COMPUTER SCIENCE

Quantum or not, controversial computer yields no speedup

Conventional computer ties D-Wave machine

By **Adrian Cho**

The D-Wave computer, marketed as a groundbreaking quantum machine that runs circles around conventional computers, solves problems no faster than an ordinary rival, a new test shows. Some researchers call the test of the controversial device, described online this week in *Science* (http://scim.ag/quantspeedup), the fairest comparison yet. But D-Wave argues that the computations used in the study were too easy to show what its novel chips can do.

"This is likely the most thorough and precise study that has been done on the performance of the D-Wave machine," says Helmut Katzgraber, a computational physicist at Texas A&M University, College Station, who was not involved in the work. However, Colin Williams, a quantum-computer scientist and D-Wave's director of business development, says the problems used as benchmarks were "not at all the right choice for probing a quantum speedup."

D-Wave Systems, a startup in Burnaby, Canada, started selling the supposed quantum computer in 2011. Although skeptics have questioned the company's claims, D-Wave has sold machines to Lockheed Martin Corp. and Google and has been written up in myriad news reports. The company claimed an earlier version of its $10 million machine was 35,500 times faster than an ordinary computer—in a test at which skeptics scoff.

To test D-Wave's machine, Matthias Troyer, a physicist at the Swiss Federal Institute of Technology in Zurich, and colleagues didn't just race it against an ordinary computer. Instead, they measured how the time needed to solve a problem increases with the problem's size. That's key because the whole idea behind quantum computing is that the time will grow much more slowly for a quantum computer than for an ordinary one.

For example, for a conventional computer running today's best algorithm, the time needed to factor a number explodes almost exponentially: according to an exponent that increases with the number of digits. For a full-fledged quantum computer, that time should grow at a far milder rate, as the number of digits cubed (see figure, top right). Thanks to that "quantum speedup," problems that would overwhelm a classical computer would merely slow a quantum one.

> **"We don't see quantum speedup, but that doesn't mean you won't see one eventually."**
>
> **Matthias Troyer**, Swiss Federal Institute of Technology in Zurich

Factoring numbers, however, requires a "universal" quantum computer. The D-Wave machine is a more limited device called a quantum annealer. Its processor consists of a 2D array of quantum bits, or qubits, made of superconducting loops that carry electric currents. The qubits act like tiny magnets that can point up, down, or—thanks to quantum weirdness—both up and down at the same time. Each qubit can interact with certain others through linkers that can be programmed so that the qubits can lower their energy by pointing either in the same direction or in opposite directions (see figure, bottom right). The idea is to encode a problem by specifying the hundreds of interactions within the chip and solve it by finding the qubits' lowest energy "ground state."

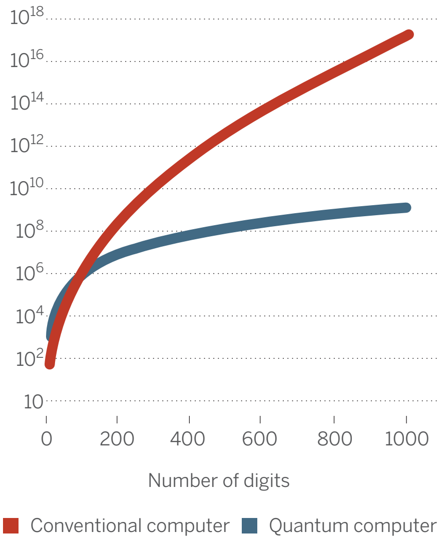
To find the ground state, the machine starts with each qubit in an up-and-down state and slowly turns on the interactions. The system then seeks the lowest energy state, like a marble rolling across an evolving energy landscape to find the deepest valley. In a nonquantum device, the jiggling of thermal energy would drive the marble over the terrain to the low spot through a process called thermal annealing. In the D-Wave machine, however, the marble supposedly also "tunnels" quantum mechanically between the low spots to find the lowest one faster. For problems such as pattern recognition or machine learning, that might give the quantum machine an edge.

But is the D-Wave chip really quicker than a conventional computer? To find out, Troyer and Daniel Lidar, a physicist at the University of Southern California in Los Angeles, tested the Lockheed Martin machine against a conventional computer programmed to simulate thermal annealing. To keep things simple for the D-Wave chip, they didn't ask it to do practical calculations. Instead, they merely set the interactions between qubits randomly and timed how long it took the machine to find its ground state.

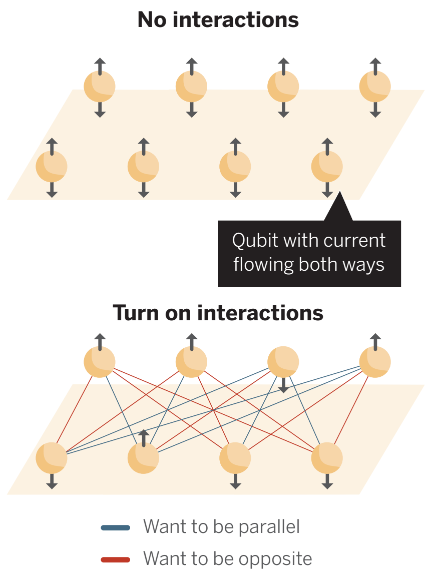
In spite of that home-field advantage,

Quantum speedup

Computational steps to factor a number



Source: Wikipedia



A universal quantum computer would factor numbers far faster than an ordinary computer (*top*). Nobody knows whether D-Wave's quantum annealing technique (*bottom*) provides a similar speedup.

DIAGRAM: G. GRULLÓN/SCIENCE

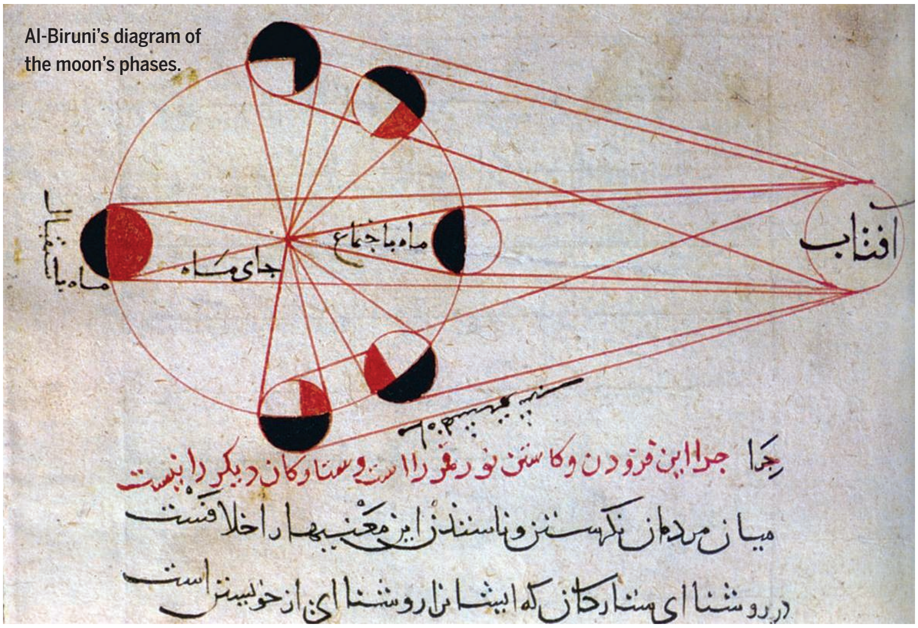
the D-Wave chip produced no quantum speedup. The researchers ran problems for different-sized groups of qubits, ranging from the chip's basic unit of eight to its total of 512. The computing time for the conventional computer increased exponentially with the number of qubits. But so did the time for the D-Wave machine. Troyer takes care not to overstate the finding: "We don't see quantum speedup, but that doesn't mean you won't see one eventually" for some other problem.

Indeed, the test problems may have been easy for the ordinary computer, too, says Texas A&M's Katzgraber. Choosing interactions at random, he explains, typically creates test problems in which qubits lock into a low-energy configuration only exactly at zero temperature. So at any higher temperature, thermal annealing can readily coax the system to the solution. Given the easiness of the problems for both machines, Katzgraber says, the study is like "two world-class skiers racing on the bunny slope." Hartmut Neven, director of engineering at Google, says his team has already found patterns of interactions for which the D-Wave machine beats simulated annealing.

However, some researchers doubt that a quantum annealer will ever produce a useful quantum speedup. Although computer scientists have proved that a dreamed-of universal quantum computer should excel at factoring, theory strongly suggests that in actuality a quantum annealer will produce no similar speedup for any problem, says Umesh Vazirani, a computer scientist at the University of California, Berkeley. "I would bet that there's not a speedup," he says. Neven counters that he is "convinced that we will be able to find problem classes for which a next-generation quantum annealer will outperform any classical algorithm."

Meanwhile, the sniping between D-Wave and its critics continues. D-Wave co-founder Geordie Rose recently told *Wired* magazine that Troyer's work was "total bullshit."

Such rhetoric rankles some researchers. By making claims that may not pan out, D-Wave could jeopardize the whole field of quantum computing, says Scott Aaronson, a computer scientist at the Massachusetts Institute of Technology in Cambridge. "If it becomes common knowledge that they're not seeing a speedup, then the same people who are backing them may turn and say, 'Well, I guess quantum computing is a failed idea,' " he says. In response to accusations of hype, D-Wave's Williams says, "We're a commercial company, and all commercial companies have to market their products and services." ■



Al-Biruni's diagram of the moon's phases.

HISTORY OF SCIENCE

Was America 'discovered' in medieval Central Asia?

Ancient texts suggest Silk Road polymath inferred the existence of unknown continents

By **Richard Stone**
in Samarkand, Uzbekistan

He was a Renaissance man long before the Renaissance. Abu Rayhan al-Biruni, born a thousand years ago in this region of Central Asia, calculated Earth's circumference with astounding accuracy and invented specific gravity, the measure of a substance's density compared to that of water. He rejected creationism, accepted that time has neither a beginning nor an end, and—5 centuries before Copernicus—argued that the sun might be the center of the solar system. Now, an influential scholar has proposed adding another laurel to that list: inferring the existence of America.

The discovery of America is bitterly contested, with vying claims on behalf of prehistoric peoples who crossed over Beringia or the Pacific Ocean, Norse seafarers who landed in Newfoundland around 1000 C.E., and the 15th century explorers Christopher Columbus and John Cabot. Biruni, who never laid eyes on any ocean, also deserves "to wear the crown of discovery," averred S. Frederick Starr, chair of the Central Asia-Caucasus Institute of the Johns Hopkins School of Advanced International Studies in Washington, D.C., at a conference on medieval Central Asia held here last month. "His tools were not wooden boats powered by sail and muscular oarsmen but an adroit combination of carefully controlled observation, meticulously assembled quantitative data, and rigorous logic."

Some experts are not persuaded. "There is a tendency these days to read too many modern discoveries into the works of the medieval scientists," says Jan Hogendijk, an authority on Biruni at Utrecht University in the Netherlands. "We don't say that Copernicus 'discovered' that the Earth moves around the sun simply based on the fact that he hypothesized that it does," adds Nathan Sidoli, a science historian at Waseda University in Tokyo, "so I don't see why we should say that al-Biruni 'discovered' the American continent."

But others think Biruni deserves credit for his prediction. "Assuming that the key passages in Biruni's texts have been correctly read, I see no reason to exclude al-Biruni from the list of early 'discoverers' of America," says Robert van Gent, a specialist on the history of astronomy at Utrecht University who attended Starr's talk here.

Biruni was one of a constellation of Cen-