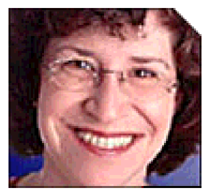
# Quantum Spookiness Oct. 29, 2001

EMAIL THIS ARTICLE
PRINT THIS ARTICLE
DISCUSS THIS ARTICLE
WRITE TO AN EDITOR

**Scientists have demonstrated that teleportation is possible, at least with a photon or two. Wendy Wolfson spoke with noted physicists about teleporting something a little larger, using quantum computing techniques. Say, an iguana.**

By Wendy Wolfson



I was attempting a delicate parallel-parking maneuver without scraping the sides of my neighbor's car when I was riveted by a yellow sign nailed to the telephone pole: "Found. Iguana."

My downstairs neighbor had found a two-foot iguana in the back yard. What was an iguana doing there? We've got pigeons and squirrels in my concrete jungle, but no iguanas.

Maybe it had been teleported, I reasoned. Things get teleported a lot, around here. I never can find my car keys, or spare change when I really need it.

My neighbor called the cops, who notified Animal Rescue. Animal Rescue workers said they would probably euthanize the iguana, as its large size and nasty personality made it unsuitable for adoption. I didn't have room for it, myself. With the clock ticking, I called colleagues to ask if they could take on a special-needs lizard. No takers. Teleportation back to where he came from could be his only hope.

But what would it take to teleport an iguana? The answer lies in

RELATED STORIES
A New Game Plan 10/29/01
Memory Of The Future 10/26/01
Don't Call Grid Peer-To-Peer 10/26/01
Compaq Posts Third-Quarter Loss 10/26/01

LATEST NEWS
Bush Signs Surveillance Law 10/26/01
Digging Deep Digitally 10/26/01
There's Money In The Air 10/26/01
Army Kicks Off New Secure Smart ID Card Era 10/26/01

But what would it take to teleport an iguana? The answer lies in the very weird world of quantum mechanics, where matter behaves in ways that boggle the imagination. Even mine.

We are all familiar with teleportation from *Star Trek* episodes (see NASA's Science of Star Trek). Science fiction takes for granted that you can dematerialize an object and reconstruct its precise atomic configuration somewhere else. Unfortunately, the Star Trek model of transportation isn't yet viable. (I keep butting against the limits of science and technology when I really need to get something important done, like get to a party on time.)

Basic teleportation is supposed to send a copy by destroying the original. In contrast, telephones, fax, and the Internet teleport sounds and images by leaving the original behind and reconstructing a copy elsewhere. The cut-and-paste procedure has to do with Heisenberg's Uncertainty Principle and letting Schroedinger's cat out of the box. (Then again, you can always sign up for Schroedinger's Cat-Sitting Service.)

It seems almost impossible to copy particles and reproduce them in another place. But in quantum physics, you can create an undefined quantum state as long as you are willing to ditch the original. Here's why:

In classic physics, nothing seems real until measured. But in the quantum world, to measure something (such as the polarization of a photon, a particle of energy that carries light), you have to include all its potential polarizations, each of which has a certain probability of being measured. But by measuring the photon's polarization, you fix it, and destroy the original, undefined photon state.

Heisenberg's Uncertainty Principle says that you cannot simultaneously know the location and the speed of a particle. In effect, the more accurately an object is measured, the more it is disturbed by the measuring process, until one reaches a point where the object's original state has been completely disrupted, still without having extracted enough information to make a perfect replica.

But if you can't know the position of a particle, then how can you teleport it?

**I'm Going To Wash That Photon Right Out Of My Hair**
In 1993, a group of six scientists, including IBM Fellow Charles H. Bennett, showed that quantum teleportation is theoretically possible, but only if the original object being

teleported was destroyed. The IBM Group sneaked around Heisenberg’s Uncertainty Principle by using a concept called "entanglement."

Albert Einstein, and his younger colleagues Boris Podolsky and Nathan Rosen, satirically theorized that in a quantum system, photons are transmissible by conventional means, but they also are inextricably paired by a "spooky connection"--an entanglement. Any operation performed on one entangled particle affects its paired counterpart--even if it is halfway around the world. (See From Here To There.)

In entanglement, at least three photons are needed to achieve quantum teleportation:

- Photon A: The photon to be teleported
- Photon B: The transporting photon
- Photon C: The photon that is entangled with photon B

If you tried to measure photon A without entanglement, you would bump it, and thereby change it. By entangling photons B and C, you can extract some information about photon A, and the remaining information would be passed on to B by way of entanglement, and then on to photon C. When you apply the information from photon A to photon C, you can then create an exact copy of photon A. But photon A no longer exists as it did before the information was sent to photon C.

We’re beyond theory. In 1997, physicists at the University of Innsbruck in Austria and, in papers published in 1998, researchers at the University of Rome and Caltech, successfully teleported a photon from one side of their lab to the other. The original photon no longer existed once the replica was made.

**A Walk On The Wild Side Of Computing**
Think this has nothing to do with IT? Just wait a couple of years.

Quantum behavior is influencing new ideas on advanced computing. Could a computer end up being a cup of liquid measured by a souped-up NMR spectrometer, for example?

So far, Moore’s Law as a metaphor for the exponential growth of physical information-carrying capacity has ruled the computing world. But present computers are limited to how much they can be miniaturized.

Scientists are looking at building quantum computing systems out of molecules. Unlike conventional binary-code computers, quantum computers encode quantum bits, or qubits, fundamental information units which occur naturally in atomic-scale objects such as an electron or an atomic nucleus. An atom can be in a state of what is called "superposition" where it exists in two different simultaneous states--both 0 and 1, and all probabilities in between. The atom’s "spins" can be entangled to wire the qubits together to make a phantom quantum computer.

But a way must be figured out to shield the quantum and mechanical works of the computer from environmental perturbations. Otherwise, the system will dissipate into "decoherence," or the constant, tenuous interactions between a system or object and its environment, a set of interactions that lets concrete behaviors emerge from the multitude of simultaneous possibilities that quantum theory allows.

Quantum computing changed from an academic curiosity to a subject with real world implications in 1994, when Peter Shor at AT&T’s Bell Labs devised the first factoring algorithm by using quantum principles of entanglement and superposition.

A quantum computer composed of qubits linked together by entanglement in a coherent system could conceivably perform a huge number of calculations simultaneously. Instead of calculating numbers sequentially as conventional computers do, a quantum computer could crack the most sophisticated codes by doing simultaneous calculations.

Suddenly, the sanctity of modern cryptographic methods based on the difficulty of factoring code combinations of very large numbers was in doubt, making the guardians of government and the financial world start to sweat. Computer scientists started paying attention to quantum mechanics for applications in secure computing as well.

Charles Bennett at IBM described a method of quantum cryptography that would conceivably require a violation of the laws of physics to break its code. To communicate, two parties, Alice and Bob, use a shared secret key to encrypt and decrypt their messages to each other. To create this key, Alice encodes information in the quantum states of individual optical photons and transmits them to Bob. Bob’s receiver sorts the photons according to their states and sends them to detectors. Potential eavesdroppers are foiled by the quantum properties of light, which dictate that any attempts to intercept the quantum information will necessarily disturb it in a way that Alice and

Bob can detect and evade.

**Spike Goes On A Road Trip**

But what would it take to teleport a two-foot long iguana? Let's name him Spike.

It looks so easy on *Star Trek*, but regrettably, teleporting Spike is infinitely more complicated than teleporting a single photon. All Spike's molecules really have to be inextricably entangled with their quantum counterparts, or iguana re-assembly will go awry. And even so, what you would get would be an identical copy of Spike's information, but not the original Spike.

In response to my urgent plea for help, Professor Samuel Braunstein, of the School of Informatics at Bangor University in Wales, kept a straight face and sent me detailed instructions in how to teleport Spike.

> Have sender somewhere outside your back yard. Have receiver hidden somewhere inside your yard. Let them share two halves of a sizable quantum computer with enough quantum bits (qubits) to describe the iguana. The number of entangled atoms would have to be about the size of an iguana, so this would be difficult to hide. These two halves of a quantum computer, or simply two separate quantum computers, would have to have pre-shared entanglement and lots of it.
>
> Next, the sender needs to do a joint measurement on the iguana and her half of the states of her qubits. Then she needs to call the receiver on her cell phone and read out zillions of bits of information describing the outcome. As I estimated, this would only take about one hundred million centuries. Then the receiver has to use this information to transform the states in his computer into that of the original system, er, iguana.
>
> Now, this is all well, but the iguana you get back has a physical form which depends on how the qubits in the receiver's machine are stored. If he is using an ion trap then the iguana would not look very recognizable. This is like what sort of paper you feed into the receiver end of the fax machine. Stick in a different sort and the message does come out, but it may not *look* anything like the original.

> Of course, were this to have happened, there would be some traces. For example, the receiving operator would still be in your yard. Also his quantum computer. Now this would be especially useful because you could probably sell it to the National Security Agency and buy an island. Like Manhattan.

So, could we ever use quantum physics to teleport people? Braunstein didn’t think that quantum physics would get me to a party on time in the near future.

"With Moore’s Law giving a doubling in computer capacity every 18 months, we can give a rough estimate for the time required for the processing and communication capacity to reach the level of being able to teleport humans or iguanas," said Braunstein. "The time scale is about one century. However, that might be considered to be very optimistic, since Moore’s Law is expected to peter out in about 15 to 20 years time. Since we’re relying on an exponential improvement for this estimate, it’s only the last four or five years of that century’s time which would see the jump from teleporting iguanas to teleporting people."

Alan Lightman, an MIT physicist and writer, also approached the iguana problem with great gravity, but was less optimistic about the viability of teleportation on the macroscopic level. He still thought that Heisenberg’s Uncertainty Principle was a barrier to transporting anything near the complexity of a human being. "If you wanted to assemble a human being somewhere else, you need to have information analogous to the raw material of the person," he said. "It’s not just a person who vanishes in one place and reappears in another. You need all the ingredients of the person. You must transmit all the information about the person’s state, including all of the positions and energy states of each of his or her atoms. You could not know the precise quantum state of all the atoms of the person. There would be a fuzziness."

For quantum entanglement to work, Lightman explained, you would need two objects that came from the same quantum state, such as two photons. "But to entangle two human beings, you need two human beings who were approximately the same. Then you are still faced with the problem of extracting accurately all the atoms in the quantum state." Lightman was dubious of the chances of exactly recreating that person with his or her brain and personality intact. "We don’t know enough about the brain to be able to reproduce a person’s mental state and memory," he said.

It seemed that some rearrangement of atoms could improve both Spike the Iguana’s personality and longevity. But if I got it wrong, Spike would rematerialize with his tail attached to his snout. Dedicated to the cause of science, however, I began to fumble frantically with the fax machine in my back yard, Braunstein’s instructions clutched in my hand.

But then the neighbor came by. "You will be glad to know," she said, "the owner showed up at Animal Rescue to claim his iguana before it was put down. He was a weird guy. All he said is that it crawls away sometimes."

*When she isn’t investigating the possibilities of bleeding-edge technology, signing up for unknowable cat-sitting services, or teleporting iguanas, you can find Wendy Wolfson in her Listening Post discussion forum.*

EMAIL THIS ARTICLE
PRINT THIS ARTICLE
DISCUSS THIS ARTICLE
LICENSE THIS ARTICLE







PCs
HANDHELDS
SERVERS
STORAGE

APPLICATION DEVELOPMENT
BUSINESS APPLICATIONS
OPERATING SYSTEMS

XML

WEB
TOOLS

JAVA

E-BUSINESS

CRM

DATABASES

ERP

BUSINESS
INTELLIGENCE

WINDOWS

LINUX

UNIX

ADMINISTRATION

NETWORK
OPERATING SYSTEMS

SECURITY

COMMUNICATIONS

WIRELESS

VIRUSES

ADMINISTRATION

ASP

CONSULTING

OUTSOURCING

TOOLS

IT TRENDS

ROI

INFORMATIONWEEK
500

COLLABORATION

WORKPLACE
TRENDS

SALARY

HOT JOBS

TRAINING