Risk

Quants needed: how finance can use power of quantum tech

New machines have big potential in AI, valuations and VAR, but tech giants like IBM need help from practitioners

RISK, Luke Clancy 26 Feb 2018

Need to know

- As early as 2020, IBM says quantum computers will be quicker than their classical equivalents.
- Machine learning, Monte Carlo simulation and options valuation are among the areas where quantum computing could massively improve calculation speeds.
- Tech giants including Google, IBM and Microsoft are racing to refine quantum systems. Smaller firms also think they can make a difference, including one – D-Wave – run by a former Goldman Sachs tech chief.
- Quants with a background in physics are needed to write hybrid algos that run on quantum machines currently under development.
- "It's particularly important we work with people in the field – finance quants – to help figure out where the low-hanging fruit is," says Bob Sutor at IBM.
- Already available quantum hardware can speed up optimisation tasks, but in the future more powerful 'universal gate' computers are expected to run a wider set of algorithms.

Are you a quant, working in finance? Do you have painful, hours-long computations to perform? Know a bit about physics? If so, IBM wants to hear from you.

The technology giant's research arm believes it will be able to deliver quantum computing-based solutions for financial firms within the next three years that will revolutionise the way numbers are crunched. Now, it needs help identifying the best applications.

"It's particularly important we work with people in the field – finance quants – to help figure out where the low-hanging fruit is. We need people in finance to start thinking about where there are new ways of mapping optimisation problems and risk analysis to quantum computers," says Bob Sutor, New York-based vice-president of strategy and ecosystem at IBM Q.

As examples, experts in the field say quantum technology could be used to continually revalue options in something close to real time, quickly identify new trading strategies, massively speed up Monte Carlo simulations and value-at-risk calculations, and make machine-learning algorithms more powerful.

Sutor expects quantum hardware to demonstrate an advantage over classical computers by 2020 or 2021, but argues banks and others should be thinking about how to use the new technology now.

"Given that financial companies are very proprietary about their algorithms, they have to jump in very quickly and be preparing for this. They need a strategic plan for adoption of quantum computing. Given the history of investment in new technologies by financial companies, I would strongly suggest that time is now, as opposed to sitting and waiting," Sutor says.

IBM is already working with Barclays and JP Morgan Chase on finance applications for a quantum computer it developed two years ago. In November, it unveiled a new version that is exponentially more powerful – connecting 50 quantum bits, or qubits, rather than the 20 available in the earlier one.

But this is a weird world, containing weird ideas: "spooky" particles that can be linked across infinite distances; technology that has to be isolated from the outside world at massively sub-zero temperatures; systems based on particles that have not yet been proven to exist; and Schrödinger's Cat behaviour by qubits that can simultaneously exist in either of two states – until you measure them, at which point their seemingly magical properties cease.

Quantum chips themselves look relatively prosaic, but because of their sensitivity are contained within large cooling tanks – the whole contraption resembles nothing so much as a high-tech experiment in brewing. It’s the kind of set-up that future generations of technology users will presumably look back at with amused nostalgia.

The key to it all, the thing that sets quantum computing apart, is the qubit.

A classical bit can be in one of two states: it can store either a one or a zero. But a qubit can exist in both states simultaneously – a phenomenon known as superposition – although when it is measured by an external observer its states collapse to either one or zero. In addition, because the behaviour of two qubits is correlated – or entangled, in the language of quantum mechanics – information is obtained via the links between all of the qubits in the system, rather than sequentially reading each one. This means quantum computers can simultaneously handle a vast number of calculations.

Or, they could, if qubits were reliable. Classical bits retain their states – zero or one – because the materials and electronics in classical computers provide stability. If a bit changes state in error, it can be detected and fixed.

In quantum computing, errors can be caused if qubits get too warm, or as a result of stray microwaves and photons, or manufacturing defects. Making them behave the way they’re supposed to behave will require “breakthroughs in materials science and better understanding of the underlying physics”, says Sutor (see box: *Physical qubits and logical qubits*).

In addition, if these systems are to be used by banks or other finance firms, then quants must develop new algorithms to run on them. Sutor says: “This is not just about dropping a piece of classical software on to a quantum computer. The new algorithms people are developing are hybrids – part of them will run on a classical computer, and at some point they will do a call-off to a quantum computer for a particular type of calculation. Then it is a case of wrapping those algorithms up into libraries so they can become useful applications.” In computer science, a library is a collection of resources used by computer programs to develop software.

The “radically different” quantum algorithms might require financial models in future to be mapped more closely with physical models – for example, using quantum chemistry to map molecules so calculations can be done using those molecules. Many quants already have backgrounds in physics as well as mathematics; it is this type of knowledge base that financial firms should look for in their new hires, says Sutor.

First to market

Apart from IBM, other players in the quantum space include Google, Hewlett-Packard, Intel, IonQ, Quantum Circuits, QxBranch, Rigetti Computing and Toshiba. But Canada-based D-Wave Systems claims to be the first company to market quantum hardware that a firm can actually buy and install. Its chief executive, Vern Brownell, previously ran global technology at Goldman Sachs for 11 years.

D-Wave uses a process called quantum annealing. Traditionally, annealing is a process that involves heating and cooling of metal; here, it is about getting particles to work in very low-energy states, reducing the errors that make quantum computing so difficult.

To reach these states, quantum annealing uses a phenomenon known as tunnelling in which a particle passes through a barrier it otherwise could not surmount: put crudely, it saunters through the barrier, rather than needing energy to get over it. D-Wave controls the energy states by applying external magnetic fields to qubits to manipulate the probability they will store a one or a zero.

But D-Wave’s systems – described sniffily by one quantum specialist as “analogue machines set up to solve one type of binary discrete optimisation problem” – differ from the more powerful universal quantum gate computers with more connectivity between their qubits that IBM and others are building.

One of IBM's quantum computers

IBM is piecing together circuits of qubits so they can be programmed to run a wider set of algorithms. The 50 qubits in IBM's latest machine can represent more than one quadrillion values simultaneously.

Microsoft is working on a third 'topological' method of quantum computing that could utilise less error-prone qubits – but the science supporting it is at an even earlier stage and is dependent on the manipulation of a particle that no scientist has definitively identified. The existence of the quasi-particles – called non-abelian anyons – is "pretty much theory at this point", argues IBM's Sutor.

Comparing IBM and Microsoft, Sutor adds: "We have had our computers on the cloud since May 2016. My mantra is 'show me your working hardware'. When they can show it, it will be a lot more interesting."

Microsoft declined to comment for this article.

Sutor is also dismissive of D-Wave's approach, use of which he says is limited to specific optimisation problems: "D-Wave refers to qubits but they aren't anything like the types of qubits that are used in mainstream quantum computing. Their qubits are not connected in the same way."

D-Wave has a pragmatic response: it is already working with a number of bulge bracket banks and hedge funds on applications for the firm's hardware, and says its systems are designed to find sufficiently good solutions to optimisation problems that don't require an exact answer. Brownell says D-Wave's system is "extremely good at getting good answers very, very quickly, but maybe not the perfect answer, particularly if operating with incomplete or imperfect datasets."

The native problem that D-Wave's computer solves is indeed an optimisation problem, Brownell says – but the solution can be crafted into many different applications. He points out that sampling – basically running an optimisation over and over again – is at the core of Monte Carlo simulations and also finds a use in evaluations of portfolios and VAR calculations.

IBM's Sutor agrees quantum computing can usefully be applied to running Monte Carlo and VAR calculations, envisaging in the next few years that "those simulations being done by literally millions of servers in the cloud or on premises could be replaced by far fewer quantum computers."

But Brownell also thinks D-Wave's system can be used in generative machine learning as it can train with less data than is required by current techniques. That would allow it to solve optimisation or sampling problems in the most complex parts of machine learning algorithms.

Further, Brownell believes trading firms could find other use cases for D-Wave's technology "if their front end is ingesting a lot of data and trying to make very quick decisions. From a very simple basis if you look at any type of portfolio evaluation or anything in finance it's all based on probabilities. If you have a basket of securities and you are able to evaluate that quickly, probabilistically and make good decisions faster than anyone else, then I think you'll have an advantage."

He adds it is likely such firms will want to protect their proprietary quantum trading applications by hosting their own machines on-site, rather than accessing quantum via a cloud service.

No latency advantage

Matt Johnson, chief executive of Silicon Valley-based QCware, a developer of software for quantum computers, has a partnership with D-Wave and is running pilot projects with several financial institutions, including quantitative hedge funds. Johnson says QCware is writing quantum algorithms "to improve risk-adjusted returns for quantitative trading and fund management strategies, and to optimise asset pricing and hedging".

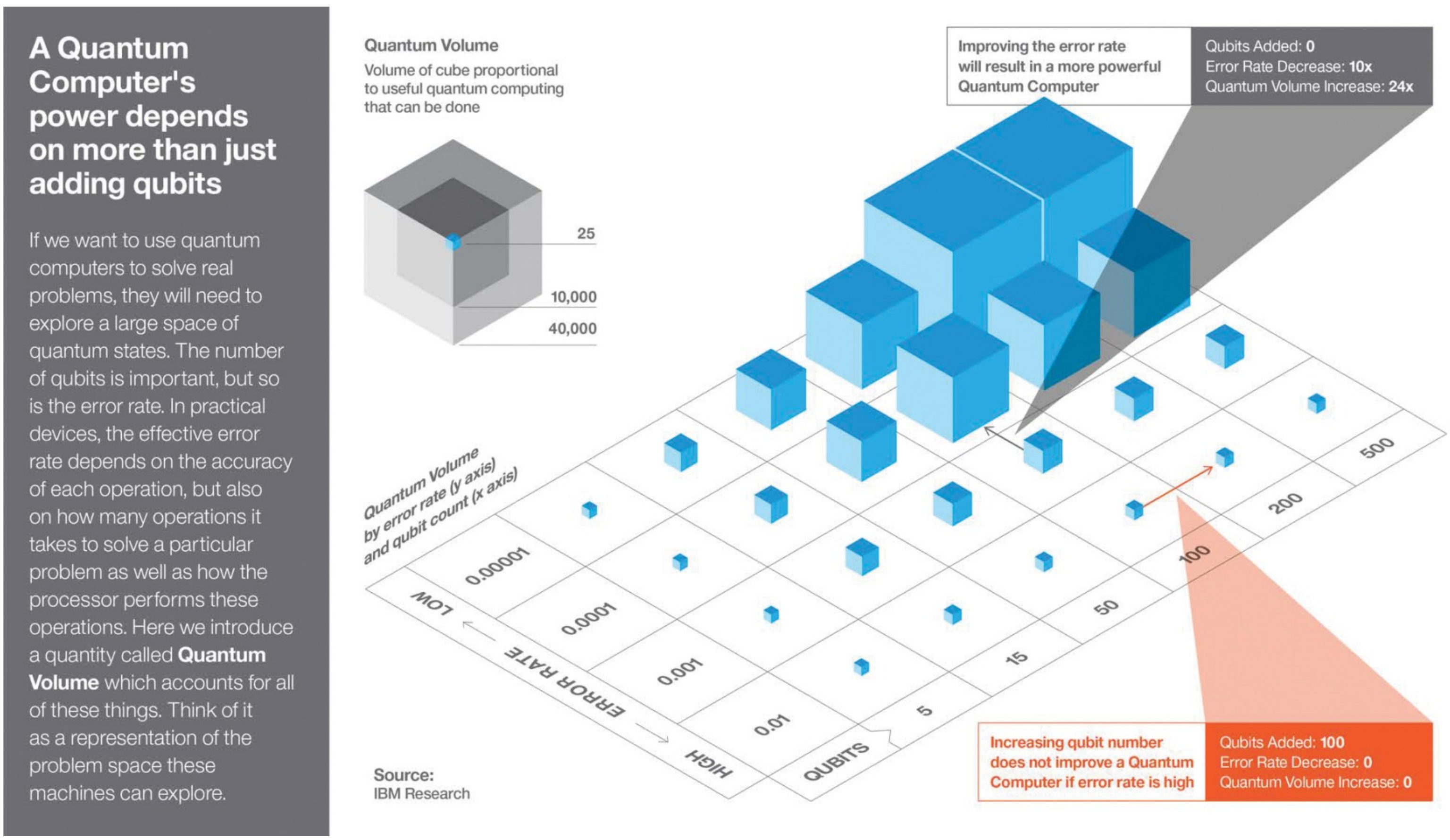
He says it is optimistic – but conceivable – that a quantum advantage could be demonstrated in trading within three years: "You'd have to get down to the math of that notional trade and figure out if in fact there's a quantum processor that in three years' time would be able to run this mathematical problem faster than any arbitrarily large cluster out there."

But Johnson is doubtful that quantum will find immediate use cases in high-frequency trading (HFT). He says: “In pure form, HFTs are trying to beat the other guys by getting in front of trades by a microsecond or a couple of milliseconds. That is not something that quantum computers are going to be able to do well. For quantum computing systems now being built, if you held a stopwatch to the time it took a quantum computer to read in the data inputs and then to process that data and then to read it out, even in the most extreme case you’re talking about perhaps hundreds of microseconds in the best case in a lab experiment.”

A spokesperson for a high-frequency trading firm agrees, saying latency would not be improved by using a quantum computer: “In electronic market-making we’re not doing anything more complex than adding, subtracting, dividing and multiplying. We’re not doing matrix math. All we need to do is process the order book and understand the state of the market and provide bids and offers. It’s hard to see how an increase in the speed of that is of incredible use until exchanges significantly improve their ability to process things sequentially.”

Physical qubits and logical qubits

In quantum computing, coherence is everything. It describes the period of time for which a qubit will occupy the required state. Beyond this point, it will start behaving randomly.



Order can be introduced by knitting qubits together; the individuals bits are known as physical qubits, and the whole as a logical qubit. A logical qubit can detect and correct errors, allowing longer periods of coherence (see figure).

If the error rate is controlled, and the qubits are entangled, then the power of the machine grows exponentially with the number of physical qubits, because each qubit can contain either a one or a zero. So, prior to the launch of its new, 50-qubit machine, IBM had one that contained 20 qubits.

The old version could represent 2 to the power of 20 states – or 1,048,576 – while the 50-qubit machine can represent 1,125,899,906,842,624.

Eventually, a quantum computer could be used to run Shor’s algorithm – a technique that can crack traditional methods of online cryptography – but scaling up to do so would require thousands of logical qubits to be connected, implying the need for multiple millions of physical qubits.

“We are likely decades away from being able to do that,” says Bob Sutor at IBM Q. “In the meantime, we are in a period of approximate quantum computing – of decreasing errors and increasing coherence time.”

Other types of esoteric mathematical problems could soon be solved more quickly on a quantum computer than the classical alternative, though. When that happens, quantum supremacy will have been demonstrated. Google had been aiming to show a proof of quantum supremacy by the end of 2017 – but has since gone silent.

Many of the challenges are physical. In order to work properly, microscopic quantum systems need to be isolated from the macroscopic environment, otherwise they decohere – particles cease to display wave characteristics – and revert to a binary state like a classical computer. Cooling the circuits keeps the qubits coherent for longer, but the temperatures required to do so are very low – close to absolute zero, or –273 degrees Celsius – meaning improvements in nanoscale refrigeration techniques are being sought.

Solving these problems simultaneously to create reliable quantum circuits is what universal gate model system builders such as IBM are grappling with. Sutor says: “We are getting better at miniaturising some of these things, simplifying the electronics and semiconductors and the other infrastructure around it.”

Glossary

Coherence: in this state, a quantum bit can exist in a superposition of 0 and 1, allowing a theoretical speed advantage over classical bits.

Decoherence: if a quantum system is not perfectly isolated from its surroundings, its coherence decays and the quantum behaviour is lost.

Entanglement: entangled particles remain connected so actions performed on one affect the other, even when separated by great distances. Albert Einstein described this as “spukhafte Fernwirkung”, or “spooky action at a distance”.

Quantum supremacy: the point at which a quantum computer performs a calculation faster than any known classical computer.

Quantum tunnelling: a phenomenon in which a particle tunnels through a barrier it could not surmount classically.

Qubit: a unit of quantum information analogous with the classical binary bit.

Shor’s algorithm: devised by mathematician Peter Shor, an algorithm for a quantum computer factoring large numbers that could decrypt the RSA cryptography used on the internet for secure data transmission.

Superposition: the ability of a qubit to store either 0 or 1, or both simultaneously.