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NEXT GENERATION COMPUTING

Summary Report

MAY 2023

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1 Introduction

Next Generation of Computing (NGC) is a field of computing methodology which has evolved from the emergence of modern technologies and research areas like cloud computing, artificial intelligence, machine learning, deep learning, distributed computing, parallel computing, grid computing, and their related applications. The advancement of next-generation computing is significantly influenced by the pivotal roles played by these computing technologies. Next generation computation is a hybrid application involving new methodologies for computation such as quantum computing, human computer interface, etc.

Many technologies are utilized to empower next generation computing, such as distributed computing (swarm computing), computational collaboration (bio-computing). These technologies are further improving performance of existing supercomputers and developing completely new way of computation that is energy efficient as well capable of processing various kinds of signals with high accuracy.

The advancement of next-generation computing is significantly influenced by the pivotal roles played by these computing technologies.

A. The concept behind the evolution of Next Generation Computing

According to Moore's Law, transistors on semiconductors would be doubled every two years, thereby rapidly increasing the functionality of the semiconductors which in turn is accelerating the development of high-density devices with lower product costs.

This law has driven the semiconductor industry for the past 40 years and has allowed the scaling down of Complementary Metal-Oxide-Semiconductor (CMOS) IC to produce small size, low power, high-speed, and high-density devices with low production costs.

However, the miniaturization of ICs has reached physical limits of scalability due to performance issues including both static performance, impacted by intrinsic leakage current and dynamic performance, which is affected by heavy data traffic and long connection delays.

We cannot ignore the prevalent physical limitations, considering critical economic factors which are affecting the future of CMOS technology. These limitations foreshadow the approaching end of CMOS in scaling within the future.

Given the multitude of options available and the early stages of research and development for each, it remains uncertain what will ultimately replace CMOS technology. Any successful replacement technology will have the following unique properties:

- Non-volatility (with inbuilt memory in logic devices).
- Efficient logic implementation (e.g., through analogue or majority gates).
- Structural / layout regularity.
- Self-adaptive property.
- Coherent or collective behaviours (e.g., low-power shift and robustness)

Despite having high performance processors like GPUs and advanced computers, these processors have few limitations as they consist of semiconductors. Physical properties of semiconductor prevent them to perform complex computations. Electronic devices work under certain conditions for computation like temperature and voltages.

Next generation computation breaks the limitations of traditional computing methodologies and techniques. It is enforcing the computation from the fundamental science like computation using bioscience, quantum mechanics, based on electron spinning etc.

Given the multitude of options available and the early stages of research and development for each, it remains uncertain what will ultimately replace CMOS technology.

B. Opportunities and Market

NGC Global Market in the Decade of 2020-2030:

The global next generation computing market size has been valued at USD 140 billion in 2021, and is anticipated to reach around USD 795.10 billion by 2030, and it is expected to expand at a CAGR of 21.29% during the forecast period of 2022 to 2030.

Report Coverage	Details
Market Size in 2022	USD 169.8 Billion
Market Size by 2030	USD 795.10 Billion
Growth Rate from 2022 to 2030	CAGR of 21.29
Base Year	2021
Forecast Period	2022 to 2030
Segments Covered	Offering, Enterprise Size, Component, Storage Type, Stroge Medium, Type, End User and Geography
Companies Mentioned	Amazon Web Services Inc., IBM Corporation, Alibaba Group Holding Limited, Cisco Systems Inc., Google Inc., HPE, Intel Corporation, Oracle Corporation, Atos SE, Microsoft Corporation.

Source: www.precedenceresearch.com

2 Types of Next Generation Computing

A. Quantum Computing

Quantum computers will revolutionise the next generation of computing. Applying ideas of superposition, entanglement and a quantum mechanical phenomenon, quantum computers could solve a few intractable problems. They will be able to solve certain specific categories of problems as well, such as factorization. Further research will identify additional quantum matching algorithms.

Market of Quantum Computing:

Quantum computing is based on quantum bits or "qubits" that can also represent 0 or 1. Oddly enough, qubits can also reach a mixed state called "superposition", where 1's and 0's exist at the same time

The market for quantum computing, which was estimated to be worth USD 785.27 million in 2022, is anticipated to grow at a CAGR of 47.29% over the course of the forecast period and reach USD 8017.34 million by 2030 (MarketWatch,2023)

How Quantum Computer works:

- Regular computers are based on "bits". Think of a bit as a little switch that points to 1 or 0.
- Quantum computing is based on quantum bits or "qubits" that can also represent 0 or 1. Oddly enough, qubits can also reach a mixed state called "superposition", where 1's and 0's exist at the same time. This ambiguity, the ability to be and not be, is the key to the power of quantum computing.
- Two bits in the computer can be in four states (00, 01, 10, or 11), but only one at a time. This constrains the computer to process one input at a time (trying out corridors in a maze, for example).
- On the quantum computer, two qubits can also represent the same four states (00, 01, 10, or 11). The difference is that superposition allows a qubit to represent all four at once. It is like running four normal computers side by side.
- Adding bits to a normal computer can only handle one state at a time. But adding more qubits would dramatically increase the power of quantum computers. For those interested in mathematics, we can say that with an 'n' qubit, we can represent 2n states simultaneously.)

Components of Quantum Computer:

1. **Quantum data plane** is the heart of a quantum computer as it defines the physical structure where q-bit resides.
2. **Control and measurement plane** is where the digital signals propagated by the control processor are translated in order to be read and carried out as analogue control signals for the qubits in the quantum data plane.
3. **Control processor plane** determines the sequence of operation and measurement that an algorithm requires.
4. **Host processor** supplies the desired program to implement the algorithm to be executed on quantum computers.

India in Quantum Computing:

To gain a computing and informational edge, India is investing in quantum technology. Indian scientists from the Defence Research and Development Organization (DRDO) and the Indian Institute of Technology (IIT) Delhi successfully demonstrated a Quantum Key Distribution (QKD) link for more than 100 kilometres between Prayagraj and Vindhyachal in Uttar Pradesh.

Quantum Key Distribution was achieved using existing commercial fibre-optic networks. The network demonstration aims to test the feasibility of creating a secure network for Indian security agencies using native technology.

Also in January 2021, The Ministry of Electronics and Information Technology (MeitY), Government of India established a Quantum Computing Applications Lab in collaboration with Amazon Web Services (AWS) to facilitate quantum computing-driven research and development.

These projects are the result of India's US$1.2 billion investment in quantum technology development as part of its National Mission on Quantum Technologies & Applications (NM-QTA), which was launched in 2020. India also approved funds of INR 6000 Crores in 2023 to scale up the scientific and industrial R&D for the National Quantum Mission.

Popular Applications and Use Cases of Quantum Computing:

- Artificial Intelligence
- Cyber Security
- Drug Development
- Traffic Optimization
- Weather Forecasting and Climate Change

Source: www.precedenceresearch.com

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A computer that processes and analyses recorded brain activity. BCI software uses specialized processing methods and algorithms to attempt to interpret the user's intended actions from incoming brain activity.

B. Brain Computer Interface

A Brain-Computer Interface (BCI) is a system that determines the functions of the human brain (the desire to change, move, control, or manipulate something in the environment) directly from brain activity.

The Brain-Computer Interface (BCI) provides users with muscle-independent communication and control capabilities. User intent is determined from activity recorded by electrodes on the scalp, cortical surface, or in the brain.[1]

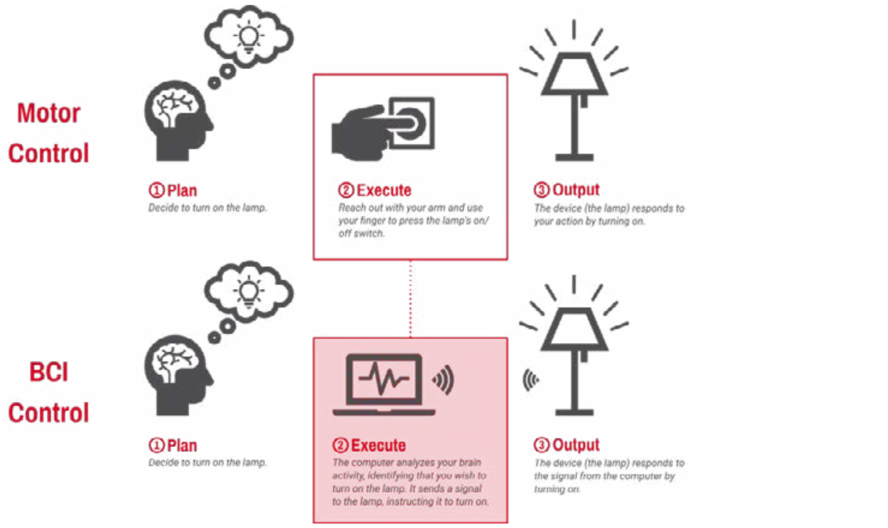
Market of Brain Computer Interface:

- Brain-computer interface technology to repair/help disability to reach approximately $1 billion by 2027.
- Brain-computer interface solutions in functional magnetic resonance imaging to reach $330 million by 2027.

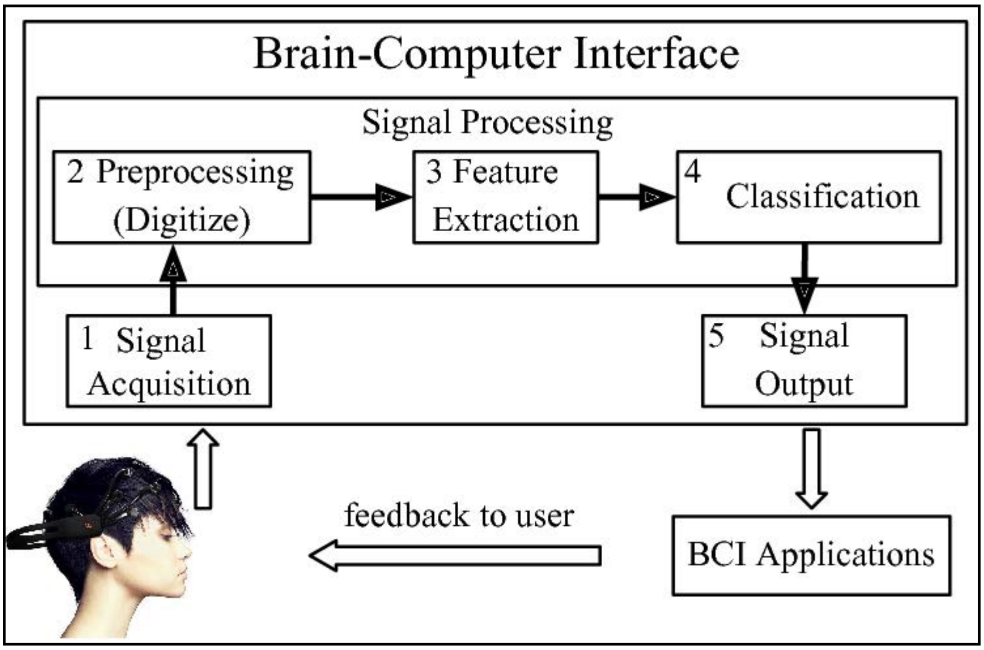
Working of Brain Computer Interface:

The Brain Computer Interface consists of three main parts:

- A device for measuring brain activity. This usually takes the form of a headset, cap, or headband that has special sensors embedded in it to detect and record signals from the brain.
- A computer that processes and analyses recorded brain activity. BCI software uses specialized processing methods and algorithms to attempt to interpret the user's intended actions from incoming brain activity.
- Application/device to control. When the computer "decides" what the user wants to do, it signals the application/device to carry out that command.



Source: Wolpaw, Jonathan R. "Brain-computer interfaces." Handbook of clinical neurology. Vol. 110. Elsevier, 2013. 67-74.



Source: ResearchGate

India on Brain Computer Interface:

Centre for Development of Advanced Computing (CDAC) in India has developed a BCI-enabled software. They have designed this software to analyse the EEG Data, EEG Microstate Analysis, Detection and Prediction of Epileptic Seizures. BEES Lab of Indian Institute of Science (IISc) also focuses on BCI research and application development.

Centre for Development of Advanced Computing (CDAC) in India has developed a BCI-enabled software. They have designed this software to analyse the EEG Data, EEG Microstate Analysis, Detection and Prediction of Epileptic Seizures

As BCI offers opportunities to solve many issues with good market potential, India can certainly focus on this area of NGC. The Centres for Brain Research and IT Research can come together for more developments in BCI.

Popular Applications and Use cases of BCI:

BCI is not capable enough to read human thoughts even with implantable, invasive BCI systems (that can record stronger electrical signals since they are placed closer to the brain), the technology is still far from being able to "read" anyone's thoughts. Instead, the BCI looks for patterns that occur in brain activity in response to specific external events or stimuli, or patterns that are produced during specific cognitive processes.

The brain-computer interface can be used routinely to replace or restore useful functions in people severely disabled by neuromuscular disorders, and can be used by pilots, surgeons, and other highly skilled individuals. It can improve the natural motor skills of professionals. Also, brain-computer interfaces have the potential to improve rehabilitation for people with conditions such as stroke and head trauma.

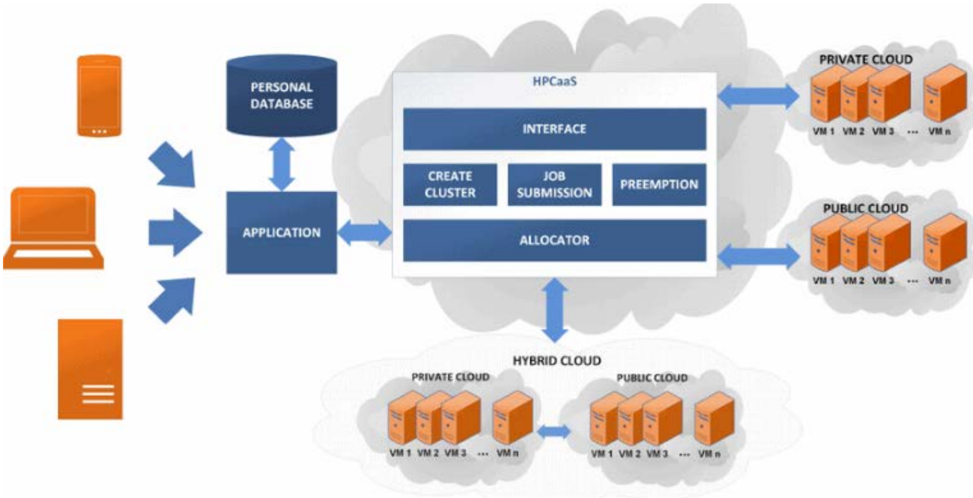
High performance computing refers to the aggregation of different computing power that can deliver enhanced computing power than the normal workstation. These computers are also known as supercomputers.

C. High Performance Computing

High performance computing refers to the aggregation of different computing power that can deliver enhanced computing power than the normal workstation. These computers are also known as supercomputers.

Motivation:

Supercomputers are used to solve challenging scientific problems. These scientific problems are recognized highly intensive in nature and then modelled in mathematical expressions. Mathematical expressions are normally differential and integral equations. These expressions cannot be directly executed on computer machines, first to be converted into parallel programs and then executed on large number of High-Performance Computers for the solution to reduce the computational time.



Source: Cloud Infrastructure Services

Market for HPC:

By 2030, the size of the worldwide high-performance computing market is projected to be USD 87.31 billion, growing at a 7.5% CAGR (Grand View Research)

Involvement of India in High Performance Computing:

India has already installed supercomputing infrastructure in 10 major institutions such as IIT, IISc, IISER Pune, JNCASR Bengaluru, various C-DAC, NABI Mohali, etc., and has launched the National Super Computing Mission to benefit researchers. (NSM) is becoming a pioneer in high performance computing. Also, from some other institutions.

Indian Institute of Science (IISc) Bangalore established his Param Pravega. With 3.3 petaflops of supercomputing power, Param Pravega is the largest supercomputer installed in an academic institution in India.

Popular Applications and Use Cases of HPC: -

- Weather Predictions
- Oil and Gas Simulations
- Engineering Simulations
- Live Game Streaming
- Financial Modelling

D. Nano Computing

Nanocomputing refers to computers that use very small or nanoscale devices (a nanometre [nm] is one billionth of a meter).

Modern digital computers use current and voltage in tens of millions of CMOS (complementary metal oxide semiconductor) transistors covering a few square centi-meters of silicon. If device dimensions can be reduced by a factor of 10 or 100, the functionality of the circuit can be increased by a factor of 100 to 10,000. Therefore, nano computing is being evolved to improve the efficiency of computing devices.

Modern digital computers use current and voltage in tens of millions of CMOS (complementary metal oxide semiconductor) transistors covering a few square centi-meters of silicon.

Market for Nano Computing:

Global Market for Nano Computing is expected to reach $5.7 billion by 2025 with a CAGR of 7.6% (Analytics Insights)

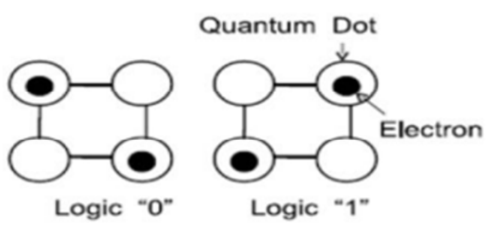
Nano computing has two major topic areas:

1. Quantum dot cellular automata which are related to reversible computing.
2. Nanomagnetic logic.

Quantum Dot Cellular Automata (or Quantum Cellular Automata, QCA) is a transistor-free, nanotechnology-based computing paradigm. QCA represents binary information in a cell that is coupled by an electromagnetic field and has no current flowing through it.

The QCA cells form a square of four dots, each dot representing an electron. The arrangements of electrons store the information.

Since electrons settle at corners, there are two minimal configurations i.e., polarization +1 (representing logic 1) and polarization -1 (representing logic 0) as shown:



The state of each cell is determined by the state of the neighbouring cell but not by distance cells, which is a natural match for nano-devices.

The state of each cell is determined by the state of the neighbouring cell but not by distance cells, which is a natural match for nano-devices. Using the different polarization values, logic operations can be performed with very low power consumption rates compared to traditional field-effect transistors. It is possible that QCA may be manufactured using very cost-effective self-assembly methods that may eventually replace expensive, top down, lithographic techniques that are currently used for traditional semiconductor logic and memory devices.

Nanomagnetic Logic (NML) can be viewed as a magnetic implementation of QCA where information signals are processed through magnetic field-interactions in nano-cells. NML can perform both Boolean and non-boolean logical operations.

NML devices have proven to meet basic tenets that are considered essential for digital systems, NML is a functionally complete logic set. NML has non-linear response characteristics due to the magnetic hysteresis loop.

NML have many advantages like non-volatility, scalability, reconfigurable logic, reduced power consumption, low energy dissipation in switching and are functional at room temperature.

India on Nano Computing:

Nano Computing is in a very introductory phase in India. IIT-Kanpur in association with one private engineering institute has written a Nano Computing fundamentals textbook. As a next-generation computing capability, India has a lot to explore.

Popular Applications and Use Cases of Nano Computing:

As Nano Computing is at an introductory phase, some of the use cases of Nano Computing can be researched in the areas of Medical and Biotechnologies.

E. Spintronics

“Spin”, like “charge”, is a property of particles such as electrons. Researchers are excited to use spin for computation because it avoids the heat problem of current computer chips.

Engineers are reaching the limit of how small and fast a chip can get before it overheats, unable to perform electronic computations faster because the movement of charges generates heat. Electronics can’t get smaller, so there’s a concern that computers can’t be more powerful and cheaper than they have been in the last 70 years. This is where spintronics comes into the picture.

When an electron is placed in a magnetic field, its spin polarization becomes bistable and can be used to encode the logical bits 0 and 1 that are the basis of spin-based quantum computing.

Magnetic tunnel junctions and spin-torque transfer devices offer potential pathways to replace CMOS technology with spin-based integrated circuits such as Magnetic Random-Access Memories (MRAM) and spin transistors.

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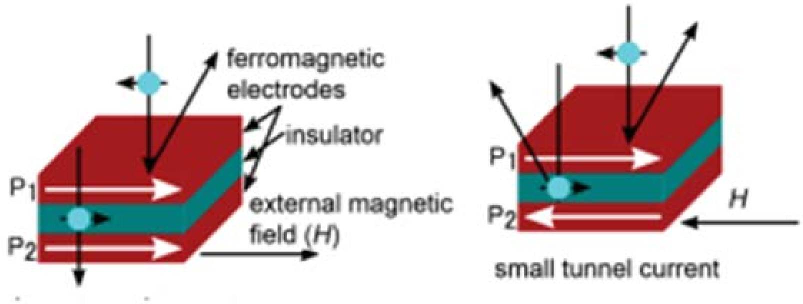
Magnetic Tunnel Junction (MTJ) occurs when two conducting electrodes of ferromagnetic material are separated by a thin dielectric layer (insulator or tunnel junction) that allows electrons to tunnel, resulting in electrical conduction.



Schematic of Magnetic Tunnel Junction

In MTJs, when a tunnelling current flows through the junction, it becomes spin-polarized, producing a torque called spin torque. Depending on the direction of the tunnelling current, the spin moment switches the magnetization of the storage layer parallel or antiparallel to that of the reference layer. By injecting a current, the direction of the magnetic moment of the MRAM memory element can be switched.

Market for Spintronics:

The market for spintronics is expected to grow by 39% CAGR from its estimated value of USD 591.8 million in 2021 to USD 5693.1 million in 2027. (GlobeNewswire)

India in Spintronics:

Spintronics is yet to be introduced in the Indian research, development, and academic fraternity. As spintronics holds good market potential some introductory research and development is recommended in India.

Emerging Applications and Use cases of Spintronics: -

- It has the potential to replace conventional memories with Magnetic Random-Access Memories (MRAM)
- It also has the potential to develop spin-based transistors, which could lead to faster and energy-efficient computing.

Neuromorphic computing is a method of computer engineering in which components of a computer are modeled based on the human brain and nervous system. This term refers to the design of both hardware and software of the computer.

F. Neuromorphic computing

Neuromorphic computing is a method of computer engineering in which components of a computer are modeled based on the human brain and nervous system. This term refers to the design of both hardware and software of the computer.

Potential of Neuromorphic Computing:

Neuromorphic computing offers a new paradigm alternative to von Neumann's architecture.

The idea behind the neuromorphic computing is to make "thinking machine" based on the bio-intelligence.

Neuromorphic systems consist of devices that mimic neurons, transmit information in the form of spikes rather than varying voltages, contain realistic plasticity mechanisms, and integrate computation and memory storage within the same circuitry.

Approaches to develop Neuromorphic devices: -

1) Using the VLSI.

Analog VLSI can contain synaptic circuits that can be integrated into large VLSI chip-based neural systems, but these circuits are still CMOS and silicon based, so they have the same scaling limitations as all other CMOS devices applies.

2) Using a memristive device.

Memristive devices, passive electronic circuit elements, nanoscale devices, offer new opportunities to build neuromorphic architectures with plastic synaptic connections.

These technologies are very attractive because they are compatible with CMOS and can be used (often decentralized) in synaptic circuits in neuromorphic architectures. Another attractive feature of these devices is their non-volatility (that is, they retain their state when power is removed), which bypasses the scaling limitations of dynamic random-access memory and flash memory.

Neuromorphic systems achieve both fast computation and low power consumption.

They are: -

- **Parallel**- can handle multiple tasks concurrently.
- **Event-driven**- respond to events based on variable environmental conditions and only the parts of the computer in use require power.
- **Highly adaptable and more in plasticity.**
- **Able to generalize.**

- **Strong and fault-tolerant-** it can still produce results after components have failed.

Materials for Neuromorphic Computing:

Ferroelectrics are characterized by their polarization changing when an electric field is applied. The polarization state is retained after the voltage is turned off. Based on Hafnium Dioxide at the 28 or 22 nm technology node, these Ferroelectric Field Effect Transistors (FeFETs) not only allow the weight values required for deep learning algorithms to be stored directly on the chip (so-called in-memory computing). Like the human brain, the chip's hardware architecture is designed so that information is already stored in the system and is non-volatile.

Hafnium Oxide based memory is CMOS compatible, lead free and scalable to very small technology nodes. As the only non-volatile memory concept, ferroelectric memory operates purely electrostatically, making it particularly energy efficient as only the transfer current of a capacitor must be used to write data.

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India on Neuromorphic Computing:

Researchers at IIT Delhi, led by Professor Manan Suri of the Department of Electrical Engineering, have invented a new spiking neuron model called DEXAT (Double EXponential Adaptive Threshold Neuron). The invention is important because it helps build accurate, fast, and power-efficient neuromorphic artificial intelligence (AI) systems for real-world applications, such as speech recognition. The

Double Exponential Adaptive Threshold (DEXAT) neuron model improves the performance of neuromorphic Recurrent Spiking Neural Networks (RSNNs) by providing faster convergence, higher accuracy, and flexible long-term short-term memory.

Neuromorphic Spiking Neural Networks (SNNs) are a promising computational paradigm that draws strong inspiration from mammalian brain workings, firing neurons, and synaptic plasticity. SNN algorithms and specialized SNN hardware have proven useful in addressing a variety of real-world, data-centric applications.

Researchers at IIT Bombay and IIT Gandhinagar have successfully created artificial neurons. This silicon neuron is an analog device that mimics a biological neuron in that it emits a spike signal when it detects simultaneous external inputs.

Advantages of neuromorphic architecture:

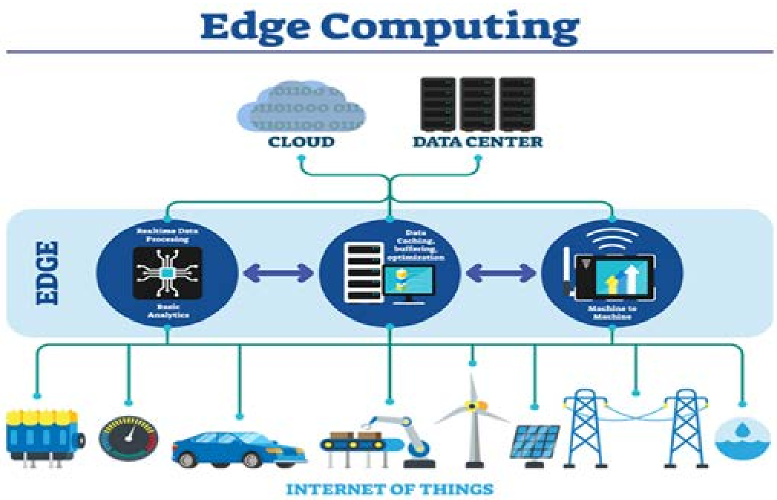
Neuromorphic computers attempt to mimic the architecture of the human brain. This architecture of crossbars based on nonvolatile memories such as ferroelectric field effect transistors is particularly promising by being energy efficient, execution speed, robustness against local failures and the ability to learn.

Edge computing is a fundamental technique for placing computation and data storage closer to the devices that collect them, rather than relying on central locations thousands of miles away.

G. Edge Computing

According to Gartner, edge computing is defined as part of a distributed computing architecture where information processing occurs near the edge.

Edge computing is a fundamental technique for placing computation and data storage closer to the devices that collect them, rather than relying on central locations thousands of miles away. Data, especially real-time data, is processed close to the device where it is collected to avoid latency issues that can affect application performance.



Source: innovationatwork.ieee.org

Market for Edge Computing:

The global Edge Computing market is expected to reach $155.90 Billion by 2030 with a CAGR of 37.9% (Grand View Research)

India on Edge Computing:

India will be one of the attractive markets for the Edge Computing. With the increased emphasis on the IoT through smart cities and digital India missions, the adoption of edge computing in India is improving. The top 3 R&D labs which are working on edge computing are:

1. Computing and Design Automation (CoDA) Lab at IIT Roorkee
2. Department of Computational and Data Science at IISc
3. Intel AI Research Centre at IIT-Hyderabad.

India also has several startups which are providing edge computing solutions defying the limits of traditional computing. With the recent push to the edge computing through IoT applications, these startups can work on data locally.

Need and Applications of Edge computing:

Edge computing has been developed with a multitude of IoT devices connecting to the internet to send and receive data. Because IoT devices generate vast amounts of data during operation, many IoT devices connect to the Internet to send and receive information.

Additionally, organizations can save costs by processing locally, so they process less data in centralized or cloud-based locations.

Some of the Popular Applications and Use Cases of Edge Computing are as follows:

- Manufacturing Monitoring
- AI Voice Assistance
- Automated Retail
- Precise Healthcare Data
- Smart Homes
- Vehicle Automation

H. Bio-Computing

A biocomputer consists of a pathway or series of metabolic pathways having biological materials that are engineered to behave in a certain manner based on the inputs of the system.

The series of reactions that follow as a result form an output that is based on the biocomputer's engineering design and can be thought of as a type of computational analysis.

A biocomputer consists of a pathway or series of metabolic pathways having biological materials that are engineered to behave in a certain manner based on the inputs of the system.

Biocomputing includes a broad range of computing approaches based on biological systems, ranging from the use of algorithms, such as swarm intelligence, to membrane computing, memetic computing, cellular automata, DNA and molecular computing, neural computing and evolutionary computing. There are diverse applications of biocomputing such as computational intelligence, bioinformatics, natural language processing, machine learning, algorithm theory, data mining and many other areas. The bio-computing devices are powerful (equivalent with Turing machines) and computationally efficient (solving NP-complete problems in a feasible/ polynomial time).

Biological computing devices are made of living cells. These computers use chemical inputs and other biologically derived molecules, such as proteins and DNA, to perform computational calculations that involve storing, retrieving, and processing data fundament of a computer. Researchers have been able to get biological computers to complete a logic gate. As logical gate is the basic component of any computing device. Researchers have found a different way to compute logical functions in-spite of electronic gate. This functionally complete approach is a notable achievement.

Although the number of biological computers is less than that of personal computers, several businesses are working to advance this still-emerging field.

Market for Biocomputing:

Research and Markets reports that Bio computing for molecular medicine and gene therapy will reach $19.1 and $12.1 billion respectively by 2028.

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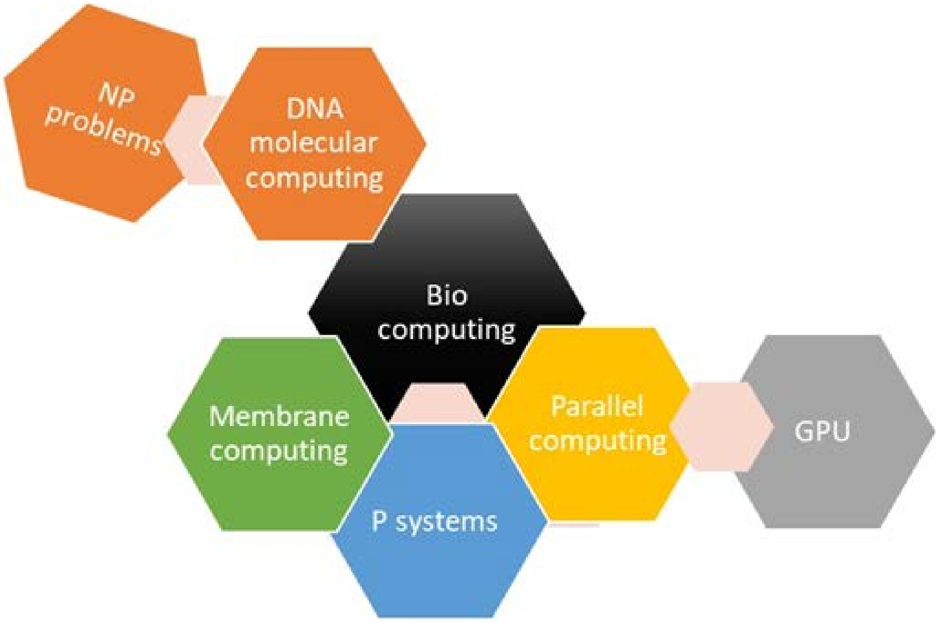
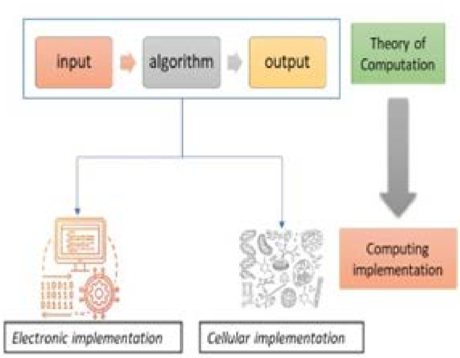


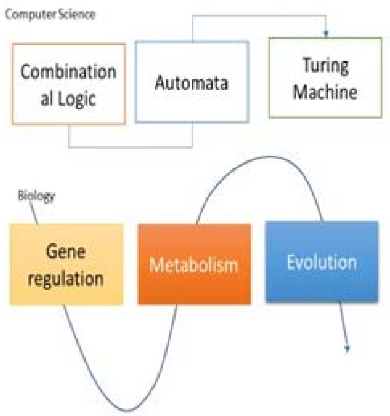
How Bio Computing Works:

- Considering the cell as "physical computer".
- Cells can sense/deliver a wide range of physical, chemical and biological inputs/outputs.
- The encoding scheme can be different from electronic implementation.

Principle:

- Gene Regulation in bioscience is a mechanism used by cells to produce specific gene products which can be responsible for adaptability and gene expression. Gene regulation is key to the ability of an organism to respond to environmental changes, so change can be input for gene regulation and its response can be the output for the same. Conclusion: Gene regulation can be used as combinational logic circuits in bio computing.
- Metabolism is the process of converting food into energy, considering this phenomenon it converts energy from one state to another (state transition takes place) which can be analogous to FSM's of Automata theory in computer science.
- As TM's in automata are used for computation similarly in bio computing cell evolution used for computation purpose.





Cells could provide more than digital logic circuits. Computer science has developed models for computation such as finite-state machines or turing machines which are more powerful than combinational logic because computational models allow the processing of a wider range of input into output than any combinatorial logic.

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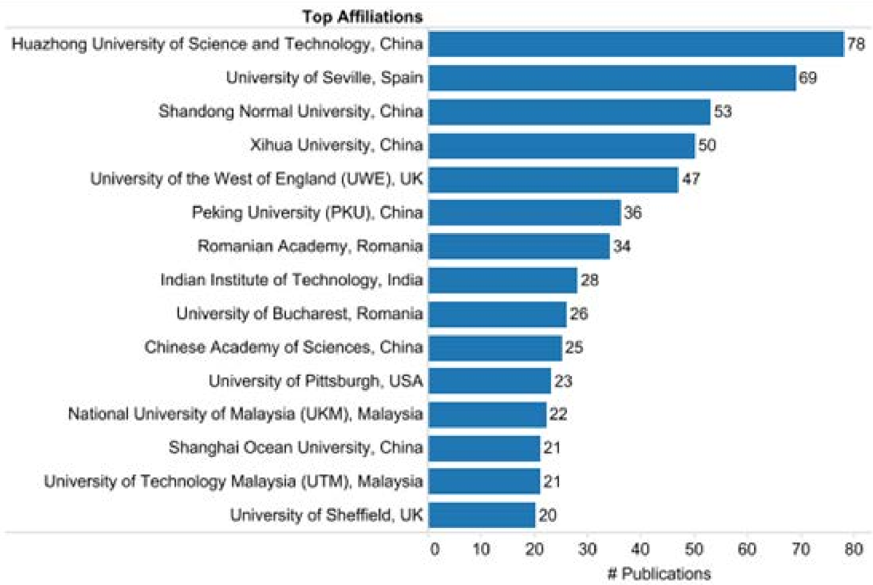
Research and Academia in Bio Computing:



Source: Defence Research and Development Canada

Popular Applications and Use Cases of Bio Computing:

- Understanding Gene Functions
- Drug Targets Analysis
- Disease Analysis
- Management of Biological Databases

3 India and Next Generation Computing

A team of researchers at the Automation, Verification and Security (AVS) Lab at the Indian Institute of Technology (IIT) Guwahati are working to develop secure and reliable Integrated Circuits (ICs) for faster and more efficient computing.

IIT Guwahati is developing secure Integrated Circuits (ICs) for next generation computing

A team of researchers at the Automation, Verification and Security (AVS) Lab at the Indian Institute of Technology (IIT) Guwahati are working to develop secure and reliable Integrated Circuits (ICs) for faster and more efficient computing. This research addresses all aspects of the automated electronics design process, including synthesis, verification, and security, and contributes to strengthening the electronics manufacturing ecosystem in our country.

Next generation computing for IoT applications

Bharti School of IIT Delhi started an IoT Lab with industry support. Today there are several ongoing research projects on various aspects of IoT. Deploying a network of sensor nodes for edge computing and ML for air pollution monitoring, water quality monitoring systems, IoT security, power harvesting on IoT edge devices, healthcare, and vision.

IITD has established and supported government funding for various laboratories focused on developing 5G technologies in different research areas. There is also a 5G COE testbed implemented with industry support. The program is designed to accelerate the implementation of the Digital India Initiative and support application development for Indian start-ups and industries. The 5G ecosystem under development at Bharti School will enable research and development investigating how advanced mobile technologies can address some of the country's key challenges.

Proposed Multi-access Edge Computing development.

Multi-Access Edge Computing (MEC) is an IoT application enabler that optimizes the delivery of IoT use cases requiring low latency and low bandwidth. A use case is defined as a specific situation in which a product or service may be used. MEC is a great enabler when some evaluation or computation is required at the edge to reduce latency to edge devices, or when lower bandwidth is required in cellular networks.

For example, a set of video edge devices are connected to an IoT gateway on a local wireless network. Basic edge computing algorithms are encoded on the edge computing device to analyze the received data and send only the data of interest to the MEC host over the cellular network. At this stage, inference analytics can be performed in near-real time, reducing next-hop latency and network bandwidth. The data analysis server in the core handles data preparation, model training, and image prediction.

India's steady moves toward achieving 'quantum supremacy.

India plans to develop a quantum computer of about 50 qubits by 2026, joining a growing number of countries such as Australia and Israel to promote widespread adoption of the technology.

India plans to develop a quantum computer of about 50 qubits by 2026, joining a growing number of countries such as Australia and Israel to promote widespread adoption of the technology.

The key here is that the Indian government is emerging as a major sponsor of quantum research. About 92% of the 100 quantum projects launched in India are funded by the government.

India's first Quantum Computer Simulator (QSim) toolkit has been launched by the Ministry of Electronics and Information Technology (MeitY). A native toolkit was introduced to enable researchers and students to conduct research in the field of quantum computing in a cost-effective manner. The project is jointly carried out by IISC Bangalore, IIT Roorkee and C-DAC with the assistance of MeitY.

In March 2021, ISRO announced it had successfully demonstrated free-space quantum communication over over 300 meters. The demonstration included a live video conference using signals encrypted with quantum keys.

In October 2021, the Quantum Communications Lab was opened at C-DOT, Delhi (a major Telecommunications Research and Development Centre, Ministry of Telecommunications, Government of India). An in-house developed Quantum Key Distribution (QKD) solution was also announced. It can support distances over 100 kilometers over standard fiber optics.

In December 2021, the Army, with the support of the National Security Council Secretariat (NSCS), established Quantum Lab at Military College of Telecommunications Engineering to advance research and training in this important developmental area.

Human Computer Interaction

Technology Innovation Hub (TIH) for Human-Computer Interaction (IIT Mandi iHub and HCI Foundation or iHub) was established at Indian Institute of Technology (IIT) Mandi as part of India's National Mission on Interdisciplinary Cyber-Physical Systems. iHub aims to make India a world-leading research center for Human Computer Interaction (HCI).

Research and technical development projects focus primarily on different aspects of user interfaces that span multiple issues in different domains. These areas include the environment, healthcare, information technology (IT), and defense and security. These domains form important sectors of the Indian economy.

4 Indian startups and their collaboration next generation computing

General Atomics Aeronautical Systems (GA-ASI) is pleased to announce a strategic partnership with 3rdiTech to develop next generation computer chips.

General Atomics announces a strategic partnership with Indian startups for next-generation computer chips.

General Atomics Aeronautical Systems has announced a strategic partnership with an Indian technology start-up that manufactures next-generation computer chips, integrated circuit and other semiconductor technologies. General Atomics Aeronautical Systems (GA-ASI) is pleased to announce a strategic partnership with 3rdiTech to develop next generation computer chips.

GA-ASI, a subsidiary of General Atomics, is the world's leading unmanned aerial system. They design and develop enhanced solutions for military, security, governance, environmental operations, and more.

Startups leading the quantum race in India

BosonQ Psi

The company is working on the world's first quantum-based engineering simulation software called BQPhy. The automotive, aerospace, and industrial sectors can all benefit from faster time-to-market and improved product quality with this software.

QRDLab

The main goal of the startup is to advance research into various aspects of quantum software. By modeling business challenges and applying academic research, QRDLab provides a platform for collaboration with independent researchers, academic institutions, and companies.

QNu Labs

The company develops quantum cryptography products and solutions that provide data security. QNu uses quantum technology to eliminate man-in-the-middle attacks and provide solutions such as data center protection and multi-factor authentication that help businesses combat phishing threats.

Qulabs

The company's vision is to provide the world with the first solutions based on quantum communications and computing, creating a completely secure internet and communications with incredible speed and security.

VUERON – HCI startup

AI-driven deep tech startups working on Human Computer Interaction (HCI) systems. They explicitly use HCI to provide touchless solutions in the healthcare and utilities sectors. This includes touchless operability for elevators, medical equipment and interactive displays (ticket sales, vending machines, social distancing monitoring).

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5 Case Study

India has already started developing a National Digital Framework to create a national digital health ecosystem. India's digital healthcare market was valued at INR 116.61 billion in 2018 and is projected to reach INR 485.43 billion by 2024, growing at a CAGR of 27.41%.

Artificial Intelligence (AI), cloud computing, 5G, and Nanotech in healthcare

India has already started developing a National Digital Framework to create a national digital health ecosystem. India's digital healthcare market was valued at INR 116.61 billion in 2018 and is projected to reach INR 485.43 billion by 2024, growing at a CAGR of 27.41%.

The Indian healthcare system is changing and will evolve significantly. The pandemic has shown that healthcare organizations can become innovative, flexible, and resilient by adopting data-centric, technology-enabled business models.

Engaging with users along the healthcare chain, whether they are patients or physicians, is essential not only to create improved products and services, but also to create a better healthcare experience.

Computed Tomography Scan Analysis

AI systems can quickly evaluate CT images from hundreds of patients, identify patterns of pneumonia caused by COVID-19, and alert doctors. This makes up for the shortage of skilled workers in this industry.

AI cannot be held responsible for poor diagnoses or ineffective courses of treatment. Instead, professionals who choose to use AI will have to make the most of this digital health trend while taking every precaution to minimize the negative impact.

Machine Learning in Biopharma and MedTech

The pharmaceutical sector can effectively benefit from technological advances in healthcare by using AI to discover new drugs.

Extensive cutting-edge research, such as molecular modeling and simulation of chemical reactions in multifactor environments, uses AI and machine learning approaches to support chemical experiments and therapeutic drug development.

Since many tests can be performed electronically, this method allows scientists to reduce the number of expensive on-site experiments with reagents and high-tech lab equipment.

Symptom Checker Chatbots

Chatbots are Artificial Intelligence (AI) computer programs (often powerful algorithms rather than real AI) that use voice, text, or optional input to simulate a conversation between humans. Have meaningful conversations.

Available 24/7 online or via mobile devices, these solutions can provide preliminary medical diagnoses and health advice based on patient feedback and complaints.

These chatbots can help patients determine their next course of action and motivate them to seek professional medical advice if needed. However, be careful as it can lead to false self-diagnosis and misinformation.

Nanomedicine

Nanomedicine uses nanoscale (microscopic) materials and objects, such as biocompatible nanoparticles, nanoelectronics devices, and even nanorobots, for specific medical applications and manipulations, such as the diagnosis and treatment of living organisms.

For example, a group of nanorobots could be injected into human blood vessels and used as scavengers for cancer cells and viruses. This method is expected to effectively combat (or provide the ultimate solution to) various cancers, rheumatoid arthritis, and other inherited, neoplastic, or autoimmune diseases at the cellular level.

Chatbots are Artificial Intelligence (AI) computer programs (often powerful algorithms rather than real AI) that use voice, text, or optional input to simulate a conversation between humans. Have meaningful conversations.

6 Common Challenges

1. **Power Consumption:** NGC technology is power hungry. Computing Techniques such as Quantum Computing and High-Performance Computing require a lot of power to function efficiently. Hence, it will be crucial for NGC to achieve power efficient solutions.

2. **Standardization:** Developing common standards for the NGC is one of the key challenges. Forming a common consensus among the various stack holders of the NGC will help in compatibility, interoperability, and wider adoption.

3. **Programming Models:** New computing technologies require newer programming languages and models to reach their full potential. Therefore, developing easier and more widely applicable programming models will be essential to achieve the goals of NGC.

4. **Cost:** NGC is still in its early stage of development. Hence, research and development, technology, and infrastructure are still very costly. Hence, it will be very crucial to address the cost relevant challenges in the development of the NGC.

5. **Ethical Challenges:** The NGC will rise the challenges of data privacy, bias, social impact, explainable artificial intelligence, etc. Hence, it becomes important to keep these ethical challenges in consideration to address during the evolution of NGC.

6. **Security and Scalability:** NGC will bring the challenges of security and scalability. Distributed and scalable computing models will be vulnerable to cyber-attacks. The data-heavy computing models will be difficult to scale. The development of encryption protocols, computing systems security, and scalability will be the concerns of the security and scalability of NGC.

7 Conclusion

Every computing device produces some data in the same or different form. The data produced of this capacity from different varieties of sources is difficult to process, store, and transmit with the present mode of computing technologies. Next generation computing helps to resolve such challenges and provides efficiency (efficiency in terms of power consumption, time consumption, cost effective, performance, accuracy etc.) and faster computing capabilities.

NGC enables machines to learn, adapt, decision-making, action, automate certain applications which require human effort and highlight hidden things beyond human thinking.

For example, one can use NGC to gain new insights from large and diverse data, including historical and current data. This technology is well suited for processing data and running algorithms and analytics on large amounts of data to find relevant relationships, entities and insights.

DSCI
PROMOTING DATA PROTECTION
A nasscom Initiative

techsagar
India's Cybertech Repository

ABOUT TECHSAGAR

About TechSagar: The office of National Cyber Security Coordinator, in partnership with Data Security Council of India conceptualized 'National Technology Capability Repository', and this gave rise to TechSagar. The office of National Cyber Security Coordinator continues to support TechSagar. TechSagar is a consolidated and comprehensive repository of India's Cybertech capabilities which provides actionable insights about capabilities of the Indian Industry, Academia & Research across 25 technology areas like IoT, AI/ML, Blockchain, Cloud & Virtualization, Robotics & Automation, AR/VR, Wireless & Networking, and more. It allows targeted search, granular navigation and drilldown methods using more than 3000 niche capabilities. TechSagar features entities from large & small enterprises, start-ups, academia, R&D centers and even individual researchers, providing a country level view of India's Cyber competencies.

Contact Us:

techsagar@dsci.in

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TechSagar_DSCI techsagar-dsci techsagar.in