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Review Paper on Bio Computing – Mechanism and Application

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ABSTRACT

Bio computing or biological computing is the future of technology that operates at the convergence of biology, engineering, and computer science. It seeks to use cells or their sub-component molecules (such as DNA or RNA) to perform functions traditionally performed by an electronic computer. The ultimate goal of Bio computing is to emulate some of the biological 'hardware' of bodies like ours - and to use it for our computing needs and for some application area like medical. From less to more complicated, Bio computing uses molecular biology parts like DNA, RNA, proteins as the hardware to implement computational devices. By following pre-defined protocols, often hard-coded into biological systems, these devices are able to process inputs and return outputs - thus computing information. The result is small; faster computing processthat operates with great accuracy. The meaning of BIO-COMPUTER is a computer that uses components of biological origin instead of electricalcomponents. It is also called DNA Computing because DNA has the capability to store, retrieve large amount of data for thousands of years. It performs trillions of operations simultaneously. It can conduct large parallel searches and efficiently handle massive amount of working memory. It is expansion of nanobiotechnology. The most important applications of bio-computers are concentrated on illness detection, cancer, drug release and other various medical purposes. Another application is speed of biological computing comparative to super computer it's predicted that Biological computing could surpass traditional computers with their unparalleled speed.

Keywords: Bio computing, biological computing, DNA computing, Nanotechnology

INTRODUCTION

Information processing and data storage are centre subject matters inPresent-day "digital" society. However, the modern-day computingand data storage modes, collectively with the constraints ofmanufacturingtechnology, are amongst the largest challenges preventing a fully sustainable "digital" life in the future. Therefore it's vitally important to reconnoitreand locate new ways of computing that process information more efficiently, and Bio computing or DNA computing is unexpectedly emerging fields towards this goal (Ma et al., 2021). Bio computing or biological computing is the future of technology that operates at the convergence of biology, engineering, and computer science. It seeks to use cells or their sub-component molecules (such as DNA or RNA) to perform functions conventionally performed by an electronic computer. Bio computers are not robot or any spiritual being but they work like a powerful computer. It has the CPU as its brain and DNA its software. Bio computers is utilising the property of DNA for massively parallel computation. The result is small, faster computing process that operates with great accuracy. Main component is DNA. Bio-computing, also known as biological computing or biocomputing, refers to the use of biological systems and processes to perform computations and solve computational problems. It involves harnessing the inherent capabilities of living organisms, such as cells and molecules, to carry out computational tasks.

Bio computers are mostly for monitor activities of body at molecular and cellular level by inducing therapeutic effects. As a new field bio-computing deals with both with computer science and biology however does not fit to both. A 'DNA computer' has been applied for the first time to get the single correct answer from over a numerous possible solution to a computational problem (Chhangani and Hussain, 2018).

In1994, Adleman first projected the conception of DNA computing using the principle of thermodynamic equilibrium of base pairing and solved a non-deterministic polynomial (NP)-complete problem in mathematics: the Hamiltonian path problem. He enciphered the nodes in the Hamiltonian path problem to different single-stranded

DNA (ssDNA) sequences and used the automatic identification ability between DNA bases and polymerase chain reaction (PCR) to find the correct Hamiltonian paths. First practical of DNA Computer unveiled in 2002, used in gene analysis.Self poweredDNA Computer unveiled in 2003,it can perform a billion operations per second 99.8% accuracy. In 2004, Okamoto for thefirsttime combined digital logic and DNA molecules to construct DNA logic gates(Ma et al., 2021).Bio computers use systems of biologically derived molecules such DNA and proteins to perform computational calculations involving storing, retrieving and processing data. The development of bio computers has been made possible by the expanding new science of biotechnology. In today's era there is demand of faster information speed and dense data storage is required. So DNA has the properties of dense data storage and extraordinary energy efficiently. DNA has dense data storage because

1 gram DNA = 2.2 petabytes
1 PB = 10^{15} bytes = 1000 terabytes
Energy efficiency is also extraordinary because modern supercomputer = 109 operations/joule
DNA Computer = 2 X 10^{19} operations/joule.

Digital computers store data in strings which is made up of 0 and 1. Living thing or DNA store information with molecules representing the letters A, T, CandG. (DNA stands for DeoxyRibo Nucleic Acid)

Moore's law states that silicon microprocessor complexity will be double in every 18 month. Solving complex problems which today's supercomputer are unable to perform in stipulated period of time. Bio computers can be successor of silicon chip. Computers store data in binary strings made up of 0 and 1. Living things or DNA store information with molecules representing the letters A, T, CandG. A single gram of DNA, can hold a much information as a trillion of compact disc.

Even if scientists don't yet completely understand biological functions, the creation and development of bio computers is an opportunity for further discoveries. Moreover, studying at the interface of biology and information technology has the potential to lead to important new information systems (algorithms, software) and computer devices (hardware).

LITERATURE REVIEW

According to Ma et al., 2021 DNA computing is still in the exploratory stage and facing some challenges:

1) Computing Complexity-: the number of DNA molecules required in the algorithm increases exponentially with higher computing complexity. A Higher number of DNA molecules in the system can lead to a correspondingly high error rate from the synthesis and purification process.

2) Accuracy: DNA biochemical reactions are easily constrained by reaction conditions and getting better reaction efficiency, a determinant of computing exactness, is an urgent problem to be solved in DNA computational models.

3) Universality: most DNA computing models can only mark A certain kind of problem. The deficiency of a universal computing system hinders the large-scale promotion of DNA computing.

4) **Environmental compatibility:** the distinctive advantage of DNA computing lies in docking with diverse physiological environments. Straight interacting with the physiological environment makes it probable to respond to biological signals in cells in vivo and, therefore, realize the application of intellectual diagnosis and cure in living organisms. It is certain that researchers will design more intellectual DNA computing systems and extend the related applications toward enhanced diagnostics and therapeutics.

According to Deaton et Al., 1997 DNA computing holds out the promise of important and significant connection between computers and living systems, as well as promising massively parallel computations. On the other hand, new directions toward a synthesis of molecular growth and DNA computing might avoid the problems that have hindered development, so far.

The future for biological handling is splendid. Biological handling could be a young field that makes an attempt to get rid of enrolling power from the overall movement of sweeping amounts of biological particles. Hardware being supplanted by biological particles remains within the so much future. The biological laptop could be a massively parallel machine wherever every processor involves one biological molecule. Slightly of the structure is fabricated from biological and therefore the alternative victimization gift or new hardware will twist up doubtlessly out there.

Kurtz et al., 1997 stated that Adleman's [Adl94] successful result of a seven-vertex instance of the NP-complete Hamiltonian Path problem by recombinant DNA Technology initiate the field of biological computing. We offer a very different model of molecular computing based on the biochemistry of RNA editing and RNA translation. In our model, individual molecules become fully proficient general-purpose computers.

Why Bio-computing?

- **Overheating and High Energy Use**
  Supercomputers use a lot of energy, heat up quickly, and require immense cooling units in order to function at full speed. On the other hand, biological matter can perform calculations and process data without using as much energy, and without heating up a lot.

- **Multitasking**
  Regular computers perform one task at a time and switch rapidly between tasks to give the user a flawless experience of multiple tasks running simultaneously. Biological systems, on the contrary, engage in 'parallel computation' - whereby multiple tasks can be executed truly concurrently.

  Early proof-of-concept work has been completed using myosin - a super family of motor proteins which cause muscle contraction and convert chemical energy into mechanical energy. Myosin-enabled bio computing could perform multiple computations concurrently.

- **Self-Organizing and Self-Repairing**
  Biological molecules also display an intelligent skill to self-organize and self-repair. So, bio computing engineers will have to find ways to simulate this intellect 'software' on top of the biological molecule 'hardware' to produce, organize, and repair the biocomputing system.

  Like a living organism the "software" in biological systems is accountable for producing and assembling the hardware which in turn will help run the software.

Exploring Fields: -This interdisciplinary field lies at the intersection of biology, computer science, and engineering. There are several ways in which bio-computing is explored:

DNA Computing
DNA, the genetic material of living organisms, can be used as a medium for information storage and processing. DNA molecules can encode data in the form of sequences of nucleotides (A, T, C, and G). Researchers have developed techniques to perform computations using DNA strands, taking advantage of the molecular interactions and reactions that occur naturally in biological systems.

Molecular Computing: -
This involves using individual molecules, such as enzymes and proteins, to perform specific computational operations. Enzymes, for example, can catalyse chemical reactions that mimic computation processes.

Cellular Computing: -
Living cells can be engineered to perform computations using genetic circuits. These genetic circuits are designed to process inputs and produce specific outputs within a living cell. Synthetic biology techniques are often used to construct these genetic circuits.

Neural Computing
Neural networks, which are inspired by the structure and function of the human brain, can be implemented using biological components. This involves creating networks of neurons that can process and transmit information.

Physarum Computing
Phys arum polycephalic, a slime Mold, has shown remarkable abilities in solving complex optimization problems by exploiting its natural ability to form networks and explore its environment. Researchers have used the behaviour of slime Molds to develop algorithms for solving computational problems.

Mechanism: -
Alreadymany researchers transformed an idea from enzyme-based Bio-computing into a bacteria-based Boolean logic gate with a digital output signal of direct electric current and we suggest future applications in this perspective.

The ultimate goal of bio computing is to emulate some of the biological 'hardware' of bodies like ours - and to use it for our computing needs. From small to large complicated, this could include:

1. Use DNA or RNA as a medium of information storage and data processing
2. linking neurons to one another, similar to how they linked in our brains
3. Design computational hardware from the genome level up

Cells are far more dominant at computing than our best computers. For example:

1. Cells store data in DNA
2. Accept chemical inputs in RNA (data input)
3. Perform complex logical operations using ribosome
4. generate outputs by synthesizing proteins

Biocomputing's engineering challenge is to gain a granular level of control of the reactions between organic compounds like DNA or RNA.

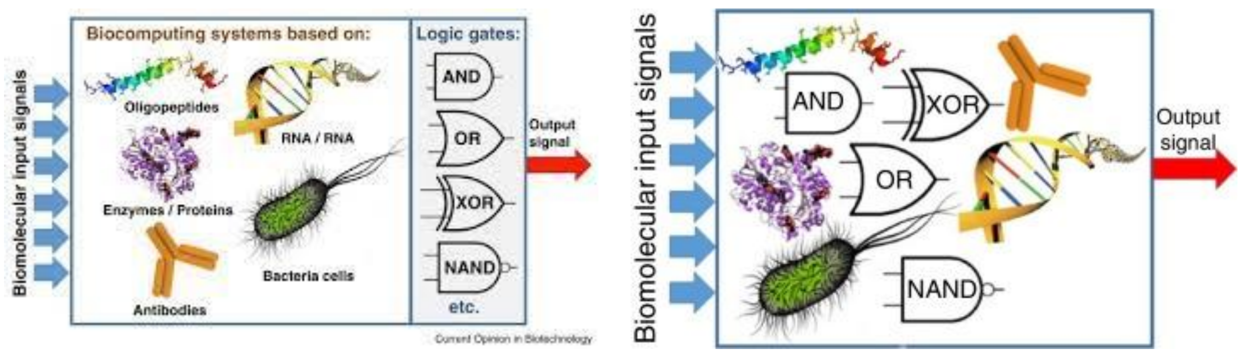

Figure: - Future vision of bio computing processor

- Bio computers can also be designed with cells as their basic components. Chemically induced dimerization systems can be used to construct logic gates from individual cells. These logic gates are activated by chemical agents that induce interactions between previously non-interacting proteins and trigger some observable change in the cell. This implantable device accomplishes these functions at the molecular or cellular level. This is comprised of RNA, DNA and proteins and can likewise execute simple mathematical calculations.
- RNA device operates on a plain system of Boolean logic. It can be programmed to respond to the commands AND, OR, NAND. By combining the RNA components in certain ways it showed different types of logic gates circuit elements common to any computer. For example, an AND gate produces an o/p only when its input detects the presence of both drugs while a NOR gate produces an o/p only neither drug is detected.

Process:-

Bio-computing is a field that explores the use of biological systems, such as DNA, proteins, cells, and other molecular components, to perform computation and information processing. The fundamental idea behind bio-computing is to leverage the inherent molecular properties of biological materials for carrying out specific computational tasks. One of the most prominent mechanisms for bio-computing is DNA computing.

DNA Computing Mechanism:
DNA computing uses the properties of DNA molecules, particularly their ability to store and process information through base pairing interactions (A-T and C-G), to perform computations. Here is a simplified explanation of how DNA computing works:

Encoding Information: Information is encoded into DNA sequences by representing data as specific sequences of nucleotides (A, T, C, G). Each nucleotide corresponds to a "bit" of information.

Molecular Operations: DNA strands can undergo various molecular operations, such as hybridization (binding together based on complementary base pairs), branch migration, and enzymatic reactions.

Parallelism: DNA computing takes advantage of the massive parallelism inherent in biological processes. Many DNA sequences can interact simultaneously, leading to a high degree of computational parallelism.

Algorithms: Specific molecular operations and interactions are designed to correspond to computational algorithms. These algorithms manipulate DNA strands in a way that the final state of the system represents the solution to the computational problem.

Readout: The final solution is read from the resulting molecular state. This could involve detecting the presence or absence of certain DNA sequences or other molecular changes that indicate the computation's result.

Applications: DNA computing has been explored for solving complex problems, such as optimization, cryptography, and NP-complete problems. However, it's important to note that DNA computing is not suitable for all types of computations and is mainly effective for specific types of problems where its parallelism and molecular interactions can be advantageous.

Advantages:-

- Cheap resources and plentiful supply.
- DNA biochips can be made cleanly so no toxic materials are used.
- Many times, smaller in sizethan the current computers.
- Amazing ability to store information.

Applications:-

- DNA chips
- Cryptography
- Genetic programming
- Cracking of coded messages
- Medical Application andPharmaceutical application: - The most important applications of bio-computers are concentrated on illness detection, cancer, drug release and other various medical purposes.
- Another application is speed of biological computing comparative to super computer it is predicted that biological computing could surpass traditional computers with their unparalleled speed.
- Bio-computing has the potential to address certain types of problems more efficiently than traditional electronic computers. For example, it might excel in solving optimization problems, pattern recognition tasks, and complex simulations. However, bio-computing also faces significant challenges, including the unpredictable nature of biological systems, the need for precise control and manipulation of biological components, and ethical considerations related to the use of living organisms for computation.

LIMITATIONS:

It willtime consuming process. It will Occasionally slower andrequired Human assistance.
While bio-computing, particularly DNA computing, is a fascinating concept with potential applications, it also faces several challenges:

Scalability: Working with biological molecules at a molecular scale can be complex and prone to errors. Scaling up bio-computing systems while maintaining reliability and accuracy is a challenge.

Error Rates: Biological processes are subject to errors due to factors like environmental conditions and enzymatic reactions. Ensuring the accuracy of computation in the presence of these errors is a significant hurdle.

Speed: Bio-computing processes are generally slower than traditional electronic computers. This is due to the time required for molecular interactions and enzymatic reactions.

Practicality: Implementing bio-computing mechanisms requires specialized lab equipment and expertise. It is not as straightforward as programming a conventional computer.

Problem Suitability: Bio-computing is best suited for problems that can be parallelized and mapped onto molecular interactions. It may not be efficient for all types of computational tasks.

CONCLUSIONS

Bio-computing is a fascinating and rapidly evolving field that explores the intersection of biology and computing. It harnesses the incredible capabilities of biological systems, such as DNA molecules and living cells, to perform computational tasks and store information. This area of research holds immense promise for revolutionizing various fields, including medicine, information storage, data processing, and even environmental monitoring.

In conclusion, bio-computing offers several exciting possibilities:

Ultra-High density Data Storage: -
DNA molecules can store vast amounts of information in a compact form. This could potentially lead to new methods of data storage that far surpass current technologies in terms of data density and longevity.

Parallel Processing: -
Biological systems can perform parallel operations naturally, which opens opportunities for massively parallel computing using cellular systems. This could significantly enhance the speed and efficiency of certain computational tasks.

Biological Sensing & Detection: -
Living cells can be engineered to detect specific molecules or environmental changes. This has applications in environmental monitoring, medical diagnostics, and even security systems.

Biological Information Processing: -
Utilizing biological components for computation could lead to the development of novel algorithms inspired by biological processes. These algorithms might find applications in optimization, pattern recognition, and more.

Medical Application: -
Bio-computing has the potential to revolutionize personalized medicine. DNA-based computing could analyse an individual's genetic information to predict disease risks, tailor treatments, and develop targeted therapies.

Ethical & Safety Considerations: -
As with any emerging technology, bio-computing raises ethical concerns, such as the responsible use of genetic data and potential unintended consequences of manipulating biological systems.

Technical Challenges: -
While the potential of bio-computing is immense, there are still significant technical challenges to overcome. These include improving the accuracy and reliability of biological computations, ensuring compatibility between biological and traditional computing systems, and developing efficient methods for programming biological components.

In the coming years, collaborations between biologists, computer scientists, engineers, and other experts will likely drive further advancements in bio-computing. As the field matures, it will be crucial to strike a balance between innovation and ethical considerations to ensure that bio-computing technologies are developed and deployed responsibly. Overall, the future of bio-computing holds promises for reshaping various industries and solving complex problems through the convergence of biology and computing.

While bio computing is in an early phase, bio computers have the potential to enable far more powerful computing than today’s best computers — while using less energy and generating less heat. Furthermore, bio computers will be able to use parallel computing, which will represent a significant improvement upon regular computing, and will be able to better self-organize and self-repair. While authoritative estimates of the eventual environmental impact of bio computing do not yet exist, bio computing could potentially reduce our reliance on the silicon and rare earth minerals that power today's computers.

It is not too hard to imagine that one day we might have small integrated desktop machine that uses DNA processor chip or DNA like biopolymer as a computing substrate along with set of designer enzymes. But still a lot of work and resources required developing it into fully fledged product.

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