Changing our Modern Society in Different Levels using Quantum Computing Device

Sanhita Koley, Aneesh Kar

Department of Information Technology, Institute of Engineering & Management, Salt Lake Electronics Complex, Salt Lake City, Kolkata, West Bengal- 700091

ABSTRACT: Today's classical computers stores information in bits, which take the discrete values 0 and 1. On the other hand information stored in Quantum computers are not up to two states buten code information as quantum bits, or qubits resulting in superposition and entanglement. The Qubits can be represented by atoms, ions, photons or electrons such that they are working together to act as a computer memory/processor and has been found to contain multiple states simultaneously. This technology has often been compared to the efficiency of supercomputers and some Computing giants consider it to be powerful than today's most powerful supercomputers ever built. Its advances in machine learning, optimization and artificial intelligence could boost efficiency and accuracy of data dramatically. Therefore, Quantum computers will emerge as a superior computational device than compared to today's modern computer. Easy access to the internet has already made a head start to learn modern technology. The main motive is to involve common people to learn such new technologies in order to embrace futuristic innovations.

KEYWORDS: Qubits, ions, photons, supercomputers, computational device.

https://doi.org/10.29294/IJASE.6.S1.2019.34-38

1. INTRODUCTION

The world of numbers has taught us the concept and tracing of development of computing from the invention of the abacus to the creation of the binary system and hence brought us to technical achievements in science that leads to the invention of the first modern computers. The world struggled to break free of the tedious labor of mental calculation and, as a result mathematician, philosophers, and scholars from every corner of the world and from every period of history witnessed illuminating discoveries such as the pocket calculator, the adding machine, the cash register, and even automata and a step towards computer development. We can find out that the initial idea of a computer originated during the European Renaissance, along with how World War II influenced the development of analytical calculation. And hence with the passage of time, technology advanced and grew accordingly to satisfy man's needs (1).

The past several years has greatly clarified both the theoretical potential and the experimental challenges of quantum computation. In a quantum computer the state of each bit is permitted to be any quantum-mechanical state of a qubit or quantum bit, or two-level quantum system. To picture these states in three-dimensional space, they can be represented as a point on the surface of a sphere, called the Bloch sphere (fig 1). Computation proceeds by a succession of 'two-qubit quantum gates', coherent interactions involving specific pairs of qubits, by analogy to the realization of ordinary digital computation as a succession of Boolean logic gates. The time evolution of an arbitrary quantum state is intrinsically more powerful than the evolution of a digital logic state and the quantum computation can be viewed as a coherent superposition of digital computations proceeding in parallel (2).

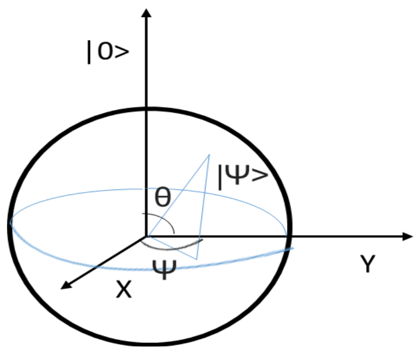

Fig 1: Bloch Sphere: A representation of the two-level quantum mechanical system also known as qubit

2. QUANTUM COMPUTING IN A NUTSHELL

Quantum computing is the use of quantum mechanical phenomena like Superposition and Entanglement to perform computation. It has been harnessing quantum mechanical phenomena to enhance the procedure of storing and processing information. This makes it more efficient in solving algorithms than classical computing. Although physicists and mathematicians were able to find out how a quantum computer could work three decades ago, the modern scientists and engineers had difficulty in building one. The technology still needs to mature in order for it to become fully enterprise-ready and deliver meaningful, cost- effective results.

In order to understand quantum computing we must first compare it to the levels of classical computing. It is not a new model of computation (i.e., it

**Corresponding Author: sanhitakoley2011@gmail.com*
Received: 21.05.2019 **Accepted:** 28.06.2019 **Published on**: 20.07.2019

is equivalent to Turing machines or the lambda calculus), the hardware for the two methods operates in very different ways. In a classical computer, the basic unit of information is a bit, which can have only one of two values—0 or 1. Were as in a quantum computer, the basic unit of information is known as a quantum bit or "qubit." Through quantum mechanical phenomena, these qubits can perform many computations simultaneously, which theoretically allows the quantum computer to solve a difficult subset of problems much faster than a classical computer (3, 4).

We know that modern classical computers can store and manipulate a unit of information called the bit, which takes either 0 or 1 as its value. Hence classical paradigm seems to be limited in solving a problem. And here enters the promise of Quantum Computers. As discussed earlier the Quantum Computer uses a different fundamental unit of information, called the Qubit. A Qubit has two base states 0 and 1. The difference between a qubit and a classical bit, is that it is possible for a qubit to be in a linear combination of states,

Denoted by:

The numbers α and β are complex numbers.

$$|\phi\rangle = \frac{|00\rangle + |11\rangle}{\sqrt{(2)}}$$

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

The property of being able to exist in multiple states is called superposition. Quantum mechanics does not allow us to view what the amplitudes, α and β, of the two base vectors are. Instead, when we measure a qubit, we get the state 0 with probability, $(\alpha)^2$ and the state 1 with probability $(\beta)^2$. Both of these probabilities must add up to 1. If a quantum operation is performed on a qubit in multiple states, then the operation is performed on all states simultaneously. When the qubit is observed, it will be a single state according to the squares of the probabilities (5).

According to the famous physicist R. Feynmann, a qubit α [0] + β [1] occupies all the states between 0 and 1 simultaneously, but collapses into 0 or 1 when observed physically. A qubit can therefore encode an infinite amount of information, but most of this information is useless as it can never be observed.

Qubit Superposition: It is one of the properties that allow the Quantum Computing paradigm to supersede classical computing. A two qubit system has four computational basis states, which are [00], [01] , [10] and [11] . The two qubit system can be in any superposition of these states (fig 2). There are four very interesting states that such a system can be prepared in. These states are referred to as the Bell States or EPR states. An example of one of these states is shown in figure 2.

Qubit Entanglement: Particles that have interacted at some point retain a type of connection and can be entangled with each other in pairs, in a process known as correlation. Now, due to the phenomenon of superposition, the measured particle has no single spin direction before being measured, but is simultaneously in both a spin-up and spin-down state. The spin state of the particle being measured is decided at the time of measurement and communicated to the correlated particle, which simultaneously assumes the opposite spin direction to that of the measured particle. When one measures the first qubit in this state, there are two possible results: 0 with probability 1/2 leaving the other qubit in the state [0 0] and 1 with probability 1/2, leaving the other qubit in the state [6]. This means that when the second qubit is measured it will always be in the same state as the first qubit. This correlation between the qubits is known as entanglement.

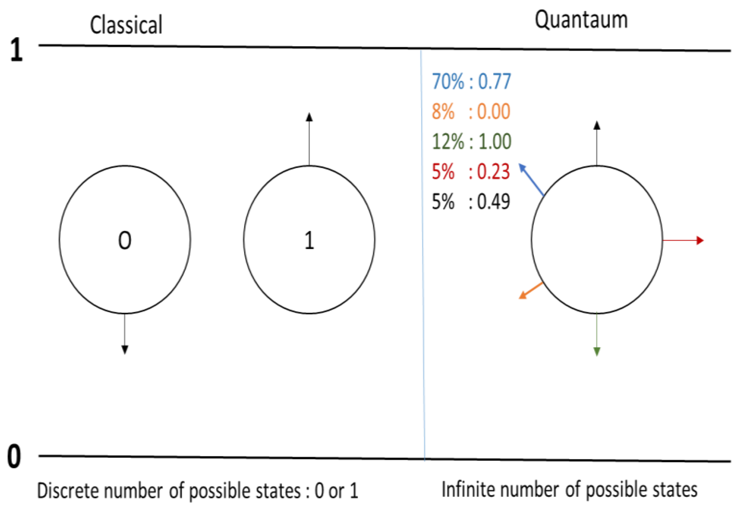

Fig: 2 Qubit superposition: a combination of two or more quantum states to result in a valid quantum state.

Sanhita Koley & Aneesh Kar

3. APPLICATIONS OF QUANTUM COMPUTING IN VARIOUS FIELDS

a. Machine Learning and Artificial Intelligence

Machine learning is now trending in the field of Information Technology. We are now witnessing aspects of every day in voice, image and handwriting recognition which are catered by the advanced technology of Machine learning and Artificial Intelligence. Indulging quantum computing is used to solve complex AI problems and obtain multiple solutions to complex problems simultaneously results in machine learning more efficiently performing complex tasks in human-like ways. Similarly, robots that can make optimized decisions in real time in practical situations will be possible once we are able to employ quantum computers based on Artificial Intelligence (6).

b. Optimization in Finance

With quantum computers we could expect a machine able to handle innumerable permutations and combinations, which could improve system design and analysis in massive ways. Finding the optimum mix for a colossal number of investments based upon projected returns, risk assessments, and other factors becomes a frustrating daily task within the finance industry as they are constantly being run on classical computers and hence consume an enormous amount of computer time. By utilizing quantum technology to perform these calculations, one could achieve improvements in both the quality of the solutions as well as the time to develop them. Because money managers handle billions of dollars, even a 1% improvement in the return is worth a lot of money.

c. Computational Chemistry

There are many problems in materials science that can achieve a huge payoff if we just find the right catalyst or process to develop a new material, or an existing material more efficiently. There is already a significant effort in using classical computers to simulate chemical interactions, but in many cases problems are faced when solved classically. So to an extent quantum computing can help out to solve the problems in material sciences including replacement of the Haber process to produce ammonia for use in fertilizers and developing a battery to improve performance of lithium-ion batteries.

d. Drug discoveries

Many of the drugs being developed still do so through the trial and error method. This is very expensive and consumes a lot of time. Hence a more effective way of simulating a drug's reaction would save a ton of money and time. Quantum computing has the potential to change the very definition of molecular comparison by enabling pharmaceutical and material science companies to develop proper procedure to analyze larger-scale molecules. With the advancement of quantum computer technology, it will be possible to compare molecules that are much larger, which will catalyze pharmaceutical advancements and cures for a range of diseases.

e. Cyber Security

Cyber security is becoming a larger issue every day as threats often familiarized as cyber bullying is faced around the world, thus increasing the need for it. We have become more vulnerable towards cyber bullying as there is an increase in our dependence upon technology and its gadgets. Various techniques to defend cyber security threats can be developed using some of the quantum machine learning to recognize the threats earlier and tackle the damage that they may do.

4. PRESENT SCENARIO OF QUANTUM COMPUTING

Quantum computing has been considered as one of those technologies that are 20 years away, and always will be. But 2019 could be the year that the field sheds its research-only image. This Technology has been applied in various fields including Machine learning, Financial Portfolio Optimization, Drug design, Cyber security, Computational Chemistry.

Computing giants like Google and Microsoft recently have set challenging goals for this year. Their ambition reflects a broader transition taking place at start-ups and academic research labs alike to move from pure science towards engineering and hence indulging qubits to their projects.

Google started working on a form of quantum computing that harnesses superconductivity in 2014. It hopes to perform a computation that is beyond even the most powerful 'classical' supercomputers and reach an elusive milestone known as quantum supremacy. Its rival, Microsoft is working on the unproven concept, of topological quantum computing, and hopes to perform a first demonstration of the technology and create a scalable quantum system that can complete the algorithms for the solutions the world needs most, provided the quantum computer contains endless error correcting qubits to solve problems in algorithms.

D-Wave's approach (another Computing giant) relied on a technique called Quantum annealing where qubits are entangled with neighbours and interact to produce, an overall quantum state, that is a minimum energy state to tackle optimization problems onto such states and use quantum effects to find such minimum points

The advantage of having control over the evolution of quantum states is that a larger class of problems can be solved (7).

5. LIMITATIONS – BIGGEST BARRIER TO QUANTUM COMPUTING

The biggest hurdle to developing quantum computers is the hardware issues in quantum technology. According to Michael J Biercuk, a primary investigator in the Quantum Control Laboratory at the University of Sydney, quantum computers are as faster versions of today's computers they can be considered as computers that function in a totally new and different way. But when it comes to building quantum computers, it remains to be an abstract idea. D-Wave systems worked a lot to shape the abstract vision of the unique computer and built the first ever early prototypes or the D-Wave's Orion Quantum Computer. The prototype was a 16-qubit quantum annealing processor, demonstrated on February 13, 2007, at the Computer History Museum in Mountain View, California.

IBM also built a 50-bit quantum computer prototype but has claimed that it is not ready for common use.

And hence the work on developing and researching of the technology still goes on (8).

6. INDIA'S ROLE IN MAKE QUANTUM COMPUTING A REALITY INFUTURE

According to articles, India ranks sixth in the most advanced technology in the world and just like the United States of America, India has its own Silicon Valley in Bangalore. Our country has witnessed great Information Technology icons like Vinod Khosla, Azim Premji, N.R Narayana Murthy and Sabeer Bhatia. All of them played important roles in advancing computer and software developments.

India, in an attempt to tap into the next big advances in computing technology, the Department of Science and Technology (DST) is planning to fund a project to develop quantum computers. The Physics departments at the Indian Institute of Science, Bangalore and the Harish Chandra Research Institute, Allahabad, have also forayed into the theoretical aspects of quantum computing, a DST official said that "the time has come to build one." However, Indian experts believes that the true quantum computers are still years away, and existing systems use principles of quantum computing to solve very limited problems

So far, there was no effort to build a quantum computer in India and the reason why India lagged behind in quantum computing is that there was no concerted effort to build a quantum computer as the concept of Quantum Computing is pretty much unknown to a lot of people in India. Coding in classical computers using different languages like C, C++, Java and Python is common among the tech freaks and students who are studying computer science for the bachelor degree, but they lack the unique technology of Quantum Computing. Little do they know that the problems they solve in the various computer languages can be solved in less time by using the qubit concept. Hence they are in debt to discover it. Even though India scientists are working on theoretical research in quantum computing, India lacks experimental facilities to carry out the work. Another reason is, that India lags behind other countries one of the reasons why in the last 10 years, there has been less than 100 international journal publications from India on quantum computing.

Among some of the Institutes in India, Raman Research Institute is dedicated to research in quantum computing and theoretical physics, astrophysics and as per the institute, RRI has accumulated infrastructural capability to a cutting edge research in the fields of quantum information, quantum computing and communication using quantum optics.

Other institutes such as IISc has set up a Centre for Quantum Information and Quantum Computation (CQIQC) in 2010 as a 5-year Research Project sanctioned by the Department of Science and Technology, Government of India. The project ended in 2015.

Some of the major breakthroughs are coming from The Quantum Measurement and Control Laboratory (QuMaC) at Tata Institute of Fundamental Research dedicated to investigating the quantum phenomena in superconducting circuits.

Chennai's The Institute of Mathematical Sciences has a Optics & Quantum Information Group with research interests pertaining to Quantum Algorithms, Quantum open systems & Quantum Information and quantum Simulations among others.

One of the most notable names in quantum computing is Dr Raja Mani Vijayaraghavan of Tata Institute of Fundamental Research whose research deals with Quantum computing and quantum simulation using superconducting quantum circuits and understanding collective behaviour in superconducting quantum bits among other areas.

Indian Pioneers Dr Vijayaraghavan, Dr Apoorva D. Patel, Professor at the Centre for High Energy Physics, Indian Institute of Science, Bangalore is well-known for his work on quantum algorithms, and the application of information theory concepts to understand the structure of genetic languages. His major field of work Quantum Algorithms and the Genetic Code also received wide publicity.

Quantum Information Science and Technology (QuST) took an aim to revolutionize the future computation and communication systems to provide a huge impact on India's Technology progression. Some objectives of QuST are to develop quantum computers and encourage the development of advanced mathematical quantum techniques, algorithms and theory of quantum information systems. The government invited proposals from noted academicians, scientists, technologists and other practicing researchers around quantum information technologies.

7. CONCLUSION

Quantum computers will emerge as the superior computational device and perhaps one day make today's modern computer obsolete. Easy access to the internet has already made a head start to learn and resolve such modern technologies. As found in all innovations whenever a difficult situation comes up, at the first glance it seems to be impossible to surpass, and hence it will be possible to accomplish quantum computing in total isolation of the external world and we are yet to design a suitable probe to get the desired outcomes in that world. The main motive is to involve common people to learn such new technologies in order to embrace futuristic innovations.

REFERENCES

[1]. Manin Yu., I; 1980. Vychislimoe in evychislimoe [Computable and Noncomputable] (in Russian). Sov.Radio. 13–15.

[2]. Feynman, R.P.u ;1982. Simulating physics with computers. International Journal of Theoretical Physics, 21,6, 467–488.

[3]. Nielsen Michael, A; Chuang Isaac L; 2010. Quantum Computation and Quantum Information (2nd ed.). Cambridge: Cambridge University Press.

[4]. Benioff, P; 1980.The computer as a physical system: A microscopic quantum mechanical Hamiltonian model of computers as represented by Turing machines. Journal of Statistical Physics,22,5,563–591

[5]. Deutsch, D , 1985. Quantum Theory, the Church-Turing Principle and the Universal Quantum Computer. Proceedings of the Royal Society of London A. 400 ,1818, 97–117.

[6]. Ambainis, A; Hassidim,A; Lloyd,S; 2008. Quantum algorithm for solving linear systems of equations. Physical Review Letters.,103 ,15, 150502.

[7]. Boixo, S; Isakov Sergei, V; Smelyanskiy Vadim, N ;Babbush ,R; Ding , N; Jiang, Z; Bremner Michael , J; Martinis John, M.; Neven Hartmut ; 2018. Characterizing Quantum Supremacy in Near-Term Devices. Nature Physics ,14 ,6, 595–600.

[8]. Mavroeidis ,V; Vishi , K; Mateusz, D; Jøsang A ; 2018. The Impact of Quantum Computing on Present Cryptography. International Journal of Advanced Computer Science and Applications, 9 ,3.

[9]. Bennett, C.H; Bernstein, E; Brassard, G;Vazirani U; 1997. The strengths and weaknesses of quantum computation. SIAM Journal on Computing ,26,5,1510–1523.

Selection and/or Peer-review under the responsibility of 2nd International Students' Conference on Innovations in Science and Technology (Spectrum – 2019), Kolkata