ISSUE 152
BOARD PERSPECTIVES

GET INTO THE QUANTUM GAME: USE CASES ARE EMERGING

A year ago, an issue of *Board Perspectives* focused on why the board should care about quantum computing — what it is, when it will become a reality and what steps companies should take to stay on top of this evolving technology market.[1] Since then, use cases for quantum computing continue to emerge.

One of the most misleading phrases found in articles about quantum computing is something like, "*When quantum computers are available … .*" It turns out that quantum machines are not only available now but also powerful enough to tackle practical problems. In fact, they already do certain things better than classical computing, if with some trade-offs.

Why it's time to get into the game. The market for quantum computing is currently in the "Noisy Intermediate-Scale Quantum (NISQ) era."[2] Quantum machines may not be able to crack encryption — yet — but they're already showing advantages in specific use cases.

No one has achieved true quantum advantage, where a quantum computer can best a classical computer at a task, considering all relevant factors such as speed and accuracy. Proving quantum advantage to the satisfaction of the scientific community requires benchmarking an application against all known classical computing methods — a difficult task.

1 "Quantum Computing: Why the Board Should Care," *Board Perspectives*, Issue 139, May 2021, Protiviti, available at www.protiviti.com/US-en/insights/newsletter-bpro139-quantum-computing.

2 The "NISQ era" means that quantum machines are not available at their full potential and are not sufficiently advanced to demonstrate superiority over classical computers.

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However, some end-user companies are claiming "customer advantage" with quantum computing — meaning they've considered several leading options and found that a quantum approach provides some advantage, considering such aspects as price and speed.

Quantum computing has the potential to revolutionise all types of optimisation and machine learning (ML) problems. Getting started now positions companies to be counted among market leaders. Think back to the first companies that took full advantage of the internet. There is only one — Amazon.

We don't know exactly when true quantum advantage will be reached; however, some use cases in optimisation could get there within a year. But the key point is that when the advantage is achieved by one or more industry players and new use cases fundamentally disrupt manufacturing, logistics and finance, companies that are not quantum-ready won't be able to simply flip a switch and get in the quantum computing game.

Imagine being able to stake a claim as an ML leader today — and that's not even considering what will happen when quantum computers reach a power level that enables them to disrupt public-key cryptography. Bottom line, this journey is about readiness, for quantum computing can disrupt and destroy.

Beginning the quantum journey. With quantum representing such a sea change in computing, companies will not be able to react by teaching a development team a new programming language. While these machines will be accessible via cloud environments, that's where any resemblance to traditional DevOps[3] ends. Laggards will pay a price.

To begin the journey to quantum readiness, companies need to task quantum technology champions with selecting areas of the business that this new technology may revolutionise.

Design thinking exercises help stakeholders recognise the possibilities by brainstorming the types of problems currently being solved with technology and ascertaining whether to attempt use cases involving quantum algorithmic approaches.

A design thinking approach enables teams to organise and map traditional and new operational problems. For example, in addressing optimisation problems, the quantum approach should be stress-tested by adding more constraints that haven't been considered before. In essence, focus on solving problems that classical approaches can't solve at speed — and improve tasks that are possible with classical approaches.

Implementing quantum use cases can't happen in a vacuum. Governance structure and support are needed. The right people from executive management, business and technology leadership should be involved. This team needs to consider the applicability and potential benefits and risks of quantum and the appropriate investment level for the business.

Next comes a resource plan. There is a serious skills shortage in quantum technology software development. Companies will have to train people, find talent and resources, and develop processes to support this radical shift in computing looming on the horizon. For example, consider hiring college graduates with relevant coursework as trainable developers. Bring in outside consultants with the right skills to help get initial proof-of-concept use cases off the ground and provide some hands-on knowledge transfer for staff.

Recognise that failure is a necessary part of the discipline. Once a quantum algorithmic approach is tweaked and ready to go, teams can deploy quantum simulators locally and in the cloud to make experimentation free or very affordable. Not every use case will work out at first and lead to a solution, and some will only provide learning

[3] "DevOps" refers to a set of practices and tools that combines software development and IT operations with the intent to shorten the system's development life cycle and provide continuous delivery with high software quality.

experiences. But some use cases may one day be modified to help the business achieve real advantage as quantum machines improve.

Compelling use cases are demonstrating value. It's difficult to draw analogies to where we are in the quantum computing timeline. Is it the early 1990s of the internet? Uses dreamed of at that time didn't even begin to capture what the internet would lead to. No one (or at least only a rare few) imagined a world with social media or powerful computers in a handheld form. The same is true for quantum use cases; we know they are just the beginning of applications for systems with infinite possibilities. With quantum, we have the potential for infinite computing power.

One of the most promising use cases gains its edge from a rapidly maturing technology. Optimisation problems are performed on quantum annealers, which map variables to thousands of qubits[4] in a way that can be thought of as a field of peaks and valleys. The computer finds the lowest energy state to give the best possible answer.

One way to visualise this process is to imagine searching for the lowest valley on a continent. With a "classical" approach, you would have to drive up and down all over the terrain to measure and find the answer. Thanks to quantum tunnelling, the annealer can quickly identify the answer by moving through all the hills without a slow road-trip approach. These "peaks and valleys" can be applied to things like asset portfolios to solve for optimal returns. Specific constraints can be assigned, such as how long to hold an asset and the minimum gain before selling.

Hybrid annealers, such as those offered by DWave Systems, allow a classical computer to parse out those parts of the problem best handled by annealing. The hybrid annealer then stitches the answer together to quickly provide the best results. This capability has already outperformed traditional computers in speed at portfolio optimisation, and it's expected to be a likely first example of true quantum advantage. Protiviti is now participating in some of the first experiments proving an edge in accuracy and improving risk-adjusted returns.

The hybrid quantum annealing approach is already showing some advantage in the classical "travelling salesman" problem — where a mythical salesperson has to visit every city in a country using the shortest routes without ever passing through a city twice. DWave has addressed a vehicle routing problem that added real-world constraints such as downed power lines and other hazards to make the problem more complex. One run had the quantum approach providing a route with 20 kilometres of driving to make deliveries. The classical solution needed 27 kilometres of driving. An edge like this would multiply quickly when dealing with thousands of miles or kilometres daily.

Many use cases are easily adaptable in this fashion, such as certain pricing decisions for hospitality and airlines. There are also gate-based quantum computers that address other kinds of use cases. In a gate-based system, quantum logic gates are applied to qubits until a precise answer is obtained from an algorithm. Unlike annealing, which is looking for a good-enough low-energy state, gate-based machines solve for specific answers to questions. One example is the application of gate-based quantum computing to ML to speed up the learning process. Quantum ML is expected to explode in popularity over the next couple of years as gate-based systems reach thousands of qubits. Note that while annealers already have thousands of qubits, they can't interact with each other the same way as qubits in gate-based computers, which only recently broke the 100-qubit barrier.

Quantum ML should be able to solve any traditional ML problem. Quantum algorithms have already been developed for classical ML approaches such as reinforcement learning, neural networks and binary

[4] Qubits (short for quantum bits) are used in quantum computing, whereas classical computers use bits. Bits represent zero or one, whereas qubits can simultaneously represent zero and one. To illustrate: A coin is binary, heads or tails — representing zero or one. When a coin is flipped, however, it is both zero and one, as well as all combinations at the same time. In quantum, what's called "superposition" takes advantage of this ability to exist in more than one state at any time. But instead of coins, quantum uses atoms to fuel this new way of computing.

classification. The latter allows for fraud detection in traditional computers, where the system decides whether a transaction is good or bad (hence binary).

Quantum support vector machines (QSVMs) work like classical SVMs to draw an imaginary dividing line between complex data structures to determine what's fraudulent and what is not. As quantum computers become more powerful, it's hoped that more accurate results can be achieved in edge cases[5] that are challenging to validate as fraud or not. Quantum computers are expected to enable working with larger amounts of data at greater speeds. For now, queue times for cloud use of quantum computers are a constraint, so experimenters should lower aspirational expectations of real-time, 24/7 fraud detection to something like batch processing of fraud detection in weekly purchase orders.

Implications for boards. Forward-thinking boards should see that their companies start planning sooner rather than later for quantum computing to avoid facing resource challenges that could leave them missing the near-term benefits and necessary long-term protections of this emerging area of computing.

Understanding the opportunity and issues with quantum computing and preparing to seize and address them when the inevitable inflection point arrives could yield dramatic business advantage and disruption. Early movers across the globe may end up as the top players in gaining quantum supremacy.

Questions for directors might include:

- Have we conducted a quantum readiness assessment?
- Are any of our competitors focusing on how to harness quantum computing? Should we sit and watch them and other industry developments, or should we appoint an executive sponsor, designate a quantum champion and get into the game?
- Are there business challenges we are unable to solve today that quantum computing will be well suited to solve? If we don't know, should we find out?
- Is there effective governance over where and how we invest in quantum computing?

How Protiviti Can Help

Our Quantum Computing Services help clients prepare today to manage risks and identify opportunities to take advantage of this powerful capability. While practical applications of quantum computing are still being developed, now is the time to prepare to ensure your business is positioned to harness the power of quantum computing rather than become a casualty of the revolution.

We help organisations in all industries identify real use cases, determine the value, assess their risk and take action to become quantum-ready.

[5] "Edge cases" represent situations occurring at an established operating parameter, meaning their nature is not patently obvious based on established criteria.