Quantum computers will require complex software to manage errors

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While rudimentary is a fair description of this early computer, the National Bureau of Standards -- SEAC, built in 1950 --prototype quantum computers have not even reached its level of sophistication. Theorists at NIST have demonstrated that quantum computer software will need to be more complex than some researchers had hoped, potentially slowing the devices' development, but also allowing scientists to focus on more promising development pathways. Credit: NIST Archives

(PhysOrg.com) -- Highlighting another challenge to the development of quantum computers, theorists at the National Institute of Standards and Technology have shown* that a type of software operation, proposed as a solution to fundamental problems with the computers' hardware, will not function as some designers had hoped.

Quantum computers—if they can ever be realized—will employ effects associated with atomic physics to solve otherwise intractable problems. But the NIST team has proved that the software in question, widely studied due to its simplicity and robustness to noise, is insufficient for performing arbitrary computations. This means that any software the computers use will have to employ far more complex and resource-intensive solutions to ensure the devices function effectively.

Unlike a conventional computer's binary on-off switches, the building blocks of quantum computers, known as quantum bits, or "qubits," have the mind-bending ability to exist in both "on" and "off" states simultaneously due to the so-called "superposition" principle of quantum physics. Once harnessed, the superposition principle should allow quantum computers to extract patterns from the possible outputs of a huge number of computations without actually performing all of them. This ability to extract overall patterns makes the devices potentially valuable for tasks such as codebreaking.

One issue, though, is that prototype quantum processors are prone to errors caused, for example, by noise from stray electric or magnetic fields. Conventional computers can guard against errors using techniques such as repetition, where the information in each bit is copied several times and the copies are checked against one another as the calculation proceeds. But this sort of redundancy is impossible in a quantum computer, where the laws of the quantum world forbid such information cloning.

To improve the efficiency of error correction, researchers are designing quantum computing architectures so as to limit the spread of errors. One of the simplest and most effective ways of ensuring this is by creating software that never permits qubits to interact if their errors might compound one another. Quantum software operations with this property are called "transversal encoded quantum gates." NIST information theorist Bryan Eastin describes these gates as a solution both simple to employ and resistant to the noise of error-prone quantum processors. But the NIST team has proved mathematically that transversal gates cannot be used exclusively, meaning that more complex solutions for error management and correction must be employed.

Eastin says their result does not represent a setback to quantum computer development because researchers, unable to figure out how to employ transversal gates universally, have already developed other techniques for dealing with errors. "The findings could actually help move designers on to greener pastures," he says. "There are some avenues of exploration that are less tempting now."

More information: * B. Eastin and E. Knill. Restrictions on transversal quantum gate sets. Physical Review Letters, 102, 110502, March 20, 2009.

Source: National Institute of Standards and Technology (NIST)