Summary of Key Concepts

Near-Term Algorithms

Week of March 3rd, 2024

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Resources

- QXQ YLC Week 19 Homework Notebook [STUDENT].ipynb
- QXQ YLC Week 19 Lab Notebook [STUDENT].ipynb
- 6. QXQ YLC 23-24 Variational Algorithms Cheat Sheet

Key Terms

Key Term	Definition
Near Term Algorithms	Near term algorithms are a class of algorithm that takes advantage of the strengths of classical and quantum computers, as well as current technology, to solve problems.
Hybrid Algorithms	Hybrid quantum algorithms utilize a classical computer and a quantum computer together to minimize the work that the quantum computer performs. Conceptually, they are similar to how CPUs and GPUs work together.
Variational Algorithms	A variational algorithm is a type of near term algorithm that uses tunable circuits to solve constrained optimization problems. The variational algorithm's parameters are tuned after each iteration with the hope of reaching the optimized solution.
Constrained Optimization Problems	A class of problems where we need to find an optimal combination of elements within certain parameters.
Tunable Circuit	A quantum circuit that allows us to tune parameters, opposed to a typical quantum circuit, such as Grover's Algorithm, whose parameters are fixed.
Circuit Ansatz	A circuit template for a tunable circuit.
Tunable Gates	Gates that can rotate a qubit about a specified axis by a specified number of degrees.
Cost Function	A function that takes a solution and outputs how "costly" or "undesirable" it is.

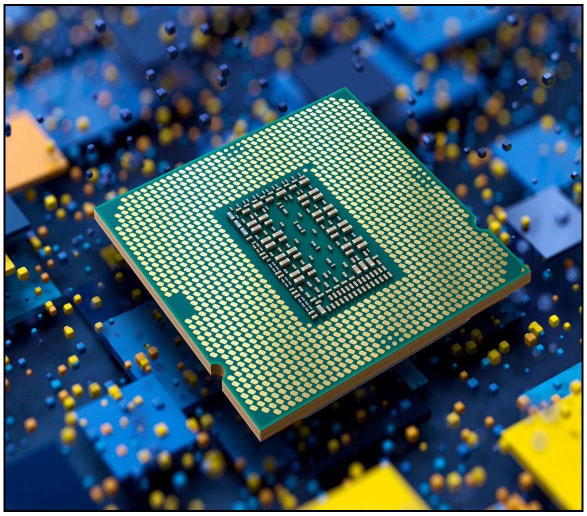
Lecture

Learning Objectives

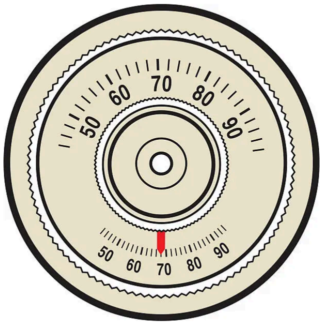
1. Recognize what a near term algorithm is.
2. Recognize what a hybrid algorithm is.
3. Recognize what a variational algorithm is.
4. Recognize that near term algorithms will serve a purpose, even after fault tolerant quantum computers become a reality.

Key Ideas

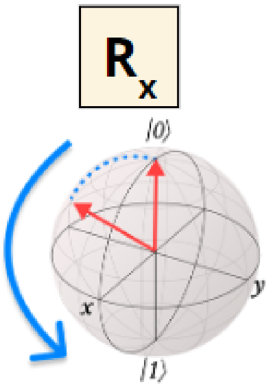
1. Near term algorithms are applicable now and take advantage of quantum properties as well as the strengths of classical computers.
2. Hybrid algorithms operate in a similar manner as how CPUs and GPUs work together.



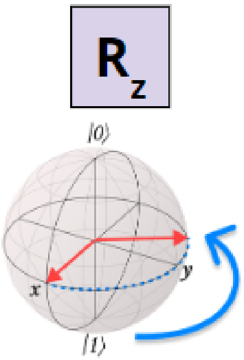
3. Variational algorithms can be tuned to find the optimal solution. Similar to how temperature can be changed using a thermostat to find the most comfortable temperature.



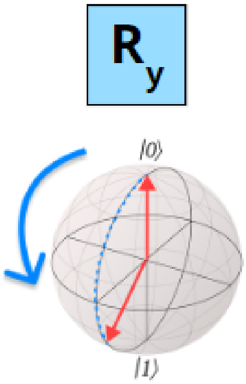
4. We use tunable gates to vary the parameters in our variational circuit.



Rotation of θ radians around the X-axis

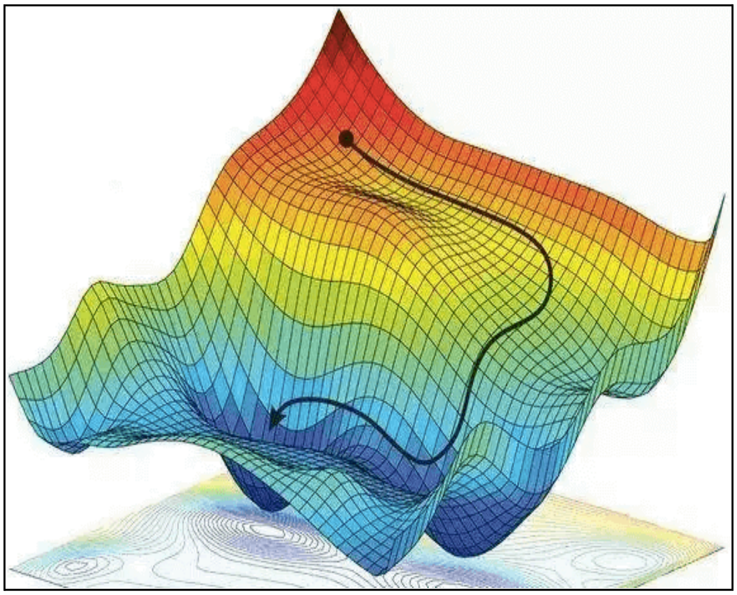


Rotation of θ radians around the Z-axis

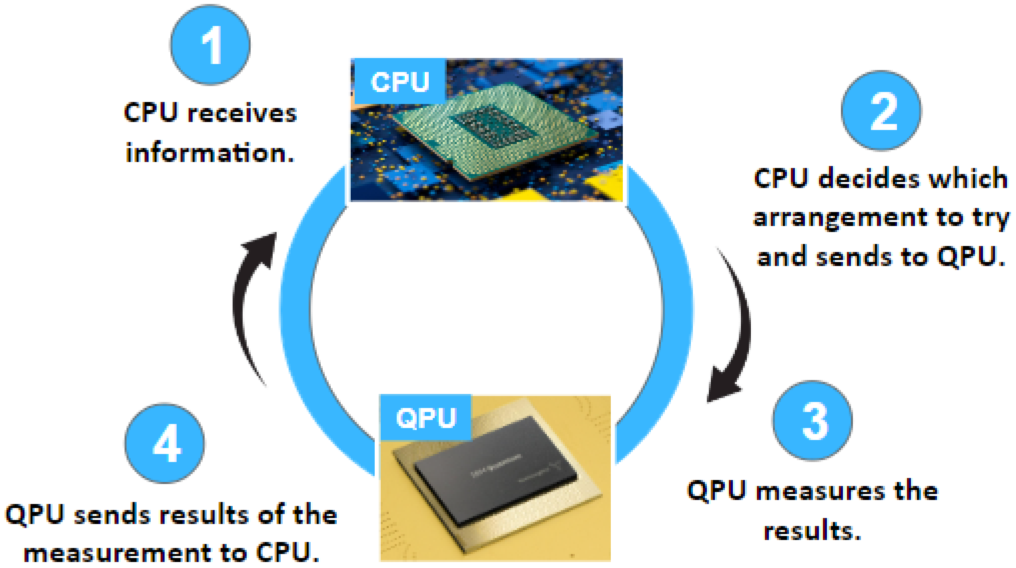


Rotation of θ radians around the Y-axis

5. Near term algorithms are very good at solving constrained optimization problems.



6. Even when fault tolerant quantum computers become a reality, we will still want to use near term algorithms for certain problems.


1
CPU receives information.
CPU
2
CPU decides which arrangement to try and sends to QPU.
3
QPU measures the results.
QPU
4
QPU sends results of the measurement to CPU.

Lab

Learning Objectives

1. Recognize what tunable gates are and how to implement them.
2. Recognize how to implement variational algorithms.
3. Recognize what cost functions are.

Key Ideas

1. Variational algorithms are a new and growing field, with new algorithms constantly being discovered.

   Variational Quantum Eigensolver (VQE)

   Quantum Approximate Optimization Algorithm (QAOA)

   Quantum Variational Classifier (QVC)

   Quantum Neural Network (QNN)

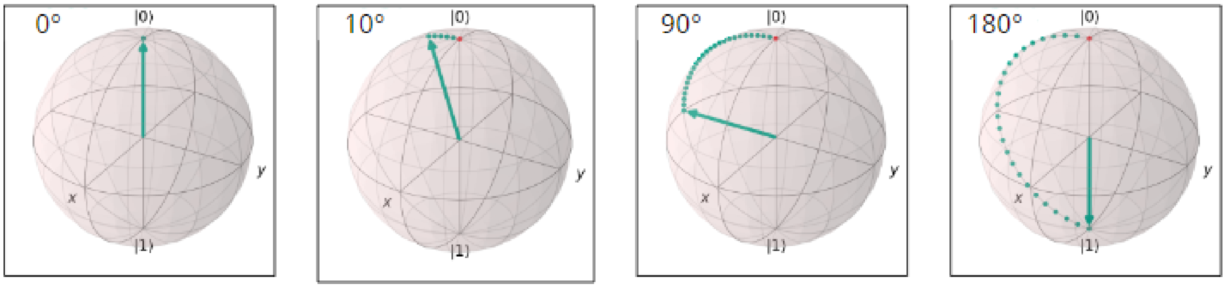
2. Variational algorithms try variations of multiple solutions to a problem to find the best one.
   a. Sometimes we settle for a solution that is just **good enough**, not necessarily the best.
3. Variational algorithms have many different options to consider when setting up, such as:
   a. The circuit ansatz to use.
   b. The first set of parameters to try.
   c. How many measurements we make.

   d. What cost function or measure of quality to use.

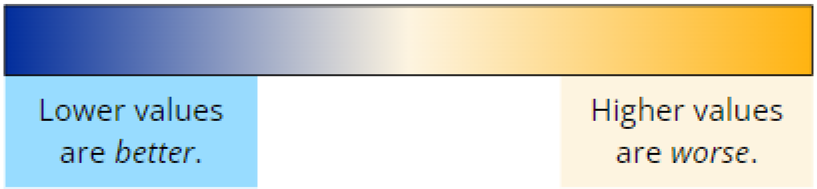
   e. What classical optimization algorithm we use to fine tune the parameters.

   f. And much more!

4. Circuit ansatz are the key to variational algorithms, and tunable gates within the ansatz are what allow us to tune our parameters.



5. The cost function is how we measure the results of a variational algorithm and compare them to each other. A lower value on the cost function is a better solution.


Lower values
are *better*.
Higher values
are *worse*.