



TECHNOLOGY FEATURE Industrial News / Technology Report / Research Communication

HUMANS AT THE INITIAL STAGE OF NEXT REVOLUTION

From Space Calender Machine from 2nd Century BC to Quantum Supremacy, We may experience next revolution of Quantum Computers.

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Introduction

Computers can be divide into three stages: analogue, digital, and quantum.

Divers found a shipwreck at the northeastern coast of Antikythera, a small Greek island located between Crete and the Peloponnese peninsula in the Aegean Sea in 1900. In that shipwreck there was a machine that belonged to 2nd Century BC. It had incredibly complex internal structure. It is the world's first analogue computer that discovered by human, which is extremely complex and belong to ancient times. It was designed to map the motion of the moon, sun and the planets to simulate the our Solar System. It allowed humans to calculate and display astronomical and solar calendar dates by cranking its gears. It can forecast the eclipses and track lunar phases. It has 30 gears and the teeth of largest gear was 13cm. It was the first stage of computer, which are called analogue computers. Analogue computers are the first stage of computer that could be abacus , tally sticks or mechanical machines like analytical engine , difference engine made by Charles Babbage (Father of Computer).



Fragment of the Antikythera mechanism



Assumed picture as complete device at 2nd Century BC

In 1936, a British Mathematician Alan Turing published the paper introducing the concept of Universal Turing



Machine. In that paper, he stated that there should be a programmable machine, that should compute if it is given the right instructions. This was the birth of distinction between hardware and software. In world war 2 (1939 - 1945), the mechanical computers were used to decode the intercepted German's communication codes, had limitations and needed a programmable, more general purpose machine. This idea provide the base for the next generation computers which are digital computers.

First Digital computer was invented between (1939 to 1942) by Professor John Vincent Atanasoff and graduate student Clifford Berry at Iowa State University. It introduced critical modern foundations like binary math. It has vacuum tubes to control the flow of electricity. Vacuum tubes were very large in size, require continuous cooling and are expensive. Then these vacuum tubes were replaced by transistor in second generation of digital computer. In third generation, integrated chips (ICs) were introduced which were more powerful then the transistors. Four generation of computers uses micro processors. These microprocessors are now being used in every computer like Mobile-phone , PCs , laptops and smart electronics. Fifth generation computers are based on Artificial Intelligence, parallel programming and superconductors that are used in machine learning and training highly efficient models.

Today, digital computers are the essential part of every field either it is Finance, Research and development, Medical science, Banking, Space, Military and Education. Digital computers had revolutionized every field of our life. This digital revolution was transistor based which works on the 0,1 binary value. Currently, we are working in stage of digital computer and initial stage next revolution in computer science and technology. Quantum Computer will change everything. This ultimate computers may computes on trapped ions, photons or neutral atoms, instead of transistor, the ultimate constituent of matter. Quantum computers are extremely faster then, the digital computers, this supremacy over digital computers is called **Quantum Supremacy**. Everyone is involved in the race of achieving the quantum supremacy.



*ENIAC (Electronic Numerical Integrator and Computer)
worlds first General purpose digital computer.*

Imagine you are given a task to solve a mathematical problem and you test the solutions one by one, you may use brute force technique to solve that problem by testing each solution or may use some technique to narrow down the solution set, this is how the drugs of diseases are produced, there are super computers that test each molecule



of virus or disease, with different possible combinations of human gene, monitors its behaviour, it can take months or sometime years in testing each individual possible bond to get desired solution (medicine) by super computers. Imagine there could be a computer that is able to test the possibilities of solution for a problem at ones and give us the right solution by amplifying the constructive interference and manipulating probability amplitude this would be far superior then digital computers, this could revolutionize the world of medicine and could enable humans to cure cancer and enable to make highly efficient jet engines, that is quantum computer.

Traditional super computers are the machines that can perform calculations at very high speed. The most powerful super computer on earth is **EL Capitan** that can perform 1.74 quintillion operations per second. But, quantum computer is 10^{27} times more powerful then today's fastest super computer. Google's willow quantum chip can process data in 5 minutes that the EL Capitan could take 10 septillion years(more then the life of our universe).

The word quantum means atomic or subatomic level and computer means a machine that can process data. Quantum Computer is a machine that uses the laws of quantum mechanics that enable it to see through all the possible solutions of a problem and then it can narrow down the right solutions with the help of **Grover and Shor's Algorithm**.

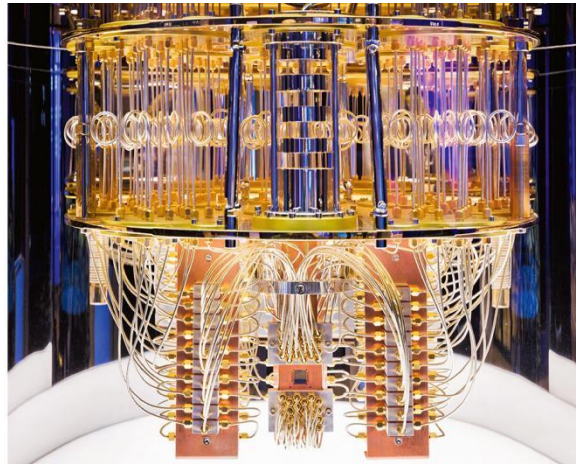
Traditional computers uses the transistors and integrated chips that can can store either 0 or 1 in single bit by allowing the current to flow or blocking, then the different combination of these bits are used to represent and process data. Computer chip can process 8 bit, 16bit, 32bit and 64bit. Mostly computers used by people today is has 64 bit processor. At a time the chip can either allow the current to flow or stop, it is impossible to have both states simultaneously, that is why a single bit can have either 0 or 1. On the other hand, the quantum computer can have both states at ones , it could have the state of zero or one at same time.

"Nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical, and by golly it's a wonderful problem, because it doesn't look so easy."

Richard Feynman (American Theoretical Physicist)

Technology Overview

Quantum Computers is the new generation of computers, works with Qbits which are different from the traditional bits, it is called quantum bits because it can have the state of 0 and 1 at same time t. It works on the principal of quantum mechanics. Quantum Mechanics is the study of matter and energy at the atomic and sub-atomic level, it reveal the tiny particles simultaneously exhibits the traits of both particle and wave, and possess the discrete packets of energy called quanta. Qbit is the true demonstration of wave particle duality property. The classical physics limits the data processing to single isolated state. By leveraging the quantum mechanics, hardware can bypass the physical boundaries to process the complex processing at insane speed.



IBM's Quantum System Two

"To me quantum computation is a new and deeper and better way to understand the laws of physics, and hence understanding physical reality as whole."

David Deutsch :Father of Quantum Computers(British Physicist)

According to Richard Feynman, Quantum systems like atoms, molecule and particles behave on the principal of quantum mechanics, which are very complicated that classical computer's straight forward 0 and 1 binary logic is not adequate to understand them. We need a computer that works on quantum laws. In which the spin of electron could represent the 0 and 1, spin-up represents 1 and spin-down represents 0.

Quantum Computers works on the principal of **Quantum Superposition** and **Quantum Entanglement**. These principals can be understand with the double slit experiment in which a light wave is passed by two slits and it shows the line pattern on the screen.

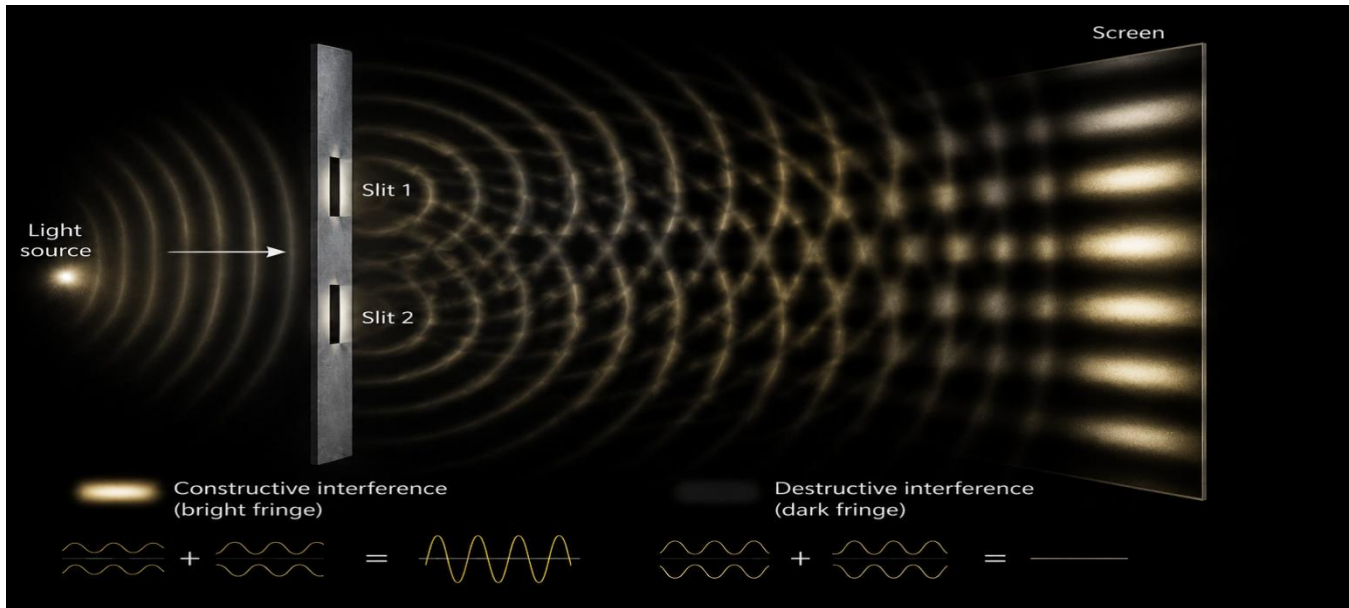


Figure 1: Two slit experiment performed by Thomas Young in 1801

The single photon coming from a light source passes through two slits at a time, means it is present on two positions at ones, this particular concept is called **Quantum superposition**. The sub-atomic particle has the traits of wave (**Wave - Particle Duality**) that is why after passing through slits it behaves like a wave and interferes in constructive (When two waves combine and make a bigger wave) or destructive (Two waves cancel each other) way.

Due to the interference, it creates a line pattern on screen called interference pattern. What if with the help of this superposition we can perform calculation and computation, this is the idea that came in mind of Father of Quantum Computer David Deutsch in 1985, which further gave the base to qubits (0 and 1 at same time). Bright spots occur due to constructive interference of light and dark spots occur due to destructive interference. We can predict easily that where there are high chances of particles to meet (bright spot) and where there are lower chances of particles to meet (dark spot) due to its probabilistic wave behaviour. In Quantum computing the same principle of interference and probability can be used to be close to our right answer. In double slit experiment the waves interact in a particular way and it can be predicted where a particle could land, similar ways in quantum computing waves can interfere, we can ignore the destructive pattern and focus on constructive interface that could lead us to our right answer. We can build our right answer by interfering many waves constructively in quantum computing.

In classical computer the 0 and 1 are decided by transistors, but in quantum computing qubits can hold both states simultaneously due to superposition, if a 1-bit processor is made it can process two states (0,1) at a time, in case of 2 bits quantum processor ($2^2=4$) it can process 4 states at the same time, in case of 3 bits ($2^3=8$) means it can process 8 states of a single problem at the same time and if we make the quantum processor of only 100 bits it can process 2^{100} (1.26 nonillion) states of single problem at the same time.

In the background the quantum computer tracks the billion of waves interference, amplifies the constructive interference and separates the destructive interference.

Quantum Entanglement is a phenomenon in which two qubits connect with each other and change in one changes other, no matter how long the distance between them. Even if one quantum particle is on earth and



other is on the other end of universe they could share information and communication is almost instantaneous. In such a ways, many qbits can communicate and compute parallel and very fast. It is very different from our traditional computer, it is made to find the right answer from billion or trillion of possibilities, or to simulate the atom or molecules and to take optimization of tasks at very high level. It is not made to run simple Microsoft Office, high end games, or the things that our digital computer does. It will be use when there are trillion or possible solutions and we have to find the correct one.

Quantum processes occurs at extremely low temperature -273°C which is maintained by special type of refrigerator called **Inner Dilution Refrigerator**. It had network of pipes in which helium or nitrogen flows to maintain the lowest temperature possible.



Dilution Refrigerator

The biggest problem with quantum computer is that they are very sensitive. Quantum particles behave like waves, but the moment they came in contact with any other energy collapses immediately, this process of collapsing is called **Quantum Decoherence**. They loose their wave nature and properties like super-position and quantum entanglement becoming useless. Any wave, particle or energy interaction d-cohere qbits immediately. That is why, they are kept at the lowest temperature (0.15K or -273°C) possible to prevent from any external heat or any other energy interference. But even then, the qbits remain active for microseconds and then d-cohere immediately, this time-frame in which the qbits remain active is called the **Coherence Time**. It is a biggest challenge for companies like google, Microsoft and IBM which are working on quantum computing.

If the quantum computer remains active for very short time and decoherence then how the quantum computer able to perform calculations? The answer is **Quantum Error Correction**. In this approach the quantum computers fix each decohere bit and each qbit forward processed information to next qbit before being collapse, every qbit process its information and then pass it to the next qbit, then next qbit does the same and so-on. If the qbits decohere at moment as it came in contact with any energy then how the quantum computer correct the decohered qbits or fix errors, so that the information could prevent from being lose? We use the qbit for this purpose also. There are two type of errors that can came during quantum processing:

- 1)**Bit Flip Error** (0 could be change into 1 or 1 could be change into 0)
- 2)**Phase Flip Error** (mean the +1 could be change to -1 that will effect how qbit interact with other qbits)



To solve these errors quantum computer uses the concept of redundancy, one qbit is encode in 3 qbits means information carried by one qbit is distribute in 3 qbits and if 1 flips to 0 (Bit Flip Error) in any of these bits then Ancillary qbits will be introduced that entangle themselves with the faulty qbits and rectify the flip with the help of quantum gates similar to traditional logic gates. These ancillary qbits are also qbits themselves that is why it is not problem for qbits to entangle with their similar kind. Then these ancillary bits are measured which gave us exact type and location of error, make them decohere immediately.

In case of Phase Flip Error the 3 sub qbits are decoded in 3 further qbits, then the ancillary qbits scan all the these qbits and rectify the flipped phase. In this whole process each qbit retains their property and do not d-cohere, because we do not use any external particle or energy to fix them, the ancillary qbits used are also qbits. In short in quantum error correction, replicas of qbits are made and in case of any d-cohere or error, qbits are reconstructed. From these rebuild qbits other qbits get information and the system remain running like a chain.

Even then, the real challenges for companies that are working on quantum computing are Stability of Quantum State, Effective Algorithm, Real Time Error Correction that preventing the humans from developing and using the quantum computers at their full potential.

Key Findings & Impact

Everyone is involved in the race of quantum computing. Anyone who is interested in security interested in quantum computers. Quantum computer can crack most of code that is based on digital technology, it can decrypt the most of encryption algorithms, it can guess passwords by simple brute force, it allows humans to develop quantum radar that can detect any type of fast moving vehicle in air or space, either any missile at hyper-sonic speed, a super-sonic aircraft no matters even it is 6gen or above. Quantum Cryptography will develop the encryption algorithm that is impossible for traditional computers to decrypt and could only be decrypt by quantum computers or practically impossible. Currently the guided system used by military equipment , vehicles , submarines , fighter-jets , missiles , naval-ships is GPS (Global Positioning System) that can be easily spoof by electronic warfare assets. After quantum computers all these military assets can easily work in GPS denial environment and can get the longitude latitude of earth by calculating the gravitational force acting at atomic level. That is why, every government that want to make itself future power investing billions of dollars in quantum computers.

In medical sector the quantum computer will allow the humans to cure cancer, rabies and other fatal disease and viruses those drugs are still unknown. This can increase the average life span of humans. The medicine which take months or years to make could develop in few weeks or days. People can make quantum medical devices that could locate and cure patient's disease .It can also be used making hyper personalize medicine that will much more effective then the traditional medicines.

In the field of automobile the quantum computer can help humans to make very efficient engines which could run on renewable fuel that can be mass produced. Highly efficient EV batteries could make because the quantum computer computes on atom, if we have the atomic level control over things. For example if we want to create a space shuttle it can tell which type of metal has which kind of properties that is suitable for our space-craft, it can also help scientist to predict the movements of planets, their trajectory, environment of the planet that will make probability of success in space mission very high.

In AI quantum computer could revolutionize the field of artificial intelligence, normally the llms are trained on huge data-set that is very difficult to collect then cleaning them before feeding the system even then the llm could excels in pattern matching rather than solving unseen and real-time problem. The quantum computer can generate data at very high speed, that allow us to make any kind of llm and it also solves the problem of model



training because it requires high computational power like GPU, RAM and storage. Quantum AI can improve itself by learning and generating new code at real-time the could excels it doing complex or multidimensional tasks. It could built the general AI that could do most of things at high speed and with high accuracy.

What's Next?

Quantum Computers may sound like myth but it can actually can be complet system in future. There are different quantum computers that already exists in different forms. But making a dedicated quantum computer and use them is extremely difficult only few countries and companies that are working on it progressing slowly because of critical issues like having not better algorithms, very small coherence time, maintaining extremely low temperature, integration with digital computers, economic scalability, very expensive and complex hardware.To solve all these issue may require years of research and development, resources and billions of dollars.

In 2024-25 Google announce a major breakthrough that it had developed quantum chip Willow that remain active for 5 minutes before being d-cohere, which is a great milestone achieve by Google because the qbits are extremely fragile that slightly temperature or even sub-atomic particle could make them decohere immediately and the processing time calculated before Willow chip was just few microseconds.

While companies like Google and IBM companies using superconductors that need to need cool down at zero degree. The researchers and scientist at the University of Science and Technology use a totally different architectural approach of using photons.In May 2026, the USTC team unveiled **Jiuzhang 4.0**, an 8,176-mode programmable photonic quantum processor. They used it to execute a highly complex mathematical task called **Gaussian Boson Sampling (GBS)**.

Many countries are working on quantum computers like USA, CHINA, JAPAN, South-KOREA, INDIA, AUSTRALIA, QATAR, CANADA, RUSSIA and many other EUROPEAN countries. But unfortunately in Pakistan, public sector universities facing budgets, administrative, educational,resources and internet crisis. And quantum computing and quantum research is only on paper, having not solid and clear vision about it. Government should allocate dedicated budget for quantum research and development and take concrete steps to improve our educational system.

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