TATA CONSULTANCY SERVICES

Building on belief

Taking the quantum leap, now

Abstract

Researchers are working on building powerful quantum computers that can handle colossal amounts of data in ultra-high speed and provide unmatched accuracy. We already have quantum computers that can solve at speed problems too complex for even the most sophisticated supercomputers. While we are still some years away from reaping the full benefit of quantum computers, businesses have started to identify use cases that can leverage quantum-inspired ways of computing. Solving complex optimization problems with quantum-inspired optimization (QIO) algorithms using current classical compute resources is a case in point. It's an approach that will make enterprises quantum-ready—when the technology becomes fault-tolerant and scalable.

Preparing for the quantum revolution

Viable, commercial quantum computers may not yet be within our reach, but large enterprises have begun to take stock of the potential opportunities. The global quantum computing market is predicted to grow at a CAGR of 30.2%, from $472 million in 2021 to $1,765 million by 2026.[1] It's no wonder then that leading players such as IBM, D-Wave, Microsoft, Regitti, Google, Honeywell, Cambridge, and Amazon are betting big on quantum computers—they are working on multiple architectures to bring quantum computers to market. A major milestone in the quantum computing space was crossed in 2016 with the first quantum computer on cloud. And industries have since begun to identify problems that could be solved the quantum way.

Quantum, applied now

Physicist and Nobel laureate Richard Feynman identified the potential of quantum computing in 1981.[2] Today, the theoretical hypotheses about data processing are becoming a reality and quantum computing is in the early stages of commercialization. Figure 1 shows the industries that could benefit from quantum computing in the near future.

As several sectors explore ways of adopting quantum, they are analyzing concerns, including the point of departure (from classical computing), upskilling their human resources, identifying the right problems for quantum computing, and whether at all the technology is worth investing their time and energy in. What's clear is that the practical and sustainable way forward is adopting quantum early—by identifying solvable business problems with the utilities available in the present ecosystem.

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[1] https://www.marketsandmarkets.com/Market-Reports/quantum-computing-market-144888301.html; accessed October 22, 2021.

[2] Richard Feynman and Quantum Computing; EE Journal; published May 24, 2018; https://www.eejournal.com/article/richard-feynman-and-quantum-computing; accessed October 22, 2021

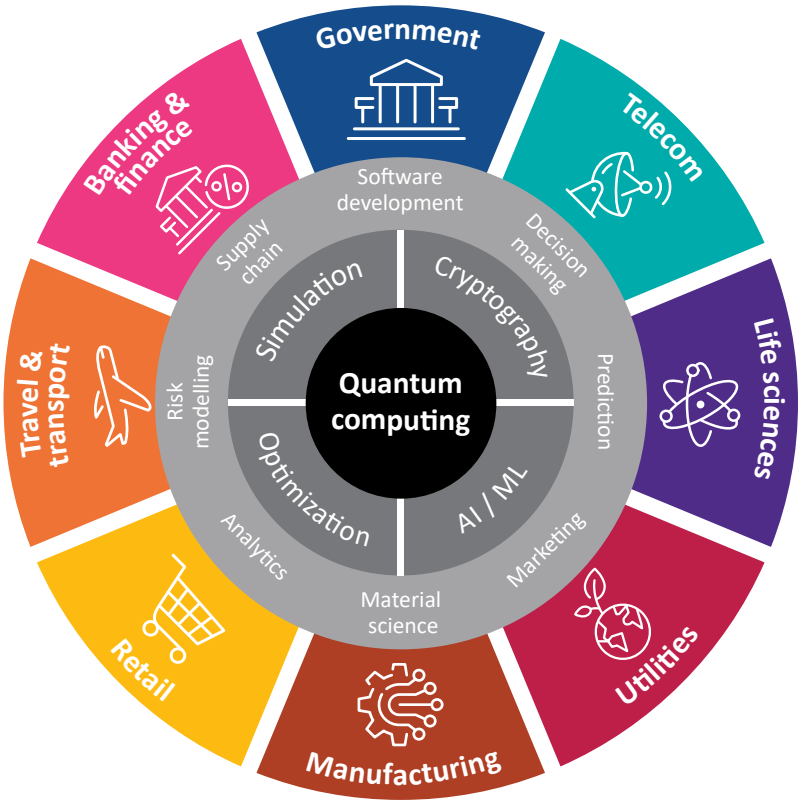

Figure 1: The future is quantum: Potential uses of quantum across industries

Overcoming quantum challenges with optimization

While the first step is to choose the right problems, the next stage is to identify the constraints and mathematically solve it with quantum-inspired ways of computing. Quantum-inspired optimization (QIO) algorithms help find the right solutions with greater accuracy as compared to classical computations. According to a recent Fujitsu study,[3] most business executives believe quantum computing will shape the way businesses are run in the future.

79%
business leaders believe that quantum computing will transform their industry.

52%
state that the technology will transform their own business.

89%
say they are being held back from carrying out optimization calculations by the limitations of today's computers.

66%
state they want optimization solutions today, rather than experimental quantum technology sometime in the far future.

QIO algorithms leverage the concept of quantum physics and can be run in classical computers. At present, Microsoft bundles a collection of optimization solvers for faster quantum adoption by leveraging classical infrastructure. Microsoft Azure Quantum offers an open platform for businesses to implement QIO algorithms.

[3] Fujitsu.com; published May 2019; https://www.fujitsu.com/global/imagesgig5/analyst-report_is-business-ready-to-make-the-quantum-leap.pdf; accessed October 23, 2021

Business use cases of QIO

While most industries would benefit from optimization, not all problems need quantum solutions. Some specific use cases include:

Finance: Dynamic asset allocation, portfolio optimization, trading trajectory optimization, and credit-risk analysis

Manufacturing and energy: Paint shop optimization, vehicle routing, robot positioning, component logistics, workflow process optimization, and job scheduling

Life sciences: Protein folding, designing peptide therapeutics, energy conformations of protein models, and mRNA codon optimization

Applying QIO to business problems

Defining a framework (Figure 2) is a critical step in solving business problems using QIO algorithms. Goal setting, problem formulation, solution definition, and measuring results are the various stages involved.

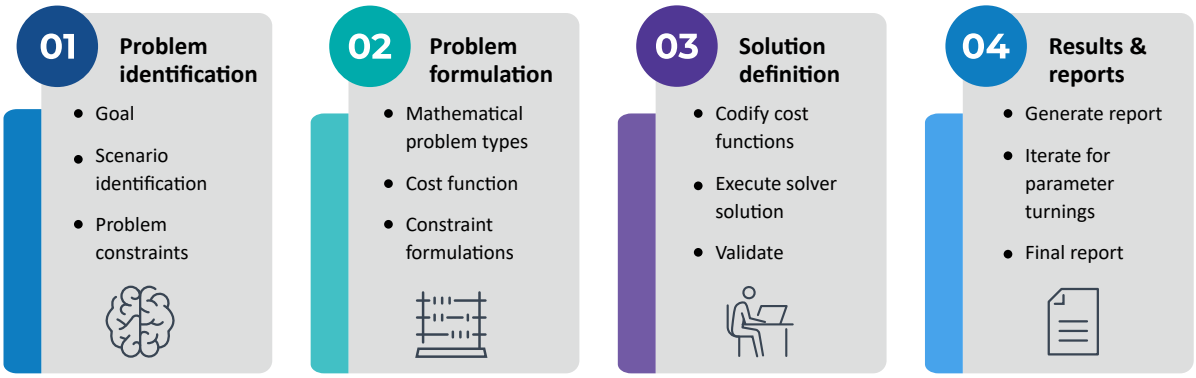

Figure 2: A framework for quantum-inspired optimization

Consider this nurse-physician scheduling problem at a COVID-19 clinic, which was solved using the QIO algorithm D-Wave Quantum Annealer[4] (Figure 3). The case involved scheduling six nurses and two physicians for 20 shifts. The objective was to arrive at optimal scheduling and cost under two specific constraints during the peak of the COVID-19 pandemic.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Nurse 1		X	X			X		X							X		X			X
Nurse 2				X		X		X		X				X			X			
Nurse 3	X			X			X		X		X				X			X		X
Nurse 4			X		X		X				X		X			X			X	
Nurse 5		X							X			X	X					X		
Nurse 6	X				X					X		X		X		X			X	
Doctor 1		X		X		X		X		X		X		X		X		X		X
Doctor 2	X		X		X		X		X		X		X		X		X		X	

Figure 3: Quantum-simulated results for a nurse-physician scheduling problem

[4] *Quantum annealing for solving a nurse-physician scheduling problem in Covid-19 clinics; Research Gate; published September 2020; https://www.researchgate.net/publication/344047176_Quantum_annealing_for_solving_a_nurse-physician_scheduling_problem_in_Covid-19_clinics; accessed October 23, 2021*

Dynamic variables in the problem, including demand spike for medical resources, sudden inflow of critical patients, simultaneous emergency care for multiple patients, doctor/nurse fatigue, and possibilities of cross-infections, complicated the scheduling. The objective of the algorithm was to identify the maximum number of shifts each nurse and physician can work per day in a week. To arrive at the optimal result, the algorithm considered the maximum number of nurses and physicians required per shift, and the number of consecutive shifts each nurse and physician can work. The researchers found dramatic improvement in solution quality with the QIO algorithm as compared to classical annealers.

Taking small steps

QIO algorithms are a breakthrough in creating a viable path to embark on the quantum computing journey. The results are promising and they have prompted the hyperscalers in the computing space to offer quantum computing as a service in the cloud, using prebuilt QIO algorithms. Here are some pointers for organizations that are considering quantum transformations:

- Involve the business teams to ensure technology and business alignment.
- Create a specialized, cross-functional team of mathematicians, data scientists, quantum engineers, quantum architects, and business leaders.
- Take an enterprise-wide approach covering different function areas and priorities.
- Identify the problems and use cases suitable for QIO.
- Measure and track results systematically.

The key challenges in the implementation of these algorithms are converting business challenges into mathematical problems, and calculating the influence of constraints to define objective functions. Choosing the right partners with the necessary capabilities can help organizations overcome the challenges and get the quantum advantage, now.

About the author

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Easwara Prasad M leads the Azure Quantum and High-Performance Computing (HPC) function at TCS' Microsoft Business Unit. He is also a consultant for the unit's innovation garage. Currently focused on quantum computing in finance and chemistry, and evangelizing quantum computing across verticals, he has worked in various areas such as test automation, performance engineering, delivery management, relationship management and consulting engagements. He is also experienced in US regulatory requirements 21CFT Part 11 for the pharmaceuticals industry.

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