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Microsoft Makes Bet Quantum Computing Is Next Breakthrough

By JOHN MARKOFF JUNE 23, 2014

SANTA BARBARA, Calif. — Modern computers are not unlike the looms of the industrial revolution: They follow programmed instructions to weave intricate patterns. With a loom, you see the result in a cloth or carpet. With a computer, you see it on an electronic display.

Now a group of physicists and computer scientists funded by Microsoft is trying to take the analogy of interwoven threads to what some believe will be the next great leap in computing, so-called quantum computing.

If the scientists are right, their research could lead to the design of computers that are far more powerful than today's supercomputers and could solve problems in fields as diverse as chemistry, material science, artificial intelligence and code-breaking.

They met here this weekend to explore an approach to quantum computing that is based on "braiding" exotic particles known as anyons — what physicists describe as "quasiparticles" that exist in just two dimensions rather than three — in order to form the building blocks of a supercomputer that exploits the weird physical properties of subatomic particles.

The proposed Microsoft computer is mind-bending even by the standards of the mostly hypothetical world of quantum computing.

Conventional computing is based on a bit that can be either a 1 or a 0, representing a single value in a computation. But quantum computing is based on qubits, which simultaneously represent both zero and one values. If they are placed in an "entangled" state — physically separated but acting as though they are connected — with many other qubits, they can represent a vast number of values simultaneously.

And the existing limitations of computing power are thrown out the window.

In the approach that Microsoft is pursuing, which is described as "topological quantum computing," precisely controlling the motions of pairs of subatomic particles as they wind around one another would manipulate entangled quantum bits. Although the process of braiding particles takes place at subatomic scales, it is evocative of the motions of a weaver overlapping threads to create a pattern.

By weaving the particles around one another, topological quantum computers would generate imaginary threads whose knots and twists would create a powerful computing system. Most important, the mathematics of their motions would correct errors that have so far proved to be the most daunting challenge facing quantum computer designers.

First proposed by the physicist Richard Feynman in 1982, quantum computing has mostly been of interest to academics, the National Security Agency and the Pentagon's Defense Advanced Research Projects Agency.

But in recent years, quantum computing has caught the attention of the corporate world. Microsoft established a significant quantum computing research effort in 2006, creating the Station Q research group at the University of California, Santa Barbara. Since then, I.B.M., Northrop Grumman and BBN Technologies have also begun quantum computing research focused on earlier efforts to create qubits based on measuring the spin of an electron or the polarization of a photon.

While scientists have created individual qubits, they are extremely fragile, and creating the arrays of hundreds or thousands of circuits necessary to build a useful quantum computer has proved daunting.

D-Wave Systems, a Canadian company that has had support from NASA, Google and Lockheed Martin, has made claims that it has been able to speed up some computing problems based on what it describes as "the first commercial quantum computer."

On Thursday, however, an independent group of scientists reported in the journal Science that they had so far found no evidence of the kind of speedup that is expected from a quantum computer in tests of a 503 qubit D-Wave computer. The company said through a spokesman that the kinds of problems the scientists evaluated would not benefit from the D-Wave design.

Microsoft's topological approach is generally perceived as the most high-risk by scientists, because the type of exotic anyon particle needed to generate qubits has not been definitively proved to exist.

That may change soon. The company has been spending heavily and is contributing to 10 of the roughly 20 academic research groups exploring a long-hypothesized class of subatomic particles known as Majorana fermions. Beyond being a scientific advance, proving the existence of the Majorana would mean that it was likely they could be used to form qubits for this new form of quantum computing.

Microsoft supported research, led by the physicist Leo Kouwenhoven at the Kavli Institute of Nanoscience at the Delft University of Technology in the Netherlands, that in 2012 produced the strongest evidence that the long-predicted particles exist.

“They have really done something very special,” said Charles M. Marcus, a physicist at the University of Copenhagen. “It’s been very enabling of our research and that’s not a statement about dollars, that’s a statement about community.”

His laboratory is now growing molecular-scale nano-wires that will work like one-dimensional train tracks, making it possible to control the movement of fermions around one another. They are hopeful that they can engineer networks of the nano-wires to move fermions around like trains in a railroad switching yard.

Ensembles of these particles that can be precisely controlled inside exotic materials at extremely low temperature can be used to construct qubits in the topological computing model proposed by the mathematician Michael Freedman and the physicists Chetan Nayak and Sankar Das Sarma in 2005. If this type of qubit can be confirmed, it will have much higher resistance to errors than other kinds of qubits that are fashioned from electrons, photons and atomic nuclei.

Microsoft began supporting the effort after Dr. Freedman, who has won both the Fields Medal and a MacArthur Fellowship and is widely known for his work in the mathematical field of topology, approached Craig Mundie, one of Microsoft’s top executives, and convinced him there was a new path to quantum computing based on ideas in topology originally proposed in 1997 by the physicist Alexei Kitaev.

Mr. Mundie said the idea struck him as the kind of gamble the company should be pursuing.

“It’s hard to find things that you could say, I know that’s a 20-year problem and would be worth doing,” he said. “But this one struck me as being in that category.”

Indeed, the researchers are quick to acknowledge that they have not yet even made a working prototype of the basic element of their system. But Microsoft is exploring what a prototype might look like should efforts to build qubits succeed.

Burton Smith, a well-known supercomputer designer who came to Microsoft from Cray in 2005 has moved to lead a new quantum hardware design group. Last week, he hired Douglas M. Carmean, an Intel Fellow who led the design of several of the firm’s microprocessors, to join the effort.

For some time, many thought quantum computers were useful only for factoring huge numbers — good for N.S.A. code breakers but few others. But new algorithms for quantum machines have begun to emerge in areas as varied as searching large amounts of data or modeling drugs. Now many scientists believe that quantum computers could tackle new kinds of problems that have yet to be defined.

Indeed, when Mr. Mundie asked Dr. Freedman what he might do with a working quantum computer, he responded that the first thing he would program it to do would be to model an improved version of itself.

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