of quantum neural networks

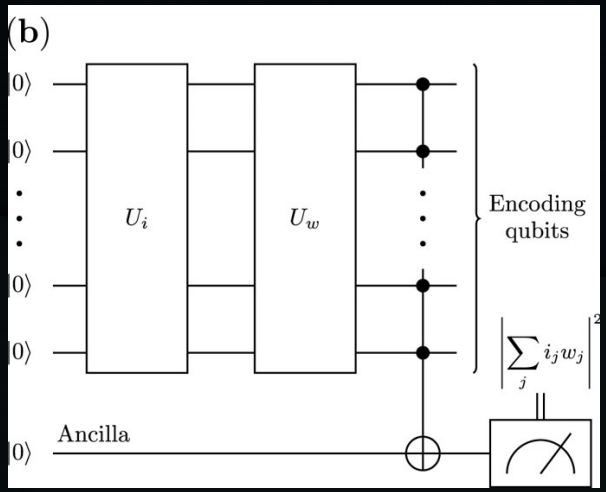
M. Schuld, I. Sinayskiy, F. Petruccione: The quest for a Quantum Neural Network, Quantum Information Processing 13, 11,(2014)
Schuld, M., Sinayskiy, I. & Petruccione, F. Simulating a perceptron on a quantum computer. Phys. Lett. A 7, 660–663 (2015).

Why Quantum Neural Networks?

- Classical
  - 2^n possible state only one at the same times
  - Problem in multiple layer and many neuron (processing neuron and complexity)



- Quantum
  - Simultaneously: exponential advantage of quantum information storage
  - Features quantum parallelism, entanglement and interference effects



Tacchino, F., Macchiavello, C., Gerace, D. et al. An artificial neuron implemented on an actual quantum processor. npj Quantum Inf 5, 26 (2019)

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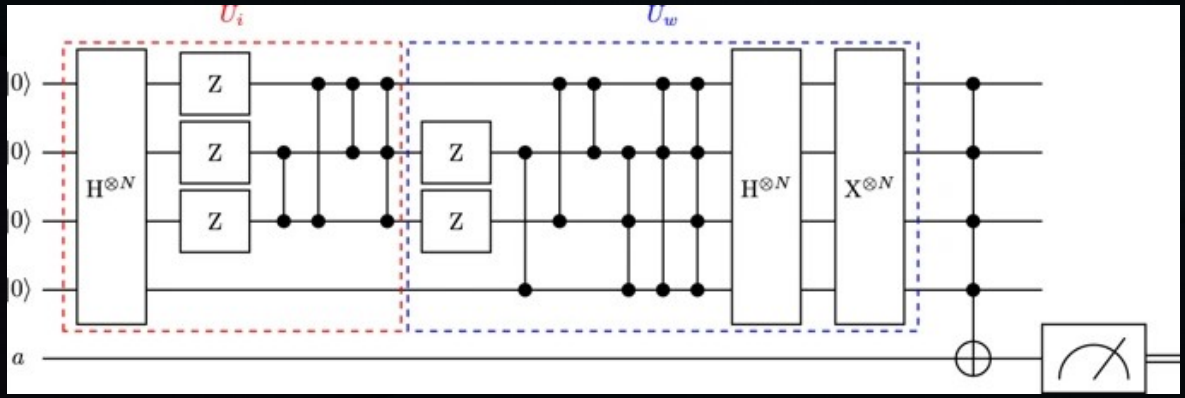
Solution Neural Network Quantum Computing



- The first two unitary operations prepare the input quantum state, $|\psi_i\rangle$, and implement the U_w transformation, respectively.
- Gate for input and weight;
  - In the paper: {-1 or 1} (Z gate)
  - Our used (continuous values): { -1 < x < 1} (Rotation gate)
- The final outcome is then written on an ancilla qubit

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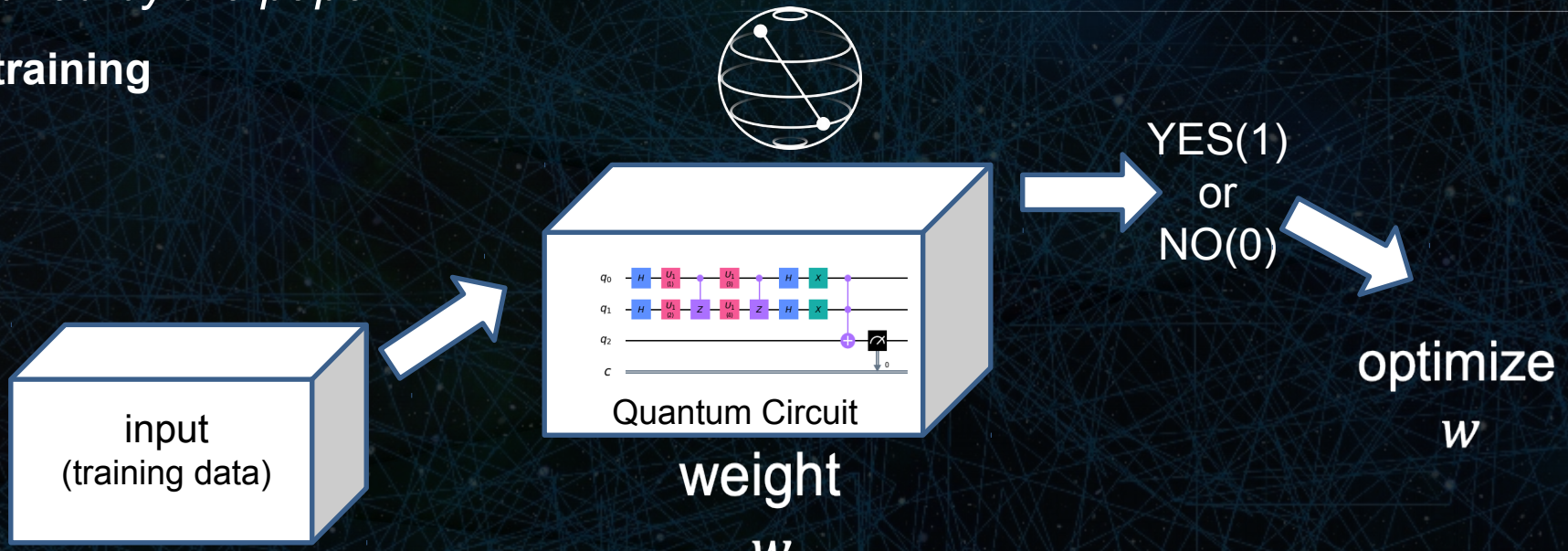
Our Strategy: Quantum Neural Networks

inspired by the paper

training



Example: AND

x1	*x2*	*y*
0	0	0
0	1	0
1	0	0
1	1	1

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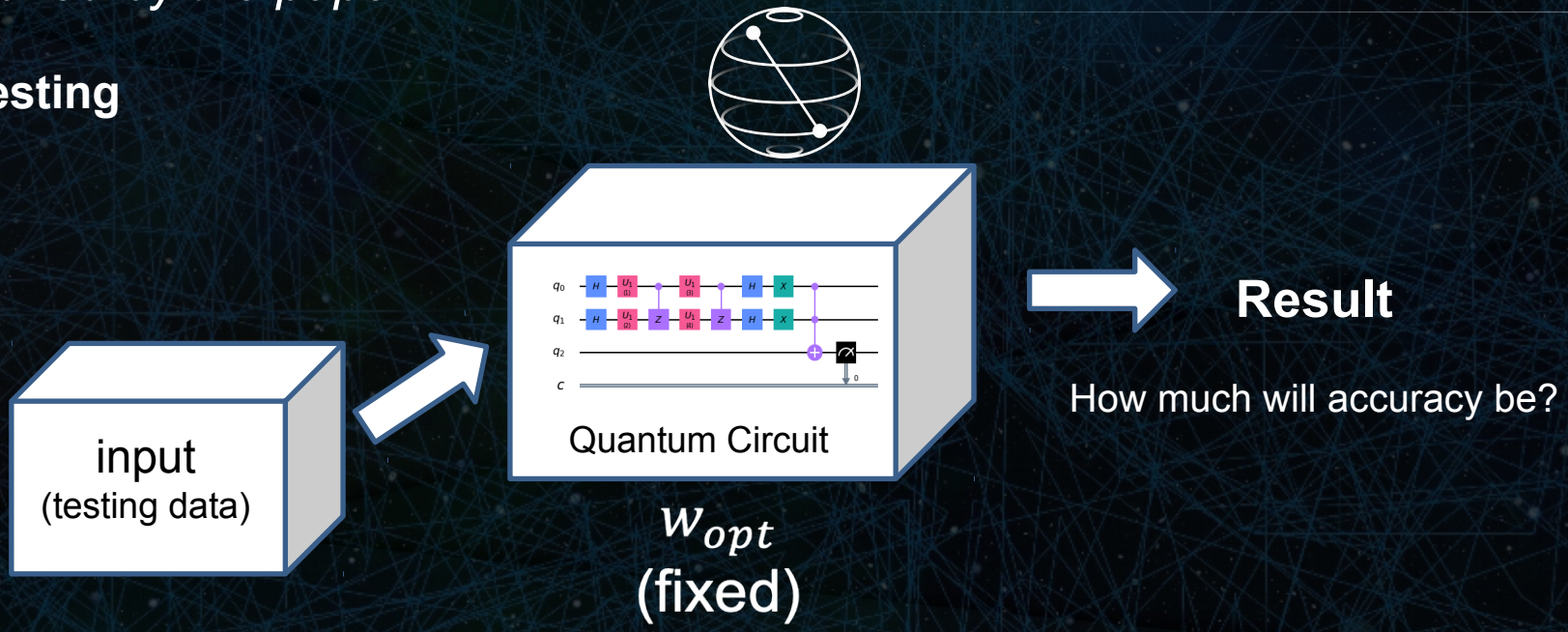
Our Strategy: Quantum Neural Networks

inspired by the paper

testing



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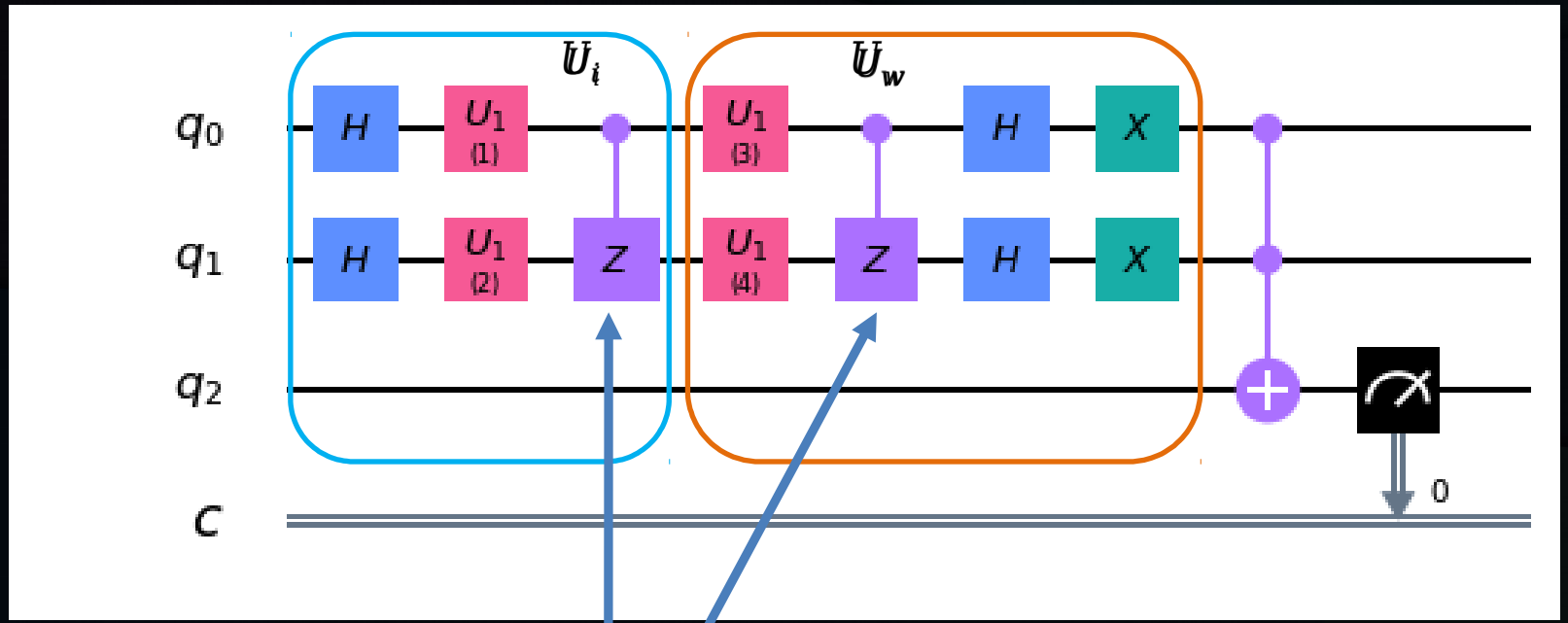
Our Quantum Circuit:

Quantum Neural Networks

Stronger Expression Power?

Rotation Gates encode input data (x_1,x_2)

Rotation Gates encode weights (w_1,w_2)



repeat many times as changing weight

make entanglement

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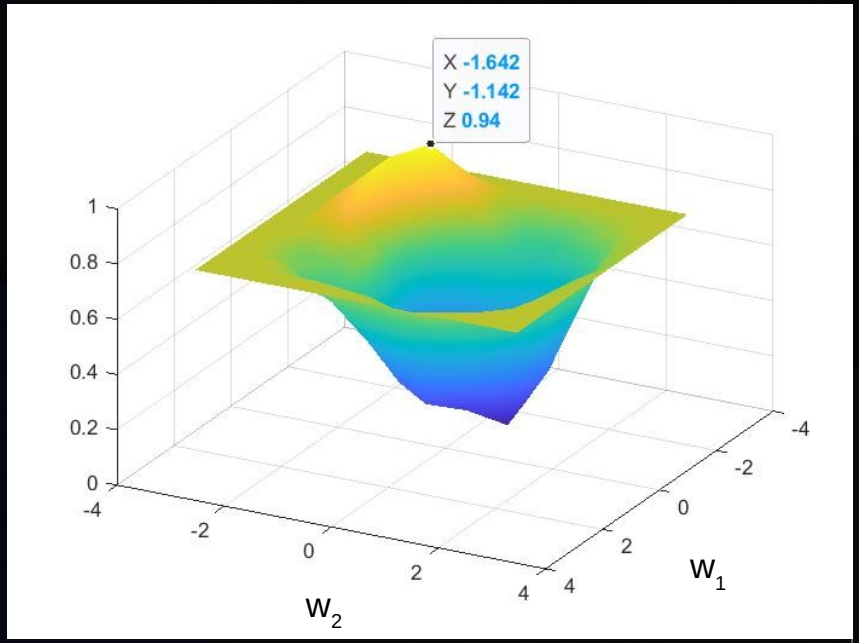
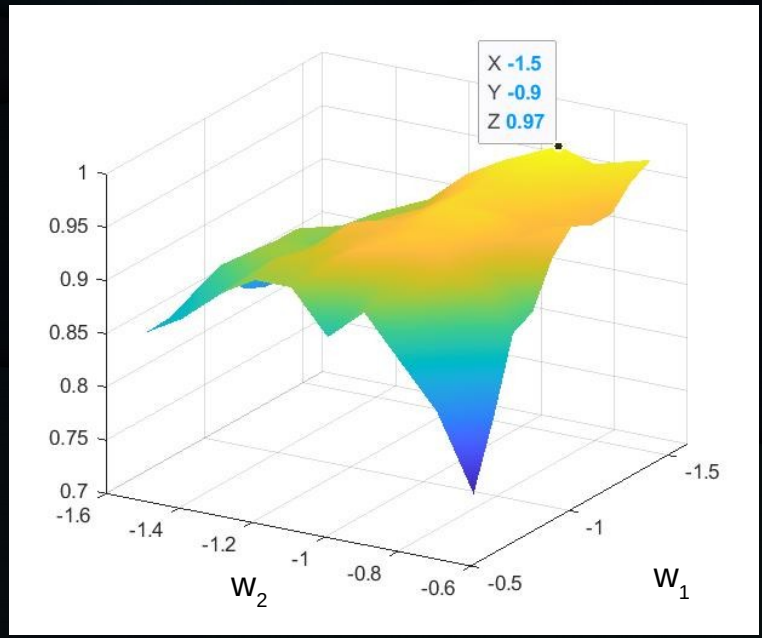
Quantum Neural Networks

Result: training data (AND Gate)

- Run on the IBM-Q Simulator with 1024 times shots
- 100 training data (same with testing)



- Choose the best weight (w_1 & w_2) from the high correction rate (accuracy),
- Max **97%** correction rate during training at $\mathbf{w_1}$=-1.5, $\mathbf{w_2}$=-0.9



Data Testing Correction Rate = 93%

Conclusion & What's next?

Quantum Neural Networks

- An AND gate is obtained by optimizing the neuron using the qubit gates.
- Multi-Layer Perceptrons Quantum Neural Network for Deep Learning Neural Network
- Improvement in the time and efficiency of training process
- More qubit usage to used for more complex problem