Quantum Computers

There is no doubt that computers are replacing humans in almost everywhere: in medicine, education, business and investing, designing, and many more. The emergence of the first computer was the beginning of the digital era and today, a typical laptop outperforms the strongest computers of the last century in speed and strength. Computer technology has developed supercomputers that operate millions of times faster than usual computers being a tool for computation – heavy tasks in the fields such as oil and gas exploration, molecular modeling, weather forecasting and quantum mechanics. But there is always a room for perfection and while talking about this perfection I want to introduce a new generation of computers which is based on a fundamentally different computation base with speed millions of times faster than the fastest supercomputer. This type of computer is a Quantum Computer.

HISTORY

We only need to go back to 1980's to see the origin of Quantum Computation. At that time, one of the most important physicists of the 20^{th} century encountered a roadblock. Richard Feynmen was hungry for a window into the quantum universe. But quantum systems, by nature, are fragile, and the information they hold are hidden from us. Because Feynmen couldn't directly observe quantum events, he wanted to design a simulation. But he quickly figured out that his computer wasn't up to the task. As he added particles to the quantum systems that he was modeling, the cost of computation began to rise exponentially. Feynmen concluded that classical computers just can't scale fast enough to keep pace with the growing complexity of quantum calculations. Then he had a breakthrough. What if he could design a tool made up of quantum elements itself? This tool would operate according to the laws of quantum physics, making it the perfect way to probe the mysteries of the quantum realm…The idea of the quantum computers was born.

DIFFERENCE

The difference between classical and quantum computer is that they operate in a fundamentally different way as I mentioned earlier. Classical computers or binary computers store and process information in a Binary Digit Unit or simply Bit, which represents either 0 or 1. For example, one character letter consists of 8 bits. Every time you press a letter on your keyboard, a computer creates a combination of 8 zeros and ones. These bits can be configured into larger, more complex units, essentially long strings of 0s and 1s encoded with data commands that tell the computer what to do. But in Quantum Computing unlike classical

computing, the basic unit of information is a quantum bit, or qubit. These are typically subatomic particles like photons or electrons. The key to a quantum machine's advanced computational power lies in its ability to manipulate these qubits. In quantum computing instead of having only two levels of zero and one that we have in a classical computation, we can build a superposition of these two states. Superposition in qubits means that unlike a binary system, it can be 0 or 1 or 0 and 1 at the same time. How is it possible? Let's take a coin as an analogy. When it is stationary, a coin has two states: heads and tails. If we spin or flip a coin, until it hits the ground the reaches a stationary condition, it has heads and tails at the same time in the air. In computing, this ability to be in multiple states at the same time gives quantum computers relatively more power in computing than traditional binary computers. For example, 8 bits are enough for a classical computer to store and represent any number between 0 and 255. But for a quantum computer, 8 qubits are enough to represent all numbers between 0 and 255 simultaneously.… In addition to its power, quantum computers are relatively small and require less energy than supercomputers. Due to the need for string processors, hardware, and storage, supercomputers can take a large area to be installed or a whole building but IBM Q System One, the first commercial quantum computer by IBM, for example, is placed in just 9-foot wide and 9-foot-tall cubic glass case.

ACHIEVEMENTS IN THE FIELDS.

IBM has several quantum computers in operation such as IBM Q 20 Austin, IBM Q 53, IBM Eagle processor and IBM Osprey. IBM Eagle processor, unveiled in 2021 IBM Summit, has 127 qubits and with this capacity, the computer can accurately simulate the quantum systems or solve complex factoring problems that are needed in cryptography. In 2022, IBM presented the next level of quantum computer in a short period: 433 qubit "Osprey" processor. This processor has the potential to run complex quantum computations far beyond the computational capability of any classical supercomputer. Also, the number of classical Bits necessary to represent the state on the IBM Osprey processor far exceeds the total number of atoms in the known universe. Dr. Dario, senior vice president of IBM said they are scaling up and advancing their quantum technology across hardware and software to meet the biggest challenges of our time and this work will be the foundation for the coming quantum-centric supercomputing. In the 2023 Summit, they are coming up with a new version of Quantum Processor that can be united with other processors exceeding its number of qubits by 8,000.

USAGE AND BENEFIT

Now, we know about Quantum Computers, their speed, and potentials. But do we really need those hyper-powerful computers? Let's see how companies who are engaged in the field answer this question. IBM has been actively researching and developing quantum computers for several decades, and it has made significant progress in this field. IBM has developed several quantum computers that are available to users through the IBM Q network, which is a cloud-based service. Alessandro Curioni, the director of IBM research lab in Zurich explained that quantum computers are going to be able to better simulate the quantum world, and this simulation enables us to discover new materials with tailored properties that can be used in energy, food, medicine, and many other fields. He claims that if they can design a new material for energy storage, or better materials as a fertilizer and CO_2 capture, they will be able to solve the problems of mobility, food deprivation and production, and global warming.

EXAMPLE

Here are examples where quantum computers have succeeded over classical supercomputers. Protein folding problem is when an amino acid sequence of a protein is transformed into a three-dimensional structure and monitored. This problem is important to solve because the structure of protein determines its function, and misfolded proteins can cause diseases such as Alzheimer's and Creutzfeldt-Jakob disease. Determining the structure of amino acid chain using Quantum Computation, it is possible to find a cure to these diseases. One research example of the use of quantum computers in protein folding is a study published in the journal Nature in 2019. In this study, researchers used a quantum computer to predict the structure of a small protein called "repressor" with near-perfect accuracy. In another research published in Journal of Science in 2020, scientists modeled the amino acid chain of protein named "ubiquitin" and the results were in a good agreement with experimental measurements of the structure of protein.

CONCLUSION

To sum up, I hope that by speaking about the history of Quantum Computers, how it works, possible usages and benefits, you have a better understanding of this type of computation. Until the mid-19^{th} century, we couldn't see atoms but today, we are using quantum mechanics to build the new era of computers. The speed and productivity of quantum computers might be even beyond our imagination and sound unrealistic but don't forget that we are already using them and even have access to them over internet. Not many years are left until we own

our quantum-computation based devices at our houses and offices. If these computers are that powerful and fast, what will happen if we build artificial intelligence on them? Imagine an AI working at the speed powered by Quantum Mechanics. We will have a dominance over tasks that are nearly impossible now. The good news is that we will be those people who witnesses the emergence of this new era in its prime. **1369 words**