Chasing Quantum Supremacy

Doug Finke, Managing Editor
Quantum Computing Report
Where Qubits Entangle with Commerce

February 13, 2018

Chasing Quantum ~~Supremacy~~ Advantage

Doug Finke, Managing Editor
Quantum Computing Report
Where Qubits Entangle with Commerce

February 13, 2018

Taxonomy for Milestones in QC Performance

	Practical (Demonstration)	Foundational (Demonstration + Theoretical Proof)
Any Problem (Includes made-up problems)	**Weak Quantum Supremacy**	**Quantum Supremacy**
Valuable Problems (Generally measured in $$$)	**Quantum Advantage**	**Strong Quantum Advantage**

Source: Medium article posted by Will Zeng, 1/31/2019

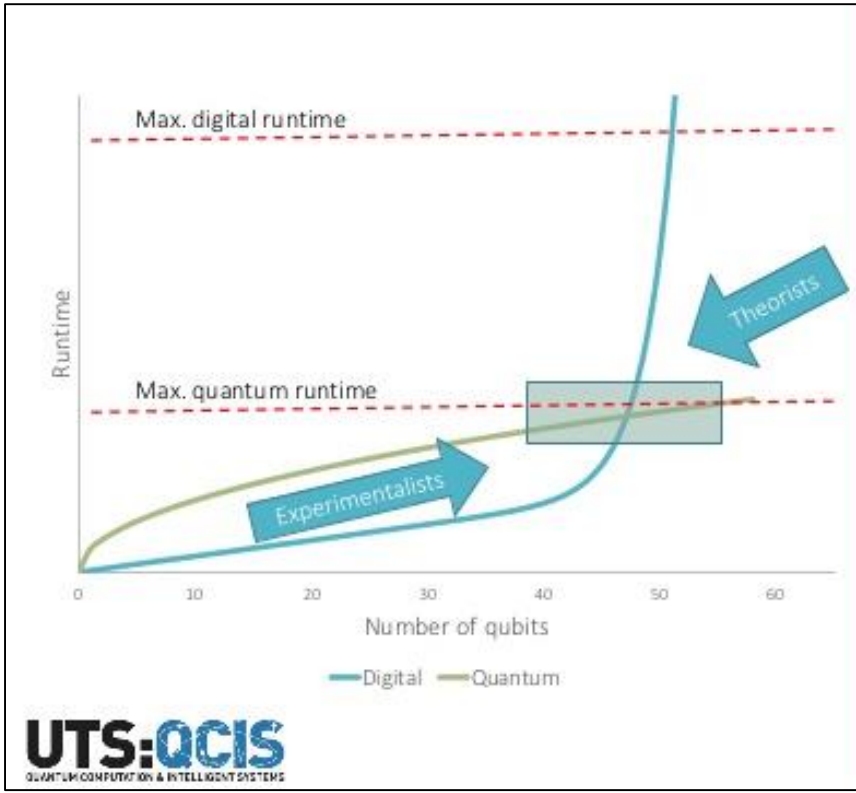
Why are We Investing in QC in the First Place?

- Create computation machine based upon quantum mechanics that can solve problems that classical computers cannot.

Why do we think that QC Could Beat Classical

- Doubling the performance of a classical computer requires doubling the HW (e.g. 1TB→2TB of memory or 1024 cores → 2048 cores)
- Doubling the performance of a quantum computer only requires adding one more qubit. (e.g. 50 qubits → 51 qubits)

Runtimes of Classical and Quantum vs. Qubits



UTS:QCIS
QUANTUM COMPUTATION & INTELLIGENT SYSTEMS

Quantum supremacy (2-7 years)

Demonstrations of applications on "intermediate quantum computers" that cannot be performed by digital computers.

Theory breakthroughs: Lowering the crossover point (MIT, UTS, Bristol, GCHQ, Cambridge)

Experimental breakthroughs: Increase in runtime/qubit.

Classical Computing Improves Every Year Raising the Bar for Demonstrating Quantum Advantage

- Classical improvements driven by:
  - Moore's Law (although expected to end soon)
  - Ever larger supercomputer installations
  - Improved hardware architectures
  - GPU's and FPGA based architectures
  - Neuromorphic and Memory-Centric Computing
  - Improved classical algorithms
  - Quantum inspired algorithms

Software Simulators on Classical Computers

Project	Qubits
Alibaba/Univ. of Michigan	144*
Atos	41
ETH Zurich	45
Huawei – HiQ Cloud Service	42-169*
IBM Research	56
Intel – qHiPSTER	43
Microsoft – PC	30
Microsoft – Azure	40
Rigetti – Forest	36
University of Melbourne	60
USTC/Origin QC	64

Note: * denotes special conditions

- General consensus is that a quantum machine needs to exceed 50-64 qubits to be to have a shot at quantum supremacy.
- The qubits also need a certain quality level so the machine can complete the calculation before making an error.
- Otherwise a classical computer can solve the problem by using a quantum simulator to execute the quantum program.
- Classical computers have another key advantage: They don't make any errors!

Hardware Qubit Counts

Company	Type	Technology	Now	Next Goal
Intel	Gate	Superconducting	49	TBD
Google	Gate	Superconducting	72	TBD
IBM	Gate	Superconducting	50	TBD
Rigetti	Gate	Superconducting	19	128
USTC (China)	Gate	Superconducting	10	20
IonQ	Gate	Ion Trap	11	79
IQOQI/Univ. Ulm/Univ. Innsbruck	Gate	Ion Trap	20	TBD
NSF STAQ Project	Gate	Ion Trap	N/A	≥64
Intel	Gate	Spin	26	TBD
Silicon Quantum Computing	Gate	Spin	N/A	10
CEA-Leti/INAC/Institut Néel	Gate	Spin	N/A	100
Univ. of Wisconsin	Gate	Neutral Atoms	49	TBD

Best candidates to have hardware in 2019 that can demonstrate quantum supremacy

- Google – 72 qubits
- Rigetti – 128 qubits
- IonQ – 79 qubits

Having hardware is a necessary, but not a sufficient condition.

Google Project to Show Quantum Supremacy

[1608.00263] Characterizing Qua

https://arxiv.org/abs/1608.00263

Apple | Suggested Sites | Yahoo! | Imported From Edge | wdc%2Cstx%2Cf%2C | Free Hotmail | Web Slice Gallery | Disney | ESPN

Cornell University

arXiv.org > quant-ph > arXiv:1608.00263

Search or A

(Help | Advance

Quantum Physics

Characterizing Quantum Supremacy in Near-Term Devices

Sergio Boixo, Sergei V. Isakov, Vadim N. Smelyanskiy, Ryan Babbush, Nan Ding, Zhang Jiang, Michael J. Bremner, John M. Martinis, Hartmut Neven

(Submitted on 31 Jul 2016 (v1), last revised 5 Apr 2017 (this version, v3))

A critical question for the field of quantum computing in the near future is whether quantum devices without error correction can perform a well-defined computational task beyond the capabilities of state-of-the-art classical computers, achieving so-called quantum supremacy. We study the task of sampling from the output distributions of (pseudo-)random quantum circuits, a natural task for benchmarking quantum computers. Crucially, sampling this distribution classically requires a direct numerical simulation of the circuit, with computational cost exponential in the number of qubits. This requirement is typical of chaotic systems. We extend previous results in computational complexity to argue more formally that this sampling task must take exponential time in a classical computer. We study the convergence to the chaotic regime using extensive supercomputer simulations, modeling circuits with up to 42 qubits - the largest quantum circuits simulated to date for a computational task that approaches quantum supremacy. We argue that while chaotic states are extremely sensitive to errors, quantum supremacy can be achieved in the near-term with approximately fifty superconducting qubits. We introduce cross entropy as a useful benchmark of quantum circuits which approximates the circuit fidelity. We show that the cross entropy can be efficiently measured when circuit simulations are available. Beyond the classically tractable regime, the cross entropy can be extrapolated and compared with theoretical estimates of circuit fidelity to define a practical quantum supremacy test.

- Task consists of sampling the output of a random quantum circuit
- Time increases exponentially on a classical computer as you add qubits
- Google will work with NASA Ames to compare results against the Pleiades petaflop supercomputer

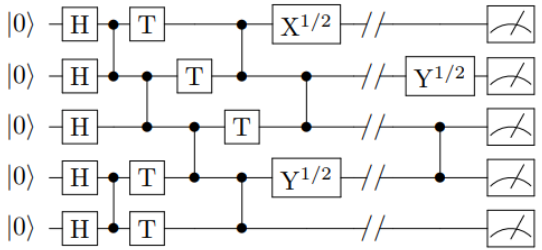
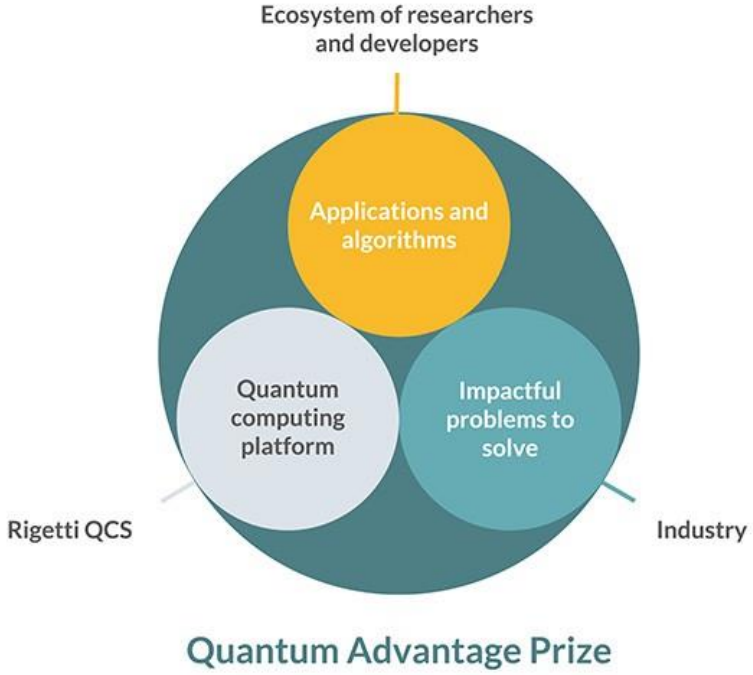


FIG. 1. Example of a random quantum circuit in a 1D array of qubits. Vertical lines correspond to controlled-phase (CZ) gates (see Sec. IV).

Rigetti $1 Million Quantum Advantage Prize

- Awarded to first team that can demonstrate Quantum Advantage on a real application.
- Key conditions:
  - Must be run on the Rigetti Quantum Cloud Service (QCS) platform
  - Have either a faster time to solution, better quality solution, or lower cost compared to the best classical solution
  - Must create real value
- All claims will be posted online for others to support or refute



Thank-You!

For more info, visit
https://quantumcomputingreport.com

Doug Finke
dfinke@quantumcomputingreport.com