Quantum Computing

Big Data

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Quantum-data nexus

DATA SCIENCE: CAPTURE, MAINTAIN, PROCESS, ANALYZE & COMMUNICATE DATA

QUANTUM (Q) COMPUTING: REPLACE BINARY INFORMATION AND BOOLEAN LOGIC BY Q INFORMATION & PROCESSING

GOAL: RADICALLY TRANSFORM ASPECTS OF DATA SCIENCE BY EXPLOITING POTENTIALLY DISRUPTIVE CAPABILITIES OF Q COMPUTING

NOW: Q COMPUTERS AVAILABLE COMMERCIALLY AS WELL AS SOFTWARE FRAMEWORKS TO EVALUATE PERFORMANCE AND BECOME Q READY
Capture
- Data Acquisition
- Data Entry
- Signal Reception
- Data Extraction

Process
- Data Mining
- Clustering/Classification
- Data Modeling
- Data Summarization

Maintain
- Data Warehousing
- Data Cleansing
- Data Staging
- Data Processing
- Data Architecture

Communicate
- Data Reporting
- Data Visualization
- Business Intelligence
- Decision Making

Analyze
- Exploratory/Confirmatory
- Predictive Analysis
- Regression
- Text Mining
- Qualitative Analysis

bit.ly/3ozT6kp
Classical computing
Information: 0011001
Processing: OR, NAND, NOT

Q computing
Q Info: $|0011001\rangle + |1100110\rangle$
Q Processing: Quantum logic
Detection:
$|0011001\rangle \langle 0011001|$
Schrödinger’s cat paradox
Q computers (eg, Xanadu, IBM, Honeywell) doi.org/cr58
Key q algorithms
This is a comprehensive catalog of quantum algorithms. If you notice any errors or omissions, please email me at stephen.jordan@microsoft.com. Your help is appreciated and will be acknowledged.

**Algebraic and Number Theoretic Algorithms**

**Algorithm:** Factoring  
**Speedup:** Superpolynomial  
**Description:** Given an \( n \)-bit integer, find the prime factorization. The quantum algorithm of Peter Shor solves this in \( \widetilde{O}(n^3) \) time [82,125]. The fastest known classical algorithm for integer factorization is the general number field sieve, which is believed to run in time \( 2^{\widetilde{O}(n^{1/3})} \). The best rigorously proven upper bound on the classical complexity of factoring is \( O(2^{n/4+o(1)}) \) via the Pollard-Strassen algorithm [252, 362]. Shor's factoring algorithm breaks RSA public-key encryption and the closely related quantum algorithms for discrete logarithms break the DSA and ECDSA digital signature schemes and the Diffie-Hellman key-exchange protocol. A quantum algorithm even faster than Shor's for the special case of factoring “semiprimes”, which are widely used in cryptography, is given in [271]. If small factors exist, Shor's algorithm can be beaten by a quantum algorithm using Grover search to speed up...
Q machine learning

- Fewer computational steps for training or classifying
- Lower sample complexity
- Rich set of data models
- Q optimize test loss function

Q device to classify or extract features

- Q Boltzmann & QNeural net
- Q algorithm, eg for principal component analysis
- Quadratic time reduction for q invertible data-training
Quantum Computing
Key Potential Applications

1. Chemistry
   100 – 200 qubits

2. Optimization
   100s – 1,000s qubits

3. Machine Learning
   100s – 1,000s qubits

4. Material Science
   100s – 1,000s qubits

5. Unknown Problems
   100,000+ qubits

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Quantum Computing

Use Cases

Science

Quantum Chemistry

Light Harvesting
Climate
N\textsubscript{2}
CO\textsubscript{2}
LNG
Pharma
Biomolecules
Chemistry
Physics

Transport
Communication
Room Temperature S/C

Differential Equations

Encryption

Quantum Communication

Linear Algebra
Code-Breaking

Quantum Algorithms

Computing

Singularity
Optimization
Route Planning
Scheduling
Robots

Autonomous Vehicles

Quantum Machine Learning

Finance
Protein Folding
Constraint Satisfaction

Machine Learning

Pattern Matching

Bioinformatics

Personalized Medicine

Biology

Search

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Commercial applications of quantum computing

Francesco Bova\textsuperscript{1,2}, Avi Goldfarb\textsuperscript{1,2} and Roger G. Melko\textsuperscript{2,3,4}*

Combinatorial optimization for the verticals:

Materials & pharmaceuticals: Solve lowest-energy molecular configuration

Banking and finance: Portfolio management

Advanced manufacturing: Predict rare failures
Q algorithms in my group

bit.ly/3rQYh1D

Wikimedia bit.ly/3ljbcXG
bit.ly/3qOv323
techrepublic.com/article/6-experts-share-quantum-computing-predictions-for-2021/

- IBM: 127 qubits with concurrent classical computing
- Gartner: Cloud providers (eg Amazon, Azure) incorporating q capability
- KnowBe4: Q computing breaks traditional public-key crypto
- Lux: Advances in optimizing q hardware to reduce resource needs
- Forrester: Trough of disillusionment