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Quantum Computers: A Review Work

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Abstract

Quantum computing presently at baby stage, even inferior to that. Although it is an enormously appealing but still an elusive goal. It is expected that by the year

2030, a first version of universal quantum computer may be physically developed by the computer scientists. In this paper the author makes a review work on the theoretical concept of quantum computers.

Keywords: qubit, qubyte, qu-register, machine state.

MSC Code (2000) : 81P10, 81P40, 81P68

1. INTRODUCTION

Quantum computing is going to be the latest tool to the world scientists and engineers. The genuine future dependence upon the quantum computing and its potential benefits over conventional computer were studied by several authors, in particular in dealing with the expanding big data [1] in 5Vs, in dealing with the cosmological universe, etc.

As on today there is no existence of any physical machine called by quantum computer, in particular any universal quantum computer. However, in near future it is expected that the scientists will develop quantum computer using quantum mechanics, which is a branch of physics dealing with tiny or very small elements.

The quantum mechanics is based upon the level of individual atoms, individual electrons, elementary particles. By proposing the laws of quantum mechanics to computation, the expectation of the scientists about very near future is that the proposed quantum computer can exponentially speed-up the processing capabilities of the processors over that of the classical computing capabilities of the existing processors. Even the existing supercomputers are becoming inefficient in processing the big data in many cases because of the key reason that supercomputers can solve one or few Vs out of 5Vs of big data [1,12]. Consequently the quantum computing is becoming very popular as a modern set of tool to the computer scientists, researchers, engineers, programmers to develop and enhance computation capabilities much better than the classical computing capabilities.

In this paper the authors discuss a review analysis of the latest concept about the of quantum computers.

2. QUANTUM COMPUTER: STILL AT IMAGINARY LEVEL

Universal quantum computer has not been physically developed by the world scientists and engineers so far (the NASA‟s proposed D-wave quantum computer of its lab QuAIL is not the quantum computer we are thinking about for universal purpose). It is expected that the first ever quantum computer is likely to be developed by 2030. Around the year 2030, computers might not have any transistors and chips. As on today, the quantum computing is a theoretical computing model that uses a completely different style for data handling to perform calculations. This new kind of computing is based on a different of data unit than the classical unit, as it has more than two possible values stored inside at a time. Can we call it a binary storage unit? Our comment is „NO‟. Then, the immediate question arises, what type of storage unit is used in quantum computing?

3.1 Components of a Quantum Computer

A quantum computer, as theoretically proposed by the world scientists, essentially consists of three parts:

(i) a memory, which holds the current machine state,

(ii) a processor, which performs elementary operations on the machine state, and

(iii) some sort of input/output which allows to set the initial state and extract the final state of the computation.

3.1.1 Quantum Memory

In Quantum computer we use quantum bit (qubit) for storing data. For classical computers, a bit is a building block of memory which is a two-state system (either at 0 or at 1 at any instant of time, can not hold both at any time). The classical computer works on bits of data that are binary, or Boolean, with only two possible values: 0 or 1. But a quantum bit (qubit) has possible values of 1, 0 or a superposition of 1 and 0. Quantum mechanics tells us that system can exist in a superposition of states, the state 0 and the state 1. Popular qubits are based on physical atoms and molecular structures. But the use of qubits makes the practical quantum computer model quite difficult to develop in a physical shape.

3.1.2 Superposition

The classical computers or supercomputers are designed with silicon chip having more than billions of transistors fixed on them. With more transistors incorporated, the present day computers are built faster and faster, and surely with a limitation. But in quantum computers it is proposed that the bits are not just normal transistor switching ON or OFF, but they are more complicated quantum mechanical system that can be ON or OFF or both ON and OFF at the same time; that"s what the beauty of the concept of quantum superposition.

Small particles like electrons, photons have spins. The spin can be measured by magnetic field. If we view an electron in a magnetic field, then we can observe that it has spin in different directions, and the most interesting observation will be that all the spins happen at a same time, called quantum superposition in the theory of Quantum Mechanics. An electron is thus like a spinning element where the spin can point up or can point down (see Figure 1), and it can also spin both up and down at the same time as shown in Figure 2! This is the beauty of the phenomenon of SUPERPOSTION (see Figure 3). No classical analog to superposition exists presently.

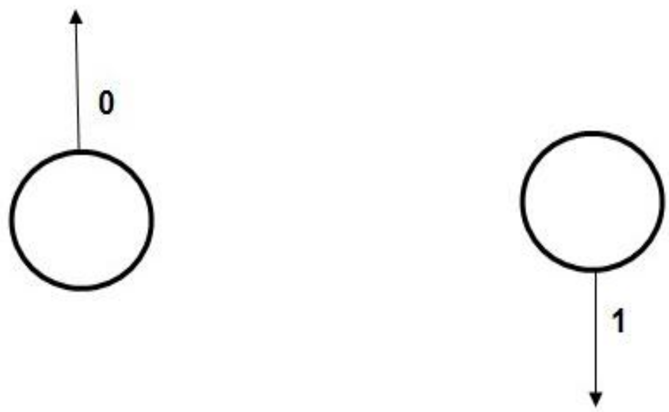

Fig.1 Electron can spin Top and Down both

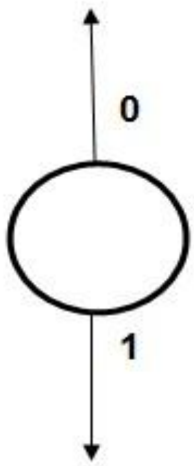

Fig.2 Electron can spin Top and Down both simultaneously

The superposition of both Top and Down spin by electron is shown in Figure 3.

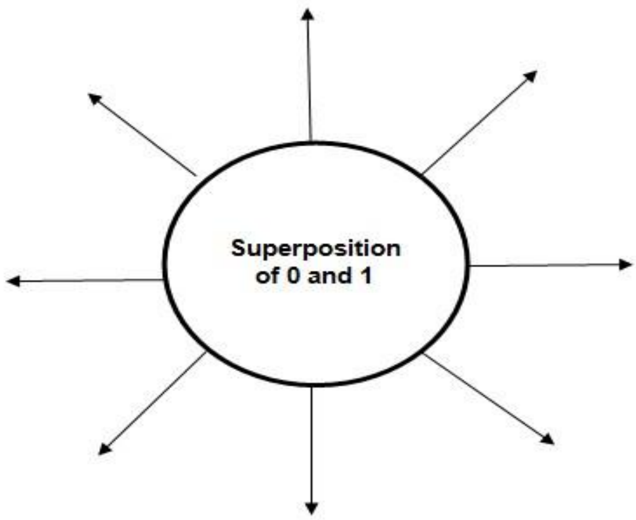

Fig.3 Superposition of Top and Down spin by electron

Two objects if they quantum-mechanically entangled then they are strongly related to each other even though they may be at vast distance apart. It ensures the concept of superposition of bits at a same time. Entanglement and scaling is the key to the power of quantum computing.

3.1.3 General state of a qubit

This means that the general state of a qubit |q> can be represented as a linear combination of |0> and |1> : q|> = a|0> + b|1>, i.e. as a superposition of |0> and |1>.

If a and b are real numbers given by a = 0 and b = 1, then a qubit reduces to a traditional bit. If a = 1 and b = 0, then also a qubit reduces to a traditional bit. But in general it is not so, and thus a bit is a qubit but not conversely.

Here a and b are probability amplitudes and are complex numbers. When we measure this qubit, the probability of outcome |0> is $|a|^2$ and the probability of outcome |1> is $|b|^2$. Because the absolute squares of the amplitudes equate to probabilities, it follows that a and b must be constrained by the equation $|a|^2+|b|^2=1$. The qubit |q can be represented as a point on a unit sphere called the Bloch sphere.

3.1.4 Machine State

If we combine 2 qubits, the general state of the resulting system is

|q> = a|00> + b|10> + c|01> + d|11>

where a, b, c and d are complex numbers such that $|a|^2 + |b|^2 + |c|^2 + |d|^2 = 1$. With this concept, we can now define the machine state of a quantum computer. The machine state q of a 2-qubit quantum computer is the current state of a combined system of 2 identical qubit subsystems. The machine state q of a 2- qubit quantum computer is thus given by

|q> = a|00> + b|10> + c|01> + d|11>

where a, b, c and d are complex numbers such that $|a|^2 + |b|^2 + |c|^2 + |d|^2 = 1$.

Generally, the machine state ψ of an n-qubit quantum computer is the current state of a combined system of n identical qubit subsystems. And the machine state ψ of an n-qubit quantum computer is thus given by

$$|\Psi\rangle = \sum_{(d_0 \dots d_{n-1}) \in \mathbf{B}^n} c_{d_0 \dots d_{n-1}} |d_0 \dots d_{n-1}\rangle \quad \text{with} \quad \sum |c_{d_0 \dots d_{n-1}}|^2 = 1$$

The above notion of n-qubit subsystems can easily be extended to arbitrary sequences of qubits to define an n-qubit quantum Register (qu-registrar) Q as a sequence of mutually different zero-based qubit positions. Quantum Mechanically, a register of n number of entangled qubits can store all of the 2^n numbers in superposition:

A classical 8-bit register R can store one and only one number from 0 to 255 at a time, i.e. not even two of them at a time.

See Figure 4 where the registrar R contains the 8-bit data 10110001.

1	0	1	1	0	0	0	1

Fig.4 A classical 8-bit registrar R containing a 8-bit data

But a 8-qubit qu-registrar Q (i.e. a qu-register of 8 entangled qubits) can contain all the 2^8 (256) number of 8-bit data simultaneously by superposition, as shown in Figure 5.

1 and	1 and	1 and	1 and	1 and	1 and	1 and	1 and

Fig.5 An 8-qubit qu-registrar Q containing 2^8 number of 8-bit data

Consider an analogous situation for the sake of understanding only. In Ludo game there is a die which have six decimal integer numbers 1, 2, 3, 4, 5, 6 stored in it simultaneously by superposition. At some state you can read only one decimal number out of the six numbers. At another state you may read another (if not same) but one and only one decimal number out of the six numbers.

Similarly, a coin has two data stored in it simultaneously by superposition (see Figure 6) which are HEAD (ON) and TAIL (OFF), say. While you toss this coin (i.e. at some state) you can read only one data, either ON or OFF. At another state you may read another data (if not same) but one and only one data out of two.

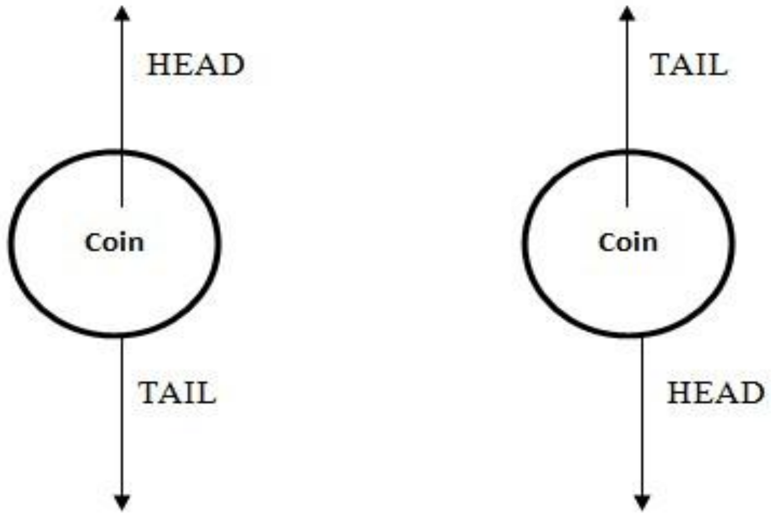

Fig.6 A coin storing two data H and T simultaneously

In general a qu-register Q of n entangled qubits can store 2^n numbers at the same time in superposition. That is the excellent and extra-ordinary power of a qu- registrar.

4. CONCLUSION

It is important that making a practical quantum computing is still far in the future. Programming style for a quantum computer will also be quite different. Development of quantum computer needs a lot of money. Even the best scientists can‟t answer a lot of questions about quantum physics. Quantum computer is based on theoretical physics and some experiments are already made. Building a practical quantum computer is just a matter of time. Quantum computers easily solve applications that can‟t be done with help of today‟s computers. This will be one of the biggest steps in science and will undoubtedly revolutionize the practical computing world.

In [4,5] Neil Gershenfeld (MIT) and Isaac Chuang (IBM Almaden Research Center) proposed a complete solution for the first quantum computer based on nuclear magnetic resonance technology. In 1998, these two scientists [4] announced about the construction of the first 2-qubit quantum computer. Besides the quantum computer proposed by Gershenfeld and Chuang, two interesting types of Quantum Computer theoretically conceptualized are: Silicon quantum Computer which uses electron spin as a quantum bit or qubit, Optical quantum computer which uses photon of light as a qubit. But the world has to eagerly wait, probably till 2030, to get the first universal quantum computer physically.

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