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Role and Prospects of Engineering in Nanotechnology: An Overview

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ABSTRACT

Background - The rapid growth of digital technology has resulted in an enormous rise in computing activities, imposing strict requirements on next-generation computing for energy efficiency and area efficiency. For matrix and logic computing, new technologies such as in-memory computing and transistor-based computing have emerged to accommodate the increasing data need. Nanocomputers - However, in order to meet the demands of the future, new materials are desperately required. In order to expand the range of electronic devices and their applications, new technologies must be created, such as Si complementary metal–oxide–semiconductor technology. Since two-dimensional materials have a wide range of electrical characteristics, they have the potential to improve computation efficiency while allowing further device downscaling. Conclusion - Paper covers the challenges, pitfalls, and potential applications of integrating nanotechnology and computer science in this overview.

KEYWORDS
Nanocomputers;
Two dimentional;
Quantum Computing;
computation efficiency

1. Introduction

Today, you can carry a computer in one hand – A computer (hundreds of times slower) was the size of a room 40 years ago. Microprocessors are now being miniaturised at nanometer sizes. Nonetheless, the style of our modern technology is similar to that of old technology, which used bulk resources to create a polished product. Bulkor top-down technology is the name given to this design. Because current methods for shrinking the size of transistors in silicon microprocessor chips are reaching their limits, and because modifying today's top-down technology to manufacture nanoscale structures is difficult and expensive, a new generation of computer components will be required. Feynman and Drexler envisioned a new technique in which individual atoms or molecules are assembled into a refined product. Drexler refers to this as "molecular technology" or "bottom-up technology."[1] This bottom-up approach to technology could be the key to the computer industry's success. Although top-down technology is still the preferred method for mass-producing electronics, nanotechnologists are increasingly succeeding in generating bottom-up technology[2]. Every 18 months, according to Moors legislation, the performance of the CPU is doubled. Every one and a half years, the feature size of a semiconductor chip shrinks by a factor of two. Every 1.5 years, the industry's ability to install more transistors on a computer chip doubles. Every three years, the cost of building a new Fab will quadruple. The question now is how to solve this dilemma, and the answer is nanotechnology. Nanotechnology plays a vital part in computer science nowadays.

2. Nanocomputers

A nanocomputer is a computer with microscopic physical dimensions. Nano computing is a subset of the emerging field of nanotechnology. Researchers and futurists have suggested or proposed several types of nanocomputers. The four types of nano computing are as follows:

2.1. Electronic Nanocomputers

Electronic nanocomputers of the future would perform their tasks in a manner that is analogous to that of microcomputers of the present day. The most notable distinction is found in their respective sizes. As more transistors are packed into smaller and smaller spaces, silicon chips continue to shrink in size year after year. Consequently, integrated circuits (ICs) with ever-increasing storage capacity and

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computational capability have been developed. The atomic structure of matter places a limit on the number of transistors that can be packed into a specific volume[4]. This limit can't be exceeded. According to the majority of engineers, technological advancement has not even come close to overcoming this barrier. In the context of electronics, the term "micro computer" refers to a relatively small computer[5]. By the standards of the 1970s, the microprocessors used today are extremely small devices.

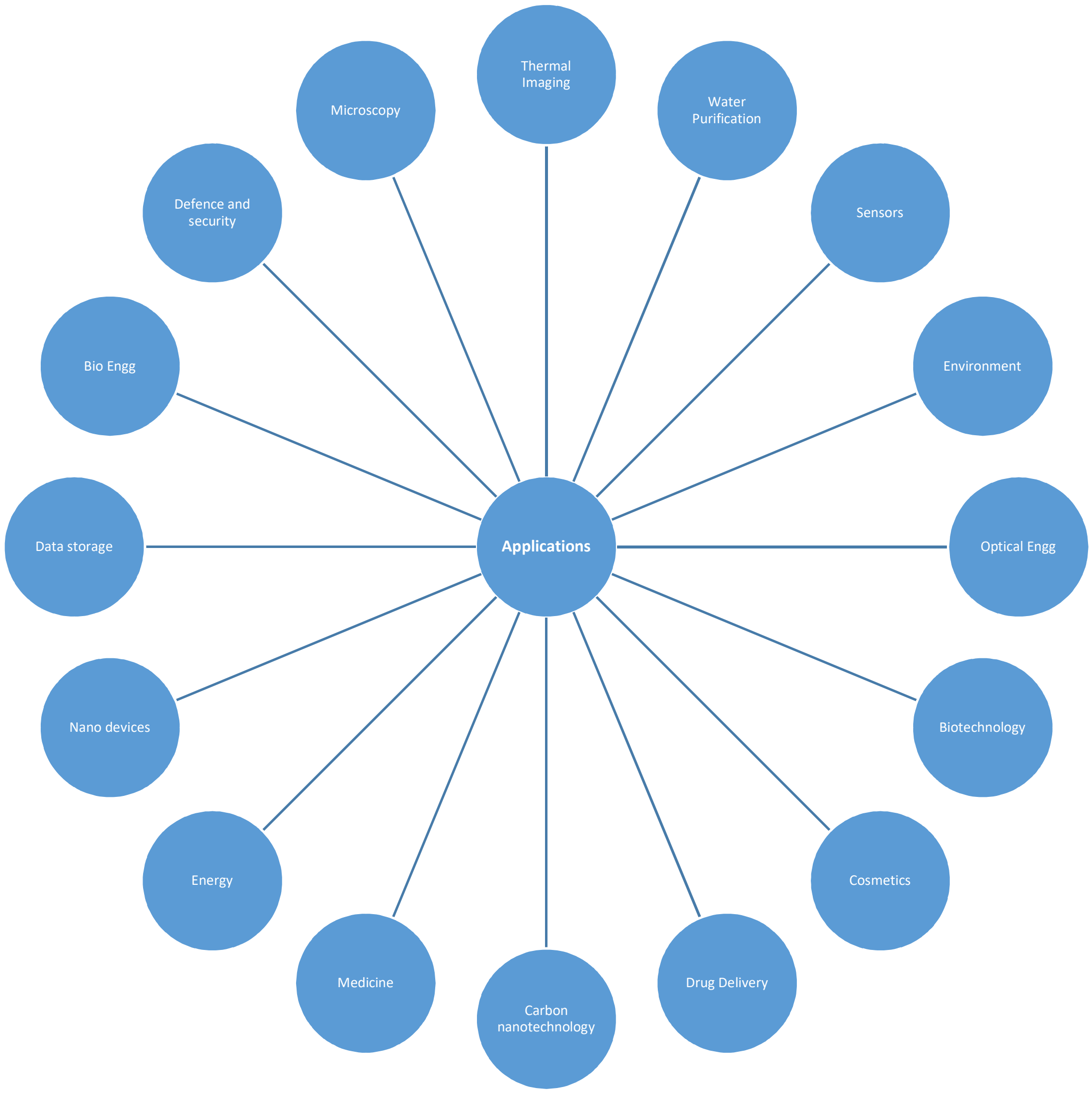

Fig. 1. Applications of Nanotechnology.

Due to our many years of experience with electronic computing devices, including the extensive research and industrial infrastructure built up since the late 1940s, it is likely that advances in nanocomputing technology will come in this direction. As a result, electronic nanocomputers appear to be the easiest and most likely direction in which to continue developing nanocomputers in the near future. The operation of electronic nanocomputers would be analogous to that of the more common microcomputers used today. One of the most important differences is the difference in physical scale. Integrated circuits (ICs) have ever-increasing storage space and processing capability as a result of the ever-increasing number of transistors that are packed into silicon chips every year. The atomic structure of matter places a ceiling on the maximum number of transistors that can be packed into a given volume. The vast majority of tech experts agree that we haven't even come close to reaching this barrier yet. The term "nanocomputer" has a relative meaning in the context of electronics; by the criteria of the 1970s, the microprocessors that are typical today may be classified as "nanodevices."[6].

2.2. Chemical Nanocomputers

If chemical nanocomputers were around, information would be stored and processed in the chemical structures and interactions of the system. All living things contain what might be thought of as biochemical nanocomputers, therefore nature already possesses them. It is believed that genetic engineering will play a role in the construction of a chemical nanocomputer[7]. Engineers need to devise a method by which individual atoms and molecules can be made to carry out computations and activities related to data storage under their direct control.

A chemical computer is a device that processes data by making and breaking chemical bonds, and then stores logic states or information in the resulting chemical (that is, molecular) structures. In general, a chemical computer is a device that processes data by forming and breaking chemical bonds. In chemical nanocomputers, information is stored and processed through the use of chemical reactions, namely the breaking and building of chemical bonds [8]. The inputs are recorded in the molecular structure of the reactants, and the outputs are derived from the structure of the products. This indicates that the information in these computers is stored and processed by the interaction of various molecules and their structures.

In order to construct a chemical nanocomputer, engineers need the ability to regulate the movement of individual atoms and molecules so that the computer may carry out operations such as controllable calculations and the storage of data. It is conceivable that the process of developing a true chemical nanocomputer will proceed in a manner analogous to that of genetic engineering.

2.3. Quantum Nanocomputing

Understanding quantum computers requires first gaining a deeper familiarity with the bit, which is the information sector's fundamental building block. A bit is a physical system that can be formed in either of the two states that reflect the two possible logical values, which are false or true, or more simply 0 or 1. One bit of information can be encoded using two distinct polarizations of light or several distinct electronic states of an atom. However, if we take an atom as our physical bit, quantum theory tells us that an atom can similarly be generated with two distinct electronic states at the same time.. In other words, the atom is simultaneously in both states 0 and 1. We're now taking the concept of number superposition one step further. Think of a register that has three physical bits inside of it. In a particular moment of time, a classical register of that sort can only hold one of eight potential configurations, such as 000, 001, 010, 111. All eight numbers can be stored in a quantum superposition in a quantum register with three qubits[9].

2.4. Mechanical Nanocomputing

Instead of employing transistors and other components that are made of solid state, mechanical computers use millions of extremely small moving parts to move electrons around in order to perform calculations. Gates, pillars, levers, and pistons are only some of the mechanisms that are used in the construction of binary switches, which are used to power the computers of today. According to scientists, nanomechanical chips will likely be utilised in a diverse array of applications in "extreme settings such as space, car engines, battlefields, and children's toys." Because they consume less electricity, they do not need the power-hungry cooling systems that are necessary for traditional computers.

Pioneers such as Eric Drexler proposed as early as the middle of the 1980s that molecular manufacturing could be used to construct nanoscale mechanical computers through a process known as "mechanosynthesis," which involves the mechanical positioning of atoms or molecular building blocks one atom or molecule at a time. This positioning of atoms or molecules would be done one at a time. Once it was built, the mechanical nanocomputer would function in a manner not dissimilar to that of a more complicated and programmable version of the mechanical calculators that were common from the 1940s through the 1970s [10]. These calculators were used before the widespread availability and low cost of solid-state electronic calculators.

In Drexler's hypothetical design, the rods would slide about in housings, and the housings would have bumps that would obstruct the travel of other rods[11]. It was a mechanical nanocomputer that encoded information with the help of incredibly small and mobile components referred to as nanogears.

3. Nanotechnology for Computer Science

The discipline of computer science appears to have limitless potential because of nanotechnology. In this brief overview, we'll go through some of the most important developments in computing and the new paths that are becoming available. The discovery of Carbon Nanotubes by S Lijima of NEC in 1991 is one of the innovations in the field of Nanotechnology. There are now numerous uses for Carbon Nanotubes. Carbon Nanotubes have been successfully used by scientists to make electronic components such as transistors, diodes, relays, and logic gates[12]. The Quantum Dots are yet another novel substance. When stimulated, the electrons in these crystals emit light with a single wavelength. The chemical response of these dots can be used to regulate their electrical, magnetic, and optical properties. A quantum dot's light emission can be used as a basis for information exchange. Later, we'll go into more detail about this. This will open up a new area of growth in the realm of computers. Researchers have made electronic components out of carbon Nanotubes which advances in nanotechnology fabrication at multiple levels. Nano-based materials are currently being investigated for use in interconnecting such components. As a result, a silicon-based nanocomputer is very certainly on its way to becoming a reality. Nanotechnology has the potential to revolutionise a wide range of computer applications. There are a variety of technologies at play in the data storage field. Using nonvolatile random access memory (RAM) that areultradense and very huge appears to be an almost definite future development. There are a lot of lower-level memory technologies being researched. In addition to using arrays with sharp points to write magnetically, optically or even to make indentations in a polymer; there are also researches into making magnetic RAMs based on quantum mechanical effects based on the spin of an electron; various types of molecular memory are being pursued; and one promising approach is the use of carbon nano tubes. You may no longer need a hard drive if some of these technologies are successful. Carbon nanotubes could be used to make displays that consume less electricity[13]. Because of their small diameter (a few nanometers), these can be employed as field emitters for Field Emission Displays with extraordinarily high efficiency (FED). The cathode ray tube's principle of operation will be very similar to that of a considerably smaller length scale.

The subject of nanotechnology is seeing substantial advancements from many well-known corporations. The following are a few examples: Carbon nano tube transistors developed by IBM researchers already outperform modern silicon devices. Hewlett-Packard: HP researchers have patented an invention that could lead to the creation of computer circuits composed entirely of individual molecules. This new generation of silicon-based circuits will be a thousand times smaller and thousands of times cheaper because to HP's efforts to improve the process. A new breakthrough in the design of chops by Intel will enable the construction of cheaper and faster microprocessors based on nano-level technology with more than 1 billion transistors compared to 125 million transistors in Intel's current Pentium IV chip. A company called Applied Materials is working on "nano chips," small computer processors that will power mobile gadgets [14]. High-speed wireless networks are expected to fuel demand for these processors. As an example of a leading business creating the basic process technology necessary to produce nanoscale optical, electrical, and energy storage applications, look no further than Nanogram in Fremont, California.

Nano-Computers

Nano computers can be approached in two different ways [15]. Quantum Computing and Molecular Computing are the two main types of computing. In the future, these two techniques will be used to replace semiconductors in our current chips. The goal of quantum computing is to do computations at the quantum level [16]. Quantum bits or Qubits, which can be in a state of 0, 1, or super position, are used instead of standard binary bits and bytes in this level of computerization (simultaneously 0 and 1) [17]. Due to the fact that quantum bits are capable of numerous states at once, millions of calculations can be performed in the same amount of time. Because we're interacting with stuff at the quantum level, we'll encounter quantum mechanics challenges [18]. This is being studied as a way to overcome it. Molecular Computing is another option [19]. We're attempting to do all of this within a single molecule. Deoxyribonucleic Acid (DNA), a molecule that carries genetic information, has shown promise in this computing. In DNA, the letters A, T, C, and G stand for the nucleotides that make up this lengthy polymer [20]. DNA's nucleotide sequence may be used to do complicated computations, because of the information provided by these nucleotides. Because DNA can hold more information than any memory chip, molecular computing can be used to execute parallel computations. As a result, the merger of

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bioscience and information technology will have far-reaching consequences for research, resulting in a new sector altogether. And the promises are going to be a lot of fun. Quantum Computers are discussed in detail in the following sections.

4. Quantum Computing

Quantum computing is a type of computing that is heavily reliant on quantum theory concepts, i.e. the behaviour of energy at the atomic and subatomic levels. While ordinary computers use ones and zeros to represent data, quantum computing uses qubits, which can be in several states at the same time. Nanocomputing has nothing to do with quantum computing but can have a huge impact on it since being able to use microscopic-sized processors can dramatically improve quantum computing performance[21].

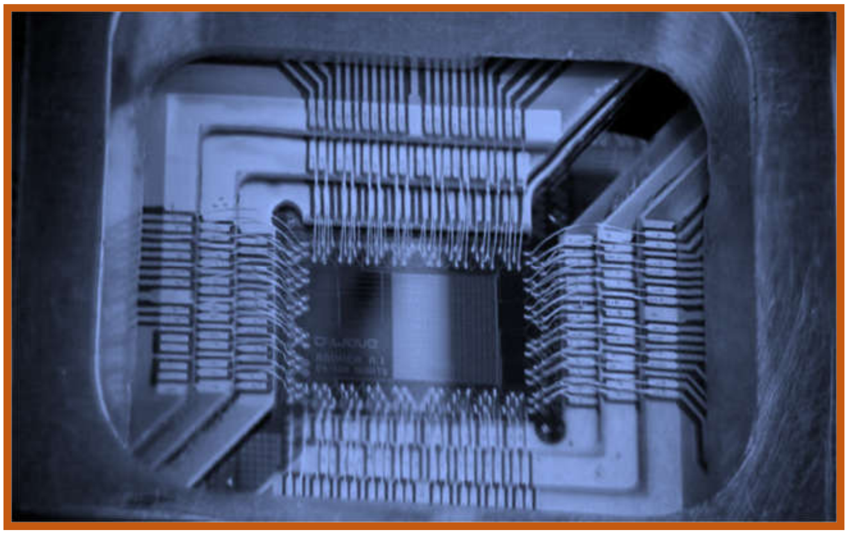

Fig. 2. Quantum Computer

Even today's high-speed computers are basically similar to their 30 tonne fore fathers, which were equipped with some 18000 vacuum tubes and kilometres of wires. The technology hasn't changed all that much from Charles Babbage's first computer and KonardZuse's final development in 1941, despite the fact that they're faster and smaller. A bit (0 or 1) is the basic unit of information in a typical digital computer like the ones we use today. The magnetization on a hard disc platter or the charge on a capacitor are two examples of macroscopic physical systems that physically materialise binary bits. As a result, a document containing n letters and stored on a computer's hard drive contains 8n bits, each of which is a 1 or a 0. This methodological approach will eventually come to a halt[9]. In other words, we need to find a new technology that will help us progress. And this is where quantum mechanics can be used to create a new way of processing information. Richard Feynman, the 1982 Nobel laureate in physics, came up with the concept of a 'Quantum Computer,' a computer that takes advantage of quantum mechanics [22]. Quantum computers have long been considered a science fiction concept, but recent advances have taken the concept into the mainstream of everyday life. The most fundamental building component of a computer can only exist in one of two unique states: 0 or 1 in a classical model. When it comes to information at a quantum level, qubits are the most fundamental unit of data. As a result, it is no longer binary, but rather quaternary in structure. The fact that a qubit can exist in states other than the binary 0 or 1 of a classical bit is due to its adherence to the laws of quantum physics. As a result, it is possible for a qubit to exist as either zero or one, or both zero and one at the same time[18]. Classical physics governs most everyday events, therefore this may appear to be counterintuitive at first glance. There are two universes in the coherence superposition of a qubit, which can be described as being in two places at once. There are two distinct values that can be represented by a single qubit. Aqubit can be used to conduct two operations at the same time. For a two-qubit system, there would be four operations taking place at the same time. As a result, the 'quantum parallelism' increases exponentially as the number of qubits increases.

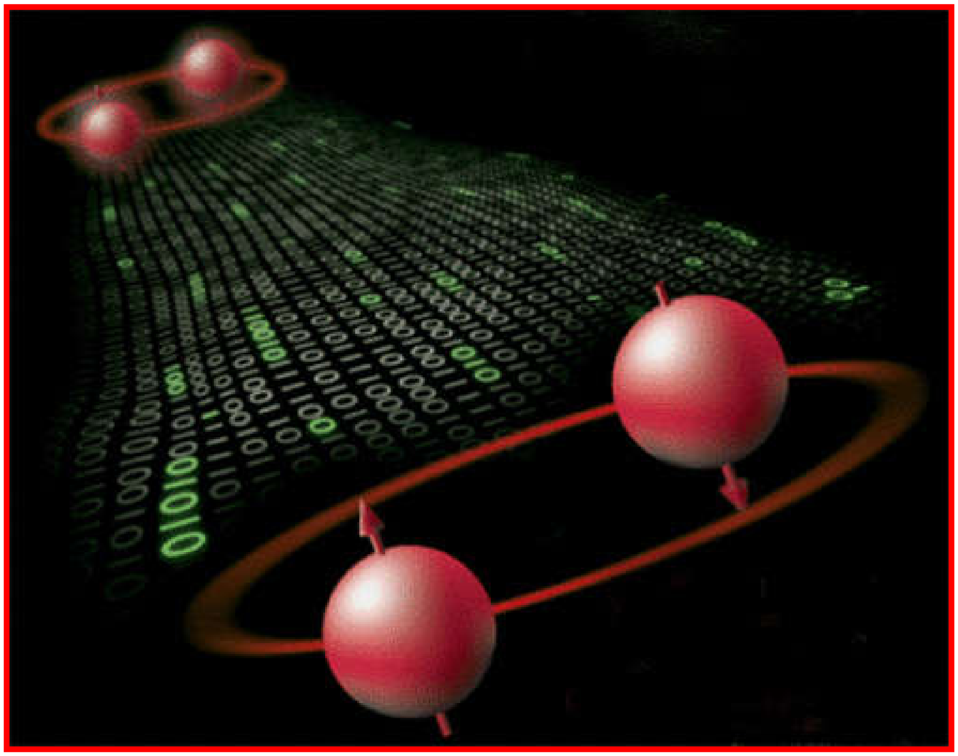

Fig. 3. Qubit exists as either zero or one, or both zero and one at the same time

A. Building a Quantum Computer

Unlike a conventional computer, a quantum computer is not built with transistors and diodes. Quantum computing requires a technology that allows "qubits" to exist in an equilibrated state between 0 and 1. There are a few methods being tested and some are showing success, but the best method is still unknown. The following are two examples of such methods:

B. Quantum Dots

This is an illustration of how a qubit might be implemented. In its most basic form, it consists of a single electron that is confined within an atomic lattice. The electron is stimulated when the dot is subjected to a laser pulse that has a specific wavelength and duration; the electron is then restored to its ground state when the dot is subjected to a second laser pulse. One is able to conceptualise the ground state and the excited state of the electron as being equivalent to the 0 and 1 states of a qubit. The laser light can be thought of as a controlled NOT function due to the fact that it toggles the qubit between the states 0 and 1, and then back again. If the pulse of the applied laser beam is just half of its normal duration, the electron will be placed in a superposition of both its ground state and its excited state [23]. One may say that this is equivalent to the coherent state of the qubit. Pairs of quantum dots can be used to describe logic functions that are significantly more sophisticated. There are, however, a number of practical issues to contend with: It takes about 1 nanosecond to excite an electron, and then it returns to its ground state, requiring only a microsecond of laser pulse time to excite an electron. Thus, there is a limit to the number of computations that can be carried out before the information is lost. " Quantum dots are extremely difficult to make because they are so small. A nanometer is the smallest unit of measurement. Quantum dots can't be used to build a computer because the technology to do so is no longer available. Quantum dots can respond to different light frequencies instead of being crammed into a limited region if users don't require thousands of laser beams.In this way, a laser capable of reliably re-tuning itself would be able to selectively target different groups of quantum dots with different frequencies of light. However, this is purely hypothetical at this point; no such technology exists.

C. Quantum Computing

The most recent development in quantum computing is a radical departure from the norm. There is no longer a requirement that the quantum medium must be small and isolated from the rest of the world. Instead, the information is stored in a sea of molecules. Nuclei within the molecules spin in specific directions when held in magnetic fields, which can be used to describe their state; an upward spin would indicate a1 and a downward spin a 0. Techniques such as Nuclear Magnetic Resonance and radio waves that are capable of flipping nuclei from spinning up to spinning down (a state of 0 and 1 respectively) can be used for this purpose. The molecule serves as both the quantum computer and the qubit in this scenario. However, a'mug' of liquid molecules rather than a single molecule is used in this technique [24]. The spin states of the nuclei within the molecule remain unchanged even if the molecules bump into each other. In this case, too, decoherence is still an issue, but it takes much longer before decoherence sets in. The researchers also believe that before the qubits begin to de-cohere, they should be able to perform a few logical operations. Liquid computing was invented by MIT's Dr. Gershenfield, who is widely regarded as a pioneer. To demonstrate the superiority of this approach, the members of his team's research team were able to add one and one together. It is necessary to have more qubits in order to perform more complex tasks, but this requires more complex molecules with a greater number of nuclei. Caffeine is an excellent candidate for this role. The transition to 10-qubit systems appears simple based on what has been accomplished thus far. Dr. Gershenfield predicts that such a system will be feasible within the next few years.

D. Quantum Communications

Researchers in quantum computing have discovered a new area of communication that could be useful in the future. The area aims to provide secure communication mechanisms by exploiting the properties of quantum mechanical effects. The polarisation of photons (i.e. the orientation of the oscillation of a photon) can encode information in quantum communication. Rectilinear orientation can be thought of as 0 and Diagonal orientation can be thought of as 1. The photons must be measured with the same polarisation as the one used to transmit the data in order to decode it at the receiver's end [25]. An eavesdropper will not be able to listen to the message undetected if it is sent using this method. It's a promising future for quantum communications thanks to British Telecom's research in this area.

E. Obstacles and Pitfalls of Quantum Computing

Two and three qubit computers have been built that are capable of performing simple arithmetic, as well as data sorting operations, in the quantum computing field since its conception. However, there are a few significant obstacles that stand in our way of creating a machine that can compete with today's digital computers. Error correction, decoherence, and hardware architecture are among the most challenging of these issues. Each has its own technical promises, which we can see in great detail. Error correction should be built into every piece of critical computer software. Mistakes are made by machines. Redundancy is built into classic computers to catch these kinds of mistakes. They perform each basic calculation multiple times and then accept the answer that is most frequently correct. However, this method will not work on a quantum machine because any observation prior to the computation will alter the effect of that computation [26]. Quantum error correction, surprisingly, is possible. One of the pioneers in the field of quantum computing was Peter W. Shor of the Massachusetts Institute of Technology (MIT) and physicist Andrew M. Steane of the University of Oxford. Detection of error is done in a manner that does not reveal any information about the current computation (and thus does not ruin the superposition). After that, another quantum computation is used to correct the error, ensuring the integrity of the quantum system as a whole. When something is so powerful, like quantum computing, it can also be very vulnerable. For instance, consider the coherent state of a qubit. After interacting with the environment, it will deco here and fall into one of the classical states. This is a decoherence issue. Quantum computers are hindered by the fact that quantum parallelism, brought about by coherent states, can only be harnessed in such systems. The difficulty of getting a solution from the quantum computer is exacerbated by the fact that even looking at a qubit can cause it to decohere. Quantum mechanics researchers use entanglement as a workaround for this issue. For a practical quantum computer, scientists must devise ways to measure the system's integrity without interfering with its functionality. It's possible to get entangled. Applying an external force to two atoms in quantum physics can cause them to be linked and give the second atom the properties of the first atom. This is called entanglement. It is therefore possible to leave an atom to spin in any direction. After being disturbed, it will immediately select one of two possible spins or values; and at the same time, the other entangled particle is likely to select the opposite. In this way, scientists can determine the value of the qubits without having to look at them in person [15]. Los Alamos National Laboratory and MIT researchers led by Raymond Laflamme in 1998 were able to spread a single qubit across three nuclear spins in each molecule of alanine(trichloroethylene) molecules in a liquid solution. This was accomplished through the use of Nuclear Magnetic Resonance technology (NMR). This was an important experiment because it made it more difficult for the data to be corrupted by dispersing it. The most widely used component of quantum hardware architecture is nuclear magnetic resonance, which has emerged as a result of a number of noteworthy experiments.

F. Benefits and Applications of Quantum Computers

There are numerous ways in which nanotechnology has helped computer science, including improving processor efficiency and ensuring the continuity of MOORE'S LAW, among others. The desired effect requires the coordinated efforts of a billion or a trillion small particles. And no one can undertake advanced programming on their own since they lack the necessary processing capacity. Bottom-up nanotechnology, like crystal growth, embryonic development, or the smart behaviour of ants, relies on the emergence of collective, emergent behaviours as a result of relatively simple interactions between the system and its environment. Bottom-up nanotech will require a strong foundation in computer science, particularly in areas like swarm intelligence [27]. Increasing amounts of data are being stored and processed on smaller, faster, and more portable systems that are powered by nanotechnology in computing, communications, and other electronic applications.

Among the many applications that are constantly evolving are:

- With nano-scale transistors that are faster, more powerful, and more energy-efficient; soon your computer will be able to store all of its memory on a single tiny chip.
- When a system shuts down or crashes, the data can be saved quickly and effectively using nanometer-scale magnetic tunnel junctions, which can also be used to gather vehicle accident data.
- Organic light-emitting diodes (OLEDs) are employed in numerous modern electronic products such as televisions, laptops, cell phones, digital cameras, and more because of their nanostructured polymer film construction. OLED screens' wider viewing angles, lower weight, and higher picture density make it possible to achieve brighter images in a flat format.
- Drug response simulation that is more efficient than existing medical studies. As a result, new medications will be developed more quickly.
- Improved computer models lead to a better knowledge of disease progression.
- Improvements in global transportation logistics.
- To avoid economic downturns, better financial modelling is needed.
- The creation of self-driving cars that can solve real-world driving difficulties faster than human drivers.
- The analysis of vast amounts of astronomical data quickly in order to find new planets.
- The ability to create quantum simulations to model the behaviour of subatomic particles without having to create the severe circumstances required to observe these particles.
- Machine learning has been improved in order to advance artificial intelligence.

G. Applications of Quantum Computers

We must keep in mind that a quantum computer will not necessarily outperform a classical computer in computational tasks unless the programme algorithms running on them are specifically tailored to do so [28]. Quantum computers must use algorithms that take advantage of quantum parallelism's real power in order to demonstrate their superiority. Developing such algorithms is a challenge. Shor's algorithm and Grover's algorithm are the only two of their kind that we know of. With the help of these algorithms, a quantum computer will outperform its classical counterpart by a wide margin. Using Shor's algorithm, even very large numbers can be factored quickly. Factoring a 1000-digit number using current algorithms would take a classical computer 10 million billion years, but just about 20 minutes on a quantum computer [29]. Thanks to Grover's algorithm's quantum parallelism, even a database with N unsorted items can be searched. In his method, root N searches can be performed. For example, the database is effectively distributed across multiple universes using quantum parallelism, allowing one search to find the desired entry.

4. Future Promises and Fears of Nanotechnology

In nanotechnology, interests from physics, chemistry, biology, medicine, and computer science are all intertwined. Here, we're interested in seeing how developments and research in computer science can help and propel inventions. Nanotechnology has the potential to revolutionise a wide range of fields, including science, medicine, engineering, commerce, and even everyday life [30]. Fears about the long-term effects of nanotechnology on human life and the environment are also prevalent. Negatively viewed, Nanotechnology appears to be too hazardous. Looking at the bright side, we can see that its promises cannot be ignored. We should not let our apprehension keep us from exploring these possibilities because the promises are simply too good. However, it is necessary to have a set of guidelines and ethical standards in place to keep such a technology from being misused. Computer science, in particular, will benefit from Nanotechnology's advances.

5. Conclusion

The advancement of nanoscience and nanotechnology has made it feasible to study and manipulate the smallest conceivable components of all matter. With the help of technology, we were able to surpass our natural limits. Owing to nanoscience and nanoscale manufacturing, we will soon be able to manipulate qualities at their very source, in the atomic and subatomic particles that make up all matter. When we apply our existing technology to nanotechnology's amazing capacity to create devices from the smallest building blocks, we are on the approach of a paradigm shift in how we perceive and control the physical world around us.. Vaccines, computers, automobile tyres, and other objects we haven't even thought of yet could all be affected by this. We've arrived at the age of nanotechnology, but we haven't yet reached its full potential. Since the invention of transistors, there has been no major breakthrough in the field of computer technology. It's imperative that computer scientists focus on developing systems made up of many nanolevel particles that automatically form a large scale integrated system capable of high performance..

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Author Contribution

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Conflict of Interest

The authors declare no conflict of interest.

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