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Quantum Computation and Quantum Bits

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Abstract - *Quantum computation is the future of technological innovations in fields such as computation cryptography and communication. As compared to classical computers quantum computers are very much powerful and faster. Quantum computing relies on quantum bit that is (qubit) to read, initialize, manipulate, and store information. The aim of this survey paper is to provide detailed examination about the structure of qubit, quantum superposition and entanglement, and importance of superposition and entanglement in quantum information.*

Key Words: **Quantum Computation; Quantum bit; Superposition; Entanglement.**

1.INTRODUCTION

It has been estimated that every two years for the past 50 years computers have become twice as fast while their components have become twice as small [1].Since the sizes of electronic devices get close to atomic scale, the quantum effects interfere in their functioning, and hence the standard approaches run up against the size limit. One possible method to overcome these difficulties is to move to a computing prototype provided by quantum information science

1.1 Quantum information science

Quantum information science studies the composition and control of the quantum states of physical systems for the purposes of transmission of information and manipulation. It includes quantum computation, quantum cryptography and quantum communication. This absolute field will allow a range of fantastic new devices to be possible.

Now it is believed that because of quantum information science, the creation of quantum computers is possible and these quantum computers can solve problems that could not be solved very efficiently on a classical computer. Continuous research efforts are going around the world to investigate the technologies that can lead to more general and more powerful quantum computers. As the theory of quantum mechanics is stochastic, uncertainty and randomness are well established in quantum computation and quantum information.

Hence the quantum algorithms are random in nature meaning the yield correct solutions only with some probabilities. Therefore, statistics has important role to play in quantum simulation, quantum computation and quantum information. Likewise, quantum computation and quantum information can tremendously revolutionize computational statistics.

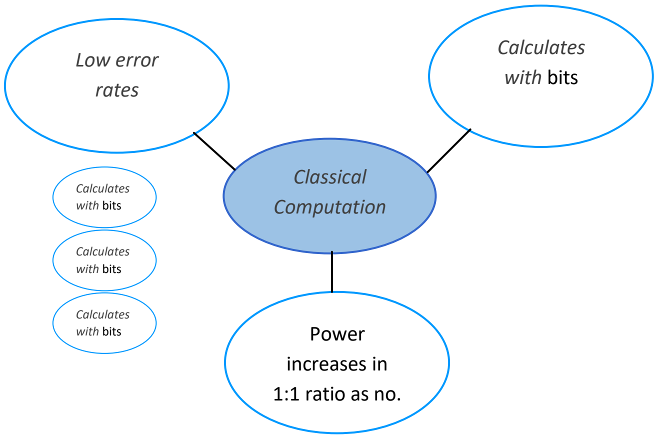

Figure -1: Facts about classical computation

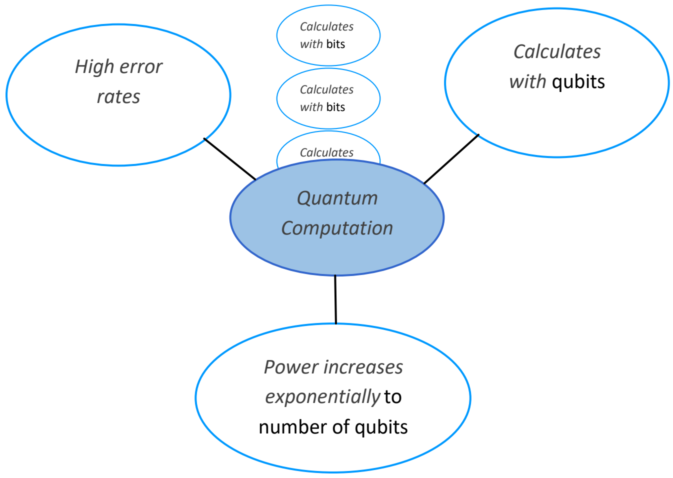

Figure -2: Facts about quantum computation

2. OVERVIEW OF QUANTUM COMPUTATION

Quantum mechanics represents phenomena such as momentum and position of an individual particle such as electron or atom, electron spin, light photon detection and absorption and emission of light by atoms at an infinitesimal level. In the paper Yazhen Wang et al.(2012) explained concepts like quantum bits, quantum gates, quantum circuits in quantum computation and discussed quantum entanglement, and presented major quantum algorithms and their advantages over other classical algorithms[2].

In the paper Arvind et al.(2018) proposed that for more than one qubit "classical qubit" system can work which do not involve entanglement. We can also say that an algorithm can only be a true quantum algorithm only if it involves entanglement.[3]

In Igor Ya. Doskoch et al(2019) incorporated that for quantum systems considered in the probability representation of quantum mechanics, the superposition principle is expressed like a specific non-linear addition rule of the probabilities determining pure quantum states.[4]

Quantum Computers are capable of revolutionizing computation by solving the problems which classical computers cannot solve.

3. QUANTUM BITS

Corresponding to the fundamental concept of bits in classical computation, its equivalent is quantum bit in quantum computation. Quantum bit is also known as qubit. Classical bits can be in a state of either 0 or 1, likewise quantum bit can be in a state of $|0\rangle$ and $|1\rangle$. However, the main difference between bit and qubit is that qubits can be in a state $|0\rangle$ and $|1\rangle$ but also qubit may take the superposition states, the equation of a qubit in superposition is described as a linear combination of,

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle$$

where α and β are probability amplitudes of the superposition state and $|0\rangle$ and $|1\rangle$ are the possible states. After calculation we can see that superposition will result in 50-50 chance of being in states $|0\rangle$ and $|1\rangle$.

$$= {}^{1}/\sqrt{}_{2}(\,|0\rangle + |1\rangle\,)$$

$$= {}^{1}/\sqrt{}_{2}|0\rangle + {}^{1}/\sqrt{}_{2}|1\rangle$$

$$= |\alpha|^2 \text{ or } |\beta|^2 \quad \text{-By Pythagorean theorem}$$

$$= ({}^{1}/\sqrt{}_{2})^2$$

$$= ½$$

Therefore, we can see that the qubit is in superposition state having ½ chance of being in $|0\rangle$ state and ½ chance of being in $|1\rangle$ state.

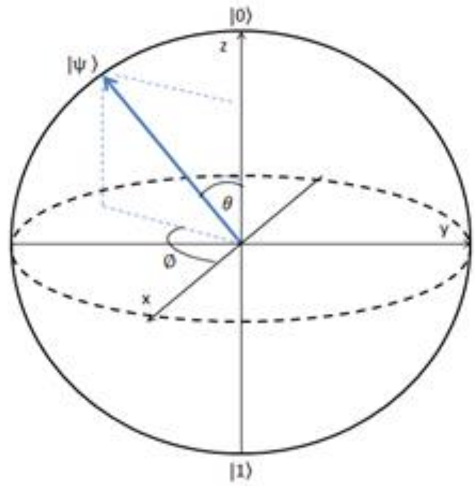

Figure -3: Bloch sphere representation of a qubit

3.1 Quantum Bit VS Classical Bit

A classical bit can either be in a state of 0 or 1 but a quantum bit (qubit) is in a state of superposition of 0 and 1. Therefore a single qubit takes two classical values at once. Hence, all the operations on qubits is done on both values at once. That is why qubits stores more information than a classical bit.

Two bits can take the following value:

- 0,0
- 0,1
- 1,0
- 1,1

Qubits can take all these values at once. Looking at this we can understand that one qubit can take value of two bits. Similarly, two qubits can take the values of four bits. Therefore, in general n qubits can take the values of 2^n

4. SUPERPOSITION AND ENTANGLEMENT

Superposition is basic of quantum mechanics. The basic principle is two or more states can be added together and result will be another valid quantum state. Probability for is given by square of absolute value of the coefficient

Entanglement is a concept in quantum computing in which a group of particles interact with each other in such a way that each particle described independently of the state of others

In entanglement measurements of position, momentum, spin and polarization which include in physical properties performed on entangled particles

4.1 How does superposition help

In quantum computing, a quantum algorithm runs on practical model of quantum computation. The most common used model is quantum circuit model of computation. A classical algorithm is a limited sequence of instructions, for solving a problem where each step of algorithm is produced on classical computer. Similarly, a quantum algorithm is also a step by step procedure for solving a problem on quantum computer. The term quantum algorithm is used for algorithms which seem to be natively quantum, or use features of quantum computation such as superposition or entanglement.

Problems that are incalculable on classical on classical computer remain incalculable on quantum computer, but quantum algorithms might be able to solve problems faster than classical algorithms because on quantum entanglement and superposition that quantum algorithms make use of and classical algorithms do not.

The difference between classical computers and quantum computers is about how they approach a problem. Two bits in a classical computer can be in four possible states (10, 01, 11, 00), but only in one of them at a time. Therefore classical can process one input at a time. In quantum computer two bits can represent exact two states but the difference is because of superposition the qubits can represent all the four states at same time.

If we add more bits to classical computer it will still process one at time. But if you add qubits to quantum computer, the power of the quantum will grow exponentially.

5. CONCLUSION

By all counts it is known that quantum information science gains huge attention in various fields and they are said to be developed under the studies of quantum information. In this paper, we introduce concepts such as quantum information, qubits, quantum superposition and entanglement We understood the major difference between classical bit and a quantum bit. We showed why quantum computation algorithms hold major advantage over classical computation algorithms.

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