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Applications of Quantum Computers in Banking

Strategic Innovation and Artificial Intelligence - Velvet Edition

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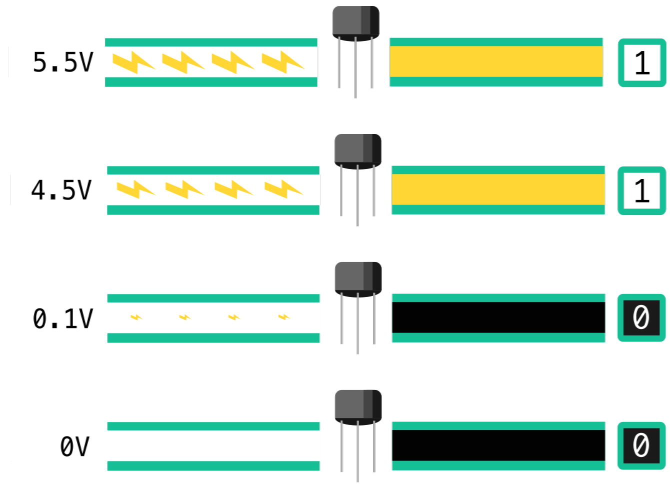

Figure 1: We use transistors to create logical states of 1 and 0.

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Classical Computers

Logical Gates

The Fastests Supercomputer: EXA FLOPS

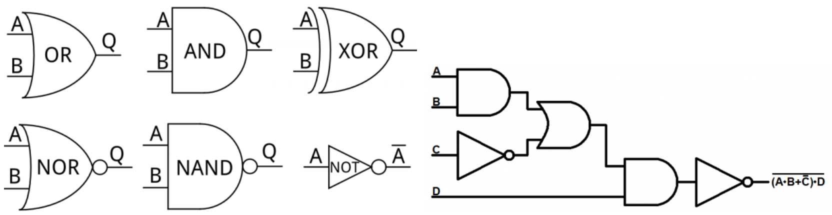


Figure 2: Those transitors are used to create logical gates that are in turn building blocks for logical circuits.

Figure 3: More info: https://en.wikipedia.org/wiki/Frontier_(supercomputer), and https://top500.org/lists/top500/2022/06/

The faster super computer today

Table 1: SUPERCOMPUTER FRONTIER

Aspect	**Details**
Site	DOE/SC/Oak Ridge National Laboratory
System URL	https://www.olcf.ornl.gov/frontier/
Manufacturer	HPE
Cores	8,730,112
Processor	AMD Optimized 3rd Generation EPYC 64C 2GHz
Installation Year	2021
Performance	
Linpack Performance (Rmax)	1,102.00 PFlop/s
Theoretical Peak (Rpeak)	1,685.65 PFlop/s
Power Consumption	
Power	21,100.00 kW (Submitted)
OS	
Operating System	HPE Cray OS

2 What Are Quantum Computers?

QBits

Operations

Aspects of Quantum Computing: Superposition

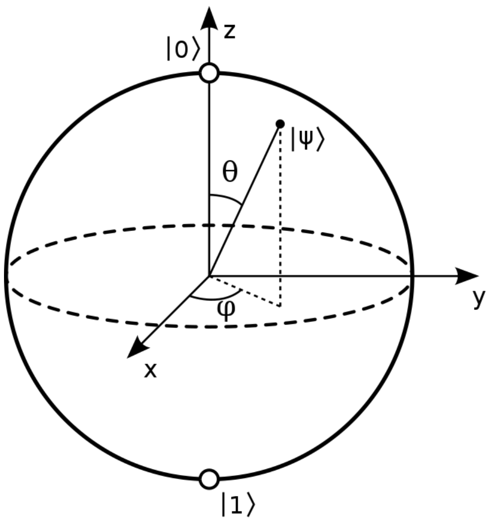


Figure 4: Source: nextplatform.com

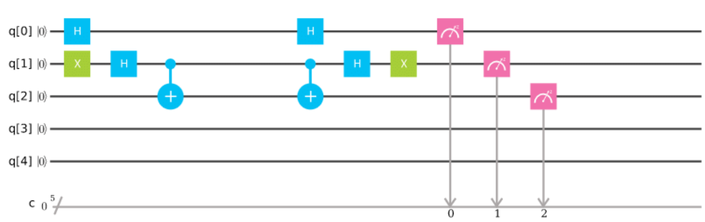
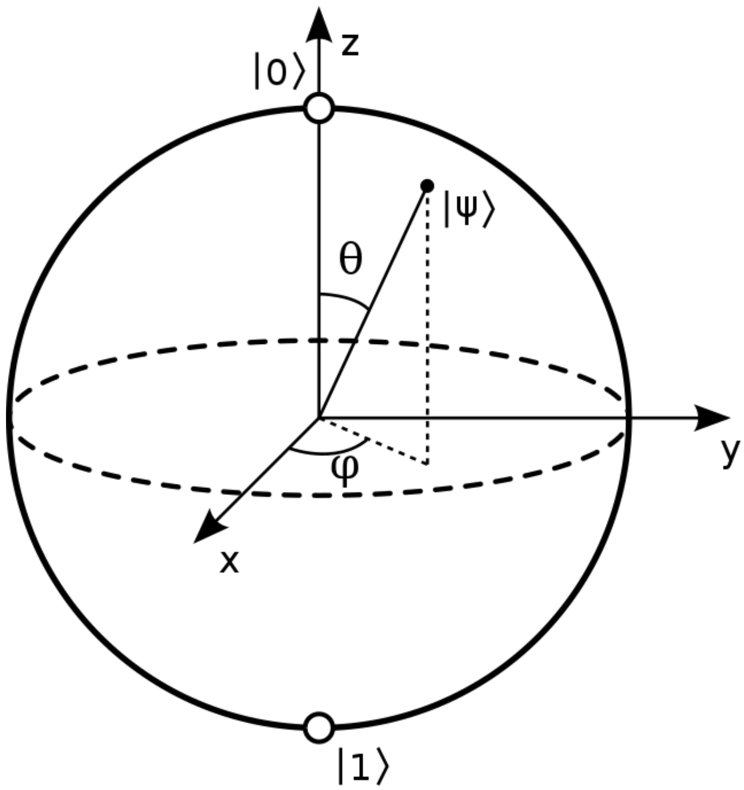


Figure 5: A quantum circuit: quantum gate operations on q-bits. Source: ibm.com



Superposition is a quantum state that is a combination of 2 mutually exclusive states

$$\alpha\ |0\rangle + \beta\ |1\rangle$$

Note that if $\alpha > 0$ and $\beta > 0$ then the qubit's state contains both $|0\rangle$ and $|1\rangle$

Aspects of Quantum Computing: Entanglement

A system of two qubits can be characterized by

$$\alpha_1\ |00\rangle + \alpha_2\ |01\rangle + \alpha_3\ |10\rangle + \alpha_4\ |11\rangle$$

where

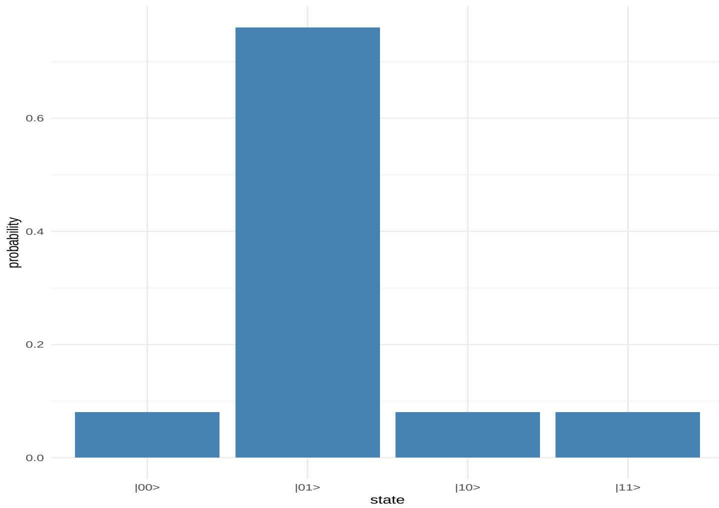
- $|01\rangle$ means that the first qubit is $0\rangle$ and the second $|1\rangle$
- $\sum_{i=1}^{4} |\alpha_i|^2 = 1$

If two or more of α_i are non-zero, and we cannot separate the states, then they are entangled. Knowing one determines the state of the other.

Example
$\frac{\sqrt{2}}{2}\ |11\rangle + \frac{\sqrt{2}}{2}\ |10\rangle$ is not entangled
$\frac{\sqrt{2}}{2}\ |01\rangle + \frac{\sqrt{2}}{2}\ |10\rangle$ is entangled

Aspects of Quantum Computing: Interference

Increase the probability of getting the correct answer (and reducing the probability of the wrong answer).



Aspects of Quantum Computing: Exponential Power

- qubit → 2 quantum states dimensions: $\alpha\,|0\rangle + \beta\,|1\rangle$
- 2 qubits → 4 states: $\alpha_1\,|00\rangle + \alpha_2\,|01\rangle + \alpha_3\,|10\rangle + \alpha_4\,|11\rangle$
- 3 qubits → 8 quantum state dimensions
- 6 qubits → 64 quantum state dimensions (card deck)
- 10 qubits → 1024 quantum state dimensions (810 listed companies on WSE)
- 20 qubits → 1.048576×10^6 quantum state dimensions (ca. number of all possible liquid investments)
- 60 qubits → 1.1529215×10^{18} states (ca. 10^{19} grains of sand on earth)
- 175 qubits → 4.7890486×10^{52} states (ca. 10^{50} atoms on earth)
- 275 qubits → 6.0708403×10^{82} quantum states (ca. 10^{82} atoms in the visible universe)

3 Existing Quantum Computers

D-Wave

Banking application with D-Wave and Multiverse Computing

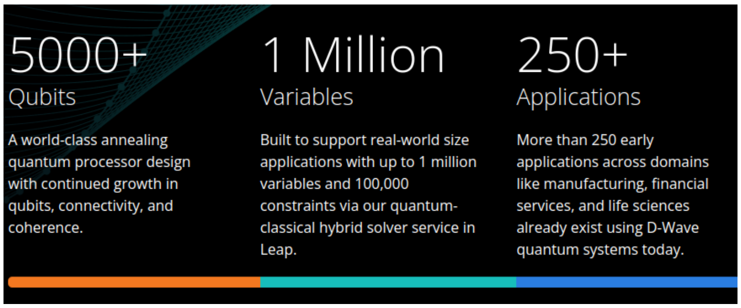


Figure 6: State of the art with D-Wave. Source: dwavesys.com

Figure 7: A paper about portfolio optimisation with the D-Wave computers. Source: arxiv.org

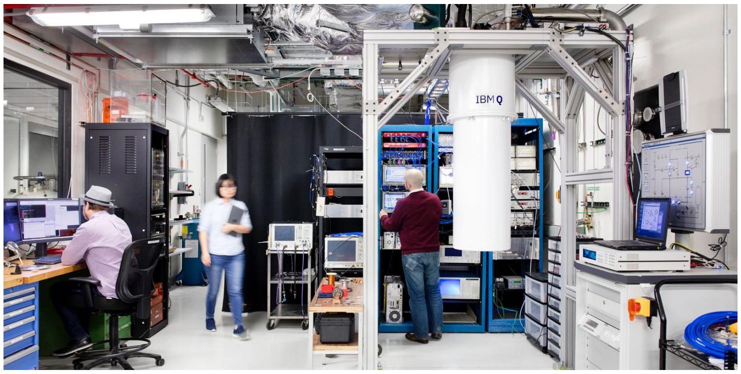


Figure 8: A quantum computer today. Source: ibm.com

IBM

4 Quantum Computing Achievements in Banking

Examples of banks's efforts

Some Real Results

- JPMC and IBM calculated prices for differnt options (European, path dependent, etc.) by Quantum Amplitude Estimation (similar to Monte-Carlo simulations)
- Goldman Sachs had a similar PoC in 2021 using QC Ware and IonQ
- JPMorgan used Honeywell's quantum computer for mathematical operations that involve Fibonacci numbers
- Caixa Bank runs a hybrid framework of quantum and classical computing to improve credit risk scoring (PoC)

5 Quantum Computing Potential

Use cases in banking

- **Optimization**:
  A. portfolio optimization
  B. collateral optimization
  C. stress testing

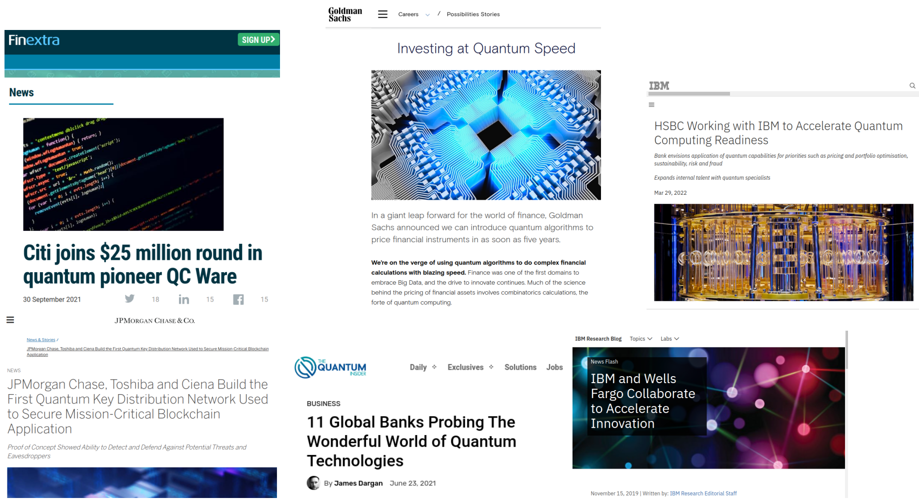


Figure 9: Sources: finextra.com, goldmansachs.com, ibm.com, and thequantuminsider.com

D. transaction settlement
E. asset pricing
F. ATM replenishment

- Machine Learning
  - fraud detection
  - credit scoring
  - synthetic data and data augmentation
- **Simulations**:
  - random number generator
  - Monte Carlo, LPDE simulations, etc.
  - asset valuation
  - ES and VaR calculations
- **Encryption**:
  - quantum key encryption
  - quantum currency
  - quantum blockchain

Resulting Advantages

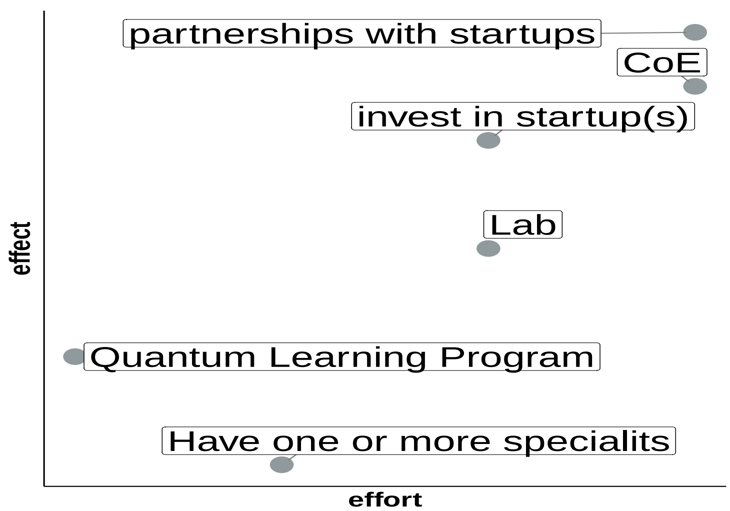
quadratic to exponential speedup

- better risk management
- lower costs
- greener computing
- better forecasting
- more suitable investment
- etc.

Boston Consulting Group estimates a value of $42B to $67B for financial institutions

6 The Route to Quantum for the Banker

Solutions



Shortcuts to solutions

- Get access to learning, online quantum computers, etc. via the IBM Quantum Accelerator for enterprise
- Use Qiskit to learn programming on quantum computers – qiskit.org and their YouTube channel

7 Conclusion

Conclusion

- Quantum computers are real and the concept works, it is a matter of time before they disrupt the financial system
- They will change how banking works by:
  - - requiring new ways of encryption (quantum key distribution and quantum resistant algorithms)
  - - solving optimizations that are not possible now (e.g. mean-variance optimisation for large groups of asssets)
  - - improved accuracy of risk calculations
  - - improved deep learning
  - - improving computational speed
  - - providing a greener solution to computational intensive tasks

Further Reading

- McKinsey, 2020, "How quantum computing could change financial services" – download
- IBM, "The Quantum Decade" (e-book) – download
- E. Rieffel and W Polak, MIT Press, "Quantum Computing, a Gentle Introduction" – download
- Quantum Computing for the Quantum Curious, C. Hughes et al., Springer – download
- a list of books: download