DNA Computing

Manan Bakshi[1], Pallavi Bhagat[2], Iti Sri[3], Mr.Piyush Kumar Pareek [4], Mrs.Priyanga P [5]

Student , Department of Computer Science, KSIT, Bangalore[1]
Student , Department of Computer Science, KSIT, Bangalore [2]
Student , Department of Computer Science, KSIT, Bangalore [3]
Asst.Professor, Department of Computer Science,KSIT,Bangalore[4]
Asst.Professor, Department of Computer Science,KSIT,Bangalore[5]
*Email ID**:s**: m.bakshi11@gmail.com[1] ,palls_saggs@gmail.com[2], iti.mishra18@gmail.com3 ,piyushpareek88@gmail.com[4], p.priyanga@gmail.com[5]*

Abstract

This paper is attributed to the most widely acknowledged technology of computer advancement i.e. DNA computing. As the name itself reveals the varied corners of the field. This paper will centre round the various tasks and modes of the fast growing technical field made easy by this invention. This will incorporate in itself the work process, the various modes of practical use and the coming future prospects in the concerned section. This paper lays forth the complete vibrant mean of conducting the work at Molecular level. This covers all the traits and applications regarding this level resulting as a new era in computing system.

1. INTRODUCTION

DNA computing is one of the most new and reliable technology in the field of computation. It has emerged in last ten year as new research field by the intersection of Computer Science, Biology, Mathematics and Engineering. Although in 1950 Feynman predicted for computation at molecular level but it came in existence in 1994, by Adleman Experiment. He gave the idea of computer technology at molecular level which was really a great job.

Here in this paper we will discuss some basic points of this field of computation. In the first section i.e. problem with traditional computing (I), we will discuss about the points that why we need DNA computing? What were the main drawbacks of silicon based computer which forced the scientist to think for alternate option for calculation rather than on silicon chip? After that we'll discuss the birth and the progress of this technology in history section (II). Next section i.e. DNA computing: Working (III), will tell the logic of gates made by DNA and their working. Section IV is the comparison between

DNA computing and Silicon based computing. At last the conclusion and the references will be given.

2. PROBLEMS WITH TRADITIONAL COMPUTING

We have made huge advances in miniaturization since the day of room sized computer and yet we the architecture given by *von Neumann.* But there exist two main causes which made scientist to think beyond the current computational system.

The first limit is miniaturization limit in which it is being said that there is a limit for silicon chip that how far it's can miniaturization can go. That limit of miniaturization hit by Heisenberg Uncertainty Principle (HUP) which states that the act of observing these component affect their behavior. Due to this became impossible to know the exact state of component without fundamentally changing its state. The second is *von Neumann* bottleneck. This is imposed by need for the central processing unit (C.PU.) to transfer instruction and data to and from the main memory by sequential logic.But these all not happened in the case of DNA computing because it refuse the limits of miniaturization, held the parallel processing which gave it the strong point for developing at this level.

In July 3, 2002. In Tokyo first practical
DNA computer was developed by Olympus Optical Co. Ltd.

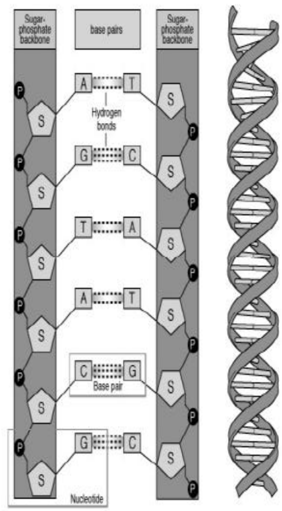
3. HISTORY

The history of DNA computing is short but full of amazing technological achievements.DNA computation started in 1994, when Learnard M Adleman, a researcher of southern California university solved a version of a mathematical problem called the “the travelling salesman problem” using DNA in test tube. The problem was to find the all possible route that passes through a certain set of cities exactly once. As the experiment took 6 days to complete but he gave the birth to an idea that molecular computation is possible. 3 years later, university of Rochester researcher created simple Boolean logic gates made from DNA. As we know that logic gates are basic of modern computing so we were one step closer to manufacture of DNA computer. The development of loic gate opened the door to make sophisticated DNA based processor.in 2002, scientist at the Weizmann institute of science in Israel unveiled a working microprocessor made of only protein structure and DNA molecule. A year later they had engineered a computer made of a single strand of DNA which can perform 33 trillion of operation in 1 second. Super computer made by IBM can perform 1.03 trillion operations per sec.

In December 3,1990, Princeton university, with the help of DNA computing solve a simple knight problem.

4. MOLECULAR BIOLOGY

Before dealing with DNA computing first we have to understand some basic terms reated to DNA. DNA i.e. Deoxy Ribonucleic Acid is composed of nucleotide building block. The nucleotides are purine: Adenine (A), Guanine (G) and pyrimidine: Thymine (T) and Cytosine(C). Single stranded nucleotide or oligonuleotide are formed by connecting nucleotide together with phosphodiester linkage. The single strand of DNA can form a double stranded molecule when the nucleotitide's hydrogen bond to their watson-crick compliments, A'=T and G'=C and vice versa. Oligonucleotide bind in an antiparallel way with respect to the chemically distinct ends 5' and 3', of DNA molecule. The Hydrogen bonding or base pairing ofone oligonucleotide to another is called hybridization. Oligonucleotide can hybridize in various alignment that are shifted from the designed one. The effect of reaction condition is characterized by hybridization stringency.

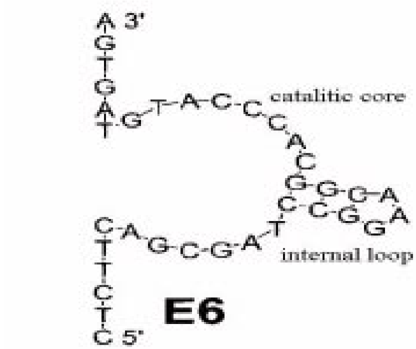


5. DNA COMPUTING: HOW IT WORK?

To build a computational system, we require some basic parts to operate the digits i.e. the logic gates and that we build by the help of some enzymes by reacting them with DNA strand to produce desired output.Aldmen has given a new theory and possibilities in the field of computing. But his process was too slow that a human being can solve that problem on paper faster than that DNA computer. So we needed some basic things by which we can challenge the silicon based computer. That basic thing was logic gate by which we can simply design a very fast computer with DNA. Basically there are various gates which have been made like sensor Gate, NOT, AND, XOR, OR and NAND Gate and Half Adder.

To construct logic gates we use oligonuleotides as input as well as output. Reason behind it is that, by this output of first can become input of second permits the connections of gate easy to make a system. A normal structure of DNA cannot be used to make gates as they will never be able to provoke reaction alone. It is necessary to intervention of an enzyme. DNA can function if it is configured in the correct way. The catalytic DNA is called Deoxyribozyme. These are of special structure of oligonucleotide configured in such a way that in contact with fixed substrate they catalyze a chemical reaction. Mainly we take E_6 DNA. It has catalytic core and an internal loop. These loops are activated with certain sequence of nucleotides. When the complementary sequence in solution then only loops open and the nucleotide anneal(pairing to form double helix structure), this is called active form. Here ‘0’ means when no input is given and ‘1’ means when there is a complimentary sequence is present. Rest of gate is done by washing, adding to the solution a complementary sequence of nucleotide. After anneal if there is cleavage(splitting of substrate from its single ribonuleotide), then there is ‘1’ in output otherwise its ‘0’.

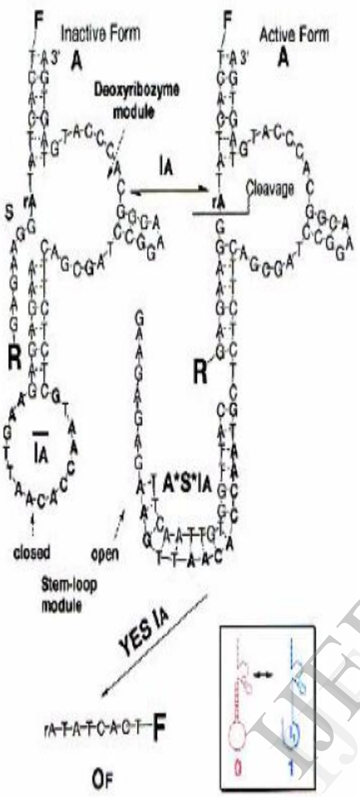
Here if no complementry of nucleotide is present then the loopwill never open and output will be zero and if there is desired compliment then the loop will open and it will anneal with the input hence output is ‘1’. Cleavage is produce and emission of one is detected using fluorescence spectrum. The molecular diagram of the sensor gate is as :



A) SENSOR GATE:

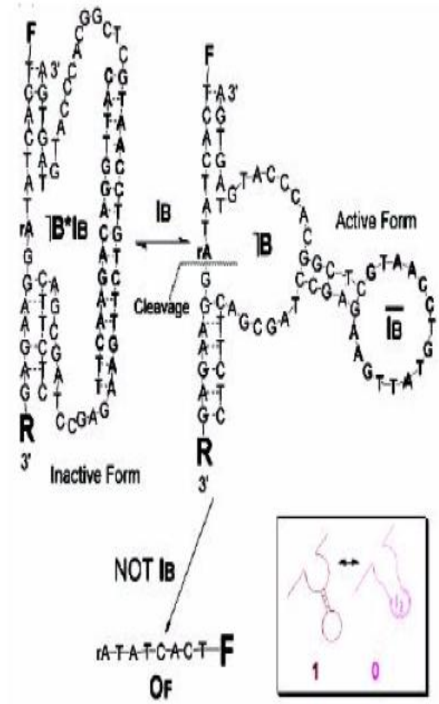
Sensor gate is a gate which transfer the detected(done to determine the presence of at least single strand) input to the output. The truth table for the sensor gate is as follows:

INPUT	OUTPUT
0	0
1	1



B) NOT GATE:

Here in not gate the output will be opposite to input i.e. if the input is given ‘0’ then output will be ‘1’ and vice versa.

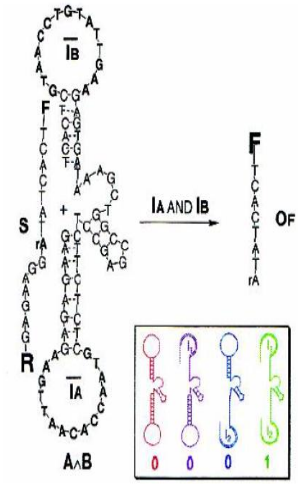


C) AND GATE

Like these there are all other gates are present which are differ in their stem loop structure so that they can be operated in that manner. If we want to make AND Gate then we use E8-17 deoxyribozyme. Basic thing about the AND Gate is that we will

Here the different stem loop structure is used from that sensor gate. Here we use an activated stem loop due to which when trere is input the hybridization took place, produces the changing of the deoxyribozyme into its inactive form. As a result no output i.e. ‘0’. And when there is no input then loop remain active and it cleave the substrate and produce output oligonucleotide. The molecular structure of NOT Gate is as:

both the input are present. The molecular diagram of the following is as follows.



6.ADVANTAGES AND DISADVANTAGES

There are some points which put this DNA computing a step ahead from the silicon based computer.

The first one is parallelism which means that in compare to silicon based computer the processing power of DNA computing is very fast[6][7]. Second property is its gigantic capacity of memory for storing data and instruction. In tha DNA molecule one square inch of it can store one gigabits of data[7]. Third is related to power consumption. A DNA computer can perform $2*10^9$ operation per Joule. A super computer can do 10^9 operations per joule[7]. Beyond these there are some other advantages too like very light weighted and consumption of electricity is very much low[7].

7. CONCLUSION

Right now, research in the this field is at primary level. as it has been proved that the operation which a silicon based computer can do, can be easily and fast performed by DNA computer. So to make DNA computer practically useful, research work in both the sections i.e. computer science and biology is necessary. Computer science needs to elaborate theDNA algorithm so that they can interact naturally with users and biology needs to develop some more advance enzymes for the reaction. if this happens then the day may come when we will be having the super computer just into our palm.

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