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Short Review on Quantum Computing and It Future Trends

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ABSTRACT
Quantum computing is fundamentally new way of communication that can solve some interactive problem efficiently. one the technology is still evolving it is forward and developing fast exponentially fast and it is expected to solve real problem at scale in few years. Application range from drug discovery to supply chain, logistics, and risk analysis to financial sector.It is likely to most destructive technology of this decade. Applications range from drug discovery to supply chain logistics to risk it is likely to be the most disruptive technology of this decade. Quantum computing has shown has shown to efficiently to solve problems that classical computers are unable to solve .Quantum computers represents information phase states in high dimensional spaces which produces fundamental quantum properties of superposition and entanglement.Quantum computers add machines that use the properties of quantum physics to store data and perform computations this can be extremely advantages for certain tasks where they could vastly outperform even our best supercomputers.

KEYWORDS: *QUBITS, SUPERPOSITION, GATES, QUANTUM COMPUTERS*

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I. INDRODUCTION

One of the most fascinating aspects of recent work in fundamental quantum theory is the emergence of new notion, the concept of quantum information, which is quite distinct from its classical counterpart. It provides a new perspective for all foundational and interpretational issues and highlights new essential difference between classical and quantum theory[1]. In this paper we will introduce the basic concept and develop a selection of its basic properties.

The theory of quantum communication was first proposed by Albert Einstein, who noticed the existence of microscopic phenomenon and defined it as “spooky action at a distance” [2].In 1976 Roman Stanisław Ingarden of the Nicolaus Copernicus University in Toruń, Poland, publishes one of the first attempts at creating a quantum information theory. In 1981 a keynote speech titled Simulating Physics with Computers, Richard Feynman of the California Institute of Technology argues that a quantum computer had the potential to simulate physical phenomena that a classical computer could not simulate. In 1992 , Deutsch–Jozsa algorithm is one of the first examples of a quantum algorithm that is exponentially faster than any possible deterministic classical algorithm. In 1996 , Lov Grover of Bell Laboratories invents the quantum database search algorithm.2002 The first version of the Quantum Computation Roadmap, a living document involving key quantum computing researchers, is published.2011, The first commercially available quantum computer is offered by D-Wave Systems. In 2012 1QB Information Technologies (1QBit), the first dedicated quantum computing software company, is founded. In 2017 Chinese researchers report the first quantum teleportation of independent single-photon qubits from a ground observatory to a low Earth orbit satellite with a distance of up to 1400 km. In 2019 Google claims to have reached quantum supremacy by performing a series of operations in 200 seconds that would take a supercomputer about 10,000 years to complete; IBM responds by suggesting it could take 2.5 days instead of 10,000 years, highlighting techniques a supercomputer may use to maximize computing speed.[3].

The race for quantum supremacy is on, to being able to demonstrate a practical quantum device that can solve a problem that no classical computer can solve in any feasible amount of time. Speed—and sustainability—has always been the measure of the jump to the next stage of computing.

To provide a thorough review, we first provide descriptions of basic components of quantum mechanics, including qubits and quantum logic gates. Then we mention the postulates of quantum mechanics and talk about the polarization and entanglement. Finally, we explain the modern applications based on quantum communication, like teleportation, cryptography and quantum networks, and discuss the advantages and disadvantages involved. In the conclusion part, we summarize the challenges the field is currently facing and talk over the future developments of quantum communication.

II. BASIC ELEMENT OF QUANTUM COMPUTING

2.1 Classical bits: A building block of classical computational devices is a two-state system or a classical bit: 0 or 1.

2.2 Quantum bits (Qubits):

The basic unit of information in quantum computing is called qbit,which is short for quantum bit. Like a normal bit, a qubit can be either 0 or 1, but unlike a normal bit, which can only be 0 or 1, a qubit can also be in a state where it is both at the same time. When extended to systems of many qubits, this ability to be in all possible binary states at the same time gives rise to the potential computational power of quantum computing. The fundamental building block of a quantum computer is Qubit as shown in the diagram (Figure.1 & 2).

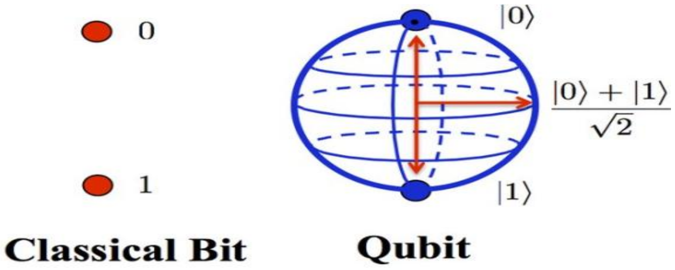

Figure 1. Classical versus quantum bit[10]

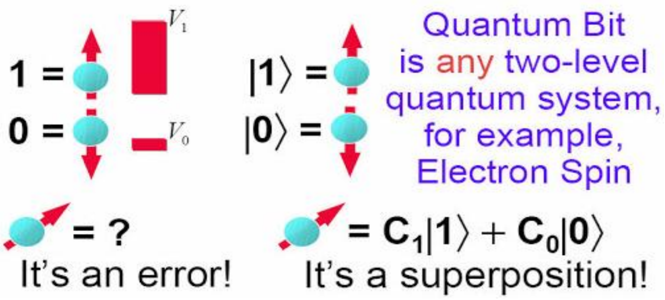

Figure 2. Classical bits and Quantum bits or Qubits[10]

2.3. Superposition

A Qubit can exist in the state |0> or the state or |1>, but it can also exist in superposition state. This is a linear combination of the state |0>and |1>.If we label this state state |Ψ.>, then a superposition state is

|Ψ.> = α |0> + β|1>.

Whereα, β are complex numbers.

2.4 Entanglement

If two qubits are entangled there is a corelation between these two qubits. If one qubit is in one particular state, the other one has to be in another particular state. If two electrons become entangled, theirspin states are corelated such that if one of the electrons a has a spin up then the other one has a spin down after measurement [4].

2.5 Bloch sphere

Bloch sphere is used to represent a single qubit in a three-dimensional space.

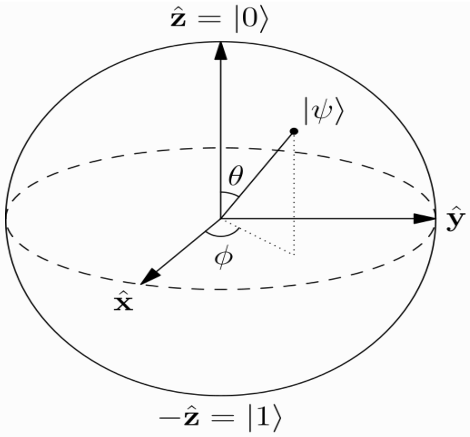

Fig. 2[10] represents a Bloch Sphere, here |ψ> represents the qubit while φ and θ is used to represent the polarization and superposition of the Qubit [9].

The quantum environment is constantly under pressure to collapse and this leads to decoherence of the system. Thus, we can conclude that until there is a higher coherence the system will collapse and resulting in an improper depiction of the qubits in the Bloch sphere [8].

cos(θ/2)|0> + eiφsin(θ/2) = |ψ> ------------------------------------- (6)

Equation (6) expresses the state of a single qubit in polar form [7].

(x, y, z) = (sinθcosφ, sinθsinφ, cosθ) -------------------- (7)

Equation (7) expresses the translation of a qubit from Cartesian to polar form [7].

III. Quantum gates

To build a universal quantum computer, a set of universal quantum logic gate is required which is similar to classical computer. All quantum gates can represent by unitary matrices. The most common quantum gates operate on spaces of one or two qubits. This means that as matrices, quantum gates can be described by 2 x 2 or 4 x 4 matrices with orthonormal rows.

3.1 Hadamard gate. This gate operates on a single qubit. It is represented by the Hadamard matrix.

$$H=\frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}$$

Fig.3

Since the rows of the matrix are orthogonal, *H* is indeed a unitary matrix [3]

3.2 Pauli X gate

This gate has only one qubit as its input, and it is equivalent to a classical NOT gate. It rotates a qubit by π radians along the X axis. It maps |0> to |1> and |1> to |0> [5]. The fig. 3 represents the matrix that is used for computing the output matrix.

$$\mathbf{X}=\begin{bmatrix}0 & 1\\ 1 & 0\end{bmatrix}$$

Fig. 4.

3.3 Pauli Y gate

It is similar to Pauli-X gate. It rotates the qubit in the Bloch sphere by π radian along the Y axis. Here the gate maps a |0> to i|1> and |1> to –i|0> [5]. The output is computed using the matrix from fig. 4.

$$Y=\begin{bmatrix}0 & -i\\ i & 0\end{bmatrix}$$

Fig. 5.

3.4 Pauli-Z gate

Operation of this gate is similar to Pauli-X and Pauli-Y gates. But the gate rotates the qubit by π radian about the Z axis. Here it leaves |0> state unchanged but it maps |1>to -|1> state [5]. Computation with the matrix in fig. 5 we get the corresponding output.

$$Z=\begin{bmatrix}1 & 0\\ 0 & -1\end{bmatrix}$$

Fig. 6.

3.5 Phase Shift gate

This gate shifts the phase of a qubit but the probability of finding the qubit gate as a |0> or |1> remains the same. It leaves a |0> basis state unchanged and |1> to eiθ|1> [9]. The phase shift is computed from the matrix in fig. 6.

$$R_{\theta}=\begin{bmatrix}1 & 0\\ 0 & e^{i\theta}\end{bmatrix}$$

Fig. 7.

Here θ is the phase shift. Pauli Z gate is a special of phase shift gate when θ=π [5].

3.6 Swap gate

This gate swaps the values of two qubits [12]. The matrix that allows the swap is represented in fig. 7.

$$\mathrm{SWAP} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

Fig. 8

. 3.7 Controlled gate

In computer science, the controlled NOT gate (C-NOT OR CNOT) is a quantum logic gate that is essential component in the construction of quantum computer. It is universal quantum gate. It is similar to the NAND classical gate. Graphically it is represented by the fig.9

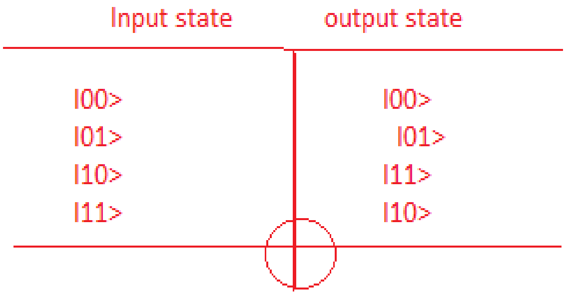

Fig.9

IV. Future of Quantum Computing

4.1. Artificial Intelligence & Machine Learning

Artificial intelligence and machine learning are some of the prominent areas right now, as the emerging technologies have penetrated almost every aspect of humans' lives. Some of the widespread applications we see every day are in voice, image and handwriting recognition. However, as the number of applications increased, it becomes a challenging task for traditional computers, to match up the accuracy and speed. And, that's where quantum computing can help in processing through complex problems in very less time, which would have taken traditional computers thousands of years.[10]

4.2 Computational Chemistry

It is believed that the number of quantum states, even in a tiniest of a molecule, is extremely vast, and therefore difficult for conventional computing memory to process that. The ability for quantum computers to focus on the existence of both 1 and 0 simultaneously could provide immense power to the machine to successfully map the molecules which, in turn, potentially opens opportunities for pharmaceutical research. Some of the critical problems that could be solved via quantum computing are improving the nitrogen-fixation process for creating ammonia-based fertilizer; creating a room-temperature superconductor; removing carbon dioxide for a better climate.

4.3 Drug Design & Development

Designing and developing a drug is the most challenging problem in quantum computing. Usually, drugs are being developed via the trial and error method, which is not only very expensive but also a risky and challenging task to complete. Researchers believe quantum computing can be an effective way of understanding the drugs and its reactions on humans which, in turn, can save a ton of money and time for drug companies. These advancements in computing could enhance efficiency dramatically, by allowing companies to carry out more drug discoveries to uncover new medical treatments for the better pharmaceutical industry. [10]

4.4 Cyber security & Cryptography

The online security space currently has been quite vulnerable due to the increasing number of cyber-attacks occurring across the globe, on a daily basis. Although companies are establishing necessary security framework in their organisations, the process becomes daunting and impractical for classical digital computers. And, therefore, cybersecurity has continued to be an essential concern around the world. With our increasing dependency on digitisation, we are becoming even more vulnerable to these threats. Quantum computing with the help of machine learning can help in developing various techniques to combat these cybersecurity threats. Additionally, quantum computing can help in creating encryption methods, also known as, quantum cryptography.[10]

4.5 Financial Modelling

For a finance industry to find the right mix for fruitful investments based on expected returns, the risk associated, and other factors are important to survive in the market. To achieve that, the technique of ‘Monte Carlo’ simulations is continually being run on conventional computers, which, in turn, consume an enormous amount of computer time. However, by applying quantum technology to perform these massive and complex calculations, companies can not only improve the quality of the solutions but also reduce the time to develop them. Because financial leaders are in a business of handling billions of dollars, even a tiny improvement in the expected return can be worth a lot for them. [3]

4.6 Logistics Optimisation

Improved data analysis and robust modelling will indeed enable a wide range of industries to optimise their logistics and scheduling workflows associated with their supply-chain management. The operating models need to continuously calculate and recalculate optimal routes of traffic management, fleet operations, air traffic control, freight and distribution, and that could have a severe impact on applications. Usually, to do these tasks, conventional computing is used; however, some of them could turn into more complex for an ideal computing solution, whereas a quantum approach may be able to do it.[10]

4.7 Weather Forecasting

Currently, the process of analysing weather conditions by traditional computers can sometimes take longer than the weather itself does to change. But a quantum computer’s ability to crunch vast amounts of data, in a short period, could indeed lead to enhancing weather system modelling allowing scientists to predict the changing weather patterns in no time and with excellent accuracy. Weather forecasting includes several variables to consider, such as air pressure, temperature and air density, which makes it difficult for it to be predicted accurately. Application of quantum machine learning can help in improving pattern recognition, which, in turn, will make it easier for scientists to predict extreme weather events and potentially save thousands of lives a year. With quantum computers, meteorologists will also be able to generate and analyse more detailed climate models, which will provide greater insight into climate change and ways to mitigate it.[10]

V. Conclusion:

In this review we describe basic quantum computing structure. This is brief review with short explanation of physics for different aspects of quantum computing. With proper research in above area, it wouldn’t be so long wait to get feasible computers on hand. By using that fast computation can be done faster.

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