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QUANTUM COMPUTING

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ABSTRACT

This paper explores the field of quantum computing and quantum theory, based on the principles of quantum physics. The paper also deliberates on Richard Feynman and Yuri Manin's theory of quantum computers. It analyses the benefits of quantum computing and their role in the future of computers and computer science. It seeks to encourage discussion and discourse around the past, present and future of computer sciences.

Keywords: Quantum Computing, Traditional Computer, Qubits, Quantum Theory

What is Quantum Computing?

Quantum computing is a type of computing that uses the principles of quantum physics to solve issues that are too sophisticated and would take a classical computer a long time to solve. Compared to supercomputers, quantum computers are smaller and use less energy. Classical computers use binary (bits) to store information in the form of 0s and 1s whereas, Quantum Computers use quantum bits or Qubits.

Qubits are made using physical systems, such as an electron's spin or a photon's orientation. These systems can be in different arrangements at the same time. This is known as quantum superposition. A phenomenon known as quantum entanglement can also be used to inseparably connect the qubits. As a result, a group of qubits can simultaneously represent multiple things.

Two bits of a classical computer can be in one of four possible states at once (00, 01, 10, or 11), but never all four. As a result, the computer can only process one input at once. Two qubits can also represent the same four states (00, 01, 10, or 11). The distinction is that the qubits can simultaneously represent all four due to superposition. That's the same as having four classical computers running simultaneously. If you add more bits to a regular computer, it can still only deal with one state at a time. But as you add qubits, the power of your quantum computer grows exponentially. We can say that if you have "n" qubits, you can simultaneously represent 2n

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states.

A traditional computer can represent any number between 0 and 255 using just eight bits. However, a quantum computer can simultaneously represent all 256 numbers between 0 and 255 with just eight qubits. More numbers than there are atoms in the universe could be represented by just a few hundred entangled qubits. A quantum computer is not merely a computer that is "faster." A quantum computer would excel at a few specific tasks, such as factoring in extremely large numbers. However, a quantum computer would perform most tasks no better than a conventional computer.

Background

Origin of Quantum Computers

Quantum computers were proposed by Richard Feynman and Yuri Manin in the 1980s. The idea for Quantum Computers was a result of one of the most embarrassing problems in physics: an incredible breakthrough in the form of Quantum Mechanics (developed between 1900 and 1925, leading to astounding progress in Chemistry and Condensed matter Physics) was met with the inability to model even the simplest systems of the Theory.

According to Quantum Theory, matter can exist in a wide variety of configurations at the quantum level (known as states). Contrary to classical probability theory, these numerous quantum state configurations might interfere with one another like waves in a tide pool. This is why the quantum state configurations cannot be obtained by statistical sampling. Therefore, if we want to comprehend quantum evolution, we must keep track of every possible configuration a quantum system might be in.

Similar to the Qubits mentioned in the working of a Quantum Computer, if a system of electrons can be in, let's say 300 positions. There will be 2^{300} possible configurations of the system. Since that is more than the number of atoms in the observable universe, we can't store them in binary. The discovery prompted the physicists to pose a straightforward but insightful question: Is it possible to turn this conundrum into an opportunity?

They thought that since Quantum systems are hard to simulate, could they build a computer that used Quantum mechanics as fundamental operations? Could they create a system to simulate particles interacting using the exact same laws that govern them naturally? These issues sparked the development of quantum computing.

What does a Quantum Computer consist of?

Classical computers are made up of bits, registers, and logic gates. And similarly, qubits,

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quantum registers, and reversible gates are the building blocks of a Quantum Computer. In contrast to traditional bits, which can only have a value of 0 or 1, qubits can hold both 0 and 1 states thanks to superposition. Qubits are the fundamental building blocks of the memory of a Quantum Computer. Qubits have been discussed in detail in the introduction.

A quantum register is a collection of qubits that can simultaneously store every possible arrangement of the input data. In other words, when a quantum algorithm is applied to an n-qubit register, all n possible configurations of 0/1 states are computed "in parallel" by the Quantum Computer. 2

A logic gate is a crucial component used to construct digital circuits. They carry out fundamentally important logical operations for digital circuits. Quantum Gates have to be Reversible. A reversible gate is a gate where the input can be found out using the output. Quantum Gates need to be reversible because of Unitarity, a key aspect of Quantum Mechanics.

Quantum Processing Unit

A Quantum Processing Unit (QBU) is the center for processing. It relies on quantum mechanics to perform a task. It consists of a:

- QRAM(Q Registers + Q Gates)
- Quantum Control Unit (takes the system to the targeted condition)
- Classical controller interface (defines the interaction between the host CPU and the QPU)

Challenges that come with Quantum Hardware

Isolation

Heat and Light are noise to the Qubit and they temper with its state causing it to lose its properties (superposition and entanglement) and its information (known as decoherence). This is why quantum computers are stored at ~0 Kelvin

Signal Control

A qubit has to be rotated in order to change its state (flipped by the logic gate). Errors can happen during these rotations. Even if the error is of 0.1 degree, an inaccurate output will be produced as a result of the accumulation of qubits rotating at this rate of inaccuracy.

Quantum error correction (QEC) is necessary to protect quantum information from errors due to decoherence and other quantum noise. Error Correction could be done using redundancy

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(storing copies of qubits); however the no-cloning theorem, which asserts that itis impossible to produce an exact duplicate of any quantum state, prevents the copying of quantum information.

Wavefunction collapse is an additional issue that quantum error correcting must deal with. In order to avoid that from happening and erasing the encoded data, monitoring qubits as part of the error correction process will require caution.

Discussion

Increasing Coherence time

An important requirement for Quantum Computers would be that the qubits shouldn't change their orientation spontaneously. Because if that were to happen, the computer would not be usable. Currently, there is a lot of "noise" in quantum systems, which reduces their coherence time (the amount of time they can hold their condition) or results in errors. Even if the noise is reduced, the computer will still raise errors. The key would be to do error correction.

The more qubits being used further will be the margin of error. The most robust quantum computers available now have roughly 50 qubits, but for them to be useful, they will probably require hundreds or thousands. Methods being used to help increase the reliability of qubits are:

Superconducting Qubits

The most advanced qubit technology at the moment is superconducting qubits. Superconducting qubits are used in the majority of current quantum computers. Scientists decrease these materials to incredibly low temperatures in order to transform them into superconductors: materials that electricity can flow through without loss. Along with other things, pairs of electrons flow through the material in a coherent manner as though they were single particles. The quantum states are longer-lasting as a result of this movement than in standard materials.

Qubits using defects

Defects are areas in the structure of a substance where atoms are absent or misaligned. The way electrons travel in the materials is altered by these gaps. These areas trap electrons in specific quantum materials, giving researchers access to and control over their spins. These qubits don't necessarily need to be at extremely low temperatures, unlike superconductors. They might be produced in large quantities and had lengthy coherence times.

Designing Materials

While some scientists are investigating how to use existing materials, others are taking a different tack – designing materials from scratch. This approach builds custom materials

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molecule by molecule. By customizing metals, the molecules or ions bound to metals, and the surrounding environment, scientists can potentially control quantum states at the level of a single particle. This method allows researchers to control the amount of nuclear spin around the qubit. It is challenging to preserve and manage electron spin because of the magnetic noise that all the atoms with nuclear spin produce. Scientists have been able to significantly reduce the nuclear spin in the environment.

Need for Quantum Computers

Combinatorics is a subset of mathematics that classical computers find particularly challenging. These calculations involve selecting an item arrangement that best achieves a particular objective. The total number of possible arrangements increases exponentially with an increase in the number of items to be arranged. Numerous significant industries, including finance and pharmaceuticals, are affected by the difficulty of combinatorics calculations. Additionally, it is a significant roadblock in the development of AI. Quantum computers can easily solve this problem.

Artificial intelligence, which frequently entails the combinatorial processing of extremely large amounts of data to make better predictions and decisions, will benefit from the use of quantum computing (think facial recognition or fraud detection). Quantum machine learning is a rapidly expanding field of study that seeks to understand how quantum algorithms might speed up AI. Due to current software and technology limitations, quantum artificial general intelligence is a relatively remote possibility.

Combinatorics lies at the heart of **Cybersecurity and Cryptography.** The idea that combinatorial calculations are essentially unmanageable, is still the foundation of encryption used today. Data security is at risk because encryption cracking will be much easier thanks to quantum computing. A brand-new sector is emerging that aids businesses in getting ready for potential cybersecurity weaknesses.

Data analysis

One of the major problems facing traditional computing is the expanding amount of data. Quantum computing becomes useful in this situation. Large data sets can be processed by quantum computers in record time. One of the first industries to adopt Big Data was **finance**. Additionally, a significant portion of the science involved in determining the price of complex assets, such as stock options, uses combinatorial calculations with projections based on simulated market movements.

Logistics

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Logistics refers to the precise planning and execution of a complex task. In logistics, quantum supercomputers would have a significant impact on route planning. Utilizing quantum computing would improve the utilization of warehouse simulation by examining all feasible routing choices and selecting the most effective one while accounting for all factors.

A warehouse management system (WMS) is a piece of software that provides insight to all of a company's inventory and controls supply chain fulfillment activities from the distribution center to the retail shelf.

Moreover, quantum computing has the potential to improve a company's logistics performance in more ways than just route modeling. Quantum computers may be able to improve supply chain resilience by accelerating scenario modeling. In **Chemical and Biological Engineering**, there is manipulation of molecules which involves interactions on the subatomic level, where Quantum Mechanics come into play. With increasing complexity of molecules, the number of arrangements increases exponentially. Therefore, we need Quantum Computers to help predict the qualities of new molecules. Quantum Computers would accelerate the discovery and development of new materials and drugs.

Weather forecasting

When there are numerous environmental factors present, it is quite challenging for classical computers to predict the weather. A quantum computer, on the other hand, is able to accurately forecast short-term weather patterns. It can also foretell the impact of climate change. Billion-dollar investments have been made recently due to the potential for quantum computing to solve complex combinatorics problems more quickly and affordably.

Conclusion

The development of Quantum Computers will affect a lot of fields like, Data Analysis, Artificial Intelligence and Machine Learning, Cyber Security (Cryptography), Logistics, Chemical and Biological Engineering, Quantum Model Simulation, Weather Forecasting, etc., and therefore, companies should be aware of all the possible developments and how they might affect their industry so that they are not left behind. Eventually, Quantum Computers will be commercialized and become more accessible. This will give startups a big boost to have access to incredible technology.

References

What is Quantum Computing? | IBM. (n.d.). Retrieved September 30, 2022, from https://www.ibm.com/topics/quantum-computing

ISSN: 2455-8834

Volume:07, Issue:10 "October 2022"

What is a quantum computer? (n.d.). New Scientist. Retrieved September 30, 2022, from https://www.newscientist.com/question/what-is-a-quantum-computer/#:%7E:text=In%20a%20qu

What is a quantum computer? (n.d.). New Scientist. Retrieved September 30, 2022, from https://www.newscientist.com/question/what-is-a-quantum-computer/#:%7E:text=In%20a%20qu

Ambainis, A. (2014). What Can We Do with a Quantum Computer? Retrieved December 07, 2020, from https://www.ias.edu/ideas/2014/ambainis-quantum-computing

Bonsor, K., & Strickland, J. (2000, December 08). How Quantum Computers Work. Retrieved December 07, 2020, from https://computer.howstuffworks.com/quantumcomputer.html

Giles, M. (2020, September). Google researchers have reportedly achieved "quantum supremacy". Retrieved December 07, 2020, from https://www.technologyreview.com/2019/09/20/132923/google-researchers-havereportedly-achieved-quantum-supremacy

Harrow, A., Hassidim, A., & Lloyd, S. (2009, October 07). Quantum Algorithm for Linear Systems of Equations. Retrieved December 06, 2020, from https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.103.150502

Holton, W. C. (2020, August 16). Quantum computer (1107908068 837841751 Encyclopædia Britannica, Ed.). Retrieved December 07, 2020, from https://www.britannica.com/technology/quantum-computer

