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DNA Computing

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Abstract:-*Biology and computer science are two different sciences but both sciences are sister.In this research I intend to show that how biology is used in computation. In future, how biology is used to make enhancement in computer sciences. Use of biology in computer science is known as biological computation. Biological computation is a subfield of computer science and computer engineering using bioengineering and biology to build computers. One of them is DNA computing. DNA computing is a way that aims at harnessing individual molecules at the nano-scopic level for computational purposes. Computation with DNA molecules possesses interest for researchers in computers and biology. Due to its vast parallelism and high-density storage facility, DNA computing approaches are used to solve many problems. DNA has also been explored as an excellent material and a fundamental building block for building large-scale nanostructures, constructing individual Nano mechanical devices, and performing computations*

Keywords:- **DNA introduction, histroy, advantages and disadvantages, working, experiments and future.**

INTRODUCTION:-Every scientist knows that every computer which is based on silicon chips has a range of speed to perform task. So in future we need

alternative of such computers to get high speed. Scientists have been searching alternative of silicon based computers to solve computational problems with a high speed. This research results into DNA

Computing.DNA computing can be a new mile stone in the world of computer sciences in order to solve

computational problems with a great speed. DNA computing is a method which can be used to solve

computational problems with the help of biological and chemical operations on DNA strand. Adleman was the first researcher who introduces DNA computing. After him more researchers are motivated by the promising future of this area and start working on it.

DNA:- DNA stands for the deoxyribonucleic acid(DNA).it is the master molecule of every cell.it passes heredity from parents to their siblings. DNA act as the basic storage mediums for living cells. It stores the heredity traits. Slight change in DNA of living cells of multicellular organisms results into variations of characteristics of species.

DNA Computation :- DNA computation, as the name implies, uses DNA strands to store information and taps the recombinative properties of DNA to perform operations.DNA computer uses the recombinative property of DNA to perform operations.The main benefit of using DNA computation to solve complex problems is that different possible solutions are created all at once. This is known as parallel processing. Humans and most electronic computers attempt to solve the problem one process at a time (linear processing).

DNA itself provides the added benefits of being a cheap, energy-efficient resource.The structure of the DNA allows the elements of the problem to be represented in a form that is analogous to the binary code structure. Trillions of unique strands of DNA

are able to represent all of the possible solutions to the problem. Some scientists predict a future where our bodies are patrolled by tiny DNA computers that monitor our well-being and release the right drugs to repair damaged or unhealthy tissue.

History of DNA computing:- This field was initially developed by Leonard Adleman of the University of Southern California, in 1994. Adleman demonstrated a proof-of-concept use of DNA as a form of computation which solved the seven-point Hamiltonian path problem. Since the initial Adleman experiments, advances have been made and various Turing machines have been proven to be constructible.

While the initial interest was in using this novel approach to tackle NP-hard problems, it was soon realized that they may not be best suited for this type of computation, and several proposals have been made to find a "killer application" for this approach. In 1997, computer scientist Mitsunori Ogihara working with biologist Animesh Ray suggested one to be the evaluation of Boolean circuits and described an implementation.

In 2002, researchers from the Weizmann Institute of Science in Rehovot, Israel, unveiled a programmable molecular computing machine composed of enzymes and DNA molecules instead of silicon microchips. On April 28, 2004, Ehud Shapiro, Yaakov Benenson, Binyamin Gil, Uri Ben-Dor, and Rivka Adar at the Weizmann Institute announced in the journal Nature that they had constructed a DNA computer coupled with an input and output module which would theoretically be capable of diagnosing cancerous activity within a cell, and releasing an anti-cancer drug upon diagnosis.

In January 2013, researchers were able to store a JPEG photograph, a set of Shakespearean sonnets, and an audio file of Martin Luther King, Jr.'s speech I Have a Dream on DNA digital data storage.

In March 2013, researchers created a transcriptor (a biological transistor).

Why we need DNA Computing.

Limitation of silicon based computers:- Conventional computer technology is based on silicon chips. Although silicon based computers have renovated the whole world from the start of computer age (1957 to till now). Since its invention, the whole advancement in siliconbased technology is according to the Moore's Law and is achieved by doubling the processing speed and memory capacity at a very high rate. These tasks of high speed and memory capacity have achieved by reducing the size of components on chip and placing large number of transistors on IC chips. On the other hand, due to this continually doubling the numbers of transistors on these chips, also reducing the size of these chips and increasing density will cause some serious physical problems in stable computing, in the next few years. Moreover, this technology is going towards its decay. This limitation of silicon based computers make mind of scientists and researchers to discover a new thing in world of computer.

Advantages of DNA computing over Silicon based computers:-

Speed:- "the speed of any computer is based on two things: (i) how many parallel process it can done at a time",(ii) how many steps it can perform per second". The better point about biology is that these factors can be very large : for example a small amount of water contains near about 1022 molecules. These factors are same among the DNA computing. DNA computing could potentially have vastly more parallelism that conventions ones".

Large memory capacity:- silicon chips have a extent up to which it can store. DNA provide extremely dense information as compare to silicon chips. One gram of DNA when dry can occupy a volume of approximately one cubic centimeter, can store as much information as can by approximately one trillion CDs.

Energy:- DNA computers follow low power dissipation. Existing super computers can execute a maximum number of 109 operations per joule. But in compare of these computers DNA computers are very energy efficient. They can perform 2*1019(irreversible) operations per joule. We know that energy is a very valuable future. So, this characteristic of DNA computers can be very important and valuable.

Combinational problems:-Experiment has proved that DNA computing are suitable for performing complex combinational problems, even until now it costs still several days to solve the problems like Hamilton path problems. But then key point us that Adelman's original and subsequent works demonstrated the ability of DNA computing to obtain tractable solutions NP-complete and other hard problems.

Clean, Chip And available:- DNA computers are clean chip and available it is clean because we have not to use any harmful material to produce it and also no pollution generates. It is cheap and available because DNA easily found in nature while it is not necessary to exploit mines. We can get it from organisms and refine to use for DNA computers. This is one of the great performances of DNA computer.

Problem with DNA computing:-

- DNA computer takes much time to solve simple problems when compared to traditional silicon computers.
- DNA computers take longer time to sort out the answers to a problem than it took to solve the sample problem.
- Sometimes there may be an error in the pairing of nucleotides present in the DNA strands.
- DNA computing requires quantity of DNA that can only be used once as reuse can contaminate reaction vessels and leads to less accurate results.
- In some cases the type of genetic sequences that would have to be synthesized to make fully functional genetic robots would be expensive using current methods.
- The DNA molecules can fracture. It means after sometime you are computing, DNA system is gradually converting into water.DNA molecules can break meaning a DNA molecule, which was part of your computer get fracture after a extent of time.

How DNA computers works:-

- **DNA** computing is basically designed for solving large mathematical problems. As we know that DNA computer works on the principal of parallelism. So it is effective to solve such type of problems. There is a no. of algorithms which can be implemented on DNA computing. These algorithms based on the dynamcic programming.
- Graph connectivity and knapsack nare some classical problems which are solvable in this way.
- DNA has a very unique data structure and has ability to perform a number of parallel operations at the same time. It provides a different point of view to look at computational problems. Transistor based computers are von Neumann machine that means CPU repeats the same" fetch and execute cycle" over and over. It fetches an instruction and suitable data from main memory and then execute it. But DNA computers are non von Neumann machines. These are stochastic machines. It approach computation in different manner from

regular used computers for solving different type of computational problems.

- DNA computers are a type of bio-molecular computers. Such type of computers works at molecular level. Biological and mathematical problems have a lot of similarities. DNA encodes information for living organisms like animals, human being extra. It is stable and very predictable in its chemical reactions. That's why it suits properly to solve mathematical problems.
- In DNA computers we do not use electric impulses for the representation bits of information. It uses the chemical properties of molecules. To get these chemical properties it examines the pattern of combination and growth of string. DNA computers use enzymes which are bio catalysts that can be considered as 'software'. Such so called software is used to execute the desired problem.
- DNA computers uses its components that is acids A(adenine), C(cytosine), G(guanine) and T(thymine) in the form of memory units. When we use DNA computers for computation, then computation is taking down in test tubes. Input and output results are shown by the strands of DNA genetic sequences of these strands encode information.
- To execute a program on DNA computer, a series of biochemical operations is executed. In there biochemical operations synthesizing extracting, modifying and cloning of DNA strands is done.
- The main and basic difference between conventional and a DNA computer is the storage capacity. Electronic computers have only two positions either on or off but DNA computers has four positions(C, G , T, H).
- To get answers of any problem each strand of DNA is concluded as we know that in DNA computers DNA strands represent information and every strand can represent a possible answer. In every experiment, DNA is checked/tested so that every conceivable answer of a particular problem can be included.
- DNA molecules are bind together in predictable manner, so it gives us a powerful "search" function. If experiment get success, then DNA computer ignore all wrong answers, except one or more molecules have right answers and further these molecules can work together. So we could therotically about 10 trillion calculations executing same time in a very little space.
- It can be happen that a lot of possible answers are wrong but few may be correct.now the task is to get that which is the right one and remove all false by using restrictive enzymes. It is done by considering all the strands simultaneously to the series of chemical reactions. It tests the mathematical computation on electronic computers on every each possible answer. Once the reactions are complete reserarchers analyze the strands to find the answer.

Experiments done in DNA computing:-

In 1994, Adlemen was the first person who used DNA molecules to solve a basic version of the "travelling salesman" problem.in this the task is to find the most efficientpath through several given cities. Adleman tells that the billions of the molecules in a single drop of DNA contained raw computational power that is much greater than silicon based computers.after it scientisits run it intotough practical and theoretical barriers and come to know that there may never be a computer which is made of DNA that can directaly rivals the silicon based computers. But it does not means that scientists have given up. Computer scientists have not found a path which fresults computer from test tube to desktop. According to Adleman DNA computing is about surprising new combinations of biology and computer science that can push the limits in both fields- sometimes in unexpected directions.

DNA tiles:-

Next approach is given by Erik Winfree, a 30 year old scientist at california institute of technology in 1999. He creates nanoscopic building blocks out of DNA. These blocks not only can store data but also designed as sayed by Winfree "programmed" to execute mathematical operations by fitting together in specific way.basically, DNA exist in the form of two intertwined strands having chemical letters A,G,C,T the familier double helix. But according to Winfree's DNA tiles are made by knotting together three or more than three of these strands, making "tiles" about fifteen nanometers i.e billionths of a meter along the longest side. Using advantage of ability of DNA i.e selectively recognize other strands of DNA, Winfree has "coded" edges of these tiles in such manner so that they can come together in just the right way to make tiny built-to-order structures. Programming DNA in this way could give chemists the kind of deft control "that may allow them to build more complex structuree than any considered so far", says Paul Rothemund, a doctrol student in Adleman's USC lab.

DNA Dominoes

Nadrian Seeman, was a chemist at New York University. He created cubes, rings , octahedrons and other unlike shapes from DNA Helix. Winfree saw a way Seeman's strange versions of DNA that could be used for computation. Winfree was inspired by the theory of Wang tiles. This theory was related to a bit of recondite mathematics related to the patterns that can be created using squares with numbered sides. Just like dominoes, the numbers present on each side of Wang tile determinde which other tiles it is allowed to touch. Establishing these matching rules very carefully,complex and interseted patterns can emerge as more tiles added. But it is more than the game of mathematical dominoes. It is because these tiles carry both data and simple rules for making their combinations. In fact ,the right set of these hypothetical constructs you could, in theory, do anything an electronic computer can. Applying this strategy to DNA computingit could side step one of the fundamental problems as it has bedeviled the field from too much lab work. DNA computing is good at producing a vast number of answers quickly but things get slow down to find right answers.

DNA can produce a lot of answers in less time but most of them are repeated and most of them are in correct. So the next task was to discard all the wrong and repeated answers, something that could be in jiffy pc but in Adlemens case it requireds a dozens of lab operations that is another time consuming step. The Dna tiles could solve these problem because DNA tiles follow simple rules to get correct answers."ideally you just put tiles in a test tube and get correct answers. Thom Labean a biochemist at Duke, Reif hopes to put the idea into practice by creating simple molecular abacus out Of DNA tiles. The main goal is to add binary numbers from zero to eight. With the genetic letters standing in for 0s and 1s, the team has designed sets of tiles, each represents a possible coulmn in an addition. Rules for combining coulmns correctly are coded into loose strands of DNA protruding from the sides of the tiles.

If all goes well, the experiment will generate several trillion multi-tile structures each of which has carried out an orderly addition of three binary bits.

Nanotech C++

The raw power of DNA computing keeps the field moving in spite of all the dauntical technical obstacles. Collabrating with Rothemund And Adleman at USC, Winfree aims to make a two-dimensional shape known as Sierpinski triangle. This triangle is named after the Polish mathematician who discovered it in 1915, the triangle is so complex and beautiful fractual produced by repeating a simple geometric rule. The team plans to construct a real world version of the triangle in a test tube using only different dna tiles.each tile type is designed to carry out a simple program-to add itself to the growing shape or not, depending on the molecular cues provided byb the triangle's outer edge.

In the hands of nanofabrication experts like NYU's Seeman, the DNA tiles could lead to easier methods to make exotic molecular structures-doing for nanotech what CAD and pre-fab building materials have done for the construction industry. Seeman says that "our expectation is that this approach can be applied to making designer materials and interesting patterns much more economically".

The futrue

DNA Manipulation technology has rapidly improved in recent years, and future advances may make DNA computers more efficient.

The University of Wisconsin is experimenting with chip-based DNA computers.

DNA computers are unlikely to feature word processing, emailing and solitaire programs.

Instead, their powerful computing power will be used for areas of encryption, genetic programming, language systems, and algorithms or by airlines wanting to map more efficient routes. Hence better applicable in only some promising areas.

Conclusions :-

DNA computing is at present on the ground of research. It is in the research of scientists. It can be milestone in the world of computer science. It may be possible that DNA technology can be integrated with more traditional approaches to create DNA/silicon hybrid architectures or with in soft wares. Since software is more flexible and suited to rapid adaption than hardware, we may see DNA computing benefits being implemented and exploited by in software first, leaving hardware to play catch up.

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