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From the Editorial Desk

"Let noble thoughts come to us from all directions."

- Rig Veda 1.89.1

This is our second edition—and something quietly powerful unfolds within it. Science begins to feel more human than ever before. It is no longer confined to laboratories or complex theories; it is stepping gently into everyday life—listening, sensing, and responding to human needs.

There was a time when healing meant waiting—waiting for reports, for results, for hope. Today, that story is changing.

Envision a world where a mere breath could convey more than machines. One of the studies in this issue reveals how artificial intelligence can "listen" to breathing patterns to detect COVID-19. It feels almost poetic—life's most basic rhythm becoming a signal for survival.

In another corner of research, machines are being trained to read the silent language of the brain, helping detect Alzheimer's before memories begin to fade. There is something deeply human in this pursuit—the desire to protect identity, dignity, and time itself.

Across disciplines, a quiet transformation is visible. Science is becoming gentler. From saliva-based biosensors that replace painful tests to contactless air-writing systems that redefine interaction, innovation is moving closer to comfort and accessibility.

What stands out in this issue is not just advancement, but intention. Behind every dataset is a patient; behind every model is a human need; and behind every breakthrough is hope.

Research may appear technical, even distant—but at its core, it is deeply emotional. It listens to breath, protects memory, and restores dignity.

Ultimately, science is not just about knowing more—it is about caring better.

Enjoy the read.

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The Future of Contactless Input: The AI Powered Air-Writing Recognition

Dr. Satish Kumar Satti, *et al.*

Air-writing is a contactless input technique that enables users to write in the air using hand gestures captured by a webcam. This work proposes a vision-based system combining ResNet, YOLO, and Transformer models for accurate detection and recognition of air-written characters. It effectively handles challenges such as overlapping characters, writing variability, and environmental noise. A fingertip tracking mechanism is used to extract motion trajectories, enhanced by an optimization algorithm for improved performance. The system achieves up to 98.89% accuracy, outperforming existing methods. It is cost-effective, scalable, and suitable for real-time applications in healthcare, public systems, and assistive technologies.

Overview

Air-writing is an emerging technology that enables users to input text by writing in the air using simple hand gestures. It eliminates the need for physical input devices like keyboards and touchscreens. This approach provides a natural and intuitive way of interaction between humans and computers. The system captures finger movements using a camera and converts them into digital text. It is a key step toward next-generation contactless interfaces.

Fig.1: *Air Writing*

Background

Traditional input methods are not always suitable in environments requiring hygiene and minimal physical contact. Air-writing offers a promising alternative but faces challenges such as lack of tactile feedback and variability in writing styles. Recognizing multiple and overlapping characters further complicates the problem. Environmental factors like lighting and motion blur also affect accuracy. Addressing these challenges is essential for practical deployment.

Why This Research

The increasing demand for contactless systems has driven the need for innovative input technologies. Applications in healthcare, public systems, and smart devices require hygienic and touch-free solutions. Additionally, assistive technologies can benefit users with mobility limitations. This research aims to provide a reliable and accessible alternative to conventional input methods. It focuses on improving accuracy and usability in real-world conditions.

Existing Approaches

Earlier approaches include radar-based systems, Wi-Fi signal tracking, and wearable sensor-based methods. While these techniques can capture motion effectively, they often require expensive and specialized hardware. Many existing models are limited to recognizing single characters. They also struggle with overlapping and continuous writing patterns. These limitations restrict their scalability and real-world adoption.

Proposed Solution

This work introduces a vision-based system that uses a standard webcam to capture hand gestures. It integrates a hybrid deep learning model combining ResNet, YOLO, and Transformer architectures. The system detects, segments, and classifies air-written characters efficiently. A hand tracking algorithm extracts fingertip motion trajectory. This approach ensures a cost-effective and scalable solution.

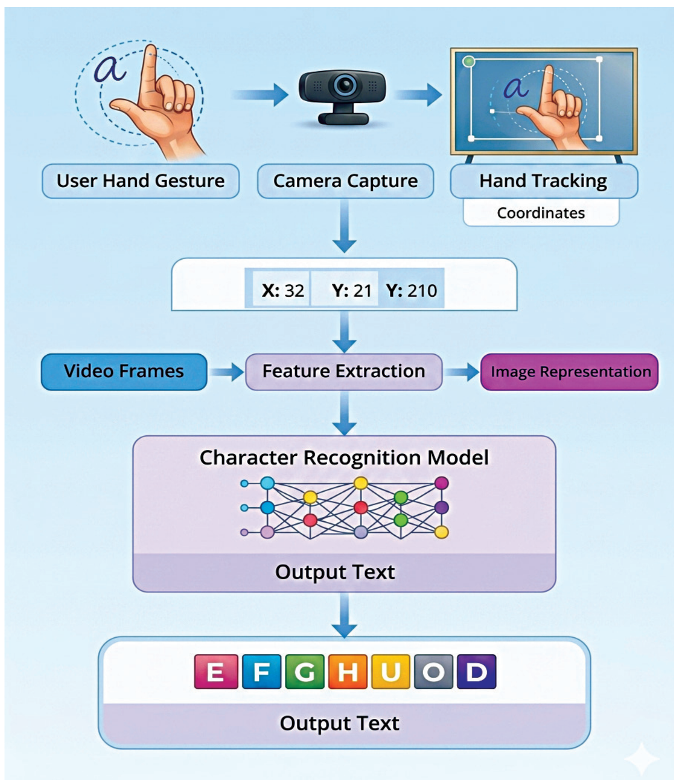

Fig.2: *Conceptual Diagram*

Novel Contributions

The proposed model uniquely combines feature extraction, object detection, and contextual learning in a single framework. It is capable of accurately recognizing multiple and overlapping characters. The integration of the Chaotic Honey Badger Optimization Algorithm enhances model performance. A custom dataset tailored for air-writing scenarios is also developed. These contributions significantly improve recognition accuracy and robustness.

Architecture

The system processes input images through multiple stages, starting with feature extraction using ResNet. YOLO is used to detect and localize character regions within the image. The extracted features are then passed to a Transformer model for contextual understanding. This pipeline ensures accurate classification of characters. The architecture is designed for efficiency and real-time performance.

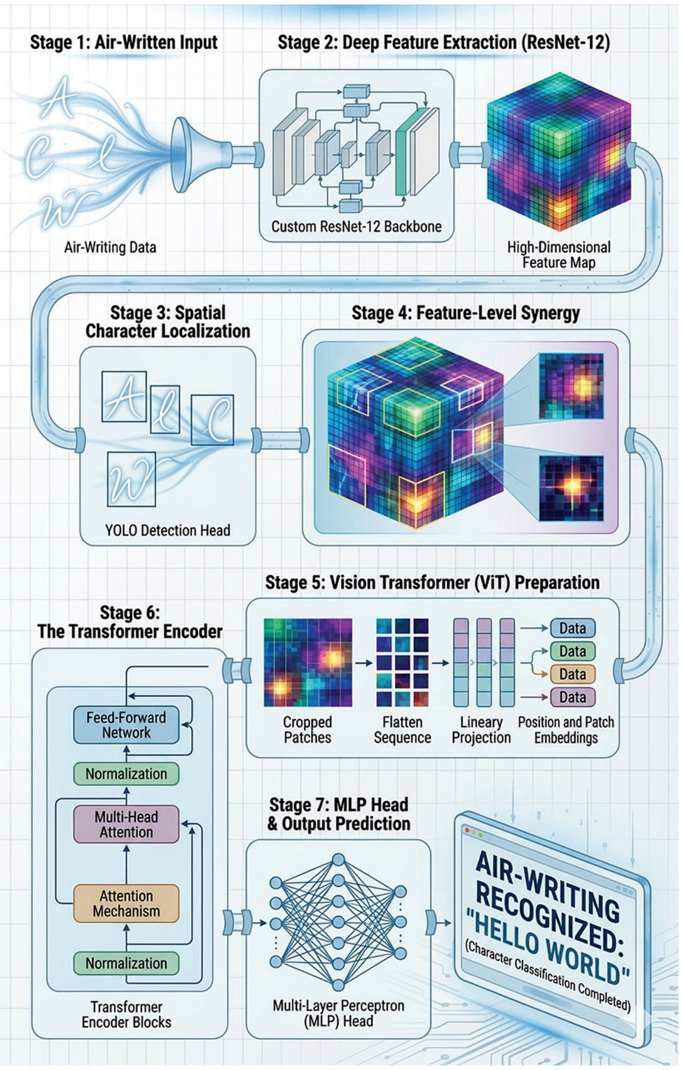

Fig. 3: AIR Writing Prediction Architecture

Key Highlights

The proposed model achieves an accuracy of 97.49%, which improves to 98.89% after optimization. It outperforms several state-of-the-art models including YOLO variants and Vision Transformers. The system effectively handles overlapping characters and noisy inputs. It is implemented using a cost-effective webcam-based setup. These results demonstrate the robustness and superiority of the approach.

Real-Time Applications

This system can be applied in smart devices for gesture-based typing and control. In healthcare, it enables touch-free interaction in sterile environments. Public systems such as kiosks and ATMs can benefit from contactless input methods. It also supports assistive technologies for physically challenged users. The versatility of applications highlights its practical significance.

Impact

The research contributes to advancements in human–computer interaction and computer vision. It promotes the development of touch-free and intuitive user interfaces. The system is scalable and suitable for real-world deployment. It reduces dependency on specialized hardware, making it accessible and cost-effective. Overall, it bridges the gap between research and practical applications.

Conclusion

This work presents a highly accurate and efficient air-writing recognition system. By combining deep learning with optimization techniques, it achieves superior performance. The model addresses key challenges such as overlapping character recognition. It demonstrates strong potential for real-time applications. The research paves the way for future innovations in contactless computing.

Reference

S. K. Satti and M. Prasad, "Air-Written Multicharacter Detection and Classification Using Vision-Based Hand Gestures and an Optimized ResYOLO-Transformer," in IEEE Sensors Journal, vol. 26, no. 3, pp. 5229-5240, 1 Feb.1, 2026, doi: 10.1109/JSEN.2025.3645357.

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Artificial Intelligence and Machine Learning in Infectious Disease Diagnostics: A Comprehensive Review of Applications, Challenges, and Future Directions

Dr. Md Oqail Ahmad, *et al.*

Infectious diseases remain a leading cause of illness and death, especially when diagnosis is delayed and treatment starts late. Traditional methods are accurate but slow, costly, and difficult to scale in low-resource settings. With digitized health data, medical imaging, sensors, and accessible computing, AI and ML can transform diagnosis by providing faster and more reliable insights. Advanced technologies analyze images, clinical data, and genomics to enable early detection, timely treatment, and better patient outcomes. With proper validation, privacy, and fairness, AI/ML can ensure scalable, efficient, and equitable infectious disease diagnosis

Infectious diseases claim roughly 17 million lives annually. While our medical knowledge has advanced, our "frontline" tools like traditional cultures and manual microscopy are often too slow or expensive for the places that need them most. In a world of emerging pandemics and rising anti-biotic resistance, the paper argues that we have reached a critical tipping point where Artificial Intelligence (AI) and Machine Learning (ML) are no longer just concepts, but clinical necessities.

The Problem with Tradition

- **Culture-based tests:** Reliable, but take 24–72 hours.
- **Molecular tests (PCR):** Accurate, but require expensive, centralized labs.
- **Clinical Subjectivity:** Human interpretation varies wildly between practitioners.

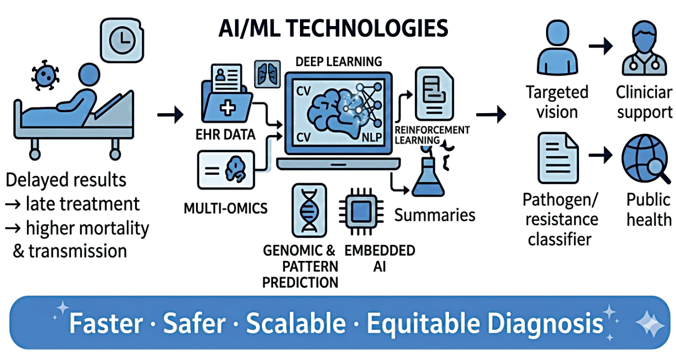

Fig.1: *Integrated AI/ML framework for accelerating infectious disease diagnostics and clinical decision-making.*

A Big Idea for Modern Medicine

What if we could turn routine medical data X-rays, blood counts, and vital signs into instant answers? Our review explores how Artificial Intelligence (AI) and Machine Learning (ML) act as a "force multiplier" for doctors. Think of AI as a high-speed digital detective that can spot patterns invisible to the human eye.

AI helps in three ways at once:

- **Speed:** It delivers results at the "point of care" in minutes instead of days.
- **Accuracy:** It identifies subtle features in medical images that even experts might miss.
- **Proactive Care:** It flags high-risk patients (like those with sepsis) hours before their condition becomes critical.

How Does the Digital Brain Work?

Fig. 2. illustrates the progression from traditional to AI-based infectious disease diagnostics, starting with the primary pathogens parasites, bacteria, viruses, and fungi and the diseases they cause, such as malaria and COVID-19 (Fig. 2A). While conventional diagnostic methods like culture tests, serology, and PCR are standard (Fig. 2B), they face significant hurdles including slow processing times, high costs, and subjectivity (Fig. 2C). To address these limitations, various AI/ML approaches, such as deep learning and NLP, are being integrated into the diagnostic workflow (Fig. 2D). Ultimately, these intelligent systems are transforming healthcare through real-world applications across diverse fields including oncology, cardiology, and neurology (Fig. 2E).

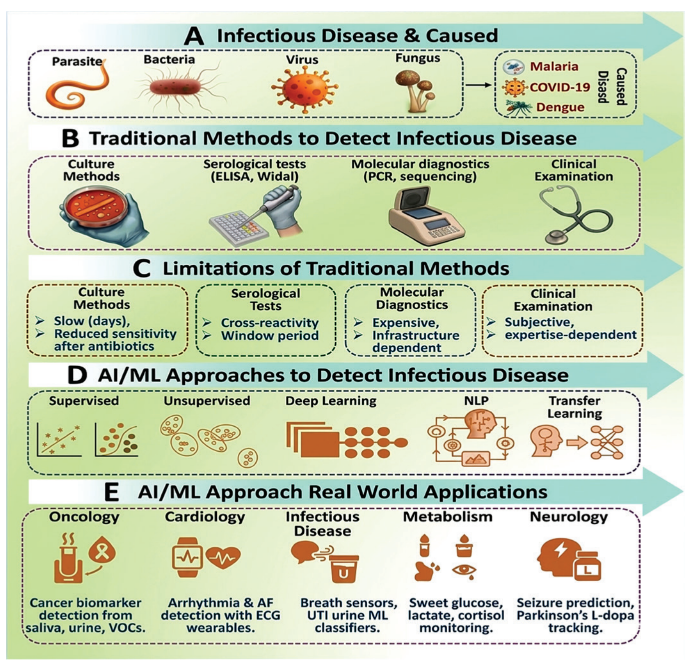

Fig.2: *From traditional diagnostic limitations to advanced AI/ML-driven infectious disease detection and real-world applications.*

Why Partnerships Matter: AI + Clinicians

AI is not meant to replace doctors; it is a Clinical Decision Support (CDS) tool.

- **Consistency:** Unlike humans, AI doesn't get tired or suffer from "reader fatigue."
- **Explainability (XAI):** New models show doctors exactly why they flagged a patient (e.g., highlighting a specific area on a lung scan), building trust and safety.

How would this look in practice?

A realistic role for AI is to act as a triage filter within the hospital workflow:

- Immediate Screening: AI scans all incoming X-rays.
- Prioritisation: It moves high-risk cases to the top of the doctor's pile.
- Treatment Support: It suggests the most effective antibiotic based on predicted resistance patterns.

Disease-Specific Applications

Pneumonia:

The diagnostic pipeline begins with the Lung Segmentation Model (Fig. 3), which isolates relevant clinical data to improve diagnostic focus. This process is part of a broader workflow: Fig. 3A establishes the foundational Detailed ML Model using CNN layers to extract features, while Fig. 3B compares model performance over various training Epochs. The segmentation process in Fig. 3C standardizes these images through cropping and normalization, preparing them for deep feature extraction within the ResNet-50 Model (Fig. 3D). In Fig. 3E, the Model Training and Evaluation stage demonstrates the system's ability to perform multi-class classification for diseases like COVID-19 and Tuberculosis, achieving high validation accuracy. Finally, Fig. F provides a technical visualization of the architectural layers and loss curves, confirming the model's stability as it reduces data dimensions from to a condensed feature set for final diagnosis.

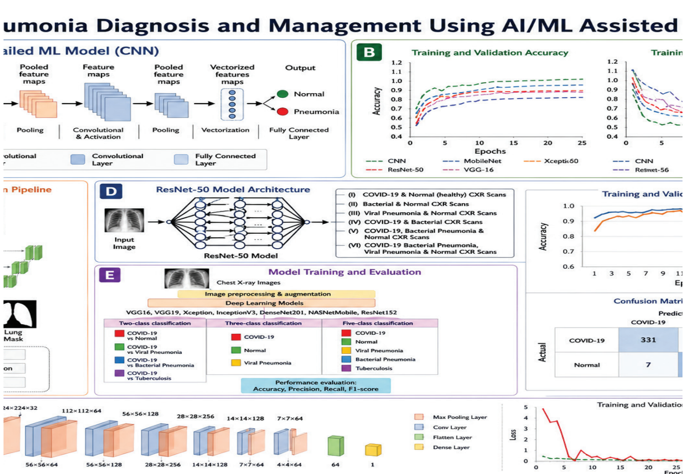

Fig.3: Pneumonia Diagnosis and Management Using AI/ML Assisted Systems

Malaria detection and management

The Fig.4. illustrated automated AI system detects malaria by analyzing microscopic blood samples through a multi-stage pipeline. The process begins with image preprocessing and segmentation (Fig. 4A), where complex blood smear images are broken down into individual cell segments to isolate red blood cells. These segments are then processed through advanced deep learning architectures, such as Capsule Networks (Fig. 4B), which utilize Inception blocks and specialized routing layers to distinguish between healthy and parasitized states. To ensure global reliability, the workflow incorporates large-scale datasets sourced from various clinical sites (Fig. 4C), including locations like Apac, Kintampo, and Navrongo, to train and validate the models across different regional conditions. The final stage of the system (Fig. 4D) focuses on a comprehensive training pipeline that employs transfer learning and fine-tuning on established architectures like ResNet-50, ResNet-34, VGG-16, and VGG-19. By applying these optimization techniques, the system achieves high-level precision, reaching over 97% accuracy (specifically visible in the VGG-19 fine-tuned results), providing fast and dependable diagnostic support for healthcare providers.

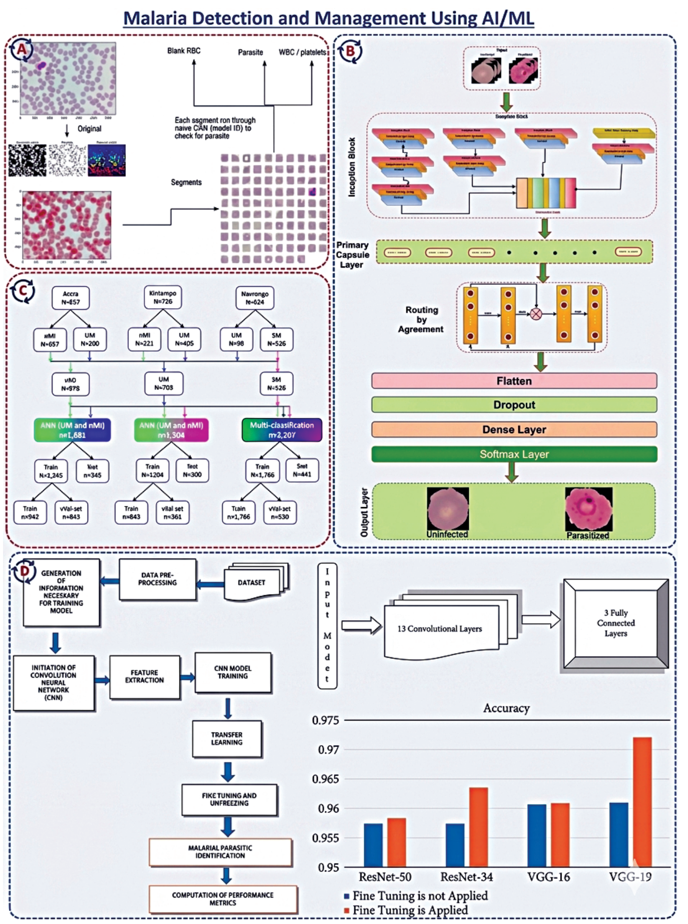

Fig.4: Malaria Detection and Management Using AI/ML Assisted Systems

The Roadmap to Global Impact

Like any technology, there are hurdles to clear:

- Data Silos: Medical records are often fragmented across different systems.
- The "Black Box" Problem: Doctors need transparent reasoning, not just a "Yes/No" result.
- Digital Divide: Ensuring these tools work in low-resource settings on basic mobile devices.
- Algorithm Drift: Keeping models updated as pathogens evolve.

Conclusion

The integration of AI and machine learning marks a pivotal shift in infectious disease diagnostics, moving from slow, infrastructure-dependent traditional methods to rapid, data-driven systems as exemplified by automated pipelines for Pneumonia/COVID-19 and Malaria. By leveraging technologies like computer vision and transfer learning, these applications transform chest X-rays and blood smears into high-precision results, achieving accuracy levels over 97% to effectively combat clinician fatigue and resource scarcity. While hurdles such as data silos and "black box" transparency remain, the transition toward these intelligent "force multipliers" is essential for building a proactive global health strategy that ensures faster, safer, and more equitable healthcare delivery in the face of emerging pandemic threats.by continuous learning, standardization, and interdisciplinary collaboration.

Reference

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Fuzzy RNN Model-Based Classification of Alzheimer's Disease and Dementia Using Brain EEG Signals

Dr. Murla Bhumi Reddy, *et al.*

Alzheimer's Disease (AD) and Dementia are serious neurodegenerative disorders that lead to progressive cognitive decline, memory loss, and reduced daily functioning. With the increasing aging population, the number of patients suffering from these disorders is rapidly growing. This research work focuses on developing an intelligent sysytem, based on a Fuzzy Recurrent Neural Network (Fuzzy RNN) for data analysis and classification.

Introduction

Early diagnosis is critical to provide effective treatment and improve patient care. Electroencephalogram (EEG) signals offer a non-invasive and cost-effective way to analyze brain activity. This project focuses on developing an intelligent system using Deep Learning techniques, specifically a Fuzzy Recurrent Neural Network (Fuzzy RNN), to classify Alzheimer's Disease and Dementia using EEG signals.

Problem Statement

Traditional diagnostic methods are often time-consuming and prone to inaccuracies due to overlapping symptoms between Alzheimer's Disease and other types of dementia. Moreover, conventional machine learning approaches fail to effectively capture temporal dependencies and uncertainty present in EEG signals. Hence, there is a need for an advanced and reliable system that can accurately classify neurological disorders using intelligent techniques.

Objectives

The main contributions of the work as follows:

- Introduces an integrated framework of fuzzy logic and Recurrent Neural Networks (RNNs) into a single hybrid model.
- This combination harnesses the adaptive learning capabilities of RNNs and the ability of fuzzy logic to handle uncertainty, creating a comprehensive framework for improved classification of Alzheimer's Disease and dementia.
- The Fuzzy RNN model is designed to capture and analyze temporal dependencies within the data, enabling a more comprehensive understanding of the dynamic nature of brain activity associated with Alzheimer's Disease and dementia.
- The extended fuzzy rules in the proposed Fuzzy RNN model provide a mechanism to deal with the inherent variability in neurological data, enhancing the model's robustness and its ability to discern subtle patterns associated with cognitive disorders.
- The proposed model is evaluated on the EEG resting state-closed eyes recordings from 88 subjects diagnosed with Alzheimer's disease, frontotemporal Dementia, and healthy subjects.

Proposed Methodology

The proposed methodology combines fuzzy logic with recurrent neural networks to create an interpretable and adaptive model for Alzheimer's and dementia classification.

It emphasizes not only classification accuracy but also the interpretability of the model's decisions, which is crucial in medical applications.

The proposed methodology leverages a Fuzzy Recurrent Neural Network (Fuzzy RNN) for the classification of Alzheimer's disease and dementia, introducing a new approach to address the challenges associated with the diagnosis of neurodegenerative disorders. The key innovation lies in the integration of fuzzy logic within the recurrent neural network architecture, allowing the model to effectively handle the inherent uncertainty and complexity of Alzheimer's and dementia-related data. Fuzzy logic is employed to capture and represent the imprecision and vagueness often present in medical datasets, particularly those derived from diverse sources such as neuroimaging, clinical assessments, and biomarker data.

The Fuzzy RNN is designed to exploit the temporal dependencies inherent in sequential medical data, providing a robust framework for capturing evolving patterns of cognitive decline over time. The model takes into account not only the traditional features associated with Alzheimer's disease but also incorporates fuzzy rules that explicitly consider the uncertainty in the diagnostic process. This makes the methodology well-suited for real-world clinical applications, where interpretability and transparency of decision-making are paramount.

The training of the Fuzzy RNN involves learning fuzzy rules and optimizing the recurrent connections simultaneously. The model is fine-tuned using a comprehensive dataset that includes a diverse range of patient profiles, encompassing individuals with Alzheimer's disease, dementia, and healthy controls. The performance of the proposed methodology is rigorously evaluated using standard metrics such as accuracy, sensitivity, and specificity, and compared with existing classification approaches to validate its effectiveness. The integration of fuzzy logic not only enhances the model's ability to handle uncertainty but also provides a human-understandable framework for clinicians and researchers. This transparency is critical in the medical field, where the interpretability of diagnostic decisions is essential for gaining trust and facilitating collaboration between the model and healthcare professionals.

The basic block diagram of the proposed methodology is shown in Figure 1. In the proposed architecture, the fuzzy inference is included in the Fuzzy RNN block whose internal architecture is shown in Figure 2.

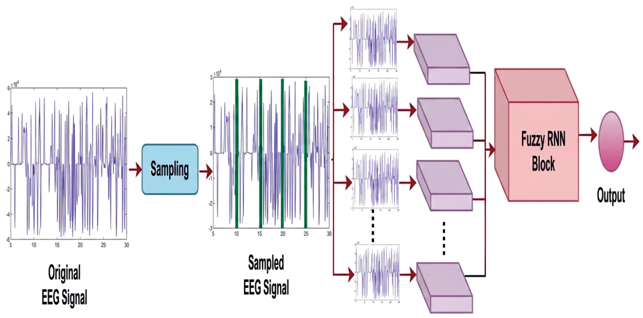

Fig.1: Block diagram of the proposed system modeling.

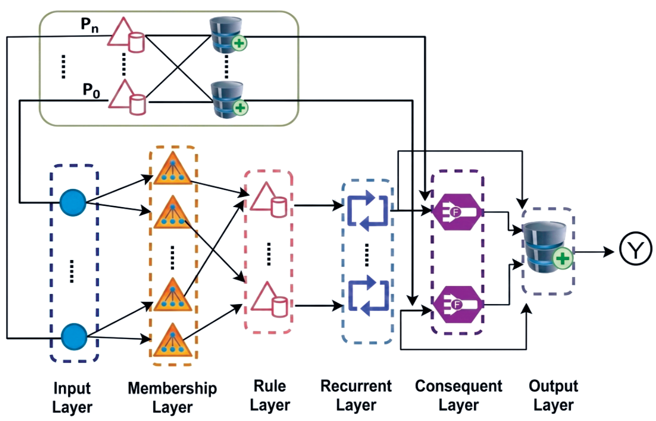

Fig.2: Block diagram of the proposed system modeling.

A. Seguential data processing of RNN

An artificial neural network type called a Recurrent Neural Network (RNN) is made for modeling and sequential data processing. RNNs are different from standard feedforward neural networks in that they feature directed cycle connections, which enable them to keep track of information from past time stamps in a hidden state. Because of its architecture, RNNs are useful for situations where there are sequential dependencies, like time series prediction. RNNs include recurrent connections that allow information to persist across different time steps.

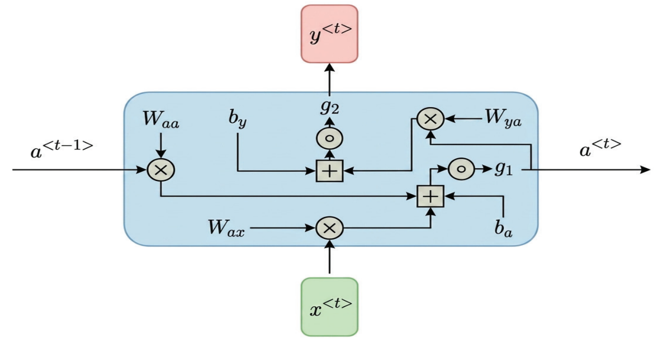

Fig.3: Cascaded architecture of the hidden units in RNN model.

This enables the network to maintain a memory of past inputs, making them effective for sequential data processing.

The cascaded architecture of the RNN model with multiple hidden neurons in a single layer is shown in Figure 3 and the internal architecture of the single input unit processing is shown in Figure 4.

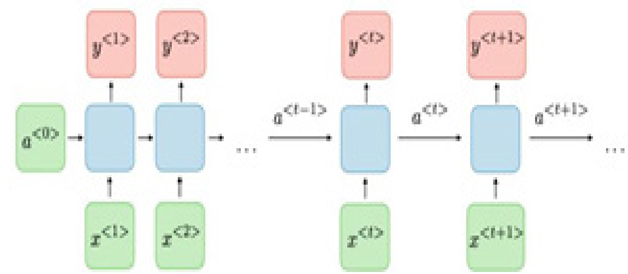

Fig.4: Internal architecture of the single unit processing in RNN model.

Results and Discussions

A. Dataset description

In the experimentation, the dataset of EEG is collected from the open-source platform.1 The EEG resting state closed eye recordings from 88 participants are included in the collection. Of them, 29 were healthy subjects (CN group), 23 had frontotemporal dementia (FTD group), and 36 had been diagnosed with Alzheimer's disease (AD group).

To generate the dataset, a skilled group of neurologists obtained recordings from the AHEPA General Hospital of Thessaloniki's 2nd Department of Neurology. The Nihon Kohden EEG 2100 clinical device was used for recording. Two reference electrodes (A1 and A2) were placed on the mastoids for an impedance check, per the device's manual, and 19 scalp electrodes (Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, and O2) were used following the10-20 international system. Every recording was made while the subjects were sitting with their eyes closed, following the clinical protocol.

At the end, the dataset will undergo the necessary preprocessing state to make it a processed signal. The dataset that contains the derivatives of preprocessed and denoised EEG recordings also includes the raw EEG recordings. The following is the EEG signal preparation pipeline. The signals were first re-referenced to A1–A2, and a Butterworth bandpass filter (0.5–45 Hz) was applied. Following that, the signals were subjected to the Artifact Subspace Reconstruction routine (ASR), an EEG artifact correction technique included in the EEGLab MATLAB software. This procedure eliminated periods of bad data that surpassed the maximum allowable 0.5-second window standard deviation of 17, which is regarded as a conservative window. Next, the 19 EEG signals were converted to 19 ICA components using the Independent Component Analysis (ICA) method

Conclusion

This study presents a comprehensive investigation into the application of Fuzzy Recurrent Neural Network (Fuzzy RNN) models for the classification of Alzheimer's Disease and Dementia using brain EEG signals. The study's primary objective was to assess the efficacy of Fuzzy RNNs in capturing the temporal dynamics and handling the inherent uncertainty in EEG data associated with neurodegenerative disorders. The results demonstrated promising performance in terms of accuracy, sensitivity, and specificity, indicating the potential of Fuzzy RNNs as a valuable tool for the early diagnosis of Alzheimer's Disease and Dementia. The research findings highlight the interpretability of the Fuzzy RNN models, providing insights into the decision making process through the incorporation of fuzzy logic. This interpretability is crucial in the medical field, as it fosters trust and collaboration between the model and healthcare professionals. Moreover, the study contributes to the existing body of literature by offering a nuanced understanding of the advantages of Fuzzy RNNs over traditional EEG classification methods. In the results section, the performance metrics of the proposed Fuzzy RNN models are presented, including accuracy, sensitivity, and specificity as baseline performance metrics. The models are assessed across a dataset comprising EEG signals from individuals with Alzheimer's Disease, dementia, and healthy controls. The proposed model shows the results with an Accuracy - 98.82 (AD/CN), 98.42 (FTD/CN), and 97.82 (AD/FTD) respectively for the classification of the EEG signals. The achieved classification accuracy is compared with existing methods, showcasing the efficacy of the Fuzzy RNN models in capturing intricate temporal patterns inherent in EEG data. Despite the promising results, it is acknowledged that further validation on larger and more diverse datasets is essential to assess the generalizability of the proposed Fuzzy RNN models. The limitations of the study, including dataset specific challenges and potential biases, are transparently discussed. Future research directions may involve exploring the robustness of the models in real-world clinical settings and integrating multimodal data sources for a more comprehensive diagnostic approach.

Reference

[1] Sreedhar, Murla Bhumi Reddy, et al. "Fuzzy RNN model-based classification of Alzheimer's Disease and dementia using brain EEG signals." IEEE Transactions on Consumer Electronics vol. 71, no. 2, pp. 5559–5568, 2025.

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Nature's Fluorescent Proteins: Structure, Function, and Industrial Potential of Phycobiliproteins

Dr. Indira Mikkili, *et al.*

Cyanobacteria—the world's oldest photosynthesizers—not only oxygenated Earth's atmosphere billions of years ago but also laid the biochemical foundations for complex life. Yet their story is far from over. Within their ancient cells lies a remarkable group of pigment-proteins called phycobiliproteins—nature's own solar collectors—now attracting intense scientific interest for their potential in medicine, food, cosmetics, and sustainable industry. From targeting cancer cells to providing natural colorants, from detecting water pollutants to enabling next-generation diagnostics, these pigments are emerging as one of biotechnology's most versatile and promising frontiers.

Billions of years before the first human drew breath, cyanobacteria had already mastered the art of harnessing light, sustaining life, and producing color. These ancient, single-celled organisms — among the earliest life forms on Earth — were the first to perform oxygenic photosynthesis, effectively transforming the planet by generating its breathable atmosphere. Today, scientists are rediscovering these remarkable microbes not as relics of the past, but as blueprints for the future.

Thriving in environments ranging from arctic tundra to scorching desert crusts, cyanobacteria demonstrate an almost supernatural adaptability that continues to astonish researchers worldwide. At the heart of their survival lies a sophisticated solar-harvesting system — the phycobilisome — a protein complex so efficient at capturing sunlight that engineers are studying it to improve solar energy technologies. These tiny organisms pack an extraordinary biochemical toolkit, producing everything from natural pigments and proteins to fatty acids and even renewable biofuels like hydrogen. Their cellular diversity and physiological resilience make them uniquely positioned at the crossroads of environmental science and industrial biotechnology.

Why it acts as Natures living prism

Inside every cyanobacterial cell, light undergoes a journey. Photons streaming from the sun strike a vast, organized complex of protein and pigment known as the phycobilisome — an antenna of almost architectural precision. Here, light energy is captured, funneled, and transferred with near-perfect efficiency to the photosystems that power life.

The phycobilisome is not monolithic. It is a cathedral of molecular organization: allophycocyanin cylinders form the core, while phycocyanin and phycoerythrin radiate outward in rod-like extensions, each tuned to capture a different slice of the solar spectrum. The result is a system that, gram for gram, harvests light more efficiently than almost any engineered photovoltaic device on the market today.

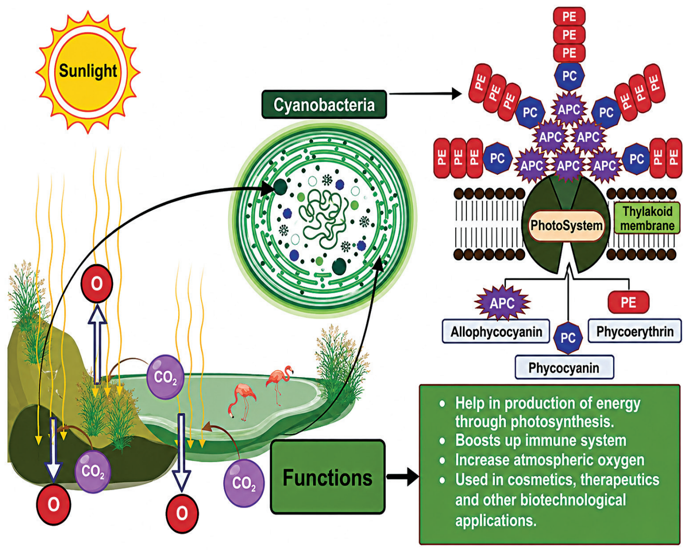

Fig.1: Structure and function of Phycobilisome (Source: https://BioRender.com/p14l561)

A language written in color

Each phycobiliprotein speaks its own chromatic language.

- Phycocyanin's brilliant blue absorbs light at 610–620 nm.
- Phycoerythrin blushes pink to red, capturing wavelengths around 540–570 nm.
- Allophycocyanin settles into a deep blue absorbs at 650–655 nm.

How they capture light: The three pigments of the Phycobilisome

- Phycocyanin: The most abundant of the three, this vivid bluish pigment transfers light energy to both Photosystem I and II, maximizing the cell's photosynthetic yield.

- Phycoerythrin: Predominantly found in red algae, this pink pigment sits at the outermost rods of the phycobilisome, capturing light under low-light, nutrient-rich conditions.
- Allophycocyanin: Anchoring the phycobilisome core, this deep blue pigment absorbs across a remarkably broad spectrum (500–700 nm), prized for its strong natural fluorescence.

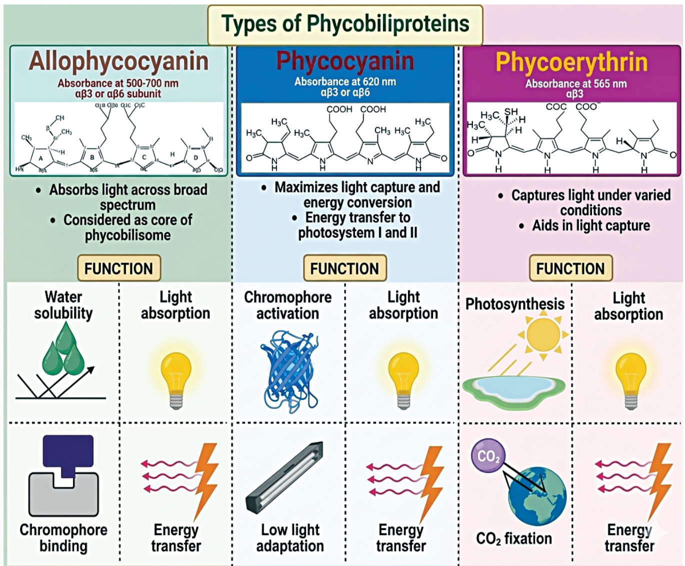

Fig.2: Types of Phycobiliproteins (Source: https://BioRender.com/bo2x2ph)

How cyanobacteria use multiple pigments to capture light very efficiently

- "Together, they form a gradient of absorption" → different pigments (like chlorophylls, phycobiliproteins, carotenoids) each absorb different wavelengths of light, creating a continuous coverage rather than a single narrow band.
- "Harvest light across nearly the entire visible spectrum" → they can utilize light from most colors (violet to red), not just specific regions.
- "A feat of biological engineering still unmatched by human technology" → even advanced solar cells cannot efficiently capture such a broad range of visible light in one integrated system.

From Open Ponds to Precision Medicine

- **Early Era:** Batch cultures and open ponds

  The first efforts to cultivate cyanobacteria at scale relied on simple open-pond systems. Researchers adjusted nutrient concentrations by hand, hoping to coax out richer pigment accumulation — a process more art than science.

- **Mid Period:** The closed photobioreactor revolution

  The shift to closed systems brought unprecedented control over temperature, light, pH, and CO_2. Contamination risks dropped. Productivity climbed. Flat-plate and tubular photobioreactors enabled researchers to study the precise effects of red versus blue LED spectra on pigment yield.

- **Modern Era:** AI, CRISPR, and genome-scale models

  Machine learning models now predict cyanobacterial growth across hundreds of environmental variables simultaneously. CRISPR-Cas9 enables precise genetic edits. Genome-scale metabolic models illuminate bottlenecks invisible to the naked eye.

- **The Frontier:** Engineered strains for tomorrow

  Synechococcus sp. PCC 11901 has emerged as a powerhouse chassis — fast-growing, naturally transformable, and pigment-stable. Researchers are now building autotrophic cell factories that use sunlight and CO_2 as sole inputs to produce biofuels and high-value compounds.

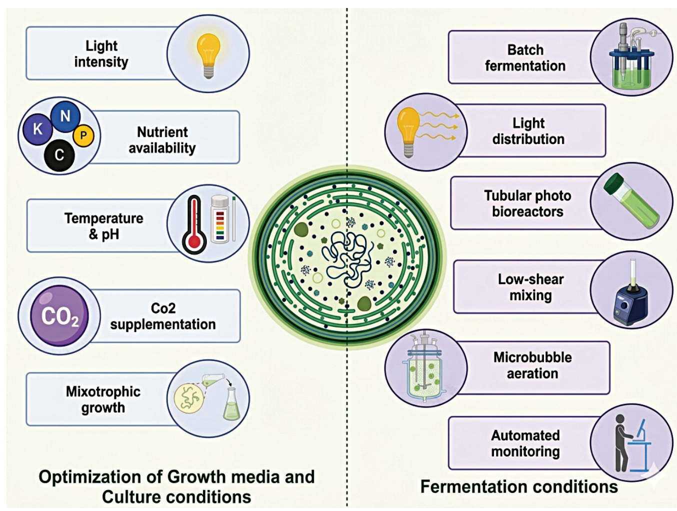

Fig.3: Process optimization parameters for Phycobiliproteins production (Source: https://BioRender.com/c68u487)

- Mechanisms Underpinning the Therapeutic Potential of Phycobiliproteins

  Phycobiliproteins exert their biological effects through multiple interconnected mechanisms that underpin their growing therapeutic relevance.

- Antioxidant activity

  Phycobiliproteins are powerful free radical scavengers, capable of neutralizing the oxidative stress that underlies aging and chronic disease.

- Anti-inflammatory effects

  By modulating inflammatory pathways, phycobiliproteins help attenuate conditions such as rheumatoid arthritis and other inflammatory disorders.

- Photodynamic action in oncology

  In photodynamic therapy — a technique that uses light-activated molecules to destroy tumors — phycobiliproteins show extraordinary promise. Their light-harvesting architecture allows them to generate reactive oxygen species with precision, targeting cancer cells while sparing healthy tissue nearby.

- Biocompatible drug delivery

  Their biocompatibility and lack of toxicity make them ideal carriers for therapeutic agents — a rare combination in drug delivery

- Wound healing and tissue regeneration

  Phycobiliproteins promote tissue regeneration by dampening inflammation and oxidative stress at wound sites, accelerating both acute and chronic healing.

- Nanotechnology-enabled targeting

  Phycobiliprotein-based nanoparticles now represent a platform for targeted drug delivery with reduced systemic side effects — a glimpse into personalized medicine's future.

From Lab Bench to Supermarket Shelf

- What began as a curiosity in photosynthesis research has rapidly evolved into a multi-industry commercial phenomenon, spanning diagnostics, food manufacturing, cosmetics, and environmental monitoring.
- Unlike most scientific discoveries, the transition of phycobiliproteins from research to real-world applications has been remarkably fast and continues to accelerate.

Bioimaging & Diagnostics

- Their exceptional fluorescence — high quantum yield and photostability — makes phycobiliproteins superior to traditional fluorophores.
- In flow cytometry, they sort and identify immune cells with extraordinary precision.
- Engineered variants emit at customized wavelengths, enabling multi-color imaging that allows simultaneous visualization of multiple biological targets in complex tissues.

Food & Natural Colorants

- Consumers are demanding cleaner labels and natural ingredients.
- Phycobiliproteins — vibrant, non-toxic, and nutritionally beneficial — are replacing synthetic dyes in beverages, confectioneries, and dairy products.
- The thermostable variant CpcBT, recently developed in E. coli, holds particular promise for heat-treated food applications where conventional pigments degrade.

Cosmetics & Skincare

- Antioxidant and anti-inflammatory properties translate directly into skincare benefits.
- Engineered phycobiliproteins with enhanced bioactivity and stability are appearing in anti-aging formulations and natural colorant lines, positioning cyanobacterial pigments as a sustainable backbone for the growing clean-beauty economy.

Environmental Biosensors

- Cyanobacteria's ancient sensitivity to environmental shifts has been harnessed in a new way.
- Engineered phycobiliprotein variants serve as biosensors for detecting heavy metals and pollutants in wastewater.

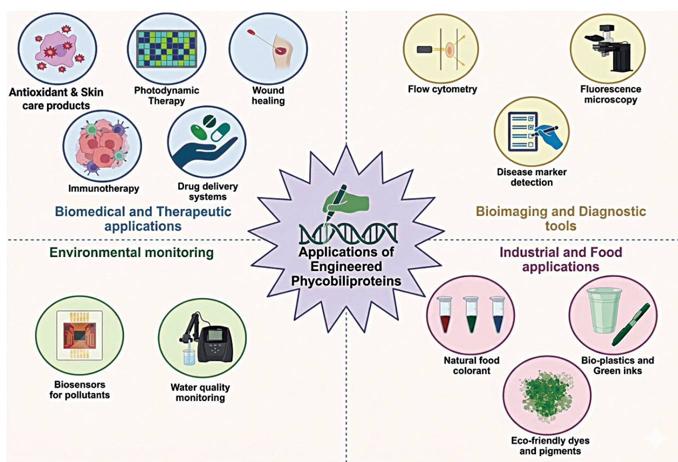

Fig.4: *Various applications of engineered phycobiliproteins (Source: https://BioRender. com/j07b019).*

The Road Ahead Is Long — and Luminous

Despite the excitement, honesty demands a reckoning with the obstacles ahead.

- Large-scale production of phycobiliproteins remains costly, with native cyanobacterial strains exhibiting slow growth and inconsistent pigment expression.

- Dense cultures further limit light penetration—a cruel irony for organisms evolved to capture it.
- Additionally, downstream purification is labor-intensive, and conventional chromatographic methods may compromise the bioactivity that underpins their value.

Regulatory hurdles add another layer of complexity

- Genetically modified cyanobacteria are governed by diverse regulatory frameworks across jurisdictions—from the relatively permissive GRAS system of the U.S. Food and Drug Administration for products like Spirulina to the European Union's stringent Regulation (EC) No 1829/2003 on genetically modified food and feed.
- Public perception of GMO products remains a significant barrier in many markets, necessitating transparent communication strategies alongside technical innovation.

Yet the trajectory is unmistakably upward

- Machine learning has already demonstrated its capacity to optimize cultivation conditions beyond what manual experimentation can achieve.
- CRISPR genome editing is enabling faster and more precise engineering of cyanobacterial chassis.
- Meanwhile, advanced bioreactor designs incorporating microbubble aeration, side-light optical fibers, and real-time sensor feedback are steadily bridging the gap between laboratory promise and industrial reality.

The phycobiliprotein story is, in many ways, the story of biotechnology itself Ancient biological systems unlocked by modern tools, transitioning from curiosity to application at a pace that continues to surprise even the most optimistic observers. Realizing this potential will require not only scientific ingenuity but also genuine interdisciplinary collaboration among biologists, engineers, food scientists, clinicians, and industry partners who share both the ambition and urgency demanded by the moment.

As research advances and technologies mature, phycobiliproteins are poised to redefine sustainable solutions across multiple industries. Their journey highlights the transformative power of integrating biology with innovation to address pressing global challenges, illuminating a future where nature-inspired technologies drive the next wave of industrial progress.

Conclusion

Cyanobacteria, among the oldest and most resilient organisms on Earth, continue to gain importance in modern science and industry through their phycobiliproteins—phycocyanin, phycoerythrin, and allophycocyanin. These pigments have applications in therapeutics, diagnostic imaging, natural food colorants, cosmetics, and environmental biosensing. Advances in photobioreactor design, fermentation, genetic engineering, and machine learning-driven bioprocessing have improved their industrial potential, while tools such as CRISPR-Cas9 and metabolic modeling enable the development of high-yield engineered strains. However, challenges such as low productivity, high processing costs, and regulatory constraints still hinder commercialization. Addressing these issues will require sustained interdisciplinary collaboration among microbiologists, engineers, clinicians, food scientists, and industry stakeholders. With their exceptional photosynthetic efficiency and biochemical versatility, cyanobacteria hold significant promise for supporting a sustainable bio-based economy.

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Non-Invasive detection of Glucose and Urea for the Diabetic and Chronic Kidney disease patients in saliva sample using Optical Biosensor

Dr. Amit Kumar Singh, *et al.*

The high-impact research outputs from the Department of Biomedical Engineering, VFSTR in 2025, collectively reflect a strategically integrated vision of biomedical engineering that addresses global priorities in the medical diagnostics field. The work converges on the central theme of diagnostic devices in the medical field, with the aim of developing sustainable human health, in collaboration with premier institutes like IIT and NIT.

This research addresses the global health burden of diabetes and chronic kidney disease. Traditional invasive testing is painful and inconvenient, often leading to poor patient compliance. A novel handheld optical biosensor provides a non-invasive diagnostic alternative using saliva. The system utilizes disposable paper-fluidic strips featuring specific enzyme-dye combinations to detect glucose and urea. A critical innovation is ambient temperature compensation, ensuring measurement accuracy despite environmental variations. Clinical validation demonstrated high correlation with blood levels for both glucose (8–358 mg/dL) and urea (5–90 mg/dL). This rapid, low-cost POCT device offers a reliable solution for effective disease management.

What is diabetic and chronic kidney disease

Diabetes and chronic kidney disease (CKD) are categorized as non-communicable diseases that represent major global health challenges due to high morbidity rates. Diabetes is typically monitored by tracking glucose levels, while kidney failure is monitored by tracking urea levels. Approximately 30 percent of patients with type 1 diabetes and 10–40 percent with type 2 diabetes are at risk of undergoing kidney failure.

What is the Impact of diabetic and chronic kidney disease at the National and International level

Approximately 830 million people worldwide are living with diabetes (WHO, 2022). The global prevalence has increased from 7% in 1990 to 14% in 2022. Diabetes caused around 1.6 million deaths in 2021, with an additional ~530,000 deaths due to kidney-related complications. Chronic kidney disease affects hundreds of millions globally, with many cases remaining undiagnosed.

India has approximately 77 million diabetic patients, making it one of the most affected countries globally. Around 25 million individuals are pre-diabetic, indicating a growing risk population. More than 50% of cases remain undiagnosed, leading to late-stage complications. These diseases have a significant economic impact on the global gross domestic product (GDP), and millions die annually because they lack access to inexpensive treatments. Increased healthcare expenditure due to long-term treatment, dialysis, and transplantation. Loss of productivity and reduced quality of life. High burden on public health infrastructure.

Existing Diagnostic Methods

Conventional monitoring of these diseases typically involves invasive and painful techniques, such as finger-prick-based self-monitoring blood glucose (SMBG) analyzers. Other methods include inconvenient wearable patches or standard chemical autoanalyzers that are not user-friendly because they often require semi-manual methods for analyte detection. Some researchers have also developed microfluidic devices using electrochemical or mechanical methodologies, but these methods can entail drawbacks such as complex strip fabrication or high costs.

Saliva as a Non-Invasive Method for Diagnostics

Saliva is a promising medium for non-invasive monitoring because it is easy to collect and handle, as it does not clot. Saliva collection is considered the fastest and most convenient throughout the day compared to other body fluids, such as urine, sweat, or aqueous humour. Scientific studies have shown strong correlations between blood glucose and saliva glucose, as well as between blood urea nitrogen and saliva urea, making it viable for point-of-care testing (POCT). Non-invasive and painless collection. Easy to handle and store, no risk of infection from needles, Suitable for repeated and real-time monitoring, Cost-effective and patient-friendly, Ideal for children, elderly patients, and chronic disease management

Novel Optical Biosensor

The novel technology is a handheld, non-invasive optical biosensor designed for multivariate analysis using saliva samples. This device utilizes paper-fluidic strips with specific enzyme-dye combinations to detect glucose and urea rapidly. A standout feature is its ambient-temperature compensation system, which addresses variations in enzyme kinetics due to temperature changes to ensure measurement accuracy.

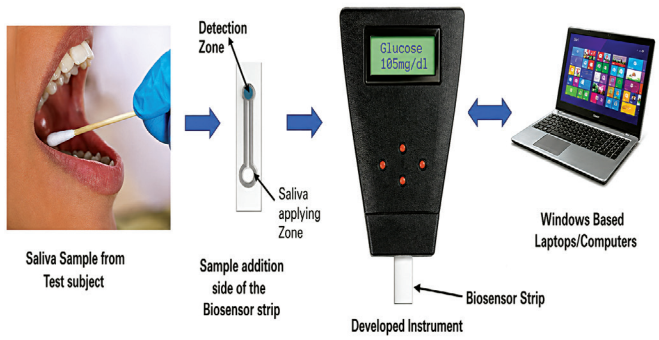

Fig.1: Block diagram of the procedure for the use of the developed system for POCT.

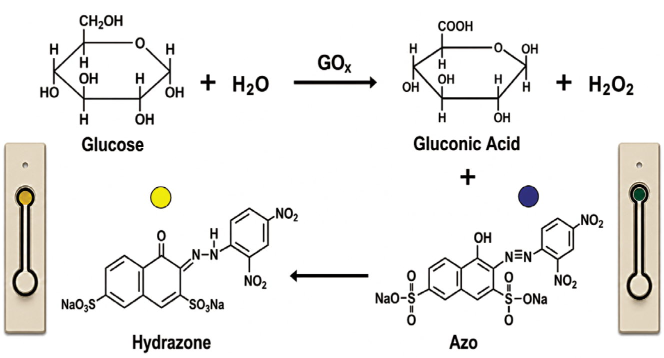

Fig.2: Schematics of glucose strip: in the reaction, β-D glucose is converted into gluconic acid in the presence of glucose oxidase (GOD), which induces a color change in nitrazine yellow (NY) from dark blue to yellow. The image on the right shows the glucose biosensor strip tested at 12 mg/dL, while the image on the left shows the strip tested at 262 mg/dL.

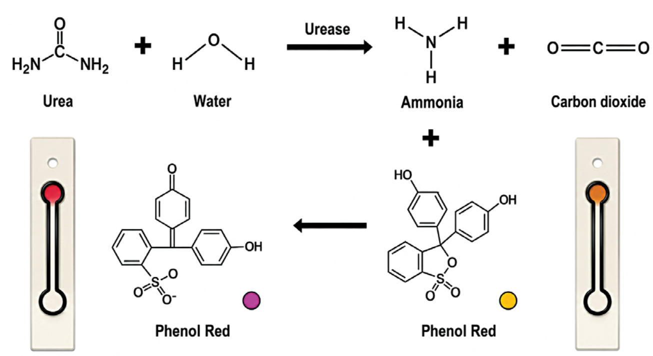

Fig.3: Schematics of the urea strip: in the reaction, urea is hydrolyzed into ammonia in the presence of urease, resulting in a color change of phenol red (PR) from yellow to pink. The image on the right shows the urea biosensor strip tested at 20 mg/dL, while the image on the left shows the same strip tested at 120 mg/dL.

Key Components of the Technology

The technology consists of several essential elements:

- Disposable Biosensor Strips: Multilayered, paper-based microfluidic devices patterned with hydrophobic wax barriers and immobilized reagents (glucose oxidase for glucose and urease for urea).
- Optical System: An RGB LED serves as a multipurpose light source (620 nm for glucose and 530 nm for urea) alongside a highly sensitive 16-bit digital color sensor.
- Processing and Data: A 16-bit microcontroller (PIC24FJ256GB110) processes the data, which can be stored on a 4GB multimedia card (MMC) or transmitted via Bluetooth to mobile phones or laptops.
- Hardware: The device includes an onboard temperature sensor (LMT86) for calibration, an LCD, and an ABS 3D-printed chassis.
- Biosensor Specifications:
- Glucose Biosensor: It showed a sensitivity of 1.93 counts per mg/dL, a linearity range of 8 to 358 mg/dL, and a rapid response time of 7.35 seconds.
- Urea Biosensor: It showed a sensitivity of 1.51 counts per mg/dL, a linearity range of 5 to 90 mg/dL, and a response time of only 3 seconds.

Clinical Validation

- Clinical validation showed a strong correlation (Pearson's R = 0.53 to 0.66) between saliva and blood glucose in diabetic patients.
- Clinical validation for CKD patients revealed a very high correlation (Pearson's R = 0.98 to 0.99) between blood and saliva urea levels.

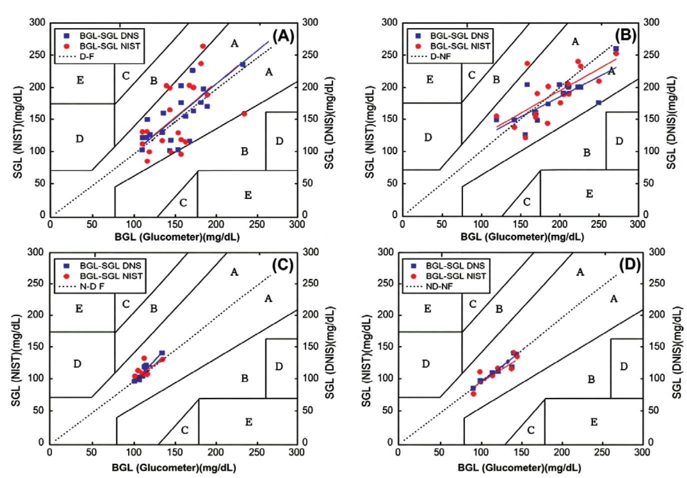

Fig.4: Clinical validation results (Clarke error grid) for glucose biosensor for (A) Diabetic subjects, pre-breakfast samples, (B) Diabetic subjects -post breakfast samples, (C) Non-diabetic subjects- pre-breakfast samples, and (D) Non-diabetic subjects- post breakfast samples.

Scientific Benefits of the Novel Optical Biosensor

- Non-Invasive and Painless: It eliminates the need for painful finger-pricks, which can improve patient compliance.
- Temperature Compensation: Unlike many commercial meters, this device corrects for ambient temperature variations that can cause up to 30% error in readings due to enzyme kinetic changes.
- Cost-Effectiveness: The device is cheaper to fabricate than standard invasive multi-analyte instruments due to its simple optical design and optimised enzyme concentrations.
- Automation: It features automatic strip recognition using an LED-LDR pair to distinguish between glucose and urea strips without user intervention.
- Response Time: Total testing time, including sample wicking, is kept under 1–2 minutes, with electronic stabilization occurring in seconds.

Conclusion

The developed handheld optical biosensor provides a rapid, reliable, and user-friendly alternative for point-of-care testing. It successfully correlates saliva markers with blood markers for both diabetes and CKD, achieving performance that approaches that of standard blood-based assays. This technology holds the potential to significantly improve chronic disease management, especially in resource-limited areas or for home self-testing (POCT).

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Magnetically Recoverable Fe-Modified Biochar (Fe-ATB) for Phosphate Remediation: Experimental and Theoretical Studies

Dr. V. Srinivasadesikan, *et al.*

Acid treatment creates surface functional groups that serve as nucleation sites for iron loading. The Fe-ATB material shows a 266% increase in pore volume and a 50.5% rise in BET surface area. Electronic properties show that the HOMO–LUMO gap reducing from 2.56 eV to 1.74 eV. A strong binding energy of 181.3 kcal/mol indicates highly stable Fe–phosphate interactions. This research work was carried out in association with NCHU, TAIWAN.

Strategic Context and Global Resource Imperatives

The remediation and recovery of phosphate from aqueous systems have evolved into a critical dual-imperative for global environmental engineering. This urgency is dictated by the need to mitigate catastrophic water eutrophication while simultaneously addressing the finite nature of phosphorus supplies, which currently face a global demand exceeding 50 million tons annually. As reserves of rock phosphate dwindle, the transition from simple effluent disposal to strategic nutrient recovery is a technical necessity.

Conventional separation methodologies- primarily chemical precipitation, ion exchange, and membrane filtration - are increasingly viewed as insufficient for sustainable large-scale operations. Chemical precipitation is burdened by significant reagent costs and the generation of voluminous sludge, which complicates phosphate reuse. Ion exchange is hindered by the high capital expenditure of resin replacement and interference from competing anions, while membrane filtration is limited by fouling issues and high energy consumption. These operational hurdles necessitate a shift toward high-capacity, magnetically recoverable adsorbents that simplify recovery cycles. To this, the engineering of the Fe-ATB composite offers a scalable pathway for high-efficiency phosphorus capture.

Synthesis Architecture and Material Engineering

The development of the Fe-ATB composite utilizes Leucaena leucocephala (River tamarind) as a sustainable biomass feedstock. This choice is strategically sound due to its high carbon density and environmental compatibility. The synthesis follows a rigorous sequential modification protocol (WB → ATB → Fe-ATB) designed to optimize the carbon framework before the introduction of magnetic functional phases.

Synthesis Protocol Overview

The material engineering process is structured into three distinct phases:

1. Pyrolysis Phase: Raw biomass is carbonized at 600°C under a nitrogen () atmosphere at a heating rate of 10°C/min, resulting in pristine wood biochar (WB).
2. Acid-Treatment Phase: The WB is treated with 0.1 M HCl. This stage is critical for unblocking existing pore networks by removing ash and mineral impurities—specifically potassium (K), calcium (Ca), and magnesium (Mg)—thereby preparing the surface for metallic loading.
3. Co-Precipitation Phase: Iron loading is performed using and precursors in an oxygen-limited environment. Magnetite nanoparticles are precipitated onto the biochar matrix under continuous purging and controlled NaOH addition.

A key differentiator in this protocol is the role of surface functional groups created during acid treatment, which act as "nucleation sites" for iron loading. This controlled aqueous synthesis at room temperature ensures a uniform distribution of magnetite nanoparticles across the biochar surface. This differentiates Fe-ATB from intercalated graphene systems, where metallic species are often trapped within layers and obscured from active participation in binding. This architectural precision provides the structural foundation for the material's enhanced physicochemical performance.

Physicochemical Transformation and Textural Evolution

The efficacy of any adsorbent is primarily dictated by its textural architecture, as surface area and pore geometry determine both the kinetics of capture and the total volumetric capacity.

Textural Property Comparison across Modification Stages

Treatment	BET Surface Area	Pore Volume	Pore Width (nm)
WB (Pristine)	68.17	0.042	2.18
ATB (Acid-Treated)	80.45	0.048	1.86
Fe-ATB (Iron-Modified)	102.58	0.112	1.78

The data demonstrates a significant textural evolution. The transition to Fe-ATB resulted in a 266% increase in pore volume and a 50.5% increase in BET surface area (reaching 150% of the initial pristine value). This expansion creates a significantly larger contact area for high-efficiency phosphorus capture. Notably, the reduction in pore width from 2.18 nm to 1.78 nm suggests the development of a refined microporous network. From an engineering perspective, this increases selectivity and facilitates inner-sphere complexation within confined spaces, a crucial differentiator from weaker outer-sphere interactions.

Structural validation was provided via X-ray Diffraction (XRD), confirming the formation of the inverse spinel structure of magnetite (). The identification of characteristic peaks at 30.1°, 35.5°, 43.1°, 57.0°, and 62.6° confirms as the dominant crystalline phase. Furthermore, Thermogravimetric Analysis (TGA) revealed a unique reactive phenomenon: a mass gain of 2–3% between 640 °C and 866 °C. This is attributed to oxidative activation and chemisorption of at carbon defect sites, validating the material's high thermal stability and unique oxygen activation capabilities.

Adsorption Performance and Isotherm Analysis

Predicting performance in real-world wastewater requires defining the maximum theoretical capacity and binding affinity. These parameters distinguish robust chemical bonding from superficial physical attachment.

Summary

Langmuir isotherm analysis indicates that Fe-ATB achieves a maximum theoretical capacity of mg/g. Crucially, the material exhibits a 17-fold increase in binding affinity compared to unmodified biochar. In comparative tests across a concentration range of 50–500 mg/L, Fe-ATB consistently outperformed WB and ATB by six-fold. At a low initial concentration of 51.3 mg/L, the material achieved a removal efficiency of 72.4%, demonstrating high effectiveness for meeting stringent environmental discharge limits.

Benchmarking Analysis

When compared to other modified biochars, Fe-ATB presents a compelling strategic profile:

- La-CL (Lanthanum-modified lignin): 107 mg/g
- FCBC (Fe/Ca oxide co-embedded): 53.3 mg/g
- MFDB (Mg/Fe-doped wheat straw): 179.2 mg/g
- Fe-ATB (This study): 12.7 mg/g

While Fe-ATB exhibits a lower absolute capacity than rare-earth-doped or highly complex systems like La-CL, it offers a distinct competitive advantage in operational kinetics, reaching equilibrium within just 60 minutes. Furthermore, its economic viability is superior; by utilizing low-cost iron precursors and explicitly avoiding rare earth elements like Lanthanum or Cerium, Fe-ATB serves as a more sustainable and scalable option for industrial-scale remediation.

Multi-Scale Mechanistic Validation: Spectroscopy and DFT

The "ground truth" for phosphate binding was established by integrating experimental spectroscopy with computational Density Functional Theory (DFT) modelling.

Analytical Summary

1. **XANES/XPS:** These techniques confirmed that Fe–P species became the dominant form of phosphorus (60.5%) on the surface. A shift in Fe 2p binding energy (711.04 eV to 710.85 eV) was accompanied by an intensification of the Fe–O signal at ~530.28 eV, providing primary evidence for the formation of the Fe–O–P inner-sphere complex.
2. **FTIR:** Post-adsorption analysis revealed the emergence of the P–O–C stretching vibration at, confirming chemical integration into the framework.
3. **DFT Modelling:** Computational results validated the enhanced electronic reactivity of the material. The HOMO–LUMO gap reduction (2.56 eV → 1.74 eV) signifies increased electronic activity, while the strong binding energy of 181.3 kcal/mol confirms the high stability of the Fe–P interaction.

The results of Density Functional Theory Studies

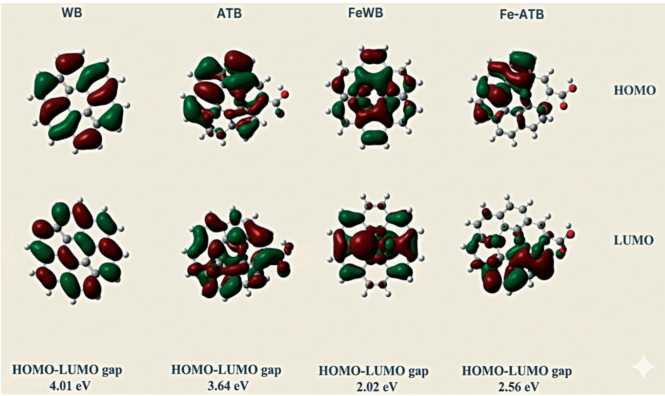

Fig.1: *DFT-calculated frontier molecular orbital distributions and HOMO-LUMO energy gaps for different biochar variants.*

Mechanistic Framework

The remediation process is governed by three primary pathways:

- Inner-sphere complexation: Direct ligand exchange and chemical bonding between phosphate and surfaces.
- Surface precipitation: Formation of iron-phosphate phases.
- Electrostatic attraction: Driven by the high charge density of centre.

6. Magnetic Recovery Efficiency and Environmental Scalability

The operational viability of an adsorbent is defined by its recovery potential. Fe-ATB enables rapid, reagent-free magnetic recovery, which is essential for sustainable water treatment.

Recovery Performance and Soil Disparity

In aqueous systems, Fe-ATB achieves recovery efficiencies exceeding 96%. However, performance varies significantly in soil-phase applications:

- Red Soil (91.2% recovery): Low organic matter and acidic pH allow for high magnetic field penetration.
- Loam Soil (38.9% recovery): High organic matter and neutral/alkaline pH led to organic “coatings” that attenuate the magnetic response, hindering separation.

Circular Nutrient Management

It is recommendation to stakeholders that Fe-ATB be integrated into a Circular Nutrient Management strategy. Once saturated with phosphate, the magnetically recovered material should be repurposed as a slow-release fertilizer. This approach not only remediates contaminated water but also returns essential nutrients to the agricultural cycle, providing a high-value end-of-life for the adsorbent.

Conclusion

Fe-ATB represents a scalable, cost-effective, and operationally efficient solution for phosphate management. By leveraging sustainable biomass, avoiding expensive rare earths, and providing rapid kinetics, it addresses the technical gaps of conventional treatment while offering a viable pathway toward phosphorus resource circularity.

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Unlocking the Potential of Nanocellulose in Biomedical Innovations: A sustainable Marvel

Dr. Chandrasekhar, *et al.*

This review comprehensively covers the production of nanocellulose (NC) from diverse sources including plants, bacteria, algae, and animals. Green synthesis pathways prioritizing sustainability are explored, emphasizing eco-friendly and low-cost production methods. NC properties (hydroxyl group modification, covalent modification, ionic functionalization) are analyzed using SEM, AFM, and XRD techniques.

Biomedical Applications: wound dressing, tissue engineering, stem cell therapy, smart drug delivery, biosensing devices are comprehensively reviewed. NC versatility extends from nanocomposites to biophotonics, 3D bioprinting, food packaging, ultra-filtration, and antimicrobial applications. A scientometric analysis (2010–2020) reveals exponential growth in NC research publications across all major databases.

Background and Global Context

The growing global demand for sustainable, eco-friendly materials has accelerated research into renewable biomaterials, such as nanocellulose. Traditionally, industrial materials relied heavily on petroleum-based resources; however, growing environmental concerns, climate change, and resource depletion have driven a transition toward bio-based and green alternatives. Nanocellulose, derived from the most abundant natural polymer, has emerged as a promising candidate due to its renewability, low toxicity, and environmental compatibility. Cellulose is widely available across terrestrial and aquatic ecosystems, including plants, algae, and microorganisms, with an estimated annual production of billions of tons. Advances in nanotechnology have enabled the extraction and nanoscale engineering of cellulose, significantly enhancing its physicochemical properties. Nanocellulose exhibits remarkable features, including high tensile strength, flexibility, a large surface-to-volume ratio, and chemical modifiability, positioning it as a versatile material across multiple disciplines. In the biomedical sector, the demand for advanced materials capable of supporting tissue regeneration, targeted drug delivery, and biosensing has grown rapidly. Nanocellulose meets these requirements due to its biocompatibility, non-toxicity, and structural similarity to extracellular matrices, making it highly suitable for regenerative medicine and healthcare applications. Additionally, its role in sustainable packaging and environmental remediation aligns with global sustainability goals and circular bioeconomy frameworks. Nanocellulose represents a paradigm shift toward sustainable materials science, bridging the gap between environmental responsibility and technological advancement.

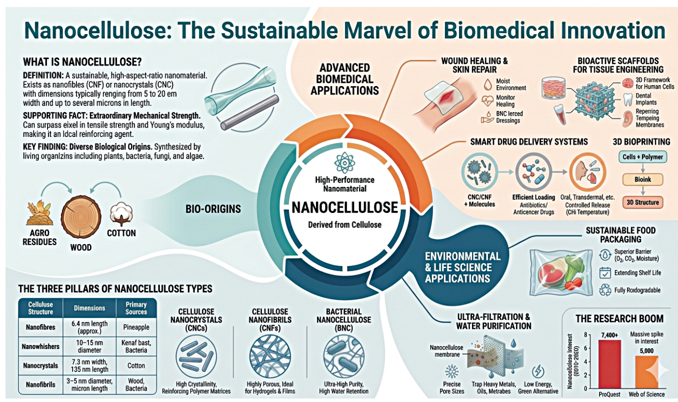

Fig.1: *Nanocellulose in Biomedical Innovation*

I. Characteristics of Nanocellulose

Nanocellulose (NC) exhibits a unique combination of structural, physicochemical, and biological properties that distinguish it as an advanced biomaterial with significant industrial and biomedical relevance. Structurally, nanocellulose is derived from cellulose, a linear polysaccharide composed of β(1→4)-linked D-glucopyranose units. The presence of abundant hydroxyl (-OH) groups at C2, C3, and C6 positions plays a critical role in defining its chemical reactivity, intermolecular hydrogen bonding, and crystallinity. These hydroxyl groups enable extensive functionalization, allowing surface modification through covalent bonding or ionic interactions, thereby enhancing compatibility with polymers and biological systems. Nanocellulose consists of both crystalline and amorphous domains, with crystallinity typically ranging between 40–70%, depending on its source and processing methods. The crystalline regions contribute to its exceptional mechanical strength, high Young's modulus, and rigidity, while amorphous regions facilitate chemical accessibility and degradation. This dual-phase structure is fundamental to its reinforcing capabilities in composite materials and its adaptability in various applications.

II. Classification of Nanocellulose (NC)

NC is a sustainable material derived from renewable sources that is classified into three primary types based on its origin and structure: Cellulose Nanocrystals (CNCs), Cellulose Nanofibrils (CNF), and Bacterial Nanocellulose (BNC). In addition to these core types, researchers also recognize hybrid and specialized forms such as NFC/BC hybrid materials, nanohydrogel polymers, and nanocellulose-based separators.

1. Cellulose Nanocrystals (CNCs)

Also referred to as nanocrystalline cellulose, nanowhiskers, or rod-like cellulose microcrystals, CNCs are extracted by removing the amorphous regions of cellulose microfibrils through mechanical, chemical, or enzymatic procedures.

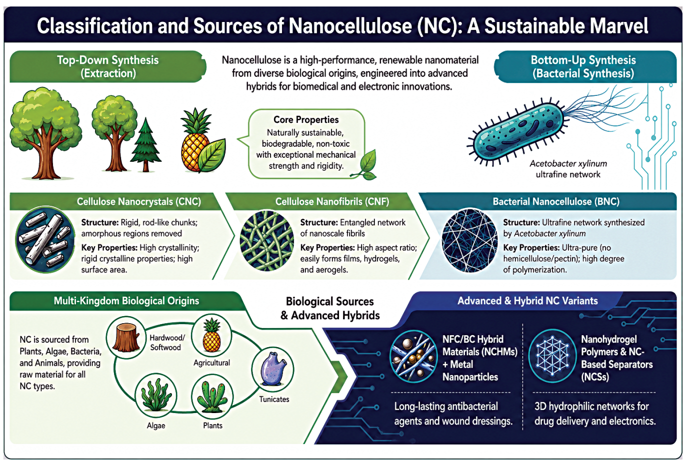

Fig.2: *Nanocellulose Classification and Biological Sources*

2. Cellulose Nanofibrils (CNF)

These are also known as nano-fibrillated cellulose (NFC) or micro-fibrillated cellulose (MFC). CNFs consist of entangled networks of nanoscale fibrils. They are typically obtained by the mechanical fibrillation of cellulose fibers from sources like wood, cotton, and other plant biomass.

3. Bacterial Nanocellulose (BNC)

Bacterial nanocellulose (BNC), also referred to as bacterial cellulose (BC), is a natural nanomaterial synthesized by various bacterial strains, most notably Acetobacter xylinum and Gluconacetobacter xylinus.

4. Hybrid and Specialized NC Types

Over the last decade, researchers have been increasingly interested in the hybridization of NC with metal and oxide nanoparticles. The NC's high surface area promotes high loading of nanoparticles as small as 5 nm, which eliminates the need for organic solvents and the wide variety of target surface functionalization, which favors selective growth and anchoring of nanoparticles on the surface of NC, are just a few of the advantages that are driving this growing interest.

5. Nanohydrogel polymers

A hydrogel based on polymeric materials with a simple hydrophilic structure that allows them to hold a significant amount of H2O in their 3D networks of natural polymers.

6. Nanocellulose-based separators (NCSs)

The NC-based film, a new kind of separator made primarily of NC, has improved inherent properties and/or multiple functions, allowing it to be used in areas where traditional paper isn't suitable.

III. Medical and Biological Applications of Nanocellulose

1. Wound Healing and Dressings

NC is a premier candidate for skin-related treatments, especially for burns and epidermal injuries. These 3D polymer networks can retain up to 100 times their dry weight in water, providing a moist environment that reduces pain and swelling. Bacterial Nanocellulose (BNC): Naturally pure and highly porous, BNC is effective in repairing both the epidermis and dermis. Commercial products like BioFill® and XCell® utilize BNC for wound care.

2. Tissue Engineering and Bioactive Scaffolds

NC serves as a framework for repairing or replacing compromised tissues by supporting cell adhesion and growth. Used for growing human kidney cells, bone osteoblasts, and smooth muscle cells due to their minimal toxicity and extreme porosity. NC scaffolds have shown efficacy in repairing bone, skin, and cartilage. In animal studies, tunicate-derived NC has specifically been shown to enhance wound healing in diabetic models.

3. Smart Drug Delivery Systems

NC's high surface area and tunable surface chemistry make it an ideal vehicle for controlled and targeted drug release. Drugs can be delivered via NC-based microspheres, hydrogels, or membranes. Combinations like BNC and polyacrylic acid create pH-responsive materials that release medication based on the environment's acidity. CNCs conjugated with folic acid are being researched as vectors for the targeted delivery of chemotherapeutic agents to cancer cells.

4. **Biosensing and Diagnostics**

NC-based platforms are used to create cost-effective and highly sensitive analytical devices. Cardiac Monitoring: NC sensors can detect crucial blood biomarkers like cardiac troponin I (cTnI) for the rapid prognosis of cardiovascular diseases. Metabolic Sensing: Researchers have developed NC-based electrochemical biosensors to detect cholesterol levels with high precision.

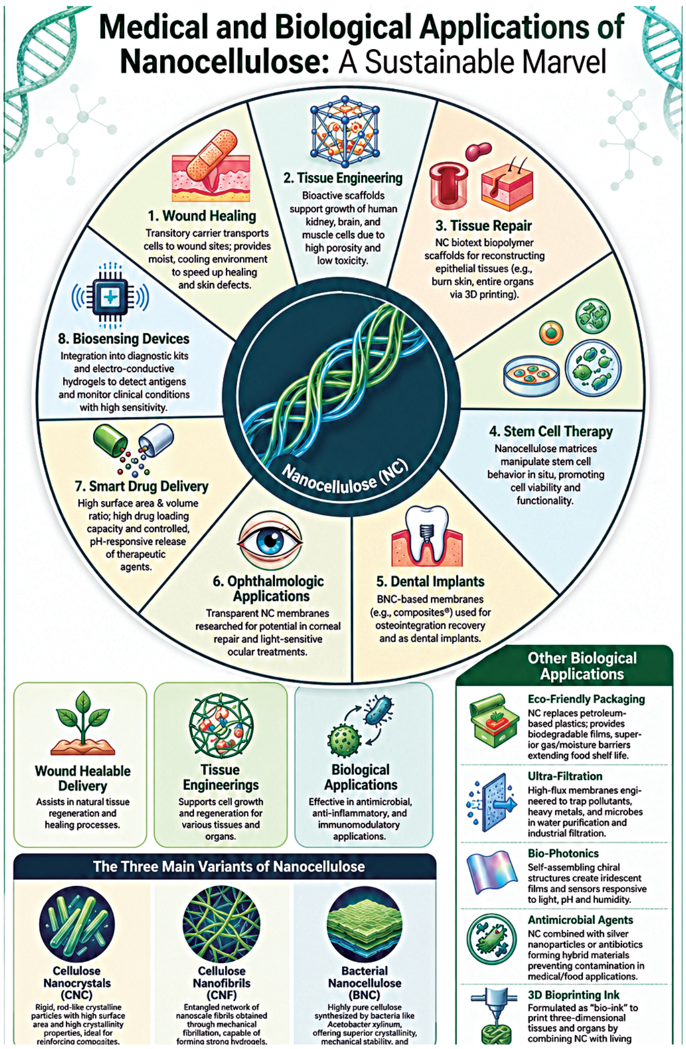

Fig.3: *Nanocellulose Medical and Biological Applications*

5. **Other Life Science Applications**

NC is used as a bio-ink to fabricate complex tissue constructs for organ transplantation research, disease modeling, and drug testing. Nanocellulosic matrices support the viability and functionality of stem cells in situ to promote the repair of damaged organs. NC membranes are used in water purification to remove heavy metals, organic pollutants, and bacteria through size-defined pores and tailored surface chemistry.

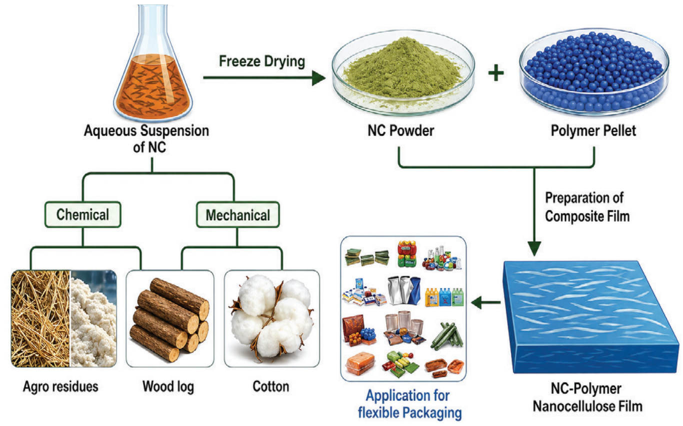

Fig.4: *Schematic of nanocellulose films preparation towards applications in flexible packaging.*

IV. The role of nanocellulose in advancing sustainable green Technologies

1. **The Role of Nanocellulose in Sustainable Green Technologies**

NC is a "sustainable marvel" used to create tissue scaffolds that promote regeneration and repair without causing toxicity. It also enables targeted drug delivery systems, such as pH-responsive carriers that release anticancer drugs specifically at target sites. NC serves as a biodegradable alternative to petroleum-based plastics.

2. **Core Properties Supporting Sustainability**

Naturally decomposes, unlike synthetic plastics. Sourced from abundant plant biomass, agricultural waste, and bacteria. Provides high tensile strength and rigidity for structural applications.

V. The current challenges in translating nanocellulose-based biomedical products to clinical use

Translating nanocellulose (NC)-based biomedical products from laboratory research to clinical implementation faces several significant hurdles. According to the sources, these challenges are categorized into five primary areas:

1. **Large-Scale Production and Reproducibility**

A major obstacle to clinical translation is the scalability of manufacturing. Current extraction methods, such as acid hydrolysis and mechanical fibrillation, are labor-intensive and lack cost-effectiveness for large-scale production.

2. **Regulatory Approval and Standardization**

The regulatory pathways for NC-based biomedical products are currently poorly defined, leading to uncertainty during the approval process. Furthermore, there is a distinct lack of standardized testing methods to assess the safety and efficacy of these materials.

3. **Biocompatibility and Toxicity Concerns**

   While nanocellulose is generally regarded as biocompatible, its interaction with the human body is complex and varies based on particle size, surface charge, and specific modifications. Both in vitro and in vivo studies have reported varying degrees of cytotoxicity and immune responses, which pose potential risks in a clinical setting. Comprehensive, long-term toxicological assessments are still required to fully understand the safety profiles of these materials inside the body.

4. **Challenges in Surface Modification**

   To enhance NC for specific medical uses—such as antimicrobial action or targeted drug delivery—surface functionalization is often required. However, achieving consistent and reproducible modification remains difficult. Variations in modification techniques and environmental conditions can lead to inconsistent material properties, which directly impacts the reliability and performance of the clinical device.

5. **Clinical Efficacy and Long-Term Performance**

   There is a pressing need for well-designed clinical trials to evaluate the actual efficacy of NC-based materials in human patients. Furthermore, long-term studies are necessary to determine:

- Durability: How the material performs over extended periods.
- Biodegradation Rates: How quickly (or slowly) the body breaks down the material.
- Bioaccumulation: Whether the material or its byproducts accumulate in organs over time.

Addressing these challenges requires collaborative efforts between researchers, industry leaders, and regulatory bodies to unlock the full potential of nanocellulose in medicine

Conclusion

Nanocellulose (NC), derived from renewable sources such as algae, plants, and bacteria, has emerged as a highly versatile and sustainable nanomaterial with significant potential across diverse scientific domains. Its unique combination of high mechanical strength, biodegradability, renewability, and biocompatibility positions it as a promising green alternative to conventional synthetic materials. The exceptional structural characteristics of NC, including its high aspect ratio and tunable surface chemistry, enable its integration into a wide range of advanced applications. This review highlights the fundamental properties, classifications, and recent advancements in nanocellulose research, supported by scientometric insights that underscore its growing global relevance. NC and its nanocomposites have demonstrated remarkable utility in biomedical fields such as wound healing, tissue engineering, regenerative medicine, drug delivery, and biosensing, while also extending to applications in food packaging, filtration systems, and 3D bioprinting. Its ability to form multifunctional nanostructures with polymers, metals, and carbon-based materials further enhances its applicability. Looking ahead, nanocellulose holds substantial promise in next-generation healthcare technologies, particularly in targeted drug delivery and smart biomaterials. Continued advancements in green synthesis, functionalization, and scalability will be critical for translating NC from laboratory research to commercial applications.

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Happy gut, Healthy you: How food polyphenols and microbiota work together?

Dr. Mithun Rudrapal, *et al.*

There is a mutual relationship between polyphenols in our diets and the microbial flora that exists within our body. The microbes found in our gut transform the plant-based polyphenols into bioactive metabolites that boost the immune system and metabolism and contribute to the prevention of illnesses. Our diet has an impact on the makeup of the microbes in our gut.

This study is important because it highlights the vital connection between dietary polyphenols and gut microbiota in maintaining human health. It explains how natural compounds from plant-based foods are transformed by gut bacteria into beneficial bioactive molecules that support immunity, metabolism and disease prevention. The findings emphasize the role of nutrition as a key factor in preventive healthcare, encouraging a shift toward healthier and more sustainable dietary habits. Overall, the study supports the idea that improving gut health through diet can lead to better long-term health outcomes and reduced disease risk.

What is this study about?

This study explains how natural compounds from plant-based foods (called polyphenols) interact with the bacteria living in our gut and how this relationship helps maintain our health. Our digestive system is not just a food-processing organ; it is a home to trillions of tiny beneficial microorganisms, known as the gut microbiota. These microorganisms play a very important role in keeping our body healthy.

At the same time, the foods we eat-especially fruits, vegetables, tea, coffee and whole grains-contain polyphenols, which are beneficial compounds that help protect our body. This study focuses on how these two polyphenols and gut bacteria work together as a team.

Key highlights

- Demonstrates the synergistic relationship between diet and gut microbiota
- Explains how polyphenols are converted into bioactive compounds
- Highlights their role in immunity, metabolism and disease prevention
- Supports the concept of sustainable and preventive healthcare through nutrition
- Aligns with holistic health and SDG goals (Good health & well-being)

Fig.1: *Synergy between dietary polyphenols and gut microbiota*

Understanding gut microbiota

The gut microbiota includes a large number of beneficial bacteria that help in:

- Digesting food
- Producing vitamins
- Strengthening the immune system
- Maintaining balance in the body

When this balance is disturbed, a condition called dysbiosis occurs. This imbalance can lead to many health problems such as:

- Digestive disorders (like inflammatory bowel disease)
- Diabetes and obesity
- Heart diseases
- Brain-related disorders

So, maintaining a healthy gut microbiota is essential for overall well-being.

What are polyphenols?

Polyphenols are natural compounds found in plant-based foods such as:

- Fruits (berries, apples, grapes)
- Vegetables (spinach, onions, broccoli)
- Tea and coffee
- Nuts and grains

They are known for their health benefits:

- Antioxidant (protect cells from damage)
- Anti-inflammatory (reduce inflammation)
- Anticancer (help prevent cancer)

However, these compounds cannot work effectively on their own-they need the help of gut bacteria.

How do polyphenols and gut bacteria work together?

The most important part of this study is the two-way (bi-directional) relationship between polyphenols and gut microbiota.

1. Polyphenols help gut bacteria

When we eat polyphenol-rich foods:

- These compounds reach the gut
- They act as food for good bacteria
- They help beneficial bacteria grow
- They reduce harmful bacteria

This improves the overall health of the gut.

2. Gut bacteria help polyphenols

Polyphenols are often too complex for our body to absorb directly. Gut bacteria:

- Break them down into simpler, useful compounds
- Make them easier for the body to absorb
- Increase their effectiveness

In simple terms, gut bacteria "activate" the benefits of polyphenols.

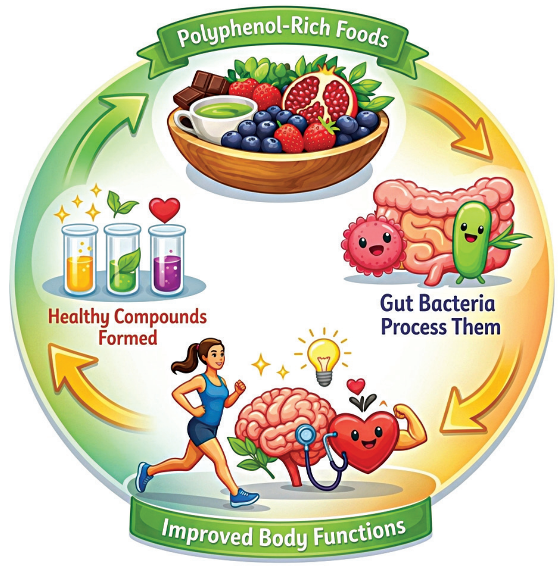

Fig.2: *Interplay among dietary polyphenols, gut bacteria and human health*

What happens inside the body?

When polyphenols and gut bacteria interact:

- New bioactive compounds are formed
- These compounds travel through the body
- They help regulate:
  - Metabolism
  - Immune system
  - Inflammation

This leads to better overall health.

Why is this important for health?

This interaction plays a role in preventing and managing many diseases:

Heart Health

- Helps reduce cholesterol
- Improves blood circulation

Diabetes and Obesity

- Helps control blood sugar
- Improves metabolism

Brain Health

- Supports the gut–brain connection
- Helps improve mood and memory

Immunity and Inflammation

- Strengthens immune system
- Reduces long-term inflammation

What did the study do?

This study is a review, meaning researchers:

- Collected many scientific studies from the past decade
- Analyzed how polyphenols interact with gut bacteria
- Studied their effects on health and disease

This gives a complete and reliable understanding of the topic.

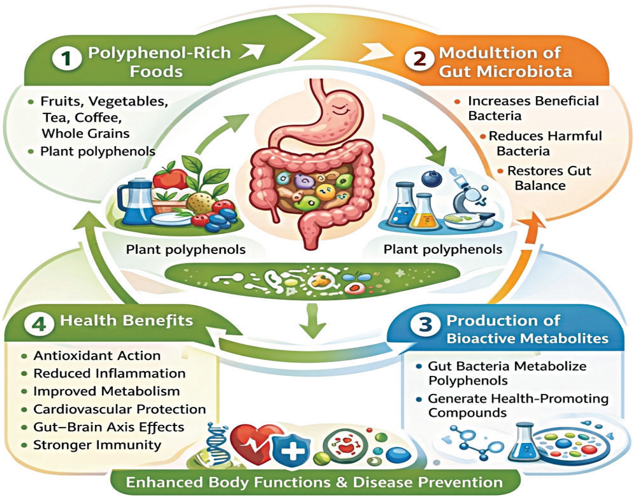

Fig.3: *Dietary polyphenols, gut microbiota-derived metabolites and associated health benefits*

Outcome of the study

The study concludes that:

- Polyphenols help maintain a healthy gut microbiota
- Gut microbiota improves the effectiveness of polyphenols
- Their interaction produces beneficial compounds
- This interaction helps prevent many diseases

In short, they work together to keep the body healthy.

Conclusion

This study highlights the strong connection between dietary polyphenols and gut microbiota. These two systems work together in a mutually beneficial way, where diet shapes gut bacteria, and in turn, gut bacteria transform dietary compounds into health-promoting molecules. This interaction plays a crucial role in maintaining overall health and reducing the risk of various diseases.

Practical importance (what this means for us)

This study suggests that we can improve our health by:

- Eating more plant-based foods
- Including fruits, vegetables, and whole grains in our diet
- Supporting gut health through diet

A healthy diet directly supports a healthy gut. Let food act as natural medicine. Small dietary changes can lead to big health benefits.

Futuristic value

- Personalized nutrition

  Diet plans tailored to individual gut microbiota for maximum health benefits

- AI-driven gut health analysis

  Use of AI to predict microbiome responses and optimize polyphenol intake

- Next-generation nutraceuticals

  Development of polyphenol-based supplements and functional foods

- Microbiome-based therapies

  Targeting gut bacteria for disease prevention and treatment

- Sustainable health solutions

  Promoting plant-based diets aligned with global sustainability goals (SDGs)

Reference

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From Motion to Power by Sn-Modification in $Bi(Mg_{1/2}Ti_{1/2})O_3$–$PbTiO_3$ Piezoceramics

Dr. Ashutosh Upadhyay, *et al.*

As portable electronic gadgets become universal, there is an urgent need to develop renewable energy solutions to meet the rising demands of such technology. Consider the idea of powering your devices by the movement of your body, typing, and ambient vibrations. It seems that such a dream is not out of reach due to the presence of piezoelectric materials.

Ceramics are inorganic, non-metallic solids processed at high temperatures, like traditional ceramics but engineered for electrical functionality. Piezoceramics are a class of ceramic materials that exhibit the Piezoelectric Effect. The Piezoelectric Effect has an ability to convert mechanical energy into electrical energy and vice versa. These materials have a special crystal structure. When force is applied, the internal charge distribution shifts, creating a voltage. When voltage is applied, the structure slightly deforms. Commonly used materials are lead zirconate titanate (PZT), while $Bi(Mg_{1/2}Ti_{1/2})O_3$–$PbTiO_3$) (BMT–PT) used in advanced research.

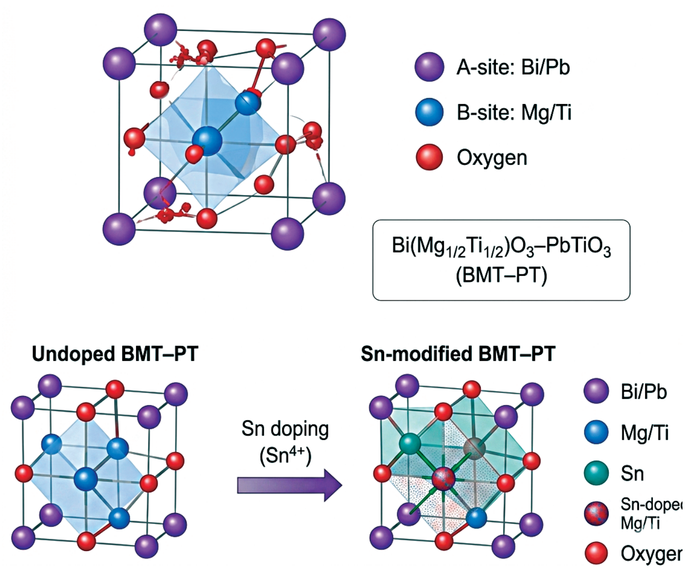

Fig.1: Crystal structure of BMT-PT perovskite with Sn modification

Key properties of Piezoceramics:

- High sensitivity to pressure
- Fast response time
- Ability to work as both sensors (microphones, pressure sensors) and actuators (precision movement devices such as in robotics).

This work revealed that there is an enhancement in the piezoelectric response by 22% and saturation polarization due to the determination of disorder after poling in the form of the cubic phase in BMT-PT piezoceramics on Sn-doping. The high thermal stability (320°C) is observed on Sn doping. It is believed that the result of this study will encourage further examination and may help to develop the materials exhibiting a large ferroelectric and piezoelectric properties with high Tc.

- Medical: ultrasound imaging
- Everyday tech: buzzers, inkjet printers, vibration control.

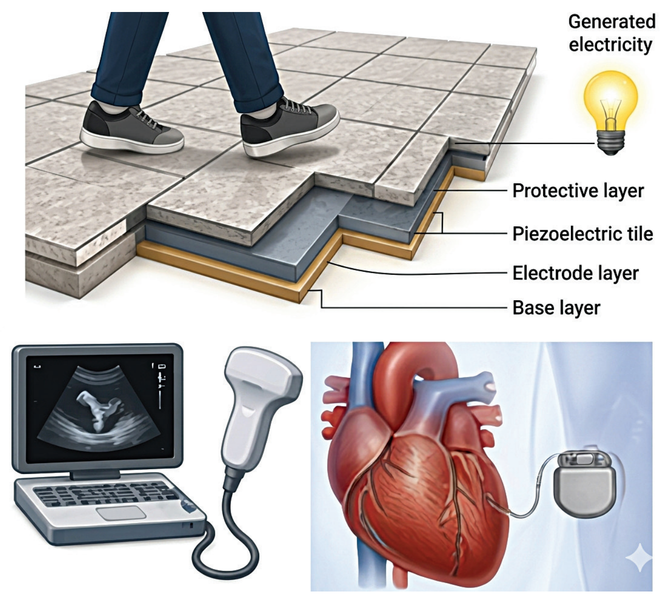

Fig.2: Applications of piezoelectric materials in different fields.

Piezoceramics are progressively explored for both energy harvesting and energy storage applications.

Piezoelectrics as Energy Harvesters: This is the primary and practical use of Piezoceramics. The mechanical vibrations or pressure converted into electrical energy. When a piezoceramic (like BMT–PT or PZT) is stressed internal dipoles shift, charges accumulate on surfaces and a voltage is generated. For examples: walking, machine vibrations, traffic, sound waves. This process can power small devices. Self-powered sensors (IoT devices), wearable electronics, road/railway energy harvesting, biomedical implants are the main applications of energy harvesters. Piezoceramics are ideal for low-power, continuous energy generation.

Piezoelectrics as Energy Storage: Piezoelectric materials do not store energy proficiently by themselves like batteries or capacitors, However, they can contribute indirectly such as temporary energy holding or hybrid systems (practical approach). In case of temporary energy holding, the piezoelectric materials may generate charge and can be momentarily stored due to dielectric behavior, but storage capacity is very low. Whereas in hybrid systems Piezo devices are combined with batteries and capacitors / supercapacitors. In this first Mechanical energy converted into piezoelectric and Electrical output stored in external storage device.

Impact of Sn-Modification: Advances in material science are continuously improving the performance of piezoceramics. For example, modifying material composition, such as incorporating elements like tin (Sn) into complex systems like $Bi(Mg_{1/2}Ti_{1/2})O_3$–$PbTiO_3$ can enhance their structural stability and electromechanical response. These improvements directly translate into better energy harvesting efficiency. The Sn-modified in BMT–PT improved the phase stability, enhance polarization response, increase electromechanical coupling. This directly improves energy harvesting efficiency.

The experiment revealed that there is an enhancement in the piezoelectric response of 22 % and saturation polarization in BMT-PT piezoceramics on Sn-modification due to the determination of structural disorder after poling in the form of the cubic-like phase. The thermal depolarization temperature (Td) was reported to be ~320◦C. It is believed that the result of this study will encourage further investigation and may help to develop the materials exhibiting a large value of d33 with high Tc.

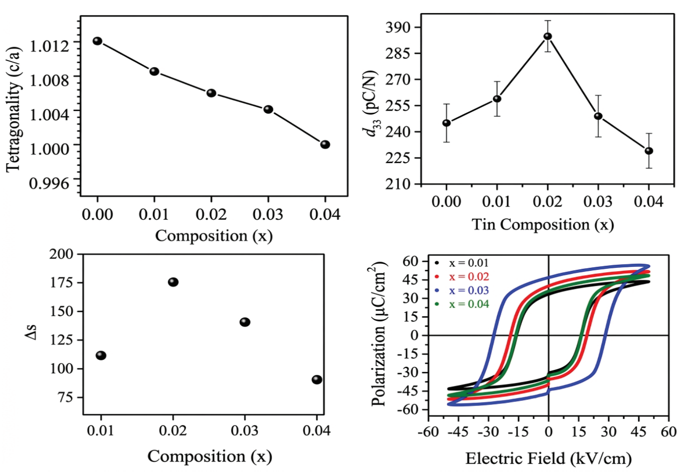

Fig.3: Variation of tetragonality, d33, Δs and polarization with Sn-composition (x) in BMT-PT.

A Sustainable Energy Companion: Piezoelectric technology may not replace conventional power sources, but it offers a compelling complementary solution. By capturing otherwise wasted mechanical energy from our surroundings, it contributes to cleaner and more efficient energy usage.

In essence, piezoelectric materials act like microscopic power plants embedded in our environment quietly converting motion into usable electricity. As research progresses, these materials could become a cornerstone of self-powered systems, paving the way for a smarter and more sustainable future.

Conclusion

The Sn-modification enhanced the structural stability and piezoelectric performance of BMT-PT piezoceramics. These improved electromechanical properties make Sn-modified BMT–PT ceramics highly promising for next-generation piezoelectric applications such as high-temperature sensors, ultrasonic transducers, precision actuators, vibration energy harvesters, and non-volatile memory devices. Their ability to maintain strong piezoelectric performance under elevated temperatures also opens opportunities in aerospace, automotive, industrial monitoring, and quantum-enabled sensing technologies.

Reference

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AI Listens to Breath: A Smarter Way to Detect COVID-19

Dr. Jawad Ahmad Dar, *et al.*

This study presents an advanced deep learning approach for COVID-19 detection using respiratory sound signals. It integrates a Deep Q Network with a hybrid optimization technique (SJHBO) to enhance classification performance. By extracting diverse audio features, the model achieves around 95% accuracy, sensitivity, and specificity, demonstrating its potential as an effective, early, and non-invasive diagnostic tool suitable for real-world healthcare applications.

Early diagnosis remains critical in controlling COVID-19 transmission and reducing mortality. While RT-PCR and CT imaging are reliable, they are often expensive, time-intensive, and less accessible in remote regions. Recent research proposes an AI-driven alternative that detects COVID-19 through respiratory sound analysis, offering a non-invasive and cost-effective screening method. Using the Coswara respiratory sound dataset, the study employs a Deep Q Network (DQN)-based deep learning model to classify individuals as COVID-19 positive or negative from breathing sounds. Audio signals are first denoised using median filtering, followed by extraction of acoustic features such as MFCC, spectral contrast, spectral centroid, FFT, zero-crossing rate, and power spectral density. These features enable the system to identify subtle respiratory patterns associated with COVID-19 infection.

Problem Statement

Respiratory diseases such as COVID-19 require early and accurate diagnosis to reduce mortality and improve treatment outcomes. Conventional methods like RT-PCR, CT scans, and X-rays are costly, time-consuming, and less accessible in resource-limited regions. Although respiratory sound analysis is non-invasive and affordable, it depends heavily on clinician expertise, leading to subjective interpretation and possible misdiagnosis. Existing AI-based approaches also struggle with noisy, high-dimensional audio signals, resulting in limited accuracy and poor generalization.

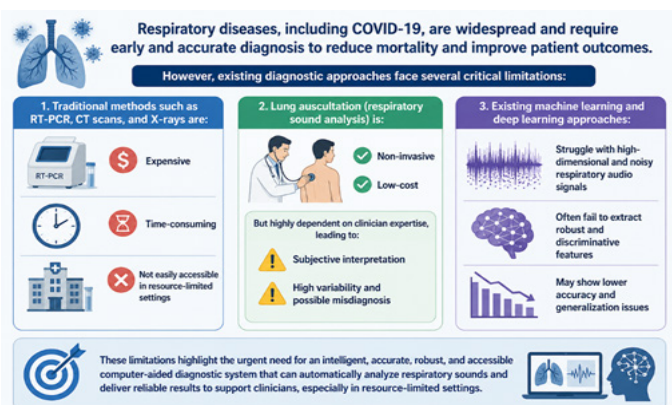

Fig.1: *Overview of challenges in respiratory disease diagnosis, highlighting limitations of traditional methods, lung auscultation, and existing machine learning approaches.*

Smart Diagnosis: Deep Learning for COVID-19 Detection via Breath Analysis

The core problem addressed in this article is: How to design an efficient, accurate, and automated deep learning-based system that can reliably detect COVID-19 from respiratory sound signals, overcoming limitations of traditional diagnosis and existing AI models in feature extraction, optimization, and classification performance. To solve this problem, the paper aims to: Develop an optimization-based deep learning framework. Improve: Feature extraction from respiratory sounds, Model accuracy and robustness and Early and cost-effective COVID-19 detection

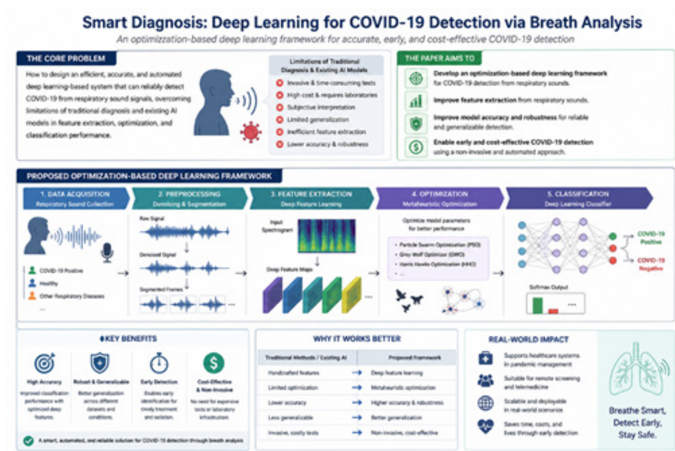

Fig.2: *Smart diagnosis: Deep learning for COVID-19 detection via breath analysis.*

Breaking Barriers: Challenges in AI-Based COVID-19 Detection

Critical Challenges in Developing Deep Learning Models for Respiratory Audio Analysis

- Noisy and Unstructured Audio Data
- High Variability in Respiratory Patterns
- Limited and Imbalanced Datasets
- Feature Extraction Complexity
- Model Optimization Issues
- Generalization and Robustness
- Dependence on Clinical Expertise (Baseline Problem)
- Real-Time Deployment Constraints

Hybrid Intelligence for High-Accuracy AI Models

What makes this research especially unique is its optimization strategy. The authors developed a novel hybrid algorithm called Snake Jaya Honey Badger Optimization (SJHBO). This combines three advanced optimization techniques, Jaya Algorithm, Honey Badger Optimization, and Snake Optimization, to fine-tune the neural network's weights for maximum accuracy. The hybrid design improves both convergence speed and prediction precision. The results are highly promising. The proposed model achieved: 95.11% Accuracy,95.06% Sensitivity and 94.69% Specificity. These figures demonstrate that AI-driven respiratory sound analysis can become a reliable tool for rapid COVID-19 screening. The results were further validated using k-fold cross-validation, confirming the robustness of the approach. Beyond the pandemic, this technology has broader implications. Respiratory sound-based AI diagnosis could transform healthcare by enabling smartphone-based screening tools, remote patient monitoring, and early detection of other lung diseases such as asthma, bronchitis, and pneumonia. Although challenges remain such as improving performance for asymptomatic patients and expanding dataset diversity the study marks a major step toward accessible digital healthcare. By simply "listening" to human breath, artificial intelligence may soon help doctors diagnose illness faster, cheaper, and more efficiently than ever before.

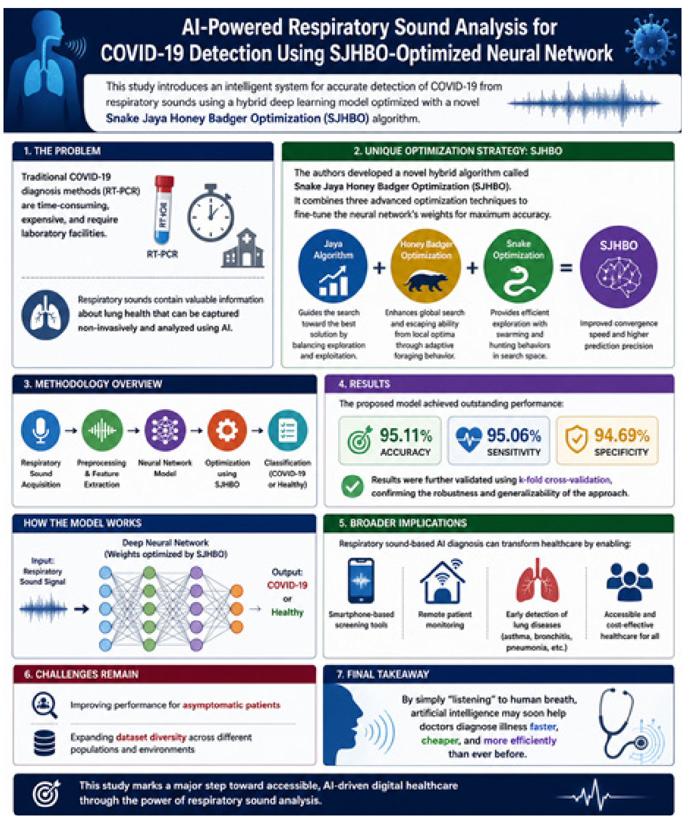

Fig.3: *AI-powered respiratory sound analysis for COVID-19 detection using SJHBO-optimized neural network.*

Next-Generation Methodology for COVID-19 Detection with Deep Reinforcement Learning

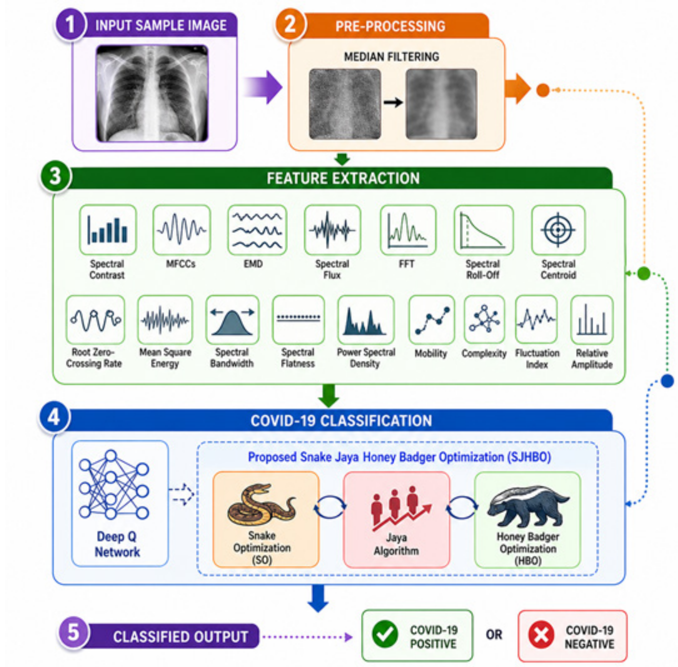

Fig.4: *From Signal to Diagnosis: AI-Powered COVID-19 Detection, Architecture of a Hybrid SJHBO-Based Deep Learning Model for COVID-19 Detection*

Conclusion

This work introduces a powerful AI-driven framework for COVID-19 detection, combining a Deep Q Network with the novel SJHBO hybrid optimization strategy. By leveraging respiratory audio signals, the model delivers high diagnostic performance, achieving over 95% accuracy with strong sensitivity and specificity. The integration of advanced optimization techniques significantly enhances learning efficiency and prediction precision, positioning this approach as a promising tool for intelligent healthcare diagnostics. Future advancements will focus on enabling real-time deployment, paving the way for rapid, accessible, and scalable COVID-19 screening solutions

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