Catching errors in scrambled quantum bits

When the noise of a party threatens to drown out a conversation, the speakers typically respond by talking more loudly or slowly or by repeating key phrases. Engineers have developed roughly analogous strategies to maintain the integrity of digital information exposed to static and other types of environmental noise, whether these bits are transmitted as a radio signal or stored in a computer or on a compact disc.

Now, researchers have developed techniques for correcting or avoiding errors when transmitting or storing quantum states such as electron spins or photon polarization angles. As a step toward superfast computation, these methods can evade the usual limitation that observations inevitably disturb the states of quantum systems.

"It's now known that you can send quantum information reliably through a noisy channel," says Charles H. Bennett of the IBM Thomas J. Watson Research Center in Yorktown Heights, N.Y. "In fact, there are two, somewhat distinct approaches for solving this problem."

The advance represents an important step toward the development of quantum computers, in which the binary logic of 0s and 1s used in conventional computers is replaced by computing elements that follow the laws of quantum mechanics (SN: 1/14/95, p. 30). Called a quantum bit, or qubit, such an element has not only a value but also a phase, which reflects the wavelike aspect of a quantum system.

In principle, quantum computers can solve certain mathematical problems, such as factoring whole numbers (SN: 5/14/94, p. 308), in dramatically fewer steps than conventional computers.

The development of quantum computers is stymied at present by the fact that no quantum system can be perfectly isolated from the rest of the world. Individual components, therefore, can't be trusted to maintain their states over long periods of time.

Moreover, because any measurement of a quantum state disturbs it, determining the values of the bits in a quantum computer would preclude knowing the phases of those bits and vice versa. Thus, engineers can't use conventional schemes, which rely on some sort of redundancy—for example, making and comparing copies of digital data—to detect and correct errors (SN: 3/12/94, p. 170).

To avoid this problem, Peter W. Shor and his colleagues at AT&T Bell Laboratories in Murray Hill, N.J., have invented an error correction method in which each original quantum bit of data is encoded in a particular way as nine quantum bits. If one of these bits is somehow spoiled during transmission, it's possible to recover the original quantum bit from the information that does get through.

That encoding operation can be imagined as shifting the original quantum bit into a protected position so that it leaks only a minimal amount of information to the environment, Bennett comments.

Bennett and his collaborators have developed an alternative strategy based on quantum teleportation (SN: 4/10/93, p. 229). This technique exploits a quantum phenomenon in which a single process within an atom simultaneously generates two photons that travel in opposite directions. According to quantum theory, neither photon has a particular electric field orientation, or polarization, until it's detected.

This measurement transforms a photon's polarization from a range of possibilities into a specific, random value. Astonishingly, measuring one photon's polarization causes the other photon to acquire the opposite polarization at the same instant—even if the second photon is at the other end of a room or across the galaxy.

Such special pairs of photons can be used to convey quantum information, such as a photon's quantum state.

Bennett and his coworkers have now shown that it's possible to send these photons through a noisy channel, which corrupts their quantum states, and still recover useful information. Applying quantum operations, one can "purify" the many corrupted photons to obtain a few "good" ones, which can be used as information carriers, Bennett says. The researchers describe this approach in a paper accepted for publication in PHYSICAL REVIEW LETTERS.

"This doesn't solve the full problem," Bennett notes. "We can now protect [quantum information] while it's being stored and while it's being transmitted, but we don't know how to protect it while it's being processed."

Quantum computation also awaits the development of components for implementing its peculiar logic. *— I. Peterson*

Infections making a deadly comeback

Infectious diseases, once thought to have been vanquished by vaccines and antibiotics, are reemerging as a serious health threat both in the United States and worldwide, researchers reported at an American Medical Association press conference in Washington, D.C, this week.

Ebola, HIV, hantavirus, and antibiotic-resistant bacteria serve as reminders that microbes remain a menacing force. A new study of death certificates shows that from 1980 to 1992, death from infectious disease increased by 58 percent; another study indicates that infections caused by a strain of streptococcus bacteria resistant to penicillin—the first line of pharmaceutical defense—increased by 14 percent from 1991 to 1994.

"We aren't facing impending calamity," says Nobel laureate Joshua Lederberg of Rockefeller University in New York City. "The war is winnable, but nobody was on watch, and we have become complacent."

Scientists are urging governments to enhance global monitoring of disease outbreaks and are imploring physicians to use antibiotics properly.

Robert W. Pinner and his colleagues at the Centers for Disease Control and Prevention in Atlanta surveyed 12 years of U.S. death certificates. As they report in the Jan. 17 JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION (JAMA), the annual death rate from all infectious diseases increased over that period from 41 to 65 deaths per 100,000 people. Even after subtracting deaths due to HIV, which became epidemic during the last decade, those from other infectious diseases increased by 22 percent. This jump largely reflects fatal respiratory and blood infections.

"Despite historical predictions that infectious diseases would wane, that hasn't been the case," says Pinner. "The things that make infectious diseases serious threats are constantly changing, and we need to be vigilant."

Joseph F. Plouffe and his colleagues at the Ohio State University Medical Center in Columbus studied severe *Streptococcus pneumonia* infections that progressed from the lungs to a patient's bloodstream. The bacteria cause 500,000 cases of pneumonia in the United States each year. Between January 1991 and April 1994, the bacteria became increasingly resistant to penicillin and other common antibiotics; 24 percent had acquired resistance to Bactrim and 12 percent to ceftazidime. The researchers report these results in the Jan. 17 JAMA.

Because bacteria tend to develop resistance after they are exposed to an antibiotic, Plouffe urges physicians to prescribe prudently. He also recommends that they rely more on the *Streptococcus pneumonia* vaccine.

Patients can also play a role in preventing antibiotic resistance, says George D. Lundberg, editor of the JAMA. They shouldn't demand these drugs whenever they have a case of the sniffles, because antibiotics can't cure the common cold or other viral infections.

— L. Seachrist