QUANTUM COMPUTING:

Fighting Corruption in the Quantum World

Andrew Watson*

- Search Medline for articles by: **Watson**, A.
- Alert me when: New articles cite this article
- Collections under which this article appears: **Computers/Mathematics**

If there is one sure thing in the computer industry, it is that sooner or later, engineers will not be able to squeeze any more circuits onto chips. But an enthusiastic group of researchers is speculating about a whole new realm of miniaturization: devices so small that they operate according to the unfamiliar quantum laws of the atomic world. Quantum computers could remain a dream unless physicists can find a way around the vexing tendency of quantum information to leak away and degrade. But now a team of Los Alamos theorists and East Coast experimenters has shown that quantum computers could identify errors and fix them.

"What we have done is demonstrated in an experiment for the first time that we can make quantum information more robust, that we can protect it against corruption," says Raymond Laflamme, a member of the team at Los Alamos National Laboratory in New Mexico. According to David Deutsch of the Centre for Quantum Computation at the University of Oxford in England, "it's an important step toward the goal of building a useful quantum computer."

Current "classical" computers process information, or bits, as digital 0's and 1's. In quantum computers the element of information, the qubit, is a blend of both a 0 and a 1, their relationship expressed by the qubit's "phase." This mingling allows an array of qubits to carry a whole swath of numbers simultaneously, even though actually reading the array will yield just one value as the quantum states "collapse." By working on entire sets of numbers all at once, a quantum computer can in principle solve certain types of problems incredibly efficiently. Factoring big numbers, for example--a taxing task for today's computers--would be a cinch for quantum computers and would render obsolete today's most secure encryption systems, which are based on the difficulty of this task.

Unfortunately, a passing atom can interact with a qubit, causing some of its information to leak away and introducing errors. Skeptics say that the fragility of quantum information threatens the whole idea of a practical quantum computer. Because there is no way to avoid the errors, the next best thing is to correct them. This is not easy for quantum information, because reading it out to check for errors or correct them instantly collapses the qubit array, spoiling its number-juggling capacity. "The whole trick of the quantum error correcting code was to find a way to know what the error was without knowing what the message is," says Laflamme.

In 1996 Peter Shor of AT&T Bell Labs and, independently, Andrew Steane at Oxford devised a theoretical scheme for doing so. The basic idea is to spread the information of one qubit into a family of linked qubits so that, should any be corrupted, the information can still be recovered from its partners. Now Laflamme and his Los Alamos colleagues have teamed up with a group of Massachusetts-based specialists in nuclear magnetic resonance (NMR) to demonstrate the scheme with atomic nuclei that encode qubits in their magnetic orientations. A nucleus can behave like a small magnet and point either up or down relative to a strong magnetic field. Thus a molecule could be used as an array of qubits, with the nuclear orientations encoding 0's (up) and 1's (down). To control such an array, the researchers used NMR to manipulate the orientation of nuclear magnets by tweaking the nuclei with radio-frequency waves.

In the 7 September *Physical Review Letters*, the team describes tests on two molecules: alanine, an amino acid, and trichloroethylene. Both provide a suitable set of three neighboring nuclear magnets: a single information qubit plus two control qubits to provide error correction. The researchers first used a radio-frequency pulse to twist the linked nuclear magnets into a particular position, then left them to the mercy of their surroundings. Errors caused the three magnets to drift out of alignment before a further radio-frequency pulse reversed the initial twisting. Because the three magnets are linked magnetically, enough information was contained in the misalignment of the two control qubits to allow the team to figure out the error on the information qubit without having to measure it directly. The experimenters then showed that they could correct the error with another pulse. "We've demonstrated in the smallest and simplest code that we had enough control to do the right operation and preserve the quantum information," says Laflamme.

Although enthusiastic about this demonstration of principle, other researchers emphasize that this is just the first step toward full quantum error correction. "It's a long way from three qubits to a quantum computer powerful enough to solve significant problems," says Shor. A future "significant step" would be to demonstrate error correction in a five-qubit system, enough to guard both the phase information and correct another type of error that flips the 0's and 1's, explains Shor. "We hope to do this in the next few months," says Laflamme.

Andrew **Watson** is a writer in Norwich, U.K.

Volume 281, Number 5384 Issue of 18 Sep 1998, p 1781