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Quantum Computing

Overview of Quantum Computing. How does it compare to conventional computer architecture?

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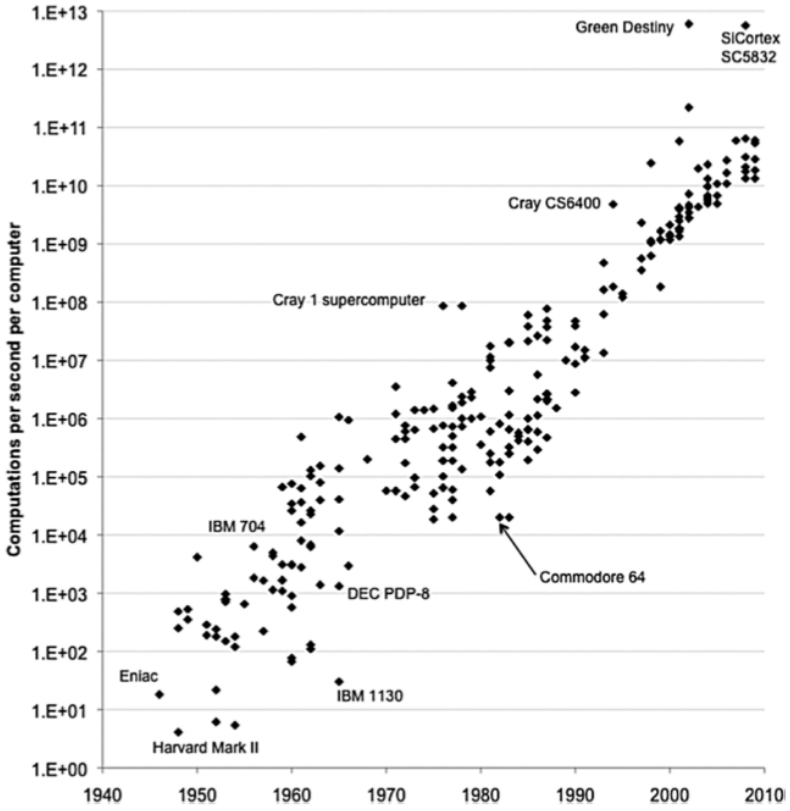
1. Introduction

Thomas Alva Edison first invented the light bulb approximately 140 years ago. Since then, the reaches of human curiosity and innovation have caused technology to advance at an exponential rate.



(Koomey et al. 2011)

The graph presented above shows the exponential increasing of computational capacity. However, certain physical limitations still pose a threat to the advancements of computer technology. Quantum computing could be the potential solution to these problems.

2. What is Quantum Computing?

Quantum Computing is a field of computing that is based on the properties of quantum physics. (Bernhardt, 2019). Quantum Physics is the study of subatomic particles and their properties. This includes particles such as protons, electrons, neutrons and photons and the manner in which they behave at this atomic level. One such quantum property is superposition which is the ability of quantum particles to be in a combination of possible states. (Telkar et al.,2020). The other property which is vital to understanding the mechanism of quantum computers is entanglement. Entanglement is when quantum particles form a connection and function as a single system. (Hidary, 2019). These phenomena are the foundation on which quantum computers are designed. Using these quantum properties, a computer that could surpass any existing conventional computer in terms of speed and power can be created. (IBM, no date).

3. Why is Quantum Computing Needed?

3.1 Limitations of Conventional Computing

With the development of technology, computers and their components are getting smaller. Computer parts, such as transistors, have now reached the size of a few atoms. At this microscopic level, the laws of classical physics cannot be used. When the size of transistors reaches such atomic levels, they cannot function as a switch because electrons can simply appear on the other side of the transistor due to a property called quantum tunnelling. (Seabaugh, 2013). This creates an obstruction for technological progress.

3.2 How can Quantum Computing Help with these Limitations?

Although these quantum properties are creating problems on conventional computers, they can be manipulated to create a computer that is able to use phenomena such as superposition and entanglement. (Bernhardt, 2019). It has since been realized that such a computer could outperform even the most powerful supercomputers developed as of now. The ability of subatomic particles to be in a superposition of states at a time provides new opportunities in the field of computing. (Gonzalez, 2020).

4. Differences between Conventional Computing and Quantum Computing

In a quantum computer, data is stored and processed using qubits whereas conventional computers use bits to do this. Bits can be in only a single state at a time, either on or off, represented by 1 and 0 respectively. Qubits, however, are able to be in a combination of states simultaneously due to the property of superposition. They can have the values 0, 1 or a superposition of 0 and 1. (Telkar et al.,2020).

This opens up a wide range of opportunities for the field of computing. Since quantum particles are able to be in a superposition of states, quantum computers can parallel-process. Where 6 classical bits can be in 1 out of 64 different arrangements at a single time, 6 qubits in superposition can be in all 64 at once. The difference grows exponentially as qubits gets added. 10 qubits can store 1024 values in parallel. Instead of analysing each combination one after the other, superposition allows qubits to represent all the possible scenarios at the same time. This greatly reduces the time taken to process large sets of data. (BBVA, 2019)

Quantum computers also process information in a fundamentally different way to conventional computers. Classical computers use logic gates which use a simple set of inputs to produce a distinct output. Quantum computers use quantum gates which get an input of superposition and output another superposition. (Ablayev, et al., 2018)

Classical computers follow the structure defined by the von Neumann architecture, where a Central Processing Unit, with a Control Unit and an Arithmetic and Logic Unit, work alongside the memory, storage unit and the input/output. The QRAM (RAM of quantum computers), addresses and output registers are composed of interconnected qubits. (Wittek, 2014). All the processing is done in-place directly on the qubits but on a classical computer, data is moved from the processing units to the memory and registers when being processed. (Hidary, 2019)

Quantum computers must also be maintained at a temperature close to absolute zero to allow quantum properties to function properly because qubits are very fragile and vulnerable to changes in the environment. (Bernhardt, 2019). This is very costly to maintain. On the other hand, conventional computers have no such restrictions.

5. Conclusion

(DW, 2021)

The figure above shows the launching of the first quantum computer in Germany on the 15th of June 2021. (DW, 2021). "The IBM Quantum System One represents the world's first integrated quantum computer system." (IBM, no date).

Although, the field of quantum computing is still in its infancy, it has been proved that a quantum computer could be vastly superior to a conventional computer when it comes to handling large collections of data. Where conventional computers fail, a quantum computer could potentially succeed. "If you wanted to find one item in a list of 1 trillion, and each item took 1 microsecond to check: Classical computer - About 1 week, Quantum computer - About 1 second" (IBM, no date). This shows how the speed and power of a quantum computer easily surpasses that of the conventional computer. (BBVA, 2019). Although quantum computers will not replace classical computers anytime soon, the existence of such a powerful computer allows us to continue making advancements and opens up a new realm of possibilities for technology.

5.1 Critical Evaluation

With its unmatched speed and power, it is almost certain that things that were previously deemed impossible for a computer to do would soon be completely possible. However, it comes with many complications. Quantum computer systems, with their extreme vulnerability to the surroundings, are much more expensive to create and maintain. They also pose a security risk as they can break encryptions. (Coughlin, 2020). With all these downsides, if further enhancements in technology and appropriate control mechanisms to

prevent them from being used for unethical practices are applied as necessary, quantum computers could well be the future of technology.

(Word Count: 1047)

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