

TECHVISTA

APRIL 2025



Electronics and Communication Engineering
Federal Institute of Science And Technology (FISAT)[®]

HoD's Desk



It gives me immense pleasure to present this edition of our Technical Magazine, a platform that reflects the creativity, innovation, and technical excellence in the field of Electronics. The field of Electronics and Communication Engineering continues to evolve rapidly, driving advancements that shape our modern world—from artificial intelligence and embedded systems to smart communication networks and sustainable technologies.

This magazine stands as a testament to the department's dedication to nurturing young minds, encouraging research-oriented thinking, and promoting a spirit of lifelong learning. Each article and contribution featured here represents the passion, perseverance, and curiosity that define our academic community.

The field of electronics today is witnessing remarkable transformations. In VLSI design, the shift toward nanometer technologies and energy-efficient architectures is opening new frontiers in chip design and semiconductor research. In Embedded Systems and IoT, real-time applications are shaping the future of automation, healthcare, and smart environments. Communication Systems continue to evolve through advancements in 5G, satellite communication, and optical networks, enabling faster, more reliable connectivity across the globe. Meanwhile, Artificial Intelligence and Machine Learning are revolutionizing the way electronic systems learn, adapt, and interact, paving the way for intelligent devices and predictive technologies.

I take this opportunity to extend my sincere appreciation to the editorial team, faculty advisors, and students for their collective effort in bringing this publication to fruition. I also express my heartfelt gratitude to the management for their constant support and encouragement in all our academic endeavors.

May this magazine continue to inspire innovation, foster collaboration, and strengthen our department's pursuit of excellence in technology and education

Editor's Word



Welcome to the latest issue of the Electronics and Communication Department technical magazine. This edition celebrates the exciting wave of new technological advancements shaping our world and redefining what's possible in the field of electronics. From emerging innovations in communication systems to breakthroughs in embedded technologies, this issue captures the passion, creativity, and perseverance that define our department. Each contribution reflects the spirit of inquiry that drives our students and faculty to explore beyond boundaries and imagine the future of technology.

As we navigate this era of rapid transformation, let us continue to learn, experiment, and innovate together—because every great leap in technology begins with a single spark of curiosity. In a rapidly evolving technological landscape, staying informed and inspired is vital, and this magazine aims to serve as a bridge, connecting knowledge, curiosity, and collaboration.. May this issue encourage everyone to explore new ideas, embrace technological challenges, and strengthen our collective commitment to engineering progress.

Extending heartfelt gratitude to the management of our institution for their constant encouragement, guidance, and support in bringing this newsletter to life. Their vision and leadership continue to inspire us to strive for excellence in every endeavor.

A special word of appreciation goes to all the students and faculty members whose enthusiasm, creativity, and hard work made this publication a success. Your valuable contributions—through articles, innovations, and ideas—reflect the true spirit of the Electronics and Communication Department. Together, we celebrate not just a newsletter, but a collective achievement that showcases our shared passion for learning and technological advancement.

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Our VISION

To emerge as a centre of excellence in Electronics and Communication Engineering churning out informed, innovative, socially committed and quality conscious engineers for the society.

Our MISSION

Foster an environment for multifaceted education rooted in science and contemporary technology

Facilitate quality research and development leading to innovations in the field of Electronics and Communication Engineering

Develop competent young engineers to complement the virtues of the society

PROGRAM SPECIFIC OUTCOMES

After the successful completion of the course, students of the Electronics and Communication Engineering Program will have:

The ability to apply the fundamental knowledge of Electronics and Communication Engineering to analyze, design and develop various types of electronic systems.

Competence in using modern hardware and software tools for developing solutions to engineering problems.

Excellent adaptability to the changing industrial and real world requirements.

PROGRAM EDUCATIONAL OBJECTIVES

Graduates of the program will have the technical expertise to analyze and design hardware and software components of electronic systems, benefiting industry and society.

Graduates of the program will be able to exhibit excellence in the field of Electronics and Communication Engineering and contribute significantly in research and development, enterprise and leadership.

Graduates of the program will be successful, ethically driven professionals with a passion for continuous learning.

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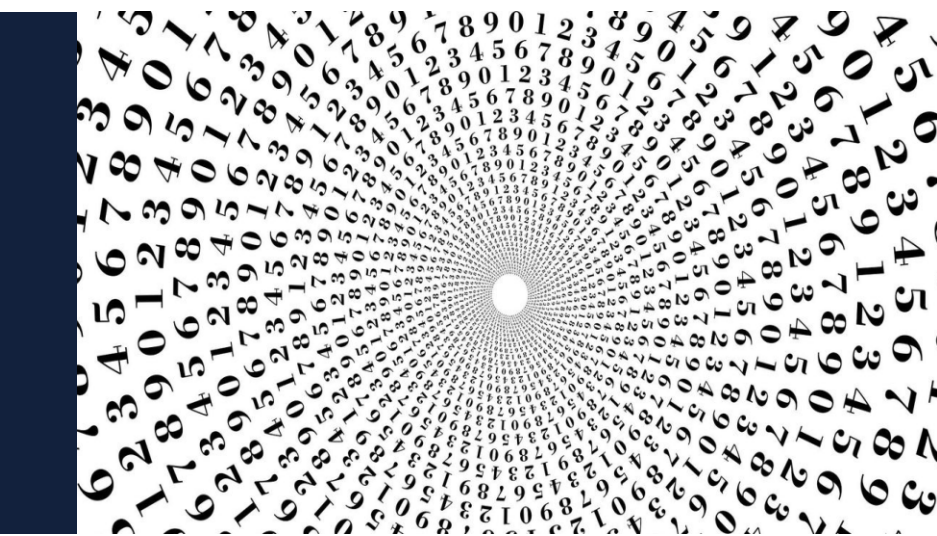
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DR. ANIL KUMAR M N
Professor, ECE FISAT

Properties of Mersenne Prime Numbers: From Abstract Algebra to Silicon Implementation

Mersenne primes, named after the 17th century French mathematician Marin Mersenne, are prime numbers of the special form $M_p = 2^p - 1$ where p itself is prime. These primes are rare and remarkable, carrying both deep mathematical significance and immense computational value. One of their most important properties is that not every prime exponent p yields a Mersenne prime; for instance, $2^{11} - 1 = 2047$ is composite, factoring into 23×89 , while $2^7 - 1 = 127$ is prime. This selective nature makes them a fascinating subject of study in number theory. In binary form, every Mersenne prime appears as a sequence of consecutive ones, such as $2^5 - 1 = 31 = (11111)_2$. This property is not only elegant but also provides practical advantages in computation, as bit patterns of ones can be handled efficiently by digital circuits. Another notable property is their intimate connection with perfect numbers. Their primality can also be tested efficiently using the Lucas–Lehmer test, which is one of the fastest deterministic methods known for very large numbers. In abstract algebra, Mersenne primes are closely tied to the structure of cyclic groups and finite fields, and their properties influence the way algebraic systems behave, giving them a deeper theoretical importance beyond simple curiosity.

The applications of Mersenne primes extend far beyond pure mathematics into the domains of modern computing and information security. They play a central role in cryptography, where the hardness of number theoretic problems is the foundation of secure digital communication. Algorithms such as RSA, Diffie–Hellman, and elliptic curve cryptography rely heavily on modular arithmetic with large primes, and Mersenne primes, due to their special form, allow these computations to be carried out more efficiently than with arbitrary primes. The reduced computational burden translates into faster encryption and decryption, which is vital in a world that transmits enormous amounts of secure data every second. Mersenne primes are also important in pseudorandom number generation. The well-known Mersenne Twister algorithm, which produces sequences with an exceptionally long period of $2^{19937} - 1$, is widely used in computer simulations, statistical sampling, numerical analysis, and machine learning, where reliable random sequences are essential. In coding theory, Mersenne primes provide the structure for constructing efficient error detection and correction codes. By linking modular arithmetic with polynomial representations, they support the design of cyclic redundancy checks and other mechanisms that ensure data integrity in communication systems. In addition, Mersenne primes serve as benchmarks in the history of computational mathematics. The largest prime numbers discovered so far, often consisting of millions of digits, have almost always been of Mersenne form. Distributed computing projects like the Great Internet Mersenne Prime Search (GIMPS) have pushed the frontiers of prime discovery, demonstrating not only mathematical curiosity but also the combined power of modern computer networks.

Equally important is the way Mersenne primes lend themselves to efficient hardware implementation, both in silicon processors and in reconfigurable FPGA devices. Modular arithmetic with arbitrary primes is normally a resource-intensive operation that requires division, a process costly in both time and energy. However, when the modulus is a Mersenne prime of the form $2^p - 1$, this process simplifies dramatically. Instead of performing division, reduction can

be achieved by splitting a number into p -bit blocks, wrapping the overflow around, and adding it back to the lower part until the result lies within the desired range. This “folding” technique is extremely efficient and can be implemented with simple additions and bit-shifts. In FPGA architectures, these reductions are realized using adder trees and barrel shifters, making the hardware design compact and fast. Such implementations are especially attractive because FPGAs are widely used in prototyping cryptographic processors and communication devices, where flexibility and speed are essential. At the silicon level, meaning dedicated integrated circuits or ASICs, the same principle enables the construction of highly efficient cryptographic engines, hardware random number generators, and error-correcting processors. Unlike general-purpose CPUs, which must handle many types of operations, silicon implementations are optimized for modular arithmetic with Mersenne primes, leading to very high throughput and low energy consumption. Because these operations can be pipelined

and parallelized, Mersenne prime arithmetic is particularly suited for high-performance computing, secure communications, and real-time signal processing. In practice, this means that abstract number theoretic ideas directly influence the design of physical chips that power our digital world.

In conclusion, Mersenne primes represent a rare synthesis of mathematical beauty and practical utility. Their special properties connect them to the ancient study of perfect numbers and modern algebraic structures, their applications advance fields as diverse as cryptography, coding, random number generation, and computational mathematics, and their hardware implementation demonstrates the seamless transition from theory to practice. From abstract algebra to FPGA prototypes and silicon processors, Mersenne primes stand as enduring examples of how deep mathematical concepts become engines of modern technology.





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Bridging Silence with AI: The Impact of Sign Language Translation Apps

In an era where communication shapes our personal and professional lives, a vast community of hearing-impaired individuals continues to face challenges in expressing themselves particularly in public, educational, and healthcare settings. While the rest of the world rapidly adopts voice-based technologies, these innovations often leave out the differently-abled. That is where inclusive technology becomes crucial. My main project, a Malayalam Sign Language Translation App, is an effort to bridge this communication divide using the power of Artificial Intelligence, speech recognition, and image mapping. This app acts as a real-time interpreter, allowing spoken Malayalam to be translated into sign visuals, opening new doors for accessibility and social participation.

How It Works

The application functions by capturing the spoken Malayalam language through a built-in microphone. This audio input is then processed through a speech recognition module that accurately converts it into text. Once the spoken sentence is transcribed, it undergoes keyword extraction and mapping with a curated database of Malayalam Sign Language images. These images are then displayed sequentially, forming a visual representation of the sentence in sign language.

The goal is to create a seamless experience for the user one where the deaf or hard-of-hearing person can instantly see what is being spoken to them. This real-time translation method ensures that conversations are not interrupted or delayed, making the app useful in fast-paced environments like classrooms or hospitals. The translation isn't just literal it's context-aware, ensuring that only meaningful and understandable signs are shown, not every filler or repeated word.

The Tech Stack

The app was built with a focus on accessibility, local relevance, and smooth performance.

- Google Speech API (for Malayalam speech-to-text)
- CNN-based image recognition and mapping
- A custom Malayalam sign language image database

The result is an app that is lightweight, fast, and ready for real-world use especially for schools, clinics, and homes where sign language communication is essential.



Real-Life Impact

The true value of this app lies in the impact it has on everyday lives. During the testing phase, we introduced the app in special education centers and received enthusiastic responses. In one instance, a teacher was able to convey classroom instructions more effectively to a student with hearing loss, who otherwise relied heavily on lip reading or slow human translation. Parents also expressed how such a tool could empower their children to participate in public activities confidently.

In healthcare, doctors and nurses appreciated how the app could assist in explaining symptoms or instructions without the need for a human translator. Especially in emergency cases where time is critical, even a basic understanding through signs can make a significant difference. In rural areas where professional sign language interpreters are rarely available, this app serves as a bridge between the spoken and silent worlds.

Challenges and Cautions

Developing this app also came with challenges. One major limitation was the lack of a standard, publicly accessible Malayalam Sign Language dataset. Most existing data is either incomplete or not digitized, requiring us to manually collect and verify visual signs. This was time-consuming but essential for accuracy.

Another issue is the complexity of the Malayalam language its rich vocabulary, regional dialects, and varying pronunciation make speech recognition a difficult task. While the Google Speech API performs well, environmental noise and different speaker tones sometimes affect recognition. There's also the ethical concern of replacing human interpreters. While the app serves as a support tool, not a replacement, we must be cautious about promoting it as a complete alternative in sensitive environments.

Lastly, maintaining user trust and data privacy is vital. Since the app listens to spoken input, we ensured that no data is stored or shared without consent. Future updates must continue this privacy-first approach.

The Future

The roadmap for this app is exciting and filled with potential. One of our key goals is to implement reverse translation allowing users to perform sign gestures in front of the camera, which the app can recognize and convert into text or speech using a CNN- or RNN-based vision module. This would make the app interactive, allowing two-way communication between hearing and non-hearing individuals.

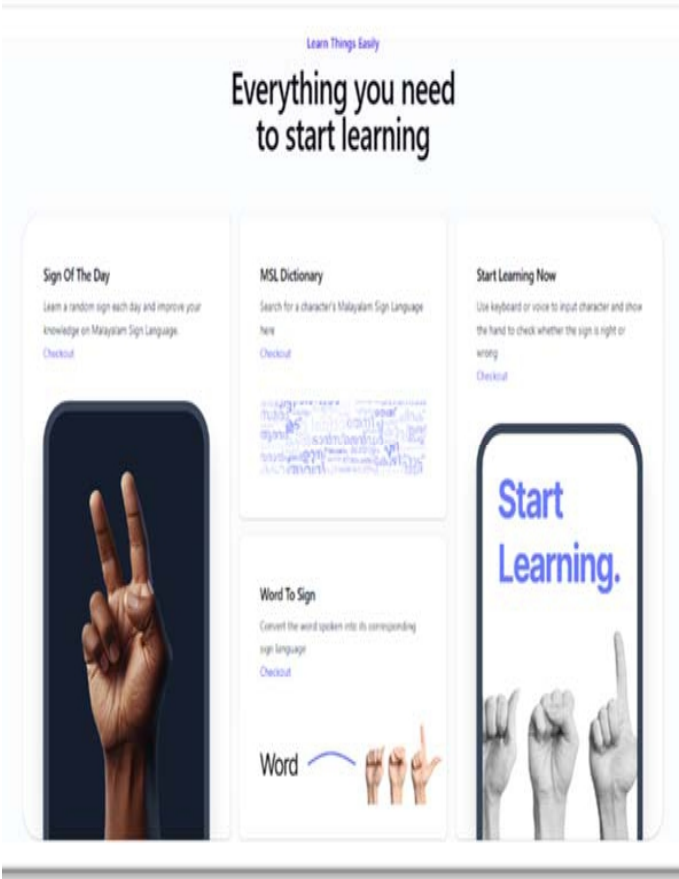
We also plan to integrate voice customization, so users can choose the tone or accent of the speech playback. This would make the app more inclusive for elderly users or children who require a slower and softer voice output. Additionally, text-to-speech integration would allow illiterate users or those with limited reading ability to hear the translated messages.

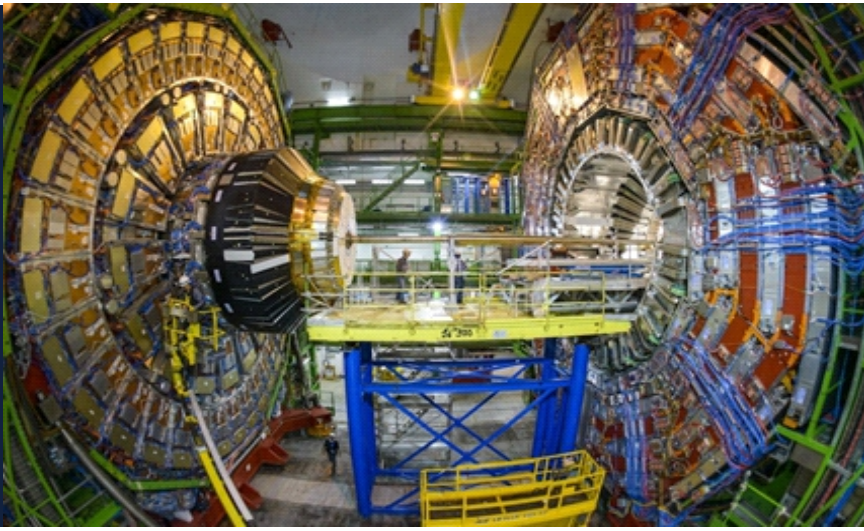
The future of the app isn't just technical; it also involves outreach. Collaborating with educational institutions, NGOs, and hospitals can help refine the app further and reach those who need it the most.

Conclusion

Artificial Intelligence, when used thoughtfully, has the power to uplift and empower. While large language models like ChatGPT revolutionize how we write and think, specialized tools like this Sign Language Translator app play a vital role in making communication accessible to all. This project is not just a technical achievement it's a mission toward inclusion, dignity, and equal opportunity.

The success of this app proves that when innovation meets empathy, it can break down even the most persistent barriers. As we continue to improve the technology, the vision remains clear: no one should be left out of a conversation because of their ability to hear or speak. And in that pursuit, this app is just the beginning.





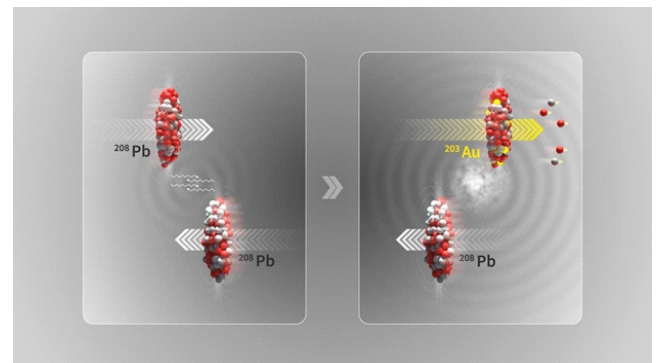
DISALFIN K SUNNY
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Lead to Gold : Marvel of Particle Physics

A Contemporary Alchemy By using high-speed, near-miss collisions of lead nuclei, scientists have achieved a remarkable feat at CERN's Large Hadron Collider (LHC): turning mercury into gold. An old dream of using nuclear physics to turn base metals into gold has come true thanks to the ALICE collaboration's observation of this phenomenon, which was published in Physical Review Journals on May 7, 2025. Even though the gold created is fleeting and insignificant, the effects are significant. This finding sheds light on the fundamental forces of the universe and demonstrates the LHC's extraordinary capabilities. This is the reason it's so exciting to reach this milestone. The Test: Nuclear Magic Near-Miss Lead nuclei are broken up at 99.999993% the speed of light by the LHC, the world's most powerful particle accelerator.

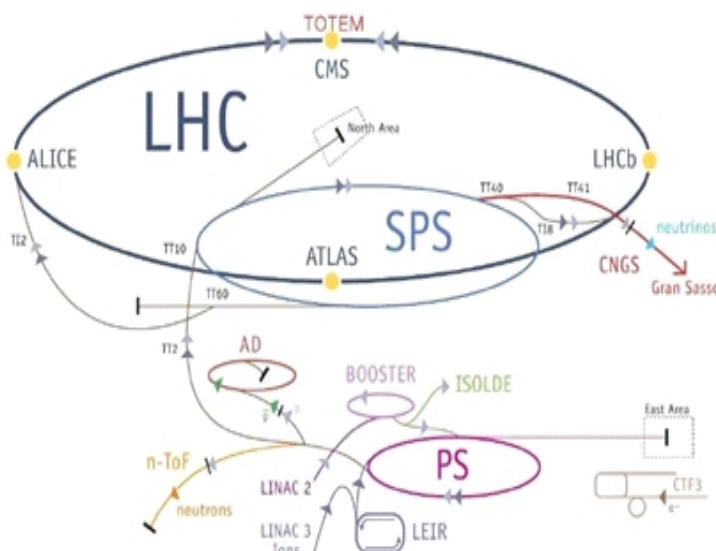
Typically, the ALICE experiment studies direct impacts that produce a quark-gluon plasma, an early universe state of matter, in heavy-ion collisions. However, a surprising effect known as nuclear transmutation has been discovered as a result of near-miss collisions, in which nuclei

pass close to one another without touching. A photon pulse is produced in these near-misses by the strong electromagnetic fields of lead nuclei. When a photon excites a nucleus, it releases protons and neutrons, a process known as *electromagnetic dissociation*, which is triggered by this pulse. Mercury, which has 81 protons, is created when a lead nucleus, which has 82 protons, loses one proton. Gold has 79 protons when three are lost, whereas thallium has 80 protons when two are lost. The ALICE team used zero-degree calorimeters (ZDCs) to find these uncommon transformations. Lead-lead collisions produced gold nuclei at a rate of approximately 89,000 per second, along with thallium and mercury.



The Reasons This Phenomenon Is Amazing

1. **Realization of Alchemy:** The conversion of base metals like mercury into gold, or *chrysopoeia*, was what ancient alchemists were looking for. They were unaware that an element's proton count determines its identity and that only nuclear processes can alter it. The transformation of mercury, a poisonous liquid metal, into gold, a representation of wealth, by the LHC is a stunning example of how myth and science can coexist. CERN's high-energy collisions accomplish this at the atomic level, making the impossible possible, whereas alchemists relied on crude furnaces.
2. **Electromagnetic Power:** One of the universe's strongest electromagnetic fields drives the transmutation, which



takes place without physical contact. These fields can remove protons from a nucleus, radically altering its identity. They are produced by nuclei traveling at relativistic speeds. This demonstrates the fundamental power of electromagnetic interactions under harsh circumstances and the LHC's capacity to manipulate matter.

3. A Transient Display: The nuclei of gold and mercury have an extremely short lifespan; they only last a few microseconds before decaying or colliding with the beam pipe of the LHC. About 86 billion gold nuclei, or 29 picograms—much less than a grain of sand—were produced during the LHC's Run 2 (2015–2018). The phenomenon's ephemeral nature makes it even more captivating, necessitating the use of the most sensitive detectors available to record such fleeting changes.

4. Cosmic Insights: The experiment illuminates the early universe in addition to converting mercury into gold. Scientists can better comprehend the quark-gluon plasma and the forces that shaped the universe after the Big Bang thanks to the same electromagnetic processes. These discoveries may influence the development of upcoming accelerators, such as the Future Circular Collider, which would further our investigation of basic physics.

5. Technological Triumph: The ALICE detector's accuracy is astounding; it can handle both subtle near-misses that yield only a few particles and catastrophic collisions that produce thousands. This dual capability is “impressive,” according to ALICE spokesperson Marco Van Leeuwen, allowing scientists to measure uncommon occurrences like mercury-to-gold transmutation. This technological achievement demonstrates how humankind can delve into the most profound mysteries of nature.

Although only a small amount of gold is produced—a single gram would require trillions of years of collisions—it has enormous scientific value. Comprehending electromagnetic dissociation advances our understanding of accelerator beam stability and particle interactions,

opening the door to more effective collider designs. By transforming an ancient quest into a contemporary reality, the experiment also captivates the imagination. It shows that even in ways that medieval alchemists could not have imagined, science can accomplish what was once thought to be magical.

Sources: Physical Review Journals, ALICE Collaboration, CERN press releases, Wikipedia

Quick Facts on Large hadron collider

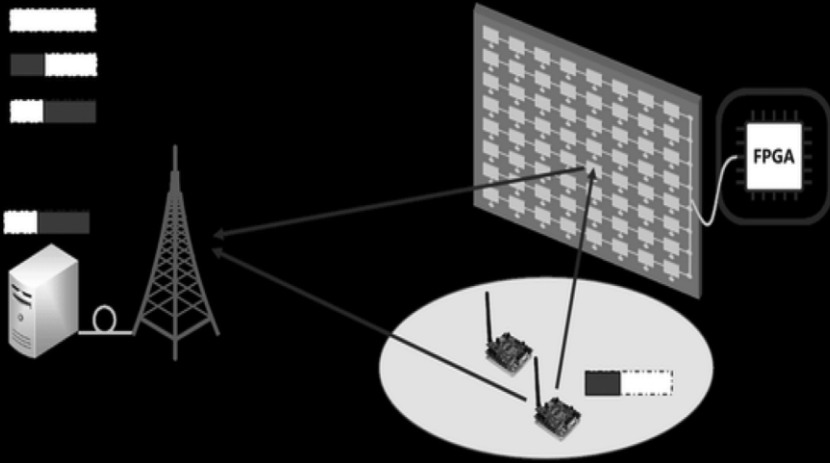
The galaxy's coldest and hottest regions can be found in the LHC, a region known for its extreme temperatures. Colder than Space: The LHC uses liquid helium to cool it to -271.3°C (1.9 K) in order to maintain the operation of its superconducting magnets. Compared to deep outer space, which is roughly -270.5°C , this is colder

Warmer than the Sun: The LHC produces temperatures of more than 5 trillion degrees Celsius when heavy lead ions collide with it. That recreates the conditions from the first microseconds of the Big Bang and is 100,000 times hotter than the Sun's center.

The speeds at which the particles travel inside the LHC are counterintuitive. The speed of light is 99.9999991% for protons in the LHC. A proton moves 11,245 times per second around the 27-kilometer ring at this speed [6.1]. The power of a freight train: 500 kg of copper can be melted by the combined energy of the circulating beams, despite the fact that each proton has very little energy. At 150 km/h, it is comparable to a 400-ton train (such as a Whillan).

Exceptional Vacuum: The beam pipes are pumped to a "ultra-high vacuum" to prevent collisions with gas molecules. Ten times less pressure exists inside than there is on the Moon..





ABHAYKRISHNAPS
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RECONFIGURABLE INTELLIGENT SURFACE

WIRELESS COMMUNICATION OF THE FUTURE

Suppose you are attempting to converse in a crowded room. You yell, you say it again-but the message simply fails to penetrate. Now picture if the walls in the room were able to assist you, softly capturing your words and carrying them straight to the listener's ears.

That's what Reconfigurable Intelligent Surfaces (RIS) are going to do for the wireless world. Rather than allowing radio waves to bounce haphazardly, RIS technology can steer, reflect, and shape them smartly-leading to better, stronger, faster communication.

So, how do you change the wireless world without installing more antennas or power?



“RECONFIGURE TO REINVENT” THE RIS ADVANTAGE

So why is RIS a game-changer? It's its software-defined flexibility. With basic electrical control, every aspect of the surface can alter its behavior on command-adjusting the way it reflects or bends a signal.

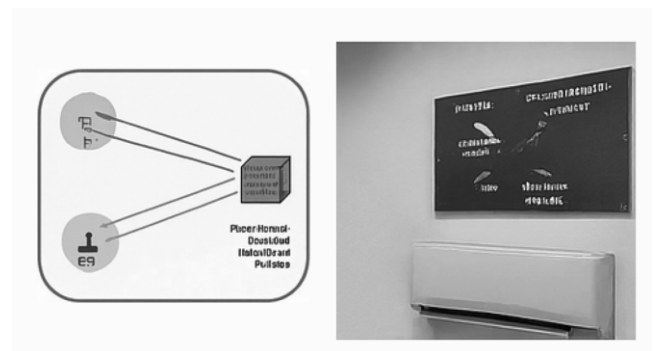
“SMART SURFACES, SMARTER SIGNALS”

RIS is a revolutionary method that entails coating surfaces-such as walls, ceilings, or buildings-with extremely thin layers composed of programmable meta-materials. These surfaces do not simply reflect signals passively like mirrors; they are actively tunable to control electromagnetic waves.

Using RIS, the communication ecosystem is dynamic. These intelligent surfaces may be adjusted in real-time to:

- ♦ Increase signal strength
- ♦ Minimize interference
- ♦ Concentrate beams on particular devices.

This allows for a controllable and energy-effective wireless world even in sophisticated environments such as urban cities or in-house networks



WHY IS THIS A GAME-CHANGER?

Because rather than competing with signal loss through buildings, walls, and obstacles, RIS makes them work for you. The previously antagonistic wireless world is now a cooperative partner in your data transmission-imagine making every barrier a stepping stone

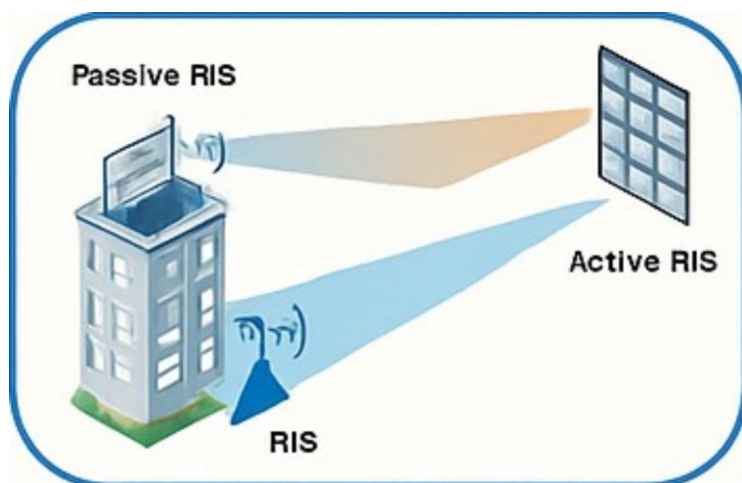
WHY IS THIS A GAME-CHANGER?

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“WHY EVERY REFLECTION COUNTS”

RIS can revolutionize the way we communicate:

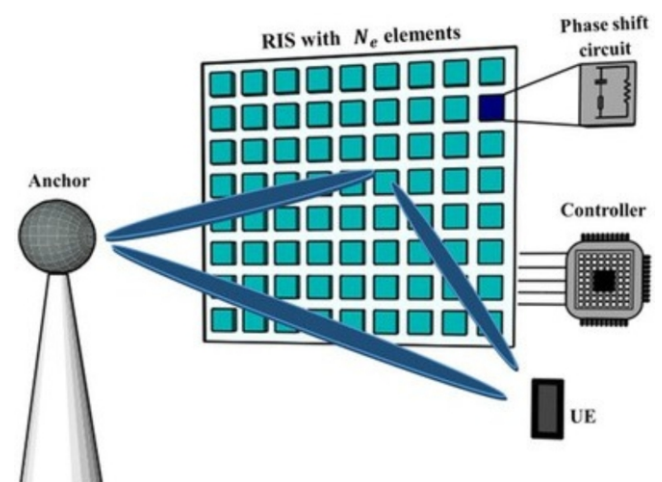
- ♦ Greener, Faster Networks: Less energy usage compared to conventional base stations or relays. Facilitates 6G-ready environments with huge connectivity.
- ♦ Intelligent Cities and IoT: Low-latency, seamless communication for smart homes, smart grids, and autonomous transport.
- ♦ Uplifted Reliability in Mission-Critical Sectors: More dependable connections in healthcare, defense, and remote operations.



“PROOF IN THE SURFACES”

Scientists all over the world—including India's top institutions—are working on RIS for next-generation communication systems. This technology doesn't merely deliver enhancements; it reframes the wireless medium itself.

- ♦ Enhances spectral efficiency while maintaining minimum power consumption.
- ♦ Enhances coverage in challenging areas.
- ♦ Opens the door to smart radio environments in 6G and beyond.



THIS PIONEERING RESEARCH IS SETTING THE STAGE FOR THE NEXT WIRELESS REVOLUTION. RIS ISN'T THE FUTURE—IT'S ALREADY STARTED CHANGING THE WORLD AROUND US



MEENAKSHI S
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Aditya-L1: India's Pioneering Solar Observatory at the Sun-Earth L1 Lagrange Point

Abstract

The Aditya-L1 mission signifies India's first dedicated venture into space-based solar physics research, spotlighting the country's expanding capabilities in astrophysics and space exploration. Positioned at the Sun-Earth L1 Lagrange point, approximately 1.5 million kilometres from Earth, Aditya-L1 is uniquely situated to provide an uninterrupted, real-time view of the Sun's activity. By observing solar phenomena such as coronal mass ejections (CMEs), solar flares, and the dynamics of the solar corona, this mission aims to deepen our understanding of space weather - phenomena that can drastically impact satellite operations, power grids, and communication infrastructure on Earth. This report outlines the mission's scientific objectives, detailed payload specifications, and the potential for transformative advances in Helio physics.

1. Introduction

The Sun, as the powerhouse of our solar system, influences the near-Earth environment through radiant energy, solar wind, and magnetic fields. Its variable activity manifests through phenomena like solar flares, CMEs, and variations in solar wind intensity, which can trigger geomagnetic storms and disrupt technological systems on Earth.



Historically, India has contributed significantly to solar research through ground-based observatories and space missions like the Chandrayaan series and the Mars Orbiter Mission. Now, with Aditya-L1, India embarks on a dedicated mission to observe the Sun continuously from a vantage point beyond Earth's atmosphere, leveraging the stable orbit at L1. This position offers an ideal platform for unimpeded solar observation — critical for early warning systems and scientific breakthroughs in understanding solar activity.

The mission will also dovetail with global efforts, such as NASA's Parker Solar Probe and ESA's Solar Orbiter, by providing complementary data, especially from the unique vantage point at L1.

2. Mission Objectives

The primary scientific goals of Aditya-L1 are strategically designed to address key questions in solar physics and space weather prediction, including:

a. Investigating Coronal Heating

Understanding why the solar corona reaches temperatures of over a million degrees Kelvin, markedly hotter than the Sun's surface, remains a fundamental question. The mission aims to analyze high-resolution imaging and spectroscopic data of the corona to identify heating mechanisms such as magnetic reconnection and wave dissipation.

b. Examining CME Initiation and Propagation

CMEs are massive expulsions of plasma and magnetic fields that can produce geomagnetic storms upon interacting with Earth's magnetosphere. Aditya-L1 will study their initiation processes, early evolution, and 3D propagation dynamics, providing vital data to improve space weather forecasts.

c. Understanding Solar Flare Phenomena

Solar flares release intense bursts of electromagnetic radiation. The mission seeks to scrutinize the trigger mechanisms and magnetic field configurations that lead to flares, particularly in the chromosphere and corona.

d. Enhancing Space Weather Prediction

By characterizing incoming solar energetic particles and magnetic disturbances at L1, Aditya-L1 aims to refine predictive models, providing earlier alerts for space weather events with higher accuracy.

e. Investigating Solar Wind Acceleration

The solar wind, a constant outflow of charged particles, shapes the heliosphere and influences planetary environments. Mapping its origins and acceleration mechanisms will deepen our knowledge of fundamental plasma physics.

3. Payload Description

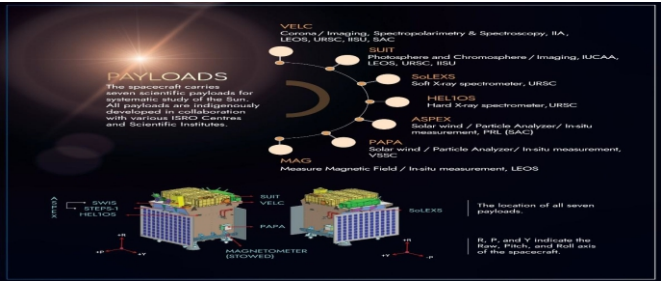
Aditya-L1's payload suite is meticulously designed to encompass a broad spectrum of solar phenomena:

Payload	Functionality	Key Instruments & Capabilities	Spectral Range & Resolution
Vanguard Coronagraph (VELC)	Observes the solar corona in visible and infrared wavelengths to study coronal mass ejections and the coronal thermal structure.	High-resolution coronagraph with a 10 cm aperture, equipped with polarization capability for magnetic field assessment.	0.55 μm to 1.0 μm; spatial resolution of 1.0 arcsecond.
Solar Ultraviolet Imaging Telescope (SUIT)	Captures images of the Sun in the ultraviolet spectrum to analyze chromospheric features and flares.	2048×2048 CCD detector covering 200–400 nm.	200–400 nm; spatial resolution of 0.5 arcseconds.
High Energy Lens Spectrometer (HELMS)	Measures the energetic particles emitted during flares and CMEs.	X-ray and extreme ultraviolet spectrometers.	1–15 keV; spectral resolution of 150 eV.
Aditya-Magnetograph (AMIG)	Records the magnetic field vector in the photosphere and chromosphere.	Vector magnetometer with high sensitivity.	Measurement of magnetic fields up to 3000 Gauss with spatial resolution of 0.3 arcseconds.

4. Data Analysis and Anticipated Outcomes

Data collected by Aditya-L1 will be processed through sophisticated solar data analysis frameworks involving machine learning algorithms, 3D reconstructions, and real-time monitoring systems. Expected scientific advancements include:

- ◆ Insights into flare triggers: Combining magnetic field and plasma data, scientists hope to delineate the magnetic reconnection processes underpinning solar flares.
- ◆ Refined space weather forecasts: By characterizing the initial conditions of solar eruptions, the mission aims to produce more reliable and earlier space weather alerts, protecting vital technological systems.
- ◆ Fundamental plasma physics: Data on particle acceleration and magnetic reconnection will contribute to theoretical models that also have implications for astrophysics and laboratory plasma studies.



- ◆ Deciphering the coronal heating mystery: High-resolution imaging and spectroscopic studies are expected to reveal the dominant heating processes, such as Alfvén wave dissipation or nanoflares.
- ◆ Enhanced CME models: Observations of CME initiation at L1 will improve the accuracy of predictive models, potentially reduce false alarms and provide hours of lead time.

5. Conclusion

The Aditya-L1 mission epitomizes India's commitment to advancing space science and contributes significantly to global Helio physics research. Its observations are expected to break new ground in understanding the Sun's complex behaviour and its influence on the heliosphere. The mission's success not only enhances India's scientific stature but also bolsters international collaborations aimed at safeguarding modern civilization from the Sun's unpredictable moods.



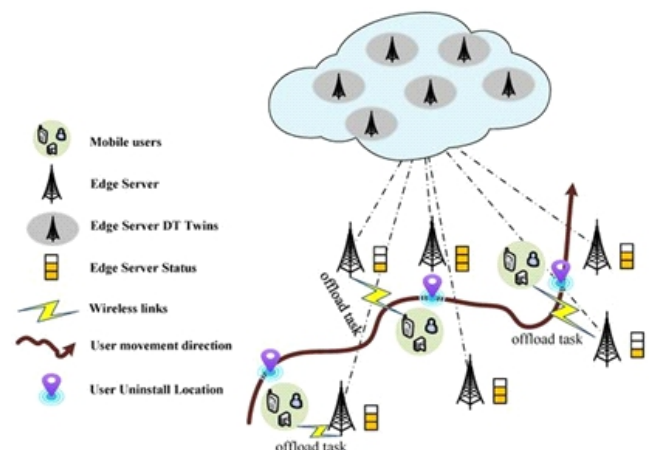
ALEENA PAUL
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Beyond 5G: How RedCap and Digital Twins are Forging the Future of IoT

Prepare to witness a new era of connectivity as the powerful convergence of 5G-Advanced Reduced Capability (RedCap) and Network Digital Twin (NDT) technologies promises to revolutionize Industrial IoT (IIoT) and smart cities, laying the very groundwork for the future of 6G!

5G-Advanced RedCap: Unlocking Next-Gen IoT Potential Forget the limitations of old IoT! 5G-Advanced RedCap is engineered to shatter throughput and latency barriers currently faced by technologies like LTE-M and NB-IoT. It's a smarter, more efficient alternative for scenarios where the full might of a 5G eMBB network isn't overkill. With 3GPP Release 18, finalized in 2024, significant enhancements are here to meet the diverse demands of advanced IoT devices. RedCap acts as the essential bridge, seamlessly connecting 5G's power with IoT's unique needs, delivering moderate data rates, incredible power efficiency, and cost-effectiveness. It comes packed with core 5G features like network slicing, enhanced positioning, and advanced beamforming for unparalleled connectivity. And the innovation doesn't stop there! eRedCap, also a product of Release 18, pushes boundaries further, slashing device complexity and cost while still delivering impressive 10 Mbps peak data rates. This is all about expanding the 5G device ecosystem, making advanced connectivity more accessible than ever.

Network Digital Twin (NDT): The Intelligent Brain of Future Networks Imagine a virtual replica of your entire network, constantly learning, adapting, and optimizing – that's the power of the Network Digital Twin! NDT is a game-changer for Smart Manufacturing and Smart City initiatives, forging a powerful, symbiotic relationship with RedCap. This virtual representation of a physical communication network can analyze, diagnose, emulate, and control, creating a real-time, interactive mirror of the physical world.



NDT's brilliance lies in its core characteristics:

- ◆ **Massive Data Hub:** A unified data repository capable of storing vast amounts of network data, ensuring accurate and timely information for models.
- ◆ **Live Interaction:** Unlike simple simulations, NDT offers real-time interactive mapping between physical and virtual networks.
- ◆ **Flexible Design:** Diverse data models can be combined to perfectly support various network applications.
- ◆ **Seamless Integration:** A standardized interface guarantees compatibility and scalability within the NDT system.

Harnessing the might of AI/ML, big data, and cloud technology, NDT empowers physical networks to conduct low-cost trials, make informed decisions, drive efficient innovation, and even perform predictive maintenance. It's the ultimate tool for closed-loop network management, from digital deployment and simulation to continuous verification. This translates into profound benefits for network operations: superior monitoring, optimized efficiency, accelerated

innovation, precise measurement, intent-based networking, and even security strategy drills. NDTs are set to redefine 5G network testing, performance assurance, and security, detecting anomalies and dynamically adjusting configurations.

A Unified Vision: Revolutionizing IIoT and Smart Cities The proposed integration of 5G-Advanced RedCap and NDT isn't just an idea; it's a blueprint for optimizing 5G verticals across their entire lifecycle – from planning to operation and maintenance.

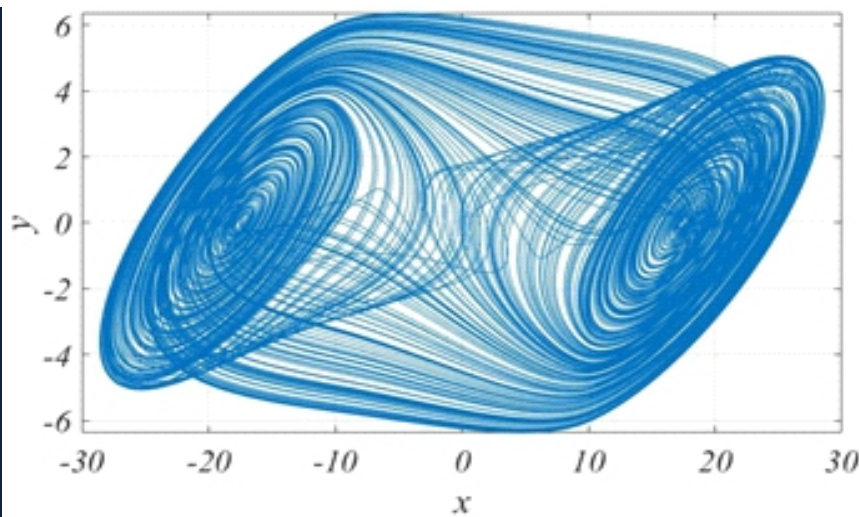
For

Smart Manufacturing and IIoT, NDT is a transformative force, perfectly integrating 5G and IIoT for unparalleled prediction, monitoring, control, and decision-making. Picture 5G RedCap connecting a vast network of wireless industrial sensors, meticulously monitoring and controlling equipment, leading to safer and more efficient industrial environments. NDTs become indispensable for optimizing industrial processes, enhancing their synergy with IoT, cloud computing, machine learning, and advanced analytics.

In the realm of **Smart Cities**, this dynamic duo is already making a tangible impact. A project has demonstrated the use of RedCap smart terminals to create a 5G monitoring network for urban environmental management. RedCap modules are transmitting vital environmental data via video surveillance, data collection terminals, air micro-stations, and noise monitoring equipment, achieving continuous, intelligent, and precise oversight. This breakthrough dramatically cuts costs for 5G modules, equipment power consumption, and data charges, making large-scale deployment feasible. It's all about ensuring data security while connecting front-end hardware, leading to visualized supervision and intelligent decision-making for comprehensive ecological management across urban districts.

The synergy between 5G networks and NDT is creating a robust ecosystem that delivers critical insights into smart connectivity and empowers the development of complex use cases.





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Riding the Chaos Wave: A New Era of Unbreakable Encryption

How we are harnessing the unpredictable power of chaos to create a new generation of cryptographic systems.

In our hyper-connected world, the security of our digital lives hinges on the strength of encryption. From banking transactions to private messages, we rely on complex algorithms to keep our data safe from prying eyes. But what if the very keys to this digital kingdom could be forged from the beautiful, unpredictable patterns of chaos? We have figured out how to do just that, developing a novel cryptographic system that generates keys from the chaotic signals of a simple electronic circuit.

This project, titled "Analog Chaotic Cryptography for Embedded Systems," bridges the gap between the abstract world of nonlinear dynamics and the practical realm of hardware security. At its heart lies a fascinating piece of electronics known as Chua's circuit, a system famous for its ability to produce deterministic chaos.

What is Chaos?

You might think of chaos as complete and utter randomness, but in the world of mathematics and physics, it has a more nuanced meaning. Chaotic systems are deterministic, meaning their future behavior is technically predictable based on their initial conditions. However, they exhibit a property called sensitive dependence on initial conditions, famously known as the "butterfly effect." This means that even the tiniest, imperceptible change in the starting state of the system can lead to wildly different outcomes down the line.

It's this inherent unpredictability that makes chaotic systems a goldmine for cryptography. A good encryption key needs to be random and unpredictable, and what's more unpredictable than a system where a microscopic change can alter the entire outcome?

The Heart of the System: Chua's Circuit

We built a modified version of Chua's circuit, an elegant and relatively simple assembly of resistors, capacitors, and operational amplifiers. When powered on, this circuit doesn't produce a stable, repeating signal like a typical oscillator. Instead, its output voltage fluctuates in a complex, non-repeating pattern. When you plot these voltage fluctuations against each other on an oscilloscope, a beautiful and intricate pattern emerges:

The iconic double-scroll attractor, visualized on an oscilloscope, confirms the circuit is operating in a chaotic state.

double-scroll attractor, also known as the "Chaotic Attractor." This mesmerizing shape is the visual signature of the circuit's chaotic nature, a fingerprint of deterministic chaos in action.

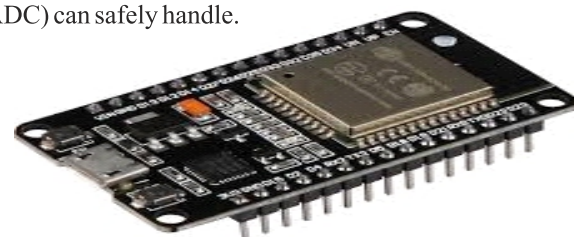
It's not necessary to use a traditional physical inductor, which can be bulky and inefficient. Instead, we can simulate one using a clever configuration of op-amps called a gyrator, making the design more compact and suitable for modern electronics.

From Analog Chaos to Digital Keys

So, how do you turn this wildly fluctuating analog signal into a secure digital encryption key? This is where the "embedded systems" part of the project comes in, specifically, the versatile

ESP32 microcontroller.

The chaotic signal from the Chua's circuit, which oscillates between -2V and +2V, is first passed through a custom-built biasing circuit. This circuit shifts the signal into the 0V to 3.3V range that the ESP32's Analog-to-Digital Converter (ADC) can safely handle.

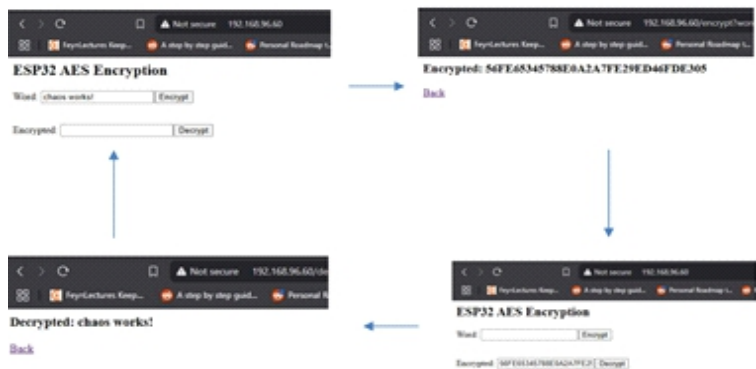


The powerful ESP32 microcontroller, the brain of the operation, digitizes the chaotic signal and handles the encryption.

The ESP32 then samples this chaotic voltage thousands of times per second, converting each analog snapshot into a digital value. But these raw numbers aren't the final key. To ensure the key is cryptographically secure and uniformly random, the students processed these raw samples using the industry-standard SHA-256 hashing algorithm. This one-way function takes the chaotic data and transforms it into a fixed-length, highly random string of characters – a secure AES encryption key.

Putting it to the Test

To prove the system isn't just a theoretical marvel, we can create a practical demonstration of its capabilities. The ESP32 was programmed to host a simple web server, accessible over Wi-Fi. Users could connect to the ESP32's network, open a web browser, and be greeted with a straightforward interface for encryption and decryption.



The web interface demonstrates the system's end-to-end functionality, from plaintext to ciphertext and back again.

A user could type in a message, and with the click of a button, the system would encrypt it using a freshly generated chaos-based key. The resulting ciphertext could then be pasted back into the interface to be decrypted, revealing the original message and proving the system's complete, end-to-end functionality.

The Future is Chaotic

This project is a fantastic demonstration of how principles from different fields of engineering and science can come together to create something truly innovative. By marrying a classic analog circuit with modern digital processing, we have created a low-cost, effective, and elegant solution for generating high-quality cryptographic keys.

As our world becomes increasingly reliant on secure communications, especially with the rise of the Internet of Things (IoT), the need for robust and efficient encryption methods will only grow. Chaos-based systems like this one offer a promising alternative to conventional random number generators, providing a source of true randomness that is difficult to predict or replicate.





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POST-QUANTUM CRYPTOGRAPHY: PROTECTING SECRETS IN THE QUANTUM ERA

Quantum computing is a revolutionary computing paradigm that uses the principles of quantum mechanics to perform computations in ways that classical computers can never compete with. It has the power to disrupt the current cryptographic techniques used due to its exponential computing speed. "Post-quantum cryptography" has become a buzzword in the tech world in recent years due to the rising threat posed by the advancements in quantum computing.

Post-quantum cryptography (PQC), sometimes referred to as quantum-proof, quantum-safe, or quantum-resistant, is the development of cryptographic algorithms (usually public key algorithms) that are currently thought to be secure against a cryptanalytic attack by a quantum computer.

The Quantum Threat to Classical Cryptography

Quantum computers have the potential to break the very foundation of today's encryption systems. Classical cryptographic algorithms such as RSA, DSA, and ECC rely on mathematical problems that are computationally hard for conventional computers. However, with Shor's algorithm, a quantum computer can factor large integers and compute discrete logarithms exponentially faster, rendering these widely used public-key systems insecure. Similarly, Grover's algorithm can speed up brute-force attacks on symmetric algorithms, effectively reducing their security by half. As a result, even AES would need longer key sizes to maintain its resistance to quantum threats

What is Post-Quantum Cryptography (PQC)?

Post-quantum cryptography refers to cryptographic algorithms that are designed to be secure even in the presence of quantum computers. Unlike quantum key distribution (QKD), PQC algorithms do not require quantum hardware. They run on classical systems and are built

on complex mathematical structures such as lattices, error-correcting codes, multivariate polynomials, and hash functions. These algorithms are intended to replace or supplement current encryption and signature schemes, ensuring long-term data protection against future quantum attacks.

Need for Post-Quantum Cryptography(PQC)

Quantum computers pose a serious threat to current encryption methods like RSA and ECC, which protect online banking, emails, and government data. Once quantum machines are powerful enough, they could break these systems, exposing sensitive information. To prevent future cyberattacks and ensure long-term data security, we urgently need quantum-resistant encryption, known as Post-Quantum Cryptography (PQC).

Types of Post-Quantum Cryptographic Algorithm

To counter quantum attacks, researchers have developed new classes of cryptographic algorithms that rely on problems believed to be hard even for quantum computers. The most promising categories include:

Hash-Based Signatures	Multivariate Cryptography	Code-Based Cryptography	Lattice-Based Cryptography
Hash-based signature schemes use one-time signature schemes as their building block. A given one-time signing key can only be used to sign a single message securely. Indeed, signatures reveal part of the signing key.	This algorithm relies on the complexity of solving systems of multivariate polynomial equations.	The private key is associated with an error-correcting code and the public key with a scrambled and erroneous version of the code. Security is based on the complexity of decoding a generic linear code.	Security is related to the difficulty of finding the nearest point in a lattice with hundreds of spatial dimensions (where each lattice point is associated with a private key) giving an arbitrary location in space (associated with the public key)
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Post-Quantum Cryptography Standards by NIST;

In 2023, the U.S. National Institute of Standards and Technology (NIST) published three Federal Information Processing Standards (FIPS) to establish the first set of quantum-safe cryptographic algorithms:



FIPS NUMBER	ALGORITHM NAME	TYPE	BASED ON	PURPOSE
FIPS 203	ML-KEM	KEY ENCAPSULATION	CRYSTALS-KYBER	SECURE KEY EXCHANGE (TLS,VPN,ETC)
FIPS 204	ML-DSA	DIGITAL SIGNATURE	CRYSTAL-DILITHIUM	DIGITAL SIGNING AND VERIFICATION
FIPS 205	SPHINCS+	DIGITAL SIGNATURE	HASH-BASED SIGNATURES	LONG-TERM SECURE SIGNATURES(FALLBACK)

Real-World Implementation of PQC

Several technology giants and research institutions are already testing and integrating post-quantum cryptographic solutions. Google has conducted large-scale trials of PQC in Chrome and Internet traffic using hybrid algorithms that combine classical and quantum-safe encryption. IBM and Microsoft are also actively developing quantum-safe cloud infrastructure. Startups and cybersecurity companies are offering post-quantum VPNs and email encryption to businesses seeking early adoption. This shift reflects a growing urgency to prepare for the inevitable arrival of large-scale quantum computers.

Future Outlook

The future of Post-Quantum Cryptography is rapidly progressing, with global efforts focused on standardization, implementation, and awareness. Organizations like NIST are finalizing post-quantum algorithms (e.g., FIPS 203–205) to replace vulnerable classical systems. Tech giants, governments, and industries are beginning early

adoption to ensure a smooth transition before large-scale quantum computers arrive. In the coming years, PQC will become a fundamental part of cybersecurity infrastructure, embedded in devices, networks, and cloud services. Continuous research, testing, and real-world deployment will shape a quantum-safe digital future.

CONCLUSION

As quantum computing advances from theory to reality, the urgency to secure our digital world has never been greater. Post-Quantum Cryptography offers a proactive solution—providing encryption methods resilient to future quantum threats. By adopting PQC early, industries and governments can ensure long-term data protection, safeguard critical infrastructure, and maintain public trust. The path to a quantum-secure future begins now, and preparedness today is the key to security tomorrow.





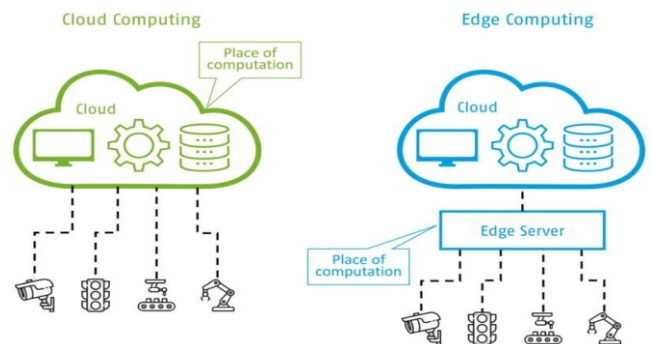
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AIoT at the Edge: Revolutionizing Smart Homes and Urban Infrastructure with Localized Intelligence

Science fiction is quickly giving way to the promise of a genuinely "smart" world, where settings automatically adjust to human needs and maximize resource use. The Internet of Things (IoT), a massive network of connected devices is at the center of this revolution. However, the massive scale and real-time demands of these ecosystems have limitations of traditional cloud-centric processing. AIoT, a powerful fusion of artificial intelligence and the Internet of Things enters the picture at this point due to the paradigm shift towards Edge AI. Edge AI is fundamentally changing the responsiveness, security, and capabilities of smart cities and homes by bringing intelligence closer to the data source.

The Paradigm Shift: From Cloud to Edge in AIoT

The traditional IoT deployment architecture involved sensors and devices gathering unprocessed data and sending it to distant cloud servers for in-depth artificial intelligence processing and analysis. After decisions were made, they were transmitted back to the devices. Latency emerged as a major problem for real-time applications where delay of even milliseconds could have significant consequences. Introduction of large volumes of raw data led to bandwidth overload, which raised operating costs and resulted in network traffic congestion. In addition, various privacy and security concerns were raised by



ongoing transportation of sensitive information to external servers, exposing systems to abuse and violations. Finally, reliance on continuous internet availability meant that it was not available where network connectivity was occasional or absent. Edge AI gets around these restrictions. Edge AI combines AI processing capability directly onto IoT devices or onto local gateways positioned at the "edge" of the network, instead of utilizing a centralized cloud setup. Devices can analyze information more quickly and respond immediately because to this local processing without data delays.

Edge AI in Smart Homes: Enhancing Security, Privacy, and Automation

Increased security and privacy are the most important benefits of having Edge AI in household environments. In the traditional IoT deployment architecture, sensitive data like videos from surveillance cameras or private voice instructions to AI assistants would be sent to cloud servers for processing. This carries the risk of unauthorized access. Edge AI changes this by doing things like recognizing faces, finding strange things, or figuring out what voice commands mean on the device itself. Additionally, Edge AI supports real-time responsiveness and automation that cloud-based systems cannot yet compete with. With localized presence detection, smart thermostats can immediately adjust temperatures, and smart lighting systems can respond in real time to change light levels. Because of this low latency, users can enjoy smooth, customized experiences where devices can adapt to their preferences without sending sensitive information to distant servers. We can improve convenience and lower energy consumption by adapting the device's operation to local and current conditions and reducing the power drawn by continuous data transmission.



Edge AI for Smarter Cities: Efficiency, Sustainability, and Resilience

Edge AI is essential to the creation of new, intelligent, and sustainable cities that address problems like traffic and infrastructure maintenance. Edge AI-enabled traffic cameras at intersections allow for real-time study of vehicle counts, speeds, and traffic patterns. In addition to enabling traffic signal control, rerouting, and hotspot congestion forecasts, this on-site processing removes the delay in cloud communications. Pilot projects using Edge AI to improve traffic lights are seen having significant decreases in carbon emissions and municipal delays as they can process data locally, they provide faster reaction times and are less prone to network failures. In order to identify irregularities and anticipate malfunctions, Edge AI algorithms examine operational data from public utilities, roads, and bridges. This increases the life of assets, and enhances public safety. Additionally, edge devices offer real-time data on air quality, noise pollution, and waste levels, allowing for more focused action and healthier urban living.



Conclusion

The path to intelligent homes and cities is being accelerated by the development of Edge AI. We are transitioning from simple connectivity by giving IoT devices localized intelligence in order to make our surroundings more secure, private, responsive, and effective. Edge AI is proving to be a game-changing force in electronics and communication engineering, from safeguarding private data in smart homes to optimizing urban traffic patterns and predicting infrastructure failures. As these technologies get better and problems are fixed, the way we interact with built environments will change. This will lead to a future where our surroundings will adapt to our needs on their own, making our lives safer, smarter, and more sustainable.

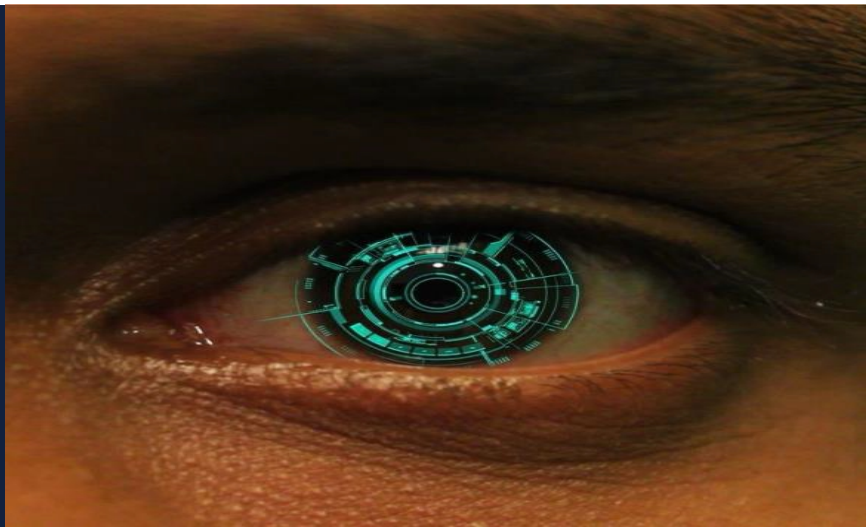
Challenges and Future Outlook

Edge AI faces challenges in widespread use in AIoT installations due to limited processing power and memory, security concerns, and moral implications. However, the future of AIoT at the edge is marked by innovation. Domain-specific AI chips are designed for edge inference. They lower prices and improve performance. On-device intelligence will grow in strength as AI algorithms get lighter and more effective. Hyper-connectivity and real-time data exchange will be made possible by the integration of Edge AI with new developments like 5G and 6G networks. AIoT will evolve into a hybrid cloud-edge architecture that integrates the best aspects of both cloud and edge computing for optimal performance, scalability, and data management.

The Hardware Revolution: Making Devices "Think" for Themselves

Bringing this vision to life actually depends on a massive shift in the hardware inside our gadgets. We are moving past general-purpose processors and toward specialized AI chips—often called Neural Processing Units (NPUs)—that can "think" on the fly while barely touching the battery. This is where "TinyML" comes in. It's a game-changer because it allows even a tiny sensor to stay powered for years, crunching through data exactly where it's collected. By moving the heavy lifting out of giant data centers and into our pockets—or even into the base of a streetlamp—we're essentially building a digital nervous system that's both fast and incredibly efficient. This doesn't just cut down on bandwidth; it makes sure our smart cities stay functional and responsive even if the internet drops out. Challenges





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A New Vision for the Future: How Bionic Eyes Are Changing Lives

Until recently, the idea of restoring sight with technology sounded like pure science fiction. But now, thanks to major progress in electronics, neuroscience, and AI, bionic vision is becoming very real—and it's already helping people see again.

Bionic vision works by using electronic implants to restore some degree of sight for people who've lost it due to conditions like retinitis pigmentosa or age-related macular degeneration. These systems often involve a camera on glasses that sends visual information to a tiny implant inside the eye or brain. The implant then sends signals to the brain, creating a basic visual image—think outlines, shapes, or movement.

The technology is still developing, but recent trials have shown impressive results.

Major Progress in Real-World Trials

In Australia, researchers have developed a second-generation bionic eye that's been tested in people with retinitis pigmentosa. The trial showed long-term stability, with 97% of the implanted electrodes still working even after 2.7 years. Participants reported being able to move around more confidently, detect obstacles, and perform daily activities more independently.

Now, the team behind it is preparing a third-generation version, with the goal of making it available more widely around the world.

Meanwhile, over in the U.S., Stanford University has been working on a

different system called PRIMA. It's a tiny chip placed behind the retina and connected to smart glasses. In trials, people who were completely blind in their central vision were able to read letters, recognize faces, and even play cards - something that was impossible before the implant.

WHAT'S NEXT

The field is moving fast. In the next few years, we could see:

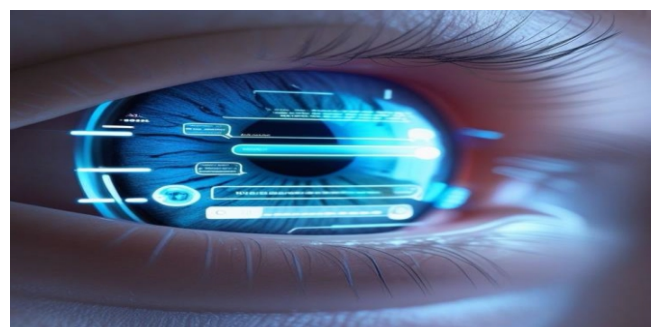
- ◆ Approval of new implants for wider public use
- ◆ More affordable and accessible devices
- ◆ AI-powered implants that provide smart visual overlays
- ◆ Direct brain interfaces that bypass the eye completely
- ◆ Rehab programs to help users learn to "see" again with tech

It's incredible to think how far we've come—from early pixelated prototypes to systems that can help people read and walk around independently again.

The Rise of AI-Powered Smart Vision

It's not just about restoring basic sight anymore -AI is taking things further. A new project involving Neuralink and the University of California, Santa Barbara is building what they call a "Smart Bionic Eye." This system doesn't just send visual signals to the brain - it processes the scene using AI to identify people, objects, and even read signs in real time.

Imagine being able to walk into a room and your implant immediately highlights where the doors, chairs, and people are. That's where the technology is heading. This could totally change how visually impaired people navigate the world.



Innovations in Simulation & Design

Developing a bionic eye isn't just about the hardware - it's also about understanding how users perceive this artificial vision. Tools like BionicVisionXR, a virtual reality platform developed using Unity Sentis, allow researchers to simulate what patients actually see through implants. These simulations are helping refine implant design and train future users.

Machine learning is also playing a major role. In one study, researchers trained AI algorithms to enhance contrast and facial features in simulated bionic vision, dramatically improving facial recognition. This kind of adaptive image processing could be integrated directly into future implants.

The bionic eye - how it works

First prototype: Wide-view neurostimulator

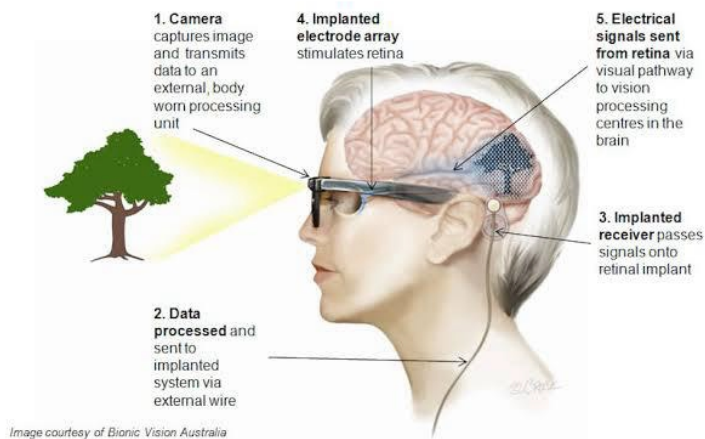


Image courtesy of Bionic Vision Australia

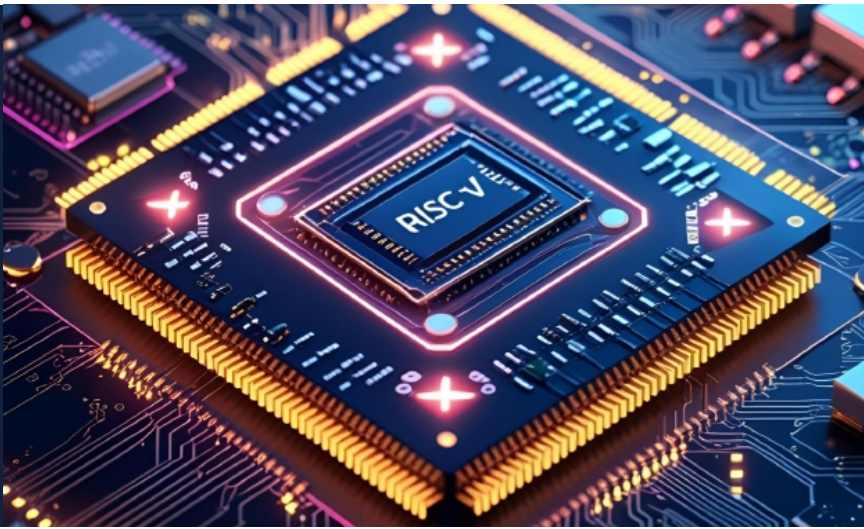
Bionic vision is no longer just a concept—it's becoming a life-changing reality for people who thought they'd never see again. With every new clinical trial, smarter chip, and AI upgrade, we're getting closer to a future where blindness can be treated with tech. This isn't just about gadgets; it's about restoring a basic human sense—and possibly enhancing it in ways we've never imagined. If you're into bioelectronics, neuroscience, or AI, this is one of the most exciting areas to watch right now

The Future: "Evobionics" and Beyond

By Vanja Jovanovic

The next phase of bionic vision may lie in what researchers are calling Evobionics - a fusion of biology and electronics that goes beyond repair, toward enhancement. Scientists are developing retina-like structures using flexible organic materials, high-resolution image sensors, and even graphene-based neural interfaces. These are designed not just to replace natural tissue, but to outperform it in speed, durability, and adaptability.





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Decoded: The RISC-V Revolution in ISA Design"

“RISC-V: The Open Road to Smarter Systems.”

Introduction

Instruction Set Architectures (ISAs) define how software communicates with hardware. Based on the RISC (Reduced Instruction Set Computer) principles, modern ISAs emphasize simplicity, speed, and efficiency. RISC-V, an open-source ISA, builds on these foundations to offer a flexible, scalable, and innovation-friendly platform for everything from embedded systems to supercomputers. This project explores the evolution of RISC-based ISAs, the rise of RISC-V, and its groundbreaking impact on computing technology.

The Emergence and Evolution of RISC

Historical Background

- 1970s–1980s: RISC emerged from academic research, notably at UC Berkeley (RISC-I) and IBM (801 project).
- Key Contributors: David Patterson and John Hennessy, pioneers who formalized RISC principles.

Breakthroughs

- RISC-I (1981): First implementation with simplified instructions.
- MIPS and SPARC: Commercial RISC architectures that gained traction in workstations and servers.

What is RISC-V?

RISC-V (pronounced "risk-five") is an open-source Instruction Set Architecture (ISA) rooted in the RISC (Reduced Instruction Set Computing) design philosophy. Developed at UC Berkeley in 2010, it emphasizes simplicity, modularity, and efficiency. Unlike proprietary ISAs such as x86 or ARM, RISC-V is freely available for anyone to use, modify, and implement—making it a gamechanger for hardware innovation. Its clean and extensible architecture allows developers to build custom processors optimized for specific tasks, without being locked into vendor-specific constraints

Current Applications

RISC-V is rapidly gaining traction across diverse sectors. In embedded systems and IoT, its low power consumption and compact footprint make it ideal for microcontrollers and smart devices. In data centers, companies are exploring RISC-V for storage controllers and specialized accelerators. It's also being used in AI and machine learning applications, where custom extensions can optimize performance for neural network inference. Even in automotive and aerospace, RISC-V is being adopted for safety-critical systems due to its transparency and verifiability

Key Features of RISC-V

Feature	Description
Open Source ISA	Freely available with no licensing fees or proprietary restrictions, enabling broad adoption and innovation
Modular Design	Supports a base ISA with optional standard extensions (e.g., for floating-point, atomic operations, vector processing), allowing tailored implementations.
Simplicity & Clean Encoding	Designed with a small, consistent set of instructions and fixed-length encoding, which simplifies hardware design and verification
Scalability	Suitable for everything from tiny microcontrollers to powerful server-grade processors, thanks to its flexible architecture.

"Uncovering the versatile applications of RISC-V in tomorrow's smart systems."

Artificial Intelligence & Machine Learning

Scope:

RISC-V is paving the way for energy-efficient, customizable AI processors, especially for edge computing and real-time inference.

Applications:

Edge AI Devices: Smart cameras, voice assistants, and autonomous drones using RISC-V-based AI accelerators.

Neural Network Processing Units (NPU): Custom RISC-V cores optimized for matrix operations and deep learning.

AI-on-Chip Solutions: Integration into wearable health monitors and predictive maintenance systems

Internet of Things (IoT) and Edge Devices

Scope:

RISC-V's low power consumption and modularity make it perfect for embedded and edge devices in smart environments.

Applications:

Smart Sensors: Environmental monitoring, agriculture, and industrial automation.

Wearables: Fitness trackers and health monitors with ultra-low-power RISC-V cores.

Smart Home Devices: Thermostats, lighting systems, and voice-controlled appliances.

Custom SoCs and Domain-Specific Architecture

Scope:

RISC-V allows companies to build processors tailored to specific industries and workloads, reducing cost and increasing efficiency.

Applications:

Automotive Control Units: Real-time processing for engine management and ADAS (Advanced Driver Assistance Systems).

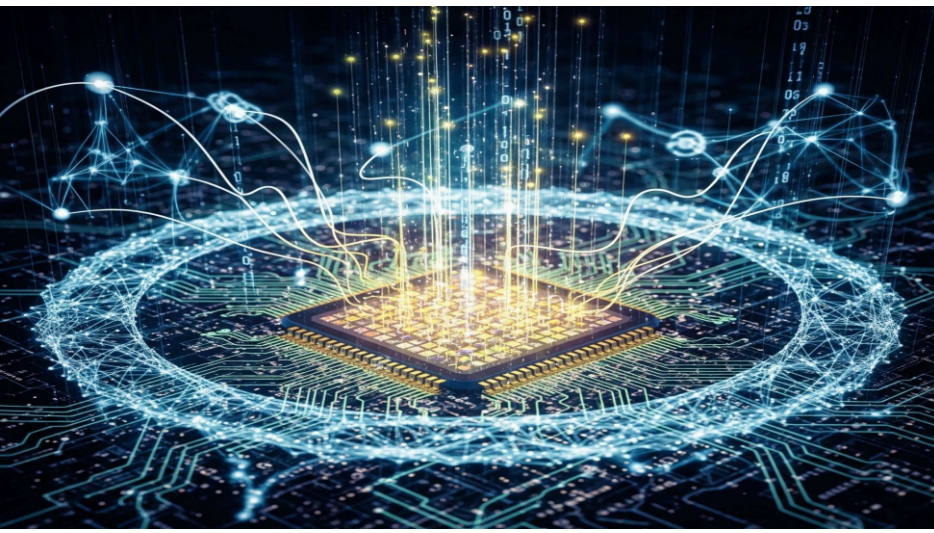
Medical Devices: Portable diagnostic tools and implantable electronics.

Industrial Robotics: Custom RISC-V chips for motion control and sensor fusion.

Conclusion

As RISC-V continues to evolve, it is expected to drive widespread innovation across sectors like AI, IoT, high performance computing, and secure systems. Its open, modular design empowers developers to create efficient, customizable processors tailored to emerging needs. With growing industry adoption and academic engagement, RISC-V is set to redefine the future of computing - making technology more accessible, scalable, and forward-looking





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When VLSI Meets AI and Quantum: The Dawn of a New Computing Era

The field of Very-Large-Scale Integration (VLSI) has already revolutionized the world by enabling the miniaturization and performance of modern electronics. As the boundaries of classical computing approach their physical limits, a new chapter is unfolding—where VLSI meets Artificial Intelligence (AI) and Quantum Computing.

VLSI+AI: Making Chips Smarter

AI is no longer confined to cloud data centers. With edge computing on the rise, intelligent processing must happen on the device itself. Enter AI accelerators—custom-designed VLSI chips capable of performing complex tasks like image recognition, speech processing, and decision-making in real time.

Key Innovations:

- ◆ **Neural Processing Units (NPUs):** Specialized VLSI circuits designed for matrix operations in neural networks.
- ◆ **In-memory Computing:** Reduces energy and delay by performing operations directly within memory cells.
- ◆ **Low-Power AI Chips:** Tailored for smartwatches, drones and IoT devices where battery life is critical.

These innovations rely on VLSI technology to pack immense computational power into a small, efficient, and affordable form.

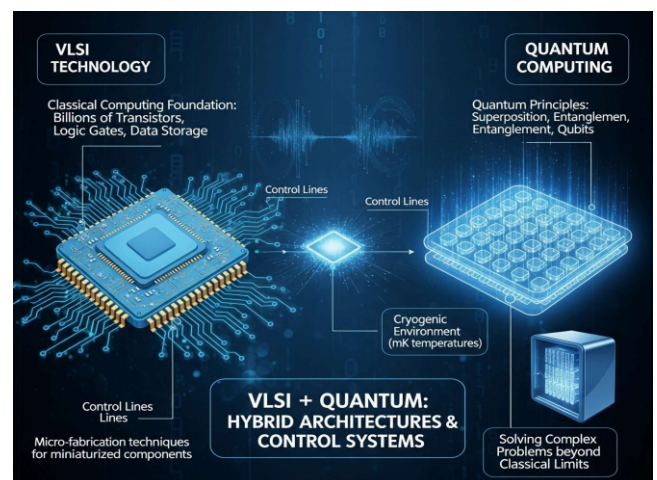
VLSI + Quantum: Beyond Binary Logic

Quantum computing is a radically different paradigm, using qubits instead of bits and operating on the principles of superposition and entanglement. While current quantum computers are in their early stages, VLSI is poised to play a key role in scaling them.

Where VLSI Helps:

- ◆ **Control Electronics:** Quantum bits require ultra-precise control signals. VLSI enables the design of cryogenic control chips that operate at extremely low temperatures.
- ◆ **Interconnects:** As the number of qubits grows, quantum processors need efficient routing and control mechanisms—an area where classical VLSI expertise is vital.
- ◆ **Packaging and Integration:** VLSI is pushing the limits of chip packaging to bring quantum and classical components closer than ever before.

In short, VLSI bridges the gap between the fragile quantum world and the robust classical systems.



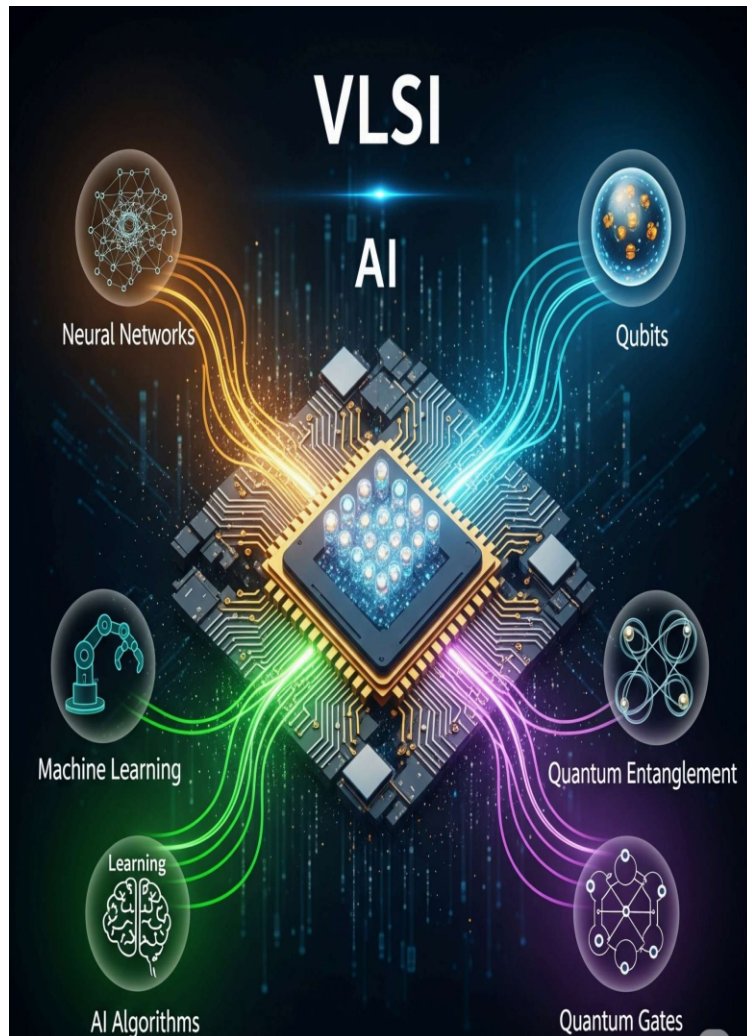
The Triple Convergence: AI, Quantum & VLSI

What happens when all three domains overlap? We get systems that are: **Smarter** (thanks to AI),

Faster & Parallel (thanks to VLSI optimization), and **Exponentially More Powerful** (thanks to Quantum principles).

For example:

- ◆ **Quantum AI Accelerators:** Chips that use quantum computing to train or run AI models faster than today's silicon can.
- ◆ **Hybrid Systems:** AI models decide which tasks should be run on classical chips and which on quantum processors-optimizing time and energy.
- ◆ **Cryo-VLSI:** Future VLSI designs may operate in cryogenic environments alongside quantum chips, using specialized low-temperature CMOS.

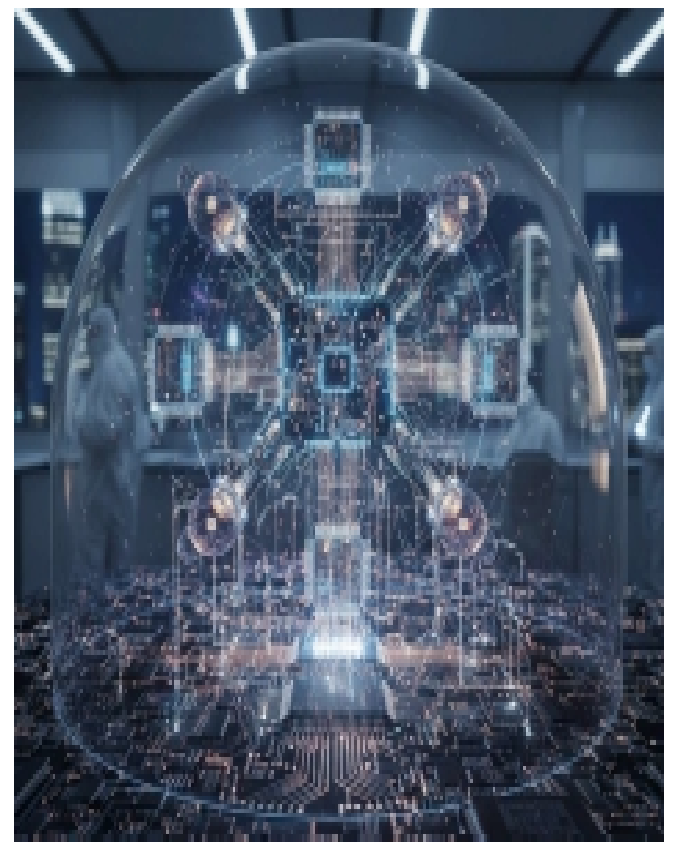


Challenges Ahead

The journey isn't easy. Quantum systems are extremely sensitive to noise, AI models are becoming increasingly complex, and VLSI designers must now think in both classical and quantum terms. New materials, tools, and design paradigms are needed.

Conclusion

The fusion of VLSI with AI and quantum computing is not a matter of "if-it's "when." As the world moves toward more intelligent, powerful, and energy-efficient computing, this intersection will shape the future of technology. For students, researchers, and engineers, now is the time to prepare for this revolutionary shift.



Role of Electronic Design Automation (EDA)

As systems become more complex, traditional design flows are no longer sufficient. Advanced Electronic Design Automation tools are evolving to

support: AI-assisted chip design that optimizes layout and power automatically Simulation of quantum circuits alongside classical hardware Verification of heterogeneous systems combining multiple computing paradigms Future engineers will increasingly rely on intelligent EDA tools to manage billions of transistors and hybrid architectures.



Bristo Sebastian
S6 ECE B, FISAT

Generative AI: Transforming Creativity and Productivity in the Digital Era

Introduction

Generative AI (Gen AI) represents a breakthrough in artificial intelligence, capable of creating new content such as text, images, audio, code, and video. Unlike traditional AI systems that analyze data or automate tasks, Gen AI can generate entirely new outputs that mimic human creativity. This transformative capability is driven by powerful models like GPT (Generative Pre-trained Transformer) and diffusion models used in tools like DALL·E and Midjourney.

The field has seen explosive growth, particularly after OpenAI's release of GPT-3 and the subsequent launch of ChatGPT, which brought conversational AI into the mainstream. Gen AI is not just a technical innovation—it is reshaping industries ranging from education and entertainment to healthcare, business, and beyond.

How Gen AI Works

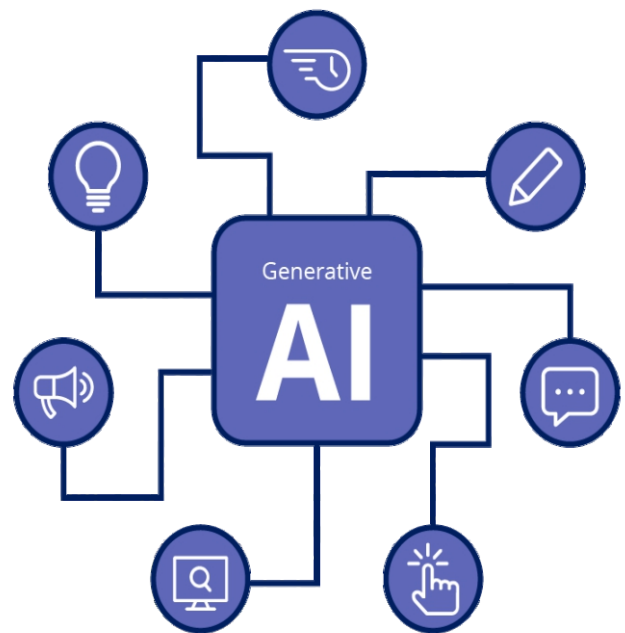
At the core of Gen AI are large language models (LLMs) trained on massive datasets. These models use machine learning techniques, especially deep learning and transformer architectures, to understand patterns in language, images, and other data types. Once trained, they can generate coherent and contextually appropriate content, simulating human-like creativity.

There are several key components:

- ◆ **Pre-training:** Models are trained on large datasets to learn grammar, facts, reasoning abilities, and styles.

- ◆ **Fine-tuning:** Models are refined for specific tasks (e.g., medical advice, legal writing).
- ◆ **Prompt Engineering:** The process of designing input prompts to get desired outputs from the model.

Applications Across Industries



Gen AI's versatility is evident in its wide range of applications:

- ◆ **Education:** Assisting in content creation, tutoring, grading, and personalized learning experiences.
- ◆ **Healthcare:** Supporting diagnostic reports, generating medical summaries, and enhancing patient communication.
- ◆ **Entertainment and Media:** Creating storylines, music, artwork, and animations with tools like RunwayML and Sora.
- ◆ **Software Development:** Tools like GitHub Copilot help developers write code faster and with fewer errors.
- ◆ **Business and Marketing:** Automating content creation, customer support, data analysis, and marketing campaigns.

Benefits and Challenges

Benefits:

- ◆ Rapid content generation with high quality.
- ◆ Cost reduction through automation.
- ◆ Enhanced creativity and productivity.
- ◆ Accessibility of high-tech tools to non-experts.

Challenges:

- ◆ Bias and Ethics: Models may produce biased or harmful content.
- ◆ Misinformation: Generated outputs can be convincing but factually incorrect.
- ◆ Data Privacy: Training data may include sensitive or proprietary information.
- ◆ Job Disruption: Automation may affect creative and technical professions.

Future Outlook

The future of Gen AI is promising but requires careful guidance. With continued innovation, we can expect:

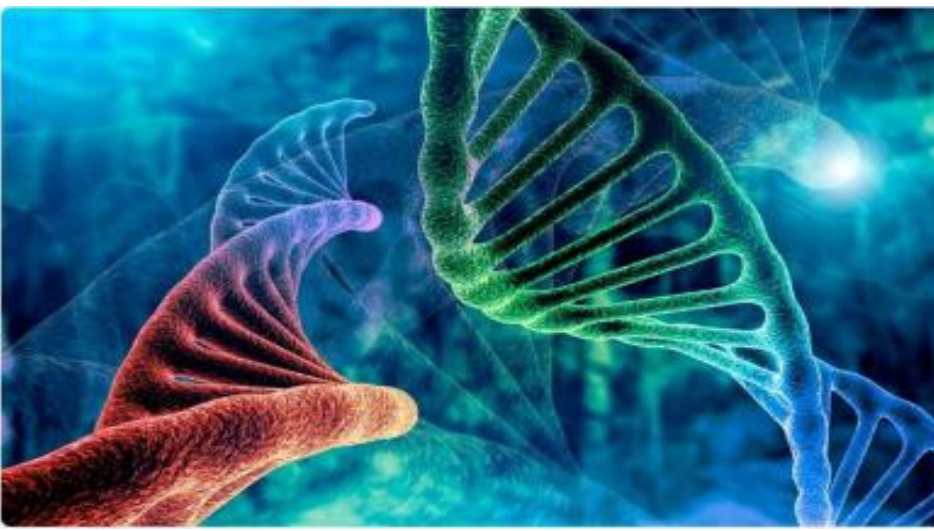
- ◆ More accurate and domain-specific models.
- ◆ Integration with robotics and virtual environments.
- ◆ Stronger regulatory frameworks for safe deployment.
- ◆ Expansion into low-resource languages and underrepresented communities.

As AI becomes more embedded in daily life, the goal is to augment human capabilities, not replace them.

Conclusion

Generative AI is more than a technological leap—it's a paradigm shift in how we think about creativity, productivity, and human-machine collaboration. While it offers tremendous benefits, it also calls for thoughtful use, ethical design, and public awareness. With balanced innovation, Gen AI can truly revolutionize the way we work, learn, and create in the digital age.





AAFINA SHAMEER
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Molecular Bytes: DNA-Based Data Storage and Communication Circuits

In the age of data-driven everything, humanity is generating more information than traditional silicon-based storage can sustainably handle. By 2030, global data is expected to reach over 1 yottabyte. This overwhelming surge presents a pressing challenge: how do we store and communicate vast volumes of data efficiently, reliably, and sustainably? One unconventional answer lies in an ancient molecule—DNA.

DNA, the fundamental blueprint of life, is now being explored as an ultra-dense, stable medium for data storage and nano-scale communication. Its potential to hold petabytes of data per gram and remain stable for thousands of years makes it a promising alternative to flash drives and magnetic tapes. But where does Electronics and Communication Engineering (ECE) fit into this bio-molecular domain?

DNA Data Storage: An ECE Perspective

At its core, DNA storage involves encoding binary data (0s and 1s) into sequences of four chemical bases (A, T, C, G). Synthesizing these sequences and later decoding them through DNA sequencing processes mimics a read/write mechanism. The challenge here isn't just biological—it's electronic and computational.

ECE engineers are essential in:

- ◆ Designing encoding algorithms to translate binary data into DNA sequences with error correction and indexing features.
- ◆ Developing low-noise communication channels to reduce signal loss during DNA synthesis and sequencing.

- ◆ Creating data retrieval systems based on signal processing, akin to decoding digital communication.

Advanced signal processing methods and modulation techniques are already being adapted from wireless systems to improve the fidelity of reading DNA-stored data.

Molecular Communication Circuits: Reimagining ECE

Beyond storage, DNA also opens the door to molecular communication circuits, a novel concept where information is transmitted not via electrons, but via molecules.

ECE contributes by:

- ◆ Modeling molecular communication using information theory, similar to how data is transmitted over radio waves.
- ◆ Designing nano-transceivers using synthetic bio-circuits that mimic modulation/demodulation of signals.
- ◆ Leveraging VLSI and MEMS technologies to integrate biological interfaces with conventional hardware.

In short, ECE engineers are enabling molecular systems to behave like micro-scale routers and receivers in an Internet of Bio-Things (IoBT).

Recent Innovations and ECE Involvement

1. Microsoft & University of Washington DNA Storage Project: Developed a fully automated system to encode digital data into synthetic DNA. ECE researchers helped in automating the controller hardware and signal processing pipeline.
2. CRISPR-based Rewritable Storage: Engineers created rewritable DNA systems—like biological flash drives—requiring precise control systems designed by embedded hardware specialists.
3. Molecular Communication for Biomedical Devices: DNA-based communication between implants and external devices is being designed using electromagnetic modeling, circuit design, and modulation theory—classic ECE domains.

Challenges and the Road Ahead

Despite its promise, DNA data storage faces:

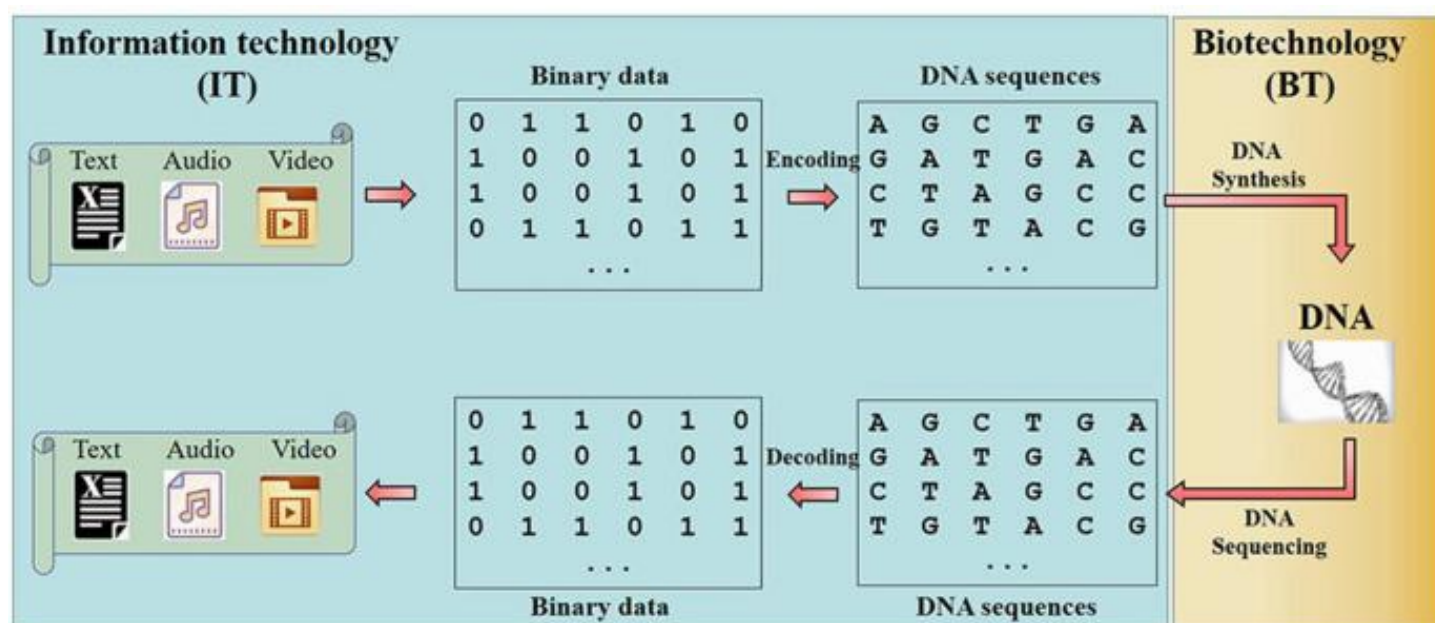
- ♦ High costs of synthesis and sequencing.
- ♦ Slow data rates compared to silicon chips.
- ♦ Error management at the nano level.

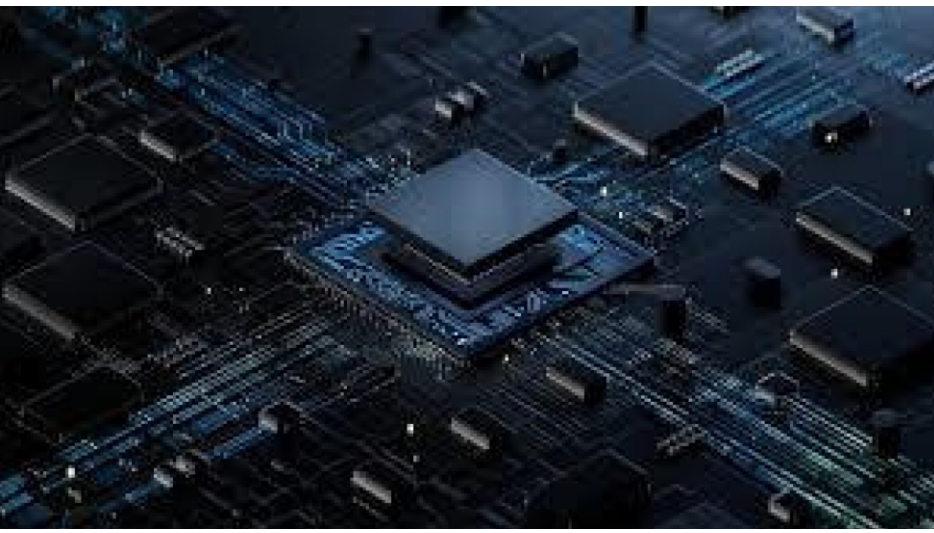
ECE can solve these by:

- ♦ Innovating faster decoding circuits and data compression algorithms.
- ♦ Improving lab-on-chip integration for real-time DNA data access.
- ♦ Designing secure communication protocols for DNA-based systems.

Conclusion

DNA is no longer just the code of life—it's becoming the next generation of data memory and communication medium. For Electronics and Communication engineers, this is an exciting frontier. Whether it's circuit design, signal processing, embedded systems, or nano-communication modeling, ECE is the bridge that connects biology with data technology. As the lines between living systems and electronic systems blur, it's time we gear up to engineer the future—one molecule at a time.





Aloysius James M
S4 ECE A, FISAT

Rise Of Advanced Semiconductors

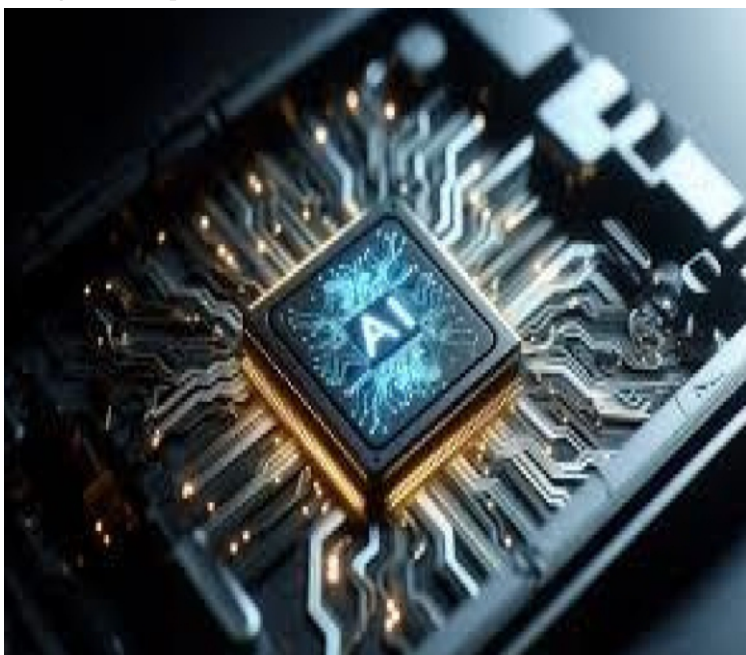
SPARKS TO CIRCUITS

INTRODUCTION

The evolution that happened in the semiconductor industry in the past decades, from radios to rocket launches is something we need to look. The beginning was a strange lab experiment which happened in the mid 1900s which has now become a backbone of our digital world.

Today, chips which are smaller than our fingernail, guide driverless cars through traffic, and train AI models that can think, paint or even to hold a conversation. But this didn't happen overnight. The advancement of semiconductors is filled with risky experiments, failed prototypes and unexpected breakthrough's which is continuing now also.

Let's take a look into how from transistor boom to today's AI driven chips had happened and what's expected to come, how a tiny component changed the shape of modern world.



Milestones, a timeline

1947: Invention of transistors

Bell Labs creates the first working transistor.

1958: First integrated circuit

Jack kilby develops the first IC.

1971: The intel 4004

World's first commercial microprocessor.

2004: FinFET technology

Intel implements FinFET transistors at 22nm.

2021: IBM, 2nm Chip

IBM builds the first 2nm chip using nano sheet technology.

2025: India's first domestic chip

India aims to launch its first domestically produced chip.

Mass production of 2nm chips by TSMC and Samsung.

What's next???

Engineering at the Atomic Scale

In 2004, Intel introduced FinFET technology, changing transistor structure for improved control and scaling. In 2022, TSMC and Samsung began mass production of 3nm chips, built with extreme UV lithography and GAAFET designs. Nvidia's H100 and Google's TPUs were also developed through various testing to handle deep learning. Moving past the crisis world faced for semiconductor supply from 2020 to 2022, now in 2025 global semiconductor industry is in a state of significant transformation. It became largely eased with the market seeing demand in AI driven semiconductors.

From Lab Curiosity to Global Gamechanger

1947 is the year in which the most important breakthrough experiment of semiconductor industry has happened. At Bell Labs, Bardeen, Brattain and Shockley invented the first working transistor using a piece of **germanium**. Before germanium several materials were tested like selenium and silicon oxide, but none were stable. The reason using germanium was success because they used **gold contact** over germanium.



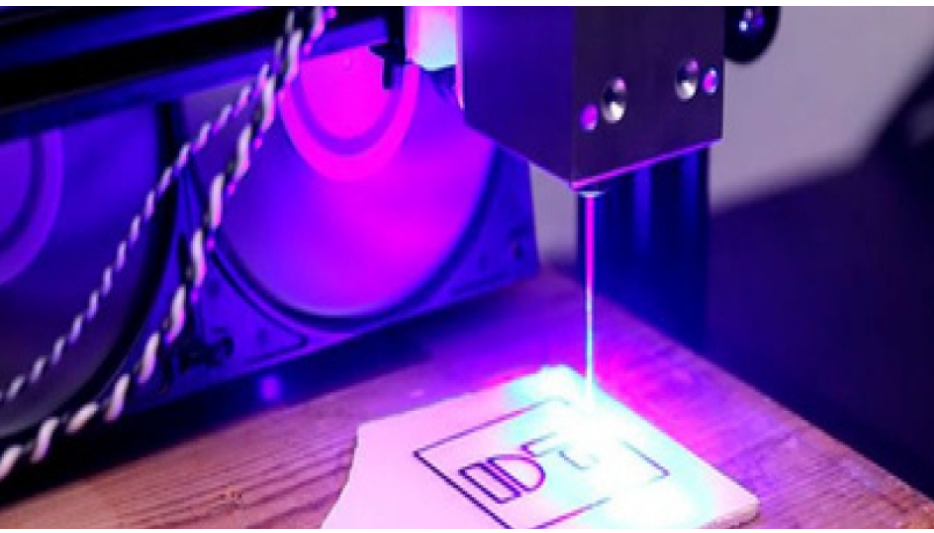
Beyond Silicon

As of now and for the future countries are heavily investing in localizing and diversifying chip production to build more resilient supply chains. New challenges like material shortages and geopolitical tensions are still shaping the industry.

The future of this industry lies in experiment which completed recently and now happening which are

- ◆ Neuromorphic Computing by Intel Loihi chip which is inspired by human brain in which Loihi processes information using spiking neurons.
- ◆ Photonic chips from MIT researchers which aims to use light instead of electrons for data movement.
- ◆ MIT researchers are also researching about high performance gallium nitride transistors on silicon and materials like cubic boron arsenide as potential to act as superior semiconductors.

“THE FUTURE IS BEING BUILT, ONE NANOMETER AT A TIME”



Srinandha S
S4 ECE B, FISAT

"Print, Melt, Repeat" IIT Bombay's Formula for Better, Faster 3D Metals

Imagine baking a cake. If you're in a rush and turn up the oven too high, you'll likely end up with a burnt outside and a gooey, undercooked middle. Now picture something much more serious—like 3D printing parts for airplanes, medical devices, or heavy machines. Here too, going too fast can ruin everything. Push the printing process too hard, and you get weak spots, cracks, and tiny holes that could make the final product unsafe or unusable.

So, how do you speed things up without sacrificing strength and quality?

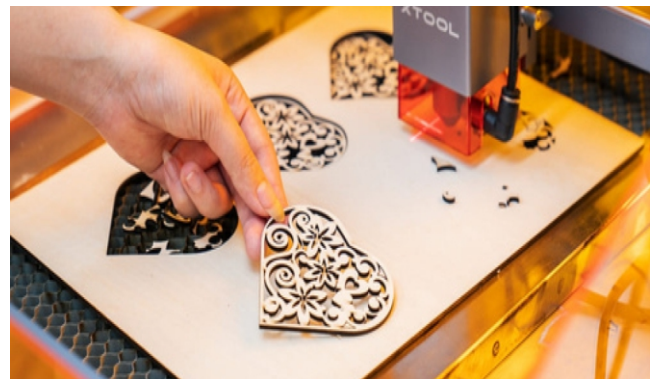
That's exactly what a team of researchers at IIT Bombay's Mechanical Engineering Department asked—and they came up with a clever solution: in-situ laser remelting. In simple terms, it means using a laser to gently reheat and smooth each layer of metal just after it's printed, before moving on to the next. This small change makes a big difference—resulting in stronger, smoother, and much faster 3D-printed parts.

"Flaws in the Shadows"

At first glance, a 3D-printed metal part can look flawless—smooth surfaces, sharp edges, and complex shapes all brought

to life with incredible precision. But behind that perfect exterior, something much less perfect might be lurking. As each thin layer of metal is melted and fused onto the previous one during the printing process, tiny internal defects—called micro flaws—can form. These flaws may be invisible to the naked eye, but they matter. They can include microscopic cracks, trapped air pockets, or uneven grain

structures within the metal. Why is that a big deal? Because these small imperfections can weaken the entire structure, making it more likely to fail when used under stress. For high-stakes applications like airplane components, car parts, or medical implants, even the tiniest defect can lead to serious safety risks. That's why improving the internal quality of 3D-printed metal is just as important as getting the outside right—and it's exactly the problem IIT Bombay's researchers set out to solve.



"Re-Melt, Reinforce, Revolutionize":

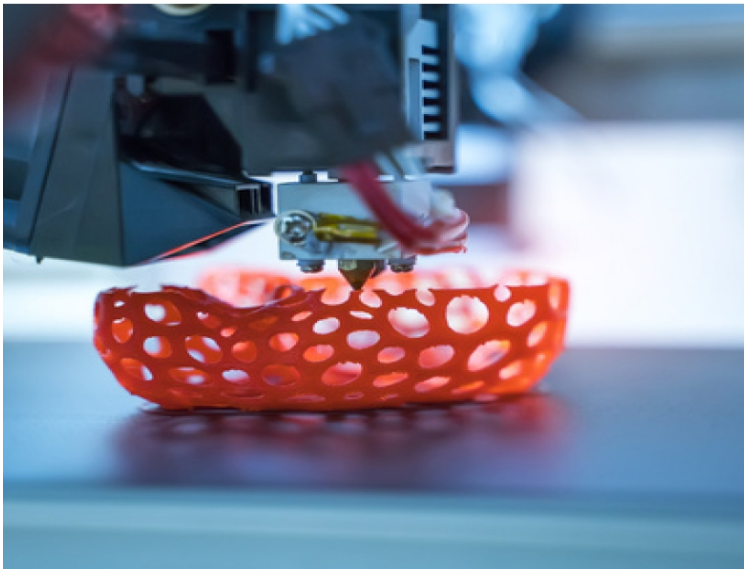
The IIT Bombay Way

That's where IIT Bombay steps in—with a brilliantly simple yet powerful fix known as laser re-melting. Instead of waiting until the end of the printing process to deal with flaws, the researchers introduced a smart tweak that corrects them as the part is being built.

Here's how it works: as each layer of metal is deposited in the 3D printing process, a high-precision laser immediately goes back over that same layer. This laser doesn't add new material—it simply reheats and re-melts what's already there.

Why do that? Because this quick blast of heat smooths out the freshly printed layer, eliminating microscopic gaps, sealing tiny voids, and refining the grain structure of the metal. The result is a denser, stronger, and more uniform build—right from the inside out.

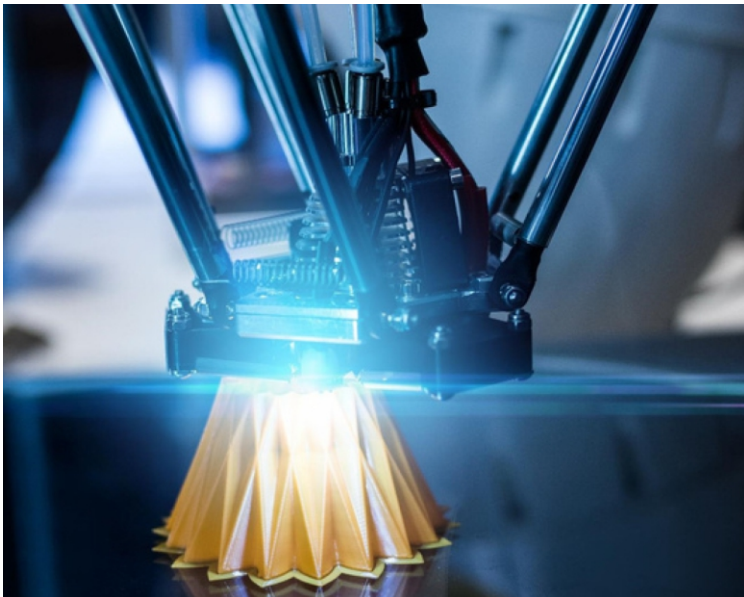
Think of it like ironing a fabric as you sew it. Instead of finishing the stitching and then fixing wrinkles later, you're perfecting each layer as you go. That's what makes IIT Bombay's technique not only efficient but also a game-changer in ensuring structural integrity without sacrificing speed.



"Why Every Layer Counts"

This innovation transforms how industries can use 3D printings:

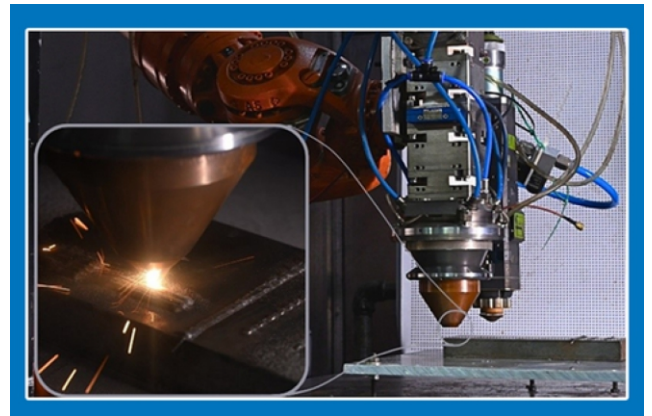
- ◆ Stronger metal parts without industries can use 3D printing.
- ◆ Faster production, since the process is built into the printing cycle.
- ◆ Wider applications in critical sectors like:
 1. Aerospace-Lightweight, durable components.
 2. Automotive-Customized, high performance parts.
 3. Biomedical-Implants and tools with high precision and safety .



"Proof in the Layers"

With IIT Bombay's Laser Re-melting technique, the future of 3D metalprinting looks solid.

- ◆ It boots reliability and reducemanufacturing risks.
- ◆ It unlocks potential for betterdesign and faster innovation.
- ◆ It brings us one step closer to thenext industrial revolution.



This groundbreaking research was developed at IIT Bombay's Machine Tool Lab. It stand as anotherexample of how Indian Institution and shaping the future of global technology.



Ashikh p k
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Electronic Skin: The Highly Stretchable Sensors Paving the Way for Soft Robotics

When we think of robots, we often picture rigid, metal machines. While they are great for manufacturing, a new kind of robot is emerging for tasks that require a gentler touch. These are 'soft robots,' designed to be inherently safe for interaction with humans and for handling delicate objects because of their compliant, flexible nature.

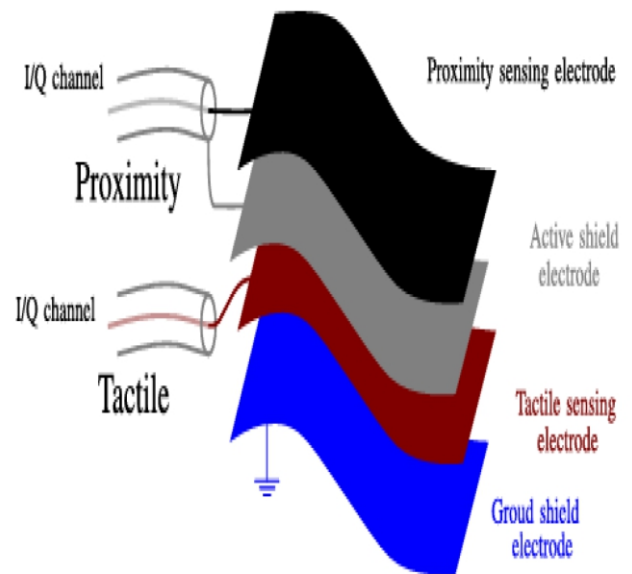
But for these robots to be truly effective, they need to be able to feel their environment. This research introduces a new kind of sensor that acts like a soft, stretchable 'skin,' giving these robots the ability to sense both touch and proximity.

So, What Exactly Is This "Electronic Skin"?

At its core, the technology is a highly stretchable capacitive sensor pad created using additive manufacturing, which is a form of 3D printing. Instead of rigid electronics, it's made from a flexible, room-temperature vulcanizing (RTV) silicone called 'Dragon Skin' and a liquid metal alloy called 'Galinstan' for the conductive parts. This unique combination allows the sensor to be stretched by more than 35% without significantly affecting its sensitivity.

The pad is designed to perform two key sensing functions at once:

- ◆ **Tactile Sensing:** It can detect direct force or touch.
- ◆ **Proximity Sensing:** It can detect when an object is near without physical contact.



The Science of Sensing: Touch and Proximity

- ◆ The sensor works by measuring changes in capacitance.
- ◆ The formula $C = \epsilon \epsilon_0 A/d$ helps explain the sensor's behavior.

Tactile Sensing (Touch)

- ◆ Applying force compresses the sensor pad.
- ◆ This compression reduces the distance between tactile electrodes.
- ◆ The reduced distance causes capacitance to increase.
- ◆ The sensor was tested with forces from 1 to 16 N.
- ◆ This produced a capacitance change between 1 and 60 pF.

Proximity Sensing (Distance)

- ◆ The sensor generates an electric field.
- ◆ A nearby object changes this electric field.
- ◆ The system detects this change in the field as a change in capacitance.
- ◆ Its proximity detection range is 20 mm.
- ◆ This can be used for contactless material classification.
- ◆ It was tested with five materials, including aluminum, wood, and nylon.

The Path Forward: Applications and Future Work

This soft, stretchable electronic skin represents a building block for the next generation of intelligent robotic and medical systems. Its immediate application lies in creating more capable soft robotic grippers that can safely handle delicate items by precisely modulating force. Beyond robotics, the technology holds promise for

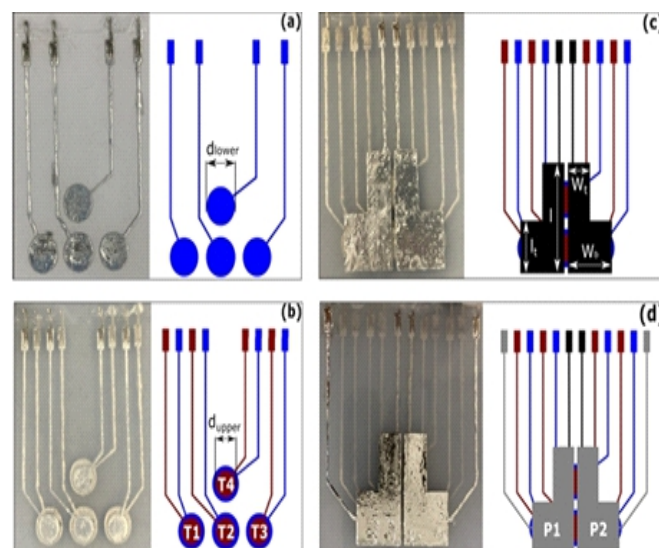
health monitoring, where it could be used to create pressure-monitoring skins for prosthetic limbs to improve comfort and fit.

Future work will focus on making the sensor even better. Researchers plan to refabricate the pad to be thinner and to incorporate more tactile and proximity elements for higher-resolution sensing. To improve robustness, machine learning models could be applied to distinguish between stretching, tactile, and proximity events, making the sensor's output even more reliable.

This stretchable, dual-function sensor pad is a significant building block for the next generation of soft, interactive robots. Its ability to be soft, flexible, and provide both tactile and proximity feedback opens the door for robots that can operate more safely and intuitively around people.

How the Sensor is Designed and Tested

One of the most impressive aspects of this electronic skin is its multilayer structure, which allows it to sense both touch and nearby objects simultaneously. The sensor consists of flexible silicone layers with embedded liquid metal electrodes arranged in stacked configurations. This design enables the device to maintain electrical performance even when stretched, bent, or compressed, a major challenge in traditional electronics.





Midhun Raj
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Brain-Computer Interfaces: The Future of Human-Machine Interaction

Introduction

Imagine controlling a computer, robot, or even a drone using just your thoughts. What once seemed like science fiction is now becoming a reality through a rapidly evolving technology called Brain-Computer Interfaces (BCIs). A brain-computer interface is a direct communication link between the human brain and external devices. It reads electrical signals from the brain and translates them into commands, allowing the brain to interact with technology without physical movement.

How It Works

The brain communicates through electrical impulses. BCIs use devices like electroencephalogram (EEG) headsets or implants to detect these signals. The raw brain data is then processed using machine learning algorithms to interpret user intentions. For instance, if a person thinks about moving their right arm, the BCI detects that signal and converts it into a command that can control a robotic arm.

There are two main types of BCIs:

Non-invasive BCIs: Use external sensors (like EEG caps); less risky but less accurate.

Invasive BCIs: Implanted directly into the brain; offer higher accuracy and speed but involve surgical procedures.

Applications

BCIs are being applied in various fields, and the possibilities continue to expand:

1. Medical Field

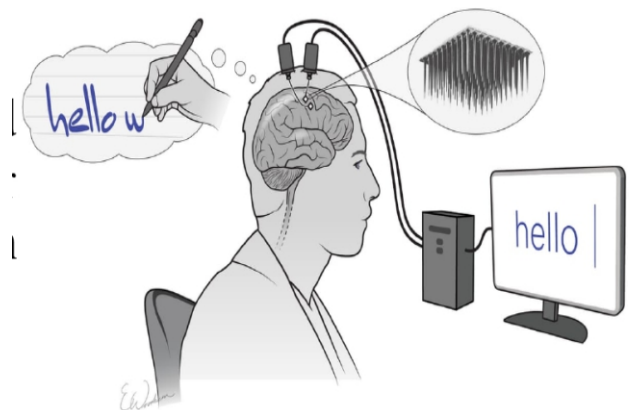
One of the most impactful applications is in helping people with disabilities. BCIs can restore movement or communication abilities for individuals with spinal cord injuries, paralysis, or ALS. Companies like Neuralink and Synchron are developing advanced brain implants to help restore lost functions.

2. Gaming and Entertainment

Gamers are testing the next frontier of immersive experiences. BCIs can allow players to control in-game characters with their minds, potentially replacing traditional controllers altogether. Companies such as NextMind have developed consumer-grade BCI headsets for such purposes.

3. Communication

For patients who cannot speak or type, BCIs can enable “mind typing,” allowing them to form sentences using only their thoughts. Researchers at Stanford recently developed a system that allows brain signals to be translated into text at record speeds.



4. Military and Defense

Defense agencies are exploring BCIs to enhance human capabilities, such as piloting drones or analyzing data in high-pressure scenarios using cognitive augmentation.

Challenges

Despite rapid progress, BCIs face several hurdles:

Data Accuracy: Non-invasive methods often pick up noisy signals.

Ethical Concerns: Issues of privacy, consent, and potential mind-hacking need serious attention.

Affordability: Most high-performance BCIs are expensive and not accessible to the general public.

Medical Risks: Invasive BCIs involve surgery and long-term implantation, which may pose health risks.

The Future of BCIs

As AI algorithms become more sophisticated and hardware continues to miniaturize, BCIs will become more accurate, faster, and safer. In the near future, we may see thought-controlled smart homes, BCI-powered education tools that adapt to your focus and understanding, or remote-controlled machinery operated by skilled professionals using just their minds.

Elon Musk's Neuralink has already demonstrated a monkey playing video games using its brain, and human trials are starting.

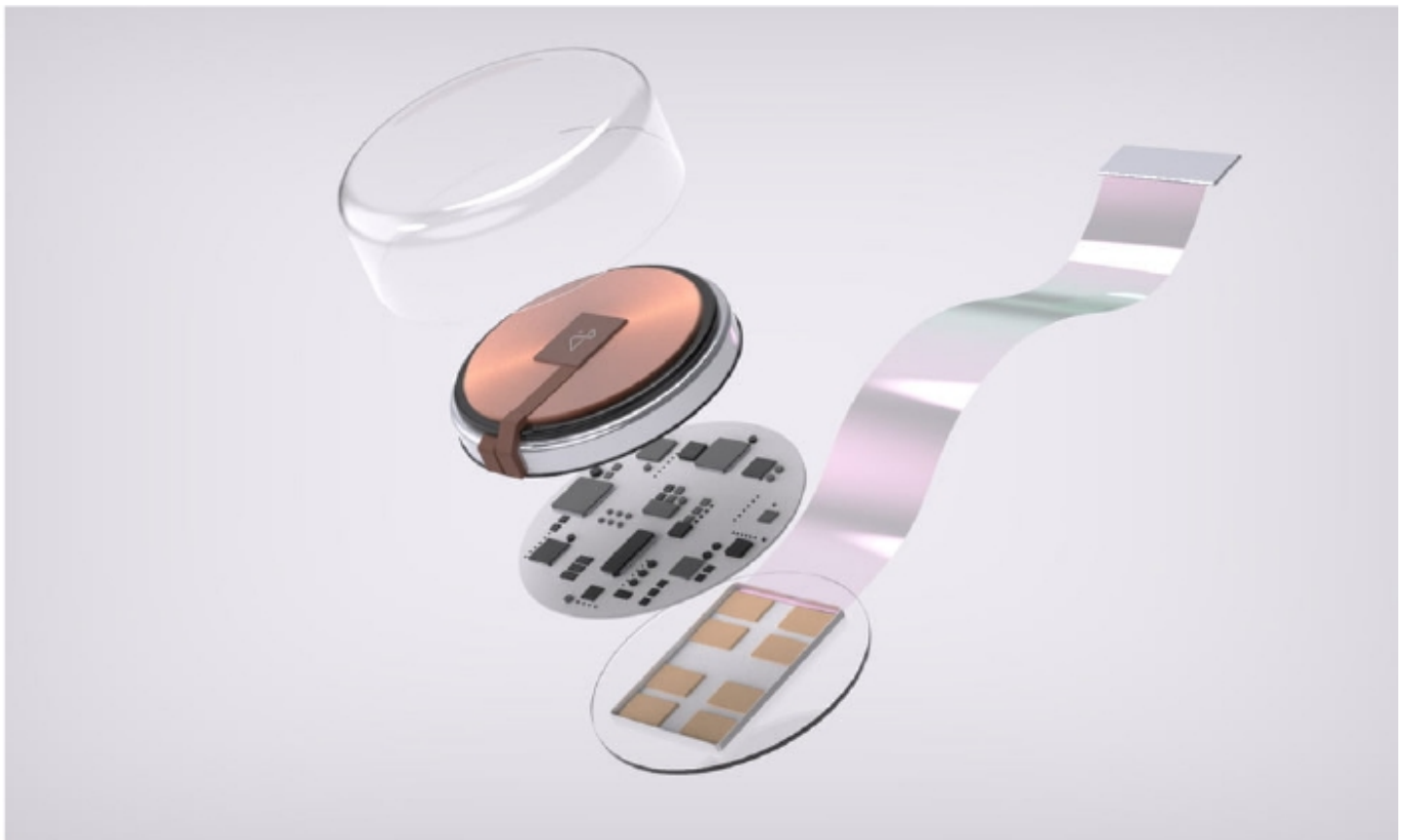
Meanwhile, OpenBCI is developing open-source tools for researchers, hobbyists, and developers to experiment with BCI tech.

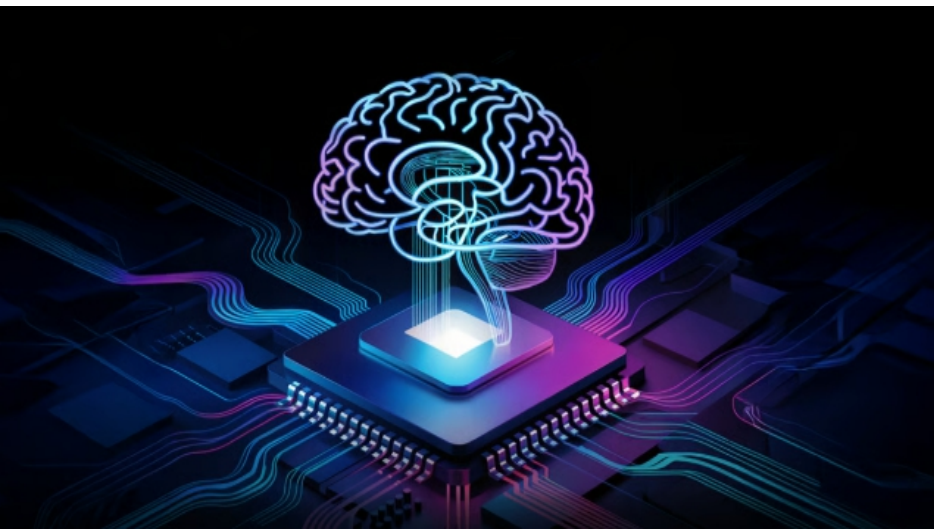
Components of a Basic BCI System

A Brain-Computer Interface (BCI) system begins with signal acquisition, where electrical signals generated by the brain are captured using devices such as electroencephalography (EEG) headsets or implanted electrodes. These signals represent neural activity and are typically very weak. Therefore, they must be carefully recorded and amplified to ensure accurate detection without interference. The captured signals are then sent to the signal processing and decoding stage. In this stage, unwanted noise is filtered out, and important features are extracted from the raw brain data. Advanced algorithms, often based on machine learning, analyze these patterns to determine the user's intention—such as moving a cursor, selecting a letter, or controlling a robotic device. Finally, the decoded information is transmitted to an output device, such as a computer, robotic arm, wheelchair, or smart home system. The device performs the intended action based on the interpreted brain signals, enabling seamless interaction between the human brain and external technology without requiring physical movement.

Conclusion

Brain-computer interfaces are no longer the stuff of science fiction. From medical breakthroughs to mind-controlled tech, BCIs are reshaping how we think about interaction with machines. Though challenges remain, the future promises a powerful symbiosis between the human brain and digital world—unlocking possibilities we are only beginning to imagine.





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NEUROMORPHIC COMPUTING

Abstract

Traditional computing constrained by the Von Neumann architecture, faces significant power and latency challenges in the era of artificial intelligence. This article explores Neuromorphic Computing, a revolutionary paradigm that overcomes these limitations by emulating the brain's neural structure and function. It delves into the core principles of neuromorphic systems such as the use of Spiking Neural Networks (SNNs), event-driven processing, and the co-location of memory and computation to eliminate the von Neumann bottleneck. The article highlights recent innovations and case studies, focusing on pioneering hardware like Intel's Loihi 2 chip, which showcases on-chip learning and extreme energy efficiency. While acknowledging challenges in software development and algorithmic design, it concludes that neuromorphic engineering represents a fundamental shift towards creating a new class of low-power, adaptive, and truly intelligent electronic systems.

Introduction

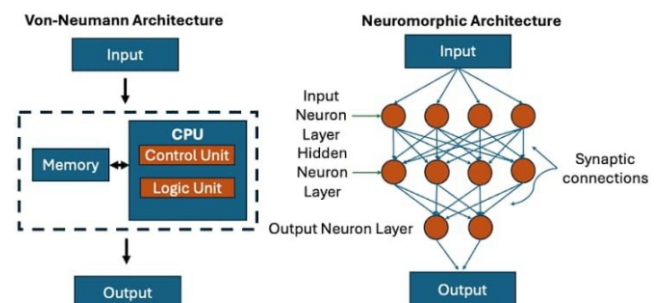
For over 70 years, modern computing has relied on the Von Neumann architecture. This design separates the central processing unit (CPU) from memory (RAM) and has been very successful. However, as we explore the limits of Artificial Intelligence (AI) and machine learning, this separation leads to a major problem called the "Von Neumann bottleneck." Constantly moving data back and forth between the processor and memory takes up a lot of time and energy, especially for data-heavy AI tasks that imitate brain functions. The human brain processes information with amazing efficiency, using only 20 watts by keeping processing and memory close together in a large network of neurons and synapses. This biological model is the inspiration for neuromorphic computing, a major shift in computer design that aims to create chips that work like the human brain.

The Brain's Blueprint: Beyond Zeroes and Ones

The core difference between traditional and neuromorphic computing is how they handle information. A conventional computer processes data one step at a time using a fixed clock cycle. In contrast, the brain works

as a massively parallel system. Its processing elements, the neurons, and their connections, the synapses, operate at the same time and without synchronization. Neuromorphic systems mimic this behavior by using Spiking Neural Networks (SNNs). Unlike traditional Artificial Neural Networks (ANNs), which work with continuous numerical values in distinct layers, SNNs communicate through "spikes," which are discrete signals based on events, similar to the action potentials that biological neurons send. A spike occurs only when a neuron's membrane potential hits a certain threshold. This event-driven approach is highly efficient because it uses computation and power only when new information is present. This is very different from the constant operation of conventional CPUs and GPUs.

Furthermore, neuromorphic designs combine processing and memory into one unit, effectively creating "synaptic processors". This removes the Von Neumann bottleneck since data does not need to travel long distances between separate parts. This is often made possible by new nanotechnologies like memristors, which are resistors with memory that can store synaptic weights and perform calculations in the same physical device, mimicking a biological synapse.



Recent Innovations: From Lab to Application

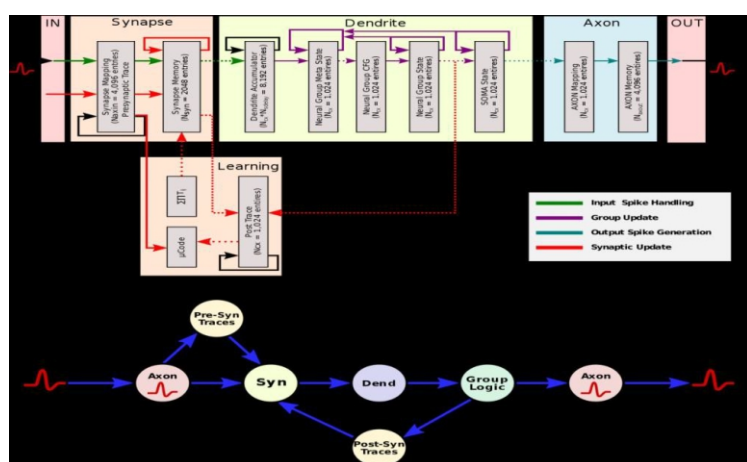
The field of neuromorphic computing has moved from theoretical ideas to real hardware. Several key players are pioneering this technological frontier.

Case Study: Intel's Loihi 2

A prominent example is Intel's Loihi 2, a second-generation neuromorphic research chip. It contains up to one million digital "neurons" on a single chip. Its key features include:

- ◆ **Asynchronous and Event-Driven:** Loihi 2 operates without a system-wide clock. It reacts only to incoming spikes, which dramatically reduces power consumption.
- ◆ **On-Chip Learning:** It has programmable "learning rules" that let the spiking neural networks (SNNs) learn from new data in real-time. This mimics synaptic plasticity, where the connections between neurons can strengthen or weaken over time, similar to how biological learning occurs.
- ◆ **Scalability:** Loihi 2 chips can be linked together to create larger neuromorphic systems. Intel has already shown systems like "Hala Point", which uses 1,152 Loihi 2 processors to simulate a network of 1.15 billion neurons.

Researchers are using Loihi 2 to tackle complex problems that are tough for regular computers. One innovative use is in olfaction, or electronic "smell." By training the SNN to recognize patterns from chemical sensor responses, a Loihi-powered system can quickly identify hazardous chemicals or diagnose diseases from biomarkers more effectively than traditional methods.



Other Key Players

- ◆ **IBM's TrueNorth:** This was one of the first large-scale neuromorphic chips. TrueNorth showed that it is possible to create low-power, brain-inspired processors for real-time sensory processing.
- ◆ **BrainChip's Akida:** This chip is built for commercial use in small, battery-powered devices at the "extreme edge." It focuses on event-based AI for tasks such as keyword spotting, vibration analysis, and visual wake-on-event applications.

The Future is Efficient and at the Edge

The primary promise of neuromorphic computing is not to replace traditional computers for every task, but to perform better where they struggle. The main application domain is Edge AI. Imagine autonomous drones that can navigate complex environments in real-time without sending data to the cloud, or wearable health monitors that continuously analyze biometric data to predict medical events, all while using much less power than a smartphone.

Key application areas include:

1. **Autonomous Systems:** Robots, drones, and self-driving cars can benefit from the quick, real-time perception and decision-making that neuromorphic chips offer.

2. **Smart Sensors:** From industrial monitoring to environmental sensing, neuromorphic sensors can analyze data locally, triggering alerts only when needed and saving significant bandwidth and power.
3. **Prosthetics and Brain-Computer Interfaces (BCIs):** By processing neural signals in a way that mimics biological systems, neuromorphic chips can enable more intuitive and responsive prosthetic limbs or assist in translating brain signals into commands for assistive devices.

Challenges on the Horizon

Despite the immense promise, the path to widespread adoption of neuromorphic computing is challenging.

- ◆ **Algorithm and Software:** The field needs a developed software ecosystem. We require new programming languages, compilers, and algorithms made for event-driven, spiking hardware. Thinking in terms of spikes and temporal dynamics is a big shift for developers who are used to traditional coding.
- ◆ **Scalability and Integration:** While chips like Loihi 2 are impressive, creating systems that can scale to billions of neurons while keeping high connectivity and low power consumption is a significant engineering challenge.
- ◆ **Finding the "Killer App":** Neuromorphic systems will not replace conventional computers for tasks they excel at, such as precise numerical calculations. The challenge is to find and lead in application areas like real-time sensory processing, robotics, and continuous online learning, where their unique benefits offer a major improvement.

Conclusion

Neuromorphic computing offers a new way to think about electronics. By taking inspiration from the brain's unique efficiency and ability to process information simultaneously, we are close to creating a new type of smart devices that use little power, adapt to their surroundings, and handle information in real time. While the Von Neumann architecture will still be essential for many computing tasks, the future of AI in our everyday lives in our homes, cars, and industries, will likely be influenced by the brain-like operations of neuromorphic processors. This field expands the limits of electronics, computer science and neuroscience, promising a future where technology doesn't just compute but also cognizes.



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