Introduction to Quantum Computing

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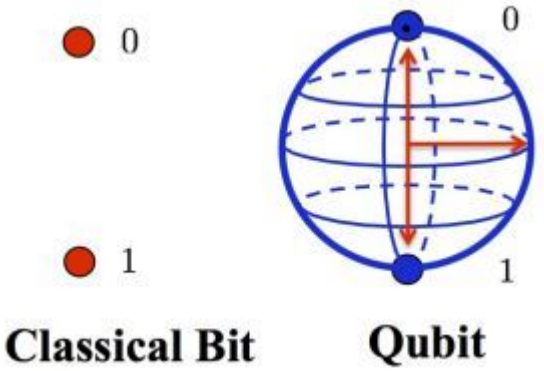
What is Quantum computing?

- Quantum computers exploit the laws of quantum mechanics to perform computation
- **Some** types of computations can be performed more efficiently on quantum computers than classical computers
- Some principles of quantum mechanics
  - Superposition
  - Entanglement
  - Decoherence

Quantum bits

- The basic unit of information in classical computing is the bit; which can either be a 0 or 1
- The basic unit of information in quantum computing is the quantum bit; or qubit can be in a linear combination of 0 and 1.



Quantum gates

- Quantum gates are used to process quantum computation
- These gates are represented by unitary matrices.
- The NAND gate is universal for classical computation
- The Hadamard, T, and CNOT gates are universal for quantum computation

$$X = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \qquad Y = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix} \qquad Z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

$$1 = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix} \qquad H = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 1 \\ 1 & -1 \end{pmatrix}$$

$$S = \begin{pmatrix} 1 & 0 \\ 0 & i \end{pmatrix} \qquad T = \begin{pmatrix} 1 & 0 \\ 0 & e^{i\pi/4} \end{pmatrix} \qquad CNOT = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 \end{pmatrix}$$

Building a Quantum computer

- DiVincenzo's criteria
  - Qubits
  - Qubit initialization
  - Long coherence times of qubits
  - Universal set of quantum gates
  - Capability of measuring the qubit state
- Superconducting quantum computers
- Ion trap quantum computers
- Silicon quantum computers

Quantum computing applications

- Simulating Quantum physics
  - Quantum chemistry
    - Variational Quantum Eigensolver (VQE)
  - Quantum field theory
- Optimization problems
  - Quantum Approximate Algorithm
    - Machine learning
- Quantum Fourier Transform
  - Factoring
- Searching unsorted databases
- Solving systems of linear equations

Programming Quantum computers

- Cloud quantum computing
  - Rigetti computing
    - Forest
  - IBM
    - QISkit
  - Microsoft
    - Q#

References

- Qubit.jpg International Business Times. June 25, 2015. Web. 2/01/2018. https://goo.gl/TQAmnr
- Schmassmann, M. Universality of Quantum Gates, (2007)
- R. S. Smith, M. J. Curtis, and W. J. Zeng. A practical quantum instruction set architecture, 2016.

Thank you for listening! Any questions?

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