Projecting Quantum Computational Advantage Versus Classical State of the Art

Dr. Jason Larkin
What is Quantum Computing?
What is Quantum Computing?

- **0**
  - \( |0>\)
  - \( |0> + |1> / \sqrt{2} \)

- **1**
  - \( |1>\)
  - \( |00> |01> |10> |11> |000> |001> |010> |011> |100> |101> |110> |111> \)
  - \( \ldots \)

**Cbit**

**Qubit**
- superposition
- entanglement

Noisy Intermediate-Scale Quantum (NISQ) computers aim to perform computational tasks beyond the capabilities of the most powerful classical computers, thereby achieving “Quantum Supremacy,” a major milestone in quantum computing.

Universal Gate Quantum Software Engineering

Algorithms

Universal Gate

Circuit

q0x…q53 = 2^53 states

Applications

Quantum High-Level Language

Intermediate Representations

Emulator

QC (QPU)
Quantum Computing Education

• By some estimates, fewer than 25,000 people can be considered genuine experts in deep learning.

• There are even fewer experts in the field of quantum computing.

• Some accounts estimate that only 1000 people worldwide can legitimately claim to be involved in leading research in the field.
Why Quantum Computing?
Quantum Supremacy?

Quantum Supremacy is the demonstration of superiority over a classical computer on some narrow (but well-defined) task. Google it (literally and figuratively).

Quantum Supremacy

Quantum Advantage refers to a quantum computer reaching a better “quality” of solution, or reaching a solution faster than a classical computer, for a useful problem.
Quantum Advantage: Cryptography

Gidney, Craig & Ekera, Martin. “How to Factor 2048 Bit RSA Integers in 8 Hours Using 20 Million Noisy Qubits.” May 24, 2019

The RSA (and some other) encryption protocols might be vulnerable over a 10-20 year time frame.

However…

NIST is currently reviewing post-quantum encryption protocols.

This projection is a demonstration of quantum advantage: doing something useful that classical computers will never be able to. What other applications will we find with this type of quantum advantage?
Quantum Computing in the NISQ Era
Research Review 2019

Quantum Software Engineering in NISQ Era

Quantum High-Level Language

Intermediate Representations

Emulator

QC (QPU)

Applications

Architectural Parameters

© 2019 Carnegie Mellon University

[DISTRIBUTION STATEMENT A] Approved for public release and unlimited distribution.
Quantum Advantage: Classical State of the Art

Classical High Level Language
- Compiler/OS
- Architecture
- VLSI
- Emulator
- IC (CPU)

• 60+ year benchmarks
• Software Defined Hardware (SDH)
  • Dr. Tom Rondeau
• Combinatorial Optimization
• Graph Analytics
• AI/ML

Quantum High-Level Language
- Intermediate Representations
- Emulator
- QC (QPU)

Applications

Architectural Parameters
Quantum Computing at the SEI and the DoD: The Future
Quantum Computing Has (or Will Have) Many Forms

Applications?

- Universal Gate
  - Superconducting Qubits
  - Trapped-Ion Qubits
  - ...
- Quantum Annealing
- Continuous Variable
- Topological

Full Stack 1

Full Stack 2

Full Stack 3
Quantum Computing Education

- By some estimates, fewer than 25,000 people can be considered genuine experts in deep learning.
- There are even fewer experts in the field of quantum computing.
  - Some accounts estimate that only 1000 people worldwide can legitimately claim to be involved in leading research in the field.
QuantumHub

Only **1000** people worldwide can legitimately claim to be involved in leading research in the field of quantum computing.

SEI: 30 users
CMU: 15 users
- ECE
- Physics
- CS
- MatSci

https://quantum.etchub.xyz
https://qhub.xyz
Noisy Intermediate-Scale Quantum (NISQ) Computers