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The growing potential of quantum computing

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The CEO of D-Wave Systems, Vern Brownell, explains how quantum computers are poised to solve important problems in industries ranging from financial services to medicine.

As modern computers continue to reach the limits of their processing power, quantum computing is starting to offer hope for solving more specialized problems that require immensely robust computing. Quantum computers were once thought an impossible technology because they harness the intricate power of quantum mechanics and are housed in highly unconventional environments. But these machines now have the potential to address problems ranging from finding drugs that can target specific cancers to valuing portfolio risk, says Vern Brownell, founder and CEO of D-Wave Systems, the Canadian company that in 2010 introduced the world's first commercially available quantum computer. In this interview with McKinsey's Michael Chui, Brownell discusses what quantum computing is, how it works, and where it's headed in the next five years. An edited transcript of their conversation follows.

Interview transcript

We're at the dawn of the quantum-computing age, and it's really up to us to execute. It sounds grand. But I think this is such an important enabling technology and can help mankind solve problems that are very, very important.

What is quantum computing?

D-Wave Systems is the world's first quantum-computing company. We have produced the world's first commercial quantum computers. A quantum computer is a type of computer that directly leverages the laws of quantum mechanics to do a calculation.

And in order to do that, you have to build a fairly exotic type of computer. You have to control the environment very carefully. The whole point of building a quantum computer is, basically, for performance, to solve problems faster than you can with conventional (or what we call classical) computers, meaning the types of computers that we all enjoy today and that have done such a great job. There are problems that scale better, or they can perform better, using quantum computers rather than classic computers. And that's really why everyone is trying to build a quantum computer: to take advantage of that capability that's inherent in quantum mechanics.

How do quantum computers work?

You probably will remember from your physics classes that a quantum mechanical object, if it's disturbed, it's frozen in one state or it becomes classical. So every quantum computer has, as its building block, something called a qubit, a quantum bit. And a quantum bit is like the digital bit that's in every computer; digital bits are sort of the building blocks of all computers.

But a qubit has this special characteristic where it can be in what's called a superposition of zero and one at the same time. So if you step back from that, this object is actually in two different states at the same time. And it's not like it's half in this state and half in the other; it's in those two states at the same time. It sounds spooky. Einstein called it spooky. But it is a fundamental law of quantum mechanics and it is the building block of a quantum computer.

So these qubits are all in this superposition, which is a very delicate state. And whenever a cosmic ray or some kind of interference hits that computation, it freezes it out to a classical state. So the trick is to keep the calculation going in this superposition for the duration of the computational cycle.

The environment in which the system operates is kept at a temperature that is near absolute zero. So you probably remember, –273 degrees centigrade is the lowest temperature, called a thermodynamic limit or the lowest temperature that's physically possible in the universe. This machine runs at 0.01 degrees kelvin, or 10 degrees millikelvin, above that.

So unless there's any other intelligent life in the universe, this is the coldest environment in the universe that this machine has to run in. For instance, interstellar space is about 4 degrees kelvin, which is much, much warmer than our operating temperature.

That's not the only part of it. We have to create a magnetic vacuum and an air vacuum. So there's this coffee-can-sized environment that has this incredibly low temperature and this magnetic vacuum that is probably among the purest environments in the universe. There are no naturally occurring environments like this.

You don't buy a quantum computer for the economics. But that will change, as I said, as the power of the machine grows. There can certainly be just an economic benefit of using this for certain problem types versus using classical computers.

What problems do quantum computers solve?

There are different types of quantum computers. The type that we build is called a quantum annealer. And so I'll talk about the types of problems that quantum annealers do. Much of what you'll hear about quantum computing is related to gate-model quantum computing, which is another approach that's very valid. The problem with it is that it's very, very hard to implement. And it's probably more than ten years away.

We believe that one of the most important applications of quantum computing is in the category of machine learning. So we've developed, together with our partners, algorithms that can leverage this quantum-computing capability to do machine learning better than you could with just classical resources alone, even though the state of the art in classical computing and machine learning is quite high. They're doing some amazing things with scale-out architectures and GPUs[1] and special-purpose hardware. We believe that the advantages that quantum computing can have can even take that to the next level.

Another is in the whole optimization area, and it's called sampling. So there are optimization problems all around us. We're trying to find the best answer out of a complex set of alternatives. And that could be in portfolio analysis and financial services. It could be trying to find the right types of drugs to give a cancer patient—lots of meaty, very impactful types of applications that are in the sampling world that we believe are very relevant to this.

Google and NASA, for instance, are customers of ours. And Google has created what they call the Quantum Artificial Intelligence Lab,[2] where they're exploring using our computer for AI applications or learning applications. And NASA has a whole set of problems that they're investigating, ranging from doing things like looking for exoplanets to [solving] logistic problems and things like that. I'd say within five years, it's going to be a technology that will be very much in use in all sorts of businesses. □

[1] Graphics processing unit.

[2] See Charles Choi, "Google and NASA launch quantum computing AI lab," *MIT Technology Review*, May 16, 2013.

Vern Brownell is the founder and CEO of D-Wave Systems. **Michael Chui** is a principal at the McKinsey Global Institute and is based in McKinsey's San Francisco office.