TECHINTELLIGENT HEALTH

Microsoft Quantum Algorithm Boosts Medical Imaging

By
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Microsoft researchers have used an algorithm designed to work on an as-yet-nonexistent quantum computer to enhance the speed and quality of medical imaging.

The advance may one day improve the treatment of breast cancer and other diseases, the company says. For instance, it might allow doctors to determine within days whether a tumor is shrinking in response to chemotherapy, rather than having to wait weeks or months.

The development is one of a number of recent cases in which researchers have used algorithms designed for future quantum computers, machines that would make today's supercomputers look like abacuses, to improve calculations running on today's existing hardware. Other examples include using quantum algorithms to find better ways to manage the load across an electrical grid, improve delivery routes in a crowded city, and control risks and returns in an investment portfolio.

Better medical scans, more quickly

In the most recent illustration, Microsoft worked with scientists at Case Western Reserve University in Cleveland, who specialize in a type of medical imaging called magnetic resonance fingerprinting (or MRF.) Like the more familiar magnetic resonance imaging (MRI), the technique uses powerful magnetic fields and radio waves to create images of internal organs and soft-tissue. But while traditional MRIs can only identify areas of light or dark, which a radiologist must then subjectively evaluate, MRF can differentiate precisely between tissue types, allowing for more detailed and interpretable images.

Mark Griswold, a pioneer in MRF at Case Western Reserve who led the project, likes to use the analogy of trying to listen to a choir, where the tissues in the body are the singers: With a conventional MRI, it is as though the entire choir is all singing the same song, and the listener can only determine if one singer is a bit louder or softer than others, a bit higher or lower pitched, and maybe if they are out of tune. With MRF, on the other hand, it is like listening to a choir in which each singer has his or her own unique song, and the listener is able to isolate that song from the other voices in the choir and use it to identify the singer.

Configuring a scanner to find a particular tissue type—to isolate those individual songs—is time-consuming. With help from Microsoft's quantum algorithm, the Case researchers found they could produce the scans in one third to one sixth of the time it took previously, while simultaneously boosting the precision of the scans by more than 25%. "The increase in precision is really important because it allows us to see smaller and smaller changes in the tissue," Griswold says.

Microsoft has been highlighting the potential of quantum algorithms in part to seed the market for its future quantum computer. But it has also been emphasizing its quantum-inspired software because, unlike some rivals, it doesn't yet have any fancy quantum hardware to show off, despite years of development.

The rise of quantum computing

Qu**a**ntum computers use quantum mechanical properties to represent and manipulate information. In a conventional computer, information is processed in a binary format called bits, which have a value of either 0 or 1. The value of each bit is independent from all the other bits being used in the calculation. In a quantum computer, information is represented using quantum bits, or qubits. These qubits can be created using any number of phenomena that have quantum properties (for instance, the spin of electrons or the polarization of photons).

Unlike bits, qubits can represent both a 0 and a 1 at the same time—or in some cases, any value between 0 and 1. What's more, the value of each qubit affects the value of other qubits in the system, opening the door to nearly instantaneous solutions instead of having to process information in a serial fashion. These two factors, in theory, give quantum computers an enormous advantage over conventional ones: Each additional qubit added to a quantum computer increase its power not linearly, but exponentially. A sufficiently large quantum computer ought to be able to do things that are beyond the ability of even today's biggest supercomputers—like find much more energy efficient processes for manufacturing fertilizer or break the encryption that protects much of the world's data.

Quantum computers were once the stuff of sci-fi novels. But in 2011, D-Wave Systems, a Canadian company, debuted the first commercially available quantum computer. (Its machine, however, can only be used for a certain sub-set of mathematical problems.) Since then, IBM, Google, and Rigetti Computing, a Berkeley, Calif.-based startup, have all built more general-purpose quantum computers that customers can access over the Internet. Meanwhile, Intel has unveiled quantum processors, although these are not yet available to commercial customers.

So far, none of these quantum computers are powerful enough to do something a conventional computer can't, although it is believed Google may be close to crossing this threshold, which is known as "quantum supremacy." Even when that happens, the quantum machines will still be too small and their calculations too prone to errors to be useful for most commercial applications.

The corporate quantum race

In the past year, Chinese company Alibaba has announced that it would build a quantum processor, Amazon has quietly hired a team of quantum computing experts, signaling it too may be building a machine, while at least a half dozen startups are also working on quantum hardware.

At Microsoft, CEO Satya Nadella has described quantum computing as one of three groundbreaking technologies —along with augmented reality and artificial intelligence—that will be essential to the company's future. Under his leadership, the company has made a big bet on quantum: hiring a team of physicists, mathematicians, computer scientists and engineers from around the globe and placing one of its most experienced engineering executives, Todd Holmdahl, a veteran of both the Xbox game console and the HoloLens mixed reality headset, in charge of the effort.

The company has chosen an untested architecture for the qubits of its quantum computer, based on an elusive sub-atomic particle physicists weren't even 100% sure existed until 2017. Those sub-atomic particles form a braid, and this shape should make them much more stable and less susceptible to buffeting interference from surrounding electromagnetic forces than those being used by IBM, Google, and Rigetti. That buffeting creates errors in a quantum computer's calculations, which then have to be corrected. With a theoretically lower error rate, Microsoft's design ought to be a safer bet for commercial applications. But, first, the company has to prove it can reliably create these braids and use them to form qubits—something it hasn't yet done.

In the meantime, Microsoft has a whole group of mathematicians and computer scientists looking at ways to program quantum computers. And, as it turns out, some of the algorithms developed to take advantage of the weird properties of quantum computers can also be used to great advantage on normal ones.

A custom algorithm

With MRF, the trick is figuring out exactly how to tune the strength, frequency, and angle of the radio pulses the scanner transmits, Griswold says. Finding the right pulse pattern is what enables the scanner to identify tissue types—to isolate the song of each singer in the choir to use Griswold's analogy. There is a mathematically optimal pattern that would allow the scanner to pick up only that tissue type with a precision down to the individual cell—but finding it involves so many variables that it is beyond the computational power of a conventional computer, he says. So researchers have relied almost entirely on educated guesswork to plan the pattern of pulses for each scan, he says. Even with this imperfect method, he says, MRF still results in much more detailed images than a typical MRI.

To get further improvements, Griswold says, he needed to get beyond human intuition. But when his team applied for a grant to research how to optimize the MRF scans using conventional algorithmic techniques, the application was rejected on the grounds that solving such a mathematically-challenging problem was simply impossible.

Then Griswold heard that Microsoft, which had worked closely with medical imaging experts at Case on a test case for its HoloLens augmented reality goggles, was looking for partners to create similar demonstration cases for quantum algorithms. Griswold, who had followed quantum computing developments closely for 20 years and knew some of the researchers now working on Microsoft's efforts, realized this might be his chance.

"We like problems that are seemingly impossible," Matthias Troyer, Microsoft quantum computing researcher who worked on the MRF project, says. What's more, Troyer, says, MRF was the kind of seemingly impossible problem—an optimization challenge—for which quantum algorithms already existed.

Troyer says the existing quantum algorithm, however, had to be tweaked for Griswold's exact problem. "What we like to stress it to really get the full power of the quantum optimizer, one really has to make a bespoke solution," he says. In this case, Troyer says, the hard part was figuring out, from the several thousand variables involved in building an MRF image, which subset of factors the algorithm should try to optimize. Once you do this, he says, "the initially impossible begins to look possible."

He also says that even though running the quantum algorithm on a conventional computer resulted in a significant increase in the speed and precision of the MRF scans, the results would have been even more impressive on a large-enough quantum computer. "It would have been much faster," he says.

But the size quantum computer Troyer is talking about would require about one million logical qubits. And machines of that size are still many years, if not a few decades, away.

This story has been updated to correct the spelling of Matthias Troyer's first name.