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Quantum Computing

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Abstract: Quantum computing is a modern calculation method that is based on the science of quantum mechanics. These phenomena include the bizarre behavior of particles at the atomic and subatomic levels, and the way that these particles can be in multiple states simultaneously. The field of computer science is a great mix of physics, math, and information theory. This technology provides high computing power, low power consumption, and exponential speed by controlling the behavior of small physical objects, such as atoms. Atoms, electrons, photons, etc. are all elements of the physical world. We would like to introduce the basics of quantum computing, and some of the ideas behind it. This article begins with the origins of the classical computer and discusses all the improvements and transformations that have been made due to its limitations thus far, then moves on to the basic operations of quantum computing and results in quantum properties such as superposition, entanglement, and interference.

Keywords: Quantum Computing, Qubits, Super Positioning, Quantum Supremacy

I. INTRODUCTION

Since the atom was first investigated in the early 20th century, quantum physics has defied reason. It turns out that the conventional laws of physics do not apply to atoms. Quantum particles have the ability to "teleport," travel through time, exist in two places at once, and more. Quantum computers want to take use of these peculiar features.

While traditional computers crunch through tasks using ones and zeroes, quantum computers use quantum bits, or qubits. Quantum computers employ ones and zeros just like classical computers do, but qubits include a third state called "superposition" that enables them to represent both a one and a zero simultaneously. Superposition enables two qubits to simultaneously express four scenarios in place of sequentially analyzing a one or a zero. As a result, there is a considerable decrease in the processing time for a data collection. We produce vast amounts of data every day. We need a lot more processing capacity to adequately process it all and derive sense from it. Quantum computers come to the rescue in this situation.

II. LITERATURE SURVEY

S.No.	Paper Title	Authors	Conclusion
1.	Quantum Technology for Analysis and Testing Computing Systems	Wajeb Gharibi, Hahanov V.I., Anders Carlsson, Filippenko I.V	Quantum computing can increase the performance of tools for analysis and synthesis of digital computing devices using quantum models, methodologies, and algorithms. It focuses on the qubit structures of diagnostic information and describes a matrix method for quantum diagnosing functional failures and stuck-at faults in software or hardware units. By introducing parallel logic operations on matrix data, the computational complexity of simulation and diagnosis can be significantly reduced.
2.	The Quantum Way Of Cloud Computing	Harpreet Singh, Abha Sachdev	In this paper, a novel cloud computing strategy that incorporates quantum computing is put forth. This strategy gives the field of cloud computing a foundation for yet another functionality of "quantum computing as a service". The elimination of security issues from cloud computing would be the main benefit. Additionally, this type of technology would open

			the door for the next generation of computing and enable more portable computing.
3.	A Heterogeneous Quantum Computer Architecture	X.Fu, L.Riesebos, L.Lao, C.G.Almudever, F.Sebastiano, R.Versluis, E.Charbon, K.Bertels	In this paper have provided the first comprehensive description of a heterogeneous quantum computer architecture. We have addressed the various system layers required to construct a quantum computer and provided a description of the datapath of quantum instructions with regard to execution and error correction. Future work includes creating a digital quantum processor that can test control logic on a higher number of qubits than what can be provided by present devices.
4.	Quantum Computing: Future Computing	Mr. V. R. Gotarane, Mr. Sushant S.M. Gandhi	Quantum computation offers the power to solve problems that, for all practical purposes, traditional computers cannot solve. Some quantum mechanics aspects that enable quantum computers to outperform traditional computers also make designing quantum algorithms and building viable hardware exceedingly challenging. We must provide some methods to increase the quality of qubit technology by boosting qubit coherence duration and quantum operation speed. We also need to fix the qubit's state for quantum error correction.
5.	Quantum Computing: An Introduction	Tony Hey	Entanglement lies at the heart of these mistake correcting systems once again. Shor and Steane have separately devised algorithms demonstrating that quantum error correction is achievable - something that had previously been questioned. The exceptional capability of quantum algorithms appears to be derived from multiparticle entangled states' characteristics.

III. QUANTUM COMPUTING NEED OF FUTURE

Quantum computers have been proposed as a possible solution to the problem of how fast computers could be in the future. Moore's law states that if technical advancements continue, the number of transistors per chip may double every 18 months. Within the next ten years, processor clock frequencies could exceed 40 GHz. By that time, one atom might stand in for one bit.

A. Properties Of Quantum Computing

1) *Superposition:* Superposition in quantum computing refers to the ability of a quantum system to have quantum particles or qubits in two different positions, or, for example, in multiple states at the same time [6]. In classical arithmetic, after combining two bits, the total possible value is 4, and only one of them is always possible. The same is true if the quantum computer has two qubits.
2) *Entanglement:* Entanglement in quantum mechanics is a physical phenomenon in which two or more quantum objects are intrinsically linked [5]. It refers to the strong correlation that exists between two quantum particles or qubits. Once tangled, they will remain connected even after separating at any distance. Adding extra bits to a quantum computer can increase its computing power exponentially.

3) Interference: The properties of interference in quantum computers are similar to those of waves in classical physics. Wave interference occurs when two waves interact in the same medium. If each particle passes through both slits simultaneously (Young's double slit experiment) due to superposition, they can cross their own path that obstructs the direction of the path. The idea of interference allows us to intentionally skew the qubit's contents to the required state.

B. Difference Between QUBITS And BITS

QUBITS	BITS
The device computes by manipulating those bits with the help of quantum logic gates.	The device computes by manipulating those bits with the help of logical gates (AND, OR, NOT).
Quantum bits are use in quantum computer	Bits are used in classical computers.
A quantum bit can be in a superposition of two different states, or qubits, where a & b are non-negative real numbers.	Information is stored in bits, which take the discrete values 0 and 1.
Qubits are fast.	Bits are slow.
Its circuit behavior based on quantum mechanics.	Its circuit behavior based on classical physics.

C. Survey Analysis Of Quantam And Classical Computers

Parameters of Comparison	Quantum Computing	Classical Computing
Error rates	Quantum computing has a high error rate	Classical computing has a less error rate
Best suitable	Quantum computing is best for analyzing data	Classical computing is best suitable for the daily use
Possible states	Continuous	Discrete
Information processing	Using quantum logic	Using Logic gates like AND, OR
Operations	Boolean algebra	Linear algebra
Works On	Qubits	Bits

IV. NEW METHODS FOR QUAMTUM COMPUTER CONSTRUCTION

Quantum computers exploit the characteristics of quantum mechanics to store data and carry out computations, are based on qubits. These computers are thought to be much quicker than the current classical computers at solving some important computational problems. Academic labs can concentrate on providing the basic understanding required to get a quantum computer running while industry can give the engineering muscle to develop such a complex system.

Below is a summary of some of the players in the field's advancements.

1) The Canadian business D-Wave has declared that it is launching the commercialization of its next-generation technology, Advantage. The system has more than 5000 qubits, more than twice as many as the older 2000Q machine's processing units. The connectivity of each of these qubits will increase by 2.5 times compared to its predecessor.
2) To accomplish the calculations, IONQ, a company in Maryland, USA, uses trapped ytterbium ions that are controlled by lasers.
3) A Californian company called Rigetti Computing uses microwaves to regulate pairs of electrons moving through superconducting circuits.
4) Microsoft is developing a "topological" quantum computer that makes use of super-cold electron interactions.
5) Psi Quantum uses photons that travel along waveguides etched into regular silicon chips to compute. Within the next five years, it aims to skip the noisy intermediate-scale quantum stage and build a full-fledged quantum computer. The company is already working with large contract chipmaker Global Foundries to produce wafers full of quantum computer chips.
6) Sequoia Capital and In-Q-Tel were among the investors who contributed millions of dollars to Australian startup Q-CTRL. Their engineers have enhanced hardware-control methods originally authored by humans using machine learning. This can lower mistake rates by 90% and variability on a single chip by the same percentage.

7) IBM's Quantum Condor processor will have 1121 qubits and be ready in 2023. The goal is to reduce error rates from one percent currently to roughly 0.0001 percent. Even with 1,000 qubits, it would still be insufficient to handle all the problems associated with full-scale quantum computing. But it would be sufficient to sustain a limited number of logical, stable qubit systems that could then communicate with one another.
8) The first photonic quantum computer has been made publicly accessible via the cloud by Canadian quantum computing start-up. Xanadu (a member of IBM's Q-network). Photon-based quantum computers may have significant benefits over their electron-based counterparts and could lead to breakthroughs in the field of quantum computing.

V. PROBLEM WITH CURRENT APROACH

Qubits are each based on a single photon, and are the foundation of the traditional method of photonic quantum computing. The Continuous Variable Quantum Computing approach does not make use of single-photon generators, but rather superpositions of several photons

VI. APPLICATIONS OF QUANTUM COMPUTER

A. Artificial Intelligence & Machine Learning

Artificial intelligence and machine learning are some of the major fields in which quantum computing has potential to play a major role. Quantum computing could enable us to solve complex problems in a fraction of the time it would have taken conventional computers to do so.

B. Computational Chemistry

IBM Company claims that even the smallest molecules have a huge number of quantum states, making it challenging for traditional computers to store all of them at the same time. It may be possible for quantum computers to map molecules with great power thanks to their capacity to concentrate on the existence of both 1 and 0 simultaneously.

C. Drug Design & Development

Drugs are typically developed through the trial-and-error process, which is not only costly but also dangerous and difficult to finish. Researchers think quantum computing might help drug companies understand medications and how they affect people, which would save them a tonne of money and effort. Quantum computing could enable businesses to conduct more drug discoveries and discover novel medical treatments for the benefit of the pharmaceutical sector.

D. Cybersecurity & Cryptography

Cybersecurity has remained a crucial worry for people all over the world. We are particularly vulnerable to these risks because of our growing reliance on technology. Machine learning and quantum computing can aid in the development of numerous strategies to counter these cybersecurity risks. Quantum cryptography, another name for encryption, can also be developed with the aid of quantum computing.

E. Financial Modelling

Quantum computing could speed up the development of business solutions and increase the quality of their results. Monte Carlo simulations are a method for achieving profitable investments, and they require a lot of computer time to run continuously on standard computers.

Another potential application is algorithmic trading, which employs sophisticated algorithms to automatically initiate share deals while analyzing market conditions. This is advantageous, especially for high-volume transactions.

F. Logistics Optimization

Quantum annealing and universal quantum computers are two popular quantum methods that can be utilized to overcome such issues. A wide range of companies will be able to optimize their supply-chain management logistics and scheduling workflows with improved data analysis and reliable modelling.

Applications may be severely impacted by the need to repeatedly calculate and recalculate the best routes for traffic management, fleet operations or air traffic control.

G. Weather Forecasting
Quantum computers could revolutionize the way we understand weather patterns, enabling scientists to predict changing weather patterns quickly and accurately. Currently, it can often take longer for traditional computers to analyses weather conditions than it does for the weather to change. Meteorologists will be able to create more intricate climate models with quantum computers, which will give them a better understanding of climate change.

VII. DIFFERENT TYPES OF QUANTUM COMPUTING

A. Analog Quantum Computer
A quantum computer is a computer that works by adapting analog values to the Hamiltonian representation [3]. This includes adiabatic quantum computing, quantum simulation, and quantum annealing. Despite having computing power comparable to gate-based computers, it does not yet have the ability to completely fix errors. Quantum gates are not used.

B. Quantum Glow
Quantum glow is used to solve digital modeling, sampling questions, and other scientific disciplines. Creating an optimal wing design takes only a few hours to model all the atoms of air flowing over the wing of an airplane at different tilt angles and velocities [6]. The shape of energy can be described using sampling problems from energy-based distributions, useful for machine learning questions.

C. Quantum Simulation
Quantum computers can simulate complex quantum phenomena, such as quantum chemistry. It can be used to create treatments and medications that are more effective. Misfolded proteins are the root cause of diseases such as Alzheimer's. Quantum computers could speed up medication discovery and testing in the future by analyzing all potential protein drug combos.

D. Adiabatic Quantum Computing
Quantum computing has the potential to completely alter artificial intelligence and machine learning. A quantum computer that is truly adiabatic will employ over a million qubits. We can currently access fewer than 128 qubits at most. Other than Shor's and Grover's algorithm, at least fifty different algorithms have been developed to operate on this quantum computer.

VIII. TOP COMPANIES UTILIZING QUANTUM COMPUTING

A. IBM
IBM researchers have discovered that entangling qubits on a quantum computer reduces the mistake rate from the data-classification experiment's untangled qubits' rate by half. Breakthroughs in deep learning will probably improve our grasp of quantum mechanics, and fully realized quantum computers may be able to recognize data patterns significantly better than conventional ones.

B. JPMorgan Chase
NatWest and Willis Towers Watson are two of the five partners that make up Microsoft's so-called Quantum Network. There are several academic universities and technical companies with a focus on quantum technology on the list, but very few business partners. JPMorgan Chase stands out in IBM's Q Network among a sea of tech-focused members.

C. Microsoft
Microsoft's quantum computing platform gives companies access to resources without the high expenses and infrastructure costs typically associated with it. Like QCI's Catalyst platform, Microsoft's Azure Quantum offers a collection of resources from more than just Microsoft itself. This range of options has attracted the attention of clients like Ford, Pacific Northwest National Laboratory, and more.

D. D-Wave Systems
D-Wave Systems was one of the first to deliver real-time cloud access to quantum computing resources, and remains a leader in the field. Leap 2 is a hybrid of quantum and classical processors that can calculate problems with as many as 10,000 variables. More people taking advantage of this accessible platform could lead to new applications and use cases for the technology.

IX. QUANTUM COMPUTING STATUS IN INDIA

India's Ministry of Electronics and Information Technology (MeitY) has released the nation's first-ever Quantum Computer Simulator (QSim) Toolkit. This local toolset will make it possible for researchers and students to conduct quantum computing research efficiently and affordably.

Highlights of QSim's features include:

1) Qassim is a quantum computing tool that enables researchers and students to design quantum programmers and visualize instant circuit construction and simulated output. Qassim provides a reliable QC Simulator integrated with a graphical user interface (GUI-based Workbench) to enable students and researchers to design, build and test quantum computers.
2) Simulate noisy quantum logic circuits: This can be used to examine how well different algorithms perform in the presence of noisy quantum components. This is necessary to replicate real-world circumstances.
3) Pre-loaded quantum algorithms and examples: QSim is pre-loaded with quantum algorithms and programmers, giving users a head start. Deutsch Jessa, Grovers, QFT, and more examples.
4) The quantum simulations are carried out on potent HPC resources, enabling several users to submit work concurrently with various qubit setups.

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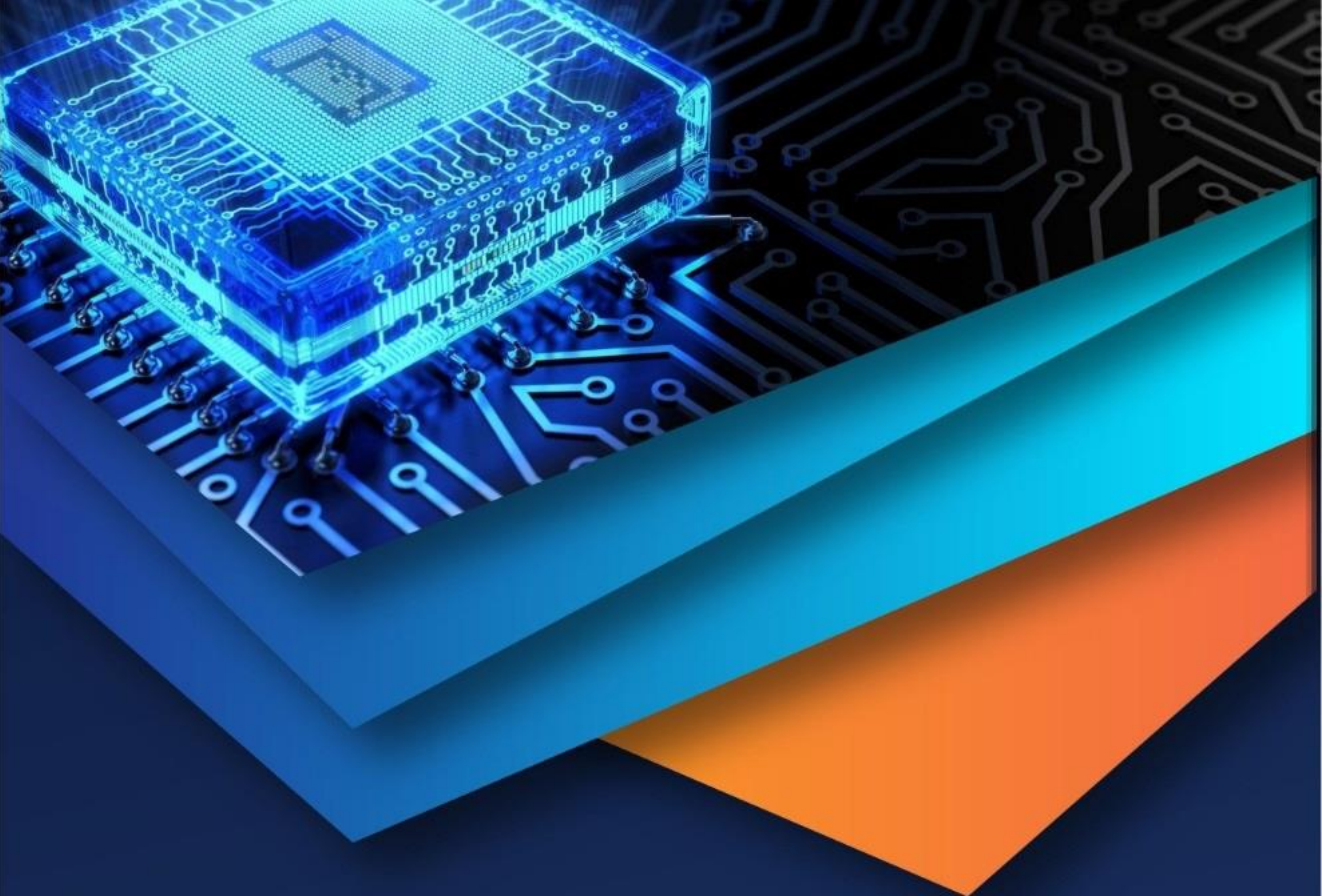

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