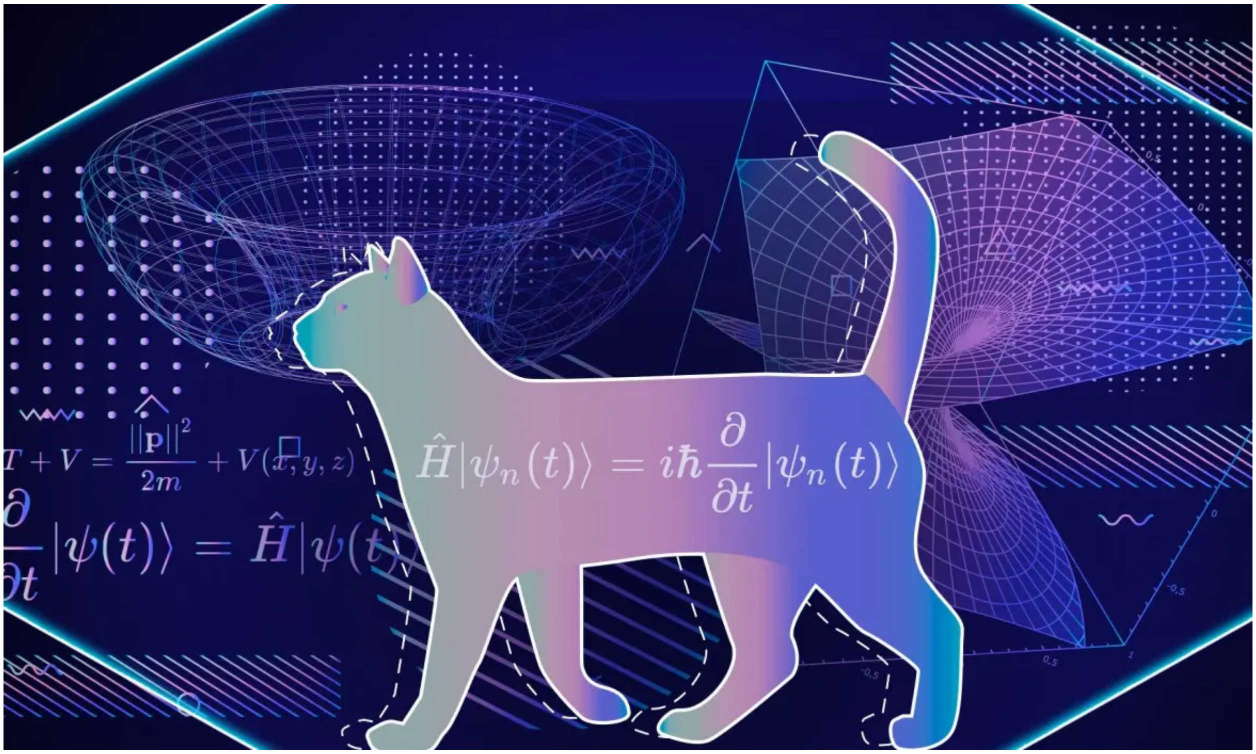

QUANTUM TELEPORTATION & ENCRYPTION

A DETAILED STUDY

ASHWITHA NOBLE

PROBLEM STATEMENT

Being so far from Earth makes operating a spacecraft around Mars one of the most challenging tasks! In fact, because Mars is so far away, it takes a while for radio signals from the spacecraft to reach Earth. This delay will be 13 minutes, 48 seconds, roughly in the middle of the minimum (4 minutes) and maximum (24 minutes) delays. Because of this, it is difficult to communicate with Mars Express and respond quickly if something unexpected occurs on board. If a problem arises and the spacecraft alerts us, Even if we react immediately to a situation that the spacecraft alerts us to, it will still take 13 minutes for our instructions to reach Mars. At Mars, a lot can happen in 30 minutes, such as the entire Curiosity landing.

INTRODUCTION

We can transmit a system's quantum state and its correlation to another system through quantum teleportation. The kind of information that teleportation can deliver is subtle, unscannable, and completely different from regular information. Teleportation serves as an ingredient in several computation and communication tasks. The development of teleportation is based on the theory of quantum entanglement.

QUANTUM ENTANGLEMENT

Two subatomic particles can be intricately connected to one another despite being billions of light-years apart thanks to a strange, counterintuitive phenomenon called quantum entanglement. Despite their great distance from one another, a change caused in one will have an impact on the other. The well-known idea of quantum entanglement serves as the foundation for quantum teleportation. Erwin Schrödinger coined the term "entanglement" in 1935. For actual teleportation, it is required that an entangled quantum state or Bell state be created for the qubit to be transferred.

METHODOLOGY

The application of the quantum teleportation principle is shown through the experimental work of Bennett et al. and subsequent theoretical and experimental work by others. This amazing technical achievement finally put an end to the persistent debate over whether quantum entanglement could be used to implement a teleportation process to noncausally transfer information between distant quantum systems (i.e., at FTL speed). This follows the outline of Bennett et al.

Let quantum state $|\chi\rangle = \alpha\,|0\rangle + \beta|1\rangle$ of a particle is to be teleported from one location to another. We prepare a pair of quantum subsystems in an EPR entangle state. John Bell proved that for a 2 q-bit quantum system there are only four possible entangled states, called the Bell states

Bell Pair Symbol	Mathematical Representation
$\|\Phi^{+}\rangle$	$\frac{\|00\rangle + \|11\rangle}{\sqrt{2}}$
$\|\Phi^{-}\rangle$	$\frac{\|00\rangle - \|11\rangle}{\sqrt{2}}$
$\|\Psi^{+}\rangle$	$\frac{\|01\rangle + \|10\rangle}{\sqrt{2}}$
$\|\Psi^{-}\rangle$	$\frac{\|01\rangle - \|10\rangle}{\sqrt{2}}$

Now send $|\phi\rangle$ to the location of sender “A”. And send $|\psi\rangle$ to the location of receiver “B”. These two subsystems are non-causally correlated via entanglement, but at this point, they contain no information about the particle that is to be teleported from one location to another. The two subsystems are now like an open quantum channel that is ready to transmit information

To perform the teleportation, now “A” brings the teleported state $|\chi\rangle$ into contact with the entangled state $|\phi\rangle$ and performs a Bell state measurement on the combined system $|\chi\rangle|\phi\rangle$.

“A” transmits to “B” a complete description of the outcome of the Bell state measurement using a conventional classical communication channel.

Let the outcome of As Bell state measurement is $|\Phi+\rangle$ then B’s photon is in the state: $|\psi\rangle = -\alpha\,|1\rangle + \beta\,|0\rangle$. So B now knows set of linear transformations (i.e., suitable unitary operation) to be applied on $|\psi\rangle$ to get exact replica of the state of $|\chi\rangle$. After linear transformation $|\psi\rangle$ is now in a state identical to the original state $|\chi\rangle$.

In the teleportation process, the quantum states of the particles or photons, not the particles or photons themselves, are destroyed and recreated. Q-Teleportation Is Fundamentally Limited by Decoherence. We made the unrealistic assumption that Alice and Bob shared an EPR entangled pair that was free of noise or decoherence in order to simplify the q-Teleportation scenario. Decoherence is the process by which information leaks to or from the environment (i.e., environmental noise) through erroneous interactions with the object, deteriorating the quantum states of the object. The loss of photons or the heating of the phonons can cause noise or decoherence in the quantum link (or EPR interaction) between two systems. Fortunately, this can be achieved by “Entanglement Purification for Quantum Computation” by W. Du¨r and H.-J. Briegel

MERITS

Teleportation will allow the transfer of quantum information in the form of quantum states from one location to another, forming a quantum network in the process. A quantum network has the advantage of allowing information to be transferred in complete privacy. Eavesdroppers cannot intercept and read messages.

This can also be a great leaping step in Astronomy because it is concerned with the formation and evolution of the universe, as well as the evolution, physics, chemistry, meteorology, and motion of celestial objects. One of astronomy's most important aspects is its ability to help us understand our place in the universe.

FUTURE SCOPE

Given the rapid progress in long-lived quantum memories and efficient light-matter interfaces, we expect that more sophisticated space-to-ground-scale teleportation will soon be realized, and will play a key part in a future distributed quantum internet. This can provide a new path for humans to think, look at, and live in. If this teleportation technique can be mastered then the data can be sent at speed that is greater than the speed of light which will lead to a great revolution in the field of technology and physics.

CONCLUSION

Now branches of it like quantum gate teleportation, quantum computing, port-based teleportation, photonic qubits, photonic qubits, optical modes, nuclear magnetic resonance, atomic ensembles, and trapped atomic qubits are achievable both theoretically and experimentally. The technologies mentioned above performed well in some aspects and failed in others, therefore certain technologies only correspond to a certain kind of practical situation. Those technologies are imperfect more or less in some aspects, which raises lots of engineering questions as most of them are expected to be solved when more experiments are devised. Future aspects of quantum teleportation might focus on long-range quantum teleportation between light and macroscopic matter or even quantum energy teleportation proposed in recent years.