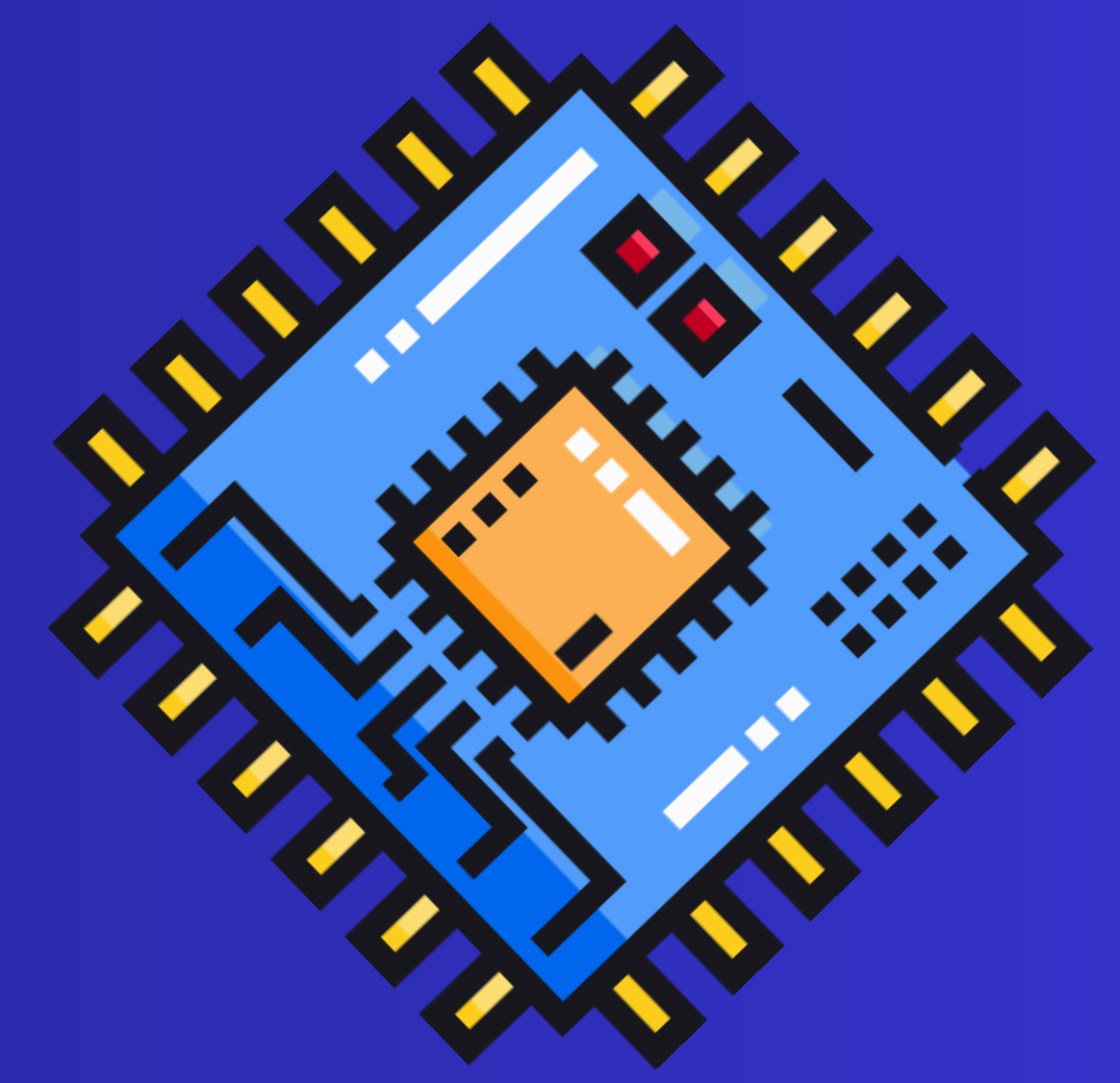


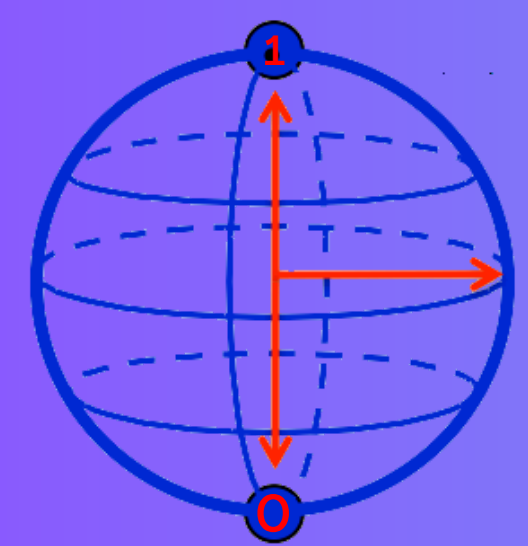
Quantum computing, Driving the Next Technological Revolution



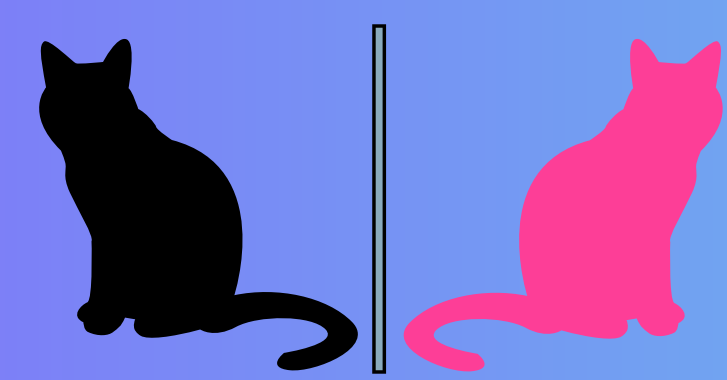
Introduction

Quantum computing is a field that combines quantum physics and computer science. By exploiting qubits, quantum computers solve complex problems faster, acting as a sort of a bridge that connects fundamental physics and advanced computation.

How does Quantum Computation work?



Quantum Computers use **qubits** which exist in a **superposition** which is a mathematical way of saying **both 0 and 1**.



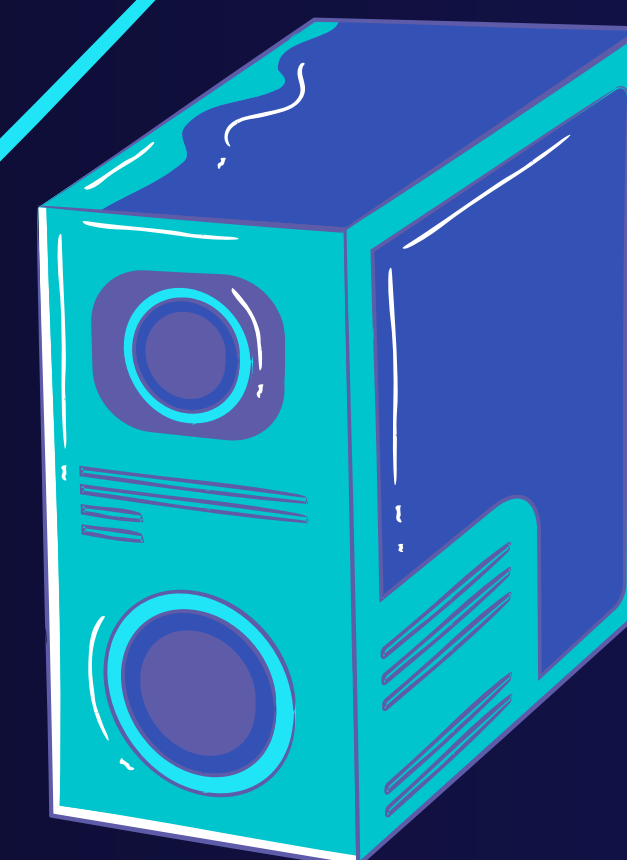
Schrödinger's cat is a thought experiment that encapsulates quantum **superposition**. A cat in a closed box is linked to an unpredictable quantum event to determine if and when it dies. While unobserved, the cat exists as both alive and dead at the same time, in theory.



Quantum logic gates are the building blocks of quantum circuits, operating on qubits through the principles of quantum mechanics such as superposition and entanglement. They differ from classical gates, which act on bits (**0 or 1**), by transforming qubits through unitary operations, which allow for complicated and complex computations.

Quantum computation involves the manipulation of **qubits**, which have the ability to be in more than one state simultaneously, in contrast to being in just 0 or 1. This is made possible by **superposition**, in which a qubit can be in a combination of both 0 and 1, thus exponentially increasing computational potential. Quantum entanglement allows for correlations between qubits, such that one qubit's state immediately affects another, thus enabling faster information processing. Quantum logic gates perform computation by executing unitary transformations in qubits, thus making possible robust algorithms that surpass classical computers in specific tasks.

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Recent Advancements

- Recent breakthroughs in quantum computers have been characterized by outstanding breakthroughs in a variety of fields. Microsoft, in fact, has unveiled the Majorana 1 chip, which utilizes the peculiar nature of Majorana fermions—a new kind of matter—to produce more stable qubits, possibly accelerating the coming of practical quantum computers. This new chip utilizes a topological superconductor, making it possible to have millions of qubits in a single, palm-sized chip, a breakthrough that could radically change the face of computational power.
- At the same time, Oxford University scientists achieved a major breakthrough in the field of quantum teleportation by successfully teleporting quantum information from one processor to another. They did it by using a photonic network interface that efficiently connected the two processors, making them a single, unified quantum computer. This new method addresses the long-time problem of scalability that has afflicted quantum computers, opening the door to smaller machines to communicate and perform calculations across a network without being limited by any theoretical bounds to how many processors can be connected.
- An Australian research team from Melbourne University achieved a historic feat by winning the prestigious Gordon Bell Prize for developing the first-ever simulation of biological processes with quantum accuracy. The new software can simulate how drugs work with a level of accuracy comparable to that of laboratory experiments, which can cut short drug development time and associated costs.
- The Willow chip, a product from Google, is a breakthrough in the field of quantum computing. The chip has attained a landmark by proving to be able to perform with decreasing error rates as it gets scaled, thus solving a long-standing problem in the field. Willow's design enhances qubit stability, enabling breakthroughs in real-world applications and solving complex problems that classical computers can't.

Real world application

- Cryptography:** Breaking conventional encryption techniques (such as RSA) and enabling secure quantum encryption processes (quantum key distribution).
- Artificial Intelligence and Machine Learning:** Enhancing pattern detection, optimisation, and analysis of vast amounts of data.
- Pharmaceutical and Material Sciences:** Utilizing simulations of molecular architectures and chemical interactions to accelerate drug and material engineering processes.
- Quantum simulation:** Understanding quantum systems to enable advancements in physics and materials science.

Conclusion

- Quantum computing is one of the computer strength paradigm shifts that employs the superposition and entanglement principles of computation that will be too burdensome for the classical computer. In contrast to bits in classical computation, which are either state 0 or state 1, qubits, or quantum bits, are in multiple possible states at the same time, and they can more efficiently explore large solution spaces using algorithms, which will revolutionize many scientific and technological fields.
- One of the most direct and significant impacts of quantum computing is on cryptography. Shor's algorithm, for example, puts traditional encryption schemes at risk by allowing efficient factorization of large numbers, the basis of RSA encryption. Quantum cryptographic protocols, like quantum key distribution (QKD), subsequently provide new paradigms for secure communication that are theoretically resistant to traditional decryption techniques. Aside from cryptography, quantum computing has the potential to transform machine learning and artificial intelligence by greatly improving optimization, feature selection, and pattern recognition to allow much more advanced models to process vast quantities of data with unprecedented speed. With such great promise is the fact that the field is in its infancy and must overcome very substantial technical hurdles.
- Quantum systems are highly susceptible, and qubits suffer decoherence and noise and hence error correction is an open but essential problem. Existing quantum error correction codes need an implausibly large amount of physical qubits to create a single logical qubit, which restricts the scalability of quantum processors. Furthermore, fault-tolerant quantum computing imposes revolutions in hardware, software, and control systems, which implies interdisciplinarity between physics, computer science, and engineering. In the future, further development in quantum hardware, better error correction methods, and scalable architecture could unleash unmatched computational power. Quantum computers can change the field of drug discovery through the simulation of molecular interactions on an atomic scale, optimize financial and logistical systems, and accelerate materials science with simulations of novel materials with predetermined properties.
- While broad-scale practical quantum computing remains several years off, research and investment in the sector are on a high velocity course toward achieving a point in the future when quantum computers will crack some of the most confounding scientific and technological issues on Earth.



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